Uttarakhand
State of the Environment Report-2012

Uttarakhand State Council for Science and Technology (UCOST)
Uttarakhand Science Education and Research Centre (USERC)

Department of Science and Technology (Govt. of Uttarakhand), Uttarakhand

Uttarakhand SOER - 2012

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U t t a r a k h a n d S O E R - 2 0 1 2

Uttarakhand : State of the Environment Report-2012

ISBN : 978-81-211-0845-4

Published by Abhimanyu Gahlot for M/s. Bishen Singh Mahendra Pal Singh, 23-A, New Connaught Place, Dehra Dun, India and Uttarakhand State Council for Science and Technology (UCOST), Dehra Dun India, Printed at Shiva Offset Press and composed by Doon Phototype Printers, 14, Old Connaught Place, Dehra Dun, India.

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Cover Photo: Devariyatal, Rudraprayag (Photo by Mr. Threesh Kapoor)

Preface

Evident from various developmental indicators like industrialization, urbanization and growth in population, Uttarakhand economy has witnessed phenomenal growth since it's carving out from Uttar Pradesh. However, these developments have accentuated and sometimes triggered the question of whether they are ecofriendly or are of sustainable approach? Incidentally, there is an increasing awareness and infusing of environmental aspects into the mainstream economy of the bio-diverse rich state. Being an essential ingredient, environmental concerns therefore have taken up an important place in planning and development programmes of the State.

It is fathomed that the capacity to produce and consume goods and services depends on the three assets of the economy: natural, industry and human resources. Natural resources consists of natural assets of biosphere supporting all life forms and the economic contributions include production of food, energy, air, water, minerals, habitat and biological diversity. Industry with the aid of human capital builds on natural resources. The ecosystem where the three assets mingle and impact each other is the 'Environment'. Thus it is essential to honor the natural resources constraint for sustainability of humanity.

As established, the environmental effects of a progressive economy can be traced through different sectoral, regional and case specific channels. An attempt therefore has been made to capture multiple facets of economy where environment makes contributions. This present 'SOER 2012' is the first in a series of reports from the state on the environmental concerns and its impacts as seen by environment policy researchers. It is designed to present the progress made towards realization of sustainable development goals and a good environmental quality. Alongside tackling local issues and challenges the outcome of the report is also meant to serve as a baseline for the state of Uttarakhand environment, in a manner that will allow measuring progress in the future.

Divided over seven broad sections, the report offers a panoramic overview of the environment of the state. The sections have reviewed the trends, status and presented some facts of the current environmental situation in the state, analyzed the pressures and underlying causes, impacts and regulatory issues as pertaining to the sector. Within each chapter, the lead authors have presented primary data (Chapters-Climate Change and Water), data drawn from R&D Projects sponsored by UCOST and secondary data from reliable government sources in the form of several portrayals and fact files. Given the fact that the environment interfacing the economy and society has very large dimensions, this report could take up only a handful. Nevertheless it is proposed to include the rest of the sectors in forthcoming issues.

For convenience of a reader the report presents a ready reckoner on nearly all aspects of the environment. This document is targeted at a wide readership ranging from policy makers and advisors to academic readers as well as the common person. The report is written with an aim to i) Provide detail, relevant and credible information and data base on environmental issues for decision makers and public; ii) Provide environment status of the state; iii) Help the decision makers to identify gaps in the environment management planning; and iv) Generate awareness for environmental issues.

Finally, I wish to thank my colleagues from UCOST, USERC and many other authors who spent months of hard working days; they are the contributors and it must be mentioned that without their dedication this report would not have been possible.

Dr. Rajendra Dobhal
Director General

Acknowledgements

Authors humbly acknowledge the inputs and support provided by concerned persons (listed below) for sharing the State sectoral data:

- Prof. A.N. Purohit
  Ex-Vice Chancellor
  HNB Garhwal University, Srinagar
- Dr. Piyoosh Rautela
  Executive Director
  Disaster Mitigation and Management Centre, Dehradun
- Director
  Department of Agriculture, Dehradun
- Officer In-charge
  Zoological Survey of India, Northern Regional Station, Dehradun
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  Botanical Survey of India, Dehradun
- Chief General Manager
  Uttarakhand Jal Sansthan, Dehradun
- Regional Director
  Central Ground Water Board, Dehradun
- Director
  National Institute of Hydrology, Roorkee
- Uttarakhand State AIDS Control Society Directorate of Medical Health & Family Welfare, Dehradun
- Cooperation Centre for Riverbank Filtration
  Haridwar
- Dr. I.D. Bhatt
  G.B.Pant Institute of Himalayan Environment and Development
  Kosi, Katarmal, Almora
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  Former Additional Director
  ZSI, Dehradun










Photo Courtesy

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Uttarakhand Forest Department, Dehradun

Uttarakhand Jal Sansthan, Dehradun

Uttarakhand Renewable Energy Development Agency, Dehradun

Himalayan Institute of Hospital Trust, Jolly Grant, Dehradun

Lal Bahadur Shastri National Administrative Academy, Mussoorie
Directorate of Industries, Uttarakhand

M/s Bishen Singh Mahendra Pal Singh, Dehradun

Mr. Abhimanyu Gahlot, Dehradun

Mr. N.C. Dhingra and Mr. Jyoti Swarup Sharma

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List of Abbreviations

AAS	:	Atomic Absorption Spectrophotometer
AIBP	:	Accelerated Irrigation Beneficiary Program
BARC	:	Bhabha Atomic Research Centre
BCM	:	Billion Cubic Metre
BHEL	:	Bharat Heavy Electrical Limited
BIS	:	Bureau of Indian Standard
BMCs	:	Biodiversity Management Committee
BOD	:	Biochemical Oxygen Demand
BR	:	Biosphere Reserve
BVI	:	Bheshaj Vikas Ikai
CAMP	:	Conservation Assessment and Management Plan
CAP	:	Centre for Aromatic Plants
CBD	:	Conservation of Biological Diversity
CBR	:	Crude Birth Rate
CCRBF	:	Cooperation Centre for River Bank Filtration
CCS	:	Carbon Capture and Sequestration
CDH	:	Conservation, Development and Harvesting
CDM	:	Clean Development Mechanism
CDP	:	City Development Plan
CDR	:	Crude Death Rate
CEA	:	Central Electricity Authority
CFU	:	Colony Forming Units
CGWB	:	Central Ground Water Board
CHC	:	Community Health Center
CII	:	Confederation of Indian Industries
CITES	:	Convention on International Trade in Endangered Species
CLL	:	Colourless
CMS	:	Convention on Migratory Species
COD	:	Chemical Oxygen Demand
CPCB	:	Central Pollution Control Board
CR	:	Conservation Reserve
Cr	:	Critically Endangered
CRSP	:	Central Rural Sanitation Programme
CSMRS	:	Central Soil and Material Research Station
CSSIHR	:	Compendium of Statistics for the States of Himalayan Region
D/S	:	Downstream
DCMG	:	District Crisis Management Group
DDMA	:	District Disaster Management Authority
DM	:	Disaster Management
DMD	:	Disaster Management Department
DMMC	:	Disaster Mitigation and Management Centre
DO	:	Dissolved Oxygen
DPAP	:	Drought Prone Area Development Programme
DRDA	:	District Rural Development Agency
DRDO	:	Defence Research Development Organisation
DST	:	Department of Science and Technology
EC	:	Electrical Conductivity
ELA	:	Equilibrium Line Altitude
En	:	Endangered
EVP	:	Evaporation Lines
Ex	:	Extinct
FC	:	Fecal Coliform
FDU	:	Field Distillation Unit
FSI	:	Forest Survey of India
GA	:	Geographical Area
GEF	:	Global Environment Fund
GIA	:	Gross Irrigated Area
GIS	:	Geographical Information System

GLOF : Glacial Lake Outburst Floods
GMVN : Garhwal Mandal Vikas Nigam
GOI : Government of India
GRAMYA : Uttarakhand Decentralized Watershed Development Project
GSI : Geological Survey of India
GW : Giga Watt
GWh : Giga Watt hour
GWMW : Ground Water Monitoring Well
Ha : Hectare
HAPPRC : High Altitude Plant Physiology Research Centre
HESCO : Himalayan Environment Studies and Conservation Organisation
HRDI : Herbal Research and Development Institute
ICFRE : Indian Council of Forestry Research and Education
IFAD : International Fund for Agricultural Development
IIE : Integrated Industrial Estate
IIT : Indian Institute of Technology
ILSP : Integrated Livelihood Support Project
IMR : Infant Mortality Rate
IPM : Integrated Pest Management
ISOPOM : Integrated Scheme of Oilseeds, Pulses, Oil Palm and Maize
ISRO : Indian Space Research Organization
IUCN : International Union for Conservation of Nature
IWMP : Integrated Watershed Management Programme
K : Potassium
KMVN : Kumaon Mandal Vikas Nigam
KW : Kilo Watt
Lc : Least Concern
LHP : Large Hydropower Projects
LMWL : Local Meteoric Water Line
LPHD : Litre Per Head Per Day
LPM : Litres Per Minute
MAPs : Medicinal and Aromatic Plants
MASL : Mean Average Sea Level
MBGL : Metres Below Ground Level
MGNREGA : Mahatma Gandhi National Rural Employment Guarantee Act
MHA : Ministry of Home Affairs
MLD : Million Litres Per Day
MMA : Macro Management of Agriculture
MMR : Maternal Mortality Ratio
MPCAS : Medicinal Plant Conservation Areas
MPN : Maximum Probable Number
MSK : Medvedev Sponheuer Karnik
MT : Metric Tonn
MU : Million Units
MW : Mega Watt
MW : Monitoring Well
N : Nitrogen
NA : Not Analysed
NAPCC : National Action Plan on Climate Change
HYV : High Yielding Varieties
NBM : National Bamboo Mission
NBWL : National Board of Wild Life
NCC : National Cadet Core
ND : Not Detected
NDBR : Nanda Devi Biosphere Reserve
NDMA : National Disaster Management Authority
NDRF : National Disaster Response Force
NEC : National Executive Committee
NEP : National Electricity Policy
NGO : Non Government Organization
NHB : National Horticulture Board
NHM : National Horticulture Mission
NIA : Net Irrigated Area
NIDM : National Institute of Disaster Management
NIH : National Institute of Hydrology
NIPHM : National Institute of Plant Health Management
NIUA : National Institute of Urban Affairs
NMPB : National Medicinal Plant Board
NP : National Park
NPOF National Project on Organic Farming
NRAA : National Rainfed Area Authority
NREP : National Rural Employment Programme
NSG : National Security Guard
NSS : National Service Scheme

NTFP	:	Non Timber Forest Products
NTU	:	Nephelometric Turbidity Unit
NYKS	:	Nehru Yuva Kendra Sangathan
ODL	:	Odourless
P	:	Phosphorous
PAN	:	Protected Area Network
PA's	:	Protected Areas
PCRI	:	Pollution Control Research Institute
PHC	:	Primary Health Center
PMU	:	Project Management Unit
QPM	:	Quality Planting Material
Qtl	:	Quintal
R&D	:	Research and Development
R	:	Rare
RBF	:	River Bank Filtration
RE	:	Renewable Energy
RET	:	Rare, Endangered, Threatened
RKVY	:	Rashtriya Krishi Vikas Yojana
RLEGP	:	Rural Landless Employment Guarantee Programme
RS	:	Remote Sensing
RSC	:	Residual Sodium Carbonate
SAC	:	Space Applications Centre
SAR	:	Sodium Adsorption Ratio
SCMG	:	State Crisis Management Group
SDMA	:	State Disaster Management Authority
SEOC	:	State Emergency Operation Centre
SERC	:	State Electricity Regulatory Commissions
SGDP	:	State Gross Domestic Product
SHP	:	Small Hydropower Projects
SIDCUL	:	State Infrastructure and Industrial Development Corporation of Uttarakhand Ltd
SMPB	:	State Medicinal Plant Board
STP	:	Sewage Treatment Plants
SWAP	:	Sector Wide Approach
TC	:	Total Coliform
TDS	:	Total Dissolved Solids
TFR	:	Total Fertility Rate
TKN	:	Total Kjeldahl Nitrogen
TSC	:	Total Sanitation Campaign
TW	:	Tube Well
U/S	:	Upstream
UCOST	:	Uttarakhand State Council for Science and Technology
UEPPCB	:	Uttarakhand Environment Protection and Pollution Control Board
UGC	:	Upper Ganga Canal
UJS	:	Uttarakhand Jal Sansthan
UNDP	:	United Nations Development Programmes
UNESCO	:	United Nations Educational, Scientific and Cultural Organization
UOCB	:	Uttarakhand Organic Commodity Board
UPJN	:	Peyjal Vikas Evam Nirman Nigam
USERC	:	Uttarakhand Science Education and Research Centre
USOCA	:	Uttarakhand State Seed and Organic Certification Agency
UV-VIS	:	Ultraviolet-Visible
Vu	:	Vulnerable
WDPSCA	:	Watershed Development Project for Shifting Cultivation Area
WHO	:	World Health Organization
WIHG	:	Wadia Institute of Himalayan Geology
WS	:	Wild Life Sanctuary
WTI	:	Water Technology Initiative

Executive Summary

The present SOER has tried to come up with a complete database on the resources of the State for ready reference and discussion making based on the facts and figures. The report has seven sections: Bio-resources, Geo-resources, Climate Change, Disaster Scenario & management, Health, Industry and Tourism. The summary of the various sections of the book is as follows:

SECTION I: BIO-RESOURCES

Biodiversity

Uttarakhand exhibits rich biodiversity because of high topographic, climatic and altitudinal variations. It is estimated that there are about 7000 species of plants in the State though till date only 85% flora is explored. Similarly, the State comprises 500 species of fauna of which 80% are invertebrates and 20% vertebrates. Of the total floral diversity explored, 74% comprised flowering plant diversity. It is interesting to note that the floral diversity of the State contributes 31% of total floral density of India. On the other hand, the faunal diversity contributes just 1.58% of the total faunal density of the country. The pteridophytic, gymnospermic and angiospermic diversity of Uttarakhand contributes 33.2, 54.5 and 28.9% of the respective diversity of the country. The moluscus, arthropod, pisces, amphibians, reptiles and aves diversity of the State contributes 2.55, 0.19, 5.58, 9.71, 15.46 and 12.69% of the respective diversity of the country.

Medicinal and Aromatic Plants

Uttarakhand harbours over 701 species of medicinal plants that are used by large number of drug and pharmaceutical industries as well as used in Ayurvedic, Unani and other traditional systems of medicine. These species are distributed at all elevations with majority towards high altitude zones. During 2004-2011, nearly 1500-2250 MT volume of medicinal plants was collected from forests while 75 to 1100 MT net volume has been produced through cultivation in past four years. Most of the demand is being met out by wild collection itself. To develop the MAP sector, seven areas have been designated as Medicinal Plant Conservation Areas (MPCAs) for its mainstream conservation and sustainable use.

Forests

Uttarakhand is covered with rich forests all across 13 districts. The forest cover in the State is 24,496 km^2, which is 45.80% of the State's geographical area. As regards the forest cover and forest area as percentage of geographical area the State lies at 11th and 5th position, respectively out of 35 State/UT whereas, forest cover and forest area occur at 9th position. The last decade has seen an increase of 1.04% forest cover in the State. Out of 13 districts, Nainital (72.69%) has highest forest cover whereas, Udham Singh Nagar (21.48 %) has the lowest. Among the 16 forest types existing in India, 8 can be found in Uttarakhand. IUCN has listed 38 forest plants species as globally threatened in the State. The total wetland area of the State is 1038.82 km^2 with Udham Singh Nagar district having the maximum wetland area (19.35%). The State forests are hea□ven for timber production, putting it at 5th and 3rd national ranking in terms of estimated production of wood and fuelwood from forests.

Agriculture and Horticulture

Agriculture is described as a key component of State economy constituting one third of the share of State's income. The major work force including 80% women population of the State is employed in agriculture sector. Total cropped area accounts for around 20.5%. The net area sown is around 13.1% and is under pressure to sustain a population of more than 10 crore, almost 80% of which is rural. Only 14% of the total area is irrigated in the hill areas, with the rest of the sown area being rain fed. The percentage of irrigated area in the plains, however, is very high. The major crops in the State include paddy, wheat, maize, soybean and other pulses and millets. As regards Horticulture, a total of 19 different type of fruits and 28 vegetables are grown in the State excluding the wild varieties. Among the fruits, mango, apple, citrus, litchi and guava form the major share while in vegetables, brinjal, cabbage, cauliflower, okra, onion, peas, potato and tomato form the major share of the State.

SECTION II: GEO-RESOURCES

Minerals and Mining

Uttarakhand has potential mineral reserves that can be exploited for industrial growth. Magnesite, Talc-Steatite, limestone, Dolomites are the minerals occurring in great abundance while ores of uranium, copper, lead, pyrite, gold and deposits of phosphorite, gypsum and graphite deposits are too small to be commercially profitable. The reserves of magnesite and cement grade limestone are tremendously large. However, non-systematic mining activity and unscrupulous practice has led to the destruction of resource and caused imbalance in local ecosystem.

Water Resources

Uttarakhand being a hilly State possesses varied hydrogeological regimes as well as fair amount of snow cover. It receives heavy rainfall during the monsoon period and snowfall, which is caused by winter depression during January to March. Two hydrogeological regimes i.e. Gangatic alluvial plain and the Himalayan mountain belt exist in the State where the former regime is capable for ground water development. Ground water in hilly parts of the State occurs mainly in fissures and fractures and emerges in the form of water streams such as, gadhera or springs. However, as regards surface water regimes, they are mainly due to three types of rivers such as, glacial fed rivers, non glacial fed rivers and rainfed rivers. Ganga, Yamuna, Ramganga, Kali, Kosi rivers etc. and their tributaries are the main surface water bodies. In addition to these, some lakes including Naini Lake, Sat Tal Lake, Naukuchiatal Lake also fulfil the water requirements in Uttarakhand. Concerning the water quality issues, the State has plenty of good quality of water except for some industrial or highly populated sites. Some problems plaguing the sector are hardness from hard rocks and coliform problems due to improper management of sewage.

Energy Resources

The energy need of the State is mostly met by hydropower. Uttarakhand has the identified capacity of hydropower potential of around 18 GW out of which only 2980 MW capacity has been tapped. There are 354 identified Small Hydro Power sites with the aggregate potential of 1478.24 MW. Among the large hydropower projects, Tehri project on Bhagirathi river is the largest with an installed capacity of 2000 MW. Besides this, solar energy generation also has scope in the State. In spite of this only 50 KW of grid and 80 KW of off-grid solar power has been generated till Jan 2011. Other sources of clean energy available in the State are geothermal, wind and biomass.

Glaciers

Upper reaches of Ganga basin falls within the Uttarakhand Himalayas, which includes Yamuna, Bhagirathi, Alaknanda, Kaliganga (Ghaghra) etc. Total number of glaciers identified in this part is 968 with 213.74 km^3. Total ice volume and the glacier covered area is about 2,883 sq. km, which is 9% of the basin area. Largest number of glaciers totalling to 407 has been identified in the Alaknanda basin that occupies 1,255 sq. km, which account for almost 11% of total basin area. Yamuna basin has the least number of glaciers, numbering 52, occupying 143.43 sq. km as the glacier covered area, which comes to just about 2% of the total basin area.

SECTION III: CLIMATE CHANGE

Climate Change

This chapter provides preliminary results of climate change impact studies on temperature and rainfall, snow cover and glaciers, biodiversity, streams and rivers, agriculture and other sectors conducted in Uttarakhand and also embraces an overview of long term action plan initiated by Uttarakhand Climate Change Center (UCCC) for climate change impacts mitigation in association with villagers, government departments and scientists. It demonstrates that due to anthropogenically accelerated climate change since the last five decades, the temperature has increased by 0.45^{o}C and the amount of annual rainfall has gone down to about 23% low; the glaciers are steadily retreating and the snow cover is depleting consequently the vegetation line is shifting towards higher altitudes; the non-glacial fed rivers are being transformed from perennial to non-perennial rivers; due to lack of water, the irrigated land is being changed into non-irrigated land, therefore, the production of irrigated crop, viz., paddy has gone down 41% to 52% during the last one decade; due to changes in rainfall rhythm, delay in onset, rainfall during maturity period of crops and erratic behavior of rainfall have caused significant loss in crop yield in the rain fed agricultural regime; and there are many signatures of phonological changes, reduction in fruits production and shifting of fruit belts towards higher elevation. It also suggests that the highly vulnerable sectors for impact of climate change in Uttarakhand are agriculture, food and livelihood security; human health and environment; glaciers and snow cover; groundwater recharge and summer flows in springs, streams and rivers; water quality; biodiversity (flora and fauna); agro forestry and ecosystem; disaster and hazard risks; tourism; industry and human settlement; trade retail and commerce; electricity; policy and governance.

SECTION IV: DISASTER

Disaster Scenario and Management

Uttarakhand due to its complex geographical setting is vulnerable to geological disasters. The State is among the most seismically active parts of India. Landslide, flash floods and cloud burst are seasonal in nature but earthquakes and road accidents are the most devastating and unpredictable. So far, in the recent years (1990 onwards) Uttarakhand has experienced 53 earthquakes of which two major ones (magnitude >6) were in Uttarkashi (1991) and Chamoli (1999) and also a series of landslides/cloud bursts. Since 2005-2011, the State has lost 785 human lives and 443 were injured due to natural disasters. Around 62 landslides have been reported across the State since 2002. The human loss pertaining to landslide/flash floods during the last decade was to the tune of 721.

SECTION V: HEALTH

Health Status

The State houses around 0.8% of the population of India. The crude birth rate (CBR), crude death rate (CDR), total fertility rate (TFR) and Infant mortality rate (IMR) are less than the national values. Immunization percentage (62.9%) of children below 23 months is also higher than the National value (54.1%). Thus, the State's efforts towards population control and achieving replacement level of population have been bearing fruits. However, maternal mortality ratio is higher than the national value and percentage of institutional deliveries are also less than the national average. Due to its unique climatic conditions disease outbreaks like malaria, kala-azhar are almost nil. However, Jaundice, Diarrhoea and food poisoning are the major outbreaks experienced in the State.

SECTION VI: INDUSTRY

Landscape of Industries

When Uttarakhand came to existence in 2000 as a separate State, it had few resources for upliftment of its economy. The State was then known as "zero industry region". Banking on the strength of the State in terms of good connectivity, perfect location, cheap and abundant power and highly educated human resource, the State was able to develop the industrial infrastructure in a very short span of time. SIDCUL successfully developed Haridwar, Pantnagar, Selaqui industrial areas. All this had a direct effect on the State GDP with an increase of more than 9% from 2000 to 2007. During this period the industrial sector growth rate was 17.2%. Afterwards also the growth of GDP was upward with 33.9% in 2007-08. The State has 36,928 registered Micro, Small and Medium Enterprises and 206 heavy industries (till 2010). The State registered an increase of 211% in MSMEs and 318% in heavy industries after its formation. The unprecedented growth of industries is due to cumulative effect of existing conducive environment and favourable policies for the industries.

SECTION VII: TOURISM

Tourism and Ecotourism

Situated among the rising peaks of Himalayas, patronizing the source glaciers of river Ganga and Yamuna, presence of exotic natural beauty, remote areas virgin from human interference, locations preserving scenic sites are features resource for tourism in the State. The State in itself is reserve of geographical resources having all major relief features from mountains to glaciers, Bugyals and plain agricultural lands of Haridwar, major river systems of Ganga and Yamuna, highland lakes like Roopkund, Nainital, Naukuchiatal & Chhatrakund, bio-diversity rich valleys like Valley of Flowers etc. Along the geographical relief the State is also blessed with a rich forest cover and bio-diversity, housing 6 National parks, 6 Sanctuaries and 1 Biosphere Reserve.

Together the two (topography and wildlife) makes the State a paradise for adventure lovers and caters them with the facilities to experience the rare. But the real jewel in the crown is spiritual essence of the State. Uttarakhand has a pleasure to have the presence of few of the major holy towns, pilgrimages and temples of Northern India. Every year lakhs of devotees from across the world visits these places in search of peace. With all these exotic locations, geographical landforms, rivers, forest and wildlife the State is the destination for all.

UTTARAKHAND : FACTS AND FIGURES[1,2]

S.No.	Items	Year/Period	Unit	Statistics
	GENERAL INFORMATION			
(A) Geographical Data				
1	Latitude	-	-	$28^0$43′ N to $31^0$27′ N
2	Longitude	-	-	$77^0$34′ E to $81^0$02′ E
3	Geographical Area	2010	Sq. Km.	53483
	(i) Hill	2010	Sq. Km.	46035
	(ii) Plain	2010	Sq. Km.	7448
4	Forest Area	2010	Sq. Km.	34651
(B) Meteorological Data				
1	Average Rainfall	2009	m. m.	1606
2	Temperature			
	(i) Minimum (Mukteshwar)	2009	^{0}C	-1.7
	(ii) Maximum (Pantnagar)	2009	^{0}C	42.0
(C) Administrative Units		-	-	-
1	Divisions	2010	No.	02
2	Districts	2010	No.	13
3	Tehsils	2010	No.	78
4	Development Blocks	2010	No.	95
5	Nyaya Panchayats	2010	No.	670
6	Gram Panchayats	2010	No.	7541
7	Census Villages (As per 01 census)	2001	No.	16826
	(i) Inhabited Villages (Including Forest Settlements)	2001	No.	15761
	(ii) Un-inhabited Villages	2001	No.	1065
8	Town/Urban Agglomeration			
	(i) Municipal Corporation	2010	No.	01
	(ii) Nagar Palika Parishads	2010	No.	32
	(iii) Nagar Panchayats	2010	No.	30
	(iv) Cantonment Boards	2010	No.	09
	(v) Census Towns	2001	No.	12
	(vi) Industrial Townships	2001	No.	02
9	Development Authority	2010	No.	06
10	Lok Sabha constituency	2010	No.	05
11	Rajya Sabha Constituency	2010	No.	03
12	Vidhan Sabha Constituency	2010	No.	70
	POPULATION (2011 Census)			
(A)	Total	2011	No.	10116752
(B)	Rural	2011	No.	7025583
(C)	Urban	2011	No.	3091169
(D)	District Population:	-	-	-

S.No.	Items	Year/Period	Unit	Statistics
	(i) Uttarkashi	2011	No.	329686
	(ii) Chamoli	2011	No.	391114
	(iii) Tehri Garhwal	2011	No.	616409
	(iv) Rudraprayag	2011	No.	236857
	(v) Dehradun	2011	No.	1698560
	(vi) Haridwar	2011	No.	1927029
	(vii) Pauri Garhwal	2011	No.	686527
	(viii) Pithoragarh	2011	No.	485993
	(ix) Bageshwar	2011	No.	259840
	(x) Almora	2011	No.	621927
	(xi) Champawat	2011	No.	259315
	(xii) Nainital	2011	No.	955128
	(xiii) Udham Singh Nagar	2011	No.	1648367
	DEMOGRAPHY			
(A) Literates (Age above 6 Years) (Provisional)				
1	**Total**	2011	Lakh	69.97
	(i) **Male**	2011	Lakh	39.30
	(ii) **Female**	2011	Lakh	30.67
(B) Literacy Rate				
1	**Total (Provisional)**	2011	%	79.63
	(i) **Male**	2011	%	88.33
	(ii) **Female**	2011	%	70.70
(C) Sex-wise Labour Force (Total Workers)				
1	Total	2001	Lakh	31.34
	(i) Male	2001	Lakh	19.96
	(ii) Female	2001	Lakh	11.38
	Rural	2001	Lakh	24.99
2	(i) Male	2001	Lakh	14.37
	(ii) Female	2001	Lakh	10.62
(D) Category-wise Labour Force				
1	Main Workers	2001	Lakh	23.22
	(i) Cultivators	2001	Lakh	10.67
	(ii) Agricultural Labourers	2001	Lakh	1.43
	(iii) Household Industry Workers	2001	Lakh	0.49
	(iv) Other Workers	2001	Lakh	10.63
2	Marginal Workers	2001	Lakh	8.12
	(i) Cultivators	2001	Lakh	5.03
	(ii) Agricultural Labourers	2001	Lakh	1.17
	(iii) Household Industry Workers	2001	Lakh	0.23
	(iv) Other Workers	2001	Lakh	1.69
	AGRICULTURE			
(A) Land-use				
1.	Total Reported Area	2008-2009	Hectare	5672568
2	Forest Area	2008-2009	Hectare	3485847
3	Culturable Waste Land	2008-2009	Hectare	303144

POLITICAL MAP OF UTTARAKHAND

Source:
Modified from planning Atlas of Uttar Pradesh, 1987
Planning Department, Government of Uttar Pradesh, Lucknow

S.No.	Items	Year/Period	Unit	Statistics
4	Fallow Land	2008-2009	Hectare	106128
	(i) Current Fallow	2008-2009	Hectare	35161
	(ii) Fallow Land other than Current Fallow	2008-2009	Hectare	70967
5	Barren & Unculturable Land	2008-2009	Hectare	224480
6	Land under Non-agricultural Uses	2008-2009	Hectare	216534
7	Permanent Pasture & Other grazing Land	2008-2009	Hectare	198737
8	Land under misc., Tree Crops and Groves not included in Net Area Sown	2008-2009	Hectare	383987
9	Net Area Sown	2008-2009	Hectare	753711
(B) Fertiliser Consumption				
1	Nitrogen (N)	2009-2010	M.T.	104101
2	Phosphorus (P)	2009-2010	M.T.	24785
3	Potash (K)	2009-2010	M.T.	6910
	IRRIGATION			
(A) Net and Gross Irrigated Area				
1	Canals	2008-2009	Hectare	95922
2	Tube Wells	2008-2009	Hectare	198193
3	Other Wells	2008-2009	Hectare	15587
4	Tanks	2008-2009	Hectare	770
5	Other Sources	2008-2009	Hectare	29657
6	Net Irrigated Area (NIA)	2008-2009	Hectare	340129
7	Gross Irrigated Area (GIA)	2008-2009	Hectare	569769
(B) Irrigation Infrastructure				
1	Length of Canals	2009-2010	Km.	11081
2	Length of Lift Canals	2009-2010	Km.	201
3	Tube Wells (State)	2009-2010	No.	981
4	Pump Sets (Boring/ Free Boring)	2009-2010	No.	54361
5	Hauj	2009-2010	No.	29507
6	Gool	2009-2010	Km.	23715
7	Hydrum	2009-2010	No.	1493
8	C.C.A. Under State Canal	2009-2010	Lakh Hect.	3.18
9	Revenue Collection by Irrigation	2009-2010	` Lakh	243.61
	LIVESTOCK AND POULTRY			
(A) Veterinary Services				
1	Infrastructure			
	(i) Veterinary Hospitals	2009-2010	No.	310
	(ii) 'D' Category Veterinary Hospitals	2009-2010	No.	12
	(iii) Livestock Centres			
	(iv) A. I. Centres/Sub Centres	2009-2010	No.	634
		2009-2010	No.	573

S.No.	Items		Year/Period	Unit	Statistics
(B) Livestock (Provisional)					
1	Cattle				
	(i)	Cow and Bullocks (Desi)	2007	No.	1895689
	(ii)	Cow and Bullocks (Cross Breed)	2007	No.	339427
	(iii)	Buffalo	2007	No.	1219518
2	Other Livestock				
	(i)	Sheep (Desi & Cross Breed)	2007	No.	290411
	(ii)	Goats	2007	No.	1335306
	(iii)	Horse & Mules	2007	No.	39525
	(iv)	Dunkeys	2007	No.	1262
	(v)	Pig (Desi & Cross Breed)	2007	No.	19822
	(vi)	Other Animals (Dogs & Rabbits)	2007	No.	257009
3	Total Livestock [Excluding cat.2 (VI)]		2007	No.	5140960
(C) Poultry					
1	Hen/Cock/Chicks		2007	No.	2562861
2	Other Birds		2007	No.	38991
		FISHERIES			
1	Departmental Fish Farms		2009-2010	No.	11
2	(i)	Fish Production	2009-2010	'000 M.T.	3,488
	(ii)	Value of Production	2009-2010	` Lakh	2219.87
3	Production of Fish Seed		2009-2010	Lakh	344.83
		HORTICULTURE			
(A) Horticulture Services					
1	Infrastructure				
	(i)	Horticulture Mobile Teams	2009-2010	No.	285
	(ii)	Fruit Preservation Centres	2009-2010	No.	48
	(iii)	State Nurseries/Orchards	2009-2010	No.	104
(B) Coverage and Production					
1	Fruits				
	(i)	Area	2009-2010	Hectare	193787
	(ii)	Production	2009-2010	M.T.	723554
2	Vegetables				
	(i)	Area	2009-2010	Hectare	58451
	(ii)	Production	2009-2010	M.T.	564281
3	Potato				
	(i)	Area	2009-2010	Hectare	24331
	(ii)	Production	2009-2010	M.T.	432236
	(iii)	Productivity	2009-2010	Qtl./ Hectare	177.6
		SERICULTURE			
1	Government Sericulture Farms				
	(i)	Farms	2009-2010	No.	72
	(ii)	Area	2009-2010	Acre.	507

S.No.	Items	Year/Period	Unit	Statistics
2	Mulberry Plantation			
	(i) In Government Farms	2009-2010	Thousand	92.6
	(ii) In Private Farms	2009-2010	Thousand	279.9
3	Cocoon Production	2009-2010	Kg.	111145
	INDUSTRY			
(A) Rural and Small Scale Industries				
1	Khadi Udhyog/Gramodhyog Units	2009-2010	No.	1210
2	Small Scale Industries (SSIs)	2009-2010	No.	35955
3	Total Employees of Khadi Units	2009-2010	No.	3750
4	Total Employees of SSIs	2009-2010	No.	142780
(B) Factories [Regd. Under Factories Act, 1948-Section 2M (I) and 2M (II)]				
1	No. of Factories	2008-2009	No.	1907
2	No. of Workers	2008-2009	No.	172861
3	Total Persons Engaged	2008-2009	No.	229727
4	Value of Product & by Product	2008-2009	` Lakh	6035210
5	Net Value Added	2008-2009	` Lakh	2843285
6	Value of Output	2008-2009	` Lakh	8292360
7	Gross Fixed Capital Formation	2008-2009	` Lakh	673613
8	Profits	2008-2009	` Lakh	2161819
	EDUCATION			
(A) Basic/Secondary Education				
1	No. of Schools/Colleges	2009-2010	No.	22379
	(i) Junior Basic	2009-2010	No.	15644
	(ii) Senior Basic	2009-2010	No.	4296
	(iii) High School/Intermediate	2009-2010	No.	2439
2	No. of Students	2009-2010	No.	2381594
	(i) Junior Basic	2009-2010	No.	1155639
	(ii) Senior Basic	2009-2010	No.	536216
	(iii) High School/Intermediate	2009-2010	No.	689739
3	No. of Teachers	2009-2010	No.	80421
	(i) Junior Basic	2009-2010	No.	36394
	(ii) Senior Basic	2009-2010	No.	12317
	(iii) High School/Intermediate	2009-2010	No.	31710
(B) Higher Education				
1	No. of Institutions	2009-2010	No.	122
	(i) Degree/Post Degree Colleges	2009-2010	No.	106
	(ii) Central Universities	2009-2010	No.	1
	(iii) State Universities	2009-2010	No.	6
	(iv) Private Universities	2009-2010	No.	5
	(v) Deemed Universities	2009-2010	No.	4
	(vi) Indian Institute of Technology (Central University)	2009-2010	No.	1
2	No. of Students	2009-2010	No.	163996

S.No.	Items		Year/Period	Unit	Statistics
3	No. of Teachers		2009-2010	No.	1684
	(i)	Degree/Post Degree Colleges	2009-2010	No.	1180
	(ii)	Universities	2009-2010	No.	504
(C) Vocational and Technical Education					
1	Industrial Training Institutes		2009-2010	No.	106
	(i)	Sanctioned Seats	2009-2010	No.	10388
	(ii)	Admission	2009-2010	No.	6275
2	Polytechnics		2009-2010	No.	37
	(i)	Sanctioned Seats	2009-2010	No.	4320
	(ii)	Admission	2009-2010	No.	4053
3	Distt. Instt. of Educ. Training		2009-2010	No.	13
	(i)	Sanctioned Seats	2009-2010	No.	1300
	(ii)	Admission	2009-2010	No.	1300
PUBLIC HEALTH AND FAMILY WELFARE					
(A) State Allopathic Hospitals and Dispensaries					
	(i)	District Level Hospitals	2009-2010	No.	12
	(ii)	District Female Hospitals	2009-2010	No.	7
	(iii)	Base Hospitals	2009-2010	No.	3
	(iv)	P.H.C./Additional P.H.C.	2009-2010	No.	250
	(v)	Community Health Centres	2009-2010	No.	55
	(vi)	State Allopathic Hospitals	2009-2010	No.	322
	(vii)	Joint/Women Hospitals	2009-2010	No.	39
	(viii)	Tehsil/Distt. Level Post Mortem Centres	2009-2010	No.	24
	(ix)	Health Posts	2009-2010	No.	9
	(x)	Tuberculosis Hospitals/Clinics	2009-2010	No.	18
	(xi)	Leprosy Hospitals	2009-2010	No.	3
	(xii)	Beds in Govt. Hospitals	2009-2010	No.	8075
(B) Family Welfare Services					
	(i)	Women & Child Welfare Centres	2009-2010	No.	2
	(ii)	Main Centres	2009-2010	No.	84
	(iii)	Women & Child Welfare Sub-Centres	2009-2010	No.	1765
(C) Ayurvedic & Unani Hospitals					
	(i)	Ayurvedic Hospitals	2009-2010	No.	540
	(ii)	Unani Hospitals	2009-2010	No.	5
(D) Homeopathic Hospitals/Dispensaries			**2009-2010**	**No.**	**107**
ELECTRICITY AND WATER SUPPLY					
(A) Installation Capacity			**2009-2010**	**MW.**	**1305.90**
(B) Electricity Generated (Gross)			**2009-2010**	**MU**	**4126.55**
(C) Length of Lines					
	(i)	400 KV	2009-2010	Km.	172
	(ii)	220 KV	2009-2010	Km.	631
	(iii)	132 KV	2009-2010	Km.	1340
	(iv)	33 KV	2009-2010	Km.	3888.15
	(v)	11 KV	2009-2010	Km.	32942.28
	(vi)	LT	2009-2010	Km.	48061.72

S.No.	Items	Year/Period	Unit	Statistics
(D) Electricity Consumption				
	(i) Domestic	2009-2010	M.U. Watt.	1387.23
	(ii) Commercial	2009-2010	M.U. Watt.	865.96
	(iii) Industrial	2009-2010	M.U. Watt.	3399.16
	(iv) Street Lighting	2009-2010	M.U. Watt.	51.42
	(v) Agriculture	2009-2010	M.U. Watt.	298.15
	(vi) Water Works/Waste Disposal	2009-2010	M.U. Watt.	247.30
(E) Rural Electrification				
1	Electrified Inhabited Revenue Villages:-			
	(i) Uttarakhand Power Corporation			
	(ii) UREDA	2009-2010	No.	15270
		2009-2010	No.	266
2	Energised Pump Sets/Tube Wells	2009-2010	No.	21915
3	Kuteer Jyoti Connections	2009-2010	No.	253802
(F) Drinking Water Supply				
1	Inhabited Revenue Villages Covered	2009-2010	No.	15545
2	Population Covered	2009-2010	No. Lakh	62.58
	(i) Fully Covered	2009-2010	No. Lakh	50.24
	(ii) Partially Covered	2009-2010	No. Lakh	12.34
3	Scarcity Villages	2009-2010	No.	02
4	Scarcity Hamlets			
	(i) Not Covered (N.C)	2009-2010	No.	2638
	(ii) Partially Covered (P.C.)	2009-2010	No.	8514
5	Hand Pump Installed by			
	(i) Jal Nigam	2009-2010	No.	21862
	(ii) Jal Sansthan	2009-2010	No.	7072
6	"Uttarakhand Koop" installed by Jal Sansthan	2009-2010	No.	1381
FOREST AND WILDLIFE				
(A) Classification of Forest Area According to Legal Status				
1	Reserved Forests	2009-2010	Sq. Km.	24643
	(i) Reserved Forests under the Control/ Management of Forest Department	2009-2010	Sq. Km.	24261
	(ii) Reserved Forests which is Completely Recorded in Van Panchayats	2009-2010	Sq. Km.	348
	(iii) Reserved Forests under the Control/ Management of other Government Agencies	2009-2010	Sq. Km.	34

S.No.	Items	Year/Period	Unit	Statistics
2	Protected Forests	2009-2010	Sq. Km.	9885
	(i) Protected Forests Under the Control/ Management of Forest Department	2009-2010	Sq. Km.	99
	(ii) Unclassified and Vasted Forests under the control/Management of Forest Department, which have Legal Status of Protected Forest	2009-2010	Sq. Km.	55
	(iii) Civil and Soyam Forest:			
	Under the Control of Revenue Department			
	Under the Control of Forest Panchayats as Village Forests	2009-2010	Sq. Km.	4769
		2009-2010	Sq. Km.	4962
3	**Private Forest (Municipal & Cantonment etc.)**	**2009-10**	**Sq. Km.**	**123**
(B) Growing Stock & Forest Produce Statistics				
1	Estimated Growing Stock	2009-10	'000 Cu. m.	249939
2	Timber Production	2009-10	Cu. m. Round	242621
3	Fire Wood Production	2009-10	Cu. m. Stack	29263
4	Resin (NTFP) Production	2009-10	Quintals	196075
(C) Wildlife				
1	National Park			
	(i) Number	2009-10	No.	6
	(ii) Area	2009-10	Sq. Km.	4915
2	Wildlife Sanctuary			
	(i) Number	2009-10	No.	6
	(ii) Area	2009-10	Sq. Km.	2420
3	Important Wild Animals			
	(i) Tiger	2008	No.	178
	(ii) Leopard	2008	No.	2335
	(iii) Elephant	2008	No.	1346
	(iv) Musk Deer	2008	No.	376
	(v) Black Bear	2008	No.	1935
	(vi) Sloth Bear	2008	No.	172
	(vii) Brown Bear	2008	No.	14
		TOURISM		
(A) Infrastructure				
1	Tourist Places	2009-10	No.	264
2	Tourist Rest Houses (T.R.H.)	2009-10	No.	184
3	Raien Basera (Night Shelters)	2009-10	No.	32
4	Beds in T.R.H.	2009-10	No.	6817
5	Beds in Raien Basera	2009-10	No.	1750
6	Hotels & paying guest Houses (as on 31-03-2010)	2009-10	No.	3126
7	Dharamshala (as on 31-03-2010)	2009-10	No.	867

S.No.	Items	Year/Period	Unit	Statistics
(B) Tourist Arrival				
1	In Tourist Places (including Pilgrims)	2010	No. Lakh	311.08
	(i) Indian Tourist	2010	No. Lakh	309.72
	(ii) Foreign Tourist	2010	No. Lakh	1.36
2	In Important National Parks and Wild Life Sanctuaries	2009-10	No.	301241
	(i) Indian Tourist	2009-10	No.	285412
	(ii) Foreign Tourist	2009-10	No.	15829
	FOOD AND CIVIL SUPPLY			
1	Distribution of Essential Commodities			
	(i) Petrol	2009-10	Kilo lts.	196004
	(ii) Diesel	2009-10	Kilo lts.	522488
	(iii) Kerosene Oil	2009-10	Kilo lts.	114740
	(iv) LPG Gas	2009-10	M.T.	152996
	(v) Levy Sugar	2009-10	M.T.	45567
	UTTARAKHAND RENEWABLE ENERGY DEVELOPMENT AGENCY (UREDA)			
1	Community Solar Cooker	2009-10	No.	210
2	Improved Gharat	2009-10	No.	137
3	Solar Photo Programme			
	(i) Solar Light-Domestic	2009-10	No.	76
	(ii) Solar Lantern	2009-10	No.	1840
	(iii) Solar Light-Street	2009-10	No.	1427
4	Winowing Fan	2009-10	No.	51
5	Solar Water Heater	2009-10	No.	33900
	RURAL DEVELOPMENT			
(A) Rural Poverty (BPL Census 2002)				
	(i) Families Below Poverty Line	2002	No.	622033
	(ii) Percentage of Families Below Poverty Line	2002	Percentage	47.1
(B) Swarn Jayanti Gram Swarojgar Yojna				
	Self Help Groups Formed (As on 31-03-2010)	2009-10	No.	27812
(C) Indira Awas Yojna				
	Construction of Houses during the year	2009-10	No.	20513

References

1. Uttarakhand at a Glance 2010-11, *Directorate of Economics and Statistics, Dehradun, Uttarakhand*; http://des.uk.gov.in/files/pdf/uttarakhand at a glance english.pdf; accessed on 20/04/2012.
2. Census of India, ***Provisional population totals***, Paper 2, Volume 1 of 2011, Rural and urban distribution, Uttarakhand Series 6, 2011.

Compiled by
Bhavtosh Sharma

Section I

BIO-RESOURCES

Biodiversity

Chapter
ONE

BIODIVERSITY

(Manju Sundriyal, DP Uniyal and Nasreen Jeelani)

1.1. Introduction

Biodiversity is the variety of life comprising plants, animals and microorganisms including the genetic information they contain and the ecosystems they form. Biodiversity is considered at three levels, *viz.* genetic, species and ecosystem diversity, which together form the complexity of life on the globe. Biodiversity provides goods and services to human beings and essential for maintaining ecological functions including stability of food production, stabilizing hydrological cycle, maintaining and replenishing fertility of soil, plant pollination and cross-fertilization, control of soil erosion and various other ecosystem functions. In other words biodiversity offers foundation for livelihoods, cultures and economies of several hundred millions of people on the earth. It provides raw material for a diverse medicinal and health care systems. India is one of the twelve mega biodiversity countries of the world. The other countries are Brazil, Colombia, Ecuador, Peru, Mexico, Madagascar, Zaire, Australia, China, Indonesia and Malaysia. The mega biodiversity countries together comprise as much as 60 – 70% of the world species. A global hot spot region must meet two strict criteria, it must contain at least 0.5% or 1,500 species of vascular plants as endemics, and it has to have lost at least 70% of its primary vegetation[1].

India contains 2.4% of the world's land area, 16.7% of the world's human population, 18% livestock and about 8% of the total global biodiversity. The Convention on Biodiversity estimated that 40% of the world's economy and 80% of the needs of the poor are derived from biological resources. Besides, the biodiversity provides the opportunities for medical discoveries, economic development, and adaptive responses to many new challenges such as climate change. Biodiversity boosts ecosystem productivity where each species has a definite role to play. For example, a larger number of plant species means a greater variety of crops, greater natural sustainability for all life forms, and healthy ecosystems that can better withstand and recover from a variety of disasters. And so, while we dominate this planet, we still need to preserve the diversity in wildlife. Unfortunately last few decades have registered a rapid erosion of biodiversity that impacted natural habitats, land, water bodies and health of the people. It is therefore important that people on the earth are educated to understand importance of the biodiversity and the implication of the biodiversity loss. Efforts are required to analyse biodiversity at regional level so as to identify issues that can be addressed for taking up mitigation measures to manage and conserve biodiversity[1,2].

1.2. Biodiversity Profile of Uttarakhand

The Uttarakhand Himalaya has its unique setting within the Western Himalayan region. It exhibits rich biodiversity because of high topographic, climatic and altitudinal variations. The floral and faunal biodiversity of the state attracted the naturalists, wildlifers, taxonomists and conservationists since time immoral. It is estimated that there are about 7000 species of plants in the state though till date only 85% flora explored.

Of the total floral diversity explored, 74% comprised flowering plant diversity. It is interesting to note that the floral diversity of the state contributes 31% of total floral density of India. On the other hand the faunal diversity contributes just 1.58% of the total faunal density of the country. The pteridophytic, gymnospermic and angiospermic diversity of Uttarakhand contributes 33.2, 54.5 and 28.9% of the respective diversity of the country, (Fig. 1.1, Table 1.1)

The faunal diversity[3,4,5,6,7,8,9,10,11,12,13,14,15,16] and floristic diversity[17,18,19,20,21,22,23] of Uttarakhand has been explored by many workers.

The mollusca, arthropod, pisces, amphibians, reptiles and aves diversity of the state contributes 2.55, 0.19, 5.58, 9.71, 15.46 and 12.69% of the respective diversity of the country

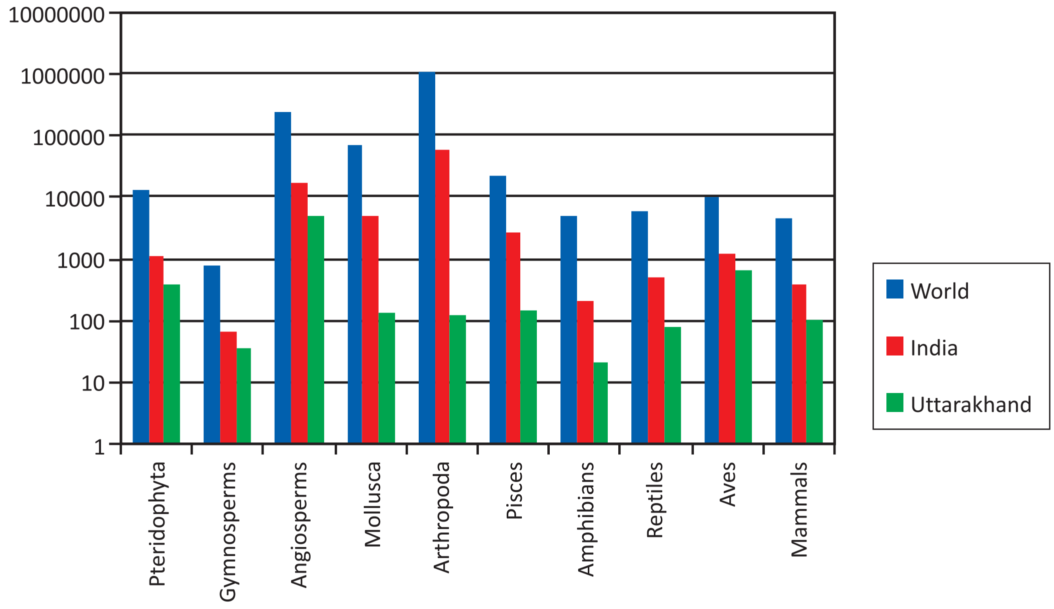


Fig-1.1.
Biological diversity of Uttarakhand state.

Table–1.1.
Comparison of the floral and faunal diversity of Uttarakhand with India and world[2,4,7,15,22,23,24,38].

Taxa	Number of Species			% of India to the World	% of Uttarakhand to India
	World	India	Uttarakhand		
Pteridophyta	13000	100	365	8.46	33.18
Gymnosperm	750	64	35	8.53	54.69
Angiosperm	250000	17500	5061	7	28.92
Mollusca	70000	5050	129	7.21	2.55
Arthropoda	1065000	60383	116	5.67	0.19
Pisces	21723	2546	132	11.72	5.58
Amphibians	5145	206	20	4.00	9.71
Reptiles	5680	485	75	8.54	15.46
Aves	9672	1228	622	12.70	12.69
Mammals	4629	372	100	8.04	26.88

(Fig. 1.1, Table 1.1). The state comprise 500 species of fauna of which 80% are invertebrates and 20% vertebrates.

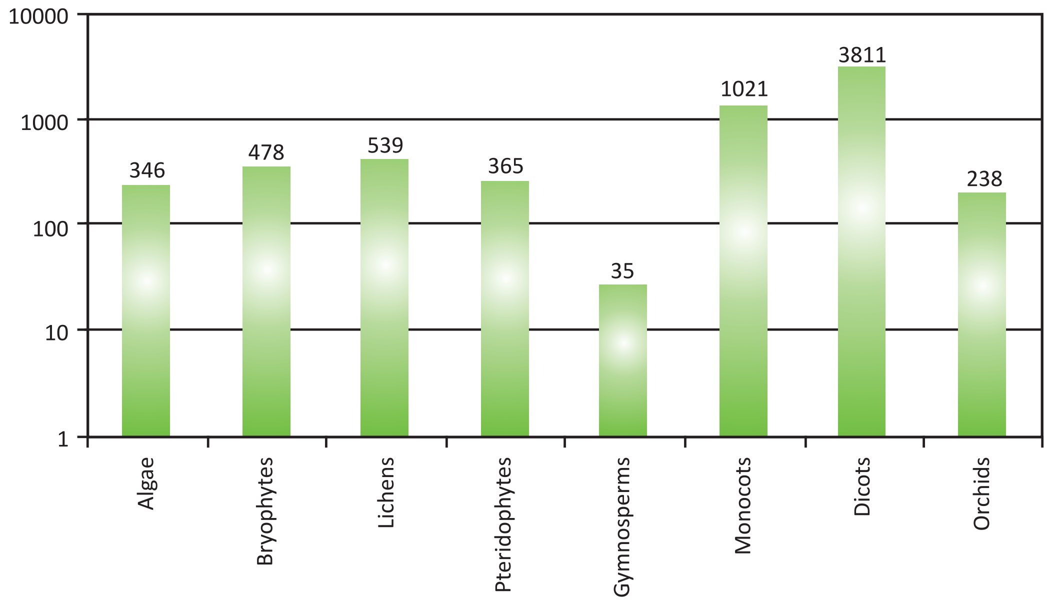
The vertebrate diversity of Uttarakhand, embracing mammals, birds, reptiles, amphibians and pisces together constitutes 28.2% of its total faunal diversity (1060 out of 3784 species). The invertebrate diversity of Uttarakhand belong to 19 major groups covering from Protozoa, Trematoda, annelida, Crustacea, Chilopoda, Aranae, Acari, Insecta, forms 71% of the total faunal diversity (Fig. 1.3) of the state (2688 species out of 3784). The total microbial diversity is depicted in Table 1.2. The total number of microbes reported[36] in the State are 1616.

The state comprises nearly 5061 angiospermic species in 1503 genera and 213 families. The state houses 27% species and 50% generic diversity of Indian flowering plants. Dicots contribute for more than 75% of flowering species, genera and families (Fig. 1.2). There

are 3811 dicot species under 1163 genera and 182 families, and 1250 monocots in 340 genera and 31 families[2].

The ratio between the Dicot and Monocot species is about 3:1 which corresponds to the ratio exhibited by the Indian flora. Many species of flowering plants are also introduced in the state.

Fig-1.2.
Floral diversity (no. of species) in different major groups in Uttarakhand[17,24,34,38,42,44,48]



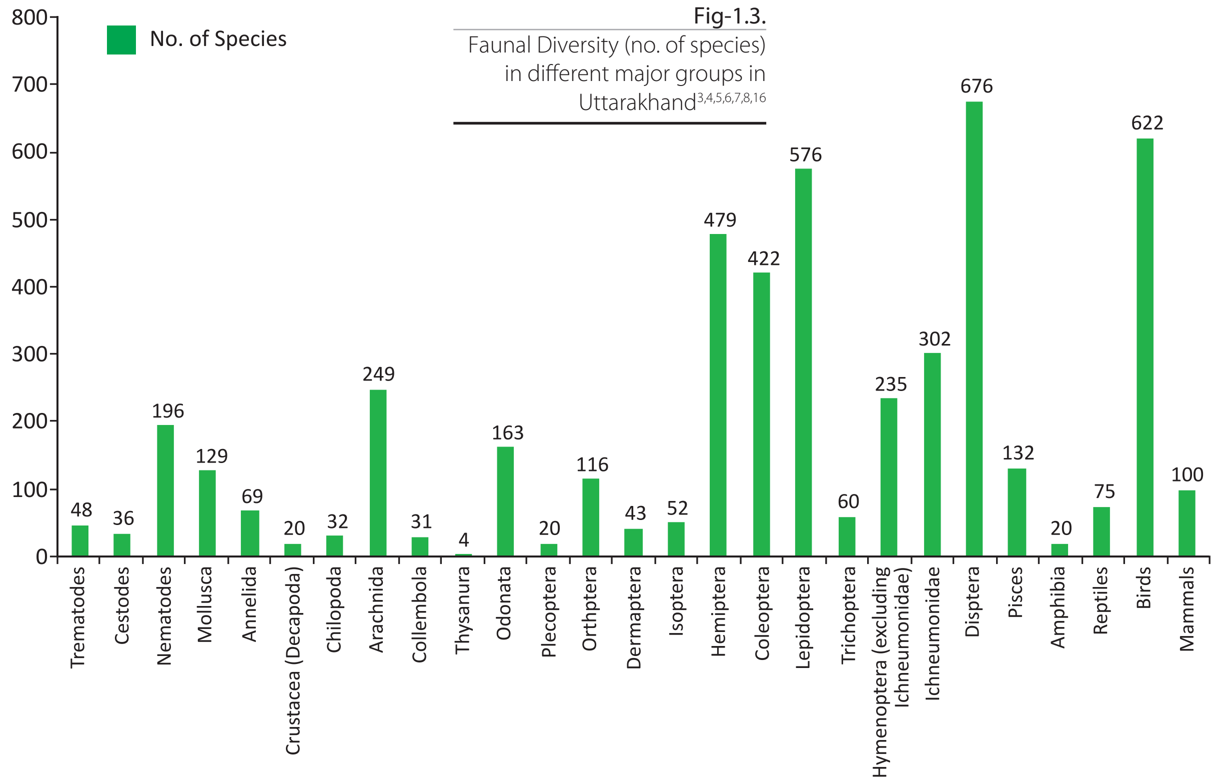


Fig-1.3.
Faunal Diversity (no. of species) in different major groups in Uttarakhand[3,4,5,6,7,8,16]

Table–1.2.
Microbial diversity in Uttarakhand[36].

Group	Number of Species
Microbes	
Bacteria	93
Fungi	1224
Diatoms	264
Protozoa (Coccidia)	35
Total	**1616**

1.2.1. Endemism in Flora and Fauna

An endemic species is only found in a given region or location and nowhere else in the world. The endemism can be defined as 'site endemic' (e.g. just a mountain), 'national endemic' (e.g. found only in India), and 'geographical range endemic' (e.g. found in the Himalayan region, which however covers several Himalayan countries and therefore is not a national endemic). The flora and fauna of Uttarakhand state exhibit considerable high endemism by virtue of being a relatively younger mountain system. The Western Himalaya is one of the three major geomorphological divisions considered as mega centres of endemic plants with Garhwal and Kumaon Himalaya. India has 5725 endemic species of flowering plants of which 3471 species found in the Himalaya comprising Uttarakhand state. Families Acanthaceae and Poaceae have the largest number of endemic genera (7 each). Ten families like Asteraceae, Apiaceae, Rosaceae, Saxifragaceae, Ranunculaceae, Poaceae have largest number of endemics. The genera like *Saxifraga, Primula, Taraxacum, Astragalus, Impatiens* and *Berberis* have maximum representation of endemic species. It is interesting to note that 119 species of flowering plants are endemic to state that exhibited 2.35% endemism in this group. There are total 35 faunal endemic species including 11 vertebrates and 24 invertebrates in the state (Table 1.3).

Table-1.3.
Some endemic flora and fauna of Uttarakhand[2,3,4,6,7,14,21,22,48,50,54]

Flora	Family
Acer oblongum var. *membranaceum* Banerji	Aceraceae
Aconogonum kuttiense Maiti, Dutta & Babu	Polygonaceae
Agrostis tungnathii S. Bhattacharyya & Jain	Poaceae
Alchemilla chthamalea Rothm.	Rosaceae
Alchemilla palii Panigrahi & Purohit	Rosaceae
Androsace garhwalicum Balodi & S. Singh	Primulaceae
Anemone raui Goel & Bhattach.	Ranunculaceae
Alysicarpus hamosus Edgew.	Fabaceae
Aphragmus oxycarpus (Hook. f. & Thomson) Jafri var. *stenocarpa* (O. Schwz) GC. Das	Brassicaceae
Aphyllorhis gollanii Duthie	Orchidaceae
Arenaria curvifolia Majumdar	Caryophyllaceae
Arenaria ferruginea Duthie ex F. Williams	Caryophyllaceae
Aristolochia gourigangaica N.C. Nair	Aristolochiaceae
Artemisia filiformilobulata Ling & Puri	Asteraceae
Artemisia austrohimalayana (Ling & Puri) Ling & Puri	Asteraceae
Artemisia tenuifolia Ling & Puri	Asteraceae
Astragalus aegacanthoides Parker	Fabaceae
Astragalus bakeri Ali	Fabaceae
Astragalus maxwellii Royle ex Benth	Fabaceae
Berberis affinis D. Don	Berberidaceae
Berberis ahrendtii R.R. Rao & Uniyal	Berberidaceae
Berberis coriaria var. *patula* Ahrendt	Berberidaceae
Berberis lambertii Parker	Berberidaceae
Berberis osmastonii Dunn	Berberidaceae
Berberis petiolaris var. *garhwalana* Ahrendt	Berberidaceae
Calamagrostis nagarum (Bor) G. Singh	Poaceae
Carex kumaonesis Kuekenth	Cyperaceae
Carex nandadeviensis Ghildyal, U.C. Bhattach. & Hajra	Cyperaceae
Choerospondias auriculata D. Chandra	Anacardiaceae
Cicerbita filicina Iduthie ex Stebbi*ns* Mamgain & R.R. Rao	Asteraceae
Clematis connate DC. var. *lanceolata* Sas Biswas	Ranunculaceae
Corydalis boweri Hemsley	Fumariaceae
Corydalis duthiei Maxim	Fumariaceae
Cotoneaster garhwalensis Klotz	Rosaceae
Cotoneaster gilgitensis Klotz	Rosaceae
Cotoneaster osmastonii Klotz	Rosaceae
Cotoneaster pangiensis Klotz	Rosaceae
Cotoneaster parkinsonii Panigrahi & Arv. Kumar	Rosaceae
Cotoneaster prostrates Baker	Rosaceae

Flora	Family
Cotoneaster stracheyi Klotz	Rosaceae
Cotoneaster wattii Klotz	Rosaceae
Crotalaria sessiliflora L. var. *sessiliflora* f. *garhwalensis* A. Ansari & Thoth	Fabaceae
Cyananthus integer Wallich ex Benth	Campanulaceae
Cyathopus sikkimensis Stapf	Poaceae
Dendrobium normal falc	Orchidaceae
Dendrocalamus somdevaii H.B. Naithani	Poaceae
Dilophia purii Rawat, Dangwal & R.D. Gaur	Brassicaceae
Dipcadi reidii Deb & Dasgupta	Liliaceae
Elaeagnus kanaii var. *osmastonii* Malhotra & Basu	Elaeagnaceae
Erythrina resupinata Roxb	Fabaceae
Euphorbia duthiei Sur	Poaceae
Euphorbia sharmae U.C. Bhattach	Euphorbiaceae
Festuca nandadevica Hajra	Poaceae
Gentiana harwanensis G. Singh	Gentianaceae
Gentiana prostrate Hance var. *acuminate* (C.B. Clarke) S. Agrawal	Gentianaceae
Gentiana saginoides Burkill	Gentianaceae
Gentiana tetrasepala Biswas	Gentianaceae
Geum aequilobatum Purohit & Panigrahi	Rosaceae
Gouania leptostachya DC. var. *nainitalensis* Bhandari & Bhansali	Rhamnaceae
Guillenia duthiei (O. Schulz) Bennet	Brassicaceae
Hedysarum astragaloides Benth. Ex Baker	Fabaceae
Hedysarum falconeri Baker var. *cachemirianum* (Benth. Ex Baker) Pramanik & Thoth	Fabaceae
Hedysarum microcalyx Baker	Fabaceae
Herminium kumaunensis Deva & H.B. Naithani	Orchidaceae
Impatiens cothurnoides C. Fisch	Balsaminaceae
Impatiensjaeschkei Hook. f.	Balsaminaceae
Impatiens kalinsis Grey-Wilson	Balsaminaceae
Impatiens langeana Hook. f.	Balsaminaceae
Impatiens laxiflora Edgew.	Balsaminaceae
Impatiens podocarpa Hook. f.	Balsaminaceae
Impatiens polysciadia Hook. f.	Balsaminaceae
Impatiens reidii Hook. f.	Balsaminaceae
Indigofera cedrorum Dunn	Fabaceae
Indigofera dosua Buch – Ham ex D. Don var. *simlensis* (Ali) Sanjappa	Fabaceae
Indigofera gangetica Sanjappa	Fabaceae
Indigofera hamiltonii grah. Ex Duthie & Prain	Fabaceae
Kedarnatha sanctuarii P.K. Mukh & Constance	Apiaceae
Listera nandadeviensis Hajra	Orchidaceae
Macrotyloma sar-garhwalensis R.D Gaur & Dangwal	Fabaceae

Flora	Family
Mahonia jaunsarensis Ahrandt	Berberidaceae
Meconopsis robusta Hook. F.& Thomson	Papaveraceae
Nervilia gleadovii Nageswara Rao	Orchidaceae
Maharanga egregium Johnston	Boraginaceae
Pimpinella stracheyi C.B. Clarke	Apiaceae
Pittosporum eriocarpum Royle	Pittosporaceae
Poa rhadina Bor	Poaceae
Poa royleana Stapf	Poaceae
Potentilla lineate var. *intermedia* (J.D. Hook) Dikshit & Panigrahi	Rosaceae
Prunus cornuta var. Integrifolia Ghora & Panigrahi	Rosaceae
Prunus glauciphylla Ghora & Panigrahi	Rosaceae
Pseudodanthonia himalaica (Hook. f.) Bor & Hubb.	Poaceae
Pueraria stracheyi Baker	Fabaceae
Ranunculus gaurii Dangwal & Rawat	Ranunculaceae
Ranunculus uttaranchaiensis Pusalkar & D.K. Singh	Ranunculaceae
Rosa hirsuta Ghora & Panigrahi	Rosaceae
Rosa macrophylla var. *hookeriana* Hook. f.	Rosaceae
Sagina purii R.D. Gaur	Caryophyllaceae
Saussurea sudhanshui Hajra	Asteraceae
Saxifraga poluniana H. Sm. var. *mucronata* U.C. Bhattach & M.V. Viswan	Saxifragaceae
Saxifraga subspathulata var. *kumaunensis* Engl. & Irmsch.	Saxifragaceae
Schulza garhwalica (H. Wolff) P.K. Mukh. & Constance	Apiaceae
Sedum duthiei Foderstrom	Crassulaceae
Senna davidsonii (V. Singh) V. Singh	Caesalpiniaceae
Sibbaldia axilliflora (Hook. f.) Chatterjee	Rosaceae
Sibbaldia perpusilla (Hook. f.) Chatterjee	Rosaceae
Silene gangotriana Pusalkar, D.K. Singh & Lakshmin	Caryophyllaceae
Sinocrassula indica var. *paniculata* Singh & U.C. Bhattach	Crassulaceae
Spiraea duthiena Zinserling	Rosaceae
Spiraea panchananii Panigrahi & K.M. Purohit	Rosaceae
Spiraea panigrahiana K.M. Purohit	Rosaceae
Spiraea parkeri Panigrahi & K.M. Purohit	Rosaceae
Spiraea raizadae Panigrahi & K.M. Purohit	Rosaceae
Spiraea rhamniphylla Panigrahi & K.M. Purohit	Rosaceae
Stellaria decumbens var. *minor* Edgew & Hook.f	Caryophyllaceae
Themada dacruzii Birari	Poaceae
Trachyspermum falconeri (Clarke) H. Wolff	Apiaceae
Trisetum micans (Hook. f.) Bor	Poaceae
Valeriana mussooriensis Ved Prakash *et al.*	Valerianaceae
Ziziphus oxyphylla var. *pedicellaris* Bhansali	Rhamnaceae

Flora	Family
Fauna	
Pisces	
Barilius pectorilus Tilak and Husain	Cyprinidae
Barilius dimorphicus Tilak and Husain	Cyprinidae
Schizothorax kumaonesis Menon	Cyprinidae
Botia alomrhae Gray	Cobitidae
Nemachilu gangeticus Menon	Cobitidae
Nemachilus doonensis Tilak and Husain	Cobitidae
Nemachilus montanus McClelland	Cobitidae
Lepidocephalus caudofurcatus Tilak and Husain	Cobitidae
Glypthorax alakandi Tilak	Sisoridae
Glypthorax garhwali Tilak	Sisoridae
Glypthorax dakapathari Tilak and Husain	Sisoridae
Odonata	
Zygoptera (2)	Odonatoptera
Diptera	
Diptera (22)	Diptera

1.2.2. RET Species

Rare, Endangered and Threatened (RET) species are important component of the biodiversity of any region. The International Union for Conservation of Nature (IUCN) is the world's main authority on the conservation status of species. The IUCN Red List of Threatened Species (also known as the IUCN Red List or Red Data List), founded in 1963, is the world's most comprehensive inventory of the global conservation status of biological species. A total of 38 plant species and 96 animal species have been identified from Uttarakhand under Red Data list, which clearly assess the risk of extinction to species within the state (Fig. 1.4, 1.5). The Red List provides criteria to evaluate the extinction risk of different species and

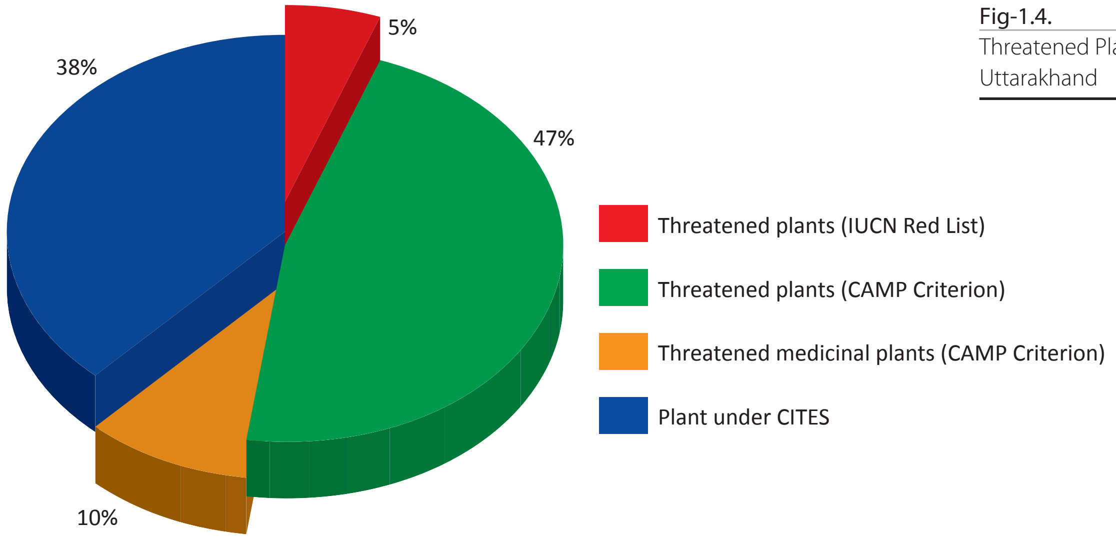
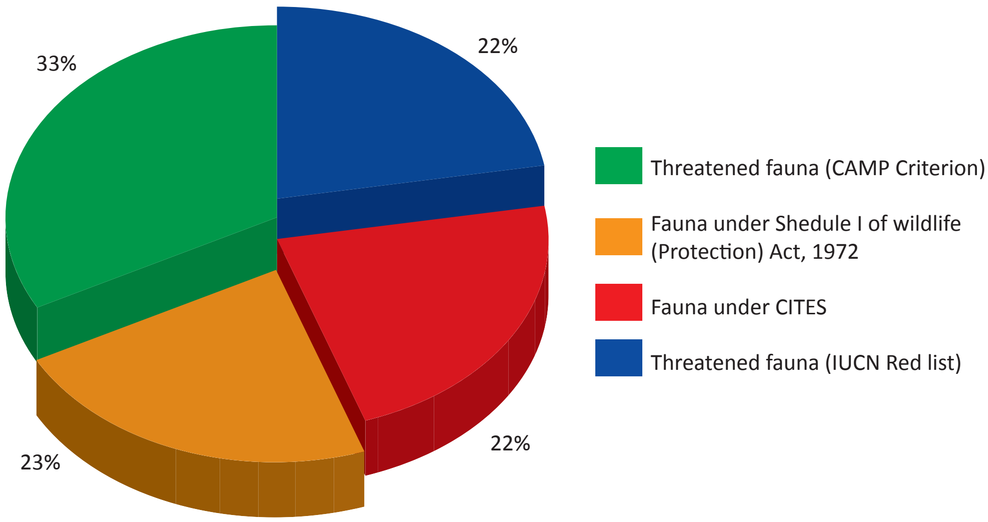


Fig-1.4.
Threatened Plants of Uttarakhand

Fig-1.5.
Threatened Animals of Uttarakhand



subspecies similar to all other plants of the world. It highlights the urgency of conservation issues to the public and policy makers, as well as also desires the help of international community to try to reduce species extinction. The species are listed as Extinct (Ex), Critically endangered (Cr), Endangered (En), Vulnerable (Vu), Rare (R) or Least concern (Lc), Nearly threatened (Nt), Lower risk near threatened (Lr/nt), Data deficient (Dd), Lower risks least concern (Lr/lc) and Schedule (I) Species on the IUCN Red List.

In Uttarakhand flora the IUCN Red list comprised 01 species as Ex, 02 species as Cr, 09 species as En, 07 species as Vu and 19 species as rare. Of the total Red list of Uttarakhand 45% species are endemic to the state or Himalayan region. Another 37 spp are under intermediate list that can be vulnerable in near future.

There are 96 species of fauna including 37 vulnerable species, 15 endangered species, 9 critically endangered and 34 threatened species[1,4,5,6,7,8,14,15,46,55,56,57].

1.2.2.1. IUCN Red List Flora and Fauna of Uttarakhand

A check list of the floral and faunal species of Uttarakhand state under different IUCN Red list is provided in Table 1.4 & 1.5 and similarly list of faunal species identified by wildlife protection act list is presented in Table 1.6 .

1.2.2.2. Flora and Fauna Under CITES List

Initiated in 1960 the CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an international agreement between governments that aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival. From Uttarakhand a total of 252 plant species and 84 animal species have known under CITES categories (Table 1.7, 1.8).

Globally the accords provides varying degrees of protection to more than 30,000 species of animals and plants, whether they are traded as live specimens, fur coats or dried herbs at global level. Widespread need of information about the endangered status of many prominent species, such as the tiger and elephants, made the need for such a convention obvious. Because the trade in wild animals and plants crosses borders between countries, the effort to regulate it requires international cooperation to safeguard certain species from over-exploitation. Appendix I species are those that are threatened with extinction and are

Table-1.4.
IUCN Red list flora of Uttarakhand[58,59,69]

Scientific Names	Family	IUCN Status
Berberis affinis Don	Berberidaceae	R
Berberis lambertii Parker	Berberidaceae	Vu/En
Berberis osmastonii Dunn	Berberidaceae	R
Berberis petiolaris Wall. ex G. Don var. *garhwalana* Ahrendt	Berberidaceae	I
Berberis pseudoumbellata R. Parker	Berberidaceae	I
Mahonia jaunsarensis Ahrendt	Berberidaceae	I
Campanula wattiana Nayar & Babu	Campanulaceae	R
Cynanthus integer Wall. ex Benth.	Campanulaceae	R
Arenaria curvifolia Majumdar	Caryophyllaceae	En
Cerastium thomsonii Hook. f.	Caryophyllaceae	I
Arenaria ferruginea Duthie ex Williams	Caryophyllaceae	I
Silene kumaonensis F. Williams	Caryophyllaceae	R
Catamixis baccharoides Thomson	Asteraceae	Vu
Lactuca filicina Duthie ex Stebb.	Asteraceae	En
Saussurea bracteata Decne.	Asteraceae	R
Saussurea foliosa Edgew.	Asteraceae	I
Sedum duthie Frod.	Crassulaceae	I
Gentiana crassuloides Bureau & Franch.	Gentianaceae	R
Gentiana infelix C.B. Clarke	Gentianaceae	R
Gentiana saginoides Burkill	Gentianaceae	R
Pittosporum eriocarpum Royle	Pittosporaceae	I
Aconitum balfourii Stapf var. *rhombilodum* Stapf	Ranunculaceae	I
Aconitum falconeri Stapf var. *falconeri*	Ranunculaceae	I
Aconitum ferox Wall. ex Seringe	Ranunculaceae	I
Rubus almorensis Dunn	Rosaceae	I
Spiraea diversifolia Dunn	Rosaceae	I
Clarkella nana (Edgew.) Hook. f.	Rubiaceae	R
Rubia edgeworthii Hook. f.	Rubiaceae	Vu
Schisandra propinqua (Wall.) Baillon	Schisandraceae	I
Heracleum jacquemontii C.B. Clarke	Apiaceae	I
Schisandra grandiflora (Wall.) Hook. f. & Thomson	Schisandraceae	I
Viola kunawarensis Royle	Violaceae	I
Allium stracheyi Baker	Alliaceae	Vu
Trachycarpus takil Becc.	Arecaceae	R
Polygonatum graminifolium Hook. f.	Liliaceae	I
Eriocaulon pumilio Hook. f.	Eriocaulaceae	I
Agropyron duthiei Meld.	Poaceae	I

Scientific Names	**Family**	**IUCN Status**
Acer caesium Wall. ex Brandis	Aceraceae	Vu
Acer oblongum Wall. ex DC. var. *membranaceum* Banerji	Aceraceae	En
Cymbopogon flexuosus (Nees ex Steud.) Watson var. *microstachys* (Hook. f.) Bor	Poaceae	R
Festuca lucida Stapf	Poaceae	I
Microstegium falconeri (Hook. f.) Clayton	Poaceae	I
Oryzopsis humilis Bor	Poaceae	I
Poa pseudamoena Bor	Poaceae	I
Poa rhadina Bor	Poaceae	En
Trisetum micans (Hook. f.) Bor	Poaceae	I
Microschoenus duthiei Clarke	Cyperaceae	I
Dipcadi reidii Deb & S. Dasgupta	Liliaceae	Ex
Iris duthiei Foster	Iridaceae	I
Lilium wallichianum Schultes	Liliaceae	I
Aphyllorchis gollanii Duthie	Orchidaceae	Ex
Aphyllorchis parviflora King & Pantl.	Orchidaceae	R
Archineottia microglottis (Duthie) S.C. Chen	Orchidaceae	R
Bulbophyllum raui Arora	Orchidaceae	I
Calanthe alismaefolia Lindl.	Orchidaceae	I
Calenthe alpina Hook. f.	Orchidaceae	R
Calanthe manii Hook. f.	Orchidaceae	R
Cypripedium cordigerum D. Don	Orchidaceae	R
Cypripedium himalaicum Rolfe	Orchidaceae	R
Dendrobium gamblei King & Pantl.	Orchidaceae	I
Dendrobium normale Falc.	Orchidaceae	I
Didiciea cunninghamii King & Prain ex King & Pantl.	Orchidaceae	En
Diplomeris hirsuta (Lindl.) Lindl.	Orchidaceae	Vu
Eria occidentalis Seidenf.	Orchidaceae	R
Eulophia mackinnonii Duthie	Orchidaceae	R
Eulophia obtusa (Lindl.) Hook. f.	Orchidaceae	I
Flickingeria hesperis Seidenf.	Orchidaceae	En
Galeola falconeri Hook. f.	Orchidaceae	I
Nervilia biflora (Roxb.) Schltr.	Orchidaceae	I
Nervilia mackinnonii (Duthie) Schltr.	Orchidaceae	I
Oreorchis indica (Lindl.) Hook. f.	Orchidaceae	I
Cautleya patiolata Baker	Zingiberaceae	I
Christella kaumaunica Holtt.	Thelypteridaceae	Vu

Table-1.5.
IUCN Red list fauna of Uttarakhand[4,5,7,14,15,56,60,69].

Scientific name	Common name	IUCN status
Mammals		
Alticola roylei Gray	Royale's Hight Mountain Vole	Lr/nt
Axis porcinus (Zimmermann)	Hog Deer or Para	Lr/nt
Bos grunniens Linnaeus	Wild Yak	Vu
Canis lupus sp. *dingo* Meyer	Dingo	Vu
Capricornis sumatraensis sp. *thar* Hodgson	Himalayan Serow (Thar)	Vu
Cervus duvauceli Cuvier	Swamp Deer or Barasingha	Vu
Coun alpinus Pallas	Dhol, Indian Wild Dog	En
Elephas maximus Linnaeus	Indian Elephant	En
Hemitragus jemlahicus H. Smith	Himalayan Tahr or Thar	Vu
Hyaena hyaena Linnaeus	Striped Hyaena	Lr/nt
Lutra lutra Linnaeus	Common Otter	Nt
Macaca mulatta (Zimmermann)	Rhesus Macaque	Lr/nt
Manis crassicaudata Gray	Indian Pangolin	Lr/nt
Melursus ursinus (Shaw)	Sloth Bear	Vu
Moschus chrysogaster Hodgson	Musk Deer or Kastura	En
Murina grisea (Peters)	Peter's Tube-Nosed Bat	Cr
Murina huttoni (Peters)	Hutton's Tube-Nosed Bat	Lr/nt
Naemorhedus goral (Hardwicke)	Himalayan Goral	Lr/nt
Ovis ammon (Linnaeus)	Argali	Vu
Panthera tigris (Linnaeus)	Tiger	En
Prionailurus viverrinus (Bennett)	Fishing Cat	Vu
Rhinolophus ferrumequinum (Schreber)	Greater Horse-shoe Bat	Lr/nt
Semnopithecus entellus (Dufresne)	Common Langur	Lr/nt
Semnopithecus entellus ajax (Pocock)	Dark-eyed Himalayan Langur	Lr/nt
Tetraceros quadricornis (Blainville)	Four-horned Antelope or Chausingha	Vu
Uncia uncia (Schreber)	Ounce or Snow Leopard	En
Urus thibetanus G. (Baron) Cuvier	Asiatic Black Bear	Vu
Aves		
Aegithalos niveogularis (Gould)	White-throated Tit	Lr/nt
Aegypius monachus (Linnaeus)	Cinereous Vulture	Nt
Anhinga melanogaster (Pennant)	Oriental Darter	Nt
Anser erythropus (Linnaeus)	LesserWhite-Fronted Groose	Vu
Aquila clanga (Pallas)	Greater spotted Eagle	Vu
Aquila helica (Savigny)	Imperial Eagle	Vu
Athyra baeri (Radde)	Baer's Pochard	Vu
Aythya nyroca (Guldenstadt)	Ferruginous Duck	Nt

Scientific name	Common name	IUCN status
Brachypteryx major (Jerdon)	White-Bellied Shortwing	Vu
Bradypterus major (W.E. Brooks)	Long-Billed Bush-Warbler	Nt
Buceros bicornis Linnaeus	Great Hornbill	Nt
Caterus wallichi (Hardwicke)	Cheer Pheasant	Vu
Chaetornis striatus (Jerdon)	Bristled Grass-Warbler	Vu
Circus macrourus (SG Gmelin)	Pale Harrier	Nt
Ephippiorhynchus asiaticus (Lathum)	Black necked Stork	Nt
Falco cherrug Gray	Saker Falcon	En
Falco cherrug J.E. Gray	Saker	En
Gallinago media (Latham)	Great Snipe	Nt
Gallinago nemoricola Hodgson	Wood Snipe	Vu
Grus antigone Linnaeus	Sarus Crane	Vu
Grus bengalensis (JF Gmelin)	Asian White-Backed Vulture	Cr
Gryps tenuirostris Gray	Slender-Billed Vulture	Cr
Gyps indicus (Scopoli)	Indian Vulture	Cr
Haliaeetus albicilla (Linnaeus)	Grey Sea Eagle	Nt
Haliaeetus leucoryphus (Pallas)	Pallas's Fish-Eagle	Vu
Houbaropsis bengalensis (Gmelin)	Bengal Bustard	En
Ichthyophaga humilis (S. Muller & Schlegel)	Lesser Grey-headed Fish- Eagle	Nt
Ichtyophaga ichthyaetus (Horsfield)	Grey-Headed Fish-Eagle	Nt
Leptoptilos dubius (Gmelin)	Greater Adjutant Stork	En
Leptoptilos javanicus (Horsfield)	Lesser Adjutant	Vu
Marmaronetta angustriostris (Menetries)	Marbled Duck	Vu
Mycteria leucocephala Pennant	Painted Stork	Nt
Ophrysia superciliosa (JE Gray)	Himalayan Quail	Cr
Pelecanus philippensis JF Gmelin	Grey Pelican	Vu
Phoenicopterus minor Geoffroy	Lesser Flamingo	Nt
Phylloscopus tytleri Brooks	Tytler's Leaf-Warbler	Nt
Ploceus megarhynchus Hume	Finn's Baya Waever	Vu
Prinia cinereocapilla (Moore)	Hodgson's Prinia	Vu
Rynchops albicollis Swaninson	Indian Skimmer	Vu
Sarcogyps calvus (Scopoli)	Indian Black Vulture	Nt
Saxicola insignis J.E. Gray & G.R Gray	Hodgson's Bushchat	Vu
Sterna acuticauda Gray	Black Bellied Tern	Nt
Threskiornis melanocephalus (Latham)	Black-Headed Ibis	Nt
Tragopan melanocephalus Gray	Western Tragopan	Vu
Vanellus gregarius (Pallas)	Sociable Lapwing	Cr

Scientific name	Common name	IUCN status
Reptiles		
Chitra indica (Gray)	Narrow-Headed Softshell Turtle	En
Crocodylus palustris Lesson	Marsh Crocodile	Vu
Elachistodon westermanni Reinhardt	Indian Egg-eater	Dd
Gavialis gangeticus (Gmelin)	Fish-Eating Crocodile	En
Geoclemys hamiltonii Gray	Black Pond Turtle	Vu
Hardella thurjii thurjii Gray	Brahminy River Turtle	Vu
Indotestudo elongata (Blyth)	Elongated Tortoise	En
Kachuga dhongoka (Gray)	Three-Striped Roof Turtle	En
Kachuga kachuga (Gray)	Bengal Roof Turtle	Cr
Kachuga smithii Gray	Smith's Terrapin	Lr/nt
Melanochelys tricarinata (Blyth)	Three-Keeled Land Tortoise	Vu
Melanochelys trijuga (Schweigger)	Indian Black Turtle	Lr/nt
Naja naja ssp. oxiana (Eichwald)	Central Asian Cobra	Dd
Python molurus (Linnaeus)	Asiatic Rock Python	Lr/nt
Amphibia		
Amolops chakrathataensis Ray		Dd
Pisces		
Macrognathus aral (Bloch & Schn.)	Spiny Eel	Dd
Odonata		
Burmagomphus sivalikensis Laidlaw		Cr
Mollusca		
Tricula montana Benson		En

Table-1.6.
List of faunal species under Indian Wildlife (Protection) Act, 1972[60,61].

Scientific Names	Common name	IWPA (1972)
Mammals		
Bos grunniens Linnaeus	Yak	Schedule I
Canis lupus Linnaeus	Wolf	Schedule I
Capra ibex Linnaeus	Ibex	Schedule I
Capricornis sumatraensis Hodgson	Serow	Schedule I
Cervus duvauceli (Cuvier)	Swamp Deer or Barasingha	Schedule I
Elephas maximus Linnaeus	Indian Elephant	Schedule I
Felis bengalensis (Kerr)	Leopard Cat	Schedule I
Felis caracal Schreber	Cracal Lynx	Schedule I
Hemitragus jemlahicus (H. Smith)	Himalayan Tahr or Thar	Schedule I
Manis crassicaudatum Gray	Indian Pangolin	Schedule I
Melursus ursinus (Shaw)	Sloth Bear	Schedule I
Moschus chrysogaster Hodgson	Musk Deer or Kastura	Schedule I
Panthera pardus (Linnaeus)	Leopard	Schedule I
Panthera tigris (Linnaeus)	Tiger	Schedule I
Prionailurus viverrinus (Bennet)	Fishing Cat	Schedule I
Pseudois nayaur (Hodgson)	Bharal or Blue Sheep	Schedule I
Tetraceros quadricornis Blanville	Four-horned Antelope or Chausingha	Schedule I
Uncia uncia (Schreber)	Ounce or Snow Leopard	Schedule I
Urus arctos Linnaeus	Brown Bear	Schedule I
Aves		
Accipiter badius (Gmelin)	Shikra	Schedule I
Accipiter gentilis (Linnaeus)	Northern Goshawk	Schedule I
Accipiter nisus (Linnaeus)	Eurasian sparrowhawk	Schedule I
Accipiter trivirgatus (Temminck)	Crested Goshawk	Schedule I
Accipiter virgatus (Temminck)	Besra sparrowhawk	Schedule I
Aegypius monachus (Linnaeus)	Cinereous Vulture	Schedule I
Aquila chrysaetos (Linnaeus)	Golden Eagle	Schedule I
Aquila clanga Pallas	Greater spotted Eagle	Schedule I
Aquila heliaca Savigny	Eastern Imperial Eagle	Schedule I
Aquila pomarina Brehm	Lesser spotted Eagle	Schedule I
Aquila rapax nipalensis Hodgson	Steppe Eagle	Schedule I
Aquila rapax vindhiana Temminck	Tawny Eagle	Schedule I
Buceros bicornis Linnaeus	Great Pied Hornbill	Schedule I
Butastur teesa (Franklin)	White-eyed Buzzard	Schedule I
Buteo buteo vulpinus (Linnaeus)	Common Buzzard	Schedule I
Buteo rufinus (Cretzschmar)	Long-legged Buzzard	Schedule I

Scientific Names	Common name	IWPA (1972)
Catreus wallichii (Hardwicke)	Cheer Pheasant	Schedule I
Circaetus gallicus (Gmelin)	Short-toed Snake-Eagle	Schedule I
Circus aeruginosus (Linnaeus)	Western Marsh-Harrier	Schedule I
Circus cyaneus (Linnaeus)	Hen Harrier	Schedule I
Circus macrourus (S.G. Gmelin)	Pallid Harrier	Schedule I
Circus pygargus (Linnaeus)	Montagu's Harrier	Schedule I
Falco chicquera Daudin	Red-headed Falcon	Schedule I
Falco peregrinus peregrinus Tunstall	Peregrine Falcon	Schedule I
Gracula religiosa Linnaeus	Hill Myna	Schedule I
Gypaetus barbatus (Linnaeus)	Bearded Vulture	Schedule I
Gyps bengalensis (J.F. Gmelin)	Indian White-backed Vulture	Schedule I
Gyps fulvus (Hablizl)	Eurasian Griffon	Schedule I
Gyps himalayensis Hume	Himalayan Griffon	Schedule I
Gyps indicus (Scopoli)	Long-billed Vulture	Schedule I
Gyps tenuirostris Gray	Slender-billed Vulture	Schedule I
Haliaeetus albicilla (Linnaeus)	White-tailed Sea-Eagle	Schedule I
Haliaeetus leucoryphus (Pallas)	Pallas's Fish Eagle	Schedule I
Haliastur indus (Boddert)	Brahminy Kite	Schedule I
Hieraaetus fasciatus (Viellot)	Bonelli's Eagle	Schedule I
Hieraaetus kienerii (Geoffery)	Rufous-bellied Eagle	Schedule I
Hieraaetus pennatus (Gmelin)	Booted Eagle	Schedule I
Ichthyophaga humilis (S. Muller and Schlegel)	Lesser Grey-headed Fish- Eagle	Schedule I
Ichthyophaga ichthyaetus (Horsfield)	Greater Grey-headed Fish-Eagle	Schedule I
Ictinaetus malayensis Temminck	Black Eagle	Schedule I
Lophophorus impejanus (Lanthan)	Monal Pheasant	Schedule I
Lophura leucomelanos Lanthan	Kaleej Pheasant	Schedule I
Milvus migrans govinda Boddert	Black Kite	Schedule I
Milvus migrans lineatus Boddert	Black Kite	Schedule I
Neophron percnopterus (Linnaeus)	Egyptian Vulture	Schedule I
Ophrysia superciliosa (J.E. Gray)	Himalayan Quail	Schedule I
Pandion haliaetus Linnaeus	Osprey	Schedule I
Pavo cristatus Linnaeus	Indian Peafowl	Schedule I
Pernis ptilorhynchus Stresemann	Oriental Honey-Buzzard	Schedule I
Platalea leucorodia Linnaeus	Eurasian Spoonbill	Schedule I
Sarcogyps calvus (Scopoli)	Red-headed Vulture	Schedule I
Spilornis cheela (Lanthan)	Crested Serpent-Eagle	Schedule I
Spizaeetus cirrhatus (Gmelin)	Changeable Hawk-Eagle	Schedule I

Scientific Names	Common name	IWPA (1972)
Spizaetus nipalensis (Hodgson)	Mountain Hawk-Eagle	Schedule I
Tragopan satyra Linnaeus	Satyr Tragopan	Schedule I
Reptiles		
Crocodylus palustris Lesson	Snub-nosed Crocodile, Mugger	Schedule I
Elachistodon westermanni Reinhardt	Indian Egg-eater	Schedule I
Gavialis gangeticus (Gmelin)	Long-snouted Crocodile, Gharial	Schedule I
Geoclemys hamiltoni (Gray)	Spotted Pond- Turtle	Schedule I
Kachuga kachuga (Gray)	Sail Terrapin	Schedule I
Lissemys punctata punctata Lacepede	Indian Flap-shell Turtle	Schedule I
Melanochelys tricarinata (Blyth)	Three-keeled Turtle	Schedule I
Python molurus molurus Linnaeus	Asiatic Rock Python	Schedule I
Trionyx gangeticus Gray	Indian Soft-shell Turtle	Schedule I
Varanus bengalensis (Linnaeus)	Monitor Lizard	Schedule I
Varanus flavescens (Gray)	Barred Yellow Monitor Lizard	Schedule I
Lepidoptera		
Chilaria othona (Hewiston)	Orchid Tit	Schedule I
Chilasa clytia clytia (Linnaeus)	Common Mime	Schedule I
Deodorix epijarbus (Moore)	Cornelian	Schedule I
Hypolimnas misippus (Linnaeus)	Danaid Eggfly	Schedule I
Nacaduba norea (Felder)	White Tiped Line Blue	Schedule I
Neptis columella (Cramer)	Short-Banded Sailer	Schedule I
Neptis sankara (Kollar)	Broad-banded Sailer	Schedule I
Parnassius stoliczkanus florenciae Tytler	Ladakh Banded Apollo	Schedule I
Spindasis elwesi Riley	Elwes's Silverline	Schedule I
Tajuria yajna (Doherty)	Royal, Chestnut and Black	Schedule I
Thecla ataxus (Doubleday & Hewitson)	Wonderful Hairstreak	Schedule I
Thecla bieti Oberthur	Indian Purple Hairstreak	Schedule I

Table-1.7.
List of plants under CITES from Uttarakhand[36,57].

Scientific Names	Common name	Family	Appendix
Cycas circinalis	Queen Sago	Cycadaceae	Appendix II
Cycas revoluta	Sago palm	Cycadaceae	Appendix II
Dioscorea deltoidea	Man-alu	Dioscoreaceae	Appendix II
Opuntia cochenillifera	Prickly pear	Cactaceae	Appendix II
Opuntia elatior	Nag Fani	Cactaceae	Appendix II
Opuntia ficus-indica	Indian Fig, Opuntia	Cactaceae	Appendix II
Opuntia stricta var. *dillenii*	Nagphani	Cactaceae	Appendix II
Opuntia vulgaris	Bantulsi	Cactaceae	Appendix II
Nardostachys grandiflora	Muskroot	Valerianaceae	Appendix II
Picrorhiza kurrooa	Kutki	Scrophulariaceae	Appendix II
Podophyllum hexandrum	Bankakdi	Berberidaceae	Appendix II
Rauvolfia serpentina	Chandrabhaga	Apocynaceae	Appendix II
Saussurea costus	Kuth	Asteraceae	Appendix II
Taxus wallichiana	Thuner	Taxaceae	Appendix II
Members of family Orchidaceae			Appendix II

Table-1.8.
List of fauna under CITES from Uttarakhand[36,57]

Species	Common name	Appendix
Mammals		
Capra ibex Linnaeus	Ibex	Appendix I
Naemorhedus goral (Hardwicke)	Goral	Appendix I
Ovis ammon Linnaeus	Argali	Appendix II
Moschus chrysogaster Hodgson	Musk Deer or Kastura	Appendix I
Canis lupus Meyer	Wolf	Appendix I
Coun alpinus Pallas	Dhol or Indian Wild Dog	Appendix III
Vulpes bengalensis (Linnaeus)	Indian Fox	Appendix III
Caracal caracal (Schreber)	Cracal Lynx	Appendix I
Panthera tigris (Linnaeus)	Tiger	Appendix I
Herpestes edwardsi (E. Geoffory)	Indian Grey Mongoose	Appendix III
Lutra lutra Linnaeus	Common Otter	Appendix I
Martes flavigula Boddaert	Yellow-throated Marten	Appendix III
Mustela kathiah Hodgson	Yellow-bellied Weasel	Appendix III
Mustela siberica Pallas	Siberian Weasel	Appendix III
Melursus ursinus (Shaw)	Sloth Bear	Appendix I
Urus arctos Linnaeus	Brown Bear	Appendix II
Ursus thibetanus G. (Baron) Cuvier	Asiatic Black Bear	Appendix I
Paradoxurus hermophroditus Pallas	Common Palm Civet or Toddy cat	Appendix III
Viverricula indica (E. Geoffory)	Rasse or Small Indian Civet	Appendix III
Pteropus giganteus (Brunnich)	Indian Flying Fox	Appendix II
Manis crassicaudatum Gray	Indian Pangolin	Appendix II
Semnopithecus entellus (Dufresne)	Common Langur	Appendix I

Species	Common name	Appendix
Elephas maximus Linnaeus	Indian Elephant	Appendix I
Aves		
Sarkidiornis melanotos (Pennat)	Comb Duck	Appendix II
Ciconia nigra (Linnaeus)	Black Stork	Appendix II
Platalea leucorodia (Linnaeus)	Eurasian Spoonbill	Appendix II
Phoenicopterus ruber Pallas	Greater Flamingo	Appendix II
Phoenicopterus minor (E. Geoffory)	Lesser Flamingo	Appendix II
Aceros nipalensis (Hodgson)	Rufous-necked Hornbill	Appendix I
Buceros bicornis Linnaeus	Great Pied Hornbill	Appendix I
Anthracoceros albirostris (Shaw)	Oreiental Pied Hornbill	Appendix II
Aquila heliaca Savigny	Eastern Imperial Eagel	Appendix I
Haliaeetus albicilla (Linnaeus)	White-tailed Sea-Eagle	Appendix I
Falco jugger J.E. Gray	Laggar	Appendix I
Falco peregrinus Tunstall	Peregrine Falcon	Appendix I
Tragopan melanocephalus (Gray)	Western Tragopan	Appendix I
Grus antigone (Linnaeus)	Sarus Crane	Appendix II
Grus virgo (Linnaeus)	Demoiselle Crane	Appendix II
Grus grus (Linnaeus)	Common Crane	Appendix II
Leiothrix argentauris (Hodgson)	Silver-eared Leiothrix	Appendix II
Leiothrix lutea (Scopoli)	Red-billed Leiothrix	Appendix II
Gracula religiosa Linnaeus	Common Hill-Myna	Appendix II
Psittacula eupatria (Linnaeus)	Alexandrine Parakeet	Appendix II
Psittacula himalayan (Lesson)	Slaty-headed Parakeet	Appendix II
Psittacula cyanocephala (Linnaeus)	Plum-headed Parakeet	Appendix II
Psittacula alexandri (Linnaeus)	Red-breasted Parakeet	Appendix II
Asio flammeus (Pontoppidan)	Short-eared Owl	Appendix II
Asio otus (Linnaeus)	Long-eared Owl	Appendix II
Athene brama (Temminck)	Spotted Owlet	Appendix II
Bubo bubo (Linnaeus)	Eurasian Eagle-Owl	Appendix II
Bubo coromandus (Lantham)	Dusky Eagle-Owl	Appendix II
Bubo nipalensis Hodgson	Forest Eagle-Owl	Appendix II
Glaucidium brodiei (Burton)	Collared Owlet	Appendix II
Glaucidium cuculoides (Vigors)	Asian Barred Owlet	Appendix II
Glaucidium radiatum (Tickell)	Jungle Owlet	Appendix II
Ketupa flavipes (Hodgson)	Tawny Fish-Owl	Appendix II
Ketupa zeylonensis (Gmelin)	Brown Fish-Owl	Appendix II
Ninox scutulata (Raffles)	Brown Hawk-Owl	Appendix II
Otus bakkamoena Pennant	Collared Scops-Owl	Appendix II
Otus spilocephalus (Blyth)	Spotted Scops-Owl	Appendix II

Species	Common name	Appendix
Otus sunia (Hodgson)	Oriental Scops-Owl	Appendix II
Strix aluco Linnaeus	Tawny Wood-Owl	Appendix II
Strix leptogrammica Temminck	Brown Wood-Owl	Appendix II
Reptiles		
Crocodylus palustris Lesson	Snub-nosed Crocodile, Mugger	Appendix I
Gavialis gangeticus (Gmelin)	Long-snouted Crocodile, Gharial	Appendix I
Varanus bengalensis (Linnaeus)	Monitor Lizard	Appendix I
Varanus flavescens (Gray)	Barred Yellow Monitor Lizard	Appndix II
Elachistodon westermanni Reinhardt	Indian Egg-eater	Appndix II
Ptyas mucosus	Rat Snake	Appndix II
Xenochrophis piscator (Schneider)	Checkered Keel-back	Appndix III
Naja naja (Linnaeus)	Binocellate Cobra	Appndix II
Naja oxiana (Eichwald)	Acellate Cobra	Appndix II
Ophiophagus hannah (Cantor)	King Cobra	Appndix II
Python molurus molurus Linnaeus	Asiatic Rock Python	Appndix I
Geoclemys hamiltoni (Gray)	Spotted Pond- Turtle	Appndix I
Kachuga dhongoka	Three-striped Roofed Turtle	Appndix II
Kachuga kachuga (Gray)	Sail Terrapin	Appndix II
Kachuga smithi Gray	Smith's Terrapin	Appndix II
Kachuga tecta	North Indian Roofed Turtle	Appndix II
Melanochelys tricarinata (Blyth)	Thrre-keeled Turtle	Appndix I
Pangshura tectum	Indian Roofed Turtle	Appndix I
Chitra indica (Gray)	Narrow-necked Soft-shell Turtle	Appendix II
Lissemys punctata punctata (Lacepede)	Indian Flap-shell Turtle	Appendix II

or may be affected by trade, and commercial trade of these species is illegal. Appendix II are those species that are not necessarily threatened. In International trade the specimens of Appendix II species may be authorized by the granting of an export permit or re-export certificate. Appendix III, species are listed after one member country has asked other CITES Parties for assistance in controlling trade in a species, though such species may not necessarily threatened with extinction globally.

1.2.2.3. Flora and Fauna Under CAMP List

Uttarakhand state identified nearly 312 plant species and 142 animal species in Conservation Assessment and Management Planning (CAMP) list that are identified through participatory consultation for securing threatened species (Table 1.9, 1.10). CAMP list is finalized by all stakeholders through sharing knowledge and data for developing conservation action plan. For example the need for action to conserve medicinal plants has long been recognized because of high dependence on herbal remedies that has threatened survival of many species. The CAMP process for prioritization of faunal and floral species helps to formulate a commonly agreed conservation action for selected species.

Table-1.9.
List of threatened Plants (CAMP Criterion) from Uttarakhand[36,56,62].

Scientific Names	Family
Acer caesium Wall. ex Brandis	Aceracae
Acer laevigatum Wall.	Aceracae
Acer oblongum Wallich. ex DC., Prodr	Aceracae
Acer osmastoni Gamble	Aceracae
Acer sterculiaceum Wallich	Aceracae
Saurauia napaulensis DC	Actinidiaceae
Allium stracheyi Baker	Liliaceae
Buchanania latifolia Roxb	Anacardiaceae
Rhus acuminate DC	Anacardiaceae
Ilex fragilis Hook.f.	Aquifoliaceae
Ilex pseudo-odorata Loes	Aquifoliaceae
Amorphophallus bulbifer (Roxb.)	Araceae
Brassaiopsis aculeate Seem	Araliaceae
Hedera nepalensis K. Koch	Araliaceae
Macropanax oreophilum Miq	Araliaceae
Calotropis gigantea (L.) R. Br.	Asclepiadaceae
Ceropegia bulbosa Roxb	Asclepiadaceae
Asplenium nesii Christ.	Aspleniaceae
Berberis affinis G. Don	Berberidaceae
Berberis chitria Edwards	Berberidaceae
Berberis lambertii Parker	Berberidaceae
Berberis lycium Royal	Berberidaceae
Berberis osmastonii Dunn	Berberidaceae
Berberis petiolaris Wallich	Berberidaceae
Berberis pseudoumbellata Parker	Berberidaceae
Berberis simlensis	Berberidaceae
Mahonia jaunsarensis Ahrendt	Berberidaceae
Mahonia acanthifolia G. Don	Berberidaceae
Podophyllum hexandrum Royle	Podophyllaceae
Alnus nepalensis D. Don	Betulaceae
Betula alnoides Var.	Betulaceae
Incarvillea emodi Chatterjee	Bignoniaceae
Ehretia acuminate R. Br.	Borginaceae
Campanula wattiana M.P. Nayar & Babu	Campanulaceae
Arenaria curvifolia Majumdar	Caryophyllaceae
Arenaria ferruginea Duthie ex Williams	Caryophyllaceae
Silene kumaonensis Williams	Caryophyllaceae
Silene nepalensis Majumdar	Caryophyllaceae
Euphorbia royleana Boiss.	Euphorbiaceae
Microgynoecium tibeticum J.D. Hooker	Chenopodiaceae
Circaester agrestis Maximowicz	Circaeasteraceae
Catamixis baccharoides Thomson	Asteraceae
Doronicum falconeri C.B. Clarke ex Hook. f.	Compositae
Lactuca filicina Duthie ex Stebbins	Compositae
Leontopodium stracheyi (Hook. f.) C.B. Clarke ex Hemsl.	Compositae
Myriactis nepalensis Less.	Compositae
Saussurea bracteata Decne.	Compositae
Saussurea foliosa (Edgew.) Hook. f.	Compositae

Scientific Names	Family
Saussurea gossypiphora D. Don	Compositae
Saussurea obvallata (DC.) Edgew.	Compositae
Saussurea roylei (DC.) Sch. Bip	Compositae
Saussurea sacra Edgew	Compositae
Tanacetum gossypinum Hook. f. Thomsom ex C.B. Clarke	Compositae
Carpinus faginea Lindl. N. Wallich	Corylaceae
Sedum duthiei Frod	Crassulaceae
Megacarpaea polyandra Bentham, Hooker's	Brassicaceae
Thlaspi andersonii (Hook. f. et Thoms.) O.E. Schulz.	Brassicaceae
Gomphogyne cissiformis Griff	Cucurbitaceae
Cyathea spinulosa Wallich ex Hooker	Cyatheaceae
Carex atrata var. *pullata* Boott	Cyperaceae
Carex kumaonensis Kuekenth	Cyperaceae
Carex myosurus var. Praestans	Cyperaceae
Carex stracheyi Boott ex C.B. Clarke	Cyperaceae
Kobresia duthiei C.B. Clarke	Cyperaceae
Kobresia nepalensis (Nees) Kuekenth	Cyperaceae
Daphniphyllum himalayense (Benth)	Daphniphyllaceae
Shorea robusta Roxb. Ex Gaertn. F.	Dipterocarpaceae
Dryopteris gamblei (C. Hope) C. Chr.	Dryopteridaceae
Polystichum duthiei	Dryopteridaceae
Elaeagnus kanaii Momiyama var. *osmastonii* Malhotra & D. Basu	Elaeagnaceae
Echinocarpus tomentosus Benth	Elaeocarpaceae

Scientific Names	Family
Gaultheria fragrantissima Wallich, Asiat. Res.	Ericaceae
Rhododendron barbatum Wallich ex G. Don	Ericaceae
Rhododendron lepidotum Wallich ex G. Don	Ericaceae
Eriocaulon pseudoquinquangulare L	Eriocaulaceae
Eriocaulon pumilio Hook. f	Eriocaulaceae
Macaranga pustulata King ex Hook. F.	Euphorbiaceae
Mallotus philippensis (Lam) Muell-Arg	Euphorbiaceae
Phyllanthus emblica L	Euphorbiaceae
Trewia nudiflora L.	Euphorbiaceae
Castanopsis indica Roxb.	Fagaceae
Castanopsis tribuloides (J.E.. Sm.) A. DC	Fagaceae
Quercus floribunda Rehder	Fagaceae
Quercus lanata J.E. Sm	Fagaceae
Quercus lanuginose D. Don	Fagaceae
Gentiana crassuloides Bureau & Franch	Gentianaceae
Gentiana infelix C.B. Clarke	Gentianaceae
Geranium nepalense var. *thunbergii*	Gentianaceae
Geranium polyanthes Edgeworth & J.D. Hooker	Gentianaceae
Swertia sikkimensis Burkill	Gentianaceae
Didymocarpus aromatica Wall.	Gesneriaceae
Didymocarpus pedicellata R. Br.	Gesneriaceae
Agropyron duthiei Melderis	Poaceae
Arundinaria jaunsarensis Gamble	Poaceae

Scientific Names	Family
Cymbopogon flexuosus var. *microstachys*	Poaceae
Cymbopogon motia B.K. Gupta	Poaceae
Cymbopogon osmastonii R.Parker	Poaceae
Elymus thomsonii Hook. f.	Poaceae
Eulalia staintonii Bor	Poaceae
Eulaliopsis duthiei Sur.	Poaceae
Festuca lucida Stapf J. D. Hooker	Poaceae
Festuca nitidula Stapf. Ex Hook. F.	Poaceae
Miscanthus nepalensis	Poaceae
Phalaris minor Retz.	Poaceae
Poa nepalensis Wall. ex Duthie	Poaceae
Poa pseudamoena	Poaceae
Poa rhadina Bor	Poaceae
Pogonatherum santapaui	Poaceae
Sehima notatum Hack.	Poaceae
Stipa duthiei	Poaceae
Themeda dacruzii	Poaceae
Trisetum micans	Poaceae
Hypericum podocarpoides N. Robson	Hypericaceae
Iris duthiei Foster	Iridaceae
Microschoenus duthiei C.B.Clarke	Cyperaceae
Ajuga brachystemon Maxim	Lamiaceae
Coleus forskohlii Briq.	Lamiaceae
Elsholtzia densa Benth	Lamiaceae
Leucosceptrum canum Smith	Lamiaceae
Nepeta campestris Benth	Lamiaceae
Pogostemon benghalensis (Burm.f.) Kuntze	Lamiaceae
Roylea cinerea **(D.Don)** Baill.	Lamiaceae
Scutellaria prostrata Jacq. ex Benth	Lamiaceae
Cinnamomum glanduliferum (Wallich) Meissn	Lauraceae
Dodecadenia grandiflora Nees	Lauraceae
Lindera bifaria Benth	Lauraceae
Litsea elongata (Nees) Hook. f.	Lauraceae
Machilus sericea Blume	Lauraceae
Persea gamblei (King ex Hook.f.) Kosterm	Lauraceae
Phoebe lanceolata Nees	Lauraceae
Phoebe pallid Nees	Lauraceae
Caragana sukiensis C. K. Schneid	Fabaceae

Scientific Names	Family
Colutea nepalensis Sims	Fabaceae
Dalbergia latifolia Roxb.	Fabaceae
Hedysarum microcalyx Baker	Fabaceae
Nomocharis nana var. *flavidum* (Rendle) Sealy	Liliaceae
Lilium nepalense D. Don.	Liliaceae
Lilium wallichianum Schult. & Schult. f.	Liliaceae
Duabanga grandiflora syn. (Roxb. ex DC.) Walpers	Sonneratiaceae
Michelia champaca var. *champaca*	Magnoliaceae
Michelia kisopa Buch-Ham ex DC	Magnoliaceae
Azadirachta indica (L.) Adelb.	Meliaceae
Morus serrata Roxb	Moraceae
Boerhavia crispa	Nyctaginaceae
Olea cuspidata Wall. ex G. Don	Oleaceae
Anoectochilus roxburghii (Eallich) Lindl.	Orchidaceae
Aphyllorchis gollanii Duthie	Orchidaceae
Aphyllorchis parviflora King & Pantl	Orchidaceae
Archineottia microglottis (Duthie) Chen	Orchidaceae
Bulbophyllum cariniflorum Rechb. F.	Orchidaceae
Bulbophyllum hookeri (Duthie) J.J. Sm	Orchidaceae
Bulbophyllum careyanum sensu Arora	Orchidaceae
Bulbophyllum polyrhizum Lindl	Orchidaceae
Bulbophyllum reptans Arora	Orchidaceae
Bulbophyllum secundum	Orchidaceae
Calanthe alismaefolia Lindl	Orchidaceae
Calanthe alpina Hook. F. ex Lindl	Orchidaceae
Calanthe brevicornu Lindl	Orchidaceae
Calanthe mannii Hook. F.	Orchidaceae
Calanthe pachystalix Reichb. F. ex Hook. F.	Orchidaceae
Calanthe plantaginea Lindl	Orchidaceae
Calanthe puberula Lindl	Orchidaceae
Chiloschista usneoides (D. Don) Lindl	Orchidaceae
Aorchis roborowskii	Orchidaceae
Cleisostoma parishii Seidenf. & Arora	Orchidaceae
Corallorrhiza trifida Chatelain	Orchidaceae

Scientific Names	Family
Cypripedium faberi	Orchidaceae
Cypripedium hookerianum Reichb. f.	Orchidaceae
Cypripedium iridioides D. Don	Orchidaceae
Cypripedium longifolium	Orchidaceae
Cypripedium mackinnonii Duthie	Orchidaceae
Cypripedium macrorhizon Lindl	Orchidaceae
Cypripedium cordigerum D. Don	Orchidaceae
Cypripedium elegans Reichb.f	Orchidaceae
Cypripedium himalaicum Rolfe apud hemsl	Orchidaceae
Dactylorhiza majhalis	Orchidaceae
Dendrobium amoenum Wallich ex Lindl	Orchidaceae
Dendrobium denudans D. Don	Orchidaceae
Dendrobium gamblei	Orchidaceae
Dendrobium heterocarpum	Orchidaceae
Dendrobium normale Falc	Orchidaceae
Dendrobium porphyrochilum	Orchidaceae
Dendrobium primulinum Lindl	Orchidaceae
Didiciea cunninghamii King & Prain ex King & Pantl	Orchidaceae
Diplomeris hirsuta (Lindl) Lindl	Orchidaceae
Epipogium aphyllum (F.W. Schmidt) Sw	Orchidaceae
Eria alba Lindl	Orchidaceae
Eria occidentalis Seidenf	Orchidaceae
Eria spicata (D.Don) Hand-Mazz	Orchidaceae
Eulophia explanata Lindl	Orchidaceae
Eulophia herbacea Lindl	Orchidaceae
Eulophia hormusjii Duthie	Orchidaceae
Galeola falconeri Hook.f	Orchidaceae
Gastrochilus distichus (Lindl) O. Kuntze	Orchidaceae
Goodyera biflora (Lindl) Hook. f	Orchidaceae
Eulophia mackinnonii Duthie	Orchidaceae
Eulophia obtuse (Lindl) Hook. f	Orchidaceae
Euonymus hamiltonianus	Orchidaceae
Flickingeria hesperis Scidenf	Orchidaceae
Galearis spathulata	Orchidaceae
Habenaria arcuata	Orchidaceae
Habenaria edgeworthii Hook. f. ex Collett	Orchidaceae
Habenaria josephii	Orchidaceae

Scientific Names	Family
Habenaria pubescens Lindl	Orchidaceae
Habenaria stenantha	Orchidaceae
Hemipilia cordifolia (Lindl)	Orchidaceae
Herminium duthiei	Orchidaceae
Herminium jaffreyanum King & Pantl	Orchidaceae
Herminium mackinnonii Duthie	Orchidaceae
Herminium pugioniforme Lindl. Ex Hook.f	Orchidaceae
Herminium quinquelobium sensu Arora	Orchidaceae
Kingidium deliciosum (Reichb.f.) Sweet	Orchidaceae
Kingidium taenialis (Lindl) Hunt	Orchidaceae
Liparis nervosa (Thunb.) Lindl	Orchidaceae
Liparis petiolata sensu Seidenf & Arora	Orchidaceae
Liparis platyrachis Hook.f	Orchidaceae
Listera longicaulis King & Pantl	Orchidaceae
Listera pinetorum Lindl	Orchidaceae
Listera tenuis Lindl	Orchidaceae
Malaxis biaurita (Lindl) O. Kuntze	Orchidaceae
Malaxis mackinnonii (Duthie) Ames	Orchidaceae
Neottia listeroides Lindl	Orchidaceae
Neottianthe secundiflora (Hook.f) Schltr	Orchidaceae
Oberonia griffithiana Lindl	Orchidaceae
Oberonia myosurus (Forst. f) Lindl	Orchidaceae
Oberonia prainiana King & Pantl	Orchidaceae
Orchis habenarioides	Orchidaceae
Orchis latifolia	Orchidaceae
Orchis indica	Orchidaceae
Orchis rolfei	Orchidaceae
Pecteilis triflora (D. Don) Tang & Wang	Orchidaceae
Pelatantheria insectifera (Reichb.f.) Ridl	Orchidaceae
Ponerorchis nana	Orchidaceae
Rhynchostylis retusa (L.) Blume	Orchidaceae
Saccolabiopsis pusilla	Orchidaceae
Tropidia pedunculata sensu Deva & Arora	Orchidaceae
Vanda pumila Hook. f.	Orchidaceae
Phoenix acaulis	Arecaceae

Scientific Names	Family
Phoenix laureirii	Arecaceae
Trachycarpus takil	Arecaceae
Wallichia densiflora	Arecaceae
Pandanus nepalensis	Pandanaceae
Tsuga dumosa	Pinaceae
Piper nepalensis Miq	Piperaceae
Pittosporum eriocarpum	Pittosporaceae
Pittosporum napaulensis	Pittosporaceae
Persicaria nepalensis	Polygonaceae
Rheum emodi	Polygonaceae
Rheum spiciforme	Polygonaceae
Rheum webbianum	Polygonaceae
Rumex nepalensis	Polygonaceae
Primula atrodentata Sm	Primulaceae
Primula macrophylla D. Don	Primulaceae
Primula reidii Duthie	Primulaceae
Aconitum deinorrhizum	Ranunculaceae
Aconitum Laeve	Ranunculaceae
Caltha palustris	Ranunculaceae
Delphinium vestitum	Ranunculaceae
Thalictrum alpinum	Ranunculaceae
Thalictrum chelidonii	Ranunculaceae
Thalictrum rostellatum J. D. Hooker & Thomson	Ranunculaceae
Clematis nepalensis Royle	Ranunculaceae
Hovenia dulcis var. *glabra* Makino	Rhamnaceae
Carallia brachiata (Lour) Merr	Rhizophoraceae
Cotoneaster marginiatus (Loud) Schlecht	Rosaceae
Fragaria daltoniana Gay	Rosaceae
Potentilla gelida C.A. Mey	Rosaceae
Potentilla nepalensis Hook	Rosaceae
Prunus napaulensis (Ser.) Steud	Rosaceae
Rubus almorensis Dunn	Rosaceae
Sorbus cuspidate (Spach) Hedlund	Rosaceae

Scientific Names	Family
Spiraea arcuata Hook.f.	Rosaceae
Spiraea diversifolia Dunn	Rosaceae
Clarkella nana (Edgew) Hook.f.	Rubiaceae
Galium cryptanthum Hemsl	Rubiaceae
Murraya koenigii (L.) Sprengel.	Rutaceae
Skimmia laureola Hook	Rutaceae
Zanthoxylum acanthopodium DC.	Rutaceae
Zanthoxylum armatum DC	Rutaceae
Salix oxycarpa Andersson	Salicaceae
Chrysosplenium trichospermum Edgew.ex Hook.f. & Thomson	Saxifragaceae
Saxifraga filicaulis Wallich ex Ser	Saxifragaceae
Saxifraga hispidula D. Don	Saxifragaceae
Schisandra grandiflora (Wallich) J. D. Hooker & Thomson	Schisandraceae
Schisandra propinqua (Wallich) Baillon	Schisandraceae
Boschniakia himalaica Hook. & Thomson ex Hook. f	Orobanchaceae
Falconeria himalaica Hook.f	Scrophulariaceae
Scrophularia obtuse Edgew. Ex Hook.f	Scrophulariaceae
Selaginella adunca A. Braun ex Hieron	Selaginellaceae
Turpinia nepalensis Wall. ex Wt. Arn	Staphyleaceae
Symplocos ferruginea Roxb	Symplocaceae
Myricaria rosea W. W. Smith	Tamaricaceae
Christella kaumaunica Holtt.	Thelypteridaceae
Holpotelea integrifolia (Roxb) Planch	Ulmaceae
Trema orientalis (L.) Blume	Ulmaceae
Ulmus chumlia	Ulmaceae
Ulmus lanceifolia Roxb. Ex Wallich	Ulmaceae
Meeboldia selinoides	Apiaceae
Nardostachys jatamansi DC	Valerianaceae
Valeriana jatamansii Jones	Valerianaceae
Athyrium duthiei (Bedd.)	Athyriaceae
Woodsia andersonii (Bedd.) Christ.	Woodsiaceae
Woodsia cycloloba Hand.-Mazz	Woodsiaceae
Woodsia hancockii Baker.	Woodsiaceae
Cautleya petiolata Baker	Zingiberaceae
Hedychium aurantiacum Rosc	Zingiberaceae
Roscoea alpina Royle	Zingiberaceae

Table-1.10.
List of threatened fauna (CAMP) from Uttarakhand[4,5,6,7,14,15,36].

Name of species	Common name	Threatened Category
Mammals		
Paraechinus micropus Blyth	Indian Hedgehog	Lr/lc
Soriculus nigrescens Gray	Sikkim Large-clawed Shrew	Vu
Soriculus macrurus Blanford	Blanford's Long-tailed Shrew	Vu
Soriculus cadudatus Horsfield	Horsfield's Long-tailed Shrew	Vu
Suncus murinus (Linnaeus)	House Shrew	Lr/lc
Suncus etruscus Savi	Savi's Pygmy Shrew	Lr/lc
Pteropus giganteus Brunnich	Indian Flying Fox	Lr/nt
Rousettus leschenaulti Dobson	Fruit Bat	Lr/lc
Cynopterus sphinx (Vahl)	Short-nosed Fruit Bat	Lr/lc
Sphaerias blanfordi (Thomas)	Blanford's Fruit Bat	Dd
Megaderma lyra Geoffroy	Indian False Vampire	Lr/lc
Rhinolophus macrotis Blyth	Large-eared Horse-shoe Bat	None
Rhinolophus luctus Temminck	Great Eastern Horse-shoe bat	Dd
Rhinolophus lepidus Blyth	Blyth's (Little Indian) Horse-shoe Bat	Lr/nt
Rhinolophus affinis Schreber	Horse-shoe Bat	Lr/nt
Rhinolophus ferrumequinum (Schreber)	Greater Horse-shoe Bat	Vu
Hippocederus cineraceus Blyth	Leaf-nosed Bat	Dd
Myotis formosus (Hodgson)	Hodgson's Bat	Lr/nt
Myotis siligoresis (Horsfield)	Horsfield's Bat	Dd
Placotus aurilus Linnaeus	Long-eared Bat	Dd
Scotophilus heathi (Horsfield)	Greater Yellow Bat	Lr/lc
Pipistrellus coromandra Gray	Indian pipistrelle	Lr/nt
Miniopterus sehreibersi (Kuhl)	Sehreiber's Bat, Long-winged Bat	Lr/lc
Murina huttoni (Peters)	Hutton's Bat	Dd
Murina grisea Peters	Peter's Tube-nosed Bat	Vu
Macaca mulatta Zimmermann	Rhesus Macaque	Lr/lc
Semnopithecus entellus (Dufresne)	Common Langur	Lr/lc
Canis familiaris Ruppell	Domestic Dog	None
Canis aureus Linnaeus	Asiatic Jackal	Lr/lc
Vulpes vulpes (Linnaeus)	Common Red Fox	Lr/nt
Vulpes bengalensis (Shaw)	Bengal Fox	Lr/nt
Urus arctos (Linnaeus)	Brown Bear	Lr/nt
Melursus ursinus (Shaw)	Sloth Bear	Vu
Mellivora capensis Schreber	Ratel or Honey Badger	Lr/nt
Mustela kathiah Hodgson	Yellow-bellied Weasel	Dd
Martes flavigula (Boddaert)	Yellow-throated Marten	Lr/lc
Lutra lutra (Linnaeus)	Common Otter	None
Viverricula indica Geoffroy	Rasse or Small Indian Civet	Lr/nt
Paradoxurus hermaphroditus Pallas	Common Palm Civet, Toddy Cat	Lr/lc
Paguma larvata Hamilton Smith	Masked Palm Civet	Lr/lc

Name of species	Common name	Threatened Category
Herpestes edwardsi Geoffroy	Indian Grey Mongoose	Lr/lc
Hyaena hyaena (Linnaeus)	Striped Hyaena	Lr/nt
Felis catus Linnaeus	Domestic Cat	None
Felis chaus Schreber	Jungle Cat	Lr/nt
Prionailurus bengalensis (Kerr)	Leopard Cat	Lr/nt
Prionailurus viverrinus (Bennett)	Fishing Cat	Vu
Panthera pardus (Linnaeus)	Leopard, Panther	Vu
Panthera tigris (Linnaeus)	Tiger	En
Uncia uncia (Schreber, 1775)	Ounce or Snow Leopard	En
Elephas maximus Linnaeus	Indian Elephant	Vu
Equus asinus Linnaeus, 1758	Domestic Donkey	
Susdomesticus Brisson, 1762	Domestic Pig	None
Sus scrofa Linnaeus	Wild Boar	Lr/lc
Cervus unicolor Kerr, 1792	Samber	Lr/lc
Axis porcinus (Zimmermann)	Hog Deer or Para	
Muntiacus muntjak (Zimmermann)	Barking Deer or Indian Muntjak	Lr/lc
Bos taurus Linnaeus, 1758.	Domestic Cattle	None
Bos grunniens Linnaeus	Yak	Cr
Bubalus bubalis (Linnaeus, 1758).	Domestic Water Baffalo	None
Boselaphus tragocamelus (Pallas)	Nilgai or Blue Bull	Lr/lc
Tetraceros quadricornis (Blainville)	Four-horned Antelope or Chausingha	Lr/nt
Capricornis sumatraensis (Bechstein)	Serow	Vu
Hemitragus jemlahicus (H. Smith)	Himalayan Tahr or Thar	Lr/nt
Capra hircus Linnaeus, 1758.	Domestic goat	None
Capra ibex Linnaeus	Ibex	Vu
Ovis aries Linnaeus, 1758.	Domestic Sheep	None
Pseudois nayaur (Hodgson, 1833)	Bharal or Blue Sheep	Lr/lc
Funambulus palmarum Linnaeus	3 striped squirrel	Lr/lc
Funambulus pennantii Linnaeus	Nortthern (Five-striped)	Lr/lc
Mus musculus Linnaeus, 1758	House Mouse	Lr/lc
Mus buduga Gray	Little Indian Field Mouse	Lr/lc
Mus phillipsi Wroughton, 1912	Fawn-coloured Mouse	Lr/lc
Vandeleuria oleracea (Bannett)	Palm Mouse	Lr/lc
Rattus rattus (Linnaeus, 1758)	House Rat or Black Rat	Lr/lc
Rattus nitidus (Hodgson)	Himalayan Rat	Dd
Rattus turkestainiculus (Satunin, 1903)	Turkestan Rat	Dd
Gollunda ellioti (Gray, 1837.)	Indian Bush Rat	Lr/lc
Nesokia indica (Gray and Hardwicke, 1830)	Short-tailed Bandicoot Rat	Lr/lc
Bandicoota indica (Bechstein, 1800)	Large Bandicoot Rat	Lr/nt
Bandicoota bengalensis (Gray & Hardwicke, 1833)	Lesser Bandicoot Rat "Indian Mole Rat"	Lr/lc
Apodemus sylvaticus (Linnaeus)	Common Field Mouse	Dd

Name of species	Common name	Threatened Category
Tatera indica (Hardwicke, 1807).	Indian Gerbile	Lr/lc
Alticola roylei Gray, 1842.	Royale's Hight Mountain Vole	Dd
Hystrix indica (Kerr)	Indian Crested Porcupine	Lr/lc
Lepus nigricolis Cuvier, 1823.	Indian Hare or Black-naped Hare	Lr/lc
Reptiles		
Crocodylus palustris Lesson	Snub-nosed Crocodile, Mugger	Vu
Gavialis gangeticus (Gamelin)	Long-snouted Crocodile, Gharial	En
Kachuga dhongoka (Gray in: Gray and Hardwicke)		Vu
Panghura tectum (Gray)		Lr/nt
Melanochelys trijuga trijuga (Schweigger)	Indian Pond Terrapin	Lr/lc
Indotestudo elongata (Blyth)		Lr/nt
Hemidactylus flaviviridis Ruppell	Yellow-bellied House Gecko	Lr/lc
Hemidactylus brooki Gray	Spotted Indian House Gecko	Lr/lc
Japalura kumaonensis (Annandale)	Kumaon Mountain Lizard	Cr
Amphibia		
Amolops afganus (Gunther)		Lr/nt
Amolops formosus (Gunther)		Lr/nt
Bufo himalayanus Gunther		Lr/nt
Bufo milanostictus Schneider		Vu
Bufo stomaticus Lutken	Indus Valley Toad	Lr/nt
Duttaphrynus himalayanus Gunther	Himalayan Toad	Lr/nt
Duttaphrynus melanostictus Schneider	Common Indian Toad	Vu
Euphlyctis cyanophlyctis Schneider	Indian Skipper Frog	Lr/nt
Fejervarya syhadrensis (Annandale)	Southern cricket Frog	Vu
Hoplobatrachus tigerinus (Daudin)	Indian Bull Frog	Vu
Microhyla ornata Dumeril & Biborn	Narrow Mouthend Toad	Lr/lc
Paa annandalei (Boulenger)		En
Paa blandfordi (Boulenger)		Lr/nt
Paa leibigii (Gunther)		Lr/nt
Polypedates maculatus (Gray)		En
Uperodon systoma (Schneider)	Marbled balloon frog	Lr/nt
Nanorana minica Dubois	Nepal Paa Frog	Dd
Pisces		
Glyptothorax brevipinnis alaknandi Tilak		Cr
Glyptothorax garhwali Tilak		Cr
Glyptothorax dakpathri Tilak & Husain		Cr
Glyptothorax saisii (Jenkins)		En
Tor putitora (Hamilton-Buchanan)	Golden Mahseer	En
Barilius vagra Hamilton-Buchanan	Hill trout	Vu
Barilius barna Hamilton-Buchanan		Lr/nt
Barilius bendelisis Hamilton-Buchanan		Lr/nt

Name of species	Common name	Threatened Category
Cirrhinus reba (Hamilton-Buchanan)		Vu
Garra gotyla gotyla (Gray)	Stone Sucker	Vu
Glyptothorax indicus Talwar		Vu
Lepidocephalus caudofurcatus Tilak & Husain		Vu
Puntius sarna sarna Hamilton-Buchanan	Oliver Carp	Vu
Schizothorax richardsonii (Gray)	Snow Trout	Vu
Aspidoparia jaya (Hamilton-Buchanan)		Vu
Labeo dero (Hamilton-Buchanan)		Vu
Labeo dyocheilus (McClelland)		Vu
Pseudecheneis sulcatus (McClelland)		Vu
Amblyceps mangois (Hamilton-Buchanan)		Lr/nt
Glyptothorax pectinopterus (McClelland)	Cat Fish	Lr/nt
Nemachilus doonensis (Tilak & Husain)		En
Noemacheilus botia (Hamilton-Buchanan)	Striped Loach	Lr/nt
Noemacheilus corica (Hamilton-Buchanan)		Lr/nt
Noemacheilus rupecola (McClelland)		Lr/nt
Schizothorax progastus Day		Lr/nt
Cobitis gongota Hamilton-Buchanan		Lr/nt
Schizothorax kumaonensis Menon		Lr/nt

1.2.3. Some Important Plant and Animal Species

The state tree of Uttarakhand is Burans (*Rhododendron arboreum*), the state flower is Brahma Kamal (*Saussurea obvallata*), the state animal is Musk deer (*Moschus chrysogaster*) and State bird is Monal (*Lophophorus impejanus*) that speaks the wilderness of the flora and fauna of the State.

1.3. Selected Useful Groups of Plants and Animals

The vegetation of the state is clearly distinguished at alpine, sub-alpine, temperate and subtropical regions comprising large variety of flowering and lower plants. The flora is an amalgamation of plants of economic and aesthetic values. There are large variety of Orchids, Rhododendrons, Bamboos, Medicinal Plants and various other groups such as geraniums, Asters, Lilies, Roses, Anemones, Marigold, Primula, Gerberas, Dahlias, Hydrangiums, Gladiolus etc. Besides a large variety of trees, shrubs and climbers also adds to the rich diversity of plants in the state. The alpine meadows comprise large variety of flowers that bloom every spring. The famous Valley of Flowers, is just one example that adds to the floral diversity within a small region. Similarly animals are also distributed all across the landscape of the state from low hill to alpine areas. Some important groups of plants and animals are described below:

1.3.1. Ethnobotanical Plant Species

The state has nearly 318 plant species utilized for various ethnobotanical uses, *viz.* nearly 150 species as wild edible plants, 13 species used as condiments and spices, 37 species for oil yielding, 20 species for alcoholic and non alcoholic beverages, 17 species in various religion and culture courses, 20 species in arts and crafts, 16 species for their sacred values, and 5 species used in religious festivals (Fig. 1.6). Recently, 96 species of plants have been reported from state for bioprospecting, while 34 plant species used for miscellaneous purposes. In addition, the state also has 44 timber yielding species and 15 social forestry species. Selected wild edible species provide good yield as fetch income to subsistence farmers[1,73,74,75,76,77] (Table 1.11)

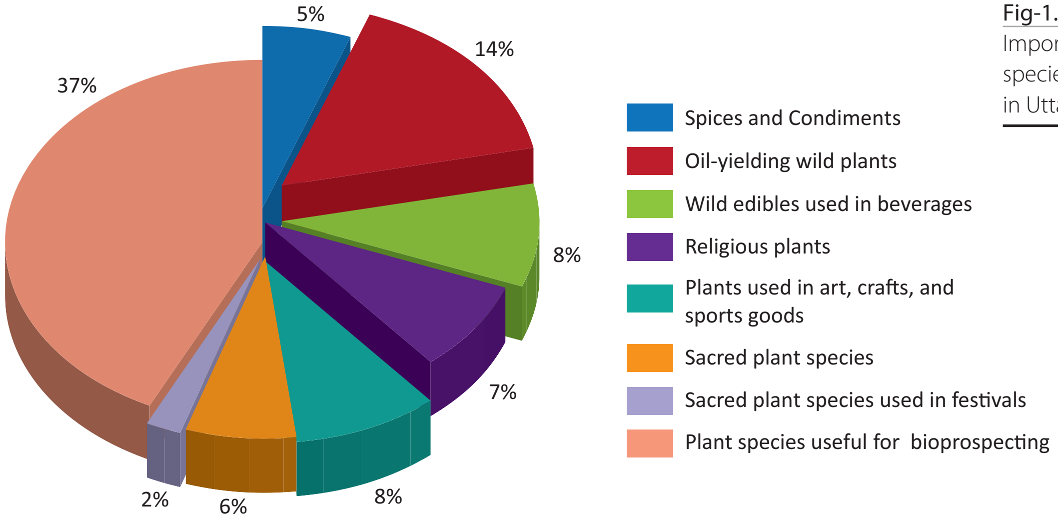


Fig-1.6.
Important ethnobotanical species used in different courses in Uttarakhand state

1.3.2. Ethnozoological Animal Species

Unlike the plants which have tremendous ethnobotanical applications, the animals have limited scope in this important aspect. However, there are reports of some animals species used for various traditional courses particularly for medicine and ritual purposes in Uttarakhand. In state nearly 8 species of trouts, snow trouts, mahseer & carps and 28 livestock species have been reported from the State that are used for their various parts in traditional cure, cultural and other uses (Table 1.12).

1.3.3. Medicinal and Aromatic Plants (MAPs)

Medicinal plants are an important component of biodiversity and the state is home to several herbal and aromatic plants. There are as many as 701 species of medicinal plants

Table-1.11. Potential wild edible plants of the state[73].

Plant species	Local name	Conservation status	Fruit yield/ plant (kg/tree)
Aegle marmelos	Bel	Vulnerable	151 ± 2
Bauhinia purpurea	Guiral	Least concern	5.3 ± 0.26
Benthamidia capitata	Bhamor	Near threatened	11.9 ± 3.7
Berberis asiatica	Kingor	Vulnerable	3.4 ± 0.2
Bombax ceiba	Semal	Near threatened	15.2 ± 0.4
Diplazium esculentum	Lingra	Least concern	-
Elaeagnus latifolia	Gewain	Vulnerable	2.6 ± 0.2
Emblica officinalis	Awanla	Vulnerable	13.3 ± 0.3
Ficus auriculata	Timla	Least concern	18.1 ± 0.5
Ficus glomerata	Gular	Least concern	51.6 ± 0.2
Ficus palmata *Ficus semicordata*	Bedu Khaina	Least concern Least concern	5 ± 0.1 14.8± 0.87
Hippophae salicifolia	Ames	Near threatened	12.4± 0.2
Morus serrata	Kimu	Vulnerable	6.3± 0.06
Myrica esculenta	Kafal	Vulnerable	10.7± 0.1
Pyracantha crenulata	Ghingaru	Near threatened	3.5 ± 02
Rhododendron arboreum	Burans	Vulnerable	6 ± 0.1
Rosa macrophylla	Jangali gulab	Least concern	0.6 ± 0.08
Rosa webbiana	Shedum	Near threatened	8.5± 0.26
Rubus ellipticus	Hinsul	Near threatened	3.5 ± 1.7
Rubus niveus	Kali hinsul	Least concern	3.8 ± 0.06
Spondias pinnata	Amara	Near threatened	27.8 ± 1.3
Viburnum mullaha	Bhatmolya	Vulnerable	5.2 ± 0.29
Ziziphus jujuba	Ber	Near threatened	5.9 ± 3.7

Table-1.12. Traditional uses of wild animals and their parts[3,85]

Species	**Family/ order**	**Common name**	**Medicinal use along with mode of intake**
Lepus nigricollis	Leporidae	Hare	Blood of rabbit is used in asthma
Rana tigrina	Ranidae	Frog	Frog boiled in oil is used for healing wounds due to burn
Palamnaeus spp.	Scorpionidae	Scorpion	Ash produced after the burning off the scorpion is commonly applied on wounds
Hemidactylus spp.	Squamata	Geckos	Used to heal eczema
Calotes versicolor	Squamata	Garden Lizard	The whole animal is boiled in oil and the oil is used to heal wounds
Tor putitora Schizothorax richardsoni	Cyprinidae	Fish	Blood of cut fish is used in foot and mouth disease; it is also applied on sore wounds
Spirobolus spp.	Myriapoda	Millipede	Dry millipede smoke is used in the treatment of piles

Species	Family/ order	Common name	Medicinal use along with mode of intake
Cimex rotundatus	Hemiptera	Bedbug	Bedbugs crushed in holy basil- *Ocimum sanctum* is applied on ringworm
Vipera russelli	Squamata	Snakes	The meat is believed to promote eyesight and facilitates the elimination of urine, stool and flatus
Ptyas mucosus			
Ancistrodon himalayans			
Pseudois nayaur	Bovidae	Bharal	It is applied on the stomach to get relieved of stomach pain or fever
Equus cabalus	Equidae	Horse	The meat is believed to be a promoter of corpulence, strength and eyesight
Equus spp.	Equidae	Ass	The meat is believed to be a promoter of strength and virility
Panthera pardus	Felidae	Leopard	The meat is believed to be a promoter of strength and virility, while the bones are supposed to be an aphrodisiac
Bubalus spp.	Bovidae	Buffalo	The meat is believed to be a promoter of strength and virility of the physique
Muntiacus muntjak	Cervidae	Barking Deer	The meat is believed to be a promoter of strength and virility
Sus scrofa cristatus	Buidae	Wild Boar	The meat is believed to be a promoter of strength, corpulence and virility, is a good appetizer and alleviator of fatigue
Rattus rattus	Rodentia	Rat	The meat is believed to be a promoter of semen
Macaca mulatta	Cercopithecidae	Monkey	The meat is believed to cure rheumatism, asthma, adiposity, anemia and parasitic infestation
Capra falconeri	Bovidae	Goat	The meat is believed to stimulate digestion and cures rhinitis
Hemitragus jemlahicus	Bovidae	Himalayan Thar	The meat is believed to be a promoter of strength and virility
Paratalphusa spp.	Crustacea	Crab	The meat is believed to be a promoter of strength, corpulence and is a good remedy for the diseases of the blood
Catreus wallichii	Phasianidae	Chir Pheasant	The meat is believed to be a promoter of strength and semen
Strix aluco nivicola	Strigiformes	Owl	The meat is believed to be a promoter of strength and virility
Bos indicus	Bovidae	Cattle	It cures poisoning, eye diseases and afflictions by evil spirits
Columba livia	Columbidae	Pigeon	Patients suffering from paralysis are often given the meat of a black pigeon

Species	Family/ order	Common name	Medicinal use along with mode of intake
Oryctolagus quiniqulus	Lagomorpha	Hare	Meat cures menstrual disorders
Canis aureus indicus	Canidae	Jackal	Meat is used to cure paralysis and arthritis
Hystrix indica	Hystricidae	Porcupine	Used in Children suffering from the stomach disorders and in asthma
Bos grunniens	Bovidae	Yak	This is believed to keep away unholy spirits from entering the room
Felis domesticus	Felidae	Cat	It is said to cure arthritis
Moschus m.moschiferous	Moschidae	Musk Deer	Musk is used in the treatment of malaria, high fever and in heart ailments
Martes flavigula	Mustelidae	Martens	Bones paste of the animal is used to cure wounds
Cypselus affinis		Swift	Its nest, made out of clay/soil is treated auspicious
Vanellus indicus		Red Wattled Lapwing	The yolk when applied on head is said to cure typhoid
Selenarctos thibetanus	Ursidae	Himalayan Black Bear	Gall bladder of animal is used in curing myriad diseases, malaria being one of them
Barilius vagra	Cyprinidae	Fish	Juice is given to weak persons
Chagunius chagunio	Cyprinidae	Fish	Juice is used to prevent cold
Masterambelus armatus	Mastacembelidae	Fish	Juice is given for curing Asthma
Lepidocephalus guntea	Cobitidae	Fish	Juice is used for curing fever
Glyptothorax pectinopterus	Sisoridae	Fish	Fat is used for curing the wounds
Nemacheillus rupecola	Cobitidae	Fish	Juice & fat is used for curing fever & itching

Burans (*Rhododendron arboreum*)

Rhododendron arboreum is an evergreen small tree that is widely popular for the processed juice of its flowers which have gained market popularity as rhodojuice / sharbat. The plant is found in the Himalaya from Kashmir eastwards to Nagaland. In Hill areas, the flowers of Burans with sweet and sour taste are used in preparation of squash, jam, jellies and local brew. Leaves are used in the treatment of headache. In Ayurveda it is used in Jaundice, Diabetes, Piles, liver disorder and Worms. Wood is used to make household implements. Various parts of the plant exhibited medicinal properties and is used for the treatment of various ailment.

Brahma Kamal (*Saussurea obvallata*)

Brahma Kamal commonly known as King of Himalayan flower. Its botanical name is *Saussurea obvallata* (DC.) Edgew., Family (Asteraceae), a rare, threatened and near-endemic medicinal herb of the Indian Himalayan region. It is native to the Himalayas, northern Burma and south-west China. The flower blooms in the alpine habitats at the upper reaches at an elevation 11,000 to 17,000 feet during mid monsoons (July-August) amongst the rocks and grass. Valley of Flowers, Rudranath and Hemkund Lake at Sapta Shringa are well known habitats of Brahma Kamal. Roots are used as local medicine for paralysis of the limbs and cerebral ischemia. G.B. Pant Institute of Himalayan Environment and Development, Almora has developed micropropagation protocol of Brahma Kamal.

Himalayan Monal (*Lophophorus impejanus*)

The Himalayan Monal is the state bird of Uttarakhand and National bird of Nepal. The natural range of the Himalayan Monal spreads from eastern Afghanistan through the Himalayas, including Pakistan, India (the state of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh), China (the Tibet region), Nepal and Bhutan. Adult males possess long crest, feathered with multi colour plumage throughout its body while the female, like other pheasants, are dull in colour with the upper parts covered with dark brownish black feathers. Female has a prominent white patch in fore neck and a white strip on tail. Their food primarily consists of tender leaves, shoots, tubers, nuts and insects and other invertebrates. Population of this species is threatened due to hunting and poaching and other human induced factors. Male Monal had been under heavy hunting pressure for its crest feather and due to this it is listed under Indian Wildlife Protection Act under Schedule I. The distribution of Monal in Uttarakhand has its significant presence in Nandadevi NP, Valley of Flowers NP, Gangotri NP, Kedarnath WS, Askot WS, Govind National Park and Binog Wildlife Sanctuary. The Kedarnath WS in particular, has several excellent locations for sighting of this beautiful bird[63].

Musk Deer *(Moschus chrysogaster leucogaster)*

The state animal of Uttarakhand is Musk Deer and is also known as 'Kasturi Mrig'. Musk Deer can be characterised by large ear, short tail, no horn, no antler, male contains musk gland (about 10gm musk per pod); that can be harvest an average of 25gm per year. Musk Deer population is decreasing due to poaching, illegal trade, habitat destruction. High value of Musk and canine teeth; price of musk is 3 – 5 times that of gold. Although musk deer have previously been classified in the family ***Cervidae*** many scientists today group them within their own separate family ***Moschidae.*** Debate continues over the taxonomy of musk deer although there is now broad agreement for five species and their distribution[63,64,65,66,67,69] as illustrated below.

Species of *Moschus* and their distribution[68,69]

English Name	Scientific Name	1996 IUCN Red List Category	CITES Listing	Distribution
Alpine Musk	*Moschus sifanicus*	Lr/nt	I	China and India
Black Musk Deer	*Moschus fuscus*	Lr/nt	I II	Bhutan, India, Myanmar, Nepal and China
Forest Musk Deer	*Moschus berezovskii*	Lr/nt	I II	China and Vietnam
Himalayan Musk Deer	*Moschus chrysogaster*	Lr/nt	I II	Afghanistan, India, Nepal, Pakistan and China
Siberian or Taiga Musk Deer	*Moschus moschiferus*	Vu	II	Russia, Kazakhstan, Kyrgyzstan, China, Korea and Mongolia

The musk gland of the Musk deer is said to give out a smell that stays for a long time. It is for their musk, above all else, that musk deer are hunted and trapped. It is used in perfume as a scent and fixative. All species of musk deer are listed in the IUCN Red List of Threatened Species. In Uttarakhand Musk Deer distributed in Govind Wildlife Sanctuary and Binsar Wildlife Sanctuary. The Kedarnath Musk Deer Sanctuary and Askot Wildlife Sanctuary that are mainly set up with the aim of conserving this animal.

Tiger (***Panthera tigris***)[69]

The Indian Tiger is also known as Royal Bengali Tiger and is regarded as the National Animal of India and Bangladesh.

There are six species of Tiger

1. **Amur tiger** (*P. t. altaica;* also known as the Siberian tiger).
2. **Bengal tiger** (*P. t. tigris*)
3. **Indo Chinese tiger** (*P. t. corbetti*)
4. **Malayan tiger** (*P. t. jacksoni*)
5. **South China tiger** (*P. t. amoyensis*)
6. **Sumatran tiger** (*P. t. sumatrae*)

Tiger is in the apex of food chain and their healthy population reflects the healthy ecosystem. It is the largest living cat, heavier than the lion but generally not taller, having a relatively large head, very robust teeth, a quite muscular body and dark vertical stripes on the trunk. Tigers are solitary; females with young forms groups. Most tigers live in forests or grasslands, hunt alone and eat primarily medium-sized herbivores such as deer, wild pigs, and buffalo. **Cause of population degradation** is poaching, illegal trade, habitat destruction and poaching for fur. Destruction of habitat have greatly reduced tiger populations in the wild, and it has been placed on the endangered species list. Also, their bones and nearly all body parts are used in Chinese medicine for a range of purported uses including pain killers and aphrodisiacs. All species of Tiger are listed in the IUCN Red List of Threatened Species and listed under CITES Appendix I. All subspecies of Tiger have been listed as endangered since 1972. **In Uttarakhand, Tigers are** distributed in Corbett National Park; the first National Park of the country where the project Tiger was launched in 1972. In addition, it is also conserved in Rajaji National Park.

Snow leopard ***(Uncia uncia)***

Snow leopards have long thick fur, tails are long and flexible, usually among cats, their eyes are pale green or gray in color. The snow leopard is a mountain dweller that lives in forested sections at the edge of the snow line, or on bare rocks, cliffs and crags. Life Span of Snow Leopard is 15-18 years. Poaching, illegal trade, habitat destruction is major cause of their population degradation. Its Fur is used for coats and other garments and their bones are also in demand for use in traditional Asian Medicine. In 1972, the International Union for Conservation of Nature (IUCN) placed the snow leopard on its Red List of Threatened Species as globally "Endangered"; the same threat category was applied in the assessment conducted in 2008[69,84]. In Uttarakhand, Snow Leopard is distributed in Gangotri NP, Askot WLS, Nanda Devi Biosphere Reserve & Valley of Flowers and State government has planned to conserve the wild habitat of this species.

Mahseer ***(Tor Spp.)***

Mahseers (*Tor spp.*) have been a legendary sport fish of India with a very high table value, popularly known as angler's delights due to its fighting sprit. Mahseer, at one time considered to be of single species, is now represented by thirteen valid species distributed all over India[83]. Out of which three species reported from Uttarakhand i.e. *Tor putitora, Tor tor* and *Tor chelynoides* **(however there is difference of opinion among the taxonomists regarding this species).**

Scientific Name	Common name
Tor putitora (Ham-Buch)	Golden or Putitora mahseer
Tor tor (Ham-Buch)	Turiya or Tor mahseer
Tor khmdree (Sykes)	Deccan or Khudree mahseer
Tor mussullah (Sykes)	Humpback or Mussullah mahseer
Tor kulkarnii Menon	Dwarf mahseer
Tor progeneius (McClelland)	Jungha of the Assamese
Tor mosal (Ham-Buch)	Copper or Mosal mahseer
Tor chelynoides (McClelland)	Kali mahseer
Tor neilli (Day)	-
Tor khudree malabaricus (Jerdon)	Malabar mahseer
Tor moyarensis Arunachalam	-
Tor megalepis Jerdon	-
Tor khudree longispinnis (Gunther)	-

Mahseer is a Local words means "The Big Mouth", it is closely related to European Bardel & Carphis creature and is known to be the toughest among the fresh water sport fish. The fish has elongated body with pointed snout and the inter orbital space is flat while the jaws are of equally sized. Barbels are in two pairs with the rostral barbel shorter than the maxillary. Its is highly finicky & moody fish. The body color is golden, greyish on dorsal side & reddish - yellow fins. The Mahseer is an important game and food fish distributed along the Himalaya in India, Pakistan, Bhutan and Bangladesh. It is a migratory fish and attains a maximum weight up to 25kg, during winters fish moves to the warm water. The fish is a column feeder and omnivorous (adult) and planktivorous (juvenile). Angling period for Mahseer can be well splited in two parts; Spring (pre Monsoon) & Autumn (Post Monsoon). Fishing is strictly prohibited during monsoon as it is the breeding time for the fish. Mahseer have suffered severe declines, and are now considered threatened due to pollution, habitat loss and over fishing. Mahseer listed as endangered Species under (CAMP) criterion 1998[3,7,83]. The distribution of Mahseer in Uttarakhand is in Nayar river, Kosi river, Ram ganga and Song river is having best population of Mahseer.

Cheura *(Diploknema butyracea)*

Cherua (*Diploknema butyracea*) belongs to the family Sapotaceae and popularly known as Indian Butter Tree which is mainly found in Uttarakhand state. It is a multi-purpose tree used as food, fodder and medicines in Kumaun hills and also known as Kalp-Vriksha. Commercially the Cheura oil extracted from the seeds is marketed as Phulwara Ghee. Cheura is a native of Nepal and distributed from India through Nepal to Philippines and from Garhwal, Kumaun eastwards to Sikkim and Bhutan (Sub-Himalayan tracts and outer Himalayan ranges). Cheura oil is used as Ghee and butter for cooking and frying of vegetables and food. Cheura butter is used for preparing medicines, ointment, candles, cream and other daily use products. The cake produced after processing of Cheura is used as manure. It has pesticide properties and used as wormicide, nematicide, rodenticide and insecticide. The cake can also be used as crude fish poison substituting the dangerous chemical pesticides. It has fair amount of saponin hence, can be served as source of saponin for industry in future. Cheura flowers are rich source of sugar and utilized for preparation of Gur like products (jaggery) and for fermentation (alcohol). Cheura kernel contains very high nutritional value. It contains 5-20% protein, 30% carbohydrate, 3.8% ash, 4.8-6.1% reducing Sugar and 38mg/100gm Vitamin C. It's juice is also used as a soft drink. Cheura starts fruiting from 7-8 years after plantation and continue to yield upto 50-60 years on alternate year basis. The average seed yield is estimated about 70 to 80 Qt/ha. The market price of Cheura seed varies from 10-15 per kg. The the average income is estimated about ₹ 70,000 to 1,20,000 per hectare/year[70]. Horticulture Department of Govt. of Uttarakhand is also working on cultivation and product making of Cheura. G.B. Pant University of Agriculture and Technology, Almora is working on development of wild Cheura project. G.B. Pant Institute of Himalayan Environment and Development has developed propagation protocol for this species.

Kaphal *(Myrica esculenta)*

Myrica esculenta, locally known as Kaphal, belongs to family Myricaceae, is a sub-temperate evergreen tree found throughout the mid-Himalayas, starting from about 1300 metres and going up to about 2300 metres especially in chir - pine (***P. roxburghii***), banj - oak (***Q. leucotrichophora***) and mixed broad leaved forests. The species is well known for its edible fruits and as an income-generating source. *Myrica* fruit is eaten raw and every year its fruits worth thousands of rupees are sold in different towns of Uttarakhand thus, forms good source of income for the villagers. In addition, the species is useful in multiple ways. The bark has commercial value as tanning and dyeing material. The oil obtained from the flowers and seeds is used in the preparation of tonic. The species is extensively used as fuel wood throughout the hilly region and competes well in fuel wood value with other priority species.

The bark of Kaphal is also used in many medicinal properties, such as heating, stimulating in catarrhal fever, cough and in the infections of the throat. Bark is also considered useful in disorders relating to vata and kapha, fever, asthma, urinary discharges, piles, bronchitis, throat complaints, tumours, anemia, chronic dysentery and ulcers. Its also useful in headache and in curing eye diseases. The oil from the flowers is a tonic, useful in earache, diarrhea and paralysis.

in the state found under diverse agro-climatic zones. Many of them are endemic to the state. There are large number of agencies, institutes working on medicinal plant sector. The state government has formulated many policies for development of MAP sector. A detailed discussion about this sector is given in Chapter No. 2.

1.3.4. Fibre Yielding Plant Species

In Uttarakhand state there is an excellent opportunities for plant based fibres. People traditionally used hemp, bhimal and gurhal fibre for their household uses and cultivated in fields. A total of 95 species of fibre yielding plants are recorded from Uttarakhand state (Table 1.13).

1.3.5. Bamboo

The bamboo is used for various purposes in all 13 districts of Uttarakhand with 1394 km^2 area underneath it. The gross commercial bamboo standing stock is estimated at 45,000 m^3 in the state[75]. Bamboo in the state is categorized into two groups; the bamboo and the ringal bamboo. Bamboo is thick, long and slender like plant while ringal is thin, reed like, spineless plant. The communities which make articles from bamboo and ringal are called as *Baruree* and *Rudia,* respectively[76]. In Uttarakhand state, 8 bamboo species belonging to 5 genera grow naturally, viz. *Dendrocalamus strictus, D. somdevai, D. patellaris, Bambusa bambos* (all bamboo species), and *Drepanostachyum falcatum, Thamnocalamus falconeri, T. spathiflorus,* and *Chimonobambusa jaunsarensis* (all ringal species[74,75,76]**)**. Ringal species grow in the mid and high hill areas of the state (>2000 m) while bamboo is found at mid and low hills (<2000 m). There are a large number of other species that have been planted in bamboosetums in FRI and other areas. *D. strictus* grows in low elevations that earn maximum revenue for the Forest Department. *D. somdevai* dominates mid-hills and the species is much similar to *D. hamiltonii* except for the wall thickness, thus often misquoted as later species. The other two bamboo species (*D. patellaris, B. bambos*) exhibit restricted distribution. Among ringal species, dev-ringal (*Thamnocalamus falconeri*) is most commonly used species. *T. spathiflorus* is recorded at highest elevations. among all the bamboo species. *Drepanostachyum falcatum* and *C. jaunsarensis* are other two species used in local system for different articles. Besides being used for making diverse utility items, the leaves of selected bamboo species are also collected as fodder during lean period. Of the total 13 districts in Uttarakhand, the district Uttarkashi has maximum area

Table-1.13. Fibre yielding plant species of Uttarakhand[74]

S.No.	Species
1.	*Abelmoschus esculentus* (L.) Moench
2.	*Abutilon indicum* (L.) sweet
3.	*Abutilon persicum* (Burm. f.) Merr.
4.	*Abutilon ramosum* (Cav.) Guill. & Perr.
5.	*Aechmanthera gossypina* (Nees) Nees
6.	*Agave americana* L.
7.	*Agave cantula* Roxb.
8.	*Annona squamosa* L.
9.	*Artocarpus heterophyllus* Lam.
10.	*Artocarpus lacucha* Buch.-Ham.
11.	*Arundo donax* L.
12.	*Bauhinia vahlii* Wight & Arn.
13.	*Betula alnoides* Buch.-Ham. ex D. Don
14.	*Betula utilis* D. Don
15.	*Boehmeria penduliflora* Long.
16.	*Boehmeria platyphylla* D. Don
17.	*Bombax ceiba* L.
18.	*Broussonetia papyrifera* Vent.
19.	*Butea monosperma* (Lam.) Taub.
20.	*Cajanus cajan* (L.) Millsp.
21.	*Calotropis procera* (Ait.) R.Br.
22.	*Cannabis sativa* L.
23.	*Careya arborea* Roxb.
24.	*Chonemorpha fragrans* (Moon) Alston
25.	*Cissampelos pareira* L.
26.	*Corchorus olitorius* L.
27.	*Cordia dichotoma* Forst.
28.	*Cordia vestita* Hook.f.
29.	*Coriaria nepalensis* wall.
30.	*Crotalaria assamica* Benth.
31.	*Crotalaria juncea* L.
32.	*Cryptolepdis buchananii* Roem.& Schult.
33.	*Daphne papyracea* Wall. ex steud.
34.	*Debregeasia longifolia* (Burm. f.) Wedd.
35.	*Debregeasia saeneb* (Forssk.) Hepper & Wood.
36.	*Desmodium elegans* DC.
37.	*Desmostachya bipinnata* (L.) Stapf.
38.	*Eriophorum comosum* Wall. ex Nees
39.	*Eulaliopsis binata* (Retz.) C.E. Hubb.
40.	*Ficus auriculata* Lour.
41.	*Ficus benghalensis* L.
42.	*Ficus racemosa* L.
43.	*Ficus semicordata* Buch.-Ham. ex Sm.
44.	*Ficus virens* Ait.
45.	*Firmiana fulgens* (Wall. ex Masters) Corner
46.	*Girardinia diversifolia* (Link) Friis
47.	*Grewia asiatica* L.
48.	*Grewia eriocarpa* A.L. Juss.
49.	*Grewia optiva* J.R. Brumm. ex Burrett
50.	*Grewia sclerophylla* Roxb. ex G.Don
51.	*Grewia serrulata* DC.
52.	*Helicteres isora* L.
53.	*Heterostemma alatum* Wight
54.	*Hibiscus cannabinus* L.
55.	*Hibiscus vitifolius* L.
56.	*Imperata cylindrica* (L.) Raeasch.
57.	*Kydia calycina* Roxb.
58.	*Linum usitatissimum* L.
59.	*Malvastrum coromandelianum* (L.) Garcke
60.	*Maoutia puya* (Hook.) Wedd.
61.	*Marsdenia roylei* Wight & Arn.
62.	*Marsdenia tenacissima* (Roxb.) Moon
63.	*Millettia extensa* (Benth.) Baker
64.	*Mitragyna parvifolia* (Roxb.) Moon
65.	*Musa balbisiana* colla
66.	*Opuntia elatior* Mill.
67.	*Oreocnide frutescens* (Thunb.) Miq.
68.	*Parkinsonia aculeata* L.
69.	*Pergularia daemia* (Forssk.) Chiov.
70.	*Phoenix humilis* Royle ex Becc. & Hook.f
71.	*Phragmites karka* (Retz.) Trin. ex steud.
72.	*Pueraria tuberosa* (Roxb. ex Willd.) DC.
73.	*Saccharum bengalense* Retz.
74.	*Scindapsus officinalis* (Roxb.) Schott
75.	*Sesbania bispinosa* (Jacq.) W.F. Wight
76.	*Sesbania sesban* (L.) Merr.
77.	*Sida acuta* Burm.f.
78.	*Sida cordata* L. (Burm.f.) Borss.

S.No.	Species
79.	*Sida cordifolia* L.
80.	*Sida rhombifolia* L.
81.	*Spatholobus parviflorus* (Roxb. ex DC.) Kuntz.
82.	*Sterculia villosa* Roxb.
83.	*Streblus asper* Lour.
84.	*Thespesia lampas* (Cav.) Dalz. & Gibs.
85.	*Trema orientalis* (L.) Blume
86.	*Trema politoria* (Planch.) Blume
87.	*Triumfetta rhomboidea* Jacq.
88.	*Typha angustata* Bory & Chaub.
89.	*Ulmus wallichiana* Planch.
90.	*Urena lobata* L.
91.	*Urtica ardens* Link
92.	*Urtica dioica* L.
93.	*Ventilago denticulata* Willd.
94.	*Vetiveria zizanioides* (L.) Nash
95.	*Wikstroemia canescens* Meissn.

under bamboo followed by Rudraprayag, Haridwar and Nainital districts. Bageshwar, Chamoli, Pithoragarh, Tehri and Uttarkashi districts have ringal species only, while Udham Singh Nagar, Haridwar and Champawat district comprised bamboo species only. Bamboo Fibre and Development Board, Dehradun has established facilities for the promotion and development of bamboo related activities in the state. Many research institutions and NGOs are working on multiplication of bamboo and bamboo craft development. Bamboo has very good future in Uttarakhand that can be used as an important resource for rural area development.

1.3.6. Orchids

In Uttarakhand, 72 genera with 236 species of orchids are recorded. Among them 17 species are medicinally important (Table 1.14). 12 Taxa are recorded in Red Data book of Indian plants. Rapid depletion of orchid species requires urgent conservation measures. Orchids are most sensitive to habitats and host specific species. A major reason for their threatened status is habitat loss. There is a need to educate people on role and importance of orchids in state biodiversity.

1.4. Biodiversity and Ecosystem Services

Besides providing a large variety of goods, the other important contribution of biodiversity is in producing ecosystem services, which help in maintaining various environmental processes that are utilized by human beings. As per Millennium Ecosystem Assessment the biodiversity services are described as **Supporting Services** that are necessary for the production of all other ecosystem services including soil formation, photosynthesis, primary production, nutrient cycling and water cycling; **Provisioning Services** that are obtained from ecosystems, including food, fibre, fuel, genetic resources, biochemicals, natural medicines, pharmaceuticals, ornamental resources and fresh water; **Regulating Services** obtained from the regulation of ecosystem processes, including air quality regulation, climate regulation, water regulation, erosion regulation, water purification, disease regulation, pest regulation, pollination, natural hazard regulation; and **Cultural Services** that are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences – thereby taking account of landscape values (Table 1.15).

These services are often considered free. However, the cost of replacing these services would be extremely expensive. It therefore makes economic and development sense to move towards sustainability. There have been a few attempts to value ecosystem services emanating from the forests of Uttarakhand state[78,79] (Table 1.16). It is astonishing to learn that various forests provide ecosystem services to the tune of US \$ 1150 ha^{-1} yr^{-1}. These

Table-1.14.
Important orchid species of Uttarakhand State[77]

Species	Nos
Acampe Lindl	2
Aerides Lour	2
Anoectochilus Blume	1
Aorchis Vermeulen	2
Aphyllorchis Blume	1
Aphyllorchis gollani Duthie	
Aphyllorchis parviflora King & Pant	
Archinottia microglottis (Duthie) Chen	
Arundina Blume	1
Ascocentrum Schltr. ex J.J. Sm.	1
Brachycorythis Lindl	1
Bulbophyllum Thouars	11
Calanthe pachystalix Reichb.f. ex. Hook f.	
Cephalanthera Rich	1
Cheirostylis Blume	1
Chiloschista Lindl	1
Cleisostoma Blume	1
Coelogyne Lindl	5
Corallorhiza Gagnebin	1
Cryptochilus Wall.	1
Cymbidium Swartz	9
Cyperipidium elegans Reichb.f.	
Cyperipidium himalaicum Rolfe Rare	
Cypripedium cordigerum D. Don	
Dactylorhiza Necker ex Neuski	1
Dendrobium Swartz	16
Didiciea king & Prain ex King & Pantl	1
Diphylax Hook f.	1
Diplomeris hirsuta (Lindl.) Lindl	
Epipactis Zinn.	3
Epipogium Gmelin ex Borkhaussen	2
Eria Lindl	8
Eria occidentalis Seid	
Eulophia R.Br. ex. Lindl	8
Eulophia mackinnonii Duthie	
Flickingeria hesperis Seid	
Galeala Lour.	1
Gastrochilus D.Don	4
Gastrodia R.Br.	1

Species	Nos
Geodorum G. Jackson	1
Goodyera R.Br.	6
Gymnadenia R.Br.	1
Habenaria Willd.	17
Hemipilia Lindl	1
Herminium Linn	8
Kingidium P.F. Hunt	2
Liparis L.C. Rich	10
Listera R.Br.	4
Luisia Gaud	3
Malaxis Soland ex Swartz.	7
Neottia Guettard	2
Neottianthe (Reichb.) Schltr	2
Nervilla Comers. ex Gaud.	7
Oberonia Lindl	9
Oreorchis Lindl	3
Ornitho chillus (Lindl) Wall ex Benth.	1
Otochilus Lindl	1
Pachystoma Blume	1
Pectellis Rafin	2
Pelatantheria Ridl	1
Peristylus Blume	9
Phaius Lour	1
Pholidota Lindl ex Hook	2
Platanthera Rich	2
Pleione D. Don	4
Ponerorchis Reichb. f.	
Pteroceras Hasselt ex Hassk	1
Rhvnchostylis Blume	1
Satyrium Swartz.	1
Smitinandia Holtt.	1
Sviranthes Rich	2
Sunivia Lindl.	1
Thelasis Bhime	1
Thunia Reichb. f.	1
Tropidia Lindl	1
Vanda W. Jones ex R.Br.	5
Vandopsis P fitz.	1
Zeuxine Lindl.	3
Genera - 72	Sp.236

ecosystem services arise as a result of interaction between biotic and abiotic components of ecosystems. Altogether the forests of Uttarakhand are reported to produce ecosystem services value worth of US$ 2.4 billion/year which is equal to ₹ 107 billion/year[78].

Table-1.15. A profile of biodiversity governed natural services to human beings

Biological resources	Ecosystem services	Social benefits
o Food	o Protection of water resources	o Research, education and monitoring
o Medicinal resources and pharmaceutical drugs	o Soils formation and protection	o Recreation and tourism
o Wood products	o Nutrient storage and recycling	o Cultural value
o Ornamental plants	o Pollution breakdown and absorption	o Aesthetic value
o Breeding stocks, population reservoirs	o Contribution to climate stability	
o Future resources	o Recovery from unpredictable events	
o Diversity in genes, species and ecosystems	o Maintenance of ecosystems	

Table-1.16. Annual value of various ecosystem services of Uttarakhand[78]

Ecosystem services	Value in US$ ha^{-1} yr^{-1}
Climatic regulation	167.6
Disturbance regulation	2.3
Water regulation and water supply	5.2
Erosion control	114.6
Soil formation	11.6
Nutrient cycling	429.6
Waste treatment	102.7
Biological control	2.3
Food production	50.7
Raw material	164
Genetic resource	18.5
Recreation	78.6
Cultural	2.3

1.4.1. Biodiversity and Carbon Sequestration

Carbon sequestration is another important ecosystem service that emanates through capturing and securely storing carbon dioxide emitted from the global energy system. Carbon capture and storage (CCS), (carbon capture and sequestration), refers to prevent release of large quantities of CO_2 into the atmosphere from fossil fuel use in power generation and other industries[78]. It is a potential means of mitigating the contribution of fossil fuel emissions to global warming (Table 1.17).

1.5. Conservation of Biodiversity

Biodiversity has intrinsic value for human beings therefore its conservation is highly demanding. Unfortunately rapid urbanization and changes in land-use cover have adversely affected biodiversity with direct impact on a large number of plant species in Uttarakhand state. It is proved as the state has 38 threatened plants, 65 threatened medicinal plants, and 312 species of threatened plants under CAMP criteria in addition to 252 plant species under the CITES of wildlife fauna and flora and 150 species of endemic plants. Similarly, the trade and utilization of faunal resources for various purposes constitute a serious threat to their biodiversity. Among the major species, musk from the Himalayan musk deer (*Moschus chrysogaster*), bile from the Himalayan black bear (*Ursus arctos*), mammalian furs, wool, and butterfly form the back bone of the species in trade from the state. To safeguard the interest of biodiversity conservation, the state has brought substantial area under Protected Area Network (PAN) comprising national parks, sanctuaries and conservation reserves. Besides there are herbal gardens, arboratums, parks, zoos, sacred groove and MPCAS.

Table-1.17.
Total carbon sequestration value of the forests of Uttarakhand[78,79]

Forest Type	Area (km^2)	Biomass (Mt C)	Net Accumulation in Biomass (Mt C yr^{-1})	Soil (150 cm depth Mt C)	Value of Carbon sequestration (million US$)
Temperate Conifer Forest	6017.06	37.15	1.59	68.54	20.67
Temperate Broad Leaved Forest	7808.81	119.30	2.29	111.95	29.77
Tropical Coniferous (Pine) Forest	5418.03	33.45	1.43	61.71	18.59
Moist Deciduous Forest	3027.25	54.45	0.92	15.10	11.96
Dry Deciduous Forest	695.31	12.51	0.21	3.47	2.73
Sub Tropical (Sal) Forest	561.59	10.10	0.17	2.80	2.21
Total	**23528.05**	**266.96**	**6.61**	**263.58**	**85.93**

1.5.1. Protected Area Network (PAN)

India has 668 Protected Areas (PAs) extending over 1,61,221.57 sq. km (4.90% of total geographic area) and comprising 102 National Parks, 515 Wildlife Sanctuaries, 47 Conservation Reserves and 4 Community Reserves. Uttarakhand state supports six national parks, six wildlife sanctuaries, one biosphere reserve, one world heritage site, and two conservation reserves, covering an area of 0.73 million ha, constituting 13.68% of the state's geographic area (Table 1.18).

Map of Protected Area of Uttarakhand

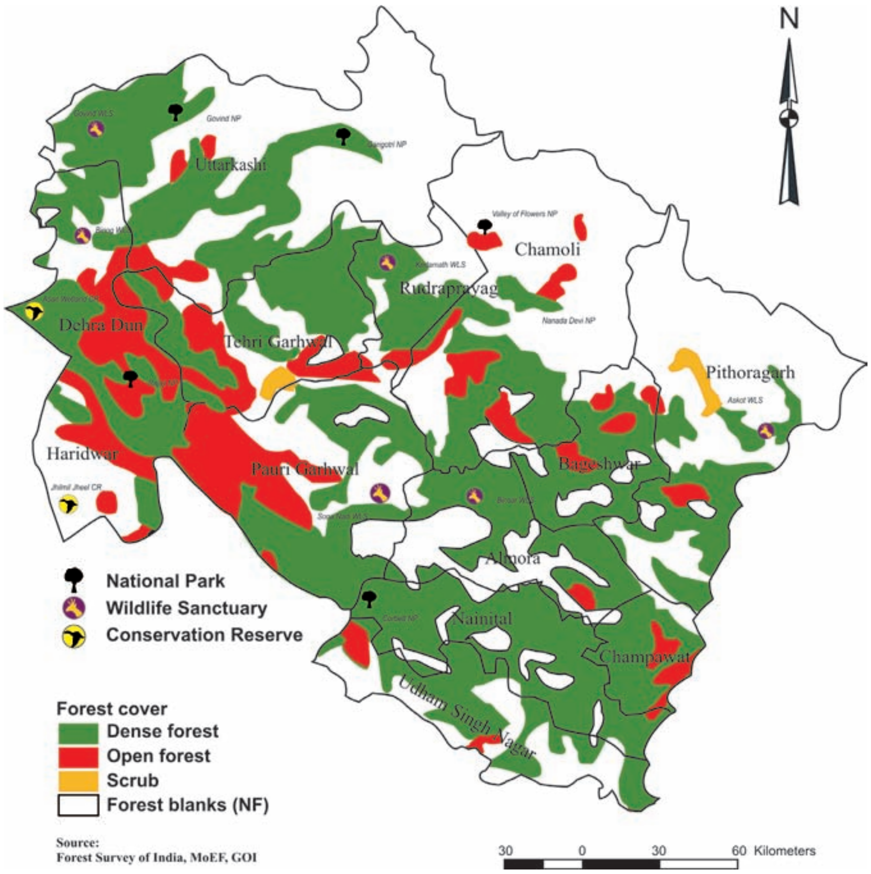


Table-1.18.
Details of protected areas in Uttarakhand (as on 01.09.2011)[5,80,81,82]

Name of the PA (district)	Year of Establish-ment	Area (km²)	Flora	Fauna
Askot WLS (Pithoragarh)	1986	599.93	Kunj, kail, Kharsu, Fir, Bhojpatra, Darkunja and Raijal.	Black bear, Brown bear, Snow leopard, Musk deer, Bharal, Serow and 227 species of birds
Binsar WLS (Almora)	1988	45.59	Pine and Oak forest.	Leopard, Musk deer, Jackal, Barking deer, common langur and 166 bird species
Govind WLS (Uttarkashi)	1955	485.89	*Rhododendron, Cedrus deodara, Quercus*, Blue Pine, Walnut and Hazel chest nut.	Black bear, Brown bear, Snow leopard, Musk deer, Sambhar, Jackal and 200 species of birds
Jhilmi Jheel CR (Haridwar)	2005	37.83	Grassland and Sal.	Sambhar, Elephant, Neel Gai, Panther, 160 sp. of birds, Spotted deer and Swamp deer
Asan Barrage CR (Dehradun)	2005	444.40	*Shorea robusta, Dalbergia sissoo, Bombax ceiba, Polygonum glabrum, Phyllanthus* sp., *Anogeissus latifolia* and *Ageratum conyzoides*.	More than 250 bird species are seen. Brahminy ducks, Rudely Shel duck, Dabbling Duck and Diving Duck.
Kedarnath WLS (Chamoli)	1972	975.24	Temperate, Alpine, Sub Alpine forest and Alpine moist scrub.	Leopard, Musk Deer, Brown Bear, Jackal, Wild boar and 240 species of birds

Name of the PA (district)	Year of Establish-ment	Area (km^2)	Flora	Fauna
Mussoorie WLS (Dehradun)	1993	10.82	Moist temperate forest, Oak and Sub alpine forest.	Leopard, Black bear, Goral, Barking Deer and Himalayan quail
Sonanadi WLS (Garhwal)	1987	301.18	Pine, Moist and Dry deciduous forest.	Tiger, Leopard, Elephant, Barking Deer, Sloth Bear and Slender billed Vulture
Nanda Devi BR (Chamoli, Almora and Pithoragarh)	1988	5,860.69 km^2	600 species of angiosperms, 30 species of Pteridophyta and 76 wood species.	Bharal, Goral, Himalayan Musk deer, Wild boar, Sambar, Snow leopard, Jungle cat, Brown bear, Common leopard, Himalayan leaf-nosed bat, Common giant flying squirrel and 546 bird species
Corbett NP (Nainital, Pauri Garhwal)	1936	520.80	Sal, Haldu, Pipal, Rohini and mango are common species. High banks and islands are dominated by *Dalbergia sissoo*.	Tiger, Elephant, Chital, Sambar, Nilgai, Gharial, King Cobra, Wild boar, Hedgehog, Indian Pangolin and nearly 600 species of birds
Valley of Flowers NP (Chamoli)	1982	87.50	*Duthiea bromoides, Herminium joshephii, Lycopodium selago, Salix calyculata* and *Saussurea atkinsonii*.	Himalayan Musk deer, Black bear, Snow Leopard, Serow, Barking deer and 82 species of birds
Rajaji NP (Dehradun, Haridwar, Pauri Garhwal)	1983	820.42	Sal, *Acacia catechu*, *Dalbergia sissoo*, Gular, Haldu, Jhingan, Tun, Gutel and many species of shrubs and herbs	Tiger, Common leopard, Jungle cat, Leopard cat, Barking deer, Nilgai, Goral, Hog deer, Wild boar, Sambar, Sloth bear, Asiatic black bear, Common palm civet and 312 species of birds
Gangotri NP (Uttarkashi)	1989	2200.00	Chirpine, deodar, Fir, spruce, oak and *Rhododendron*	Asiatic Black bear, Brown bear, Leopard, Snow leopard, Barking deer, Bharal, Goral, Himalayan musk deer, Himalayan tahr, Himalayan Monal, Himalayan Snow cock and 150 species of birds
Govind NP (Uttarkashi)	1990	472.08	*Pinus, Cedrus, Acer, Quercus, Juglans, Aesculus* and *Rhododendron*	Asiatic black bear, Brown bear, Leopard, Snow leopard, Barking deer, Bharal, Goral, Himalayan Thar, Himalayan musk deer, Wild boar, Sambar, Serow, Jackal, Indian porcupine, *Rhesus macaque*, Himalayan weasel and 200 species of birds

The mammalian diversity in Uttarakhand is one of the richest in the country, exceeding 75 species; about 50% of these are threatened. A detailed analysis of the data shows that 37.8% of species fall under lower risk least concern category and 19.51% under lower risk not threatened status. The critically endangered species constitute 6.09%, while vulnerable species account for 12.91%. The mountain ungulates of Uttarakhand not only hold a great ecological value but they are also part and parcel of cultural ethos and heritage of this Himalayan state. All concerted efforts are being made to save them for posterity and for the healthy sustainable ecological balance. The distribution and status of mountain ungulates in Uttarakhand in different PAs (as per the record contained in the management plans of the PAs and information collected from the field) has been reported.

Table-1.19.
Important sacred grooves of Uttarakhand[72]

Name of the Sacred Grooves	Location	Area (in acres)
Chamoli District		
Ghanteyal ki cheevi, Devika mandi	Badheth	500.00
Ghandiyal Devataka van	Majyanitalli	0.50
Laxmivan, Mandaaur Ghantakaran ki Phulwari	Mana	500.00
Nanda Aur Ghantakaran ki Phulwari, Laxmivan	Mana	2.50
Amdar ki Kyor, Surai ka Ped, Panyaltha Jaisort	Anusuya	1250.00
Fulana (Chinap Sink Bugyal), Jaldhara, Mandir ke Ped	Thaing	250.00
Nanda ki Phuwari, Bugyal, Mandir ke Ped	Bhundar	3.00
Bugyal, Nanda ki Phulwari, Mandir ke Ped	Bhundar	-
Thai	Irani	250.00
Sivalaika Jungle	Irani	2.00
Bhagwatika Jungle	Irani	3.00
Saimyar	Irani	0.50
Anand Van	Irani	2500.00
Kotgadi ki Kokila Mata ka Sthan	Madigaon	1.00
Kotgadi Devi ke Samrakshit Van	Madigaon	50.00
Pravasi Pavasu Devata	Deuti	500.00
Devrada	Koti	250.00
Pithoragarh District		
Thal Ke Dhar	8 Km from Pithoragarh	1315.60

1.5.2. Herbal Gardens, Arboretums, Parks and Zoos

In Uttarakhand states herbal gardens being established by the Forest Department to preserve gene pool bank of important plant species. Universities and Institutes in Uttarakhand also have their own arborata. Forest Research Institute also possess large number of species in its Herbal gardens. The zoos are maintained by Forest Department of which Nainital and Almora zoos are worth mentioning. All the zoos, Herbal gardens, arborata are good source of awareness and information to public and researchers.

1.5.3. Sacred Grooves in Uttarakhand

Sacred grooves (small or large) are patches of vegetation of varying sizes, conserved on the basis of the religious beliefs of the community. In India there are over 13,720 sacred grooves. These grooves are treasure houses of many rare and endemic plants. These grooves harbour rich biodiversity and play a significant role in the conservation of biodiversity. Uttarakhand has 18 sacred groove (Table 1.19). Several forest areas in Almora and Pithoragarh have also been dedicated to local deities. In the state large number of species are also conserved for religious belief of the local people.

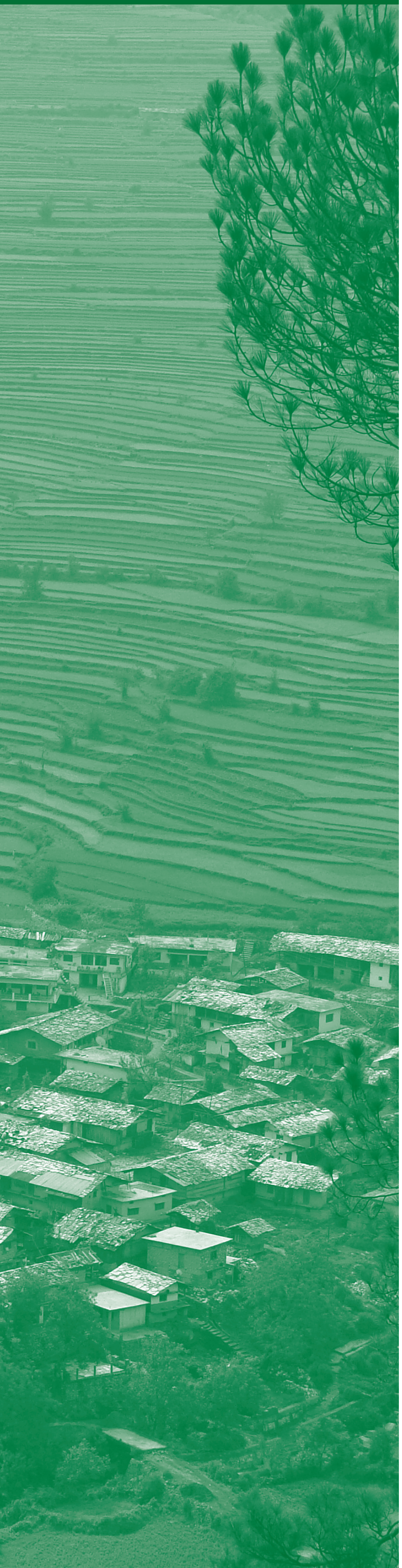
Some important sacred plant species of the state are *Cynodon dactylon* (Doob) *Ficus religiosa* (Pipal), *Ficus benghalensis* (Bargad), *Ocimum sanctum* (Tulsi), *Artemisia* sp. (Kunju), *Musa paradisica* (banana), *Desmostachya bipinnate*, *Aegle marmelos* (Bel), *Emblica officinalis* (Amla), *Mangifera indica* (Mango), *Pinus roxburghii* (Pine), *Prunus cerasoides* (Paiya), *Cedrus deodara* (Deodar), *Zanthoxylum aceanothopodum* (Timru), *Azadirachta indica* (Neem), and *Quercus* spp (Oak).

1.5.4. Medicinal Plant Conservation Areas (MPCAs) in Uttarakhand

As the state is home for large number of medicinal plants, efforts are being made to conserve important medicinal plants in their natural habitats. A total of seven MPCAs have been identified covering an area of 102 sq km and distribution to an elevation of 600-4000 m. Further details of MPCAs is given in medicinal plant section (Chapter 2).

1.6. Policies Related to Biodiversity Conservation

The Indian Constitution entails the subject of forests and wildlife in the Concurrent list. There are large number of policies relate to conservation of biodiversity in the country. Most of them are applicable in the state of Uttarakhand as well. The Federal Ministry (Ministry of Environment and Forests, Govt. of India) acts as a guiding torch dealing with the policies and planning on wildlife conservation, while the provincial Forest Departments are vested with the responsibility of implementation of national policies and plans. The National Board for Wildlife (NBWL), chaired by the Prime Minister of India provides policy framework for wildlife conservation in the country. The National Wildlife Action Plan (2002-2016) was adopted in 2002, emphasizing the people's participation and their support for wildlife conservation. India's conservation planning is based on the philosophy of identifying and protecting representative wild habitats across all the ecosystems. The PAs are constituted and governed under the provisions of the Wildlife (Protection) Act, 1972; which has been amended from time to time, with the changing ground realities concerning wildlife crime control and PAs management. Implementation of this Act is further complemented by other Acts viz. Indian Forest Act, 1927; Forest (Conservation) Act 1980; Environment (Protection) Act, 1986; and Biological Diversity Act, 2002; and the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006. The Wildlife Crime Control Bureau of the Central Government supplements the efforts of provincial governments in wildlife crime control through enforcement of CITES and control of wildlife crimes having cross-border, interstate and international ramifications. In order to strengthen and synergise global wildlife conservation efforts, India is a party to major international conventions, *viz.*



Convention on International Trade in Endangered Species of wild fauna and flora (CITES), International Union for Conservation of Nature (IUCN), International Convention for the Regulation of Whaling, UNESCO-World Heritage Committee and Convention on Migratory Species (CMS). The Department of Forest Govt. of Uttarakhand is the nodal agency at state level to implements various biodiversity forest conservation measures. It implement various Centrally Sponsored Schemes for Wildlife Conservation, such as, Integrated Development of Wildlife Habitats, Project Tiger, Project Elephant, etc.

Considering the biodiversity richness of the state of Uttarakhand, various important initiatives were taken by central and the state governments. In 1936, the first National Park in the Asian Mainland was established as Corbett National Park. Subsequently in 1955 Govind Wildlife Sanctuary, in 1972 Kedarnath Wildlife Sanctuary, in 1982 Valley of Flowers National Park, and in 1983 Rajaji National Park were established in the state. Thereafter other areas were also brought under protected area network. In 1956, the undivided U.P. became the first state in the country to establish a separate Wildlife Preservation Cell as part of the Forest Department. 1st April 1973 witnessed the launching of Project Tiger in Corbett National Park. In 1988, India's second Biosphere Reserve was established as Nanda Devi Biosphere Reserve. 14th August 2005 the President of India dedicated to the Nation the country's first conservation Reserves as Asan Wetland and Jhilmiltal. In 2002, Biological Diversity Act was implemented in the state, besides Uttarakhand State Biodiversity Authority and State Medicinal Plant Board (SMPB) were also instituted. At the same time the state Wildlife Advisory Board was also set up under the Chairmanship of the Hon. Chief Minister of the state. An anti poaching unit was established for the prevention and control of wildlife offences. The state has also established 10200 hectares area of Reserve Forest as Medicinal Plant Conservation Areas (MPCAs) and trying hard to conserve the germplasm of 224 medicinal plants. The state is progressing forward with the help of various institutions in the state to protect various rare and endangered species by developing propagation protocols to conserve them. Uttarakhand Biodiversity Board is formed as per the recommendation of Biology Diversity Act (2002) under which it was made mandatory to form the State Biodiversity Board for sustainable use of natural resources. The main objective is to sensitize the citizens of the state towards biodiversity and sustainable use of natural resources, by forming the BMCs (Biodiversity Management Committee) in every block .

1.7. Institutes Working in the Field of Biodiversity

There is a network of institutes, universities, departments, NGOs and intellectual persons that are working in the field of biodiversity. An effective knowledge sharing and data exchange mechanism among all could benefit the state in long run. Some of these institutions are:

1. Botanical Survey of India, Dehradun

Head : Scientist In-Charge
Address : Northern Regional Centre
192, Kaulagarh, PO-KDMIPE,
Dehradun-248195
Telephone : 0135-2753433
Fax : 0135-2755478
E-mail : bsinc2001@rediffmail.com
Website : www.bsi.gov.in

2. Zoological Survey of India, Dehradun

Head : Scientist In-Charge
Address : Northern Regional Centre 218,
Kaulagarh Road Dehradun-248001
Telephone : 0135-27563149, 27533949
Fax : 0135-2758362
E-mail : zsisiwal@sanchar.net.in
Website : www.zsi.gov.in

3. Forest Research Institute, Dehradun

Head : Director
Address : Forest Research Institute
P.O.New Forest-Dehradun
Telephone : +91 135-2755277
Fax : +91 135-2756865
E-mail : director@icfre.org
Website : http://fri.icfre.gov.in

4. Forest Survey of India, Dehradun

Head : Director
Address : Ministry of Environment & Forest,
Govt. of India Kaulagarh Road,
P.O. KDMIPE, Dehradun-248195

Telephone : 0135-2756139
Fax : 0135-2759104
E-mail : directorfsi@yahoo.co.in
Website : www.fsi.org.in/www.envfor.nic.in

5. G.B. Pant Institute of Himalayan Environment & Development, Almora
Head : Director
Address : Kosi Katarmal, Almora-263643
Telephone : 05962-241015
Fax : 05962-241150
E-mail : director@gbpihed.nic.in
Website : www.gbpihed.com

6. Wildlife Institute of India, Dehradun
Head : Director
Address : Post Box no. 18, Chandrabani Dehradun-248001
Telephone : 0135-264910
Fax : 0135-2640117
E-mail : dwii@wii.gov.in
Website : www.wii.gov.in

7. National Bureau of Plant Genetic Resources (NBPGR), Nainital
Head : Director
Address : Rewa Bhawan, Mukteshwar Road, Bhowali, Nainital-263132
Telephone : 05942-220027
Fax : 05942-220027
Website : www.nbpgr.ernet.in

8. Hemwati Nandan Bahuguna Garhwal University, Srinagar (Garhwal)
Head : Vice Chancellor
Address : H.N.B. Garhwal University, Srinagar–Dist. Pauri Garhwal (Uttarakhand) India–246174
Telephone : 01346-252143(o) 01346-252168 (R)
Fax : 01346 – 252247
E-mail : registrar.hnbgu@gmail.com
Website : http://www.upes.ac.i

9. Kumaun University, Nainital
Head : Vice Chancellor
Address : Mallital, Nainital
Telephone : +91-05942-235563
Fax : +91-05942-236187
Website : http://www.kuntl.in

10. G.B. Pant University of Agriculture & Technology, U.S Nagar
Head : Vice Chancellor
Address : Pantnagar - 263145, Dist. Udham Singh Nagar, Uttarakhand
Telephone : +91-5944-233320, 233350,233333,233663
Fax : +91-5944-233473
E-mail : vcgbpuat@gmail.com
Website : http://www.gbpuat.ac.in

11. Gurukula Kangri Vishwavidyalaya, Haridwar
Head : Vice Chancellor
Address : Gurukula Kangri Vishwavidayalaya, P.O. Gurukula, Kangri - Haridwar Pin-249404
Telephone : 01334-249013
Fax : +91 135-2756865
E-mail : registrargkv@yahoo.co.in
Website : http://www.gkvharidwar.org

12. Indian Institute of Remote Sensing, Dehradun
Head : Director
Address : 4 Kalidas Road, Dehradun-248001
Telephone : 0135-2744583
Fax : 0135-2741987
E-mail : director.iirs.gov.in
Website : www.iirs.gov.in

13. National Research Centre on Cold Water Fisheries, Nainital
Head : Director
Address : Thandi Sadak, Bhimtal, Nainital
Telephone : 05942-247280, 247279
Fax : 05942-247693
E-mail : director@dcfr.res.in
Website : www.dcfr.res.in

14. Doon University, Dehradun
Head : Vice Chancellor
Address : Motharowala Road, Kedarpur, PO Ajabpur, Dehradun
Telephone : +91-135-2532012, 2533102
Fax : +91-135-2533115
E-mail : doonvc@gmail.com
Website : http://doonuniversity.ac.in

15. State Biodiversity Board, Dehradun
Head : Director
Address : 108 Vasant Vihar, Phase-II Dehradun
Telephone : 0135-2760254, 2622653
E-mail : sbbuttarakhand@gmail.com
Website : sbb.uk.gov.in

16. State Medicinal Plant Board, Dehradun
Head : Chief Executive Officer (CEO)
Address : 94, Phase-II, Vasant Vihar, Dehradun
Telephone : 0135-2760254, 2622653

17. Herbal Research and Development Institute, Gopeshwar
Head : Director
Address : Gopeshwar, Mandal, Distt-Chamoli
Telephone : 01372-254210
Fax : 01372- 254273
E-mail : director_hrdi@yahoo.in
Website : hrdiuk.org

1.8. References

1. Myers, N., Russell, A.M., Cristina, G.M., Gustavo, A.B., da Fonseca and Jennifer, K., Biodiversity hotspots for conservation priorities. *Nature*, 2000, **403**: 853-858.
2. Uniyal, B.P., Sharma, J.R., Choudhrey, U. and Singh D.K., *Flowering Plants of Uttarakhand* (A check List), Bishen Singh Mahendra Pal Singh, Dehradun, 2007, p. 404.
3. Uniyal, D.P. and Kumar, A., Fish diversity in the selected streams of Chakrata and Shiwalik hills (District: Dehradun, Uttranchal) India. *Rec. Zool. Surv. India*, 2006, p. 253 1-120 + 40 .
4. Bahuguna, A and Bhutia, P., Amphibia., *In: Fauna of Uttarakhand, State Fauna Series*, (ZSI, Kolkata), 2010, **18** (1), 505-532.
5. Tak, P.C and Sati, J.P., Aves. *In: Fauna of Uttarakhand, State Fauna Series*, (ZSI, Kolkata), 2010 **18**(1), 505-532.
6. Tak, P.C., Sati, J.P and Bhutia, P.T. An Overview *In: Fauna of Uttarakhand, State Fauna Series,* (ZSI, Kolkata), 2010, **18**(1), 1-26.
7. Uniyal, D.P., Pisces. *In: Fauna of Uttarakhand, State Fauna Series*, (ZSI, Kolkata) 2010, **18**(1), : 505-532 (ZSI, Kolkata).
8. Negi, K.S. and Malik D.S., Fish Fauna of Ganga River at Rishikesh**.** *Him. J. Env. Zool*.**,** 2005, **19**(2),145-148.
9. Fauna of Rajaji National Park., Fauna of Conservation Areas, (ZSI, Calcutta), 1995, 5:i-ii +1-323.
10. Editor-Director, Fauna of Uttarakhand, State Fauna Series (Published by the Director ZSI, Kolkata) 18 (Part-1), 2010, 1-621.
11. Fauna of Nanda Devi Biosphere Reserve . A World Heritage Site. Fauna of Conservation Areas, (ZSI,Calcutta)., 1997, 9:i-iii +1-166+ I-IV,
12. Fauna of Asan Wetland, *Wetland Ecosystems Series*, (ZSI, Kolkata), 2003, **5**, 1-60+30.
13. Fauna of Corbett Tiger Reserve, Conservation Areas Series, (ZSI, Kolkata), **35**, 1-230
14. Walker, S. and Molur, S., Species Summaries of Conservation Assessment and Management Plan (CAMP) Workshops, 1995-2000, 1-2.
15. Husain, A., Pisces. In: Fauna of Western Himalaya, U.P. Zool. Surv. India**,** *Himalayan Ecosystem Series,* (eds Arora, G.S. and Arun Kumar), 1995, 17-22.
16. Mehta, H.S. and Uniyal, D.P, Amphibia. In Faunal Diversity Western Doon Shiwaliks.ZSI, 2007, 61-64.
17. Duthie, J.F., Flora of the upper Gangetic plain and of the adjacent Siwalik and sub Himalayan tracts, Calcutta, 1903-1929, 3.
18. Duthie, J.F., The Orchids of North West Himalaya. *Ann. Royal Bot. Garden, Calcutta*, 1906, **9**(2), 1-211.
19. Osmaston, A.E., A Forest Flora of Kumaon, Allahabad, 1972.
20. Rau, M.A., High altitude flowering plants of W. Himalaya, Calcutta, 1975.
21. Naithani, B.D., Flora of Chamoli Distt, New Delhi, 1984, Vol. I.
22. Naithani, B.D., Flora of Chamoli Dist, BSI Howrah, 1985, Vol. II.
23. Gaur, R.D., Flora of the District Garhwal, North West-Himalaya (with Ethnobotanical Notes), Srinagar (Garhwal), 1999.
24. Hooker, J.D. Flora of the British India, London, 1875, Vol. I-VII.
25. Karthikeyan, S., A Statistical analysis of flowering plants of India. In: Flora of India, Introductory Volume, part II (eds Singh, N.P., Singh, D.K., Hajra, P.K. and Sharma, B.D. BSI, New Delhi, 2000, p. 201-207.
26. Sharma, B.D., Balakrishnan, N.P., Rao, R.R and Hajra, P.K.,(eds) Flora of India, Ranunculaceae – Barclayaceae BSI, Calcutta, 1993, Vol. I.
27. Sharma, B.D. and Sanjappa, M. (eds). Flora of India Portulaceae-Ixohanthaceae,BSI, Calcutta, Vol. 3.
28. Hajra, P.K. and Balodi, B., Plant Wealth of Nanda Devi Biosphere Reserve, BSI Calcutta, 1995, (a).
29. Hajra, P.K., Rao, R. R., Singh, D.K. and Uniyal, B.P. (eds). Flora of India Asteraceae, BSI, Calcutta, 1995b, Vol. 12 & 13.
30. Hajra P.K., Sharma, B.D. and Sanjappa, M., (eds). Flora of India Introductory, BSI, Calcutta, 1996, Vol. Pant-I.
31. Hajra, P.K., Nair, Y.J. and Daniel, P., (eds). Flora of India Vol. 4, Malpighiaceae – Dichapetalaceae, BSI, Calcutta, 1997.
32. Mudgal, V. and Hajra, P.K., (eds). Floristic Diversity and conservation strategies in India Dehradun, 1995-1999, Vols. I-III,

33. Srivastava, S.K. and Singh, D.K., *Glimpses of the Plant Wealth of Uttaranchal;* Bishen Singh Mahendra Pal Singh, Dehra Dun, 2005, p. 158.
34. Singh, N.P., Singh, D.K., Hajra, P.K. & Sharma, B.D., (eds) Flora of India, BSI, New Delhi. 2000, Vol, II, p. 201-217.
35. Arora, G.S. and Kumar, A., Fauna of Western Himalaya, U.P. Pt. I, ZSI, *Himalayan Ecosystem Series,* 1995.
36. Kumar, A. and Rawat, S., Bioresource of Uttarakhand: Their Conservation and Management. Bishen Singh Mahendra Pal Singh and Uttarakhand State Council for Science and Technology (UCOST) , Dehradun, 2011, p. 791.
37. Atchinson, J.E.T., (Rep, 1982), A Catalogue of the plants of Punjab & Sindh Dehradun, 1869.
38. Atchinson, J.E.T., *Flora of the Himalayas with special reference to Kumaun, Garhwal, Nepal and Tibet*, (Bishen Singh Mahendra Pal Singh, Dehradun, 1998, p.18-82.
39. Sharma, P., Semwal, D.P. and Uniyal, P.L., Gymnosperms of Uttarakhand. In: *The Plant Wealth of Uttarakhand,* (eds Uniyal P.I., Chamola, B.P. and Semwal, D.P.), New Delhi; Jagdamba Publishing Company, 2010, 305-316.
40. Shantanu, S.S. and Uniyal, P.L. Bryophytes of Uttarakhand. In: *The plant wealth of Uttarakhand,* (eds Uniyal, P.L., Chamola, B.P. and Semwal, D.P.), New Delhi; Jagdamba Publishing company, 2010, p. 197-276.
41. FSI (Forest Survey of India), State of Forest Report 1999. Supplementary, Forest Survey of India, Ministry of Environment and Forests, Dehradun, 2000.
42. Babu, C.R., Herbaceous Flora of Dehradun, C.S. 12. New Delhi,1977.
43. Gaur, R.D. and Barthwal, B.S., A Contribution to the Forest Flora of Pauri District, Garhwal Himalaya, Higher Plants of Indian subcont. (eds Gupta, B.K.), 1995, Vol.1-135.
44. Naithani, H.B., Flowering Plants of India, Nepal and Bhutan (not recorded in sir J.D. Hooker's Flora of British India) Surya Publications, 1990.
45. Samant, S.S. and Pangtey, V.P.S., Additions to a forest flora for Kumaun. Higher plants of India. Subcont. (eds Gupta, B.K.), 1995, Vol. 285-315.
46. Nayar, M.P. and Rama Murthy. Third list of species and genera of Indian Phanerogams not included in J.D. Hooker's Flora of British India. Bull. BSI, **15**, 204-234.
47. Uniyal, D.P. and Mehta, H.S., Pisces. In: Faunal Diversity Western Doon Shiwaliks.ZSI, 2007, 36-45.
48. Dobhal, R., Kumar, A. and Rawat, S., Conservation and Management of bioresearches in Uttarakhand, India. In: *Community based Biodiversity Conservation in the Himalayas*., (eds Gokhale, Y. and Negi, A.K.), The Energy and Resource Institute (TERI) New Delhi, 2011, p.1-19.
49. Rana,T.S., Datt, B., Saklani, A. and Rao, R.R., Endemic and endangered taxa of Compositae in Western Himalaya, India. *J. Econ. Tax. Bot.*, 2004, **28**(1), 25-30.
50. Rau, M.A., Check list (supplement) of flora of the upper Gangetic Plain of the adjacent Siwalik and Sub-Himalayan tracts. *Bull. Bot. Surv*. India to (Suppl.), **1**-87, 1968.
51. Rawat, G.S. and Pangtey, V.P.S., Some interesting plant needs from Kumaun Himalaya. *J. Econ. Tax. Bot.*, 1985, **6**, 697-698.
52. Rawat, G.S. and Pangtey, V.P.S., Additions to the flora of U.P. Hills. *J. Econ. Tax. Bot.,* 1985, **6**(3), 693-695.
53. Naithani, B.D., Flora of Chamoli Dist- New Delhi, 1984, Vol. I.
54. Naithani, H.B. and Tiwari, S.C., Flowering plants of Pauri and its Vicinity. *Ind. J. for.* 1983, **6** :70-74.
55. Nayar, M.P. and Sastry, A.R.K., Red Data Book of Indian Plants., BSI, Kolkatta, 1987.
56. Sethi, P., Bhujang Rao, D.D., Mohan, D., Mohapatra, K.K., Upadyaya, S., Hanfee, F. and Khalid, M.A. Strategies and action plan for Biodiversity Conservation in Uttaranchal, 2002.
57. CITES., Checklist of Cites Species 2003. Edit by IUCN-www.ngbs.com/checklist/species_2003_2003/132269.htm
58. Nayar, M.P. and Sastry, A.R.K., (eds) Red Data Book of Indian Plants, BSI, Calcutta,1988, Vol. 2.
59. Nayar, M.P. and Sastry, A.R.K., (eds) Red Data Book of Indian Plants. BSI,Calcutta, 1990, Vol.3.
60. Kumar, A. and Khanna, V., Globally Threatened Indian Fauna-Status, Issues and Prospects. ZSI, 2006, p.1-104.
61. The Wildlife (Protection) Act (1972). As amended upto 2003, with rules upto 2003. Wildlife Trust of India, New Delhi, 2003.

62. Kumar, A., Bahuguna, A., Rawat, G.S., Mohan, D., Sinha, S., Srivastava, S.K. and Banerjee, A.K., Biodiversity Strategy and Action Plan (BSAP) Uttaranchal. FD Uttaranchal, TERI and ZSI, DDN; 2002, Vol. I-III, p. 515.

63. Sathykumar, S., Prasad, S.N., Rawat, G.S. and Johnsingh, A.J.T., Ecology of Kalijand Monal Phesants in Kedarnath Wildlife Sanctuary, Western Himalaya., (eds Jenkins, David), *Proceeding of the fifth International Symposium on Pheasants* in Asia, 28 September - 4 October Lahore, Pakistan, 1992, p. 83-90.

64. Flower, W.H., On the Structure and Affinities of the Musk Deer *(Moschus chrysogaster, Linn.) Proc. Soc. Lond.* 1875,159-190.

65. Brooke, V., On the classification of the Cervidae, with a synopsis of the existing species. *Proceeding of the Zoological Society of London*, 1878.

66. Flerov, C.C., Fauna of the USSR, 1 (2). Mammals: Musk Deer and Deer. USSR Academy of Sciences, Moscow. (Translated from Russian by Israel Program for Scientific Translations), 1952, p.14-45.

67. Groves, C.P. and Grubb, P., Relationships of living Deer., In: (eds Wemmer, C.M.), The Biology and Management of the Cervidae. Smithsonian Institution Press, Washington, DC, USA, 1987, p. 21–59.

68. Wemmer, C., Deer Status, Survey and Conservation Action Plan. IUCN/SSC Deer Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK, 1998.

69. IUCN, Red List of Threatened Species., http://www.iucnredlist.org. 2005.

70. Cheura – A wonder the Borne oilseed. National oil seed and vegetable oil development board (Ministry of Agriculture, Govt. of India). www.novodboand.com

71. Badoni, A. and Badoni, K. Ethnobotanical Heritage. In Garhwal Himalaya Nature, culture and Society, (eds Kandari, O.P. and Gusain, O.P.), Srinagar; *Transmedia*, 2001, 125-148.

72. Anthwal A., Sharma R.C., and Sharma, A., Sacred Grooves; traditional way of conserving plant diversity in Garhwal Himalaya, Uttarakhand. *Journal of American Science*, 2006, **2**(2); 35-43.

73. Vikram, S., Negi, Maikhuri, R. K. and Rawat., Non timber forest product (NTFPS): a viable option for Biodiversity Conservation and livelihood enhancement in Central Himalaya. 2011, **20**, 545-559.

74. Lepcha, S.T.S., Bhat, S. and Kumar, A., Common Fiber yielding plants of N.W. Himalayas with special reference to Uttarakhand, (UBFDB), Bishen Singh Mahendra Pal Singh, Dehradun, 2009.

75. Sundriyal, M. and Sundriyal, R.C. Bamboo trade and future prospects in the Central Himalaya: A case study of the traditional artisans of Uttarakhand**.** *Ethnobotany Research & Applications,* 2011, **9**, 445-454.

76. Sundriyal, M. and Sundriyal, R.C. Vanishing trade of Bamboo: A case study of traditional artisans of Uttarakhand. Published in VIII WBC Congress (Sept 15-18 Sept), 2009, **7**, 29-36.

77. Joshi, G.C., Lalit M., Tewari, Nidhi Lohani, Kanchan Upreti, Jeevan, S. Jalal and Geeta Tiwari. Diversity of orchids in Uttarakhand and their conservation strategy with special reference to their medicinal importance. Report and Opinion, 2009, I (3).

78. Singh, S.P., Himalayan Forest Ecosystem Services, (CHEA), 9, Waldrof Compound, Nainital, Uttarakhand, 2007.

79. Semwal. R., Tiwari, A., Negi, G.C.S., Thadani, R. and Phartyal. P., Valuation of Ecosystem Services and Forest Governance: A Scoping Study from Uttarakhand Lead India, New Delhi, 2007.

80. FSI. *State of Forest Report*. Forest Survey of India, Dehradun, 2010.

81. Mathur, V.B., Rogers, W.A., and Panwar, H.S., Wildlife Protected Area Network in India. A Review Summary of Protected Area Proposals considered to be National Priority Status. Wildlife Institute of India, Dehradun, 2002.

82. Negi, A.S., Status, Distribution and Management of Mountain Ungulates in Uttaranchal. (eds Sathyakumar, S. and Bhatnagar, Y.V.), ENVIS Bulletin Wildlife & Protected Areas, Wildlife Institute of India , Dehradun, 2002.

83. Jayaram, K.C., The Deccan Mahseer Fishes: Their ecostatus and threat percepts, *Rec. Zool.Surv. India* (Published- Director, ZSI, India, Kolkata), 2005, p. 238, 1-102 + XV.

84. Forest Department, The Snow Leopard in Uttaranchal: An Action Plan for its Conservation, 2006.

85. Negi, C.S. and Palyal, V.S. Traditional uses of animal and animal products in medicine and rituals by the Shoka tribes of district Pithoragarh, Uttaranchal, India. *Ethno Med.*, 2007, **1(1)**: 47-54.

Section I

BIO-RESOURCES

Medicinal and Aromatic Plants

Chapter

TWO

MEDICINAL AND AROMATIC PLANTS

(RC Sundriyal and Manju Sundriyal)

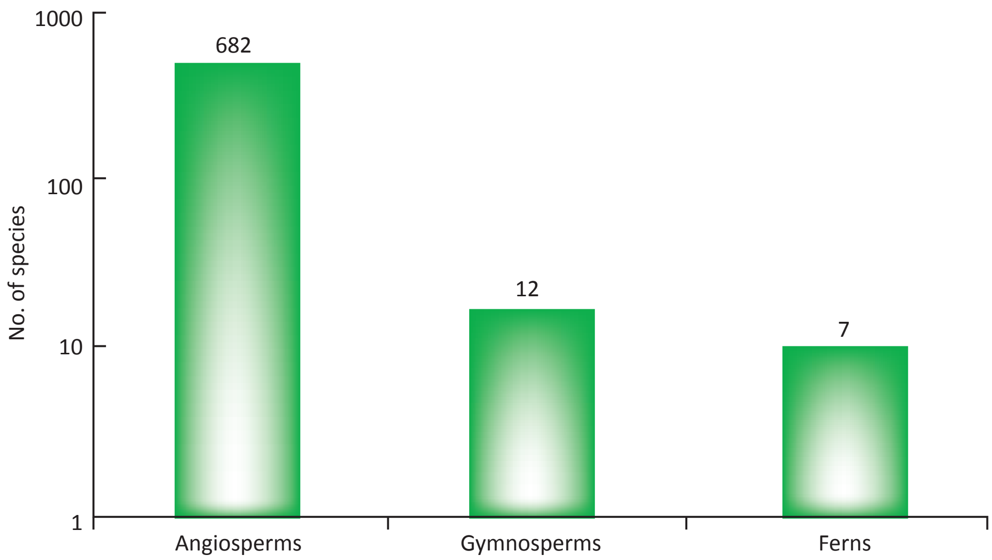
2.1. Introduction

Medicinal plants are more appreciable and in great demand due to their unique curative properties. Recorded evidence of herbal medicine dates back to 5000 years ago[1,2,3]. It is well understood that the drugs derived from plants have negligible side effects as compared to their chemical counterparts[4]. Although, tremendous progress has been made in synthetic chemistry and biotechnology, hundreds of plants species are recognized as having therapeutic value for specific ailments and diseases; surprisingly 40% drugs in modern pharmacopoeias are derived either as pure pharmaceutical extracts from plant or their remedies as they are considered being free from side effects. Plant derived medicines are comparatively cheaper, and locally available. Even today most of the effective systems of treatments such as, Ayurvedic, Chinese and Tibetan are dependent on natural sources comprising plants in majority. There is a growing demand of consumers worldwide for herbal and natural products to meet both, the healthcare needs and dietary supplements, which has opened up new opportunities for the medicinal plant based industries[5]. However, this market propelled demand has created tremendous pressure on the natural resources. More than 90% of the species used in trade continued to be sourced from the wild of which 2/3rd are harvested by destructive means to meet ever-increasing pharmaceutical requirements, which led to threat natural regeneration and at times leads several plants at the verge of extinction[6]. There is a need to look into to harvest growing medicinal plant sector as well as conserve these resources in natural habitats[7].

2.2. Medicinal Plant Diversity in Uttarakhand

Uttarakhand state has rich vegetation wealth, which constitutes vast range of important medicinal plants in the natural conditions in view of varied topography and climatic conditions[8]. The state has 701 medicinal plants[9], which comprise 97% species as flowering plants (Fig. 2.1) with 135, 138 and 421 species as tree, shrubs and herbs, respectively. These species are distributed at all elevations, more so on high altitude areas (Table 2.1). There is high endemism among species with increase in altitude. There is vast scope to develop medicinal and aromatic plants in the state so as to expand this sector as an important vehicle for rural area development.

Fig-2.1.
Medicinal plant diversity in Uttarakhand[9]



2.3. History of Medicinal and Aromatic Plant Sector Development in the State

The development of medicinal and aromatic plant (MAPs) sector started in 1949 by initiation of Bheshaj Vikas Yojna under the Cooperative Department at Ranikhet, district Almora. Initially, this scheme was meant to neutralize collection and trade of MAPs derived from the wild by middle man so that it could provide direct benefit to collectors. In the late 1980s District Bheshaj Sanghs were also formed as a cooperative body for collection and marketing of MAPs collected from the wild. After creation of Uttarakhand state, Bheshaj Vikas Ikai is working for the promotion of the map cultivation in each District of the state and District Bheshaj Sanghs are working as collection agency of MAPs from wild. More than 100 assorted herbs were collected from wild and traded to different parts of the country, some important species comprised Atees (*Aconitum heterophyllum*), Bhoj-patra (*Betula utilis*), Meetha (*Aconitum atrox*), Choru (*Angelica glauca*), Gandrayan (*Angelica archangelica*), Balchadi/Lal jadi (*Arnebia benthamii*), Pashanbhed (*Bergenia* spp.), Meetha Atees (*Chaerophyllum villosum*), Hatajari (*Dactylorhiza hatagirea*), Wild Yam (*Dioscorea deltoidea*), Som (*Ephedra gerardiana*), Kapoor-kachri (*Hedychium spicatum*), Guggal (*Jurinea dolomiaea*), Bhitaru (*Juniperus* spp), Jatamansi (*Nardostachys grandiflora*), Kutki (*Picrorhiza kurrooa*), Takkar (*Pleurospermum brunonis*), Van-kakdi (*Podophyllum hexandrum*), Archa/Dolu (*Rheum* spp), Chirayita (*Swertia chirata*) and Tagar (*Valeriana wallichii*). Besides, species of Ashtaverga and large variety of lichens, mosses and mushrooms were also collected. In recent times, however the collection of many species is completely banned whereas some species are approved for sustainable collection.

Table–2.1.
Elevational distribution of medicinal plants of Uttarakhand[9]

Elevation	No. of species	Endemic species
< 900 m	278	44 (9%)
901-1800 m	230	
1801-2800 m	299	57 (19%)
2801-3800 m	202	69 (34%)
>3800 m	114	

2.4. Some Important Medicinal Plants of the State

***Tejpatta* (*Cinnamomum tamala*)**

Tejpatta (*Cinnamomum tamala* Fr. Nees.) belonging to the family Lauraceae, is known as Indian cassia and the leaves commonly known as Bay leaves. In central Kumaun region, it emerges as a potential cash crop for the local farmers. Bay leaves have been used by mankind from time immemorial and recent times is a potential and economic and promising agroforestry species in Uttarakhand Himalaya. The genus *Cinnamomum* is represented by about 350 species worldwide. It is native to South-east Asia, some Pacific Islands and Australia, growing mainly in tropical rain forests at varying altitudes. Historically, it is one of the oldest known and used spices. *C. tamala* is an evergreen tree up to 8m in height and is also cultivated. Natural habitat is in the tropical and sub- tropical Himalayas at altitudes of 900-2500 m.

In Uttarakhand *Cinnamomum* or Bay leaf is distributed along altitude of 500-1600 m. *Cinamomum* is abundantly found in Nainital, Champawat, Pithoragarh, Chamoli, Bageshwar and Tehri districts. The leaves are widely used as a food flavouring spice in India and the western countries due to the aromatic essential oil found in them. It is used to flavour soups, meats, vegetables and in rice dishes all over the world. Indian Bay leaves are used to relieve colic. They have hypoglycemic, stimulant, carminative, anti – rheumatic, anti – diarrhoeal and hypo lipidemic properties. Bay leaf is also used as a clarifier in the dye industry. The average production per ha is near about 7500 kg and average income is ₹ 187,500 after 8 to 10 years of plantation, so it is an important plant for agroforestry systems. In recent years development of nurseries for selling of seedlings has become a major source of income in some areas of Uttarakhand. Herbal Research and Development Institute, Gopeshwar has been supporting large scale cultivation of this species in the state.

Ashtavarga Plants[10,11,12]

The Ashtavarga group comprised eight medicinal herbs are found in Himalayan region, and Uttarakhand houses all these species. The eight ashtavarga species are Jeewak (*Malaxis muscifera*), Rishwak (*Malaxis acuminata*), Ridhi (*Habenaria intermedia*), Vridhi (*Habenaria edgeworthii*), Meda (*Polygonatum verticillatum*), Mahameda (*Polygonatum cirrhifolium*), Kakoli (*Roscoea procera*) and Kshira Kakoli (*Fritillaria roylei*). The Ashtavarga plants are extensively used in traditional Ayurvedic formulations. All these plants are considered to have high rejuvenating and health promoting properties, thus strengthen the immune system and cell regeneration capacity. It also used to treat sexual problems, physical disability, respiratory problems and pains, fever and urinary problems as well as anti-ageing agents. Unfortunately in recent times many of these species are threatened in view of large scale collection. *H. edgeworthii* (Vridhi) is listed in CITES Appendix II, thus considered a rare Himalayan medicinal orchid. *M. muscifera* (Rishbhak), *P. verticillatum* (Meda) species have become rare and need immediate action for conservation. There is need to propagate Ashtavarga species for large scale production. Recently G.B. Pant Institute of Himalayan Environment and Development, Almora has developed *in-vitro* propagation technology of *H. edgeworthii.* The High Altitude Plant Physiology Research Centre (HAPPRC), Srinagar has done survey on availability and uses of Ashtavarga plants in the state.

Ashtavarga group of medicinal plants of Uttarakhand

Local Name	Botanical Name	Family	Altitude (M)	Uses
Jeewaka	*Malaxis muscifera*	Orchidaceae	1800-3600	Bulb used as rejuvenating agent.
Rishwak	*Malaxis acuminata*	Orchidaceae	1800-3500	Bulb used as a tonic and to cure tuberculosis
Ridhi	*Habenaria intermedia*	Orchidaceae	1500-2800	Tubers used as tonic, also cures emaciation, epilepsy, cough, skin diseases, haematemesis
Vridhi	*Habenaria edgeworthii*	Orchidaceae	1500-2800	Used as an ingredient of Chyavanprash, considered blood purifier and rejuvenator
Meda	*Polygonatum verticillatum*	Liliaceae	1600-3500	Rhizome beneficial in phthisis, burning sensation, pitta, cough, ulcers, skin diseases and in fever
Mahameda	*Polygonatum cirrhifolium*	Liliaceae	1500-2700	Rhizome beneficial in burning sensation, vata-pitta, as tonic, anorexia and body weakness
Kakoli	*Roscoea procera*	Zingiberaceae	1000-2700	Roots used to cure pains due to pitta, vata, blood purification, thirst, rakta pitta
Kshira Kakoli	*Fritillaria roylei*	Liliaceae	1500-3500	Used as an appetite and pacifies vata, pitta, blood purification. Efficacious in bleeding disorders, cardiac diseases, bronchitis, rheumatalgia and weakness

Daru Haldi (Berberis aristata)[13]

The genus, ***Berberis*** belonging to family Berberidaceae consists of spiny shrubs widely distributed in temperate and sub-tropical regions of Northern hemisphere and temperate South-America. ***Berberis*** has about 650 species world wide of which 54 have been reported from Indian Himalaya and 22 species are found in Uttarakhand. ***B. aristata*** popularly known as Kingora and Daru Haldi is an important ingredient of Ayurvedic system of medicine. It is used as a single plant remedy or in polyherbal formulation in organized systems of medicine such as, Ayurveda, Siddha and Unani. It has diverse uses such as, fuel wood, fodder for goats, fruits, live-fence and high medicinal value. Roots of this species yield valuable alkaloid, berberin of isoquinoline nature. The species is distributed between altitudinal ranges of 1,850 - 3,300 m amsl spreading over the Himalaya. ***B. aristata*** so far has been traditionally obtained from the forests. Fruits are edible and sour in taste. It has been over exploited for the last few years due to presence of berberin content in its root and for that it is categorized as critically endangered species of Indian Himalaya. ***Berberis*** is used as a remedy for eye disease, diarrhoea, etc. The roots are extensively used in various indigenous systems of medicine for treating eye, ear diseases, rheumatism, jaundice, diabetes, fever, stomach disorder, skin disease, malarial fever, etc. For past many decades the species has been used for its root because of which it is categorized as critically endangered species of Indian Himalaya.

Keera-Jari (Cordyceps sinensis)[14,15]

Keera Jari (*Cordyceps sinensis*) family Clavicipitaceae has attracted global attention in recent times. It is a highly demanding species because of high prices and immense medicinal properties. Keera Jari is highly valued in Chinese and Tibetan medicine. It is found in India, Bhutan, China, and Western Nepal. In India, it is distributed in Arunachal Pradesh, Uttarakhand and Sikkim. Keera Jari is a 5-8 cm long and 3-4 mm diameter club shaped mushroom that comes out from the anterior end of caterpillar during the month of April to June. It is a parasitic fungus, that is found in subalpine and alpine regions (3200 to 4000 m asl) in grassy habitats. The Lepidopteran larvae hibernate underground in winter and the spore of the fungus enters the body of the larva and feed on it and causes its death. Collection of Keera Jari is a new income-generation opportunity in the recent years that has brought a drastic change in the economy of villagers involved in collection of keera jari. The market rate of Keera Jari is reported as high as Rs 3 lakh/kg in India. Globally many species of *Cordyceps* being harvested for medicinal purposes, viz. *C. sinensis, C. militaris, C. sobolifera, C. subssesilis, C. ophioglossoides*. In U.S Keera Jari is sold at $75,000/kg in 2008. It is used specifically for excess tiredness, chronic cough and asthma, impotency, anemia, to build the bone marrow and reduce excess phlegm. It is well known as a significant nourishing boost.

There is need for scientific exploration and research on biological screening of the Indian strains of this fungus, assess status in natural habitats, and develop cultivation protocols to meet large scale demands. Defence Research Institute, Haldwani, DRDO, has succeeded in culturing mycelium of *C. sinensis* in the laboratory. The technology has been recently transferred to Biotech International, New Delhi for its production. Forest Research Institute is working on molecular variability in *C. sinensis* isolates financially supported by Uttarakhand State Council of Science and Technology.

Seabuckthorn (H. salicifolia)[18]

Seabuckthorn (*Hippophae rhamnoides* L.) – popularly known as Leh berry, is indigenous to the high altitudes and grows widely in the Himalayan region. The dry temperate and cold desert areas of the Himalaya form ideal habitats for the Seabuckthorn to grow. The species is found in Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh.

Major species of Seabuckthorn in India are *H. rhamnoides, H. salicifolia* and *H. tibetana*. Out of these species, only two species, *i.e., H. salicifolia* D. Don and *H. tibetana* S. are reported in Uttarakhand. *H. salicifolia* is the most common and widely distributed species.

This species has great ecological significance as its roots possess excellent soil binding properties. Frankia present in its root nodules fixes atmospheric nitrogen @ 180kg/ha/annum.

Almost every part of the plant, particularly fruits and leaves, are a rich source of vitamins and other bioactive substances like carotenoids, flavonoids and sterols etc., which provide it rich nutritional and medicinal properties. The fruit pulp and seed contains valuable oil which is used in preparation of various health foods, cosmetics and medicines. Recently, it has attracted attention of researchers, industrialists and ecologists, for its multipurpose value.

Natural forest of Seabuckthorn can yield 750-1,500 kg of berries/ha. The fruits have a distinctive sours taste and are the rich source of vitamin C, caretonoids, minerals, vitamin B, vitamin E and vitamin K. Seeds contain high quality oil which has many bioactive substances.

In Uttarakhand fruits of *H. salicifolia* are also used for making pickles and beverages.

2.5. Priorities of MAP Sector Development in Uttarakhand

The major focus for medicinal plant sector development in the state has been to increase household income by promoting cultivation of MAPs and conserve natural habitats of the medicinal plants. It also include to protect traditional knowledge on MAPs and develop the State as a herbal destination as per international standards. Many agencies are working in MAPs sector. Herbal Research and Development Institute (HRDI) and Centre for Aromatic Plants are mandated to work on research and development in Medicinal and Aromatic Plant sectors, respectively. HRDI and Bheshaj Vikas Ikai are jointly working for promotion of cultivation and processing of medicinal plants. Department of Forest works for conservation of MAPs, while Forest Development Corporation, Kumaun Mandal Vikas Nigam (KMVN) and Garhwal Mandal Vikas Nigam (GMVN) work for collection of MAPs from wild habitats. District Bheshaj Sangh and Forest Development Corporation are major marketing agencies for MAPs.

2.6. Major Policies for Promotion of MAPs

To cultivate medicinal and aromatic plants, the Government of Uttarakhand has prioritized 28 species for mass scale cultivation along with subsidy on them. Since many of the cultivated species are restricted for collection, the Government has initiated the process of cultivator farmers' registration and so far over 22000 farmers have been registered. The State has simplified transit mechanism to market cultivated species. It is developing infrastructure for MAP sector development in the state. The Herbal Research and Development Institute (HRDI), Gopeshwar has been identified the nodal agency for development of MAP sector in the State. Similarly, the Centre for Aromatic Plants (CAP) works for development of aromatic plant sector. At present nearly 38 species are being cultivated in the state (Table 2.2). It has established 27 field distillation unit (FDU) for extracting oil from aromatic plants and also established buy-back guarantee for oil of aromatic plants. Recently a revolving of 200 lakhs has also been established for procurement of selected medicinal plant material. The state has also established three herbal *Mandis* (depot) at Rishikesh, Ramnagar and Tanakpur being run by Forest Development Cooperation. As such, the State is implementing conservation, development and harvesting (CDH) plan for promotion of MAP sector.

2.7. Selected Prioritized Species for Cultivation

Table-2.2.
Major medicinal and aromatic plants (MAPs) being promoted for cultivation.

S. No.	Species	Botanical name
1	Atis	*Aconitum heterophyllum*
2	Kutki	*Picrorhiza kurrooa*
3	Kuth	*Saussurea costus*
4	Jatamasi	*Nardostachys jatamansi*
5	Chirayata	*Swertia chirayita*
6	Bakkakri	*Podophyllum hexandrum*
7	Sarpgandha	*Rauvolfia serpentina*
8	Kalihari	*Gloriosa superba*
9	Jamboo/Faran	*Allium stracheyi*
10	Kalajira	*Carum carvi/Bunium persicum*
11	Satawar	*Asparagus racemosus*
12	Patharchoor	*Coleus barbatus*
13	Manjisth	*Rubia cordifolia*
14	Ammi majus	*Ammi majus*
15	Silybum	*Silybum marianum*
16	Tilpushpi	*Digitalis lanata*
17	Stevia	*Stevia rebaudiana*
18	Pyrathrum	*Tanacetum cinerarifolium*
19	Large cardamom	*Amomum subulatum*
20	Chhippi	*Pleurospermum angelicoides*
21	Pippali	*Piper longum*
22	Brahmi/ Mandukparni	*Centella asiatica/ Bacopa monnieri*
23	Lemongrass	*Cymbopogon flexuosus*
24	Geranium	*Pelargonium graveolens*
25	Rosemary	*Rosemarinus officinalis*
26	Chamomile	*Matricaria chamomilla*
27	Tagar	*Valeriana wallichii*
28	Tejpat	*Cinnamomum tamala*
29	Ritha	*Sapindus mukorossii*
30	Harad	*Terminalia chebula*
31	Baheda	*Terminalia bellirica*
32	Chiura	*Madhuca butyracea*
33	Amla	*Emblica officinalis*
34	Pachauli	*Pogostemon patchauli*
35	Citronella	*Cymbopogon nardus*
36	Rose	*Rosa sp.*
37	Mint	*Mentha sp.*
38	Artemisia	*Artemisia annua*

2.8. Volume of MAP Collection from Wild as well as from Cultivation

In Uttarakhand the collection of MAPs from wild habitats has been done for centuries. The cultivation process of MAP species started since 2004-05. However, still more volumes of MAPs come from wild than the farmers fields. Based on the data collected from Mandis, 1500 to 2250 MT volume of medicinal plants are collected from the forests during 2004-05 to 2010-11 comprising 18 to 42 species. It was alarming to note that the number of species being collected has decreased significantly during the said period. Based on the data on transit pass a net volume of 75 to 1100 MT has been produced through cultivation in past four years.

Table-2.3.
Comparative data of industrial demand and production

Year	Total Demand	Collection from Wild	Cultivated Produce
2007-08	1500 MT	1600.93 MT	74.63 MT
2008-09	7500 MT	2243.94 MT	1110.47 MT
2009-10	9000 MT	1950.10 MT	739.43 MT
2010-11	10000 MT	1589.77 MT	747.00 MT

An analysis of demand and supply gaps revealed that there is huge demand of medicinal plants than actually being supplied through wild collection and cultivation (Table 2.3). In other words there is huge scope to cultivate MAPs to meet the growing need of pharmaceutical firms in the State. The State is striving hard to increase the area under cultivation and net production of medicinal and aromatic plants. Data on quantities sold in mandis is given in Table 2.4.

Table-2.4.
Species sold from mandis (2007-08)

Species	Quantity sold (Qtl)	Rate (₹/Qt)	Total sale (₹)
Jhula	3272.31	6869.15	22477954.00
Patharchur	6.88	949.24	6526.00
Prashta parni	45.23	900.00	40707.00
Tejpat	10.64	2246.17	23906.00
Pashanbhed	5.33	1414.08	7530.00
Moss Grass	56.46	1818.35	102655.00
Shatavar	20.76	1150.00	23874.00
Bidari kand	0.88	1250.00	1100.00
Dadansha	114.67	13780.38	1580238.00
Nirvishi	8.67	700.02	6072.00
Katela	14.61	425.00	6211.00
Chir farrata	346.56	720.24	249602.00
Kadu	73.61	413.63	30447.00
Kadu (Whole)	9.70	309.96	3006.00
Safed Bel	33.66	670.39	22568.00
Kali Bel	20.31	792.96	16105.00
Chir Guliya	660.24	1489.66	983,530.00
Kapoor Kachri	11.23	345.57	3879.00
Bel	18.02	655.49	11,810.00
Padam Kasth	169.08	719.11	1,21,588.00
Indrayan Beej	0.14	8000.00	1,112.00
Indrayan Chilka	0.11	504.76	53.00
Marra Ghas	6.99	250.00	1,748.00
Gauj Bel	13.36	700.00	9,352.00

2.9. Ongoing Programmes on Medicinal Plants

The State Government has taken many new initiatives to enhance cultivation of MAPs.

2.9.1. Chief Minister Jari Buti Vikas Yojna

The main scheme being run in the state is called as 'Chief Minister Jari Buti Vikas Yojna' that is being implemented in all 13 districts. The program envisages to cover 6500 ha area and 48000 farmers in next five year (Table 2.5). This scheme envisaged for integrated development of MAP sector and related infrastructure covering all stakeholders. It has also declared 4th August of the year as 'Jari-Buti Day' to mark the significance of this sector to the state. To take the work in unified way, HRDI, Bheshaj Development Unit and Bheshaj Sanghs are brought together under single umbrella. Accordingly, the state is also strengthening ground network and infrastructure.

2.9.2. National Mission on Medicinal Plants

The National Mission on Medicinal Plants in the State is being implemented with the support of National Medicinal Plant Board, which aims to establish model & small nurseries in public/private sector for ensured supply of quality planting material (QPM), promote mass cultivation of selected species in identified clusters, set up quality testing laboratories, strengthen marketing infrastructure (mandis and storage facilities), commence rural collection centers for effective marketing of MAPs, promote district level herbal expo for market promotion, promote institutional linkages, training to nursery growers/farmers / NGOs and develop extension material for information dissemination. So far over 100 nurseries have been established and a net area of over 500 ha targeted for cultivation of 11 prioritised species.

2.9.3. Amla Awareness and Value Link Development Programme

Amla is an important species in Indian health system. It is an important ingredient of triphala, chawanprash and various other Ayurvedic products. With the support from National Medicinal Plant Board (NMPB) a project has been initiated on Amla (*Emblica officinalis*) to generate mass awareness among all section of society along with sustainable strategy for

Table-2.5.
Profile of Chief Minister Jari-Buti Vikas Yojna (2010-2015)

S. No.	Districts	Total blocks	Total clusters	Targeted area for cultivation (ha)	Total beneficiaries (farmers)
1	Chamoli	09	33	935	3800
2	Rudraprayag	03	13	475	1700
3	Pithoragarh	08	29	1045	5800
4	Bageshwar	03	16	320	3360
5	Champawat	04	16	345	4700
6	Nainital	08	24	485	5550
7	Almora	11	38	760	6240
8	Tehri	09	30	300	4170
9	US Nagar	07	21	630	2970
10	Pauri	15	45	675	5175
11	Uttarkashi	06	18	270	3630
12	Haridwar	06	17	238	595
13	Dehradun	06	18	252	630
Total		95	318	6530	48590

harvesting of wild Amla and introduction of newer cultivars of commercial varieties. Mass scale plantation of high yielding varieties of Amla will be done in all districts of the State and at present, work on 19 clusters is in progress. Attempts will be made to establish value chain development of Amla in near future.

2.9.4. Establishment of Medicinal Plant Conservation Areas

An important aspect of MAP sector development is to conserve its wild diversity as a large variety of species are collected from forest areas, which also comprised many endangered species. Therefore, seven selected areas are being established as medicinal plant conservation areas (MPCAs) with the help of a UNDP-GEF-GOI supported project (Table 2.6). It aims to mainstream conservation and sustainable use of medicinal plants in Uttarakhand by upgrading the capacity of the officials of concerned department as well as of local people. The state has large number of globally significant medicinal plants in MPCAs, their *in-situ* conservation and ecological survey for baseline status is under progress. The project will also aim to revise forest working plans to conserve medicinal plant species in their wild habitats and also help in documentation of traditional knowledge. Local management groups will be formulated and strengthened at each site through their training and capacity building for long term management of such areas. State Medicinal Plant Board (SMPB) is the nodal agencies for implementing this project.

Table-2.6.
Medicinal Plant Conservation Areas (MPCAs) in Uttarakhand

Name of MPCAs	Forest Divisions	District	Agro-climatic Zone	Vegetation type	Altitude (m)
Kandara	Uttarkashi	Uttarkashi	Alpine	Alpine	4000
Khalia	Pithoragarh	Pithoragarh	Sub-alpine	Sub-alpine and Moist-temperate	3000
Jhuni	Bageshwar	Bageshwar	Temperate	Moist-temperate Forests	2500
Gangi	Tehri	Tehri Garhwal	Temperate	Moist-temperate Forests	2200
Mandal	Kedarnath WLS	Chamoli	Temperate	Moist-temperate Forests	1800
Purnagiri	Champawat	Champawat	Sub-tropical	Subtropical Dry Deciduous Forests	1200
Mohan	Almora	Almora	Sub-tropical	Subtropical Semi Evergreen Forests	600

2.10. Globally Significant MAPs of Uttarakhand

87 GSMPs have been listed in India. In Uttarakhand, 36 GSMPs have been identified comprising several critically endangered species (Table 2.7).

2.11. Traditional Health Care System

The state has traditional health care system and nearly 70% population get primary health cure with traditional methods till date. A large number of medicinal plant species are used locally that are either collected from wild or grown in small quantities in kitchen gardens. The traditional Vaidyas currently used nearly 156 medicinal plant species in traditional system[19]. Some of the major diseases treated by Vaidyas using local plants are fever, stomachache, pain, kidney stones, high blood pressure, toothache, piles, diabetes, reproductive disorder, skin disease, worms in stomach, jaundice, diabetes, paralysis, internal injuries, sciatica, cataract, snake bite, dog bite, migraine, heart disease, malaria, typhoid, leucoderma, cancer in uterus, low blood pressure, pneumonia, rheumatism and bone fracture There is strong need to conserve rare and threatened medicinal plants that are used in traditional health care systems[20]

2.12. Institutes Working in MAP Sector Development

Many Institutes and University departments have been independently doing R&D work on various aspects of the medicinal plants in the state of Uttarakhand. The Forest Research Institute, a premier Institute under ICFRE setup has been working for past several decades

Table-2.7.
Globally significant Medicinal Plants[19]

Species	Family	Parts use
Abies pindrow Royle	Pinaceae	Leaf
Abies spectabilis (D. Don) Spach.	Pinaceae	Leaf
Aconitum balfouri Stapf	Ranunculaceae	Tuber
Aconitum heterophyllum Wall.	Ranunculaceae	Tuber
Aconitum violaceum Jacq.ex Stapf	Ranunculaceae	Tuber
Aegle marmelos (L.) Corr.	Rutaceae	Leaf, Fruit
Allium consanguineum Kunth	Liliaceae	Whole Plant
Angelica glauca Edgew.	Apiaceae	Root
Anogeissus latifolia (Roxb. ex DC.) Wall. ex Guill. & Perr	Combretaceae	Leaf, Bark
Arnebia benthamii (Wall.ex G. Don) Johnston	Boraginaceae	Root
Berberis aristata DC.	Berberidaceae	Root, Bark
Bergenia ciliata (Haw.) Sternb.	Saxifragaceae	Rhizome, Leaf
Bergenia stracheyi (Hk.f. & Thomson) Engl.	Saxifragaceae	Rhizome, Leaf
Dactylorhiza hatagirea (D.Don) Soo	Orchidaceae	Tuber
Dioscorea deltoidea Wall. ex Griseb.	Dioscoreaceae	Tuber
Emblica officinalis Gaertn.	Euphorbiaceae	Fruit
Fritillaria roylei Hk.	Liliaceace	Bulb
Habenaria intermedia D.Don	Orchidaceae	Tuber
Malaxis muscifera (Lindl.) O.Kuntze	Orchidaceae	Pseudobulb
Nardostachys grandiflora DC.	Valerianaceae	Rhizome/Root
Paeonia emodi Wall. ex Royle	Paeoniaceae	Roots & Leaf
Paris polyphylla Smith	Liliaceae	Roots
Picrorhiza kurrooa Royle ex Benth.	Scrophulariaceae	Rhizome/Root
Podophyllum hexandrum Royle	Scrophulariaceae	Rhizome/Root
Pueraria tuberosa (Roxb. ex Willd.) DC.	Fabaceae	Root
Rheum emodi D. Don	Polygonaceae	Root
Rheum moorcroftianum Royle	Polygonaceae	Root
Rhododendron campanulatum D.Don	Ericaceae	Root & Leaf
Selinum candollii DC	Apiaceae	Root
Selinum vaginatum (Edgew.) C.B. Clarke	Apiaceae	Root
Swertia chirayita (Roxb. ex Fleming) Karsten	Gentianaceae	Whole plant
Taxus baccata L.	Taxaceae	Leaves, Bark
Terminalia bellirica (Gaertn.) Roxb	Combretaceae	Fruit
Terminalia chebula Retz.	Combretaceae	Fruit
Tinospora cordifolia (Willd.) Hook. F.C. Thoms.	Menispermaceae	Tuber
Valeriana jatamansii Jones	Valerianaceae	Whole Plant

on medicinal plants of the state. The **High Altitude Plant Physiology Research Centre (HAPPRC)** has worked for over three decades on selected medicinal plant species and developed propagation protocols for cultivation of MAP species. The **G.B. Pant Institute of Himalayan Environment and Development**, an autonomous Institute of Ministry of Environment and Forests, Govt. of India has taken up significant work on survey and mapping, and developing propagation protocols of selected medicinal plant species. The **Wildlife Institute of India** has also taken up work on survey and inventorising medicinal plants in the state using rapid mapping exercise in certain forest lands. The **Defense Research Laboratory** at Pithoragarh and Auli has taken up work on many medicinal plants and also prepared many formulations for making drugs. The State also houses over 200 pharmacies and pharmaceutical firms that use over 300 species of medicinal plants and produce a large variety of formulations that are sold in the market.

Researchers in H.N.B. Garhwal University, Srinagar, Kumaon University, Nainital, G.B. Pant University of Agriculture and Technology, Pant Nagar, Gurukul Kangri University, Haridwar and other Universities/Institutions (such as CIMAP, CDRI, CCRAS) have also done significant work on various aspects MAP of Uttarakhand.

There are also State Govt. run agencies and institutions working in MAP sector development. **The Herbal Research and Development Institute (HRDI) and Centre for Aromatic Plants (CAP)** are mandated to work on research and development in MAP sector in the state. HRDI and **Bhasaj Vikas Ikai** are jointly working for promotion of cultivation and processing of medicinal plants. Department of Forest works for conservation of MAPs, while **Forest Development, Forest Corporation, Kumaun Mandal Vikas Nigam (KMVN)** and **Garhwal Mandal Vikas Nigam (GMVN)** work for collection of MAPs from wild habitats. District Bhasaj Sangh and Forest Development Corporation are major marketing agencies in the state of Uttarakhand. State Medicinal Plant of Board (SMPB) has been declared as a main policy guiding agency for developing MAP sector in Uttarakhand. The Herbal Research and Development Institutes is mandated to take up work on survey, conservation, cultivation and quality control of medicinal plant in the state. It has so far covered 2500 ha area

under MAP cultivation with over 15000 registered farmers. Over 100 nurseries have been established for production of quality planting material. A quality testing laboratory has also been established. A revolving fund of Rs. 200 lakh has been created for medicinal plant marketing.

Centre for Aromatic Plants (CAP) is mandated to take up R&D work on aromatic plants in Uttarakhand state. The centre has established 25 Field distillation units (FDUs) and released Uttarakhand D Rose water released in market. Minimum Support Prices has been offered for 22 aromatic oils. Revolving Fund created. Single-window Facilitation Centre set up. Approximately 6100 aromatic-farmers trained. An NABL accredited quality control Laboratory for analysis of essential oils and products has also been setup.

2.13. Future Thrusts

The development of medicinal and aromatic plant species have many comparative advantages in the State, therefore the sector needs due weightage for its role in rural area development. The State provides suitable microclimate for development of MAP species at all elevations. Accordingly the State has prioritized 38 MAP species for cultivation, of which 28 are also covered for giving subsidy for cultivation. The State has huge advantage to promote high altitude medicinal and aromatic plants because of considerable area under such habitats. There is a global demand for high altitude MAPs and Uttarakhand State should harvest it. If properly planned selected high altitude MAPs can become unique selling proposition (USP) for the State. The State will continue working to strengthen MAP sector so that it could be developed as an important asset of rural area development. It will strengthen nursery network for production of quality planting material, bring more area under cultivation, developing agro-techniques for new potential species. The State will also establish quality control laboratories and value addition facilities along with post-harvest management. Rural collection centres and godowns are being constructed to promote market, and if possible buy-back arrangements are being strengthened. For this strong institutional linkages are to be developed along with capacity building of local people. It is believed that in the years to come the State would be developed as an important herbal destination and Ayush Pradesh.

2.14. References

1. Kirtikar, K.R. and Basu, B.D., *Indian Medicinal Plants*, Vol. 1-4, Allahabad, India, 1933.
2. Nadkarni, A.K., *Indian Materea Medica*, Vol. 1 (3rd ed), Popular Book Depot, Bombay, 1954.
3. Chopra, R.N., Nayar, S.L. and Chopra, I.C., *Glossary of Medicinal Plants*, Publication and Information Directorate, CSIR, New Delhi, 1992. p. 330.
4. Anonymous, *Demand Study For Selected Medicinal Plants*, Vol I & II, Centre H. WHO, New Delhi, 2000.
5. Anonymous, *Demand Study For Selected Medicinal Plants*, Vol.-I. Center for Research Planning and Action, Hailey Road (CRPA), New Delhi, 2001.
6. Akerele, O., Heywood V. and Synge, *Conservation of Medicinal Plants*, Cambridge University Press, Cambridge, UK., 1991.
7. Sundriyal, R.C., Medicinal plant cultivation and conservation in the Himalaya: An agenda for action. *Indian Forester* **131**(3): 410-424, 2005.
8. Nautiyal, A.R., Nautiyal, M.C. and Purohit, A.N., Harvesting herbs-2000 medicinal and aromatic plants- An action plan for Uttarakhand. Bishan Singh Mahendra Pal Singh, Dehradun, 2000, p. 196.
9. Samant, S.S., Dhar, U. and Palni, L.M.S., *Medicinal Plants of Indian Himalaya: Diversity, Distribution, Potential Values*. HIMAVIKAS Publication No. 13, Gyanodaya Prakashan, Nainital, 1998, p. 163.

10. Jalal, J.S., Kumar, P. and Pangtey, Y.P.S., Ethnomedicinal Orchids of Uttarakhand, Western Himalaya, *Ethnobotanical* ***Leaflets***, **12**: 1227-30, 2008.

11. Dhyani, A., Nautiyal, B.P. and Nautiyal, M.C., Importance of Ashtavarga Plants in traditional system of medicine in Garhwal, Indian Himalaya. *International Journal of Biodiversity Science, Ecosystem Services and Management,* 6, (1-2), 2010.

12. Giri, L., Jugran, A., Rawat, S., Dhyani, P. and Andola, H., *In vitro* propagation, genetic and phytochemical assessment of *Hebenaria edgeworthii* an important Astavarga Plant. *Acta Physiologiae Plantarum*. 34, (3), 869-875, 2012, DOI: 10.1007/s11738-011-0884-8

13. Ali, Majid, Malik, A.R. and Sharma, K. Rai. Vegetative propagation of *Berberis aristata* DC. An endangered Himalayan Shrub. *Journal of Medicinal Plant Research* 2, 374-377, 2008.

14. Singh, Narayan, Pathak, R., Kathait, A.S., Rautela, D. and Dubey, A., Collection of *Cordyceps sinensis* (Berk.) *Sacc***.** in the interior villages of Chamoli District in Garhwal Himalaya (Uttaranchal) and its social impacts, *Journal of American Science*, 2010, 6(6).

15. Bhandari, A.K., Negi, J.S., Bisht, V.K., Rana, C.S., Bharti, M.K. And Singh, N. Chemical Constituent, Inorganic Elements and properties of Cordyceps sinensis - a review. *Nature and Science*, 8 (9), 2010.

16. Kinhal, G.A. and Jagannath Rao, R., Conservation Action and Research Group, FRLHT, Bangalore.

17. Shah, Megha. and Panchal, Mayank., Ethnopharmacological properties of Cinnamomum tamala- A review. 5, November - December (3), 2010, Article 025.

18. Dhyani, D., Maikhuri, R.K., Rao, K.S., Kumar, L., Purohit, V.K., Sundriyal, M. and Saxena, K.G., Basic nutritional attributes of *Hippophae rhamnoides* (Seabuckthorn) populations from Uttarakhand Himalaya, India. *Current Science,* 92, (8), 25, 2007.

19. Kala, C.P., Current status of medicinal plants used by traditional vaidyas in Uttaranchal State of India. *Ethnobotany Research & Applications,* 3, 267-278, 2005.

20. Kala, C.P., Indigenous uses, population density and conservation of threatened medicinal plant in protected areas of Indian Himalayas. *Conservation Biology* **19**(2):368-378 (2005)

Section I

BIO-RESOURCES

Forests

Chapter
THREE

FORESTS

(Ashutosh Mishra and Kirti Joshi)

3.1. Introduction

An environmental report is incomplete without a mention of the forests. Forests play an important role in defining how the economy has been developing with the perspective of safeguarding its natural resources as well as its judicious use. In a sense it is a parameter of gauzing the health of the environment. Forests in Uttarakhand have been an essential part of the state development as nearly 46% land is under forest cover and 80% people are directly or indirectly dependent on forest either for their sustenance or subsistence.

Though the State has witnessed vagaries of climate change (refer climate change chapter) however, since its formation the forest cover has risen steeply (Fig. 3.1). The last decade has seen an increase of 1.04% forest cover in the state.

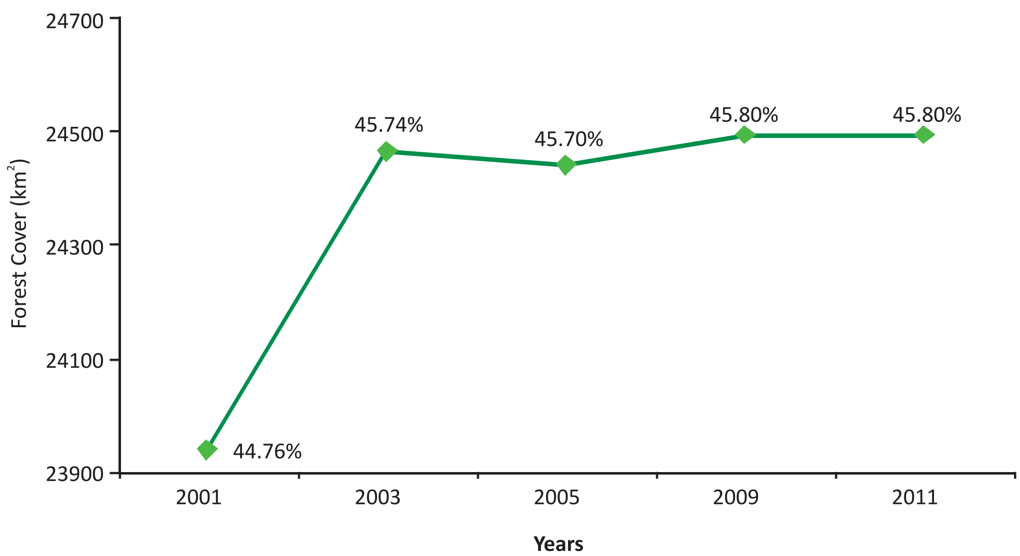
Forest Indicators[1]

Description	Value (National Ranking*)	Description	Value (National Ranking*)
Geographical area '000' ha	5348.3 (18)	Forest cover '000' ha	2449.6 (9)
Forest area '000' ha	3465.1 (9)	Per capita forest cover in ha	0.2421 (8)
Forest area as percentage of geographical area	64.79 (5)	Forest cover as percentage of geographical area	45.80 (11)
Population in '000'	10120 (20)		

**Based on 35 State/UT*

Fig-3.1.
Trend of Total Forest Cover of the State.

Source: Authors construction from various India State of Forest Report



3.2. Status of Forests

Uttarakhand is situated in the northern part of India and shares international boundary with China in the north and Nepal in the east. It has an area of 53,483 km^2 and lies between latitude 28^{0}43' and 31^{0}28' N and longitude 77^{0}34' and 81^{0}03'E.

Topographically the State can be divided into three zones namely the Himalayas, the Shiwaliks and the Tarai region. The State has a temperate climate except in the plain areas

where the climate is tropical with temperatures ranging from sub-zero to 43^{0}C. The average annual rainfall is 1,550mm.

3.2.1. Recorded Forest Area

Uttarakhand is covered with rich forests across all 13 districts. The recorded forest area of the State is 34,651 km^2, which constitutes 64.79% (Table 3.1) of its geographical area[1]. Reserved Forests constitute 71.10%, Protected Forests 28.52% and Unclassed Forests 0.35% of the total forest area. District Rudraprayag (90.91%) has the maximum land under forest area followed by Uttarkashi (90.03%), Tehri Garhwal (88.29%) and Almora (75.24%). Eight districts have above 60% of forest area while the rest namely Bageshwar, Pauri Garhwal, Udham Singh Nagar, Haridwar and Pithoragarh have a forest area between 49.05% to 28.96%.

3.2.2. Protected Areas

The State has 6 National Parks, 6 Wildlife Sanctuaries and 2 Conservation Reserves covering an area of 7,376 km^2, which constitutes 13.79% of its geographical area. The famous Corbett Tiger Reserve is located in the State covering an area of 0.13 million ha, Nanda Devi Biosphere Reserve, with an area of 0.59 million ha, is also located in this State.

3.2.3. Forest Cover

The forest cover of the country as per 2011 assessment is 692,027 km^2 which is 21.05% of the geographical area of the country[1]. The Uttarakhand Forest Statistics (2009-2010) recorded 1,141 km^2 increase in forest cover after creation of Uttarakhand[2]. The forest cover in the State, based on interpretation of satellite data of October – December 2008, is 24,496 km^2, which is 45.80% of the State's geographical area (Table 3.2). In terms of forest canopy density classes, the State has 4,762 km^2 very dense forest, 14,167 km^2 moderately dense forest and 5,567 km^2 open forest (Fig. 3.2). The distribution of forest cover of the State is shown in Fig 3.3[1].

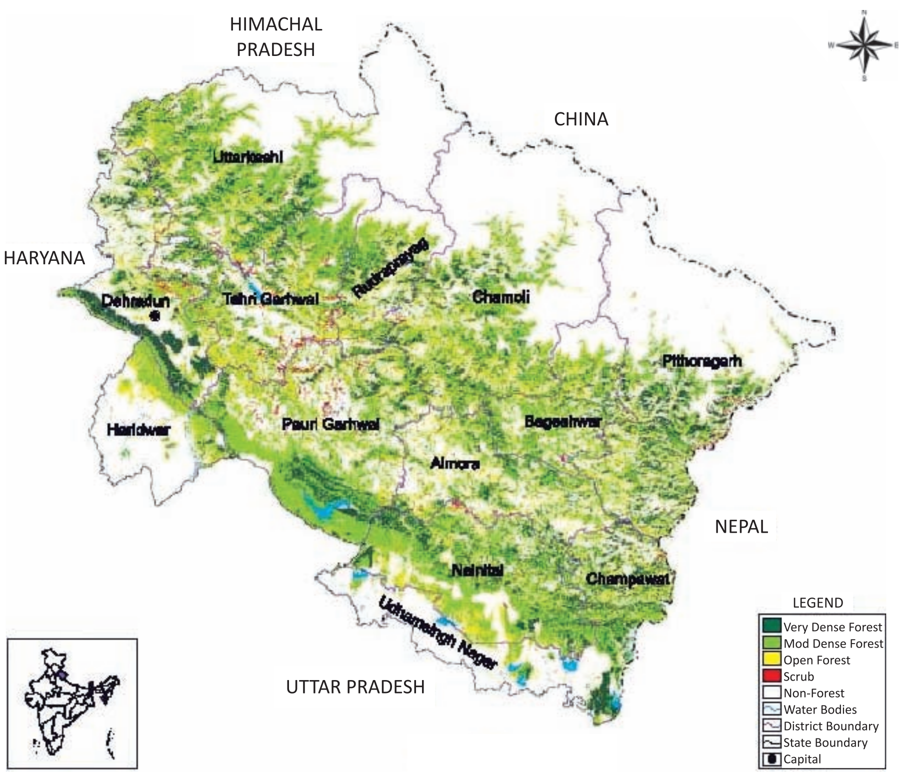


Fig-3.2.
Forest Cover Map

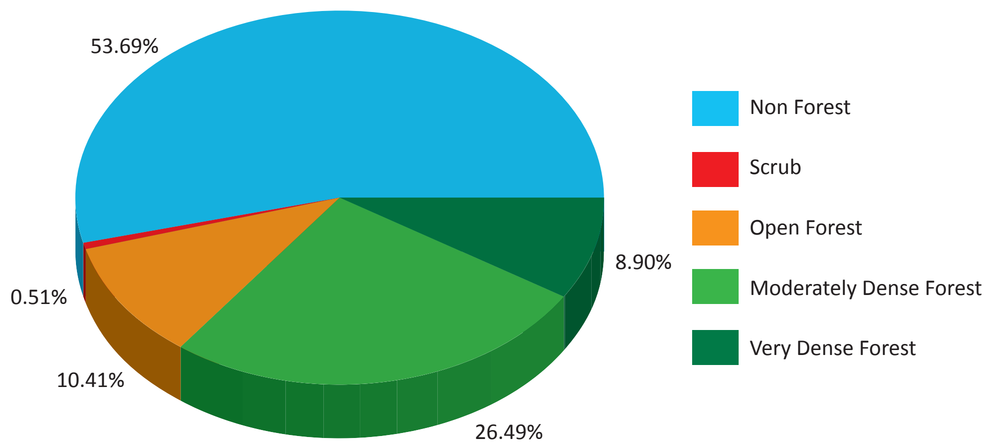
Source: FSI, 2011.

Table-3.1.
Detail of district-wise geographical area and forest area of Uttarakhand[2]

District	Forest Area (km²)					
	Under Forest Department	Civil Soyam forest under Revenue Department	Area completely recorded under Van Panchayat	Under Private/ other agencies (Municipal, Cantt., Central Deptt. etc.)	Total forest area	Total forest area as percentage of geographical area
Almora	785.195	848.558	698.531	29.557	2361.841	75.24
Bageshwar	690.333	23.021	387.829	0.413	1101.596	49.05
Chamoli	2817.198	447.174	1786.706 96.846*	9.924	5061.002	63.03
Champawat	735.379	275.480	312.328	0.188	1323.375	74.94
Dehradun	1522.708	342.016	76.586	76.991	2018.301	65.36
Pauri Garhwal	2327.024	983.675	528.140	12.103	3850.942	43.67
Haridwar	724.307	0.000	0.000	0.000	724.307	30.69
Nainital	2574.452	111.892	280.678	15.338	2982.360	70.16
Pithoragarh	751.966	417.480	870.537	13.003	2052.986	28.96
Rudraprayag	1277.783	318.854	207.016	0.000	1803.653	90.91
Tehri Garhwal	2315.175	768.665	131.80	0.000	3215.640	88.29
Udham Singh Nagar	938.370	0.000	0.000	0.000	938.370	36.91
Uttarkashi	6954.914	231.889	29.838 42.807*	0.000	7216.641	90.03
Total	**24414.804**	**4768.704**	**5449.642**	**157.517**	**34651.014**	**64.79**

**Area under control of Van Panchayats but recorded in reserved forests of Forest Deptt.*

Fig-3.3.
Distribution of Forest Cover



The forest cover is highest in Nainital (72.69%) followed by Champawat (66.87%), Pauri Garhwal (61.72%), Bageshwar (61.49%), Tehri Garhwal (58.95%), Rudraprayag (56.7%), Dehradun (52.04%) and Almora (50.24%). Rest all the districts have below the average forest cover. Nainital (12.62%) also tops in having very dense forest cover, trailing behind are Dehradun (12.26%), Pithoragarh (11.90%) and Uttarkashi (11.90%). However Chamoli

District	Geographical Area	2011 Assessment				Percent of GA	Scrub
		Very Dense	Moderate Dense	Open Forest	Total Forest		
Almora	3,139	222	928	427	1,577	50.24	10
Bageshwar	2,246	194	883	304	1,381	61.49	4
Chamoli	8,030	427	1,586	682	2,695	33.56	6
Champawat	1,766	336	571	274	1,181	66.87	8
Dehradun	3,088	584	695	328	1,607	52.04	24
Pauri Garhwal	5,329	523	2,094	672	3,289	61.72	59
Haridwar	2,360	26	353	240	619	26.23	0
Nainital	4,251	601	1,923	566	3,090	72.69	13
Pithoragarh	7,090	567	1,115	412	2,094	29.53	32
Rudraprayag	1,984	246	581	298	1,125	56.70	5
Tehri Garhwal	3,642	298	1,232	617	2,147	58.95	89
Udham Singh Nagar	2,542	171	247	128	546	21.48	0
Uttarkashi	8,016	567	1,959	619	3,145	39.23	21
Total	**53,483**	**4,762**	**14,167**	**5,567**	**24,496**	**45.80**	**271**

Table-3.2.
District-wise Forest Cover of Uttarakhand (in km^2)

Forest Cover Change

Forest cover shows a gain of 1 km^2 as compared to 2009 report.
The change matrix reveals that there has been an increase of 2 km^2 in moderately dense forest and a decrease of 1 km^2 in open forest.

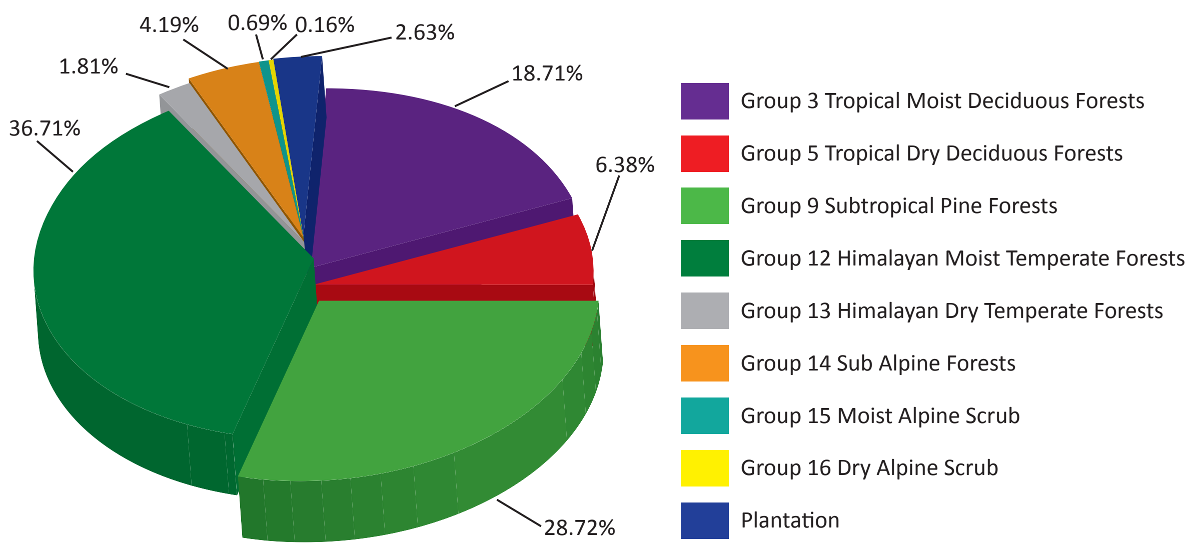
(12.25%) outstrips other districts in open forest areas followed by Pauri Garhwal (12.07%) and Uttarkashi (11.12%). Haridwar and Udham Singh Nagar are the two districts which are at the bottom of the line with respect to forest cover for both dense as well as open forest areas.

The altitudinal variation in the state is quite visible with gradients ranging from 0-500m to above 3000m. Based on SRTM Digital Elevation Model, the altitudinal zone wise forest cover is given in Table 3.3. Considering the fact that most of the parts of Uttarakhand are hilly, with 20.62% land lying above 4000m altitude, if this area is excluded from the total forest and tree cover, then the percentage of forest cover goes up to 59.21% of total geographical area. Both dense and moderately dense forests are concentrated in the range from 1000-3000m. In case of open forests 1000-2000m range is best suited. Nevertheless, the maximum concentration of total forest cover lies in 1000-2000m range.

Altitude Zone	VDF	MDF	OF	Total
0-500m	528	1,759	708	2,995
500-1000m	956	2,166	847	3,969
1000-2000m	1,546	5,560	2,635	9,841
2000-3000m	1,586	3,262	1,009	5,857
>3000m	146	1,420	268	1,834
Total	**4,762**	**14,167**	**5,567**	**24,496**

Table-3.3. Altitude Zone wise Forest Cover (in km^2)

Fig-3.4.
Forest Types of Uttarakhand



3.2.4. Forest Cover in Different Forest Types

The State has 37 forest types which belong to 8 forest type groups viz. Tropical Moist Deciduous, Tropical Dry Deciduous, Subtropical Pine, Himalayan Moist Temperate, Himalayan Dry Temperate, Sub Alpine Forests, Moist Alpine Scrub and Dry Alpine Scrub[3]. Distribution of forest cover in different forest type groups found in the State is given in Fig 3.4[1].

As the altitude of the state varies from 300m to 3,500m and above, 8 out of the 16 forest types (Table 3.4) existing in India can be found in Uttarakhand[3].

3.2.5. Bugyal

A **Bugyal** is a high altitude alpine grass lands, or meadows, in the state of Uttarakhand in India. They are colloquially referred as 'nature's own gardens'. They can be flat or sloped, and are carpeted with green grass and seasonal flowers. These provide an outstanding grazing ground and pastures for tribal herdsmen. At elevations ranging between 3300m and 4000m, these alpine meadows remain snow covered in winter. In the summer, the meadows throw forth a multitude of beautiful flowers and grass. The basins of Nanda Devi, Kedarnath, Gangotri and Bandarpunch have extensive bugyals. Bugyals constitute a fragile ecosystems, and hence need to be cautiously managed. The meadows are composed mostly of perennial mesophytic herbs, with little grasses. Conspicuous among the herbs

Table-3.4.
Forest Types

S.No.	Forest Type	Region	Major Species Found
1	Tropical Moist Deciduous Forest	Moist regions of the lower Himalayas and Tarai arc	*Adina cordifolia, Anogeissus latifolia, Shorea robusta, Terminalia tomentosa* etc and patches of Bamboo, climbers and canes
2	Tropical Dry Deciduous Forest:	Dry southern face of Shiwaliks and adjoining plains	*Anogeissus latifolia, Shorea robusta, Terminalia tomentosa* etc
3	Sub-Tropical Pine Forest:	Lower regions of the Himalayas	Pines as the dominant species
4	Himalayan Moist Temperate Forest:	Occurs between 1600-2900m altitudes in the Himalayas	Coniferous species such as *Abies pindrow, Betula* spp, *Cedrus deodara, Picea smithiana* and *Quercus* spp
5	Himalayan Dry Temperate Forest:	Inner dry trans-Himalayan valleys	*Cedrus deodara, Juniperus* spp and *Pinus wallichiana*.
6	Sub-Alpine Forest:	Exists at altitudes of 2,900m to 3,500m in the middle and upper Himalayas	Patches of *Abies-Betula* forest interspersed with shrubby growth and grassy patches or alpine grasslands called bugyals
7	Moist Alpine Scrub:	Occurs at tree line around an altitude of 3,500m	*Betula utilis* and *Rhododendron campanulatum*
8	Dry Alpine Scrub:	Found in the dry zones of the higher Himalaya	Main species are *Juniperus* spp., *Artemisia* spp and *Primula* spp

are *Primula, Anemone, Fritillaria, Iris, Gentiana,* etc. The important Bugyal[4] and their region are given in Table 3.5.

3.2.6. Soils

Soils are primarily a consortium of numerous inorganic and organic materials formed consequently because of various natural processes occurring over geological times. Forest and soils are interrelated as they provide the fundamental resource for each other. The physical characteristics of soil often determine the soil productivity and hence, the potential impacts on the forests. Uttarakhand has various types of soil, all of which are susceptible to soil erosion. In the north, the soil ranges from gravel (debris from glaciers) to stiff clay (Table 3.6).

3.3. Wetlands

Wetlands defined as areas of land that are either temporarily or permanently covered by water exhibit enormous diversity according to their genesis, geographical location, water regime and chemistry. They are one of the most productive ecosystems and play crucial role in hydrological cycle. Utility-wise, wetlands directly and indirectly support millions of people in providing services such as storm and flood control, clean water supply, food, fiber and raw materials, scenic beauty, educational and recreational benefits.

3.3.1. Statistics

Area estimates of various wetland categories and structural components for Uttarakhand have been carried out using GIS database. Structural components include wetland

Table-3.5.
Estimated Area under Bugyal Region in Uttarakhand

S. No.	Sub Region/ Block	Estimated Area (Sq km)	Livestock Population	Important Bugyal (Altitude in Meter)
1	Byans	365	15000 (S. G) 250 (C. B.)	Palang Gad, Kuti (3929), Chiyalekh (3350), Gabaryang (3200), Kalapani (3400), Nabi Dhang (4110), Jiolingkong (4535), Lipu Lekh (5200), Nampa (3788), Sela Yangti (3933)
2	Malla Darma	185	12500 (S. G) 400 (C. B.)	Bedang (3985), Daave, Bon, Dugtu (3726), Sipu (3677), Mahadevkhola (3900), Lisar Ghati
3	Panchchuli	145	1500 (S. G) 100 (C. B.)	Balchi Dhura, Chipla Gwar, Shyama Molpani, Kot, Dhunkhan, Primula Ghati, Khalia, Rurkhan
4	Ralam (3640m)	75	3500 (S. G) 250 (C. B.)	Dudu-Marjhali, Kalvillan, Rajrambha, Yangchari, Sibugwar, Rajthod (4361)
5	Johaar	750	8000 (S. G) 400 (C. B.)	Milam (3524), Lwa, Vilju, Mapa (3306), Ganghar (3832), Pachu, Burfu (3300), Tola Bhidal Gwar (3248), Salang (3950), Sumtu, Khilanch, Laspa-Pontig, Martoli (3574)
6	Girthi Ganga and Rimkhim (4400-5500m)	485	12000 (S. G) 350 (C. B.)	Topidhunga (4625), Lapthal (4604), Salsal (4704), Chayudhang, Sangchamalla, Kyogad, Chujan, Rimkhim (4452), Chotahoti, Barahoti
7	Niti-Gamsali (3484m)	280	18500 (S. G) 350 (C. B.)	Chorhoti, Kalajowar, Niti (4000), Malari, Timar Sen, Dhamanpayar, Gothing, Gyaldung
8	Pindari and nearby region	125	2000 (S. G) 600 (C. B.)	Sunder Dhunga, Pindari, Kafni, Namik
9	Nanda Devi National Park	215	4500 (S. G) 500 (C. B.)	Dharansi, Bhitartoli, Sarson Paatal, Bedini-Auli (3354), Rupkund
10	Badrinath Valley	220	4800 (S. G) 300 (C. B.)	Satopanth (3935), Dhanu Payar, Semkharak, Devwan, Khiron Ghati, Neelkanth Adhaar, Valley of Flowers, Rajkharak, Kakbhusandi
11	Kedarnath Wild life Sanctuary (Panchkedar)	235	14000 (S. G) 150 (C. B.)	Rudranath, Tungnath (3200-3300), Visuri Tal, Manini, Kham, Madmaheswar, Kedarnath, Vasukital
12	Bhilangana and Bal Ganga upper valley	125	3500 (S. G) 1500 (C. B.)	Khatling (3704), Chauki, Panwali Kantha (3400-3800), Sahastratal, Kayarki (3850), Kuskalyani (3768), Chuli (3626), Anderban
13	Gangotri/Nilang	680	15000 (S. G) 50 (Horse)	Tapowan, Bhojwasa, Jadung, Neelapani, Rudugera
14	Bandarpunch S. East	170	7500 (S. G) 750 (C. B.)	Kayarkoti, Bhu, Kandara, Gidara (4048), Multhat, Dayara (3950)
15	Govind Wild life Sanctuary/ National Park	250	35000 (S. G) 2000 (C. B.)	Seema Bugyal, Harki Doon, Swarg Rohini, Ruisera Tal, Changsheel, Kedarkantha
	Total	**4305**	**157300 (S.G)** **7900 (C.B.)** **50 (Horse)**	

S-Sheep; G-Goat; C-Cow; B-buffalo

Forest Statistics[2]

S.No.	Description	Status as on 31.03.2011
1	Forest area under Forest Department	24414.804 Sq km
2	Panchayati forest under Van Panchayats: *Number* *Area*	 12,089 5,449.642 Sq km (Out of which 348.138 Sq km is reserved forest)
3	Diversion of forest land for development works after creation of Uttarakhand *Number* *Hectare*	 2313 15,072
4	Private forest (Municipal & Cantonment etc.)	157.517 Sq km
5	Area planted under departmental plantation schemes Hectare after creation of Uttarakhand	259659 ha
6	Plantation done by Forest Department during year 2009-10 *Plantation area* *Total no. of plants planted*	 10561 ha 67.31 lakh
7	Status of nurseries (as on 31.03.2010) *Number of nurseries* *Area of nurseries* *Number of plants available*	 405 422.83 ha 199.091 lakh

Table-3.6.
Soil Classification

S.No.	Type of Soil	Characteristics	Distribution
1	Brown forest soil	Often shallow, gravelly and rich in organic matter content	Uttarkashi, Rudraprayag, Chamoli, Pithoragarh, Bageshwar, Champawat, Parts of Almora, Pauri Garhwal & Dehradun
2	Bhabar soil	Coarse-textured, sandy to gravelly, highly porous, and largely infertile.	Distributed in parts of Dehradun, Pauri Garhwal, Nainital & Champawat districts
3	Tarai soils	Mostly rich, clayey loams, mixed to varying degrees with fine sand and humus; they are well suited to the cultivation of rice and sugarcane.	Parts of Haridwar, Pauri Garhwal, Nainital and Udham Singh Nagar
4	Alluvial soil	Clayey in texture, dark in colour and a fine-grained fertile soil deposited by water flowing in river beds.	Parts of Haridwar only

boundary, water-spread, aquatic vegetation and qualitative turbidity of water. Total 994 wetland are mapped, including 816 small wetlands (<2.25ha area)[5]. The total area under the wetlands is 103882ha which is 1.92% of the total geographical area of the state (Table 3.7). Graphical distribution of wetland type is shown in Fig. 3.5.

3.3.1.1. District-Wise Wetland Statistics

The major wetland districts, which contributed more than 10.0% of the wetland area of the state, are Udham Singh Nagar, Haridwar, Nainital and Dehradun. The districts having high altitude wetlands are Chamoli, Pithoragarh, Uttarkashi and Rudraprayag. Chamoli has the highest number of high altitude wetlands (16) followed by Pithoragarh (11). District-wise wetland area estimates[5] are given in Table 3.8.

Table-3.7.
Area Estimates of Wetlands in Uttarakhand

S No.	Wetland Category	Number of Wetlands	Total Wetland Area (ha)	% of Wetland Area	Open Water (ha)	
					Post-monsoon area	Pre-monsoon Area
	Inland Wetland- Natural					
1	Lakes/Ponds	12	2081	2.00	1747	757
2	Ox-bow lakes/ Cut-off meanders	15	63	0.06	49	57
3	High altitude wetlands	29	142	0.14	142	115
4	Riverine wetlands	-	-	0.00	-	-
5	Waterlogged	1	9	0.01	5	9
6	River/Stream	81	80133	77.14	37567	34945
	Inland Wetlands – Man-made					
7	Reservoirs/Barrages	10	20319	19.56	14411	10213
8	Tanks/Ponds	21	108	0.10	89	108
9	Waterlogged	9	211	0.20	211	40
10	Salt pans	-	-	0.00	-	-
	Sub- Total	178	103066	99.21	54221	46244
	Wetlands (<2.25 ha)	816	816	0.79	-	-
	Total	**994**	**103882**	**100.00**	**54221**	**46224**

Fig-3.5.
Type-wise wetland distribution in Uttarakhand

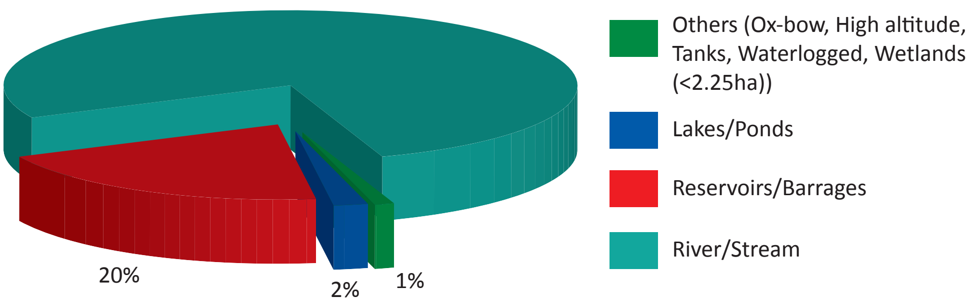


Table-3.8.
District-Wise Wetland Area

S. No.	District	Wetland Area (Sq km)	% of Total Wetland Area
1	Almora	33.26	3.20
2	Bageshwar	21.87	2.11
3	Chamoli	32.40	3.12
4	Champawat	32.22	3.10
5	Dehradun	104.32	10.04
6	Haridwar	124.80	12.01
7	Nainital	138.35	13.32
8	Pauri Garhwal	146.31	14.08
9	Pithoragarh	60.23	5.80
10	Rudraprayag	17.02	1.64
11	Tehri Garhwal	41.73	4.02
12	Udham Singh Nagar	200.99	19.35
13	Uttarkashi	85.32	8.21
	Total	**1038.82**	**100.00**

The wetlands of the state comprise of a large as well as small wetlands in the southern portion of the Uttarakhand valley. The lakes besides the rivers constitute the major part of the wetlands of the state. The premier lakes of the state are Arolital, Badhanital, Bhikaltal, Devtal, Hemkund, Roopkund, Sahstrabahu lake, Ramganga reservoir, Nainital lake, Kedartal, Nanak Sagar, Tehri reservoir, Dhauliganga and Tumaria reservoir etc. Major wetlands of the State and their area, latitude, longitude, flora and fauna are given in Table 3.9.

3.4. Floral Biodiversity in Forest

Forests are reservoirs of floral and faunal biodiversity (refer chapter biodiversity). However, more than 50% species of this region are non-native species[6]. The area has received plant elements from adjoining regions of tropical Asia (Indo-China and Indo-Malaya)[7] and Indo-Gangetic plains[8]. The distribution of non-native species is known from the Himalaya[9].

List of Invasive Plant Species in Uttarakhand– 29 spp.

Gomphrena serrata (Bogada Banthi), *Grangea maderaspatana* (Mustaru, Bhediachim), *Impatiens balsamina* (Impatiens, Balsam), *Indigofera astragalina* (Hairy indigo), *I. linifolia* (Narrow leaf indigo, Torki), *I. trita* (Asian indigo), *Ipomoea eriocarpa* (Morning glory), *I. obscura* (Obscure morning glory), *Lagascea mollis* (Silk leaf), *Lantana camara* (Lantana, Wild sage), *Ludwigia adscendens* (Water primrose), *L. perennis* (Ludwigia), *Malachra capitata* (Brazil jute), *Martynia annua* (Tiger claw), *Melilotus alba* (White sweet-clover), *Mimosa pudica* (Touch-me-not, Sleeping grass), *Mirabilis jalapa* (4'0 clock plant), *Nicotiana plumbaginifolia* (Tex-Mex tobacco), *Opuntia stricta* (Prickly pear, Snake hood fig), *Parthenium hysterophorus* (Congress grass), *Pennisetum purpureum* (Elephant grass, Napier grass), *Peristrophe paniculata* (Panicled Peristrophe), *Physalis angulata* (Goose berry), *Pilea microphylla* (Gun power plant), *Portulaca oleracea* (Purslane), *Prosopis juliflora* (Mesquite), *Rorippa dubia* (Hairypink), *Sida acuta* (Common wireweed) and *Urena lobata* (Caesar weed)[10].

Chir Pine (Table 3.10) is reported to be the most dominant tree species of the area occupying around 16% of the area followed by oak (15.69%) and Sal (12.2%). A quarter of the land is habitated with mixed/ miscellaneous species. Temperate broad leaved mixed forest has high tree and herb diversity, while pine mixed forest exhibits high shrub diversity[11]. The wasteland which includes barren areas either due to water logging, sandy, riverbank or rocky terrain, pasturelands, degraded and snow covered areas constitute 22% of the area.

The distribution of the tree communities in the forest stands are governed mainly by the gradients of altitude, slope and canopy cover. The main species of forests below 1000m are *Eucalyptus* and *Dendrocalamus* spp. While as we go higher up Pines take over the coverage. The temperate zone (between 1600m to 2600m) is covered by *Abies pindrow, Cedrus deodara, Picea smithiana* and *Quercus* spp. whereas the alpine meadows touching the snowline are dominated by herbs[12].

Uttarakhand contains 38 species of plants considered globally threatened by IUCN belonging to 24 different families. Among them two are critically endangered, 15 rare, 1 possibly extinct, 9 endangered, 7 vulnerable and 4 in the indeterminate category.

List of Threatened Plants (IUCN Red list) from Uttarakhand[13-16]

IUCN Category	Family	Botanical name	IUCN Category	Family	Botanical name
Critically Endangered	Aceraceae	*Acer oblongum var. membranaceum*	**Endangered**	Aceraceae	*Acer osmastonii*
	Ranunculaceae	*Aconitum heterophyllum*		Asteraceae	*Lactuca filicina*
Rare	Arecaceae	*Trachycarpus takii*			*Saussurea costus*
	Asteraceae	*Saussurea bracteata*		Caryophyllaceae	*Arenaria curvifolia*
	Berberidaceae	*Berberis affinis*			*A. ferruginea*
		B. osmastonii		Orchidaceae	*Calanthe pachystalix*
	Campanulaceae	*Campanula wattiana*			*Didiciea cunninghamii*
		Cyananthus integra			*Flickingeria hesperis*
	Caryophyllaceae	*Silene kumaunensis*	Vulnerable	Aceraceae	*Acer caesium*
	Orchidaceae	*Aphyllorchis parviflora*		Alliaceae	*Allium stracheyi*
		Archineottia microglottis		Asteraceae	*Catamixis baccharoides*
		Calanthe mannii		Berberidaceae	*Berberis lambertii*
		Cypripedium cordigerum		Fabaceae	*Hedysarum microcalyx*
		C. elegans		Orchidaceae	*Diplomeris hirsuta*
		C. himalaicum		Thelypteridaceae	*Christella kaumaunica*
		Eria occidentalis	Indeterminate	Berberidaceae	*Berberis petiolaris var. garhwalana*
		Eulophia mackinnonii			*B. pseudoumbellata*
Endangered, Possibly Extinct	Orchidaceae	*Aphyllorchis gollani*		Cyperaceae	*Microschoenus duthiei*
Endangered	Aceraceae	*Acer oblongum*		Pittosporaceae	*Pittosporum eriocarpum*

Table-3.9.
Important Wetlands of Uttarakhand

S No.	Major Wetlands	Location	Area (ha)	Climate	Turbidity	Vegetation	Fauna
1	Bahgul Dhora	$28^0 52' 56''$N and $28^0 56' 20''$N latitudes $79^0 35' 46''$E and $79^0 40' 55''$E longitudes	2278	8° to 41.5°C	Low-Moderate	*Hydrilla, Myriophyllum,* and *Potamogeton* in the ponds, and *Carex* sp., other sedges, grass and *Lantana* as bushes	Important breeding area for several species of waterfowl
2	Bour Dam	$29^0 06' 26''$N and $29^0 09' 41''$N latitudes $79^0 15' 12''$E and $79^0 22' 22''$E longitudes	2612	-	Moderate	-	Reported to be attracting waterfowl
3	Nanaksagar	$28^0 56' 13''$N and $28^0 59' 54''$N latitudes $79^0 47' 28''$E and $79^0 53' 09''$E longitudes	3330	-	Moderate-High	Species of *Hydrilla, Myriophyllum, and Potamogeton* are dominant sp of the lake	Information on phytoplankton and zooplankton and fish fauna is not available
4	Ramganga	$29^0 31' 05''$N and $29^0 38' 66''$N latitudes $79^0 39' 26''$E and $79^0 52' 49''$E longitudes	7093	1.3° to 45°C	Moderate	Forests are crowded with Himalayan cypress, Deodar, Blue pine, Rhododendron, Fir and Long leafed pine	Famous for the fishes like Mahseer, Malee, Rohu, Goonch and Trout
5	Tehri Dam	$30^0 21' 54''$N and $30^0 26' 45''$N latitudes $78^0 25' 44''$E and $78^0 33' 08''$E longitudes	1245	3° to 28°C	Low-Moderate	Trees like Chir, Oaks, Sal, Conifers, Deodar, Haldu, Birch, Alder, Rhododendron, Cypress, Yew, Horse-Chestnut, Willow and variety of medicinal herbs, shrubs and bushes like Brahmi and Ashwagandha are found here	Animals like Monkey Langur, Wild-Cat, Goat, Pig, Fox, Wild-Dog, Black Bear, the Flying Squirrel and the critically endangered Musk Deer or the Kastura.
6	Tumaria	$29^0 18' 08''$N and $29^0 21' 05''$N latitudes $78^0 52' 59''$E and $78^0 57' 39''$E longitudes	2094	-	Low- Moderate	Vegetation dominated by reeds during summer otherwise it devoid to hydrophytes	A great diversity of ichthiological fauna is recorded from this lake

Table-3.10.
Species Wise Classification of Forest Areas under Forest Department[2]

S.No.	Species	Area (Ha.)	Percentage
1	Sal	3,13,054.20	12.82
2	Teak	20,209.16	0.83
3	Sissoo	15,114.19	0.62
4	Catechu	5,796.61	0.24
5	Eucalyptus	21,411.73	0.88
6	Oak	3,83,088.12	15.69
7	Miscellaneous/mixed	6,14,361.00	25.17
8	Chir Pine	3,94,383.84	16.15
9	Deodar	18,783.35	0.77
10	Blue Pine	18,548.83	0.76
11	Fir and Spruce	92,464.84	3.78
12	Cypress	2,965.11	0.12
13	Barren, Wasteland etc	5,41,299.43	22.17
	Grand Total	**24,41,480.41**	**100.00**

3.5. Forest Resources

About 80% people in Uttarakhand reside in the remote areas and they are fully or partially depended on the adjoining forests to fulfill their day to day needs on NTFP species[17]. The existing plant biodiversity is utilized for fodder, fuel, timber, construction material and various other non timber forest products (NTFP) by local communities. In the state very little fodder is grown on agricultural land and livestock graze mainly in pastures and forests. Tree fodder is predominant in the region.

Timber and firewood form the major produce group, while bamboo, medicinal plants, grasses, gum, resins, etc. constitute the minor produce group. Forests are the major source of raw materials for industries, buildings, railways and other tertiary sectors, but the increased pressure on forests for fuel, fodder and timber requirements has increased the exploitation of forests.

3.5.1. Timber and Fuel Wood Production

In Uttarakhand, income from forest products has always been a major source for people dwelling in forests or nearby areas. Timber constitutes the major chunk of the products obtained from forests. There is a huge demand and market for timber by paper & pulp, plywood, rubber, furniture etc. The sources of supply are generally the forests, the private plantations or the block plantations on non forest lands. As per the latest statistics, 7.87% of wood and 4.06% of fuel wood is being estimated to be produced in Uttarakhand (Table 3.11).

Table-3.11.
Estimated Production of Wood and Fuel Wood from Forests (Annual)[1]

	Recorded Forest Area (km^2)	Estimated Production of Wood (million cum)	Estimated Production of Fuel wood (million tonnes)
Uttarakhand	34651	0.250	0.05
India	769538	3.175	1.232
% production in terms of India	-	7.87	4.06
Ranking based on 23 State/UT	-	5	3

The data indicates a fluctuating trend in the production of timber and fuel wood (Fig 3.6). In the last half decade the amount of timber and fuel wood extracted from the forest has declined dramatically[2]. Nainital followed by Udham Singh Nagar has been the major producer of both timber and firewood. While minimal timber is being collected from Pithoragarh and Chamoli. However, as regards firewood, Tehri Garhwal, Rudraprayag and Bageshwar are less dependent on firewood from forest (Table 3.12).

3.5.2. Non Timber Forest Produce

Not much study has been done on the quantification of total NTFP products from the state. Products like medicinal plants, bamboo, bhabhar grass, baint, gulia and resin are collected from the forests (Table 3.13).

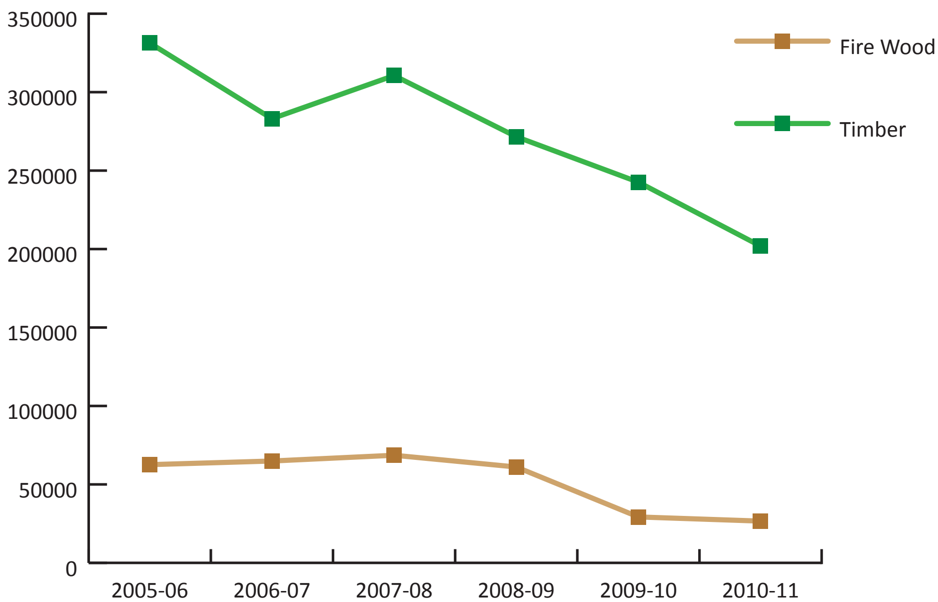


Fig-3.6.
Pattern of Timber & Firewood collection from forests (2005 to 2011)

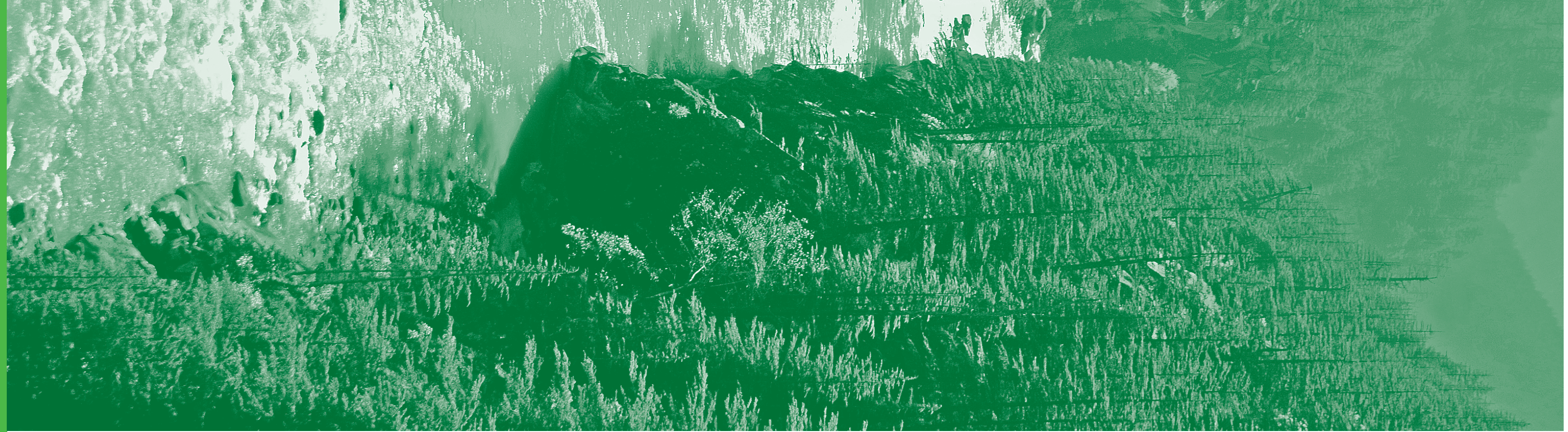


Table-3.12.
District wise Production of Timber and Fire Wood

District	2005-06		2006-07		2007-08		2008-09		2009-10		2010-11	
	Timber	Fire Wood	Timber	Fire Wood	Timber	Fire Wood	Timber	Fire Wood	Timber	Fire Wood	Timber	Fire Wood
Almora	10243	350	5448	575	6780	125	5297	175	10183	326	8065	105
Bageshwar	-	-	6861	296	8713	-	4290	193	4794	160	7049	108
Chamoli	-	-	7015	1948	9647	1856	4025	1962	1736	1500	2348	1131
Champawat	25514	13473	13165	5673	16071	4622	47559	17173	25633	2636	19737	2887
Dehradun	51439	8416	32375	7126	34089	4363	30416	4819	19939	2143	19874	3024
Haridwar	27012	7158	21073	3620	16976	1293	4447	503	17551	1537	27599	4338
Nainital	155041	28085	88909	20516	94899	36870	89044	24698	43249	9523	47454	8238
Pauri Garhwal	16760	3707	11075	686	4198	2230	14258	2784	17027	1219	11015	614
Pithoragarh	12692	190	1510	70	8570	970	11568	624	2564	370	1456	110
Rudraprayag	-	-	22	-	2251	201	756	263	3222	202	3524	264
Tehri Garhwal	7808	139	6582	1005	5114	431	5229	469	4993	226	3747	160
Udham Singh Nagar	-	-	69482	22447	86538	15048	42985	6026	76895	8961	39785	4634
Uttarkashi	24810	1074	19558	950	16732	572	11749	1412	14835	460	10247	997
Total	**331319**	**62592**	**283075**	**64912**	**310578**	**68581**	**271623**	**61101**	**242621**	**29263**	**201900**	**26610**

Timber in Cubic mt. round and fire wood in Cubic mt. Stack

Table-3.13.
Non Timber Forest Produce

NTFP Year	Bamboo	***Eulaliopsis binata*** (Bhabhar grass)	Baint	Gulia
Unit	Score	Quintal	Bundle	Cu mt
2005-06	85	75		
2006-07	124	78		
2007-08	203	61	180	2725
2008-09	114	79	227	
2009-10	316	60		7704
2010-11	111	3343		13335

Among them, resin hogs the major share. Last two decades has seen an enormous increase (50%) of resin production with a slight dip in 2010-11 (Fig. 3.7). Same effect has been seen in the revenue generated from the sale of resin. However, a conspicuous thing to note is that the margin of revenue is increasing at a faster rate as compared to the extraction. This indicates the ever increasing demand with a shrinking supply of resin.

3.5.2.1. Bamboo Production[1]

The extent of bamboo bearing area in the forests is 451 km^2. Density wise details, number of culms by soundness and equivalent green weight are given in Table 3.14 and 3.15.

3.6. Livelihood Based on Forest

Rural occupations based on farming are generally seasonal in approach. There comes in between a period when the farmer is out of work and tends to switch over to non farming jobs. To stay put near his fields and get engaged in an activity which will enhance his livelihood during those lean periods is one of the major concerns. Collection of forest products from nearby forests, animal husbandry and water management are some of the attractive options for them. It appears that the mix of farm-forestry and water management jobs helps them get over and in a way lead a self sustaining life.

Fig-3.7.
Resin Production and Revenue Generated

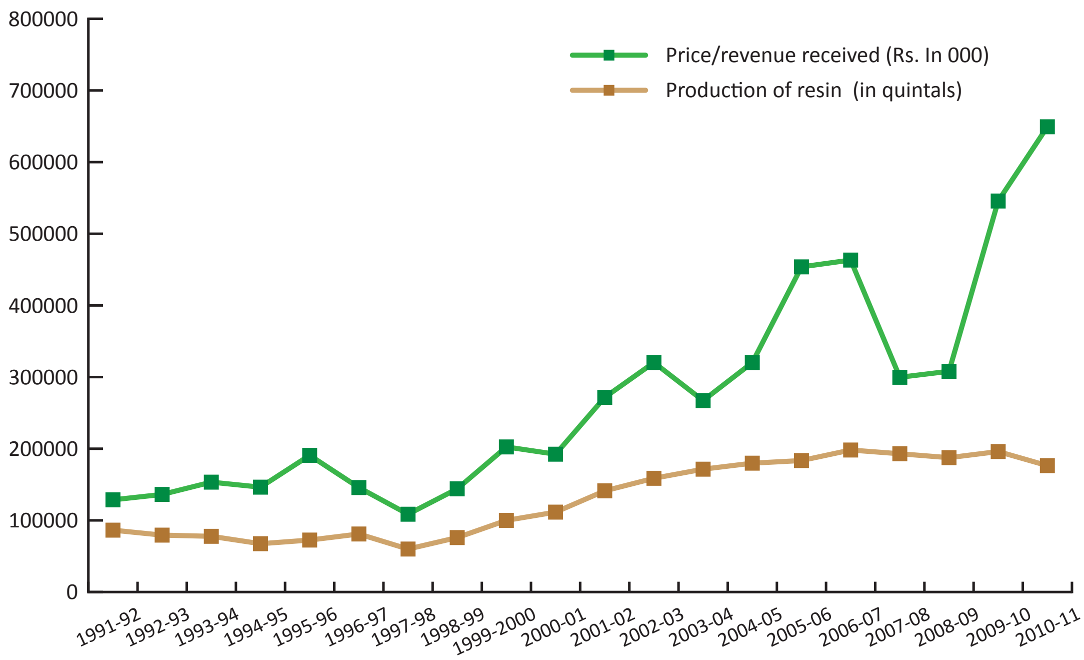


Table-3.14.
Bamboo bearing Area by Density in Recorded Forest Area (in km^2)

Recorded Forest Area	Pure Bamboo	Dense Bamboo	Scattered Bamboo	Clumps hacked	Bamboo Regeneration	No Bamboo
34651	0	67	329	47	8	34200

Table-3.15.
Estimated Number of Bamboo Culms and Equivalent Green Weight

Number of Culms (in millions)				**Equivalent Green Weight (in '000' tonnes)**		
Green	Dry	Decayed	Total	Green	Dry	Total
143	92	24	259	690	506	1196

An estimated 80% people in rural areas depend on forests for at least a part of their livelihoods. Forest dwellers including the tribals, are among the poorest and most vulnerable groups in society. These forest fringe communities depend upon forests for their cultural, economic and spiritual needs. Evidence provided by the latest report of FSI, 2011 states that the maximum percentage share of wood extracted from forests for industrial use is being used for construction purposes mainly followed by furniture making and crafting agriculture implements (Table 3.16).

Table-3.16.
Quantity of Wood Used in House Construction, Furniture and Agriculture Implements[1]

	House Construction	Furniture	Agriculture Implements
Uttarakhand	4.781	0.503	0.072
India	340.172	58.42	21.588
% use in terms of India	**1.41**	**0.86**	**0.33**
Ranking based on 23 State/ UT	**22**	**22**	**18**

3.6.1. *Van Panchayat*[18]

Van Panchayats (VP) are basically community management institutions that have had a long history in the hill region of Uttarakhand that date back to 1932. There are 12,089 Van Panchayats in Uttarakhand formed under the Joint Forest Management or other programmes by the State Forest Department. These Van Panchayats/ Forest protection committees look after an approximate area of 5.44 lakh km^2 of forest area in the state. The Van Panchayats manage forest lands under their control and members are entitled to usufructuary rights. The Forest Department provides necessary technical help in the management of panchayati forests. The share of forest panchayat income is about 80 per cent of the total produce. The net income sharing is in the proportion of 30:40:30:: Gram Panchayat: VP: Community development works by VP. The area under each VP ranges from a fraction of a hectare to up to over 2000 hectares. Among them 60% VPs are having less than 15 ha while 13% have less than 3 ha forest area under their management.

Van Panchayats

Unique to Uttarakhand Highest number of VPs with nearly one lakh members.

JFMC

Uttarakhand ranks second to Madhya Pradesh in the number of villages which have taken up Joint Forest Management.

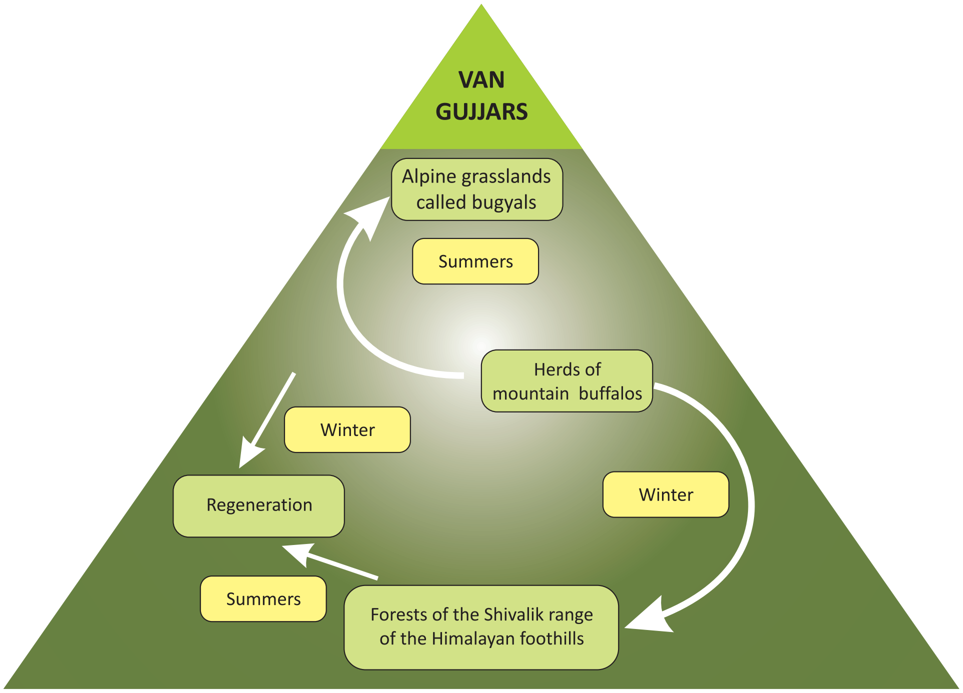
3.6.1.1. Joint Forest Management (JFM) Programme

It is the partnerships between fringe forest-user groups and the Forest Department on the basis of mutual trust and jointly-defined roles and responsibilities with regard to forest protection and development. The basic concept is to develop forests with the participation of the people.

3.6.2. *Tribes*[19]

In Uttarakhand, there are five major tribal communities, namely Bhotia, Jaunsari, Raji, Tharu and Buksa. The tribal population of Uttarakhand is concentrated in the remote/forest areas of Tarai and Bhabar and higher reaches of Pithoragarh, Chamoli, Uttarkashi districts and Jaunsar-Bhabar area of Dehradun district. Cultivation and livestock rearing is their main occupation.

3.6.3. *Forest Settlement*



Nomadic Movement of Van Gujjars

Local Tribes

Tribes	Distribution
Tharu and Buksa	Tarai- Bhabar region
Bhotia (Shauka, Tolcha, Marcha and Jad)	Higher altitudes of Dharchula, Munsyari (Pithoragarh Distt.) Kapkot (Bageshwar Distt.), Joshimath (Chamoli Distt.), Bhatwari and Dunda blocks (Uttarakashi Distt.)
Raji	Kanalichhina and Champawat blocks
Jaunsari	Chakrata and Kalsi blocks of Dehradun district

3.7. Government Schemes

Majority of the collection from the forest repositories is by destructive harvesting, due to which many useful plant species are becoming endangered or threatened. To check this rampant destruction and over excessive use of forest resources, government is responding by initiating various programmes and schemes for regeneration and afforestation of depleted areas.

3.7.1. Key Schemes

The various government schemes for increasing the forest cover include National Afforestation Programme, Integrated Forest Protection Scheme, Eco-Development Force (EDF) Scheme, Grants-in-Aid for Greening India Scheme, Gram Van Yojana (GVY) for afforestation on non-forest lands, Assistance for Development of National Parks and Sanctuaries for Afforestation, Regeneration of Degraded Forests, Accelerated Programme of Restoration and Regeneration of Forest Cover, MGNREGA, Campa fund, Integrated Forest Management Scheme, Ministry of New and Renewable Energy Resources, XIII Finance Commission Grant, Integrated Watershed Management Programme, NREP, RLEGP, DPAP, DRDA etc. A brief profile of the various government schemes under the five year plans is presented in Fig. 3.8.

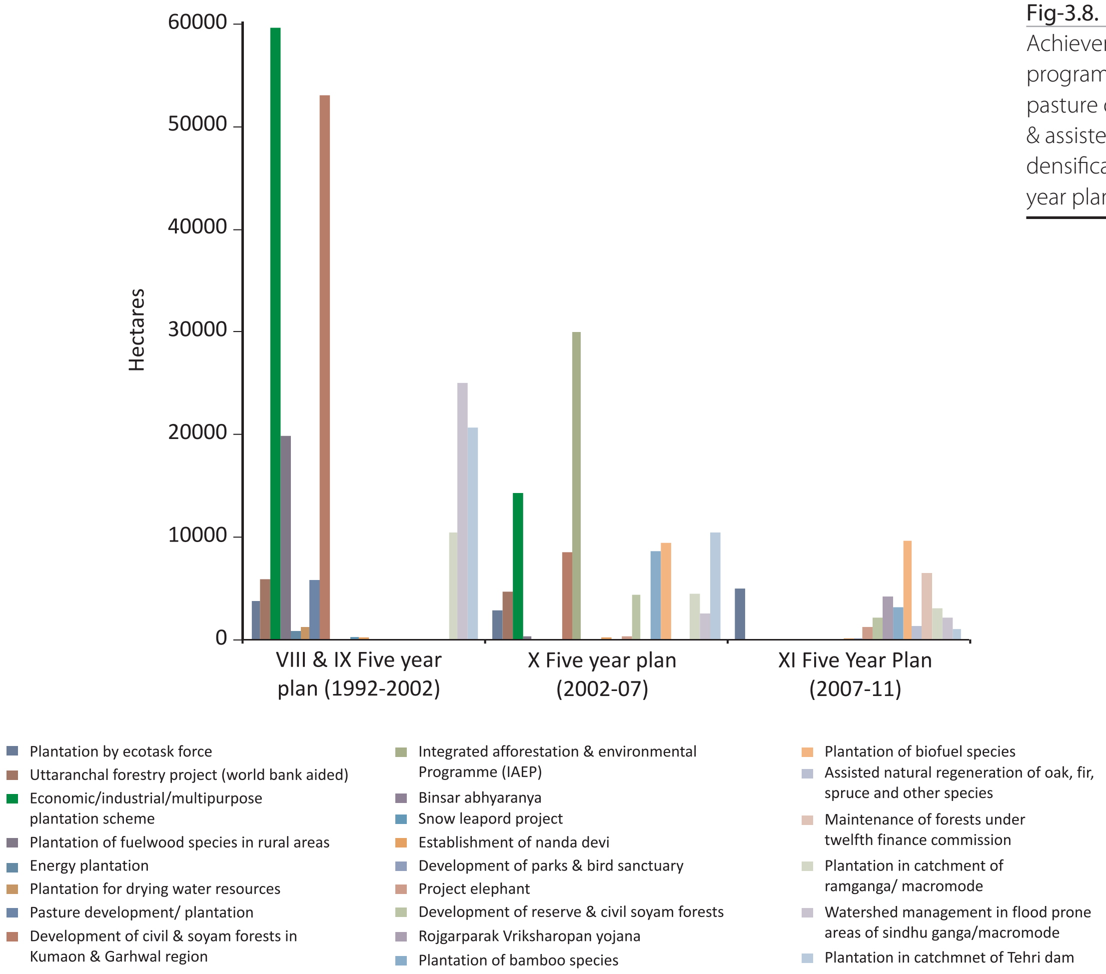


Fig-3.8.
Achievements of Plantation programmes (plantation, pasture development, natural & assisted regeneration, densification etc.) under five year plans in forest department[2]

Realizing the above mentioned schemes and programmes for taking up plantation activities, the funds released are showing an increasing trend, emphasizing the critical nature of its impact in years to come (Table 3.17).

3.7.2. The National Afforestation Programme Scheme

The NAPS is implemented by the Ministry of Environment and Forests, Govt. of India, which aims to support and accelerate the ongoing process of devolving forest protection, management and development functions to decentralized institutions of Joint Forest Management Committee (JFMC) at the village level, and Forest Development Agency (FDA) at the forest division level, has been one of the most significant schemes in Uttarakhand. The overall objective of the scheme is to develop the forest resources with people's participation, with focus on improvement in livelihoods of the forest-fringe communities, especially the poor. Major activities envisaged in the state under this scheme are presented in Table 3.18.

3.7.3. Budget Allocation

Investment and expenditure on Forest development and protection in Uttarakhand has been rising over the years. Computation of total spending is difficult because agencies from public and private invest or spend on several items that may not be directly accounted for under the respective heads of forest budget.

Table-3.17.
Realization of Government Schemes in Uttarakhand[20]

Schemes	2008-09	2009-10	2010-11
Plantations raised on public and forest land covered under afforestation activities (in Ha)	120848	27163	20044
Amount released for development of forests under intensification of forest management scheme in India (in lacs)			134.57
Funds released under Drought prone areas Programme (in crores)	7.07	411	15.01
Funds released to forest development agency projects under National Afforestation Programme (in crores)	9.24	7	4.47

Table-3.18.
Snippet of National Afforestation Programme in Uttarakhand[21]

	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	Total
Area (ha)	815	4122	18186	10346	5665	-	18867	3510	4065	65576
Funds (in crores)	0.40	2.34	5.81	10.54	13.10	11.52	12.39	9.24	7.00	72.34
JFMC Formed	40	457	628	405	188	29	0	0	153	1900

The annual plan budget expenditure of the forest department in the last decade reveals that during 2005-06 maximum funds were allocated but after that the trend is in a declining mode. In case of forest revenue and expenditure taken from the final grant progress report, the shortfall in revenue generated from the investment incurred is quite visible (Fig. 3.9). An interesting point to be observed is that the trend of deficit is concurrent with the annual budget expenditure of the forest department.

3.8. Regulatory Mechanism

It is pertinent to mention the laws/acts/schemes formulated by Government of India for conservation of forests, which directly or indirectly protect the forests as well as the wild flora & fauna**.** Understanding the regulatory scenario in this sector is extremely crucial not only due to the rapid and excessive use of forest products largely with reference to timber and non timber forest produce but also due to the onus on the regulatory bodies to ensure an environment which is safe and sustainable for generations to come. A review and assessment of regulatory issues and existing laws pertaining to forestry conservation is chronicled in Table 3.19.

3.9. Organizations Involved

A large number of specialized research institutes have come up over the years. The Table 3.20 gives an idea of the various central government, state government and private sector institutions with their respective numbers involved in scientific research and training. There are, moreover, a large number of S&T/R&D institutes under central departments followed by the state managed and state supported S&T/R&D institutes. The regional distribution of the institutes is skewed in nature with most of the central government institutes are positioned in the capital of the state. However, the state funded ones distributed among 4 districts.

3.10. Problems and Threats to Forest

The major threats to forest ecosystems are large scale wildfires and conversion of forest land for other developmental purposes. In addition, illegal felling/ logging and mining are also degrading the forests.

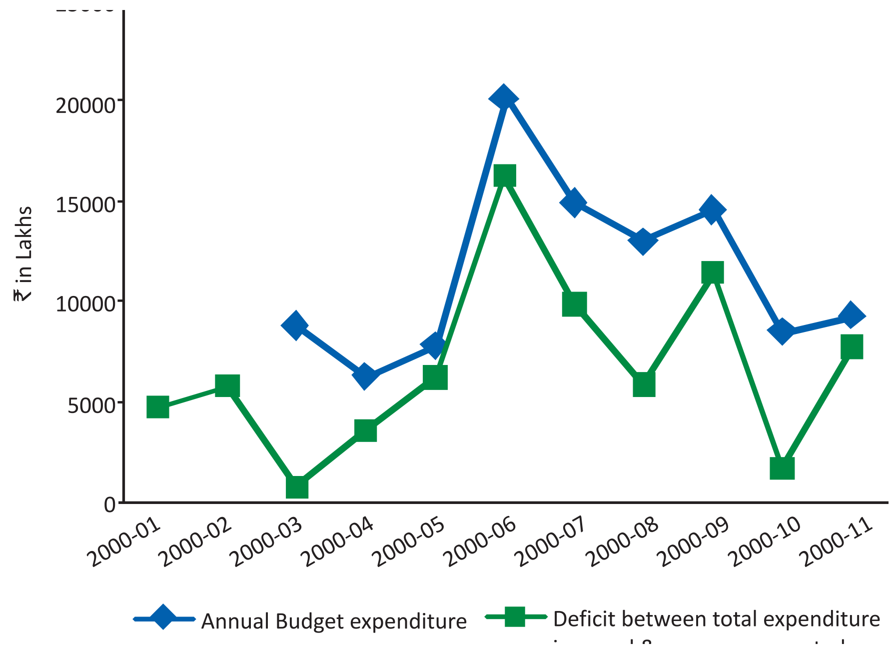


Fig-3.9.
Time series pattern of Revenue and Budget Allocation[2]

Table-3.19.
Post-Independence temporal progression of Indian environmental legal mechanisms for forest conservation

Year	Legislation	Description
1972	Wild Life (Protection Act)	*Medicinal plants present in the protected areas like national parks and sanctuaries are also accorded protection*
1980	The Forest conservation act (amended 1988)	*It put a restriction on the dereservation of forests or use of forest land for non-forest purpose which included the cultivation of tea, coffee, spices, rubber, palms, oil-bearing plants, horticultural crops or medicinal plants*
1986	The environment (Protection act) 1986 (amended 1999, 2002)	*Provides a holistic framework for the protection and improvement to the environment. List out the specifications for obtaining environmental clearances for specific types of new / expansion projects (addressed under Environmental Impact Assessment Notification, 1994) and for submission of an environmental statement to the State Pollution Control Board annually*
1988	National Forest Policy	*Provides a regulatory framework for conservation and protection of forests and wildlife which include medicinal plants. It states that special attention should be paid for Protection, regeneration and optimum collection of minor forest produce along with institutional arrangements for the marketing of such produce.*
1992	The environmental audit notification (amended 1993)	*Mandatory submission of environmental statement*
1993	The environmental standards notification	*General standards of discharge of environmental pollutants*
1994	Environmental clearance: restrictions & prohibitions on the expansion & modernization of any activity or new projects (amended 2002)	*Environment clearance required from MoEF for new projects as well as for expansion/ modernization*

Year	Legislation	Description
1995	The environmental tribunal act	*Provides strict liability for damage arising out of any accident occurring while handling any Hazardous substances for effective and expeditious disposal of cases arising from such accidents with a view to give relief and compensation for damages to persons, property and the Environment and for matters connected therewith.*
1997	The national environment appellate authority act	*To address cases in which environment clearances are required in certain restricted areas.*
1999	Environment (siting of industrial projects) rules	*Lay down detailed provisions relating to areas to be avoided for siting of industries, precautionary measures to be taken for site selecting as also the aspects of environmental protection which should have been incorporated during the implementation of the industrial development projects.*
2002	The National Bio-diversity Act	*Regulates access to forest resources & to provide for the conservation of biological diversity, sustainable use of its components, and fair and equitable sharing of the benefits arising out of the use of biological resources and knowledge associated with it*
2003	Forest conservation rules (amended 2004)	*Provide procedure for the diversion of forest land for non-forestry purpose*
2006	The scheduled tribes and other traditional forest dwellers (recognition of forest rights) Act	*States forest rights of forest dwelling scheduled tribes and traditional forest dwellers: i.e. right of ownership, access to collect, use and dispose of minor forest produce which has been traditionally collected within or outside village boundaries. Where minor forest produce includes all non-timber forest produce of plant origin including bamboo, brush wood, stumps, cane, tusser, cocoons, honey, wax, lac, tendu, medicinal plants and herbs, roots, tubers and the like.*

3.10.1. Forest Fire

Within last 10 years mitigating the forest fires has been a major concern of the forest department. The vagaries of the climate have however, proved this to be an uphill task. In the year 2003-04, nearly 5000 ha land was affected by forest fires (Fig. 3.10). Though a dip was seen afterwards however, three years later again a rise in affected area was observed. The cause of this instability and variation is due to natural occurrences or to human interventions is still unexplained.

Majority of the forest fires occur in the district of Pauri Garhwal (Table 3.21) as evidenced by the number of fire spots in the area. Though just 43.27% area is under forest in the district but still it is at high risk.

3.10.2. Conversion of Forest Land for Developmental Programmes

Under the provisions of Forest (Conservation) Act, 1980 prior approval of the Central Government is essential for diversion of forest lands for the non-forestry purposes. This was done basically to maintain a balance between developmental requirements and the conservation of our natural resources. However, in the State of Uttarakhand most of the area is under harsh climate and treacherous hilly terrain covered with forests. To make reach the ongoing developmental programmes involving supplying of basic amenities like water, electricity and food to such an area generally traverses through forests. Construction projects like schools, hospital, railways, laying of water pipelines, transmission lines, roads etc. all have to seek permission from Ministry of Environment and Forest for clearing the site.

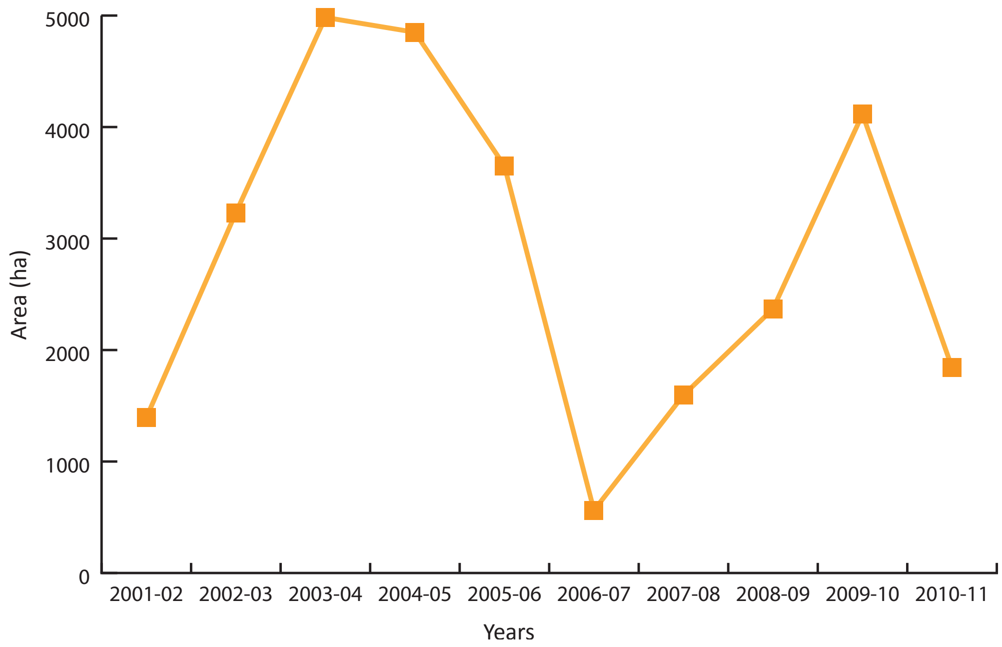


Fig-3.10.
Forest area affected by fire[2]

Table-3.20.
Central and State Government Organization

1	Indian Council of Forestry Research & Education Post Office New Forest Dehradun - 248006 Uttarakhand E bahugunavk@icfre.org W www.icfre.org, P 135 - 757021, F 135 – 756365	10	Gobind Ballabh Pant Institute of Himalayan Environment and Development Kosi-Katarmal Almora - 263643 Uttarakhand E ao@gbpihed.nic.in, W www.gbpihed.gov.in P 5962 - 241041, F 5962 – 241150
2	Research and Testing Station P.O. Pauri Pauri Garhwal - 246001 Uttarakhand P 1368 - 222438	11	Pantnagar Centre for Plant Genetic Resources P.O. Pantnagar U.S. Nagar - 263145 Uttarakhand
3	Research Station P.O. Lohaghat Champawat - 262524 Uttarakhand P 5965 - 234820	12	Research Station Pauri Garhwal - 246001 Uttarakhand
4	Indira Gandhi National Forest Academy Post Office New Forests Dehradun - 248006 Uttarakhand E ignfa@ignf.up.nic.in W www.ignfa.gov.in, P 135 - 2754647, F 135 – 2757314	13	Wildlife Institute of India Post Box -18, Chandrabani Dehradun - 248001 Uttarakhand E wii@gov.in, W www.wii.gov.in P 135 - 2640112, F 135 – 2640117
5	Defence Institute of Bio Energy Research Post Box No. 40, Goraparao Haldwani - 263139, Uttarakhand W www.drdo.org, P 5964 – 225564	14	Agro-forestry Research Centre P.O. Haldi, U.S. Nagar - 263145, Uttarakhand P 5944 – 210151
6	Central Soil & Water Conservation Research & Training Institute 218 - Kaulagarh Road Dehradun - 248195 Uttarakhand E vnsharda@rediffmail.in W www.cswcrtiweb.org, P 135 - 2758564, F 135 – 2754213	15	College of Forestry and Hill Agriculture Hill Campus Ranichauri, Tehri Garhwal - 249199 Uttarakhand P 1376 – 252138

7	Directorate of Forest Education Post Office New Forest Dehradun - 248006, Uttarakhand W www.envfor.nic.in P 135 - 757326, F 135 – 757326	16	Medicinal & Aromatic Plants Research and Development Centre, P.O. Haldi, U.S. Nagar - 263145 Uttarakhand P 5944 – 210147
8	Forest Survey of India Kaulagarh Road, Post Office IPE Dehradun – 248195, Uttarakhand E ignfa@ignfa.up.nic.in W www.fsi.nic.in, P 135 - 756139, F 135 – 759104	17	Wimco Seedlings Ltd. Post Box. No. 4, Kashipur Road, Bagwala, Rudrapur U.S. Nagar - 263153 Uttarakhand E dhimanramesh@yahoo.com P 5944 - 261760, F 5944 – 261761
9	Botanical Survey of India, Northern Regional Centre, 192, Kaulagarh Road, Dehradun–248195, Uttarakhand E bsinc2001@rediffmail.com P 135 2753433, 2755478, F 135 2757951		

Table-3.21. Forest Fire Spots (From 2005 till Feb 2012)[22]

Districts	No. of Fire Spots
Almora	135
Bageshwar	79
Chamoli	171
Champawat	118
Dehradun	200
Haridwar	135
Nainital	543
Pauri Garhwal	813
Pithoragarh	62
Rudraprayag	8
Tehri Garhwal	317
Udham Singh Nagar	135
Uttarkashi	127
Total	**2843**

Since 1981, a total of 4135 projects have been approved for various developmental programmes in the state while 252 were rejected. As regards the pending cases nearly 142 are still waiting the light of the day. Most of the approved projects were for road construction followed by supply of drinking water as depicted in Table 3.22.

3.10.3. Illegal Felling/Logging

Systematic destruction of forest resources across the State has posed a serious threat to environment. Though the government ban remains in force an ever increasing number of cases are reported where unscrupulous people are felling trees with full liberty. The quantity of timber seized by the forest department in last 10 years has ranged between 440 cu. mt. to nearly 868 cu. mt (Fig. 3.11).

3.10.4. Excessive Use of Forest Resources

Anthropogenic disturbance is altering the diversity and distribution of vegetation in these forests, which influence the other ecological and environmental conditions. Over excessive

Table-3.22.
Forest Clearances in the State (1981 onwards)

Types	Approved Projects	Rejected Projects	Pending Cases
Defence	10	3	-
Dispensary/hospital	16	2	-
Drinking water	991	6	3
Hydel	92	5	4
Irrigation	260	6	1
Mining	16	3	3
Others	673	69	29
Railways	1	-	-
Rehabilitation	7	-	-
Road	1895	151	97
School	49	4	1
Thermal	3	0	-
Transmission line	121	2	2
Village electricity	1	-	-
Forest village conversion	-	1	2

Source: Authors construction from MoEF site (accessed on 13/02/2012)

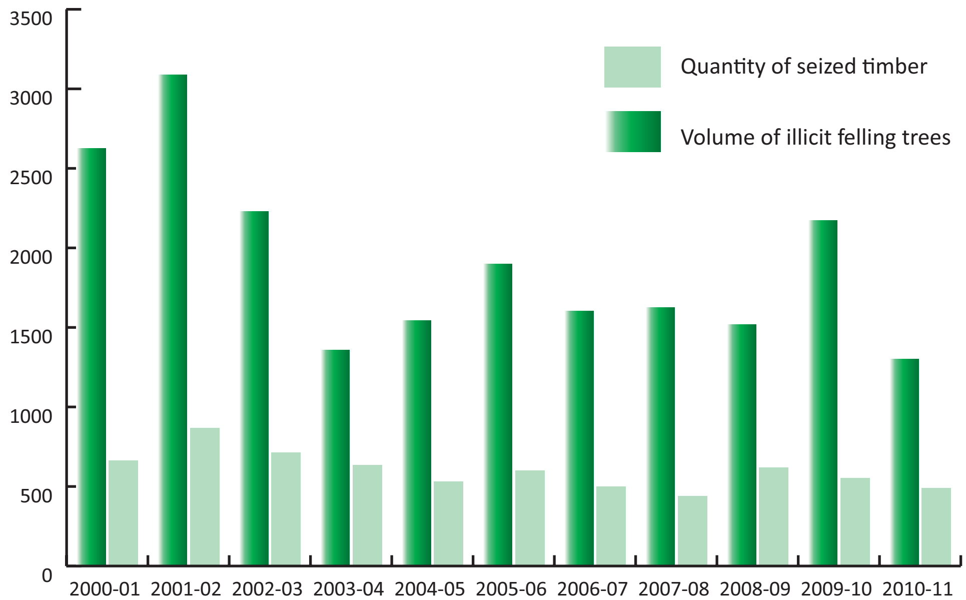


Fig-3.11.
Illicit Felling in the State[2]

collection of forest produces is depleting the forest of its natural biodiversity. Lack of proper knowledge of method of collection is resulting in destructive harvesting of many economically important and highly demanded plants. If this practice is not curbed soon then the day is not far when the economically important flora will come under endangered category. Therefore, there is an urgent need to conserve and manage these forests for sustainable development of environment and ecology of the region.

3.11. Key Findings

I. **Our forest cover is changing in response to new developmental priorities:**
Due to various developmental activities, forest land is being progressively diverted for non forestry purposes. Though last decade has seen a one percent change in forest

cover, however, the dense forest area has remained stagnant. Consequently protection and retaining of very dense forest cover area which is just 8.90% of the total forest cover is the major concern. Besides this, districts which have below the average forest cover should also be targeted for afforestation activities.

II. **Unwarranted collections of forest produce and illegal felling are denuding the forests:**
There is abundance of forest resources in the state. These biodiversity rich forests lures unscrupulous people to extract economically viable forest produce from the forests through destructive collection. Timber and firewood form the major produce group while bamboo, medicinal plants, grasses, gums and resins constitute the minor group. Absence of strict rules and regulations for penalizing the traders is flourishing the illegal trade.

III. **Widespread natural pressures particularly those due to invasive species and inappropriate fire regimes continue to threaten forests of the state:**
The plantation of exotic tree species like Pine in the state has overshadowed other native species. by their rapacious growth. In addition to this, nearly 29 invasive species have been reported from the state. This is a cause of concern as they are in turn destroying the natural grassland ecosystems and the habitats for the native flora and fauna. Uttarakhand contains 38 species of plants considered globally threatened by IUCN belonging to 24 different families. Therefore, protection and regeneration of native and endangered species either through natural or artificial cultivation should be prioritized. Forest fires are impacting our environment in a significant way as the frequency, intensity and timing of forest fires have major consequences for vegetation distribution, composition and condition, and soil bareness and erosion.

IV. **Regulatory mechanisms and institutional arrangements for management of the forests need improvement and levels of investment are inadequate:**
The regulations related to conservation have changed significantly during the last half century. Although substantial funding has been allocated, however, the levels of investment in management of forests through various governmental schemes and programmes remain inadequate for adaptive and sustainable environment.

3.12. References

1. FSI, *India State of Forest Report 2011*, Forest Survey of India, Ministry of Environment & Forests, Government of India, Dehradun, 2011.
2. UFD, *Uttarakhand Forest Statistics (2010-11),* Forest Department, Uttarakhand, Dehradun, 2011.
3. Champion, H.G. and Seth, S.K., *A Revised Survey of the Forest Types of India***,** New Delhi, India, 1968.
4. Rawat, G.S., *Uttaranchal Ke Bugyal,* Bishen Singh Mahendra Pal Singh, Dehra Dun, 2005, p. 213.
5. ISRO, *National Wetland Atlas: Uttarakhand,* SAC/EPSA/ABHG/NWIA/ATLAS/24/ 2010, Space Applications Centre (ISRO), Ahmedabad, India, Sponsored by Ministry of Environment and Forests, Government of India, 2011, p. 130.
6. Dhar, U., Rawal, R.S. and Samant, S.S., Structural diversity and representativeness of forest vegetation in a protected area of Kumaun Himalaya, India: Implication for Conservation, *Biodiversity and Conservation* 1997, **6**, 1045-1062.
7. Mani, M.S., Biogeography of the Himalayas, In *Ecology and Biogeography in India* (eds Mani, M.S.) The Hague, 1974, pp. 664-681.
8. Spate, O.H.K., *India and Pakistan: A General and Regional Geography,* London: Mathuen & Co., 1957.
9. Maheswari, J.K., Studies on Naturalized Flora of India. In ***Proceedings of a*** *Summer School of Botany* (eds Maheshwari, P., John S. and Vasil I.K.), Sree Saraswati Press, Darjeeling, Calcutta, 1962, pp. 156-170.
10. http://www.ncbi.org.in/invasive/serch/index.html
11. Singh, K.K. and Joshi Hema, Floral Diversity Assessment in Four Forest Types of Garhwal Himalaya, Uttarakhand, *Vegetos - An International Journal of Plant Research,* 2010, **23**, 76-85.
12. Sethi, P., Bhujang Rao, Mohan, D.D., Mohapatra, D., Upadhayay, K.K., Hanfee, S. and Khalid, M.A., *Strategies and Action Plan for Biodiversity Conservation in Uttaranchal,* Vol. I. TERI, New Delhi, (Report No. 1999SF61), 2002.
13. IUCN, *IUCN Red List of Threatened Species.* www.iucnredlist.org, 2004.
14. Nayar, M.P. and Sastry, A.R.K., *Red Data Book of Indian Plants,* Botanical Survey of India, Kolkata. 1987.
15. Srivastava, S.K. and Singh, D.K., *Glimpses of the Flora of Uttaranchal;* Bishen Singh Mahendra Pal Singh, Dehra Dun, 2005, p. 158.
16. Uniyal, B.P., Sharma, J.R., Choudhery, U. and Singh, D.K., *Flowering Plants of Uttarakhand; A checklist*; Bishen Singh Mahendra Pal Singh, Dehra Dun. 2007, p. 404.
17. Bartwal, M., Chandra, V. and Rajwar, G.S., Ethnomedicinal Plant Diversity among the Jaunsaries in Tons Valley, Uttarakhand. In: *National Conference on Forest Biodiversity: Earth's Living Treasure*, http://www.upsbdb.org/pdf/Souvenir2011/15.pdf; accessed on 09 March 2012, 2011.
18. Mittal, S., Tripathi, G. and Sethi, D., *Development Strategy for the Hill Districts of Uttarakhand*, Working Paper No. 217, ICRIER, 2008.
19. Pant, B.R., *Tribal Demography of Uttarakhand.* http://gbpihedenvis.nic.in/HTML/Vol%2018/TRIBAL%20DEMOGRAPHY%20OF%20UTTARAKHAND.pdf; accessed on 30 March 2012.
20. http://www.indiastat.com; accessed on 28 February 2012.
21. http://www.naeb.nic.in/statics.html
22. http://www.fsi.org.in/forest_fire.php

Section I

BIO-RESOURCES

Agriculture & Horticulture

Chapter

FOUR

AGRICULTURE & HORTICULTURE

(Kirti Joshi)

4.1. Introduction

The nucleus of most human activities in the state of Uttarakhand, which engages 70% of the population, is agriculture. The farming is deeply grounded in the ecology of the region. Agriculture is seen not in isolation but in totality to include not only crops, livestock and forest but also all other available natural resources. Agriculture and allied activities with an average share of about 37.3% during 1993-94 to 2001-02, is a significant contributor to the state domestic product as against the national average of 27.8% during the period considered.[1]

Succinctly, it is a major component of State economy, mainly because of three reasons. (i) agriculture constitutes one third of the share of State's income, (ii) major work force including 80% women workforce of the State is employed in agriculture sector and (iii) growth of overall economy depends on performance of agriculture that is a source of livelihood and food security for large majority of vast population.[2]

4.2. Land Use

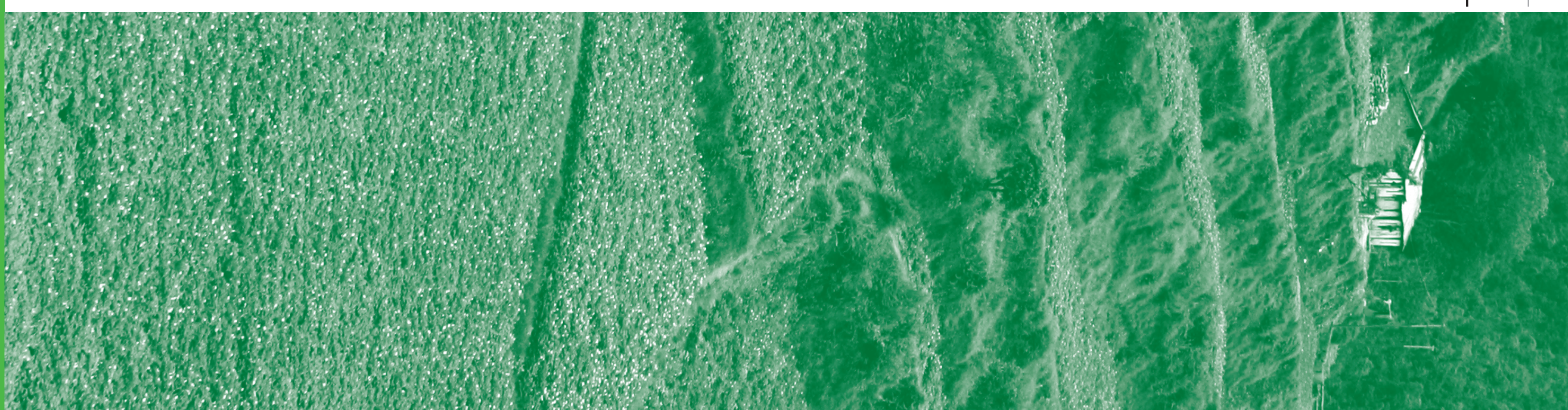
The state has 53483 km^2 geographical area under its jurisdiction of which 86.1% is hilly while rest is plain. The area under non –uses including the barren and unculturable land is 7.8%. Nearly 10.3% land is either permanent pastures or under miscellaneous tree crops and groves which are not included in net sown area. Culturable waste land covers around 5% area. While 2% land is fallow (Table 4.1). Most of the barren and not usable land is present in the hills while the plains have just 20% barren land. However, the hills have more than 90% probability of supporting cultivation. Agriculture pattern in this region is very complex. Terraced slopes covers about 80% of the hill agriculture land, which is completely dependent on the rain whereas, remaining 20% area lies in the valleys and plains, which is fairly irrigated.

Agriculture statistics at a glance

Area under agriculture	15.48 lakh ha
Net cultivated area	7.67 lakh ha
Net irrigated area	3.45 lakh ha
Net sown area	7.41 lakh ha

Table-4.1.
Land use pattern of Uttarakhand[3,4]

	Reporting area for land utilisation statistics	Forest	Land not available for cultivation	Other uncultivated land excluding fallow land				Fallow Land			Net area sown	Total cropped area	Agri. Land /Cultivable land/ Culturable land/ Arable land	Cropping Intensity
				Permanent-pastures & other grazing lands	Land under Misc. tree crops & groves not incl. in net area sown	Culturable waste land	Total	Fallow lands other than current fallows	Current fallows	Total				
	Values in thousand hectares													
2006-07	5667	3465	472	220	269	367	856	64	44	108	765	1210	1509	158.1
2007-08	5673	3484	441	199	384	302	885	72	36	108	755	1187	1549	157.3
2008-09	5673	3486	441	199	384	303	886	71	35	106	754	1188	1547	157.7
2009-10	5673	3484	441	198	383	309	891	80	34	114	741	1166	1548	157.4



4.2.1. Pattern of Land Use

Only 14% land area is under agriculture in Uttarakhand. The extent of net sown area is around 13.1% (Fig. 4.1). Nearly 25.1% of the geographical area of the state has been classified as not suitable for agricultural purposes. About 33% of the total area in Uttarakhand is either rocky/snow covered/glaciated or otherwise unproductive and degraded land. With 64% land covered by forests and wastelands, there is hardly any land left for cultivation.

Over the period of ten years it is being observed that the total area sown has decreased from 1226 thousand ha to 1166 thousand ha i.e nearly 60,000 ha. The reason quoted is that in hill agriculture, the productivity is not as remunerative as compared to other sources of income. Subsequently, the farmers are diverting to other income generating occupations and hence, the decrease in farming.

4.2.2. Physiographic Details of State

The state has been put into zone 9 and 14 as per agro climatic zonation followed by Central Government. It has a variety of plain and hill region. It has been further divided into four parts as per the altitude (Table 4.2). All these zones have different climatic conditions, slope, aspect and height, the variations extending to even short distances, where the micro-climate changes due to interaction of various factors. The soils range from alluvial to sandy loam in Zone A i.e. the foothills while in mid hills it is purely sandy loam. In Zone C and Zone D red to dark black clay is present. The Zone C and D are mostly rainfed regions.

4.3. Irrigation

Irrigation facilities are mainly present in the outer Himalayan plains – the Duns and the Terai regions. Traditional irrigation methods in the hill area have made use of the topography of the region, the steep slopes and have relied on gravity for watering the fields. These irrigation canals dug along the contours of the fields to maintain the flow of water are locally called guls. The state has an area of 338000 ha under irrigation (Table 4.3) which is about 21.9% of the total agriculture land. Gross irrigated area over agricultural land is 36.6%.

4.3.1. Area Under Irrigation

The state has 3.45 lakh ha area under net irrigation and 7.67 lakh ha of net cultivated area. The trend of irrigation over the last decade is increasing (Fig. 4.2). There has been a steep decrease in unirrigated area proclaiming that more area (88000 ha) has come under the ambit of irrigation.

Fig-4.1.
Area sown in Uttarakhand[3]

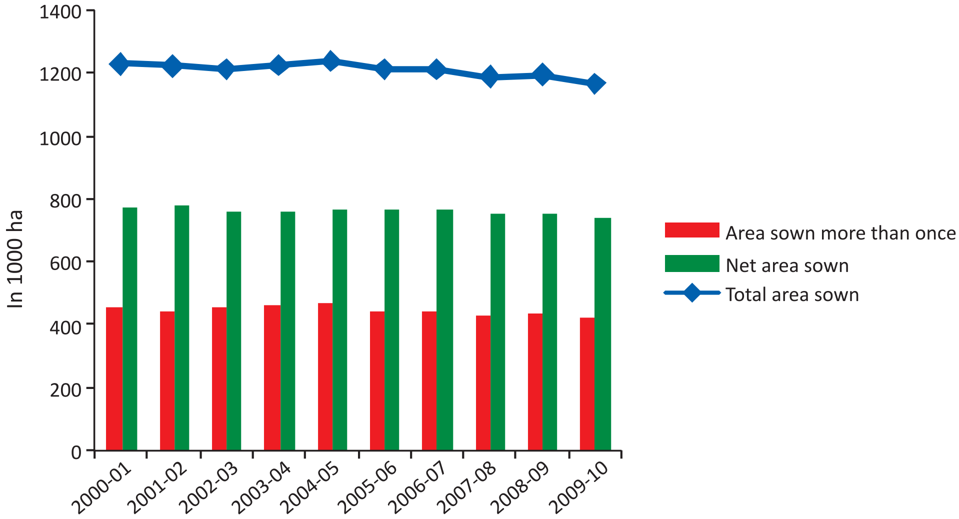


Table-4.2.
Physiographic details of State[1]

S. No.	Zone	Farming situation	Soil	Rainfall (mm/ year)	Districts	Principal farm produces and Livestock
1.	Zone A upto 1000 m	Tarai irrigated	Alluvial	1400	U.S. Nagar, Haridwar	Rice, wheat, sugarcane, lentil, chickpea, rapeseed-mustard, mango, litchi, guava, peach and plums. Livestock: Buffalo and cattle.
		Bhabar irrigated	Alluvial mixed With boulders and shingles	1400	Nainital, Dehradun and Pauri Garhwal	Rice, wheat, sugarcane, rapeseed-mustard, potato, lentil, mango, guava, and litchi. Livestock: Buffalo and cattle
		Irrigated lower hills (600-1000 m)	Alluvial sandy soil	2000-2400	Champawat, Pauri Garhwal, Dehradun, Nainital, Tehri Garhwal	Rice, wheat, onion, chillies, peas, potato, radish, cauliflower, pulses, oilseeds, soybean, mango, guava, plums and peaches. Livestock: Buffalo and cattle
		Rain-fed lower hills (600-1000 m)	Residual sandy loam	2000-2400	Champawat, Nainital, Pauri Garhwal, Dehradun, Tehri Garhwal, Bageshwar	Finger millet, maize, rice, wheat, pulses, mango, guava, plums, and peaches. Livestock: Buffalo, cattle and goat
2.	Zone B 1000-1500m	Mid hills south aspect (1000-1500 m)	Sandy loam	1200-1300	Champawat, Nainital, Almora, Dehradun, Tehri Garhwal, Bageshwar	Rice, finger millet, wheat, potato, tomato, peas, Cole crops, pulses, peach and plums. Livestock: Cattle, sheep & goat
3.	Zone C 1500-2400m	High hills (1500-2400 m)	Red to dark	1200-2500	Pithoragarh, Almora, Chamoli, Bageshwar	Amaranth, finger millet, French- beans, Cole crops, potato, peas, peaches, plums, pear, apple and stone fruits. Livestock: Cattle, sheep and goat
4.	Zone D >2400 m	Very high hills	Red to dark Black clay	1300	Pithoragarh, Chamoli, Uttarkashi	Amaranth, buckwheat, peas, Cole crops, apple and potato. Livestock: Sheep, goat

Fig-4.2.
Crop area under irrigation[3]

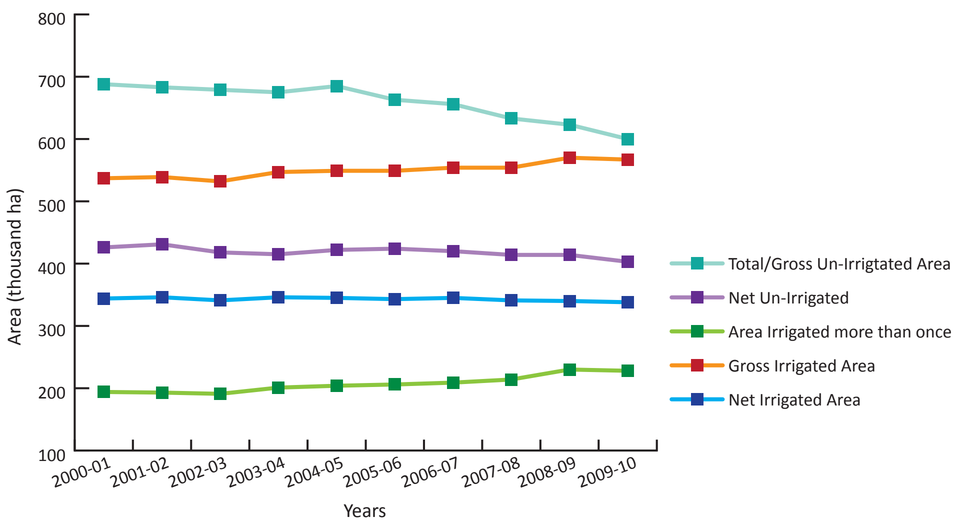


Table-4.3.
District-wise Irrigated Area in lakh ha (2008-09)[1]

Districts	Net Cultivated Area	Net Irrigated Area	Gross Cultivated Area	Gross Irrigated Area
Almora	0.83	0.05	1.31	0.1
Bageshwar	0.22	0.04	0.39	0.08
Chamoli	0.35	0.02	0.53	0.03
Champawat	0.25	0.02	0.42	0.04
Dehradun	0.47	0.21	0.74	0.34
Haridwar	1.2	1.07	1.74	1.5
Nainital	0.47	0.28	0.8	0.4
Pauri Garhwal	0.81	0.08	1.24	0.14
Pithoragarh	0.48	0.04	0.88	0.07
Rudraprayag	0.2	0.03	0.31	0.05
Tehri Garhwal	0.61	0.09	0.99	0.16
US Nagar	1.51	1.48	2.59	2.48
Uttarkashi	0.27	0.05	0.42	0.09
Total	**7.67**	**3.45**	**12.35**	**5.49**

In Udham Singh Nagar, 98% land is irrigated followed by Haridwar which has 89% irrigated land. However, the hilly districts are virtually rainfed areas. Barring US Nagar, Haridwar, Nainital and Dehradun nearly 80% or more area in the rest of the districts is rainfed (Fig. 4.3).

4.3.2. Source Wise Irrigation

The main source of irrigation in this region is natural streams covering more than 63% of the total irrigated area followed by tubewells and canals. Irrigation is done by conveying the water from streams through kuchha channels locally called Guls to different terraces using the natural gravitational flow of water. The state constructed canals operate on the same principle, except where new technologies such as electricity driven lift systems, pump sets and hydraulic rams have been installed. These however, are limited up to foot hills and valleys.

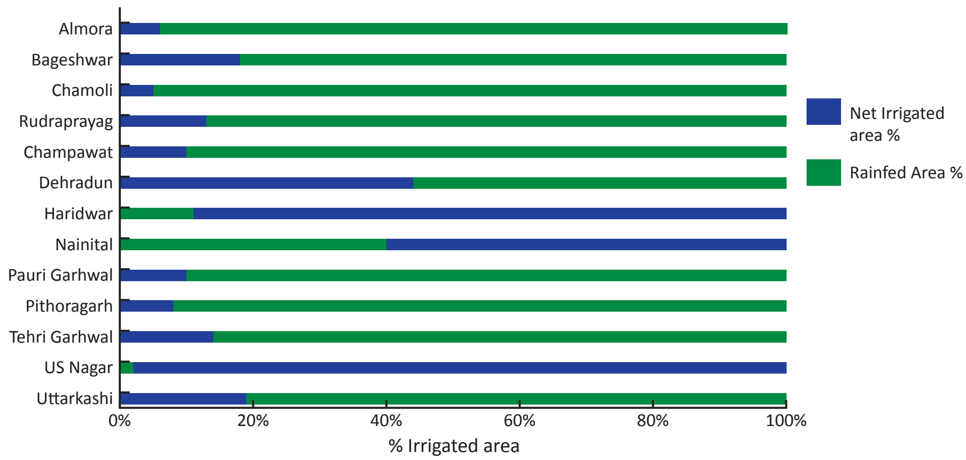


Fig-4.3.
Percent irrigated area (2008-09)[1]

The source wise irrigation pattern during the last decade portrays marked increase in uses of tubewells as well as other wells for irrigation purposes. Using canal network as source of irrigation has decreased drastically (Table 4.4, 4.5). The total irrigated area as stated earlier is on the rise and the main supply of the water is the wells.

Source wise irrigation facility in the form of tubewells is maximum being 50%. The canal and other irrigation sources utilizing surface water is nearly 23% of the total capacity (Fig. 4.4).

4.3.3. Crop Area Under Irrigation

Most of the land in Uttarakhand is rainfed. Consequently, the crops growing in this area are unirrigated. Besides this, the farmers are cultivating such crops for their sustenance only. It is basically the cash crops which are being grown in irrigated land. This is evident from the fact that the cash crops occupies more than 80% irrigated land. Sugarcane and Cotton have nearly 100% (Fig. 4.5) land under irrigation. The traditional crops like maize, barley, soybean, tuar/ arhar and coarse cereals are mostly rainfed.

Table-4.4.
Trend of different sources of irrigation[3]

In Thousands hectares								
	Gross area irrigated from Canals			Tanks	Wells		Other sources	Total irrigated area
					Tube-wells	Other wells		
	Govt	Pvt.	Total					
2000-01	168	5	174	3	272	30	59	537
2001-02	167	3	170	3	261	46	59	539
2002-03	161	7	168	3	248	61	51	532
2003-04	151	6	156	5	273	59	54	547
2004-05	170	6	175	3	263	52	57	549
2005-06	164	6	170	0	293	25	61	
2006-07	148	10	158	3	311	31	51	554
2007-08	139	42	181	1	216	98	58	554
2008-09	143	4	146	1	293	76	54	570
2009-10	123	5	128	0	283	104	52	567

Fig-4.4.
Percent usage of different sources of irrigation (2009-10)[3]

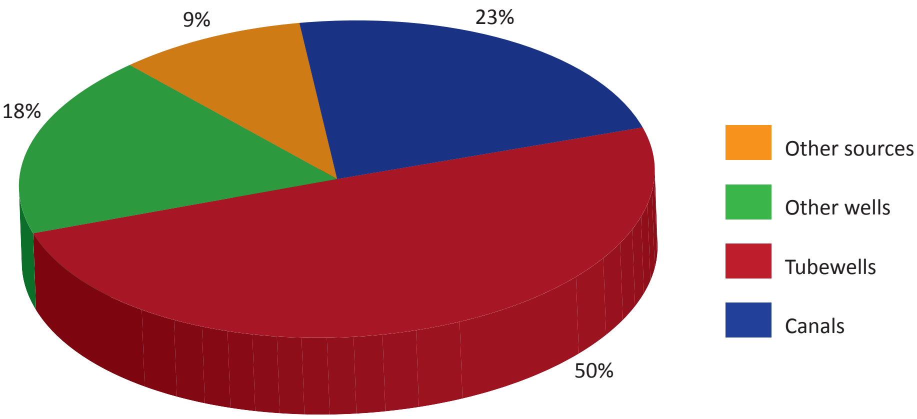
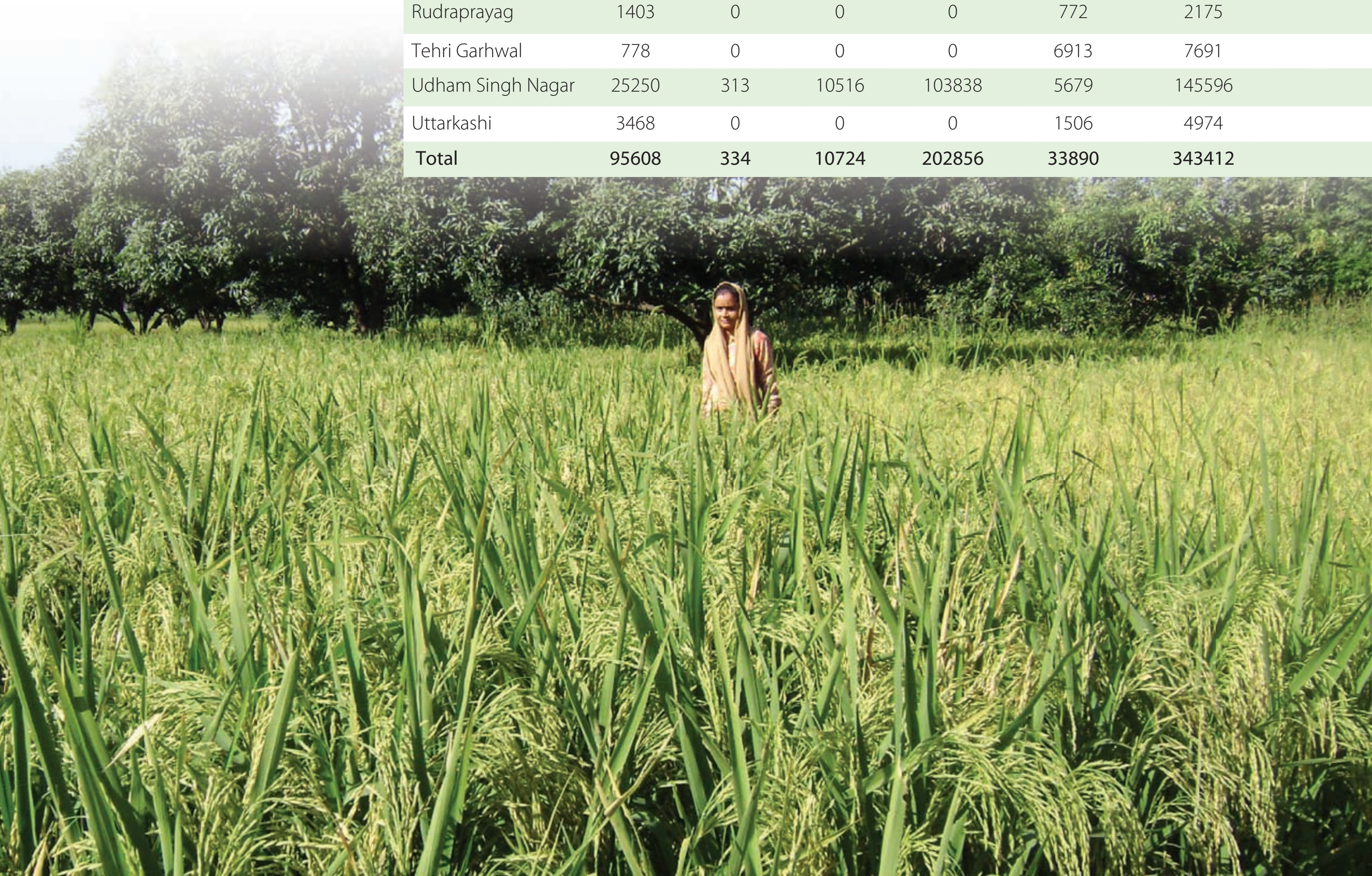


Table-4.5.
Source wise Area Irrigated (Area in Hectares)[1]

Districts	Canals (Area)	Tanks	Open wells	Tube/Bore wells	Other Sources	Total
Almora	3178	0	0	0	1840	5018
Bageshwar	4633	0	0	0	1176	5809
Chamoli	841	0	0	0	991	1832
Champawat	1325	0	0	655	197	2177
Dehradun	13997	0	72	3237	5181	22487
Haridwar	15080	0	136	90073	2064	107353
Nainital	21363	0	0	4577	152	26092
Pauri Garhwal	3037	21	0	476	4504	8038
Pithoragarh	1255	0	0	0	2915	4170
Rudraprayag	1403	0	0	0	772	2175
Tehri Garhwal	778	0	0	0	6913	7691
Udham Singh Nagar	25250	313	10516	103838	5679	145596
Uttarkashi	3468	0	0	0	1506	4974
Total	**95608**	**334**	**10724**	**202856**	**33890**	**343412**



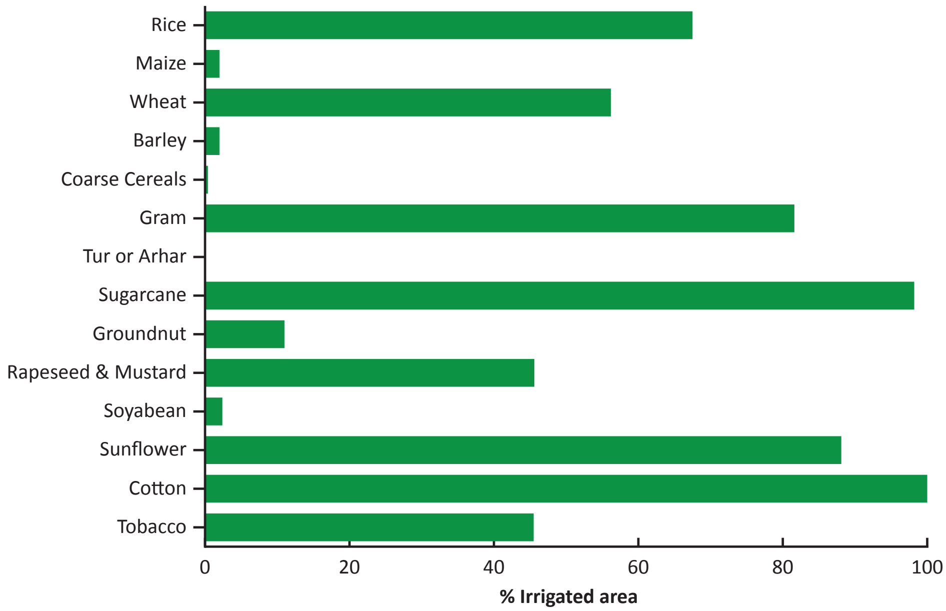


Fig-4.5.
Percentage area of crops under irrigation (2009-10)[4]

4.4. Major Crops

The state produces about 40 different crop species of cereals, pseudo cereals, millets, pulses, oilseeds etc. (Table 4.6) and many associated varieties are cultivated throughout the latitudinal gradient[5]. In the monsoon, typically farmers of the lower and middle Himalayas can harvest twelve crops, popularly known as *BaraNaza* (twelve grains) from tiny holdings. Generaly, in an average field, three or four subsidiary crops are raised with one main crop. It is still very common to see farmers cultivate Mandua (Finger millet), Gahat (Horse gram) Urd (Black gram), Soyabeans, Riains (Adjuki bean) and Sonta (Cow pea) in the same field. Kodo occupies the middle portion of the field and pulses are sown in the upper and lower portions, where soil is less fertile and prone to soil erosion. This practice is used traditionally to utilize the difference in the fertility of the soil for economic advantage and simultaneously conserve the soil. The traditional crops which are not so popular are: Chaulai (Amaranth), Ogal and Phapar (Buck wheat) and Cheena (Hog-millet). Besides being rich in protein content, they have good productivity on inferior soil and are more capable of withstanding the vagaries of nature. For instance, the average productivity of Chaulai is around 15 quintals/ha, Ogal 13.5 quintal/ha and Phapar 12.5 quintals. The main traditional pluses are Tor (*Pigeon pea*), Gahat (Horse gram), Urd (Black gram), Soyabeans, Riains (Adjuki bean), Sonta (Cow pea) and Rajma (Kidney beans)[6].

Food-crop statistics[2]

2009-10	Area (in million ha)	Production (in million tonnes)	Yield (in Kg/Ha)	Area under irrigation (%) 2008-09*
Foodgrains (% of all India)	1.009 (0.83 %)	1.796 (0.82 %)	1780	42.9
Coarse cereals (% of all India)	0.26 (0.93%)	0.30 (0.89 %)	1160	0.4
Sugarcane		5.84 (2.00 %)	0.10 (2.30%)	98.2

Table-4.6.
Edible plant species grown in Uttarakhand hills[7]

Crop Group	English/Common/Botanical names	No. of crops
Cereals and Pseudocereals	Barley (*Hordeum vulgare* Linn.), Maize (*Zea mays* Linn.), Rice (*Oryza sativa* Linn.), Wheat (*Triticum aestivum* Linn.), Amaranth/Chaulai (*Amarathus viridis* Linn.), Amaranth/Kedari chuwa (*Amaranthus caudatus* Linn.), Buckwheat (*Fagopyrum esculentum* Linn.) and Chenopodium (*Chenopodium album* Linn.)	08
Millets and minor millets	Barnyard millet (*Echinochloa crus-galli* Linn.), Finger millet (*Eleusine coracana* Linn.), Foxtail millet (*Setaria italica* Linn.), Proso millet (*Panicum miliaceum* Linn.), Kodo (*Paspalum serobiculatum* Linn.) and Sorghum (*Sorghum vulgare* Linn.)	06
Pulses	Pigeon pea (*Cajanus cajan* Linn.), Chickpea (*Cicer arietinum* Linn.), Soybean (*Glycine max* Linn.), Khesari (*Lathyrus sativus* Linn.), Lentil (*Lens culinaris* Medik.), Horsegram (*Macrotyloma uniflorum* Lam.), French bean (*Phaseolus vulgaris* Linn.), Scarlet bean (*Phaseolus coccineus* Linn.), Lima bean (*Phaseolus lunatus* Linn.), Garden pea or Pea (*Pisum sativum* Linn.), Adzuki bean (*Vigna angularis* Willd.), Green gram (*Vigna radiata* Linn.), Blackgram (*Vigna mungo* Linn.), Rice bean (*Vigna umbellata* Thunb.) and Cowpea (*Vigna unguiculata* Linn.)	15
Oilseeds	Yellow sarson /Indian mustard (*Brassica juncea* Linn. cv. yellow sarson), Brown sarson (*B. juncea* Linn. cv. brown sarson), Toria (*B. campestris* Linn.), Sunflower (*Helianthus annuus* Linn.), Linseed (*Linum usitatissimum* Linn.), Perilla (*Perilla frutescens* Linn.), Sesame (*Sesamum orientale* Linn.), Indian butter tree (*Aesandra butyracea* Roxb.), Litsea (*Litsea elongata* Nees.), Principea (*Prinsepia utilis* Royle) and Lepidium (*Lepidium sativum* Linn.)	11

4.4.1. Area, Production, Yield of Major Crops

Cereals, pulses, oilseeds form the major food crops of the state. Nearly 1.7% nation's foodgrains and coarse cereals are produced in the state. Major area is covered under cereals production which includes mainly rice, wheat, barley, maize, mandua etc. followed by pulses and oilseeds (Table 4.7 & 4.8). All of them are grown, both during Kharif and Rabi season. On an average, 63% of land under cereals and 77.5% land under pulses is rainfed.

The time series pattern of the area under various foodcrops in the state depicts that it is decreasing at a faster rate (Table 4.9). The decline can be linked to the increase in fallow land and even loss of interest in cultivation. The area under cereals & millets has decreased significantly as compared to pulses or other cash crops like sugarcane and condiments. A noticeable fact is that production of pulses and oilseeds is nearly insignificant as compared to other crops in the state.

Table-4.7.
Major crops of Uttarakhand[8]

	Crops	Area Under Principal Crops (Provisional) 2009-10 in Hectares	Agriculture Productivity (Provisional) in qtl/ha
1	**Cereals**	**944982**	**18.73**
	Rice	294223	20.85
	Wheat	394633	21.42
	Barley	23739	11.15
	Maize	27960	13.61
	Mandua	131795	12.36
	Sanwan	63636	10.55
	Other	8996	
2	**Pulses**	**56895**	**7.43**
	Urad	12707	7.58
	Masoor	12500	5.75
	Peas (Mattar)	5568	9.79
	Gahat (Kulthi)	11032	6.19
	Rajma	4767	9.9
	Gram	663	6.68
	Bhatt (Black Soyabean)	5559	8.94
	Other pulses	4099	
3	**Oil Seeds**	**29785**	**10.81**
	Rape and Mustard	14847	8.17
	Seasmum (Til)	2445	2.05
	Groundnut	1340	14.31
	Soyabean	11153	15.82
4	**Other Crops**		
	Sugarcane	96072	526.87
	Onion	2317	38.58

4.4.2. Non Food Crops

Over the years, the area under all the non-food crops has decreased. Similar is the case with the fodder crops as well as the green manure crops (Fig. 4.6).

The irrigated area under non-food crops is quite miniscule. It is evident from Table 4.10 that farmers have increased the irrigated area (thousand ha) under fodder cropping over the past decade.

4.4.3. High Yielding Varieties

The High Yielding Varieties (HYV) of different crops being used in Uttarakhand are mostly of rice and wheat. As per Directorate of Agriculture, Dehradun in the year 2009-10 (Table 4.11), 2730.08 quintals seeds of HYV of paddy was distributed to farmers which means that 6825.2 ha of land was sowed with HYV. Similarly in wheat 26455.75 HYV seeds were distributed.

Table-4.8.
Area, Production and Yield of Major Crops in Irrigated / Rainfed Conditions during Kharif & Rabi Season[4]

Crops	Area (ha.)					Production (q)					Yield (q/ha.)		
	Irrigated	%	Rainfed	%	Total	Irrigated	%	Rainfed	%	Total	Irrigated	Rainfed	Average
Kharif Season													
Cereals	172381	34%	334622	66%	507003	3689560	43%	4920250	57%	8609810	21.40	14.70	16.98
Pulses	1560	4%	37604	96%	39164	10390	3%	334120	97%	344510	6.66	8.89	8.80
Oilseeds	6812	40%	10033	60%	16845	106000	53%	93720	47%	199720	15.56	9.34	11.86
Others	821	25%	2449	75%	3270	6660	40%	9980	60%	16640	8.11	4.08	5.09
Total	181574	32%	384708	68%	566282	3812610	42%	5358070	58%	9170680	21.00	13.93	16.19
Rabi Season													
Crops	Area (ha.)					Production (q)					Yield (q/ha.)		
	Irrigated	%	Rainfed	%	Total	Irrigated	%	Rainfed	%	Total	Irrigated	Rainfed	Average
Cereals	170194	40%	251252	60%	421446	5583470	66%	2819540	34%	8403010	32.81	11.22	19.94
Pulses	9197	41%	13410	59%	22607	91810	62%	56060	38%	147870	9.98	4.18	6.54
Oilseeds	6929	48%	7444	52%	14373	61190	69%	27610	31%	88800	8.83	3.71	6.18
Others	12986	100%	0	0%	12986	429900	100%	0	0%	429900	33.10	0.00	33.10
Total	199306	42%	272106	58%	471412	6166370	68%	2903210	32%	9069580	30.94	10.67	19.24

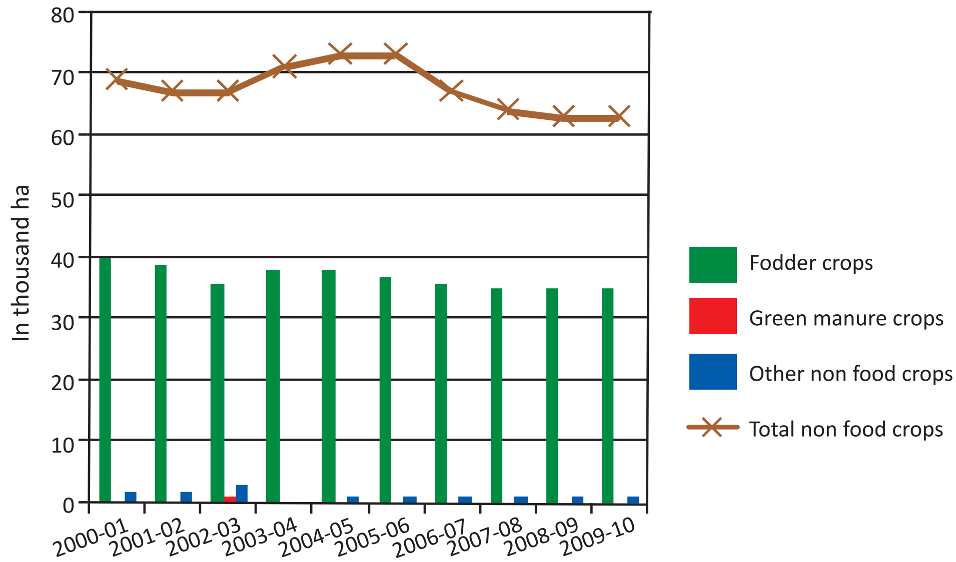


Fig-4.6.
Area under Non food crops[3]

Table-4.9.
Area of major food crops[3]

	Total Cereals & Millets	Total Pulses	Total Foodgrains	Sugarcane	Total condiments	Total oilseeds
	Area in Thousand hectares					
2000-01	933	54	987	116	8	25
2001-02	931	52	983	119	8	25
2002-03	914	50	964	122	8	28
2003-04	924	51	975	117	9	30
2004-05	937	59	996	106	9	32
2005-06	919	52	970	108	9	34
2006-07	912	53	965	119	9	28
2007-08	891	51	943	123	9	27
2008-09	914	51	965	108	9	25
2009-10	890	51	941	100	9	26

Table-4.10.
Non food crops Irrigated area (in'000 ha)[3]

	Fodder crops	Other non food crops	Total non food crops	Total irrigated area under all crops
2000-01	21	1	29	537
2001-02	20	1	28	539
2002-03	19	2	27	532
2003-04	21	1	29	547
2004-05	22	1	32	549
2005-06	22	1	31	549
2006-07	22	1	30	554
2007-08	21	1	29	554
2008-09	22	1	30	570
2009-10	22	1	31	567

Table-4.11.
High Yielding Varieties (2009-2010)[4]

	HYV of Kharif (in numbers)							HYV of Rabi (in numbers)			
Districts	Paddy	Maize	Mandua	Ram-dana	Urd	Arhar	Soyabean	Wheat	Gram	Masoor	Mustrad/ tuaria
Almora	2		2	2	2	1	2	13	2	2	2
Bageshwar	7	2	2	2	2	1	3	10	2	2	1
Chamoli	3	1	2	2	1	1	1	9	0	2	1
Champawat	8	1	0	2	3	1	2	13	1	2	1
Dehradun	11	1	0	1	3	1	2	18	2	2	1
Haridwar	6	0	0	0	3	1	0	11	2	2	1
Nainital	14		2	2	3	2	5	18	2	2	1
Pauri Garhwal	5	1	2	0	3	1	3	11	2	2	1
Pithoragarh	6	2	0	2	3	1	3	16	2	2	1
Rudraprayag	4	2	1	2	2	1	3	9	0	2	1
Tehri Garhwal	8	1	2	2	2	1	1	13	2	2	1
Udham Singh Nagar	3		0	0	3	0	1	9	1	2	2
Uttarkashi	6	2	1	2	1	1	2	9	1	2	1
Total Varieties	18	3	3	2	4	2	6	26	2	3	4
Total quantity in quintals	2730.08	54.85	41.90	19.36	1011.45	507.81	534.15	26455.75	135.15	1640.62	103.62
Total area in Ha	**6825.2**	**274.25**	**419**	**1290.67**	**5057.25**	**2539.05**	**NA**	**NA**	**168.94**	**4101.55**	**2072.4**

Rice status[9]

2009-10	Rice Facts
Rice growing area	2.8 lakh hectares
Production	5.7 lakh quintals (Production in Plains is $2^1/_2$ times the production in hills)
Productivity of hills	12.55 q/ha
Productivity of plains	27.55 q/ha
Productivity in hill district Highest Lowest	 Tehri Garhwal 1.6 t/ha Almora and Pauri Garhwal 1t/ha
Two Rice Ecosystems	Irrigated- US Nagar, Haridwar, Nainital & Dehradun Rainfed- rest nine districts
Major diseases	Disease: Blast, Brown spot, Sheath rot, Sheath blight, Bacterial blight, Deficiency: *Khaira (Zn)* Insects : Hopper, Stem borer, Hispa, Leaf folder, Kurmula
Causal organisms	*Magnaporthe grisea (Pyricularia grisea), Helminthosporium oryzae, Rhyncosporium oryzae, Sarocladium oryzae, Rhizoctonia solani, Ustilaginoidea virens, Xanthomonas oryzae pv oryzae.* Insects : *Sesamia inferens, Scirpophaga incertulas, Cnaphalocrocis medinalis, Sogatella furcifera, Dolycoris indicus, Anomala dimidiata, Holotrichia seticollis and H. longipennis*
Organic basmati (2007-08)	Area-1829 ha, Productivity – 20q/ha, Export 1000-1500 tonnes (estimated)
Basmati varieties	Type 3, Basmati 370, Pusa basmati-1, Kashuri, Pusa 1121, Taraori basmati, Pant Sugandha Dhan 15, Pant Sugandha Dhan 17
Local germplasm	Dehradun basmati, Tapovan basmati, Hansraj, Tilakchandan, Bindli, Thapachi, Jolia, Bamni China 4, Kashmiri, Kaladhan, Nabba Dhan, Dudhia, Kasturi, Naaj

4.5. Horticulture

Horticulture is one of the critical sectors in the economy of the hilly State of Uttarakhand. Horticulture provides the much needed opportunity, for diversification in agriculture especially in the context of peculiar topography and agro-climatic conditions of the hill states where the scope for production of conventional field crops is limited. Horticulture development is an effective tool for accelerating development in hill areas due to limited land available for cultivation, availability of cultivable waste lands and necessity of supplementary job and income opportunities.

4.5.1. Major Fruits and Vegetables

Various topographic and agro-climatic conditions are congenial for different kind of fruits cultivation at different altitudes. For example apples, peaches, plums, apricots, walnuts, pecans, cherry are grown successfully between altitudes of 2000 – 3000 meters, almonds, kiwis etc, at 1000 – 2000 meters (Table 4.12). In areas below 1000 meters and in fields of Terai and Bhabar, mango, litchis, jackfruits, aonla, and papaya can be easily grown. A total of 19 different type of fruits and 28 vegetables are grown in the state excluding the wild varieties (refer bio-diversity chapter).

Chilli[10]

Botanical name	*Capsicum fruitescens* L
Family	Solanaceae
Nutritional value	Vit A & C
Local Chilli Varieties	Lakhori, Dada, Jamari, Talwari, Janjeeri, Hansraj, Kujni march, Janpuri march, Saknyard march
Recommended varieties	Pant C-1, Pant C-2, Pusa sadabhahar
Production area	All 13 districts
Leading hill district in production	Almora
Leading plain district in production	US Nagar
Production (2008-09)	7270 tonne
Area (2008-09)	1928 ha

Amaranth (Chaulai, marsa, chaua)[11]

Varieties	*A.Hypochondriacus L., A. caudatus L. , A. cruentus, A. hybridus, A. spinosus, A. viridis* (ornamental)
Nutritional value	Protein, Iron, Folic acid, Vit A, Vit C
Native cultvars (on the basis of colour)	White, Red, Black
A.hypochondriacus	Major grain spp., High yielding cultivars (Rudraprayag & Chamoli), Distribution: from valleys to higher hills
Distribution of *A. Caudatus*	Confined to high hills
Distribution of *A. cruentus, A. hybridus*	Middle hills
Distribution of *A. spinosus*	Lower hills
Major distribution	Chamoli, Uttarkashi, Rudraprayag, Tehri, Almora, Pauri and Bageshwar
Major pest & disease	Amaranth leaf webber, banded leaf blight
Area (2008-09)	5638 Ha
Production (2008-09)	2779 (MT)

Table-4.12.
Major fruits and vegetables of Uttarakhand[7]

Core group	English/Common/Botanical names	
Fruits	Papaya (*Carica papaya* Linn.), Orange [*Citrus sinensis* (Linn.) Osbeck], Lemon [*Citrus limon* (Linn.) Burm. f.], Masumba [*Citrus sinensis* (Linn.) Osbeck], Kaku (*Diospyrus kaki* Linn.), Loquat [*Eriobotrya japonica* (Thunb.)Lindl.], Walnut (*Juglans regia* Linn.), Chestnut (*Castanea sativa* P. Mill.), Mango (*Mangifera indica* Linn.), Apple (*Malus domestica* Borkh.), Pear (*Pyrus communis* Linn.), Peach [*Prunus persica* (Linn.) Batsch.], Apricot (*Prunus armeniaca* Linn.), Mulberry (*Morus serrata* Linn.), Banana (*Musa bauensis* Hakkinen & Meekion), Guava (*Psidium guajava* Linn.), Pomegranate (*Punica granatum* Linn.), Grape (*Vitis vinifera* Linn.) and Ber (*Ziziphus mauritiana* Lam.)	19
Vegetables	Okra (*Abelmoschus esculentus* Linn.), Elephant foot yam (*Amorphophallus campanulatus* Blume ex Decne.), Jack fruit (*Artocarpus heterophyllus* Lam.), Waxgourd (*Benincasa hispida* Thunb.), Spinach (*Spinacea oleracea* Linn.), Cabbage (*Brassica oleracea* var. *capitata* Linn.), Elephant ear yam (*Colocasia esculenta* Linn.), Cucumber (*Cucumis sativus* Linn.), Pumpkin (*Cucurbita moschata* Duch. ex Poir.), Meetha karela (*Cyclanthera pedata* Linn.), White yam (*Dioscorea rotunda* Poir.), Tarur (*Dioscorea belophylla* Prain and *D. deltoidea* Wall.), Lablab bean (*Lablab purpureus* Linn.), Bottle gourd (*Lagenaria siceraria* Molina), Ridge gourd [*Luffa acutangula* (Linn.) Roxb.], Sponge gourd (*Luffa cylindrica* Linn.), Snake gourd (*Trichosanthes anguina* Linn.), Bitter gourd (*Momordica charantia* Linn.), Tomato (*Lycopersicon esculentum* Miller), Radish (*Raphanus sativus* Linn.), Chow-chow (*Sechium edule* Jacquin), Brinjal (*Solanum melongena* Linn.), Potato (*Solanum tuberosum* Linn.), Broad bean (*Vicia faba* Linn.), Lai [*Brassica juncea* var. *rugosa* (Roxb.) Prain], Turnip (*Brassica rapa* Linn.), Carrot (*Daucus carota* Linn.) and Bell pepper (*Capsicum annuum* var. *aviculare* Dierb.)	28
Spices and Condiments	Wild *Allium* spp., Onion (*Allium cepa* Linn.), Garlic (*Allium sativum* Linn.), Cleome (*Cleome viscosa* Linn.), Dalchini (*Cinnamomum tamala* Buch-Ham), Coriander (*Coriandrum sativum* Linn.), Turmeric (*Curcuma longa* Linn.), Fenugreek (*Trigonella foenum-graecum* Linn.), Ginger (*Zinziber officinale* Rosc.), Hemp (*Cannabis sativa* Linn.)	10

4.5.2. Area, Production and Productivity

As per the latest statistics of National Horticulture Board, in the year 2010-11 of the total horticultural crops, 66% (179.3 thousand ha) area is under fruits while 31% (85.8 thousand ha) is under vegetables in Uttarakhand. The area under spices (6.7 thousand ha) and flowers (1.3 thousand ha) is quite miniscule as compared to other horticulture plants (Fig. 4.7).

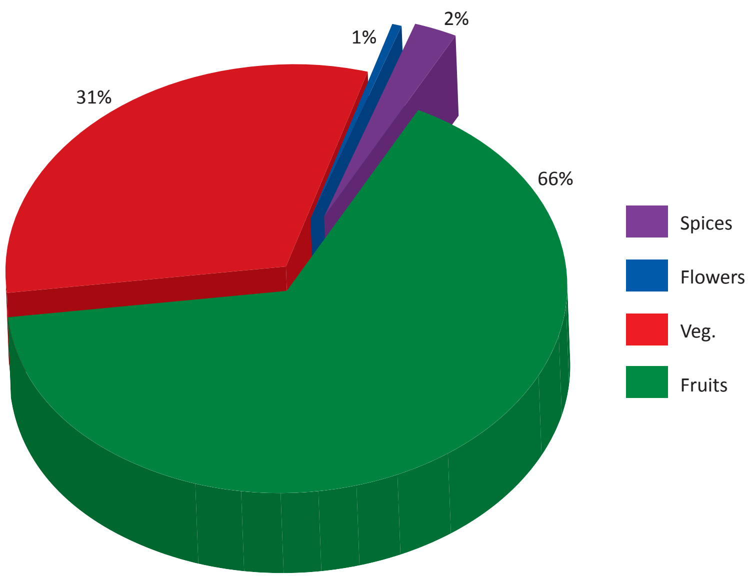


Fig-4.7.
Percent area of horticultural crops in 2010-11[12]

However, the area and production of fruit and vegetable crops in the state during 2008-09 was 190686 ha & 7.3 lacs MT and 56209 ha & 5.6 lacs MT (Table 4.13) which in 2009-10 has risen to 193787 ha & 7.2 MT and 58451 ha & 5.6 MT, respectively. The area and production of spices is 0.066 lacs ha and 0.499 lacs MT, respectively[4]. The maximum area of fruit crops is occupied by mango followed by apple, but the productivity of all these crops has been lower than the national average. The low productivity in apple is basically due to increase in non/low productive areas as a result of adverse climatic changes and also inadequate provision of pollinisers. The Citrus fruits occupy third position in terms of area but ranks first in production. The major citrus fruits available in the State are Malta, Santra, Lime, Galgal etc. This group of fruits has lot of importance for the State on account of quantity of production, longer availability and shelf life and amenability for processing. However, the data on different Citrus species is not available, which is required in order to evolve strategies for further development of these species.

Among the fruits, mango, apple, citrus, litchi and guava form the major share of the State. Mango groves cover over 39 thousand ha, hogging 35% of the total fruit share. Apple trails behind with 33 thousand ha (30%) followed by Citrus growing in 27.4 thousand ha (25%) (Fig. 4.8)

The analysis of area under mango production shows a marginal increase (2000 ha) within the last decade. However, area under apple has remained nearly stationary (Fig. 4.9).

On the other hand the high remunerating crops like vegetables have garnered support from the cultivators of the State. The area under the vegetables has increased drastically i.e. nearly doubled within the last decade. Potato also finds large patronage as the area is substantially seeing an increasing trend (Table 4.14). The diverse agro-climatic condition of the State gives it a unique advantage as well as a competitive edge over other States in production of vegetables (offseason vegetables in context of plains) that fetch high value in the market.

The major vegetables grown in the State are brinjal, cabbage, cauliflower, okra, onion, peas, potato and tomato. The potato constitute a major share among the vegetable and the area under potato cultivation has shown an increase during the last decade. The area of these vegetables is given in Fig 4.10.

Fig-4.8.
Percent Area covered by major fruit crops 2010-11[12]

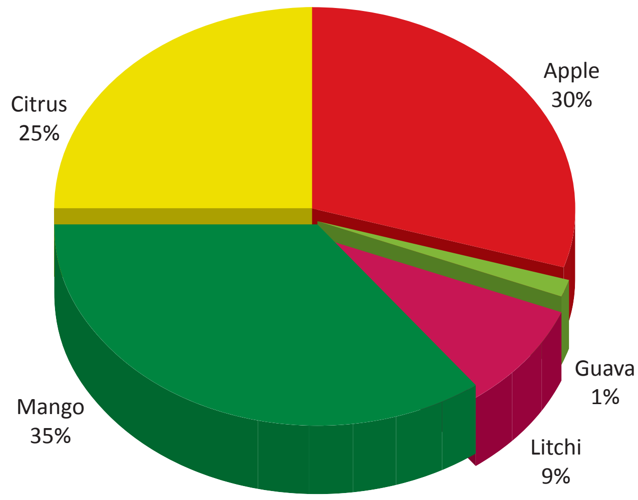


Table-4.13.
Area, Production and Yield of Major Horticulture Crops (2010-11)[13]

Sl. No.	Component	Champawat			Dehradun			Pauri			Tehri			Chamoli		
		Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	1 – Fruits															
a)	Apple	581.00	614.00	1.06	4710.00	12619.00	2.68	1016.00	2684.00	2.64	3427.00	2742.00	0.80	4073.00	23406.00	5.75
b)	Pear	862.00	2605.00	3.02	1335.00	5036.00	3.77	1177.00	3095.00	2.63	1761.00	4579.00	2.60	893.00	7635.00	8.55
c)	Peach	673.00	924.00	1.37	474.00	1980.00	4.18	864.00	739.00	0.86	148.00	780.00	5.27	834.00	5774.00	6.92
d)	Plum	871.00	790.00	0.91	958.00	2969.00	3.10	930.00	1375.00	1.48	1127.00	2930.00	2.60	296.00	2282.00	7.71
e)	Apricot	617.00	585.00	0.95	1124.00	3027.00	2.69	1151.00	1383.00	1.20	1460.00	1275.00	0.87	414.00	2885.00	6.97
f)	Walnut	778.00	124.00	0.16	2683.00	3005.00	1.12	2363.00	1245.00	0.53	4688.00	1125.00	0.24	1049.00	5287.00	5.04
g)	Citrus varieties	2208.00	3490.00	1.58	2480.00	7377.00	2.97	2321.00	5132.00	2.21	1486.00	3091.00	2.08	5627.00	42118.00	7.48
h)	Mango	2138.00	2541.00	1.19	5944.00	17681.00	2.97	2967.00	5455.00	1.84	3237.00	7736.00	2.39	1122.00	5418.00	4.83
i)	Litchi	495.00	601.00	1.21	3723.00	8413.00	2.26	167.00	241.00	1.44	30.00	9.00	0.30			0.00
j)	Anola	5.00	2.00	0.40	130.00	287.00	2.21				35.00	140.00	4.00			
k)	Guava	39.00	47.00	1.21	143.00	485.00	3.39				69.00	276.00	4.00			
l)	Other Fruits	1800.00	3639.00	2.02	1898.00	3687.00	1.94	7203.00	7313.00	1.02	2660.00	1463.00	0.55	658.00	4990.00	7.58
	2 – Vegetables															
a)	Pea	515.00	1230.00	2.39	1567.00	21198.00	13.53	319.00	2852.00	8.94	1940.00	17460.00	9.00	375.00	2956.00	7.88
b)	Radish	250.00	2193.00	8.77	276.00	3225.00	11.68	580.00	2948.00	5.08	381.00	1894.00	4.97	320.00	3481.00	10.88
c)	French Bean	500.00	1050.00	2.10	962.00	5751.00	5.98	575.00	3449.00	6.00	596.00	4800.00	8.05	261.00	1562.00	5.98
d)	Cabbage	495.00	2060.00	4.16	583.00	6791.00	11.65	340.00	1875.00	5.51	608.00	6013.00	9.89	366.00	3663.00	10.01
e)	Cauliflower	53.00	395.00	7.45	782.00	14636.00	18.72	150.00	502.00	3.35	71.00	216.00	3.04	215.00	2095.00	9.74
f)	Onion	95.00	790.00	8.32	425.00	4870.00	11.46	620.00	4634.00	7.47	740.00	6704.00	9.06	333.00	2626.00	7.89

Sl. No.	Component	Champawat			Dehradun			Pauri			Tehri			Chamoli		
		Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
g)	Capsicum	280.00	365.00	1.30	77.00	667.00	8.66	201.00	699.00	3.48	254.00	1143.00	4.50	103.00	513.00	4.98
h)	Okra	167.00	800.00	4.79	754.00	5352.00	7.10	210.00	831.00	3.96	256.00	1275.00	4.98	166.00	834.00	5.02
i)	Tomato	759.00	3430.00	4.52	1061.00	18327.00	17.27	774.00	3533.00	4.56	620.00	3098.00	5.00	299.00	3566.00	11.93
j)	Brinjal	155.00	1150.00	7.42	365.00	4733.00	12.97	171.00	754.00	4.41	95.00	413.00	4.35	206.00	2418.00	11.74
k)	Other Vegetables	438.00	2373.00	5.42	2252.00	21543.00	9.57	1389.00	5218.00	3.76	1483.00	15185.00	10.24	245.00	1930.00	7.88
	3 – Spices															
a)	Turmeric	44.00	264.00	6.00	73.00	601.00	8.23	65.00	390.00	6.00	55.00	329.00	5.98	104.00	1038.00	9.98
b)	Chilli	110.00	220.00	2.00	142.00	364.00	2.56	146.00	253.00	1.73	135.00	250.00	1.85	103.00	155.00	1.50
c)	Coriander	55.00	131.00	2.38	128.00	492.00	3.84	128.00	441.00	3.45	16.00	32.00	2.00	85.00	174.00	2.05
d)	Garlic	94.00	748.00	7.96	121.00	1210.00	10.00	92.00	274.00	2.98	135.00	463.00	3.43	134.00	939.00	7.01
e)	Ginger	375.00	3815.00	10.17	421.00	4884.00	11.60	193.00	1098.00	5.69	1587.00	11707.00	7.38	204.00	2221.00	10.89
f)	Other Spices	25.00	125.00	5.00			0.00	58.00	139.00	2.40			0.00	29.00	36.00	1.24
	4 – Flowers									**0.00**						
a)	Gerbera			0.00	20.00	1300.00	65.00						0.00			
b)	Rose			0.00	6.50	3.60	0.55	9.50	8.60	0.91			0.00	60.00	64.10	1.07
c)	Gladiolus	7.00	11.40	1.63	50.00	62.00	1.24	6.50	9.98	1.54				7.20	13.00	1.81
d)	Marigold	1.08	1.30	1.20	62.00	60.00	0.97	18.50	49.00	2.65	8.00	64.00	8.00	13.10	14.55	1.11
e)	Carnation			0.00	4.50	93.00	20.67	0.50	0.06	0.00						0.00
f)	Others Flowers	1.10	1.27	1.15	24.00	17.00	0.71	2.00	1.10	0.55				19.50	20.90	1.07

Sl. No.	Component	Nainital			Udham Singh Nagar			Almora			Bageshwar			Phithoragarh		
		Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	1 – Fruits															
a)	Apple	7806.00	30443.00	3.90			0.00	1570.00	14147.00	9.01	166.00	182.00	1.10	1594.00	3250.00	2.04
b)	Pear	1912.00	20283.00	10.61	81.00	706.00	8.72	3312.00	35043.00	10.58	585.00	5030.00	8.60	1241.00	12500.00	10.07
c)	Peach	2536.00	11919.00	4.70			0.00	1636.00	20508.00	12.54	164.00	445.00	2.71	991.00	3200.00	3.23
d)	Plum	963.00	4333.00	4.50			0.00	2581.00	20538.00	7.96	105.00	168.00	1.60	915.00	1515.00	1.66
e)	Apricot	831.00	2533.00	3.05			0.00	2288.00	17891.00	7.82	182.00	44.00	0.24	752.00	1090.00	1.45
f)	Walnut	1210.00	588.00	0.49			0.00	2825.00	8450.00	2.99	383.00	184.00	0.48	1886.00	605.00	0.32
g)	Citrus varieties	2294.00	7799.00	3.40	167.00	1348.00	8.07	4306.00	33389.00	7.75	845.00	3780.00	4.47	3335.00	18900.00	5.67
h)	Mango	6075.00	18835.00	3.10	3688.00	24720.00	6.70	4608.00	23381.00	5.07	540.00	2035.00	3.77	2863.00	2815.00	0.98
i)	Litchi	1181.00	3153.00	2.67	1354.00	1682.00	1.24	279.00	70.00	0.25	10.00	14.00	0.00	817.00	560.00	0.69
j)	Anola	53.00	2.00	0.04	31.00	3.00	0.10							145.00	219.00	1.51
k)	Guava	30.00	7.00	0.23	985.00	7763.00	7.88	34.00	102.00	3.00				165.00	246.00	1.49
l)	Other Fruits	563.00	2319.00	4.12	379.00	3228.00	8.52	579.00	1582.00	2.73	560.00	3585.00	6.40	1235.00	1815.00	1.47
	2 – Vegetables															
a)	Pea	1936.00	10938.00	5.65	2201.00	14865.00	6.75	612.00	3413.00	5.58	86.00	728.00	8.47	160.00	1140.00	7.13
b)	Radish	320.00	6557.00	20.49	194.00	3367.00	17.36	804.00	15657.00	19.47	261.00	2395.00	9.18	790.00	9500.00	12.03
c)	French Bean	320.00	2955.00	9.23	53.00	339.00	6.40	572.00	4488.00	7.85	125.00	560.00	4.48	850.00	9800.00	11.53
d)	Cabbage	970.00	15535.00	16.02	375.00	6409.00	17.09	237.00	3582.00	15.11	108.00	1040.00	9.63	680.00	9600.00	14.12
e)	Cauliflower	216.00	1298.00	6.01	267.00	4786.00	17.93	230.00	2307.00	10.03	56.00	485.00	8.66	71.00	800.00	11.27
f)	Onion	157.00	1021.00	6.50	320.00	3500.00	10.94	238.00	1548.00	6.50	120.00	1490.00	12.42	405.00	4620.00	11.41
g)	Capsicum	233.00	1101.00	4.73	171.00	664.00	3.88	407.00	1200.00	2.95	51.00	195.00	3.82	370.00	4400.00	11.89
h)	Okra	252.00	2633.00	10.45	481.00	4926.00	10.24	154.00	1369.00	8.89	46.00	480.00	10.43	400.00	4800.00	12.00
i)	Tomato	2022.00	21249.00	10.51	894.00	13589.00	15.20	282.00	4900.00	17.38	66.00	425.00	6.44	850.00	9800.00	11.53
j)	Brinjal	209.00	2720.00	13.01	364.00	5625.00	15.45	10.00	927.00	92.70	47.00	387.00	8.23	170.00	2940.00	17.29
k)	Other Vegetables	2048.00	16704.00	8.16	785.00	7102.00	9.05	585.00	3615.00	6.18	485.00	3355.00	6.92	550.00	14000.00	25.45
	3 – Spices															
a)	Turmeric	26.00	255.00	9.81	36.00	350.00	9.72	104.00	757.00	7.28	115.00	755.00	6.57	45.00	778.00	17.29
b)	Chilli	148.00	802.00	5.42	170.00	1302.00	7.66	403.00	1060.00	2.63	54.00	75.00	1.39	58.00	67.00	1.16
c)	Coriander	67.00	167.00	2.49	247.00	979.00	3.96	184.00	848.00	4.61	78.00	148.00	1.90	156.00	755.00	4.84
d)	Garlic	50.00	500.00	10.00	148.00	1223.00	8.26	159.00	968.00	6.09	82.00	295.00	3.60	43.00	215.00	5.00
e)	Ginger	168.00	2594.00	15.44	232.00	3053.00	13.16	270.00	5100.00	18.89	128.00	1110.00	8.67	125.00	2300.00	18.40
f)	Other Spices	22.00	97.00	4.41	17.00	98.00	5.76	30.00	106.00	3.53	40.00	285.00	0.00	38.00	190.00	5.00
	4 – Flowers															0.00
a)	Gerbera	32.17	928.04	28.85	23.20	1252.26	53.98						0.00			0.00
b)	Rose	7.02	7.47	1.06	2.00	1.40	0.70	4.50	4.50	1.00			0.00			0.00
c)	Gladiolus	43.09	80.96	1.88	176.50	326.64	1.85	9.50	21.50	2.26	3.00	5.60	1.87	1.25	2.25	1.80
d)	Marigold	4.61	6.63	1.44	8.00	10.40	1.30	1.10	1.10	1.00	10.00	15.00	1.50	1.15	1.56	1.36
e)	Carnation	9.58	239.55	25.01	10.00	102.32	10.23	0.70	20.00	28.57			0.00			0.00
f)	Others Flowers	4.14	3.41	0.82	7.50	7.40	0.99	0.06	0.10	0.00	6.00	9.00	1.50	1.80	3.80	2.11

Sl. No.	Component	Rudraprayag			Uttarkashi			Haridwar			Total		
		Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity
1	2	3	4	5	6	7	8	9	10	11	12	13	14
	1 – Fruits												
a)	Apple	366.00	604.00	1.65	7714.00	45203.00	5.86			0.00	33023.00	135894.00	36.48
b)	Pear	185.00	524.00	2.83	1457.00	10075.00	6.91	115.00	1471.00	12.79	14916.00	108582.00	91.69
c)	Peach	159.00	282.00	1.77	222.00	1298.00	5.85	142.00	681.00	4.80	8843.00	48530.00	54.19
d)	Plum	120.00	275.00	2.29	715.00	3980.00	5.57			0.00	9581.00	41155.00	39.36
e)	Apricot	44.00	119.00	2.70	145.00	1232.00	8.50			0.00	9008.00	32064.00	36.44
f)	Walnut	242.00	85.00	0.35	1376.00	1008.00	0.73			0.00	19483.00	21706.00	12.45
g)	Citrus varieties	704.00	1657.00	2.35	288.00	948.00	3.29	1339.00	5434.00	4.06	27400.00	134463.00	55.40
h)	Mango	380.00	359.00	0.94	212.00	520.00	2.45	5220.00	23824.00	4.56	38994.00	135320.00	40.81
i)	Litchi	26.00	5.00	0.19				1503.00	3984.00	2.65	9585.00	18732.00	12.91
j)	Anola										399.00	653.00	8.25
k)	Guava										1465.00	8926.00	21.20
l)	Other Fruits	600.00	1632.00	2.72	1272.00	2570.00	2.02	6049.00	68229.00	11.28	25456.00	106052.00	52.37
	2 – Vegetables												
a)	Pea	168.00	362.00	2.15	947.00	5573.00	5.88	361.00	4222.00	11.70	11187.00	86937.00	95.04
b)	Radish	74.00	601.00	8.12	223.00	2766.00	12.40	141.00	2347.00	16.65	4614.00	56931.00	157.08
c)	French Bean	74.00	357.00	4.82	178.00	1362.00	7.65	110.00	1639.00	14.90	5176.00	38112.00	94.98
d)	Cabbage	107.00	903.00	8.44	170.00	2557.00	15.04	570.00	10433.00	18.30	5609.00	70461.00	154.97
e)	Cauliflower	25.00	91.00	3.64	30.00	329.00	10.97	384.00	6026.00	15.69	2550.00	33966.00	126.49
f)	Onion	56.00	333.00	5.95	35.00	629.00	17.97	235.00	5228.00	22.25	3779.00	37993.00	138.13

Sl. No.	Component	Rudraprayag			Uttarkashi			Haridwar			Total		
		Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity	Area (ha)	Production (MT)	Productivity
1	2	3	4	5	6	7	8	9	10	11	12	13	14
g)	Capsicum	16.00	35.00	2.19	35.00	318.00	9.09	121.00	1439.00	11.89	2319.00	12739.00	73.36
h)	Okra	58.00	177.00	3.05	124.00	923.00	7.44	183.00	2685.00	14.67	3251.00	27085.00	103.03
i)	Tomato	87.00	525.00	6.03	378.00	5293.00	14.00	691.00	9342.00	13.52	8783.00	97077.00	137.89
j)	Brinjal	37.00	199.00	5.38	33.00	301.00	9.12	276.00	3303.00	11.97	2138.00	25870.00	214.04
k)	Other Vegetables	216.00	1113.00	5.15	905.00	18544.00	20.49	605.00	8655.00	14.31	11986.00	119337.00	132.56
	3 – Spices												
a)	Turmeric	38.00	183.00	4.82	34.00	400.00	11.76	59.00	551.00	9.34	798.00	6651.00	112.78
b)	Chilli	190.00	206.00	1.08	212.00	772.00	3.64	221.00	2100.00	9.50	2092.00	7626.00	42.13
c)	Coriander	27.00	32.00	1.19	161.00	1635.00	10.16	144.00	1314.00	9.13	1476.00	7148.00	51.99
d)	Garlic	63.00	164.00	2.60	35.00	280.00	8.00	111.00	1178.00	10.61	1267.00	8457.00	85.54
e)	Ginger	161.00	1266.00	7.86	42.00	421.00	10.02	247.00	2375.00	9.62	4153.00	41944.00	147.79
f)	Other Spices	9.00	11.00	1.22				53.00	188.00	3.55	321.00	1275.00	32.11
	4 – Flowers												
a)	Gerbera										75.37	3480.30	147.82
b)	Rose	3.50	3.80	1.09	1.82	3.00	1.65	52.00	44.72	0.86	146.84	141.19	8.89
c)	Gladiolus	1.75	1.97	1.13			0.00	85.00	160.06	1.88	390.79	695.36	18.88
d)	Marigold	9.00	8.45	0.94	11.00	100.00	9.09	439.00	551.38	1.26	586.54	883.37	31.81
e)	Carnation			0.00			0.00	4.20	106.10	25.26	29.48	561.03	109.74
f)	Others Flowers	6.00	7.10	1.18	1.40	2.00	1.43	43.00	34.94	0.81	116.50	108.02	12.33

Fig-4.9.
Area under fresh fruits[3]

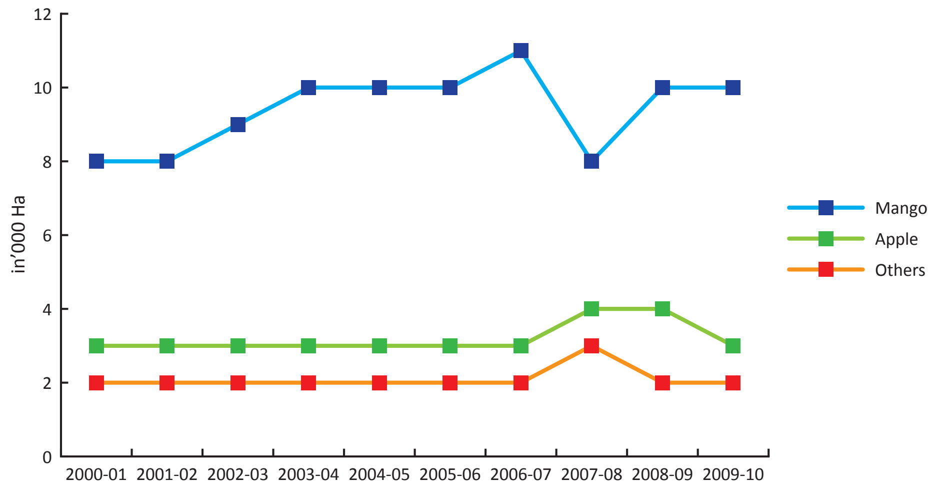


Table-4.14.
Area (in thousand hectares) under fruits and vegetables[3]

	Potato	Onions	Others	Total vegetables	Total fruits & vegetables	Other food crops	Total food crops
2000-01	13	2	3	18	32	12	1157
2001-02	14	2	2	17	31	11	1154
2002-03	15	2	4	20	34	12	1144
2003-04	16	2	15	33	48	0	1151
2004-05	14	2	17	33	49	0	1162
2005-06	16	2	17	35	51	0	1139
2006-07	15	2	15	32	49	0	1143
2007-08	14	2	17	34	48	0	1124
2008-09	14	2	17	33	49	0	1131
2009-10	16	2	19	37	52	0	1103

4.6. Organic Agriculture

Amid growing consciousness of the health hazards from intake of food products produced conventionally has resulted in the revival of the old form of traditional agriculture. Pro – environment and healthy being the two major factors bestowing it with the great demands. With increasingly strong market demands, the production line totally rests upon the farmers/ cultivators involved. It can be proclaimed with no doubt that this growing exigency has a direct bearing on the rural populace as it holds a deemed option for sustainable source of income and in addition is contributing towards rural livelihood opportunities.

However, Uttarakhand being a hilly and difficult terrain State, since ages has large tract of lands which are so far untouched by any chemicals. They are still productive and are by default organic in nature. Besides, the agriculture diversity and the long history of cultivation by natural means are conducive for organic farming. Inadvertently, this combination of factors has made the State apposite for organic farming.

4.6.1. Major Organic Products

Millets, Amaranths, buckwheat, spices, mustard, maize, spices like ginger, chilly and turmeric, the major crops of the State do not need the high nitrogenous fertilizers therefore, are best suited for organic cultivation. Some of the major certified organic products of the state as per UOCB are listed in Table 4.15.

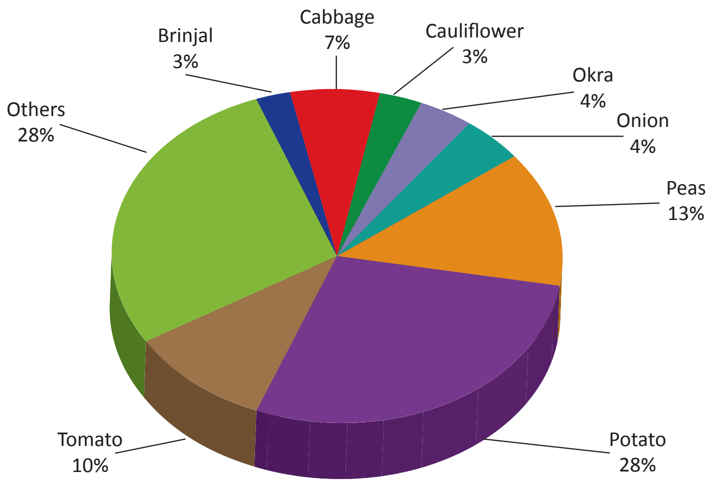


Fig-4.10.
Percent Area under vegetables[12]

Table-4.15.
Organic products of Uttarakhand[14]

Paddy	Dehraduni Basmati, Taraouri Basmati, Pusa -1121, B-370, Pusa-1, Red Ric, Basmati Rice
Spices	Red Chilly, Yellow Chilly, Turmeric Dry/ Powder, Ginger Dry/ Powder, Coriander Whole/Powder, Hemp Seeds, Jamboo Fern, Black Carve, Ginger Whole, Onion Whole, Fenugreek
Pulses	Rajma (Kidney Bean), Arhar/Tuar dal, Urd, Gram, Horse Gram, Soyabean White, Soyabean Black, Naurangi Dal, Pea, Lentil, Lobia
Cereals	Maize Whole, Wheat Whole, Barely Whole
Millets/ Small Cereals	Foxtail Millet, Barnyard Millet, Finger Millet, Prosomillet, Amaranthus, Buck wheat (Kuttu)
Medicinal and Aromatic Products	Rosemary, Thyme, Kutki, Oregano, Parsley
Others	Soap nut, Honey, Apple Juice, Wild Apricot Oil, Hemp Seeds Oil

4.6.2. Area Under Organic Farming

In 2010, the total area registered by USOCA (both certified and in conversion) in Uttarakhand was 41910.95 with 61990 registered farmers (Table 4.16). This has grown to 74100.34 ha with 115155 registered farmers in 2011. The growth of farmers has nearly doubled within last year. Reason was the recent notification where the size of the number of members in a grower group was made to limit to a maximum of 500. Otherwise earlier there were around 64 projects running in 13 districts of the State where each project had a grower group of more than 1000 farmers each. But since this regulation each group was broken down into groups having 500 farmers each. Hence, this inflation in the numbers of registered growers was observed.

4.7. Consumption of Fertilizers

The use of fertilizer in hill regions is very low (ranging between 4 to 6 Kg/ha) whereas, it is more than 200 Kg/ha in plain regions. During last three years, consumption of fertilizers in agricultural sector in the State is depicted in Fig. 4.11 & 4.12.

In addition to the consumption of fertilizer various fungicides and insecticides are also used to protect the plants in the State.

4.8. Integrated Pest Management

Crops are raised on poor and less productive soils with very little inputs. Their production is further marred by the impact of diseases and insect pests. The usage of conventional

Table-4.16.
Projects certified by USOCA in Uttarakhand (2010-11)[15]

S. No.	Name of District	No. of Projects	Area (ha)	Registered farmers
1	Almora	45	7377.52	13398
2	Bageshwar	18	2418.36	6384
3	Chamoli	50	7178.80	14198
4	Champawat	21	4055.01	5626
5	Dehradun	27	6413.91	6161
6	Haridwar	13	4724.54	3757
7	Nainital	41	6398.29	11819
8	Pauri Garhwal	13	3498.45	5826
9	Pithoragarh	4	6232.90	9604
10	Rudraprayag	13	2882.20	5862
11	Tehri Garhwal	52	8790.39	15950
12	U. S. Nagar	31	6483.72	6383
13	Uttarkashi	28	7646.25	10187
	Total	**356**	**74100.34**	**115155**

Fig-4.11.
Fertilizer consumption[4]

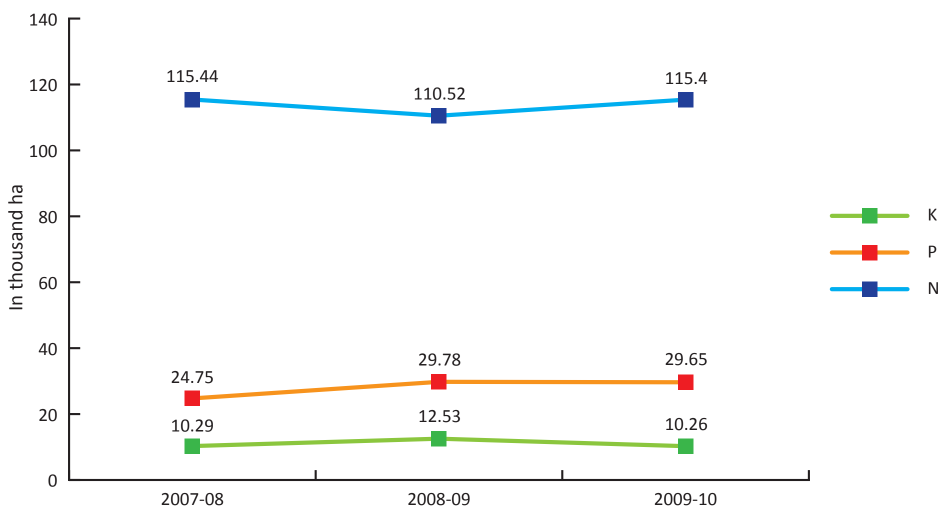
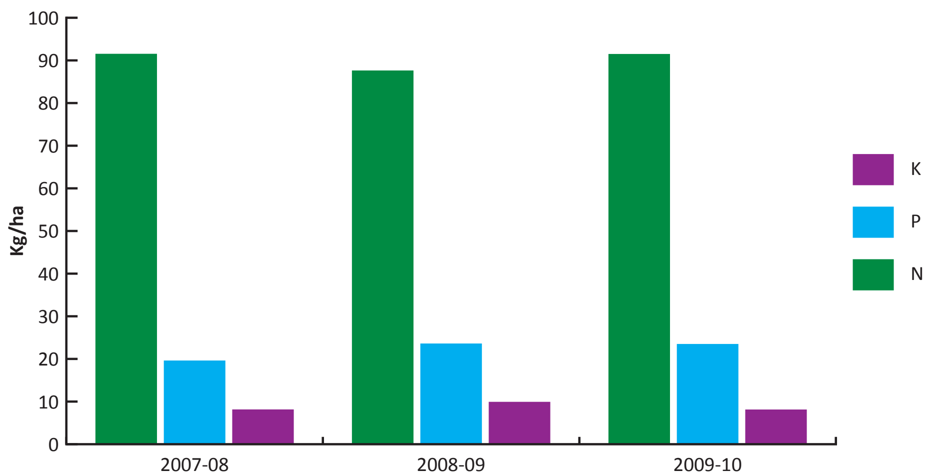


Fig-4.12.
Estimated fertilizer consumption per hectare[4]



and organic pesticides is depicted in Fig. 4.13. The prevalence of some of the menacing pests like white grubs, cutworm and wooly aphids; and diseases like hill bunt and rusts in wheat; blasts in rice and millets; late blight in potato and scab in apple cause severe losses. Suitable integrated pest and disease management practices need to be adopted, which is necessary for reducing reliance on the use of synthetic chemicals and saving environment deterioration. In hill regions other than Tarai there is negligible use of pesticides.

Various programmes and government schemes are running in the State for proliferating the usage of biocontrol methods of protection. Some of the biocontrol methods used to curb the prevalent diseases are mentioned in Table 4.17.

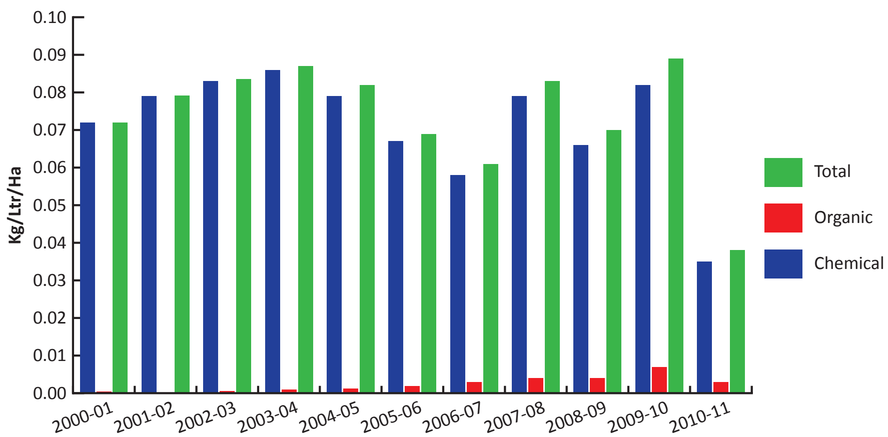


Fig-4.13.
Usage of pesticides[4]

Table-4.17.
Changing pattern in use of Chemical Pesticides and Fungicides to Bio-Pesticides in various crops under IPM[16]

Pest and Disease	Bio pesticides & IPM products under use	Chemical Insecticide/ fungicide	Crops
White-fly, Jassids, Thrips and Mites	Neem 1500 PPM, *Chrysoperoa, Veticillium, Baeuveria*	Metarystore, Demecron, Rogar, Thiodon	Cucurbitaceous, groups of vegetable, Palmgranatem, Citrus groups
Yellow Stem borer, Leaf folder, Hopper	Traps, Lures, B.T., *Trichogramma*, Neem 1500 PPM, *Baeuveria*	Thiodona or indosulphan	Paddy
Sheath Blight Leaf Spot, Cutworm/ Bollworms	*Trichoderma, Pseudomonas,* Traps, Lures, B.T., *Trichogramma*	Indophill (Diathan M-45) or Diathen Z-78, Chloropyriphos or Alddrin	Paddy, Grams, Arhar, Urad, Moong, Tomato, Cabbage
Borers	*Trichogramma*	Thiodon	Brinjal
Caterpillars	Traps, Lures, B.T., *Trichogramma*	Thiodon	Soyabean Radish, Bhindi, Apple
Aphids	Neem 1500 PPM, *Chrysoperla*	Metasystox, Rogar, Demecron	Mustard, Cabbage, Cauliflower, Peach
White rust & Leaf spot	*Trichoderma, Pseudomonas*	Diathen M-45, Diathen Z-78	Mustard, Vegetable pea
Diamond back Moth, Heliothis	Traps, Lures, B.T., *Trichogramma*	Metasystox, Indosulphan	Cabbage, Cauliflower
Wilt	*Trichoderma, Pseudomonas*	Diathen M-45, Babesteen	Cabbage, Cauliflower
Heliothis	Traps, Lures, B.T., *Trichogramma*	Metasystox Thiodon	Tomato & Capsicum
Wilt	*Trichoderma, Pseudomonas*	Diathen M-45, Babesteen	
Fruit Borers	Traps, Lures, B.T., *Trichogramma*	Thiodon, Seven	Brinjal, Lady finger
Mites	Neem 1500 PPM, *Verticillium*	Metasystox & Rogar	Brinjal, Lady finger
Cutworms	Traps, Lures, B.T.	Chloropyriphos, Aldrin	Potato

4.9. Tea Cultivation

Agro climatic condition of Uttarakhand is unique and quite suitable for finest quality tea production both in flavour and productivity. The altitude of selected areas range from 1100-1900m (average mean sea level). However, the majority of sites are located at 1400-1700m. Rainfall is adequate for tea cultivation. Winter rains, though light, occur almost every month. During the major part of the year, relative humidity remains above 60%. Since, it is a labour intensive venture, 22 lakh man days have been generated for the local people. At present, about 1500 labourers are deployed in tea gardens of which women have the representation of 60%.

The total area under tea cultivation as on Feb 2011 is 710.61 ha of which 52% is under inorganic cultivation while, rest of 48% under organic cultivation (Table 4.18). Some facts about tea cultivation are presented in Table 4.19, 4.20 and 4.21.

Table-4.18.
Tea Estates/Gardens[17]

Inorganic Tea Gardens (Till February, 2011)	
Kausani (Almora/Bageshwar)	206 h
Harinagari under special component plan (Bageshwar)	112.43 h
Dharamghar under special component plan	
1. Kapkote Block, Bageshwar	18.8 h
2. Berinag Block, Pithoragarh	30.7 h
Organic Tea Gardens (Till February, 2011)	
Champawat (Champawat)	131.66 h
Ghorakhal (Nainital)	71.81 h
Nauti (Chamoli)	139.21 h

Table-4.19.
Present Status of Nursery (Till February, 2011)[17]

Nursery	No. of plants
Champawat (Champawat)	8,94,194
Ghorakhal (Nainital)	4,29,079
Nauti (Chamoli)	72,568
Kausani (Almora)	1,55,829

Table-4.20.
Plant Material used for Tea plantations[17]

Features	Varieties
Highly flavoury standard Darjeeling clones	Takdah-78, Takdah-383, Ambari- AV2 and Phoobsering-312
High yield clones with average flavour	Rungli- Rungliot 17/144 (Darjeeling clones) and Upasi 9 (United Planters Association of South India, Coonoor, Tamilnadu)
High yield BSS with average flavour	TS 379 & TS 378 (Darjeeling BSS) and TS 449, TS 520, TS 462 (Assam BSS)

Table-4.21.
Manufacturing capacity of Tea factories[17]

	Tea factory	Established on	Capacity in kg made tea/ year
1	Ghorakhal	2007-08	11,000
2	Kausani	2000-01	70,000
3	Champawat	2005-06	11,000
4	Nauti	2006-07	11,000

4.10. Electricity Consumption

Agriculture sector in Uttarakhand is mostly rainfed. Though district wise data is not available but still the tarai regions and the plain areas are the major consumer of electricity for agriculture purposes. Out of the total electricity consumption, agriculture sector utilizes, just 6.34% of the total generated electricity (Table 4.22).

Table-4.22.
Consumption of Electricity for Agriculture purpose in 2008-09[4]

Electricity Consumption for Agricultural Purpose (GWh)	300.2
Total Consumption (GWh)	4736.11
% Share of Consumption for Agricultural Purpose	6.34

4.11. Government Schemes

A) Agri-Schemes[18]

- **Integrated Nutrient Management:** The National Project on Management of Soil Health and Fertility, National Project on Organic Farming (NPOF)
- **Macro Management:** Macro Management of Agriculture (MMA)
- **Mechanization & Technology:** Promotion and Strengthening of Agricultural Mechanization through Training, Testing & Demonstration, Post Harvest Technology and Management
- **Natural Resource Management:** Soil and Land Use Survey of India, Watershed Development Project for shifting Cultivation Area (WDPSCA) – Additional Central Assistance to State Plan Scheme
- **Plant Protection:** Strengthening and Modernization of Pest Management Approach in India, Strengthening and Modernization of Plant Quarantine Facilities in India,

Monitoring of Pesticides Residues at National Level, National Institute of Plant Health Management (NIPHM)

- **Rainfed Farming System:** National Rainfed Area Authority (NRAA)
- **Seeds:** Development and Strengthening of Infrastructure Facilities for Production and Distribution of Quality Seeds**,** Implementation of Protection of Plant Varieties and Farmers' Right Act, 2001
- **Trade:** Capacity Building to Enhance Competitiveness of Indian Agriculture & Registration of Organic Products Abroad
- **Technology Mission on Oilseeds and Pulses:** Integrated Scheme of Oilseeds, Pulses, Oil Palm and Maize (ISOPOM), Integrated Development of Tree Borne Oilseeds
- **Rashtriya Krishi Vikas Yojana:** Rashtriya Krishi Vikas Yojana (RKVY)– Additional Central Assistance to State Plan Scheme

B) Irrigation Schemes:

Accelerated Irrigation Beneficiary Program [AIBP], Participatory Irrigation Management (PIM), CADWM (₹ 845.405 Lakhs released in XI year plan)[19]

C) Horticulture Schemes:

National Horticulture Mission (NHM), Technology Mission for Integrated Development of Horticulture in North Eastern States, Sikkim, Jammu & Kashmir, Himachal Pradesh and Uttarakhand (TMNE), Micro Irrigation, National Horticulture Board (NHB), National Bamboo Mission (NBM)

4.12. Regulatory Mechanism

- The National Agriculture Policy (2000) – to take advantage of the vast growth potential of Indian agriculture
- The Uttarakhand State Krishi Niti (2001) implemented by the State government which is an agriculture led growth strategy for poverty reduction and overall economic development of the State aims to increase the agricultural growth and emphasizes that commercially oriented agriculture has a significant impact both in terms of increased income and in terms of the environment. The plan has three major focus areas: crop diversification, high growth of agriculture for employment and agriculture as a lead sector for economic transformation.
- The National Seeds Policy (2002) – to protect plant varieties and regulate seed production
- The National Biodiversity Authority (NBA) (2003)
- The Biological Diversity Rules (2004) – to safeguard biodiversity and regulate access to biological resources and associated traditional knowledge to ensure sharing of benefits
- The National Policy for Farmers (2007) – to improve the economic viability of farming through substantially improving net income of farmers
- The National Action Plan on Climate Change (NAPCC) (2008) – focusing on concerns like sustainable agriculture, sustaining Himalayan ecosystems / Green India

4.13. Organizations Involved

Table-4.23.
Agri based S&T organizations stated in Uttarakhand[20]

1	Vivekanand Parvatiya Krishi Anusandhan Sansthan, Almora - 263601, Uttarakhand E vpkas@nic.in, W www.vpkas.nic.in P 5962 - 230208, F 5962 – 231539	8	Irrigation Research Institute Yamuna Colony, Dehradun - 248001 Uttarakhand P 9411 - 353710
2	Govind Ballabh Pant University of Agriculture & Technology, Pantnagar, Udham Singh Nagar - 263145 Uttarakhand, W www.gbpuat.ac.in P 5944 - 233333, F 5944 - 233473	9	Horticultural Research and Extension Centre, P.O. Ranikhet, Almora - 263651 Uttarakhand P 5966 - 222113
3	Agro-Forestry Research Centre, P.O. Haldi, U.S. Nagar - 263145, Uttarakhand P 5944 - 210151	10	Horticultural Research and Extension Centre, P.O. Srinagar, Pauri - 246174, Uttarakhand P 1346 - 252269
4	Dr. Shankar Lal Shah Vegetable Research and Extension Centre, P.O. Kosi, Almora - 263643 Uttarakhand. P 5962 - 241248	11	Horticultural Research Centre, P.O. Pantnagar, U.S. Nagar, - 263145 Uttarakhand. P 5944 - 230269
5	Breeder Seed Production Centre, P.O. Pantnagar, U.S. Nagar - 263145 Uttarakhand P 5944 - 233230	12	Horticultural Research Station Dunda, Uttarkashi - 249151, Uttarakhand P 5942 - 245538, F 5942 - 245538
6	College of Forestry and Hill Agriculture, Hill Campus Ranichauri, Tehri Garhwal - 249199 Uttarakhand. P 1376 - 252138	13	Horticultural Research Sub Centre, P.O. Kotdwar, Pauri - 246149, Uttarakhand P 1382 - 225232
7	Crop Research Centre P.O. Pantnagar, U.S. Nagar - 263145 Uttarakhand P 5944 - 233544	14	Institute of Biotechnology P.O. Patwadangar, Nainital - 241129, Uttarakhand P 5942 - 241129
15	Fish Seed Hatchery and Instructional Fish Farm, P.O. Nagla, U.S. Nagar - 263145 Uttarakhand. P 5944 - 233377	23	Model Floriculture Research Centre, P.O. Pantnagar, U.S. Nagar - 263145 Uttarakhand. P 5944 - 234563
16	Horticultural Extension and Training Centre, Chaubattia, Ranikhet, Almora - 263651 Uttarakhand. E des@gbpuat.ernet.in. P 5966 - 222450, F 5966 - 221074	24	Organic Farming Research Centre, P.O. Pantnagar U.S. Nagar - 263145 Uttarakhand
17	Horticultural Research and Extension Centre, Pithoragarh - 262501 Uttarakhand. P 5964 - 252175	25	Sugarcane Research Centre, P.O. Kashipur, U.S. Nagar - 244713 Uttarakhand. P 5947 – 265581
18	Horticultural Research and Extension Centre, P.O. Chakrata, Dehradun - 248123 Uttarakhand	26	Sugarcane Seed Production Centre, P.O. Pantnagar, U.S. Nagar - 263145 Uttarakhand. P 5944 – 233230
19	Horticultural Research and Extension Centre, P.O. Dhakrani, Dehradun - 248142 Uttarakhand. P 1360 - 224272	27	VCSG College of Horticulture, P.O. Pauri, Pauri Garhwal - 246001 Uttarakhand P 1348 – 226070
20	Horticultural Research and Extension Centre, P.O. Dunda, Uttarkashi - 249196 Uttarakhand	28	Vegetable Research and Extension Centre, P.O. Gagar, Nainital - 263137 Uttarakhand P 5942 - 281463
21	Horticultural Research and Extension Centre, P.O. Jeolikote, Nainital - 263127 Uttarakhand. P 5942 - 224547	29	Vegetable Research Centre, P.O. Pantnagar, U.S. Nagar - 263145 Uttarakhand P 5944 - 210149
22	Zonal Agriculture Research Station, P.O. Garampani, Nainital - 263135 Uttarakhand. P 5942 - 245538	30	UP Irrigation Research Institute Roorkee - 247667 Uttarakhand P 1332 - 265174 F 1332 - 262487

4.14. Livelihood Based on Agriculture

Among the total population of Uttarakhand, 31.34 lakhs are the total workers in which 23.22 lakhs are the main workers including 19.96 lakhs male & 11.37 lakhs female and 8.11 lakhs are marginal workers. Total male workers constitute 23.52% of total population and female workers 13.40% of total population (Table 4.24). This distribution varies from district to district. There is a higher proportion of female workers in work force in Uttarakhand.

The work force engaged in agricultural activities is 58.39% of total work force. The occupational classification of female workers in Uttarakhand indicates that 36.31% of them are engaged in agricultural sector (Table 4.25). This is because agriculture in Uttarakhand is largely a women's job and the participation is confined only to a few selected operations.

4.15. Constraints in Agriculture

- Low productivity of crops – The productivity of crops especially of the hills is low, as they are mostly relied on for subsistence farming and is mostly rain-fed. The crops grown are also not agro-climatically best suited for cultivation in the area.
- Fragility of ecosystem: Steep slopes and shallow soils in the hill leads to increased erosion leaving behind less productive soil for crop production
- Irrigation facilities are poor – Hills are mostly rain-fed.

4.16. Key Findings

- The land use pattern of crops in Uttarakhand reflects a declining trend in the acreage of conventional crops like barley and at the same time increase in non-conventional crops like soyabean and other vegetable crops. Farmers are gradually shifting from low value crops to high value crops.

Table-4.24.
Classification of workers-2001[3]

Classification	Rural	Urban	Total
Total Population	6310275	2179074	8489349
Total Working Population	2498842	635194	3134036
Total Main Workers	1745562	576785	2322347
Total Marginal Workers	753280	58409	811689
Total Non Workers	3811433	1543880	5355313
Male Population	3144590	1181334	4325924
Male Working Population	1436711	559466	1996177
Male Main Workers	1123925	515317	1639242
Female Population	3165685	997740	4163425
Female Working Population	1062131	75728	1137859
Female Main Workers	621637	61468	683105

Table-4.25.
Classification of Cultivators – 2001[3]

Classification	Rural	Urban	Total
Cultivators (Main and Marginal)	1556202	13914	1570116
Agricultural Labour (Main and Marginal)	244520	15163	259683
Male Cultivators (Main and Marginal)	675459	8963	684422
Male Agricultural Labour (Main and Marginal)	177989	12505	190494
Female Cultivators (Main and Marginal)	880743	4951	885694
Female Agricultural Labour (Main and Marginal)	66531	2658	69189

- Small and scattered land holdings lead to economical unviable agriculture. More than seventy percent of the land holding are less than one hectare in size and the average per-capita land holding is about 0.91 hectare making farm mechanization difficult.
- Limited area under irrigation. Only about 22% of the cultivated land in the state is irrigated the rest is rainfed. Even in this 22% there is a stark variation in the amount of land under irrigation in different districts. The rainfed agriculture restricts the number of crop taken in a year and thus reduces the cropping intensity of the State.

4.17. References

1. Planning Commission Report. *Impact of Irrigation and Minor Irrigation under AIBP in Uttarakhand State, 2008;* http://planningcommission.nic.in/reports/sereport/ser/imi_aibp.pdf (accessed on 16 Apr 2012).
2. Agriculture Statistics at a Glance, Department of Agriculture & Cooperation. Ministry of Agriculture, GoI, 2011; http://agricoop.nic.in/Agristatistics.htm (accessed 07 Apr 2012).
3. Directorate of Agriculture, Dehradun, 2012.
4. Uttarakhand State perspective and Strategic Plan 2009-2027, Watershed Management Directorate, Dehradun, 2009; www.gramya.in/.../gramya.../*Perspective%20Plan%202009-2027.pdf*
5. Semwal, R.L., Maikhuri, R.K. and Rao, K.S. *Agriculture-Ecology, Practices and Productivity,* Garhwal Himalaya, Nature, Culture and Society (eds. Kandari, O.P. and Gosain, O.P.), Trans Meda, Media House, Srinagar Garhwal, 2001.
6. Rais, M. and Farooquee, N.A., Agri biodiversity and livelihoods R&D in Uttarakhand, India S&T Report 2010-11, 2012; http://www.nistads.res.in/indiasnt2010-11/index_India_S&T_2010-11.html (accessed on 19 Apr 2012).
7. Mehta, P.S., Negi, K.S. & Ojha, S.N. Native plant genetic resources & traditional foods of Uttarakhand Himalaya for sustainable food security & livelihood. *Indian Journal of Natural Products and Resources* Vol (1) March 2010, p 89-93
8. Uttarakhand Government Portal, 2012; http://uk.gov.in/pages/view/429-agriculture (accessed on 19 Apr 2012).

9. Mani, S.C., Status Paper on Rice in Uttarakhand, Rice Knowledge Management Portal, 2011; http://www.rkmp.co.in/sites/default/files/ris/rice-state-wise/Status%20Paper%20on% 20Rice%20 in%20 Uttarakhand.pdf (accessed on 07 Apr 2012).
10. Negi, D.S., Chilli in Uttarakhand, Monograph on traditional crops of Uttarakhand, Uttarakhand Organic Commodity Board, 2011, p. 69.
11. Negi, D.S., Amaranth in Uttarakhand Hills, Monograph on traditional crops of Uttarakhand, Uttarakhand Commodity Board, 2011, p. 68.
12. India Horticulture Database, National Horticulture Board. Ministry of Agriculture, GoI, http://nhb.gov.in/area%20_production.html, 2011 (accessed on 14 Apr 2012).
13. Horticulture Production Data (from 2002-03 to 2010-11). Department of Horticulture & Food Processing, Uttarakhand, Udyan Bhawan, Chaubatia-Ranikhet, Almora, p.27-29.
14. Uttarakhand Organic Commodity Board, 2012; http://www.organicuttarakhand.org/products.html (accessed on 15 Apr 2012).
15. Uttarakhand State Organic Certification Agency Dehradun, Personnel Communication, 2011.
16. Integrated Pest Management, Watershed Management Directorate Uttaranchal, Dehradun 2004; http://www.gramya.in/documents/gramyarelateddoc/Integrated_pest_management_strategy.pdf.
17. http://agricoop.nic.in/Compedium7410.pdf (accessed on 17 Apr 2012).
18. Uttarakhand Tea Development Board, 2012; http://utdb.uk.gov.in/(accessed on 20 Apr 2012).
19. Ministry of Water Resources, 2010; http://wrmin.nic.in/writereaddata/linkimages/Release_2010-113306072073.pdf
20. Directory of R&D Institutions, DST. Ministry of Science & Technology (NSTMIS Division), New Delhi, 2010.

Section II

GEO-RESOURCES

Minerals and Mining

Chapter

ONE

MINERALS AND MINING

(VP Dimri and Prabha Pandey)

1.1. Introduction

The State of Uttarakhand lying between the borders of Nepal and Himachal Pradesh has a unique geographical setting as it constitute of Himalayan mountain belts of Garhwal and Kumaun along with the Tarai regions of the Gangetic plain. The mountain belt of Uttarakhand is constituted of east-west trending latitudinal zones of characteristic tectonics and litho-stratigraphic subdivisions of various geological formations, namely Sub-Himalaya, Lesser Himalaya, Higher Himalaya and Tethys Himalaya from south to north. The litho-stratigraphic units are highly deformed in the form of various thrust sheets and nappes and are traversed by transverse faults during Himalayan orogeny. These litho-stratigraphic units host range of rocks and minerals, some of which could be exploited as resource with economic viability. The first systematic pursuit for economic minerals was led by Capt. G.D. Herbert[1] over the period from 1818 to 1825 who carried out extensive mineralogical survey of the region between the rivers Kali and Satluj[2]. This led to the first ever systematic geological mapping of Himalayan region of Uttarakhand. Though there are records of extensive mining for copper (Cu), lead (Pb) and iron (Fe) in Garhwal and Kumaun Himalaya region prior to this expedition. Placer gold in alluvium of Uttarakhand was exploited during the Gorkhali rulers. Loushington[3] gave an account of experimental work carried out in Pokree (Pokhri) copper mines referred to as the "Chowmutee" mine and the Raja's mine in the then Garhwal district under Mr. Wilkin supervision. The mines at Dhanpur and Dobri in the Garhwal were the most significant ones. The reports of Capt. H. Drummond, G. T. Lushington, Kilkins and Glassford on the Pokhri - Dhanpur mines demonstrated the keen interest and the activities to exploit the mineral resources of Uttarakhand. In pre-independence period, the mining of economic minerals and rocks were difficult and less cost effective because mining was labour intensive, there was lack of mining skill, and transportation was difficult due to difficult terrain, which hindered the mining activity. Further with the advent of import of cheaper mineral and metals, the indigenous mining became very uneconomical and difficult to sustain and therefore, mining ventures were stopped. However, after independence extensive and intensive search for mineral deposits was undertaken by the Government of India to assess the extent and quality of existing mineral resource throughout the country and Uttarakhand was no exception. The task was taken vigorously by Geological Survey of India (Fig. 1.1) and some individual efforts. The geological map of Uttarakhand is depicted in Fig. 1.2.

Several economically viable mineral and rocks were identified. Some mines were developed for exploitation, however non-systematic mining activity and unscrupulous practice led to the destruction of resource and caused imbalance in local ecosystem. Some important mineral resource along with their occurrence and distribution are listed under (Fig. 1.1).

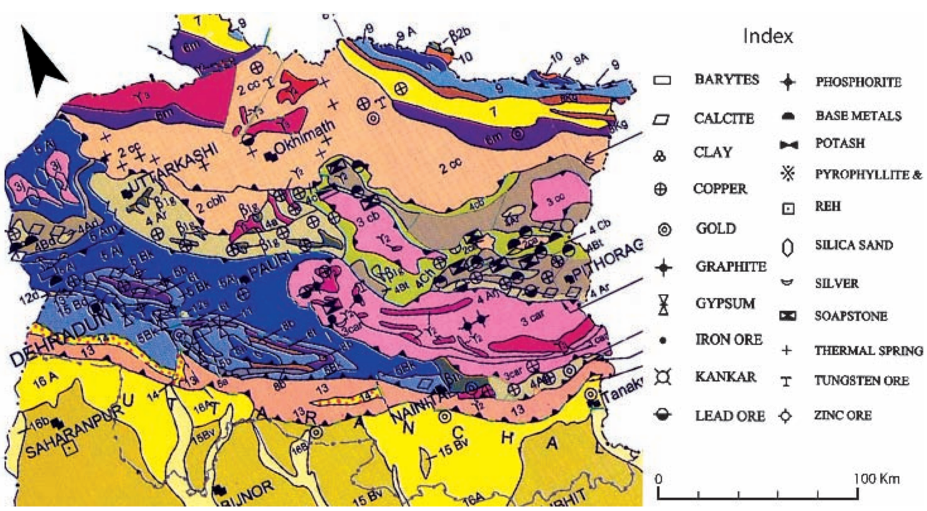


Fig-1.1.
Map showing distribution of minerals in Uttarakhand[4].

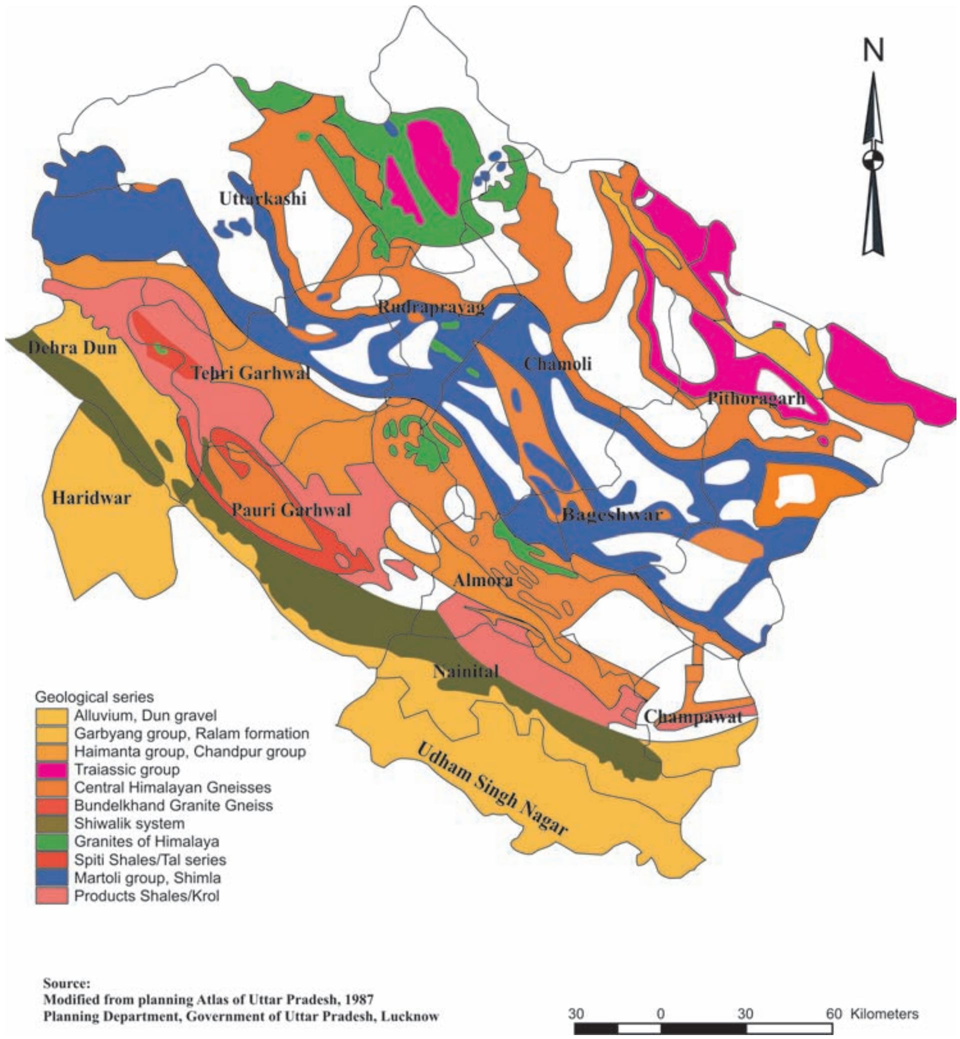


Fig-1.2.
Geological Map of Uttarakhand

1.2. Mineral Occurrences

The economically important minerals include metallic ores from which a metal is extracted and the industrial minerals, which itself are used for one or more industrial purposes. The mineral resources of Uttarakhand can be categorized into

(i) Minerals occurring in great abundance and commercial exploitation is beneficial, e.g. Magnesite, Talc-Steatite, limestone, dolomites, building and roofing material;

(ii) Mineral deposits are too small to be commercially profitable, but they are of great strategic and industrial value, e.g. ores of uranium, copper, lead, pyrite, gold and deposits of phosphorite, gypsum and graphite etc.;

(iii) Minerals whose presence is known in minor amount e.g. garnet, kyanite, barite, asbestos, glass sand etc.

The occurrence and distribution of these mineral resources are listed below.

1.2.1. Magnesite-Talc

Large deposits of magnesite occur in association with calcareous zone of Tejam Formation (=Pithoragarh Formation) of the Garhwal Group in Lesser Himalaya. The calcareous zone

comprises dolomite, dolomitic limestone, limestone inter bedded with thin bends of slate and quartzite and occasional soapstone. Magnesite is of crystalline variety and occurs as lenticular bodies in parts of Kumaun and Garhwal as under. They are exploited by open pit mining method particularly in Kumaun region.

Magnesite occurs north of Bageshwar dist. between (i) Harap and Jakh Harbar in the Lahore valley, (ii) Loharkhet and Badiakot and (iii) Doya and Dophar in the Pungar Valley. In the area south of Bageshwar deposits are located in (i) Girichhinna pass, north of Chhana and Doaba (ii) Baldeo Hill (iii) Pagna Khol and Bhurgaon (iv) Chhani (v) Nail (vi) Thelapatan (vii) Naugaon (viii) Khardli (ix) Jhiroli (x) Dewaldhar and (xi) Bauri. Jhiroli deposit is the most promising and is exposed over a strike length of about 2.5 km. A total of 14 million tonnes of reserves have been estimated, out of which 9.30 million tonnes have been proved.

In Pithoragarh district, magnesite deposits occur in a zone extending over 4 km from Gol and from Kholi to Amtal, near Seraghat in Sarju valley, Chandag-Bisabajer near Pithoragarh, Dewalthal and Kanalichhina, Phadyali, Bora Agar-Seri.

In Chamoli district, the magnesite deposits with a total inferred reserve of 20 million tonnes occur around Pipalkoti in the Alaknanda valley, around Bagoli in Pindar valley and around Ghuni-Ramni, Sutol and Sitel areas in the Nandakini valley.

Talc occurs as irregular lenses and pockets in these carbonate host rocks, showing close association with magnesite and restricted with dolomite. Bands, intercalations and pockets of talc also occur at the contact of dolomite and magnesite. The magnesite, quartz and talc are intimate partner in an assemblage, which shows development of talc at the expense of magnesite and silica.

1.2.2. Phosphorite

Phosphorite and phosphatic deposits occur in different stratigraphic units in different geographic areas. The Precambrian Gangolihat dolomite of the Pithoragarh area is poorly phosphatic. Phosphorite occurs as thin layers of nodules and beds in bedded deposits of Cambrian and Proterozoic periods. Subathu group rocks also have reports of phosphorite. However, deposits occur in Dehra Dun and Tehri Garhwal district.

Mussoorie Phosphorite occurs prominently around Maldeota and Durmala in the Tal Group of Cambrian age. The phosphorite layers inter bedded with thin layers of shale and chert are found in the Chert Member of the basal unit of the lower Tal Formation. The important deposits are at Maldeota, Chamsari, Pari Tibba and Chaunpa Kumali. In Mussoorie hills, Durmala deposits are located in the northern limb whereas deposits around Maldeota occur on the southern limb of Mussoorie syncline. The Maldeota and Pari Tibba deposits are economically workable and have been commercially exploited. The proven reserve is about 19 million tonnes of which Maldeota accounts for 5 million tonnes and Durmala 4.5 million tonnes.

Minor occurrences of Phosphorite have been reported from Baldiyakhan and Darimkhet in Nainital dist. associated with limestone bed of Krol Group. In the Lansdowne hills they are associated with the lower carbonaceous shale of the Tal contains phosphatic nodules.

1.2.3. Base Metals

Base metals are important resources for industrial growth and economic development of a country. Mineralization for base metals copper, lead, zinc is known from Paleoproterozoic rocks of the Garhwal Group and associated granitic rocks and from Mesoproterozoic

Dudatoli Group. Some insignificant occurrences in Dehra Dun district and Chamoli district are also reported. Base metal mineralization in the Paleoproterozoic Garhwal Group and its equivalents are of two types, (i) copper associated with hydrothermal veins and pockets of magnesite is commonly occur, and (ii) the polymetallic or monometallic sulphides copper free from magnesite. Followings are some notable base metal deposits in Uttarakhand.

1.2.3.1. Askot (Pithoragarh)

The mineralization is found in the south-eastern closure of Askot synform exposing Askot crystallines. The mineralization is polymetallic and represented by *chalcopyrite, galena, sphalerite* and *arsenopyrite, marcasite, chalcocite, pyrite, pyrrhotite* and *cubanite* in small amounts. Sulphides occur as disseminations, blebs, specks, veins, stringers and occasionally as loads and pockets. The veins containing metallic sulphides are either parallel or oblique to schistosity. A probable reserve of 1.14 million tonnes of ore has been estimated.

1.2.3.2. Baphila Prospect

The mineralization occurs near northwestern closure of the Askot synform as thin veinlets, stringers and specks of *chalcopyrite, bornite* and *pyrite* along with *malachite* and *azurite* encrustations.

1.2.3.3. Shiskhani-Chanapani-Baladeo area

Mineralization is polymetallic and shows zoning. At Shiskhani it is mainly lead, copper; at Chanapani and Baldeo it is copper and lead. The reserves are of the order of 0.55 million tonnes.

1.2.3.4. Tons valley

Mineralization occurs in dolomite carbonaceous shale and tuff of the Suali Formation of the Deoban Group. Sulphide mineralization in the form of stringers, disseminations, vug fillings and veins of *galena, sphalerite, chalcopyrite* and *pyrite* in Amtiyar gad. Copper mineralization (chalcopyrite) is confined to Shallukhad atoll area.

1.2.3.5. Amritpur and Galpakot areas

Copper and *lead* mineralization has been recorded from the Bhimtal Formation and granitoids from Galpakot in the Nainital district.

1.2.3.6. Dhanpur Dobri area

Mineralization is in carbonate sequence.

1.2.3.7. Pokhri- Mohankhal area

The area is well known for ancient mining. Mineralization in the form of stringers, veinlets of *chalcopyrite, pyrite* and *pyrrhotite* associated with quartz- calcite veins and lenticular bodies of coarsely crystalline magnesite occur along shear zones in sericite quartz schist.

1.2.3.8. Mineralization in the Jaunsar Group and its equivalents

Lead and *silver* mineralization reported from Birgana in the Pauri Garhwal distt and occurs in the interbedded phyllite and quartzite sequence of Maithana formation.

1.2.3.9. Mineralization in the Krol Group

Lead and zinc occurs in the form of isolated pockets, veins, fracture and joint fillings in the crystalline dolomite of the Krol C near Shastradhara.

1.2.3.10. Mineralization in Martoli Group and Ralam Formation

Veins of quartz and quartz-calcite containing *chalcopyrite, bornite* and *arsenopyrite* as disseminations, stringers and veinlets are seen traversing quartz-phyllite of the Martoli Formation and conglomerate of the Ralam Formation in Girthi valley near Malari.

1.2.4. Uranium

Uranium occurs in association with carbonaceous shale and Chert of Lower Tal Formation of Cambrian sediments of Lesser Himalaya. Part of Cambrian Tal Group of rocks are present in Lesser Himalaya and occur in five major synclines viz. Nigali Dhar, Korgai, Mussoorie, Garhwal and Nainital synclines, which extends for over 300km. In general uranium mineralization is confined to the Phosphorites, Chert and Black shale association. In 1 to 5m thick phosphorites beds the Uranium mineralisation is restricted to the bottom 1.5m of the horizon. Uranium concentration is high (200 – 980 ppm) because of the intimate association of carbonaceous shale but not exploited by so far. The distribution of Uranium[5] in Uttarakhand is tabulated as under in Table 1.1.

Extensive uraniferous black shale deposits of Garhwal Himalaya contain low grade Uranium 20 to 390 ppm, which is not exploited and no systematic evaluation of deposit is done. Uranium occurrences have also been reported from Dhanaur Rao, Naugajia Rao and Shakumbari Rao areas. Similar uranium occurrences have also been located in the Berinag quartzites. Shear-controlled uranium mineralisation of significant dimensions and grade are hosted by chlorite-sericite schists of Pokhri area, Chamoli dist. and by granite gneisses in Brijrani gad area, Tehri dist. Explorations in the Himalaya are greatly hindered by geological complexities and lack of infra-structural facilities.

1.2.5. Limestone/Dolomite

Limestone/Dolomite is found in many parts of Uttarakhand. The Gangolihat Formation of eastern part is predominantly constituted of dolomite. Large deposits of dolomite/ limestone occur in Krol belt of Nainital Hills and Dehradun-Mussoorie syncline, where the main deposit is reported from Sisoli, Bhatta, Hathipaon, Jharipani localities. These deposits belong to Krol C Formation of Krol Group. The good quality limestone deposits

Table-1.1.
Distribution of Uranium in Uttarakhand[5]

Area	Black Shale (Phosphatic) U3O8 (ppm)	Grey Earthy Shale U3O8 (ppm)	Limestone/ Calc mudstone U3O8 (ppm)
Dobighat	25 – 940	25	
Baradwara	25 – 940	25	
Daunk	25 – 390		
Loharigarh	50 – 400		
Chamasari	130 – 2800	12 – 920	2 – 520
Timli	200 – 560		100 – 290
Sarkhet	44 – 520		
Loarkha	25 – 1100		15 – 100
Narayanpur	56 – 970	51	6
Kokliyalgaon	45 – 67		7 - 110
Ghuttu	58 – 100		
Durmala	95 – 190	22	

are exposed around Sahastradhara area as well. The limestone deposits exposed around Kalsi and Dagura, Tila Gwar and Bhadsi near Lansdowne are also of significant quality. The basal part of the Gangolihat Dolomite consists of limestone at a number of places. In the Pithoragarh district, three distinct belts of limestone are recognizable. The dolomite deposits also present in Nainital Kaladhungi road with total indicated reserves of over 100 million tonnes.

Cement-grade limestone is also found near Jirauli (Matela area) where the total reserve is of the order of 8.77 million tones. The calcareous tuffa of the Krol Formation of Nainital is of the cement grade. A reserve of about 7 million tonnes of cement-grade limestone has been estimated at Jaurasi. It will be evident that the reserves of limestone are quite large, and investigations so far carried out have shown the possibility of setting up of mini cement plants at a number of places, e.g. at Jaurasi, Chaunala, Betalghat, Matela (Jhirauli area) and Bhulgaon.

1.2.6. Marble
Small deposit of marble occurs in association with chemical grade limestone of the Krol C (Kauriyala Formation) of the Krol Group of Mussoorie syncline, Dehradun distt and Tehri dist. About 15 million tonnes of reserve have been estimated.

1.2.7. Sulphur
There are records of old sulphur mine near Sutal, Nandakini valley, Chamoli distt. Further cold water sulphur springs are reported from Manjhera, Sahastradhra in the Baldi river and Sera in the Song valley near Dehra Dun.

1.2.8. Graphite
Low grade Graphite occurs in the Pauri Garhwal and Pithoragarh districts. The Munsiari Formation is insignificantly graphitic locally and pockets have been observed near Munsiari, Garjoli, Palsima and Palon villages.

1.2.9. Gypsum

Gypsum deposits are known from Dehra Dun, Nainital, Pauri Garhwal and Tehri Garhwal districts. The gypsum is confined to the rocks of the Krol Group in Dehra Dun district. Total estimated reserve of gypsum is about 353500 tonnes[2].

1.2.10. Iron Ore

Magnetite and hematite concentration in the Rautgara, Deoban and Nagthat formations used to be mined for iron in Bhukanda, Ali, Pokhri-Agar (Chamoli), Kala Agar (Nainital) and other places in Uttarakhand.

1.2.11. Slate and Paving Stones

Slate has been used since times immemorial as a roofing material. The Sor Slate, Chandpur and Gumalikhet formations are the main sources of valuable roofing slates and paving stone material. The deposit of Kanalichhina, Baldhoti, Chiteh near Dwarahat and Labha near Garisen are of good quality and traditionally mined. The Ramgarh Groups also comprises good-quality slates at various places. The Chandpur phyllite and slates in the SW Almora and Pauri, Aglar valley in Tehri and near Dehra Dun are especially quarried.

1.2.12. Other Minerals

1.2.12.1. Abrasives

Garnet is the chief abrasive found in the sand of the Himalaya. It occurs associated with schists and gneisses of the Central Crystallines and the Dudhatoli Group of rocks, but seldom in sufficient concentration.

1.2.12.2. Asbestos

Small deposits of asbestos in associated with calc-silicate rocks are reported from Mandakini valley, Chamoli district.

1.2.12.3. Barytes

It has been reported from the sedimentary sequences of Lesser and Tethys Himalaya. Several veins containing Barytes occur in Nagthat Formation and Blaini Formations in Dehra dun area. The estimated reserves are about 5000 metric tonnes.

1.2.12.4. Mica

It occurs in mica pegmatite of small dimensions emplaced in biotite schist of the Dudatoli Group around Thalisain and Pauri Garhwal district. It is reported from Jallu, Badnikhal, Godoli, Kunet and Ghuri villages in the form of mica books.

1.2.12.5. Soapstone

The total reserves of talc/steatite/soapstone are assessed at 312 million tonnes of which reserves 115 million tonnes and remaining resources are 197 million tonnes, respectively. Substantial quantities of resources are established in Uttarakhand.

1.2.12.6. Antimony

Stibnite (Sb2S3) occur as thin veins and small lenticular pockets associated with quartz veins traversing granites and granodiorites and is marked prominently on the surface by extensive limontization. It has been recorded from Pokhri. The mineral occurs associated with biotite schist.

1.2.12.7. Arsenic

The occurrence of ***Arsenopyrite (FeS2.FeAs2)*** in association with the base metal mineralized is reported from Chamoli dist. The deposit occurs as vein in the contact of quartzite with metabasic rocks of Garhwal Group. The mineral is also reported with polymetallic mineralized zone at Askot, Pithoragarh district. ***Realgar (AsS)*** and ***Orpiment (As2S3)*** are reported from the lateral moraine of Shunkalpa glacier in Ralam valley, Pithoragarh.

1.2.12.8. Gold

Primary gold is been reported from quartz veins in association with base metals deposit at Askot and in association with polymetallic mineralization in Galpakot and Chalthi area. The gold content is 1-13.2 ppm (Askot), 2-5 ppm (Chalthi) and 50 ppm-0.25 ppm at Galpakot. In addition to primary gold, ***placer gold*** is also reported from the Siwaliks from Sona Nadi, Pauri Garhwal dist., Durgapipal and Katol areas and Pithoragarh district where the panning of the pebble conglomerate showed presence of mesoscopic grains of gold. Neo-placer gold is recorded from the channel alluvium of the Alaknanda river in Chamoli distt, near Thalisain, Ganga river at Laxman jhula. These are also reported from the Gomti river in Gwaldam area, Almora and in Panar river in Nainital dist. In Tanakpur area analysis of stream sediments gave fire assay gold values varying from 0.1g/t to 3.8 g/t.

1.2.12.9. Silver

It is found to be associated with lead or Zinc mineralization at Birgana, Pauri Garhwal, Askot in Pithoragarh, Shishakhani in Bageshwar and Chamri and Barmatiya in Chamoli.

1.2.12.10. Tourmaline

The semi precious variety of tourmaline ***dravite*** has been reported from the Almora Formation.

1.2.12.11. Tin

Cassiterite associated with leucogranite in garnet mica schist of the Almora Group.

1.2.12.12. Tungsten

Scheelite has been reported from the Dudatoli-Almora Formation near Almora, Chamoli and in Pindar valley.

1.2.12.13. Clays

Good quality ***clay*** is found in Shyampur Formation, Dun valley which is quarried locally for the manufacture of bricks.

1.2.13. Strategic Minerals and Rare Earth Element (REE)

Strategic minerals and metals such as Tin, Cobalt, Lithium, Germanium, Gallium, Indium, Niobium, Beryllium, Tantalum, Tungsten, Bismuth, Selenium etc. and Rare Earth Elements (REE) have critical applications in modern technology. Rare earths are relatively abundant in the Earth's crust, but discovered minable concentrations are less common than most other ores.

The REE do not have any satisfactory substitutes and do not occur concentrated in geological environments like those of other metallic deposits. They are finding applications in various sectors as Neodymium, Samarium in Magnets, Lanthanum as Catalysts, Praseodymium, Scandium as Metal alloys, Cerium as Polishing, Neodymium, Praseodymium, Erbium, Yttrium as Ceramics / Glass, Yttrium as Lasers, Erbium - Fiber optics. In case of India, exploitation of rare earths is confined to Monazite based lanthanides and the actinides thorium and uranium. There is plenty of scope for exploration for ores like xenotime, bastnesite etc, containing naturally occurring REE, phosphorites contain REEs, chiefly the LREEs, La, Ce and Nd in the mineral francolite (carbonate-rich fluorapatite), wherein bivalent lanthanides[6] substitute for Ca^{2+}. Though REE are mainly hosted by carbonatites and associated alkaline rocks, there are reports of exploring Granitoids for Uranium and REE mineralization potential. Granitoids related to such mineralisation are rich in volatile, mica rich, weakly to strongly peralurminous, or potassic emplaced along structurally major weak zones, Proterozoic and younger in age, and S - or I-type, the latter with notable crustal contamination are supposed to have a potential for Uranium and REE mineralisation either in granite-pegmatites or their nearby derived placers[7]. Since, similar granitoids also occur in Uttarakhand the possibility may also be explored as potential targets for REE; though the exploitation of REE is more into domain of metallurgy than mining.

1.3. Concluding Remark

As discussed in previous sections, the Uttarakhand has potential mineral reserves that can be exploited for industrial growth and has potential to contribute to the nation's economy. The reserves of magnesite and cement grade limestone are tremendously large. But the State being an eco-sensitive region, the sustainable rational exploitation of mineral resource is with careful planning and execution strategy to preserve very sensitive environment is a very challenging task.

1.4. References

1. Herbert, G.D., Report of the mineralogical survey of the region lying between the rivers Satluj & Kali, with the geological map. *Jour. Asiatic Soc. Bengal*, 1842, 11 & 13 (map).
2. Valdiya, K.S., *Geology of Kumaun Lesser Himalaya.* Wadia Institute of Himalayan Geology, Dehradun, 1980, p. 291 .
3. Loushington, G.T., Account of the experiment carried on at the Pokhree Copper mines, Garhwal, under Mr. Wilkins, with notices of other copper mines in that district. *Jour. Asiatic Soc. Bengal*, XII, 1843, **1**, 454-472.
4. Kothiyal, D.L., Srivastava, V.C. and Verma, R.N., *Geology and mineral resources of the states of India, Uttar Pradesh and Uttaranchal.* Geological Survey of India Misc. Publication, No 30, Part XIII, 2002, p. 73.
5. Maithani, Prem B., Personal communication, 2012.
6. Sukumaran, P.V., The need to explore for rare earth minerals. *Current Science,* 2012, **102**(6), 839-841.
7. Dhana Raju R., Granitoids for Uranium, Rare Metal and Rare Earth Mineralisation Potential: Some Indian Examples, *Antarctic Geoscience, Ocean-Atmosphere Interaction and Paleoclimatology*, 2002, 284-306.

Section II

GEO-RESOURCES

Water Resources

Chapter

TWO

WATER RESOURCES

(Bhavtosh Sharma and DP Uniyal)

2.1. Introduction

Water, the elixir of life, forms the chief constituent of the ecosystem. Besides providing drinking water, water resources play a crucial role in various sectors of economy like agriculture, industrial activities, hydropower generation, livestock production, forestry, fisheries and creative activities. Water seamlessly integrates all the sectors. It can be said that an economy having large endowments of water will prosper to its hilt.

In this sense, Uttarakhand is blessed with natural sources of fresh water in the form of river networks and glaciers emanating from the Himalayas and ample ground water system.

With presence of mighty glaciers and perennial rivers, Uttarakhand is a water rich state. Also, due to its topographical positioning, the state receives heavy amount of rainfall. The state possesses huge hydro-resource in forms of various major and minor water sources and thus often called as 'Water Tower' of India. Ironically, while Uttarakhand serves the water demands of other states of northern India, the natives of Uttarakhand are facing water crisis, specifically w.r.t. drinking water. Uttarakhand being the hilly state and possessing an uneven terrain, comprising of mountains and valleys make situation more complicated in terms of water availability to the rural masses in remote areas.

2.2. Hydrogeology and Water Scenario of Uttarakhand

Uttarakhand, being a hilly state possess a varied hydrogeological setup. The hydrogeology of Uttarakhand (Table 2.1) can be divided broadly into two distinct hydrogeological regimes- (i) Gangetic alluvial plain and (ii) the Himalayan mountain belt[1].

2.3. Water Requirement in Uttarakhand

The constantly snow covered are high altitude mountain ranges of the state are perennial source of water for Uttarakhand and also for the downstream states. From 2001 to 2011 , the population of Uttarakhand has increase from 84.89 Lacs to 101.16 Lacs, with an estimated 4.88% increase in urban population[2]. According to Confederation of Indian Industries (CII)[3], only 52% of the state population have full access safe drinking water supply and 36% population possess partial access. As per Bureau of Indian Standard (BIS)[4] minimum 70-100

Water Statistics

Drinking Water Supply	By tube wells and dug wells in plain areas, By springs and hand pumps in hilly terrain
Ground Water Exploration	EW: 49 OW: 02 Total: 51
Depth To Water level (Pre-monsoon & post monsoon during 2006)	Pre-monsoon 2006: from 2.01 m bgl to 61.96 m bgl; Post-monsoon 2006: from 2.01 m bgl to 72.03 m bgl
Ground Water Structure Feasible	Deep Tubewell, shallow Tubewell and Dug Well
Ground Water Quality	In general potable

Source: CGWB

Table-2.1.
Hydrogeology of Gangetic alluvial plain and Himalayan mountain belt[1]

Hydrogeology of Uttarakhand		
Gangetic Alluvial Plain	Axial Belt	Alluvial Plains, composed of a mixture of gravel, sand, silt and clay deposited in alternating layers, aquifers of this zone are unconfined to confined nature.
	Tarai	Sedimentary units consisting of a mixture of gravel, sand and clay (sometimes also referred to as Tarai Formation), Due to the highly porous and permeable nature of the constituting material of sedimentary origin, aquifers having ground water of good chemical quality exist, unconfined aquifers occur (down to depths of 30 meters below ground level (m bgl) and confined aquifers (at depths greater than 30m bgl under very high hydrostatic pressure).
	Bhabar	Mixture of clastic material having different size fractions (e.g. boulder, pebble, gravel, sand, silt and clay) constitutes this unit and the zone is promising hydrogeological entity though the occurrence of ground water at deeper levels (generally greater than 100m bgl) poses a problem for ground water exploitation. Perched water bodies having smaller water resource potential are frequently encountered in this zone.
Himalayan Mountain Belt	Outer Himalaya (Shiwalik Mountain Range)	Composed dominantly of sandstone, ferruginous shale and clay and is younger in age as compared to the other units of the belt, elevation of the zone is less than 1000m above mean sea level, and a number of valleys developed as a result of tectonic activities (e. g. Doon Valley) in Shiwalik range. Lower, middle and upper Shiwaliks are exposed in the area, and the Doon Gravels, a post-Shiwalik formation, were deposited with the evolution of the valley, the water levels in the aquifers of this zone range from 20m bgl in the southern part of the valley to about 100m bgl in the northern part.
	Lesser Himalaya	Unit is dominantly composed of metasedimentary rocks and minor plutonic intrusives (granitoids) and is represented by mountains bounded by Main Boundary Thrust (MBT) in the south and Main Central Thrust (MCT) in the north having an elevation ranging between 1000 - 3000m above mean sea level, springs form the most important source of ground water in this zone.
	Central Himalaya	Central Himalayan zone lies to the north of Main Central Thrust (MCT) with an elevation ranging from 5000 - 8000 m above mean sea level, both cold and hot water (thermal) springs are present in this zone. So far a total of 25 thermal springs have been investigated with temperatures ranging from 32^{0}C to 70^{0}C and discharge varying between 60 to 600 lpm, due to highly inaccessible, snow-covered areas in this zone and a very steep hydraulic gradient, the possibility of ground water development is almost negligible.

Hydrogeology of Uttarakhand	
Tethyan Himalaya	Situated to the north of Central Himalayan zone and is predominantly occupied by the highly fossiliferous sedimentary rocks ranging in age from Precambrian to Jurassic. The zone is generally suitable for ground water development due to the porous and permeable nature of the litho units.

Status of Water Supply schemes	
No. of Tube wells	504 (90% automation)
No. of Mini tube wells	121 (100% automation)
No. of Hand pumps	7030
No. of Chal-Khals	2814
No. of Private connections	506865
Rural	205194
Urban	301671
No. of Private connections	506865
Domestic	473876
Commercial	32989
No. of Stand Post	61404

Status of Urban Water Supply schemes

No. of Town	63
Towns Having Population	
More than 1 lac	4
50 thousand to 1 lac	3
20 thousand to 50 thousand	14
less than 20 thousand	42
Per capita water supply	
Upto 70 lpcd	23
Between 71 and 135 lpcd	25
More than 135 lpcd	15
No. of Urban W/S Scheme	63
No. of Pumping Scheme	47
No. Gravity Scheme	16

Status of Rural Water Supply schemes

Rural W/S Schemes	
No. of Rural W/S Schemes	5408
No. of Gravity Scheme	5187
No. of Pumping Scheme	221
No. of Low Head Scheme	153
No. of High Head Scheme (Surface pumping)	68
No. of Single Village Scheme	2424
No. of Multi Village Scheme	2762
No. of W/S schemes devoluted/ new single village under SWAp schemes (993 habitations)	499
Total Target (Under SWAp) habitations	2754
SVS 1154 habitations Devolution habitations	1600

Status of Habitations of Rural Water Supply Scheme (As on 1.4.2011)

S. No.	% of coverage	No. of habitations	Rate of Water Supply (lpcd)
1	0 – 25	4592	10
2	25 – 50	2412	20
3	50 – 75	2165	30
4	75 – 100	3007	40
5	100	26966	> 40
	Total	**39142**	

Source: UJS 2011

litre per head per day (lphd) is considered to be adequate for domestic needs in urban communities without flushing requirement (Table 2.2).

In most of the major cities, a deficit in water supply is observed (Table 2.3). Rudrapur, Kashipur, Haridwar and Dehradun are at the apex apparently because of the large number of human settlements. In case of excess water available (Table 2.4) only a handful cities exists[5].

Table-2.2.
Minimum water requirement in litre per head per day (lphd) in different communities[4]

Description	Minimum water requirement (lphd)
For communities with population upto 20,000 and without flushing system a. water supply through standpost b. water supply through house service connection	 40 lphd 70 – 100 lphd
For communities with population 20,000 – 100,000 with full flushing system	100 – 150 lphd
For communities with population above 100,000 with full flushing system	150 – 200 lphd

2.4. Water Sources of Uttarakhand

Springs or gadheras, rivers, lakes, tube wells, dug wells, RBF wells, Uttaranchal Koops etc. are the main drinking and irrigation water sources. Besides these, "Chal or Khal" are also important sources of water. Uttarakhand Jal Sansthan (UJS) has regenerated total 1804 Khals upto 2008 in whole Uttarakhand (Table 2.5) for water supply to the mass population. Some of which are listed in (Table 2.6), of which Pauri (126) has maximum number of Khals[6].

UJS has collected year-wise discharge data during 2005, 2006 and 2008 for 213 Gadheras and Springs, which are providing drinking water in various parts of the state, in the (Table 2.7.). It shows that Almora has maximum number of water sources (72) followed by Tehri (51) and Pauri (35)[7]

Table-2.3.
Cities or towns with deficit rate of water supply[5]

District	Town	Population of Town			Rate of Water Supply Reorganization including 15 % Losses (135+15 %)	Water Requirement for Reorganization w/s including 15 % Losses (in mld)	Water Available (in mld)	Deficit in Water Supply
		2001 Census	Base Year 2005	Design Year 2035				
Garhwal Zone								
Uttarkashi	Uttarkashi	16218	17191	26922	155.25	4.18	2.30	1.88
	Barkot	6095	6461	10118	155.25	1.57	0.86	0.71
Chamoli	Joshimath	13204	13996	21919	155.25	3.40	0.81	2.59
	Chamoli-Gopeshwar	19833	21023	32923	155.25	5.11	0.79	4.32
	Karanprayag	6977	7396	11582	155.25	1.80	0.93	0.87
	Gaucher	7303	7741	12123	155.25	1.88	0.64	1.24
Tehri Garhwal	New Tehri	25423	26948	42202	155.25	6.55	1.50	5.05
	Devprayag	2175	2306	3611	155.25	0.56	0.20	0.36
	Kirti Nagar	1040	1102	1726	155.25	0.27	0.10	0.17
	Narendra Nagar	5304	5622	8805	155.25	1.37	0.18	1.19
Dehradun	Mussoorie	26075	27640	43285	155.25	6.72	5.50	1.22
	Rishikesh	59540	63112	98836	155.25	15.34	12.38	2.96
	Dehradun	426674	452274	708279	155.25	109.96	102.17	7.79
	Vikas Nagar	12486	13235	20727	155.25	3.22	2.28	0.94
	Herbertpur	9243	9798	15343	155.25	2.38	1.39	0.99

District	Town	Population of Town			Rate of Water Supply Reorganization including 15 % Losses (135+15 %)	Water Requirement for Reorganization w/s including 15 % Losses (in mld)	Water Available (in mld)	Deficit in Water Supply
		2001 Census	Base Year 2005	Design Year 2035				
Pauri Garhwal	Kotdwar	24947	26444	41412	155.25	6.43	6.00	0.43
	Pauri	24743	26228	41073	155.25	6.38	3.50	2.88
	Srinagar	19658	20837	32632	155.25	5.07	1.00	4.07
Haridwar	Roorkee	97516	103367	161877	155.25	25.13	17.00	8.13
Total Garhwal		**804454**	**852721**	**1335394**	**2949.75**	**207.32**	**159.53**	**47.79**
Kumaun Zone								
Pithoragarh	Pithoragarh	44964	47662	74640	155.25	11.59	3.40	8.19
Champawat	Tanakpur	15811	16760	26246	155.25	4.07	0.60	3.47
	Champawat	3959	4197	6572	155.25	1.02	0.20	0.82
	Lohaghat	5829	6179	9676	155.25	1.50	0.20	1.30
Bageshwar	Bageshwar	7803	8271	12953	155.25	2.01	0.30	1.71
Almora	Almora	30154	31963	50056	155.25	7.77	7.50	0.27
Nainital	Haldwani cum Kathgodam	129015	136756	214165	155.25	33.25	33.00	0.25
	Ramnagar	46205	48977	76700	155.25	11.91	7.25	4.66
Udham Singh Nagar	Kashipur	92967	98545	154325	155.25	23.96	9.40	14.56
	Rudrapur	88676	93997	147202	155.25	22.85	3.26	19.59
	Jaspur	38937	41273	64635	155.25	10.03	2.33	7.70
	Kichha	30503	32333	50635	155.25	7.86	0.90	6.96
Total Kumaun		**534823**	**566912**	**887806**	**1863.00**	**137.83**	**68.34**	**69.49**
Total Uttarakhand		**1339277**	**1419634**	**2223200**	**4812.75**	**345.15**	**227.87**	**117.28**

Table-2.4.
Towns with sufficient rate of water supply in Uttarakhand[5]

District	Town	Population of Town			Rate of Water Supply Reorganization including 15 % Losses (135+15 %)	Water Requirement for Reorganization w/s including 15 % Losses (in mld)	Water Available (in mld)	Excess Available Water
		2001 Census	Base Year 2005	Design Year 2035				
Garhwal Zone								
Uttarkashi	Gangotri	605	641	1004	155.25	0.16	1.00	0.84
Chamoli	Badrinath	1682	1783	2792	155.25	0.43	1.35	0.92
Rudraprayag	Rudraprayag	2250	2385	3735	155.25	0.58	0.80	0.22
	Kedarnath	482	511	800	155.25	0.12	0.32	0.20
	Muni-Ki-Reti	7880	8353	13081	155.25	2.03	6.70	4.67
Haridwar	Haridwar	175340	185860	291064	155.25	45.19	53.01	7.82
Total Garhwal		**188239**	**199533**	**312477**	**931.50**	**48.51**	**63.18**	**14.67**
Kumaun Zone								
Nainital	Nainital	38630	40948	64126	155.25	9.96	13.00	3.04
Total Kumaun		**38630**	**40948**	**64126**	**155.25**	**9.96**	**13.00**	**3.04**
Total Uttarakhand		**226869**	**240481**	**376603**	**1086.75**	**58.47**	**76.18**	**17.71**

Table-2.5.
Regenerated "Chal – Khal" by Uttarakhand Jal Sansthan[6]

District	Year 2000-01	Year 2001-02	Year 2002-03	Year 2003-04	Year 2004-05	Year 2005-06	Year 2006-07	Year 2007-08	Total
Dehradun	-	-	-	-	05	10	-	08	23
Pauri	-	-	05	57	29	82	95	41	309
Chamoli	-	-	23	08	10	20	64	58	183
Rudraprayag	-	-	-	06	30	16	58	06	116
Tehri	-	18	05	07	46	69	123	106	374
Uttarkashi	-	-	17	23	24	31	116	-	211
Haridwar	-	-	-	-	-	-	-	-	-
Total (Garhwal Region)		**-**	**50**	**101**	**144**	**228**	**456**	**219**	**1216**
Nainital	-	-	16	05	01	08	13	-	43
Almora	-	-	13	-	17	74	39	33	176
Bageshwar	-	-	04	-	-	13	63	36	116
Champawat	-	-	02	04	03	01	29	12	51
Pithoragarh	-	-	22	06	43	64	51	16	202
Udham Singh Nagar	-	-	-	-	-	-	-	-	-
Total (Kumaun Region)		**-**	**57**	**15**	**64**	**160**	**195**	**97**	**588**
Total		**-**	**107**	**116**	**208**	**388**	**651**	**316**	**1804**

2.4.1. Rainfall in Uttarakhand

The heavy annual rainfall amounting to 1606 mm is sufficient to fulfil the water requirement of state[8] but incidently 95% of the rainfall flows as runoff due to high slopes[9]. The available seventy years data from 1901 to 1970 of 09 districts for normal monthly and annual (Table 2.8) shows that maximum rainfall occurs in the month of July and August. Highest annual rainfall received by district Pithoragarh followed by Dehradun while Haridwar receives the minimum[1]. The annual rainfall varies from 1256 mm to 2426 mm in Haridwar and Pithoragarh district of state, respectively. Annually the average rainfall varies from 927.7 mm in Joshimath of Chamoli district to 2599.4 mm at Munsyari of Pithoragarh district.

At present situation, Almora is receiving 23% less annual rainfall in comparison to its 53 years record while Manora peak in Nainital is receiving 16% less rainfall than last 39 years

Table-2.6.
Important khals in Uttarakhand[6]

Khal Name	Area	Khal Name	Area
Agra Khal	Tehri	Kheda Khal	Rudraprayag
Adhari Khal	Pauri	Kheda Khal	Pauri
Adali Khal	Ghumakot area, Pauri	Khamba Khal	Narendra Nagar, New Tehri
Eda Khal	Pauri	Khandon Khal	Pauri
Uphren Khal	Thalisen area, Pauri	Khaneta Khal	Rikhni Khal area, Pauri
Kandi Khal	Tehri	Gum Khal	Pauri
Kilvo Khal	Pauri	Geendhi Khal	Pauri
Kaddu Khal	Pauri	Gond Khal	Vamansyuen, Pauri
Kaddu Khal	Tehri	Gudiyan Khal	Pauri
Kando Khal	Pauri	Gudiyal Khal	Tehri
Kanden Khal	Pauri	Gindon Khal	Pauri
Kanda Khal	Rudraprayag	Gahad Khal	Rudraprayag, Chamoli
Kankhi Chauri Khal		Moti Khal	Yunud area, Pauri
Kamed Khal	Pauri	Godkhya Khal	Pauri
Kalji Khal	Pauri	Ged Khal	Yamkeshwar area, Pauri
Keti Khal	Pauri	Pween Khal	Veeronkhal area, Pauri
Kirti Khal	Pauri	Gwah Khal	Pauri
Ketuna Khal	Chopra area, Pauri	Goli Khal	Pauri
Karen Khal	Dugadda area, Pauri	Ghodo Khal	Pauri
Kingodi Khal	Pauri	Ghoda Khal	Nainital
Queela Khal	Ghansali area, Tehri	Ghimtoli Khal	Chamoli
Kola Khal	Pokhra, Pauri	Ghaulkhet Khal	Jahri Khal area, Pauri
Kot Khal	Rudraprayag	Ghai Khal	Nelgaad area, Dugadda Pauri
Kot Khal	Ekeshwar area, Pauri	Chilbatiya Khal	Pauri
Kulas Khal	Lansdowne area, Pauri	Chamthara Khal	Kaljikhal Block, Pauri
Kota Devi Khal	Veero Khal, Pauri	Chaubatta Khal	Pauri
Kur Khal	Ekeshwar area, Pauri	Chakhulya Khal	Pauri
Kundja Khal	Pokhra, Pauri	Chauri Khal	Quveesed area, Pauri
Kanodha Khal	Pokhra, Pauri	Chee Khal	Pauri
Kunj Khal	Pokhra, Pauri	Chamkot Khal	Udaipur, Pauri
Khanjur Khal	Karanprayag area	Chauras Khal	Chamoli
Khareni Khal	Bhachula area	Chillar Khal	Lansdowne area
Chandni Khal	Chamoli	Diloli Khal	Veeron Khal area, Pauri
Chaud Khal	Yamkeshwar Pauri	Devi Khal	Chamoli
Chimliya Khal	Pauri	Dev Khal	Dugadda area, Pauri
Chametha Khal	Pauri	Dev Khal	Chamoli
Chanchi Khal	Rudraprayag area	Dilvali Khal	Chamoli
Jamna Khal	Pauri	Digoli Khal	Chamoli
Jakhot Khal	Srinagar area, Pauri	Deval Khal	Dugadda area, Pauri
Jamla Khal	Pauri	Divoli Khal	Veeron Khal area, Pauri
Jamni Khal	Pauri	Thari Khal	Rudraprayag

Khal Name	Area	Khal Name	Area
Jaikhuri Khal	Chandrabdani patti, Tehri	Nali Khal	Pauri
Jehri Khal	Pauri	Narangi Khal	Pauri
Jaspur Khal	Baijron area, Pauri	Nagchulla Khal	Gairsend area, Pauri
Jadau Khal	Dugadda area, Pauri	Na- Khal	Pauri
Jakhmol Khal		Naud Khal	Dugadda area, Pauri
Jairaj Khal	Pauri	Naugaon Khal	Pauri
Jitopi Khal	Pauri	Nathu Khal	Dugadda, Pauri
Ja. Khal	Rudraprayag	Peeron Khal	Pauri
Dera Khal	Pauri	Pokhri Khal	Pauri
Danji Khal	Narendra Nagar area, Tehri	Pou- Khal	Tehri
Doliyar Khal	Nanidada area, Pauri	Pou- Khal	Pauri
Dyod Khal	Ranikhet area, Nainital	Parsunda Khal	Pauri
Dhadoli Khal	Pauri	Pongar Khal	New Tehri
Dhaddu Khal	Maniyarsyun Patti, Pauri	Pokhar Khal	Yamkeshwar, Pauri
Dhanw Khal	Rikhnikhal Patti, Pauri	Pauri Khal	New Tehri
Tungeshwar Khal	Tharali area, Chamoli	Pandawa Khal	Karanprayag, Chamoli
Tuna Khal	Dugadda area, Pauri	Patan Khal	Tehri
Tilthar Khal	Yamkeshwar area, Pauri	Par Khal	Chamoli
Turan Khal	Ritheni Khal area, Pauri	Pasi Khal	Nainidanda, Pauri
Timal Khal	Pavo area, Pauri	Buwa Khal	Pauri
Tun Khal	Chamoli	Boong Khal	Pauri
Tuna Khal	Naugaon Khal area, Pauri	Banj Khal	Pauri
Dwari Khal	Pauri	Veeron Khal	Pauri
Tuthan Khal	Pauri	Bagani Khal	Pauri
Devral Khal	Pokhda area, Pauri	Bacheli Khal	Tehri
Minari Khal	New Tehri	Badeth Khal	Pauri
Kinara Khal	New Tehri	Beri Khal	Pauri
Disauli Khal	Gopeshwar, Chamoli	Bahera Khal	Pauri
Deval Khal	Dugadda area, Pauri	Vishal Khal	Gopeshwar
Bun- Khal	Thalisen area, Pauri	Liya Khal	Pokhda area, Pauri
Buchcha Khal	Jahrikhal, Pauri	Laludi Khal	Tehri
Bda Khal	Dugadda area, Pauri	Shashi Khal	Tarad-jakh area, Nainital
Buransi Khal	Veeron Khal, Pauri	Seeku Khal	Pauri
Volka Khal	Chamba, Tehri	Sidhi Khal	Pauri
Virak Khal	Ghansaali, Tehri	Seeran Khal	Rudraprayag
Bhrigu Khal	Pauri	Santera Khal	Chamoli
Bhairang Khal	Bainjron area, Pauri	Sabdhar Khal	Chamoli
Bhamrai Khal	Pauri	Swari Khal	Chamoli
Bharoli Khal	Bainjron area, Pauri	Sounp Khal	Bainjron area, Pauri
Bhagdwari Khal	Raipur area, Dehradun	Sameela Khal	Chamoli
Mentala Khal	Narendranagar area, Tehri	Sundri Khal	Chamoli

Khal Name	Area	Khal Name	Area
Bhairang Khal	Sanraikheit, Nainital	Sungar Khal	Chamoli
Bhoun Khal	Nainital	Sirko Khal	Tehri
Baisala Khal	Pratap Nagar, Tehri	Silka Khal	Tehri
Mohan Khal	Chamoli	Siddha Khal	Rikhanikhal, Pauri
Manda Khal	Chamoli	Satya Khal	Pauri
Mond Khal	Chamoli	Sirala Khal	Pauri
Molkha Khal	Rudraprayag	Simar Khal	Satpuli area, Pauri
Maud Khal	Lansdowne area, Tehri	Santa Khal	Bhilangana area, Tehri
Mend Khal	Chamba area, Tehri	Sundar Khal	Veeron Khal, Pauri
Mast Khal	Pauri	Sediya Khal	Pokhara, Pauri
Mayadevi Khal	Devprayag Tehri	Sajja Khal	Kaljikhal area, Pauri
Male Khal	Almora	Hinsara Khal	Pauri
Maithan Khal	Rudraprayag	Haldu Khal	Pauri
Rikhni khal	Pauri	Hadeti Khal	Pauri
Rehad Khal	Rudraprayag	Hindola Khal	Narendra Nagar area, Tehri
Reetha Khal	Pauri	Hinsaria Khal	Tehri
Rawai Khal	Bageshwar	Hathi Khal	Lalkuan area
Rayalkham Khal	Nainidanda, Pauri	Shrikot Khal	Yamkeshwar area, Pauri
Rathi Khal	Pauri		

Table-2.7.
Year-wise discharge of water sources (Gadhera/Spring)[7]

Source Name	Block & District	Year-wise Discharge (L.P.M.)		
		2005	2006	2007
Chargaadkhadda Gadhera	Kalsi, Dehradun	20	18	18
Kimodhikhadda Gadhera	Kalsi, Dehradun	7	6	8
Chapnukhadda Spring	Kalsi, Dehradun	6	5	7
Dandapani Spring	Kalsi, Dehradun	9	8	8
Bairaadkhadda Spring	Kalsi, Dehradun	12	11	12
Pothi Spring	Kalsi, Dehradun	5	4	5
Khadig Spring	Kalsi, Dehradun	18	16	18
Khauldakhadda Gadhera	Kalsi, Dehradun	5	4	6
Paneerkhadda Gadhera	Kalsi, Dehradun	5	4	6
Churani Spring	Kalsi, Dehradun	1	1	1
Bairaadkhai Spring	Kalsi, Dehradun	5	4	4
Pankhal Gadhera	Raipur, Dehradun	5	4	4
Mahadevkhala Gadhera	Doiwala, Dehradun	90	60	60
Khajritok Gadhera	Dwarikhal, Pauri	2.50	7	7
Sand Gadhera	Dwarikhal, Pauri	15	18	18
Silla Gadhera	Dwarikhal, Pauri	5	5	10
Datmiya Gadhera	Dwarikhal, Pauri	10	9	13
Moligadhar Gadhera	Dwarikhal, Pauri	9	8	18
Khera Gadhera	Dwarikhal, Pauri	4	4	8
Bhasund Dhar Gadhera	Dwarikhal, Pauri	10	10	14

Source Name	Block & District	Year-wise Discharge (L.P.M.)		
		2005	2006	2007
Danda Gadhera	Dwarikhal, Pauri	8	8	15
Palla Gadhera	Dwarikhal, Pauri	3	3	6
Pawal Gaad Spring	Dwarikhal, Pauri	2	1	3
Odaltok Gadhera	Dwarikhal, Pauri	4	3	5
Dhuliya Gadhera	Dwarikhal, Pauri	8	7	16
Kirmoli Gadhera	Dwarikhal, Pauri	9	8	15
Jwadkapani Gadhera	Dwarikhal, Pauri	6	6	8
Budhani Spring	Dwarikhal, Pauri	5	5	7
Pagaari Gadhera	Dwarikhal, Pauri	3	7	10
Bakariyatok Gadhera (Simalkhal Scheme)	Dwarikhal, Pauri	4	12	13
Bakariyatok Gadhera (Sarramsogi Scheme)	Dwarikhal, Pauri	5	14	15
Kafalgedi Spring	Dwarikhal, Pauri	5	14	14
Gwind Gadhera	Dwarikhal, Pauri	8	10	15
Kaludighat Gadhera	Dwarikhal, Pauri	15	12	35
Khitdiya Spring	Dwarikhal, Pauri	6	14	13
Ghursingi Gadhera	Dwarikhal, Pauri	12	15	20
Kalodighat Gadhera (Kola Scheme)	Dwarikhal, Pauri	10	16	16
Bhalugaad Spring	Dwarikhal, Pauri	6	18	18
Motipani Spring	Dwarikhal, Pauri	7	7	10
Patalkhali Gadhera	Dwarikhal, Pauri	8	8	10
Naugarh Spring	Dwarikhal, Pauri	5	3	10
Syalin Gadhera	Dwarikhal, Pauri	8	8	9
Kalodighat Gadhera (Bhalgaon Scheme)	Dwarikhal, Pauri	12	10	12
Chinwau Gadhera (Dholkheit Khal Scheme)	Jairikhal, Pauri	17	16	21
Gudalgaad Spring	Jairikhal, Pauri	19	18	20
Bangarh Gadhera	Jairikhal, Pauri	15	15	12
Goiyon Gadhera	Jairikhal, Pauri	21	18	20
Chinwau Gadhera (Asankheit Scheme)	Jairikhal, Pauri	10	18	22
Dugaddagaad Gadhera	Tholdhar, New Tehri	15	18	21
Chotapani Spring	Tholdhar, New Tehri	8	8	10
Buranskhal Gadhera	Tholdhar, New Tehri	5	8	9
Kodiya Spring	Tholdhar, New Tehri	12	12	17
Bhenger Scheme Spring	Tholdhar, New Tehri	Maintained by UPJN		23
Oriyagaad Gadhera	Tholdhar, New Tehri	8	8	10
Baginamitik Spring	Tholdhar, New Tehri	5	6	11
Gaddugaad Gadhera (Uppu Sirai Scheme)	Tholdhar, New Tehri	8	6	18

Source Name	Block & District	Year-wise Discharge (L.P.M.)		
		2005	2006	2007
Kiyagaad Gadhera	Tholdhar, New Tehri	5	6	11
Hadgigaad Gadhera	Tholdhar, New Tehri	Completely Merged Area		
Borgaad Gadhera	Tholdhar, New Tehri	25	29	30
Sankari Santro Gadhera	Tholdhar, New Tehri	Completely Merged Area		
Uttisa Gadhera + Tyaadgaad Spring	Tholdhar, New Tehri	3	3	7
Bildiyana Spring	Tholdhar, New Tehri	12	1	3
Rigliyaan Gadhera + Drigddagaad Spring	Tholdhar, New Tehri	20	21	42
Kaithogigaad Gadhera	Tholdhar, New Tehri	8	9	64
Bholapani Kafalpani Spring	Tholdhar, New Tehri	1	0	1
Kulegalagaad Gadhera	Tholdhar, New Tehri	5	8	13
Gholdsari Gadhera	Tholdhar, New Tehri	5	8	11
Gaddakheit Gadhera	Tholdhar, New Tehri	2	4	6
Chiliyasa Gadhera	Tholdhar, New Tehri	20	20	27
Badadungagaad Gadhera	Tholdhar, New Tehri	15	17	20
Ramolsari Gadhera	Tholdhar, New Tehri	15	16	24
Khamoligaad Gadhera	Tholdhar, New Tehri	10	9	7
Gaddugaad Gadhera (Plas Dobra Scheme)	Tholdhar, New Tehri	5	6	13
Kodia Dabri Scheme Spring	Tholdhar, New Tehri	5	9	17
Chakpali Gadhera	Tholdhar, New Tehri	6	7	11
Devidhar Scheme Gadhera	Tholdhar, New Tehri	4	4	3
Riyankhapani Gadhera	Tholdhar, New Tehri	3	3	7
Grakheit Mandel Gadhera	Tholdhar, New Tehri	1	1	9
Raipali Scheme Gadhera	Tholdhar, New Tehri	1	1	6
Kundkhala Gadhera	Jaunpur, New Tehri	10	10	11
Khadidhar Hariyapani Spring	Jaunpur, New Tehri	7	12	9
Sarwala Gadhera	Jaunpur, New Tehri	18	30	29
Genwali Spring	Jaunpur, New Tehri	8	10	7
Siyapani Spring	Jaunpur, New Tehri	15	10	11
Sathkhala Spring	Jaunpur, New Tehri	40	15	13
Khaluda Gadhera	Jaunpur, New Tehri	10	2	8
Ganjar Spring	Jaunpur, New Tehri	2	2	2
Munkhala Spring	Jaunpur, New Tehri	5	5	6
Gunmani Spring (Patwada Scheme)	Jaunpur, New Tehri	7	2.5	3
Gunmani Spring (Patwada Gunwani Scheme)	Jaunpur, New Tehri	8	8	9
Headkhadda Spring	Jaunpur, New Tehri	5	5	6
Amarkhala Spring	Jaunpur, New Tehri	2	3	2

Source Name	Block & District	Year-wise Discharge (L.P.M.)		
		2005	2006	2007
Mudia naametok Scheme Spring	Jaunpur, New Tehri	-	4	3
Chaukikhala Spring	Jaunpur, New Tehri	2	2	2
Duwaliyaan Spring	Jaunpur, New Tehri	2	2	2
Davyaana Spring	Jaunpur, New Tehri	1	2	3
Daudhsdilakhala Spring	Jaunpur, New Tehri	0	0	1
Bithwal Spring	Jaunpur, New Tehri	2	8	10
Loharkhalspring	Jaunpur, New Tehri	40	25	27
Gadhriyan Gadhera	Augustyamuni, Rudraprayag	48	46	50
Andhergaddi Spring	Augustyamuni, Rudraprayag	10	10	15
Naagkheit Gadhera	Augustyamuni, Rudraprayag	10	10	15
Vidhyadhar Spring	Augustyamuni, Rudraprayag	15	15	20
Aarukhark Spring	Augustyamuni, Rudraprayag	14	14	15
Masaanmeeta Spring	Augustyamuni, Rudraprayag	12	12	15
Dolya Gadhera	Augustyamuni, Rudraprayag	54	54	60
Kothila Spring	Augustyamuni, Rudraprayag	72	72	60
Kalabanj Spring	Augustyamuni, Rudraprayag	20	20	40
Radadungi Spring	Augustyamuni, Rudraprayag	36	26	30
Silica Spring	Augustyamuni, Rudraprayag	15	15	18
Kandara Spring	Augustyamuni, Rudraprayag	14	14	15
Sogla Spring	Augustyamuni, Rudraprayag	15	15	15
Urantoli Spring	Augustyamuni, Rudraprayag	30	30	35
Manigaad Spring	Augustyamuni, Rudraprayag	18	18	30
Segdam Spring	Augustyamuni, Rudraprayag	40	40	25
Langhat Spring	Augustyamuni, Rudraprayag	32	32	90
Golani Spring	Augustyamuni, Rudraprayag	29	29	30
Buransgaad Spring	Augustyamuni, Rudraprayag	29	29	40

Source Name	Block & District	Year-wise Discharge (L.P.M.)		
		2005	2006	2007
Bhainrogaad Spring	Augustyamuni, Rudraprayag	29	15	20
Rikhnau Spring	Augustyamuni, Rudraprayag	20	15	18
Banj Spring	Augustyamuni, Rudraprayag	30	30	30
Thapli Gadhera	Augustyamuni, Rudraprayag	15	15	30
Surnaodiyaari Gadhera	Gairsain, Chamoli	12	12	15
Dhuma Gadhera	Gairsain, Chamoli	2	2	3
Dwarigaad Gadhera + U. Koop No. 2	Gairsain, Chamoli	33	95	97
Uroli Gadhera (Jaamad Scheme)	Dwarahat, Almora	-	-	-
Khiru Gadhera	Dwarahat, Almora	12	12	13
Vimandeshwar Gadhera	Dwarahat, Almora	12	8	7.5
Bubudham Gadhera	Dwarahat, Almora	-	3.7	5
Tumdi Spring	Dwarahat, Almora	6	5	5
Banali Gadhera	Dwarahat, Almora	19	17	17
Bamsyari Gadhera	Dwarahat, Almora	32	31.20	33
Bubuman Gadhera (Naini Scheme)	Dwarahat, Almora	16	14	13
Paltharkhari Gadhera	Dwarahat, Almora	44	40	38
Bubuman Gadhera (Chanbheit Scheme)	Dwarahat, Almora	54	59.50	46
Dashek Gadhera	Dwarahat, Almora	0.0	0.0	6
Dosaad Gadhera (Mallamelta Scheme)	Dwarahat, Almora	4	3	3
Kaligaad Gadhera	Dwarahat, Almora	9	7.5	10
Bainoli Gadhera	Dwarahat, Almora	11	9	12
Uroli Gadhera (Babarkhola Scheme)	Dwarahat, Almora	14	10	10
Uchal Gadhera	Dwarahat, Almora	25	21.50	23
Riskan Gadhera	Dwarahat, Almora	55	49	45
Dosaad Gadhera (Chabbisatok Scheme)	Dwarahat, Almora	5	4	4
Cheeda Gadhera	Chaukhutia, Almora	19	16	18
Jaitha Gadhera	Chaukhutia, Almora	13	11.50	11
Jalaganj Spring	Chaukhutia, Almora	5	2.5	3
Mahatgaon Gadhera	Chaukhutia, Almora	5	4	4
Dantola Gadhera	Chaukhutia, Almora	14	13.50	10
Aamdali Gadhera	Chaukhutia, Almora	15	12	11
Bhosifgaad Gadhera	Chaukhutia, Almora	19	16.50	18
Taralgaon Gadhera	Chaukhutia, Almora	13	10.50	10

Source Name	Block & District	Year-wise Discharge (L.P.M.)		
		2005	2006	2007
Bmangaon Gadhera (Bmangaon Scheme)	Chaukhutia, Almora	10	6	7
Majgad Gadhera	Chaukhutia, Almora	15	13	11
Cheeda Gadhera	Chaukhutia, Almora	13	9.50	8
Sungadi Gadhera	Chaukhutia, Almora	3	2.60	2.50
Talai Gadhera	Chaukhutia, Almora	0.0	0.0	2
Kotyuda Gadhera	Chaukhutia, Almora	1.0	1.0	1.50
Taalgaon Gadhera	Chaukhutia, Almora	13	11.50	11
Maludhar Spring	Chaukhutia, Almora	5	4.50	4.50
Fadeekwasikhalen Gadhera	Chaukhutia, Almora	13	11	12
Aamdali Gadhera	Chaukhutia, Almora	18	15.50	14
Dhargaad Gadhera	Chaukhutia, Almora	15	13.50	12
Majhgad Gadhera	Chaukhutia, Almora	10	9	8.50
Dobri Gadhera	Chaukhutia, Almora	9	3	7
Kaugaad Gadhera (Kotyuda Simar Scheme)	Chaukhutia, Almora	29	26.50	28
Pandeykhatta Gadhera	Chaukhutia, Almora	19	18	17.50
Garj Gadhera	Chaukhutia, Almora	13	10.50	10
Kaugaad Gadhera + Cham Gadhera (Chabisa Gramsamuh Scheme)	Chaukhutia, Almora	23	21	20
Bijrani Gadhera	Chaukhutia, Almora	9	7.50	10
Tdagtal Gadhera	Chaukhutia, Almora	55	52	54
Dobri Gadhera	Chaukhutia, Almora	15	16	10
Koldi Gadhera	Chaukhutia, Almora	13	12	14
Bmangaon Gadhera (Naugaon Akhedia Scheme)	Chaukhutia, Almora	24	21	24
Agragaad Gadhera	Chaukhutia, Almora	17	15	14
Ulenigaad Gadhera	Chaukhutia, Almora	18	17.50	14
Kunigaad Gadhera	Chaukhutia, Almora	48	43	46
Querali Gadhera (Khdkta Scheme)	Chaukhutia, Almora	23	21	20
Paludhar Gadhera	Chaukhutia, Almora	16	14	12
Bmangaon Gadhera (Gwali Gram Sabha Scheme)	Chaukhutia, Almora	18	15.50	15
Querali Gadhera (Querali Scheme)	Chaukhutia, Almora	18	14	12.50
Jukani Pandeykhatta Spring	Chaukhutia, Almora	19	16	15
Kanyali Gadhera	Chaukhutia, Almora	18	15	14
Dholgaad Spring	Chaukhutia, Almora	10	6	8
Munya Gadhera + Mutiya Spring	Chaukhutia, Almora	65	60	58
Lalu Gadhera + Lalu Spring	Chaukhutia, Almora	15	13.50	12

Source Name	Block & District	Year-wise Discharge (L.P.M.)		
		2005	2006	2007
Nakot Gadhera	Sult, Almora	2	2	3
Khila Gadhera	Sult, Almora	8	6	4
Kumaad Gadhera	Sult, Almora	10	8	4
Dhanedi Gadhera	Sult, Almora	12	10	6
Khepda Gadhera	Sult, Almora	9	7	5
Jauhaar Rkta Spring	Sult, Almora	4	4	4
Charan Gadhera	Sult, Almora	6	6	6
Kahuaarola Gadhera	Sult, Almora	8	5	6
Bansliya Gadhera	Sult, Almora	3	3	4
Suvapani Gadhera	Sult, Almora	5	5	5
Chachdi Gadhera	Sult, Almora	5	5	5
Kande Gadhera	Sult, Almora	5	5	5
Godkheit Gadhera	Bageshwar, Bageshwar	22	25	25
Gwad Spring	Bageshwar, Bageshwar	3	7	5
Kulodiya Gadhera	Bageshwar, Bageshwar	15	12	12
Laksuna Gadhera	Bageshwar, Bageshwar	8	20	-
Kaligaad Gadhera	Bageshwar, Bageshwar	18	20	20
Simkuni Gadhera	Bageshwar, Bageshwar	8	10	10
Local Spring (Manikheit Scheme)	Bageshwar, Bageshwar	6	10	5
Kheravgari Gadhera	Gangolihaat, Pithoragarh	26	25	20
Samoda Fulai Gadhera	Gangolihaat, Pithoragarh	30	28	28
Tundil Gadhera	Gangolihaat, Pithoragarh	20	15	15
Simlata Gadhera	Gangolihaat, Pithoragarh	22	18	18
Nardiya Gadhera	Gangolihaat, Pithoragarh	23	15	10
Sanni Gadhera	Vin, Pithoragarh	15	10	10
Bhalu Patal Spring	Vin, Pithoragarh	10	10	5
Amar Singh Thaud Spring	Vin, Pithoragarh	10	8	6
Gurnatoli Majhela	Munakot, Pithoragarh	Source dried completely, UPJN is regenerating this source.		

Table-2.8.
District wise normal monthly and annual rainfall data (in mm) of Uttarakhand (from 1901 to 1970)[1]

District	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Dehradun	57.4	55.8	37.6	17.1	34.0	178.9	686.9	751.5	314.5	47.1	7.8	37.4	2212.0
Haridwar	48.1	45.8	24.5	9.8	19.9	108.9	360.1	393.8	190.2	34.3	5.4	15.4	1256.2
Chamoli	103.0	107.8	114.5	57.2	47.9	117.1	314.4	322.0	169.0	51.4	23.5	47.0	1474.8
Tehri Garhwal	64.1	50.5	57.5	25.9	47.0	120.7	374.3	339.8	207.2	62.5	10.6	34.5	1394.6
Uttarkashi	102.4	59.2	90.4	46.6	72.7	128.8	400.3	426.5	301.4	46.9	20.4	36.5	1732.1
Pauri Garhwal	58.9	59.8	41.9	23.5	45.0	151.4	412.9	402.5	188.9	43.7	6.8	23.0	1458.4
Almora	54.8	56.5	49.8	32.4	56.8	162.4	345.5	321.5	165.5	56.0	7.5	21.6	1330.3
Nainital	37.7	33.4	18.7	8.6	27.2	173.6	466.2	454.7	239.7	52.2	3.9	11.9	1527.8
Pithoragarh	257.8	193.4	190.9	78.2	70.9	239.4	496.7	441.8	290.9	57.2	32.4	76.3	2425.9

(1964-2003)[10]. The rainfall rythm is gradually changing due to climate change which is clear from the shifting of rainfall peak in annual hyetograph of Almora and Salla Rautela village[10].

2.4.2. Surface Water Resources

In the past, several organizations and individuals have estimated water availability for the nation within the limitations of physiographic conditions and socio-political environment, legal and constitutional constraints and the technology of development available differently. Utilizable water resource is the quantum of withdrawable water from its place of natural occurrence. The National Commission for Integrated Water Resources Development (NCIWRD, 1999)[11] has estimated the basin-wise average annual flow in Indian river systems as 1953 km^3 and the utilizable annual surface water of the country is 690 km^3. Water Resource assessment is an arduous task as it is dynamic in nature. However an attempt has been made to capture and present the best possible data available.

2.4.2.1. River Basins and Rivers

A River basin is considered as the basic hydrological unit for planning and development of water resources. There are 12 major river basins with catchment area of more than 20000 km^2 in India. The total catchment area of these rivers is about 25.3 lakh km^2. Uttarakhand has three main river basins as:

- Bhagirathi – Alaknanda basin – Ganga basin
- Yamuna – Tons basin and
- Kali system

Table 2.9 presents the comparison of ground water potential of Ganga basin with North-east composite basin[12].

Uttarakhand is the birth state of several Indian rivers out of which Ganga, Yamuna, Ramganga and Sharada are the main rivers. The state also possess total 968 Himalayan glaciers which have 213.74 cubic km total ice volume and cover 31449.3 km^2 basin area and 2883.37 km^2 (i.e. 9.17%) glacierised area including Chorbani, Gangotri, Khatling, Nandadevi glaciers etc[13] (refer Glacier Chapter). The state has a long network of perennial and seasonal streams and is drained by number of rivers and local water streams like Gad, Gadhera, Naula etc.

The Ganga river system drains a major part of Garhwal. The main tributaries of the Ganga river are Alaknanda, Bhagirathi, Bhilangana, Saraswati, Jad Ganga, Dauli Ganga, Berahi

Table-2.9.
Ground water potential in river Ganga and Northeast composite basins of India (in km³/year)[12]

Name of the basin	Total replenis-able ground water resources	Provision for domestic, industrial and other uses	Available ground water for irrigation	Net draft	Balance ground water potential	Level of ground water development (%)
Ganga	170.99	26.03	144.96	48.59	96.37	33.52
Northeast Composite	18.84	2.83	16.02	2.76	13.26	17.20

Ganga, Nandakini, Mandakini, Madhu Ganga, Pinder, Atagad, Kaldi Gad etc. The Yamuna river which emerges from Yamunotri, has Giri and Tons rivers as its main tributaries. Other than these rivers, glaciers, lakes, innumerable streams, springs etc. also constitute a major part of water resources.

The northern part of Uttarakhand is formed by Indo-Chinese border, the southern part by terai and Gangetic plain region of Uttar Pradesh, western part by Tons-Yamuna rivers bordering Himachal Pradesh and eastern part by rivers Kali-Sarda bordering Nepal. A major part of Uttarakhand is drained by the Ganga system which originates from Gangotri Glacier and named as Bhagirathi and joined by Bhilangana at Tehri and Alkananda at Devprayag and from where it acquires the name of 'Ganga'. Dhauliganga, Pindar and Mandakini rivers join Alaknanda river as the major tributaries besides other smaller rivers. In downstream of Devprayag, Nayar from the east and Song from the west then draining Dun valley, join finally to river Ganga. One fourth part of the Kumaun region is drained by Kali river (also named as Sharda in the lower part). The important tributaries of Kali river are Gori Ganga, Ramganga, Dhauli Ganga, Ladhiya and Sarju. Kali river also drains whole of the Pithoragarh, Champawat districts, the eastern part of Bageshwar; Almora and Nainital district. Some parts of Udham Singh Nagar district and Garhwal region are drained by Western Ramganga which originates from Dudhatoli range of Pauri district and meets the river Ganga in plain.

2.4.2.2. River Water Pollution

The Himalayan Rivers are the lifelines of a majority of population residing in Uttarakhand and other parts of country. Beside being a source of Drinking Water, the holy water of these rivers is being utilized by masses for routine bathing and holy drips during festival seasons. Various soaps, detergents, milk products like curd, ghee, idols, flowers, ashes of cremenated ones, flowers, sewage, polythene bags etc. are being disposed in the rivers there by polluting these water bodies. Water stretches of the rivers and tributaries as per the pollution level are classified in Table 2.10. However, a study of the Himalayan river water quality, the biological water quality of classes A, B, C, D and E, did not show significant change in the levels of physico-chemical parameters of water (Table 2.11 and Table 2.12)[14].

Table-2.10.
Classification of water stretches of the rivers and tributaries in Uttarakhand[14]

Rivers & Tributaries	River Stretch's Location	Taxa/families of benthic macro-invertebrates present in water bodies
Class A i.e. Clean Water Stretches of the Rivers and Tributaries in Uttarakhand		
Bhagirathi	Gangotri, District Uttarkashi Downstream Lohari Nag-pala Hydroelectric Project U/S Maneri Bhali, Phase-I, Near Jhulapul Inlet Maneri Bhali, Phase-I, Keshavpuram Outlet Maneri Bhali, Phase-I Inlet Maneri Bhali, Phase-II 2 km downstream Maneri Bhali, Phase II Upstream Uttarkashi Downstream Uttarkashi Upstream Nagon Gadhera, Dharasu Bhagirathi Upstream Old Tehri, Malideval	**Ephemeroptera:** Ephemerellidae, Heptageniidae, Caenidae, Pothaminthidae, Ephemeridae, Siphonuridae, Baetidae **Plecoptera:** Nemouridae, Perlidae, Capniidae, Leuctridae, Perlodidae, Taeniopterygidae, Cryptoperla **Trichoptera:** Leptoceridae, Hydropsychidae, Brachycentridae, Rhyacophilidae, Sericostomatidae, Polycentropodidae, Georidae, Philopotamidae, Hydroptilidae.
Bhilangana	Before confluence to River Bhagirathi at Kandal village in Old Tehri area	**Hemiptera:** Aphelocheiridae
Alaknanda	Badrinath, Second Hydel Project, Bamni 250 m upstream Vishnuprayag Barrage, access on NH-58 In front of Switch Yard, Downstream Power House of Vishnuprayag Hydroelectric Project Birahi, after confluence of Birahiganga Rudraprayag, opposite temple, upstream of sangam Rudraprayag, after confluence to River, Mandakini, GMVN Guest House Kaliyasaur, Near Dhari Devi Temple	**Coleoptera:** Hydrophilidae, Psephenidae, Dytiscidae, Gyrinidae **Planaria:** Planariidae **Diptera:** Blepharoceridae, Tipulidae, Simulidae, Chironomidae, Tabanidae
Nagon Gadhera	Downstream in Dharasu	**Odonata:** Euphaeidae, Gomphidae, Libellulidae
Dhauliganga	Tapovan village, Vishnugad barrage site in District Joshimath	---
Birahiganga	Birahi, before confluence to River Alaknanda, 6 km from Chamoli	Lymnaeidae, Mollusca/Viviparidae
Pindar	Meeng, near Karanprayag bridge, before confluence to River Alaknanda	Cordyladidae/Megaloptera
Nandakini	Near bridge in Nandprayag, before confluence to River Alaknanda	Hirudinea/Erpobdellidae, Glossiphonidae, Hirudidae

Rivers & Tributaries	River Stretch's Location	Taxa/families of benthic macro-invertebrates present in water bodies
Mandakini	2 km from Tilwara before confluence to River Alaknanda upstream Rudraprayag	Polychaeta/Gordiidae
Kosi	Jorasi in District Almora	---
Dhauliganga	Baity village, 7 km upstream Dhauliganga barrage in District Pithoragarh Near Tawaghat, Downstream of Dhauliganga barrage before confluence to Kali River	Oligochaeta/Oligichaetes
Kali	2 km upstream Tawaghat on NH-29, 13 km from NHPC Guest House. After confluence to River Dhauliganga at Tawaghat of District Pithoragarh, Upstream Power House	---
Saryu	Saling Udiyar, 3 km from Loharkhet Micro Hydel Project near Tapt-Kund Maziakhet, 3 km from KMVN in downstream of Bageshwar Ghat, before confluence to Kali River in District Pithoragarh	---
Ganga	Kaudiyala, Near Rafting Club Downstream Veer Bhadra Barrage in Rishikesh	---
Song	14 km from Haridwar, Near Satyanarayan Temple	---
Gomti	Kailasu, in upstream Bageshwar before confluence to Saryu River	---
Yamuna	Juddo village, near Panchayat Bhawan Lakhwar Dam downstream Dak Pathar	---
Class B i.e. Slightly Polluted Water Stretches of the Rivers and Tributaries in Uttarakhand		
Bhagirathi	Gangotri in District Uttarkashi (May 2005)	**Ephemeroptera:** Leptophlebiidae, Heptageniidae, Baetidae Ephemeridae, Ephemerellidae
Sarju	Harsila, downstream Kapkot	**Trichoptera:** Leptoceridae, Polycentropodidae,Goeridae, Hydropsychidae
Sharda	In Upstream of Tanakpur barrage, Hanumangadi, District Champawat	**Plecoptera:** Perlidae, Nemouridae.
Gomti	Kukarigad , upstream Bageshwar	**Mollusca:** Lymnaeidae
Ganga	Muni Ki Reti in Rishikesh	**Hemiptera:** Aphelocheiridae, Gerridae **Diptera:** Simulidae, Chironomidae **Coleoptera:** Hydrophilidae, Dytiscidae, Psephenidae **Megaloptera:** Corydalidae **Hirudinea:** Glossiphonidae **Crustacea:** Grabsidae
Class C i.e. Moderately Polluted Water Stretches of the Rivers and Tributaries in Uttarakhand		
Bhagirathi	In Downstream Dharasu after confluence of Nagon Gadhera	Ephemeroptera/Heptageniidae, Ephemeridae, Caenidae, Bactidae

Rivers & Tributaries	River Stretch's Location	Taxa/families of benthic macro-invertebrates present in water bodies
Alaknanda	In Downstream of Vishnu Prayag barrage, (opposite NH-58)	Trichoptera/Rhycophilidae, Polycentropodidae, Hydropsychidae
Sharda	In Upstream of Tanakpur barrage, Brahmdev, District Champawat In Downstream of Power House, Tanakpur (Near NHPC) rehabilitation village on NH-125 of District Champawat	Hemiptera/Nepidae Coleoptera/Dytiscidae Diptera/Simulidae, Tipulidae, Chironomidae Megaloptera/Cordyladidae
Kali	Naya Basti in downstream of Dharchula, District Pithoragarh	Odonata/Libellulidae, Euphaeidae, Gomphidae
Ramganga	In Downstream of Kalagadh barrage, Afjalgarh, Kalagadh	Mollusca/Thiaridae, Hirudidae, Hirudinea/Glossiphonidae, Lymnacidae
Class D & E i.e. Highly Polluted Water Stretches of the Rivers and Tributaries in Uttarakhand		
Heavily polluted Bhagirathi	Maneri Bhali Phase-I, Reservoir	Planaria/Planariidae Oligochaeta/Oligochaetes Mollusca/Thiaridae Hemiptera/Corixidae
Severely polluted Bhagirathi	Old Tehri, near Mosque Downstream Tehri Dam, Zero point Inlet of diversion tunnel, THDC Ltd., Koteshwar 2 km upstream of Devprayag, near Hydel Colony, Bagwan	No families of benthic macro-invertebrates
Dhauliganga	Upstream Dhauliganga barrage near bridge, District Pithoragarh Chirkila, Damsite, District Pithoragarh	---
Ramganga	Upstream Kalagarh Dam, Dhikala, Corbett National Park, District Pauri Garhwal	---

Table-2.11.
Average values of physico-chemical water quality levels for various biological water quality classes[14].

Characteristic/ Parameter	Class A (Clean)	Class B (Slight pollution)	Class C (Moderate pollution)	Class D (Heavy pollution)	Class E (Severe pollution)
pH	7.25	7.36	7.23	7.23	7.36
Conductivity (μ mho/cm)	151.96	172.75	175.0	165.0	164.28
Air Temp. (°C)	21.69	23.83	24.08	21.5	26.34
Air Temp. (°C)	15.32	17.41	14.66	14.0	16.0
Hardness (Total, mg/l)	65.0	73.0	73.25	61.0	79.0
Alkalinity (Total, mg/l)	76.5	69.0	96.0	37.0	62.8
COD (mg/l)	11.08	18.33	14.25	--	11.0
BOD (mg/l)	1.243	1.325	1.675	<1.0	<1.0
DO (mg/l)	9.671	9.19	9.84	12.87	9.936
TDS (mg/l)	90.23	121.33	120.0	98.0	107.20
TSS (mg/l)	126.5	236.5	--	--	--

Calcium (mg/l)	17.60	13.66	19.50	9.0	17.6
Magnesium (mg/l)	5.5	11.0	--	--	--
Chloride (mg/l)	8.88	20.0	14.0	9.0	8.8
Sulphate (mg/l)	11.52	9.66	1.66	20.0	16.82
Fluoride (mg/l)	0.175	0.126	NT	0.14	0.21
Nitrite-N (mg/l)	0.0053	0.035	NT	0.006	0.008
Nitrate-N (mg/l)	0.315	0.246	NT	NT	0.0532
NH_3-N (mg/l)	0.644	0.501	NT	0.22	0.0111
TKN-N (mg/l)	0.775	3.5	0.28	0.56	0.513
Sodium (mg/l)	2.31	--	1.13	--	2.0
Potassium (mg/l)	1.73	--	1.3	--	1.5
Phosphate (mg/l)	0.0366	0.068	0.0122	--	0.0654
Boron (mg/l)	0.406	0.406	--	--	--

NT: Not traceable

Table-2.12.
Average values of heavy metal and pesticides residues in water of rivers[14]

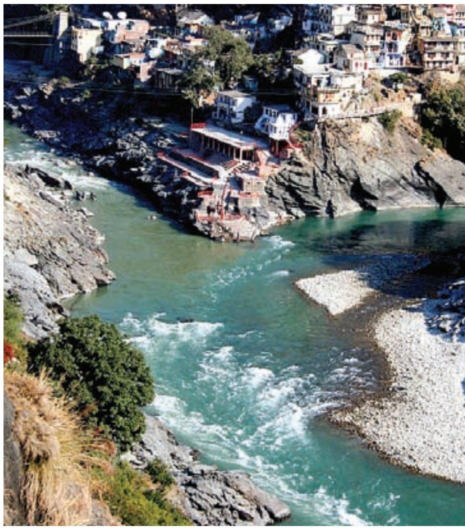
Average Values of Heavy Metal Residues in Water of Rivers

Biological Water Quality	Biological Water Quality Class	Iron (mg/l)	Nickel (mg/l)	Lead (mg/l)	Zinc (mg/l)	Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)
Clean	A	0.6621	NT	NT	0.16	NT	NT	NT
Slight Pollution	B	--	--	--	--	--	--	--
Moderate Pollution	C	1.613	NT	NT	1.276	NT	NT	0.0233
Heavy Pollution	D	--	--	--	--	--	--	--
Severe Pollution	E	3.86	NT	NT	0.143	NT	NT	NT

Average Values of Pesticides Residues in Water of Rivers

Biological Water Quality	Biological Water Quality Class	Total Endosulfan (ng/l)	Dieldrin (ng/l)	Total DDT (ng/l)	Total BHC (ng/l)	Aldrin (ng/l)
Clean	A	2.34	3.280	11.864	NT	NT
Slight Pollution	B	NT	NT	NT	NT	NT
Moderate Pollution	C	16.41	11.075	91.20	NT	NT
Heavy Pollution	D	NT	NT	NT	NT	NT
Severe Pollution	E	NT	NT	NT	NT	NT

NT: Not traceable, --: Not done.



In a National Programme "Monitioring of National Aquatic Resource" (MINARS), Central Pollution Control Board (CPCB) is supporting the state for water quality monitoring of major rivers. Uttarakhand Environment Protection and Pollution Control Board (UEPPCB), Dehradun is regularly monitoring the water quality of rivers and lakes of Uttarakhand (Table 2.13)[15].

2.4.2.3. River Ganga

Government of India has declared the holy River Ganga as the "National River" of India in November, 2008. However, the holy river is becoming dirtier and more polluted every day. The Ganga basin is the biggest river basin in India which covers the entire Uttarakhand state, and is bound in the north by the Himalayas and in the south by the Vindhyas. The main Ganga river stream originates in the northern-most part of Uttarakhand and flows through Uttar Pradesh, Bihar and West Bengal and finally it drains into the Bay of Bengal[16].

2.4.2.3.1. Water Quality Assessment Studies of Ganga River in Uttarakhand

The water quality monitoring of the Ganga riverine systems has been done by CPCB in terms of DO, BOD and FC studies during 1999-2008. The locations include Bhagirathi at Gangotri, Alaknanda B/C Mandakini at Rudraprayag, Mandakini B/C Alaknanda at

Table-2.13.
Characteristics of water quality of Ganga, Alaknanda, Bhagirathi, Mandakini and Yamuna River[15]

Month, Year	Station Code	Temp.⁰C	pH	DO (mg/L)	BOD (mg/L)	Fecal Coliform (MPN/100 ml)	Total Coliform (MPN/100 ml)
April, 05	1060	18.0	7.5	9.0	-	Nil	23.00
	1061	21.0	7.5	6.8	-	21.00	1600
	1484	15.0	7.5	12.6	-	Nil	Nil
	1485	15.0	7.5	12.6	-	Nil	Nil
	1486	14.0	7.5	12.8	-	Nil	Nil
	1487	18.0	7.5	10.2	-	Nil	Nil
	1488	19.0	7.5	11.4	-	Nil	Nil
	1489	18.0	7.5	10.0	-	Nil	Nil
	1490	22.0	7.5	9.4	1.7	0.0	00.00
	1494	19.0	7.5	11.0	-	0.0	00.00
May, 05	1060	21.0	7.5	8.8	-	Nil	23.00
	1061	22.0	7.5	6.0	-	17.00	1600
June, 05	1060	20.0	7.5	7.6	-	Nil	13.00
	1061	20.0	7.5	6.4	-	17.00	1600
July, 05	1060	20.0	7.5	9.9	-	Nil	Nil
	1061	22.0	7.5	7.0	-	23.00	1600
	1484	20.0	7.5	11.6	-	Nil	Nil
	1485	20.0	7.5	11.6	-	Nil	Nil
	1486	19.0	7.5	10.8	-	Nil	Nil
	1487	19.0	7.5	10.6	-	Nil	Nil
	1488	19.0	7.5	10.6	-	Nil	Nil
	1489	20.0	7.5	10.8	-	Nil	Nil
	1490	22.0	7.5	9.8	-	0.0	00.00
	1494	22.0	7.5	10.0	-	0.0	00.00

Month, Year	Station Code	Temp.^{0}C	pH	DO (mg/L)	BOD (mg/L)	Fecal Coliform (MPN/100 ml)	Total Coliform (MPN/100 ml)
Aug., 05	1060	21.0	7.5	9.9	-	Nil	17.00
	1061	22.0	7.5	6.9	-	-	1600
Sept., 05	1060	20.0	7.5	9.9	-	Nil	23.00
	1061	23.0	7.5	7.2	-	17.00	1600
Oct., 05	1060	19.0	7.5	7.0	1.4	Nil	23.00
	1061	20.0	7.5	7.0	4.4	17.00	1600
	1484	18.0	7.5	11. 3	Nil	Nil	Nil
	1485	18.0	7.5	10. 6	Nil	Nil	Nil
	1486	18.0	7.5	10.1	Nil	Nil	Nil
	1487	19.0	7.5	10.6	Nil	Nil	Nil
	1488	19.0	7.5	10.6	Nil	Nil	Nil
	1489	19.0	7.5	10.1	Nil	Nil	Nil
	1490	20.0	7.5	9.2	-	0.0	00.00
	1494	19.0	7.5	11.0	0.0	0.0	00.00
Nov., 05	1060	19.0	7.5	9.4	-	Nil	23.00
	1061	20.0	7.5	7.4	4.1	17.00	1600
Dec., 05	1060	11.0	7.5	10.1	-	Nil	23.00
	1061	13.0	7.5	6.1	4.2	23	1600
Jan., 06	1060	11.0	7.5	9.0	-	Nil	Nil
	1061	13.0	7.5	7.0	4.1	17	1600
	1484	10.0	7.5	9.6	Nil	0.0	00.00
	1485	10.0	7.5	11.8	Nil	0.0	00.00
	1486	10.0	7.5	11.8	Nil	Nil	00.00
	1487	9.0	7.5	10.0	Nil	0.0	00.00
	1488	10.0	7.5	10.7	Nil	0.0	00.00
	1489	10.0	7.5	9.8	Nil	0.0	00.00
	1490	13.0	7.5	9.8	Nil	0.0	00.00
	1494	12.0	7.5	10.0	Nil	0.0	00.00
Feb., 06	1060	18.0	7.5	9.2	-	0.0	23.00
	1061	20.0	7.5	6.9	-	17	1600
Mar., 06	1060	-	7.5	9.4	-	Nil	17.00
	1061	22	7.5	6.5	-	23	1600

Note: *Station code of each station;Laxman Jhula, Rishikesh-* **1060** *(Monthly Monitoring), Haridwar-* **1061** *(Monthly Monitoring), Alaknanda B/C Mandakini Rudraprayag –* **1484** *(Quarterly Monitoring), Mandakini B/C Alaknanda Rudraprayag –* **1485** *(Quarterly Monitoring), Alaknanda A/C Mandakini Rudraprayag –* **1486** *(Quarterly Monitoring), Alaknanda B/C Bhagirati Devprayag –* **1487** *(Quarterly Monitoring), Bhagirathi B/C Alaknanda Devprayag -* **1488** *(Quarterly Monitoring), Alaknanda A/C Bhagirathi Devprayag –* **1489** *(Quarterly Monitoring), Yamuna U/S Dakpathar, Dehradun –* **1490** *(Quarterly Monitoring), Yamuna U/S Lakhwar Dam, Dehradun –* **1494** *(Quarterly Monitoring)*

Significant Features of River Ganga[16]	
(i) Total Length	2,525 Km
(ii) Length in Uttar Pradesh and Uttarakhand	1,450 Km
Boundary between Uttar Pradesh and Bihar	110 Km
Bihar	445 Km
West Bengal	520 Km
Geographical area of India	3.28 million sq km
Reported area of river basins	3.05 million sq km
Catchment area of the Ganga basin	8,61,404 sq km (26.4%)
Average annual discharge	4,93,400 million cubic metre
Main sub tributaries	Chambal, Sindh, Betwa, Ken, Tons, Sone, Damodar and Kangsabati Haldi
Tributaries	Yamuna, Ramganga, Gomti, Ghaghara, Gandak, Kosi and Kali
Total population residing in the Ganga basin	33.78 crore (Including 6.78 crore forms the urban population, Cenus 2001).
Total population residing in the Ganga basin of Uttarakhand	8489349 (Including the urban population 2179074).
Industrial effluent discharged into the River Ganga (in Uttarakhand)	3.5 MLD
Municipal sewage into the River Ganga (in Uttarakhand)	61.3 MLD

Rudraprayag, Alaknanda A/C Mandakini at Rudraprayag, Alaknanda B/C Bhagirathi at Devprayag, Bhagirathi B/C with Alaknanda at Devprayag, Alaknanda A/C with Bhagirathi at Devprayag, Ganga river (U/S) at Rishikesh and Ganga River at Haridwar (D/S). DO and BOD values were found according to standard values while the FC values were higher in some of the locations. Nevertheless, the river Ganga in Uttarakhand was found relatively clean in comparison to the other states of India[16].

The seasonal variation in surface water quality at upstream and downstream of river Ganga in Haridwar during summer, winter and post monsoon seasons was studied (Table 2.14)[17]. The water quality parameters (physical and chemical) were within BIS limits except total coliforms and fecal coliforms which were higher in number.

2.4.2.3.2. Surface and Ground Water Quality of Haridwar during Kumbha Mela 2010:

The impact of Kumbha Mela on surface water i.e. 11 different locations of Ganga River/ Canal and 7 ground water sources for ground water quality in and around Haridwar city was studied by National Institute of Hydrology, Roorkee from January to June in 2010. The water quality parameters like pH, electrical conductivity, total dissolved solids, alkalinity, hardness, COD, BOD, major cations and anions, total coliform (TC) and faecal coliform (FC) were examined. Metal ion concentrations were found within the limit of BIS for drinking water in all these samples but higher values of TC (>2400) were reported in Ganga river water and in few ground water samples in January, April, May and June of 2010. All these water samples were found suitable for irrigation purpose after the study of total soluble salts, SAR and RSC[18].

Pollution Control Research Institute (PCRI) has monitored the water quality of River Ganga for bacteriological analysis during Mahakumbh Snan on 14 April 2010 in Haridwar from 4.00

Table-2.14. Seasonal variation in surface water quality during 2010 at U/S & D/S of River Ganga at Haridwar[17].

Parameters	Post Mon.		Winter		Summer		S-W Mon.		Average	
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S
pH	7.6	7.90	7.40	7.70	7.8	7.9	7.2	7.4	7.5	7.7
Conductivity (ml mhos/ cm)	188.6	198.4	185.60	195.40	196.6	206.4	170.2	180.5	185.25	195.2
DO (mg/l)	8.6	6.1	8.4	6.4	8.2	5.8	8.8	6.2	8.5	6.1
BOD (mg/l)	0.81	2.1	0.6	1.8	1.5	2.5	0.75	1.5	0.915	2.0
COD (mg/l)	8	12	6	10	12	16	7	14	8.25	13.0
Hardness (mg/l)	144	160	139	155	152	168	140	155	143.75	159.5
Alkalinity (mg/l)	168	200	163	195	176	208	160	190	166.75	198.3
Oil & Grease (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloride (mg/l)	8	10	6	8	16	20	10	15	10	13.3
Total Coliform (MPN/100 ml)	130	340	120	320	140	410	125	330	128.75	350.0
Fecal Coliform (MPN/100 ml)	50	130	45	60	65	140	48	110	52	110.0
F. straptococcus (MPN/100 ml)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND: Not Detected.

AM to 6.00 PM when about 14.5 lacs people took the holy dip in Ganga. The total coliform and fecal coliform bacterial count were very high on that day (Fig 2.1)[19].

2.4.2.4. River Yamuna

Yamuna River is also a prominent and sacred river, the largest tributaries of river Ganga and originates from Yamunotri Glacier of Uttarkashi district of Uttarakhand and merges with Ganga at Triveni Sangam of Allahabad in Uttar Pradesh covering about 1376 km. Yamuna river covers a total 3771 km^2 catchment area in Uttarakhand. Yamuna basin is highly fertile and high crop yielding basin in plains. CPCB has monitored the water quality status of Yamuna River in different states during 1999-2005. The summary of water quality statistics for Yamuna River at Yamunotri, Shyanachatti, Lakhwar dam, Dak Patthar sampling sites of Uttarakhand (Table 2.15) showed that total coliform and fecal coliform numbers were very high[20].

2.4.2.5. Lakes in Uttarakhand

The Indian Himalaya covers about 591,000 km^2 i.e. 18% of Indian land surface. The lakes lying above 3000 m elevation are termed as high altitude lakes. The total area of high altitude wetlands in Uttarakhand is 103882 ha including 231 ha of high altitudinal lakes i.e. 0.22% of total wetland area for 118 lakes covering <1% of total wetland area of the state. The altitude-wise and size-wise statistics of all the lakes (Table 2.16)[21].

Water Quality Assessment of Lakes / Tals of Uttarakhand: The lakes and tals in upper parts and middle Himalaya form an important part of total drainage system. The tals like Bhimtal, Sat tal, etc. of Nainital district are important sources for drinking water and also for irrigation purposes. Hemkund, Rupkund and Vasukital are some of the glacial lakes while on the other hand, Nachiketatal, Nainital, Dodital, Bhimtal and Naukuchiatal are the distinguished lakes of middle Himalaya. CPCB has divided the surface water quality into A, B, C, D and E

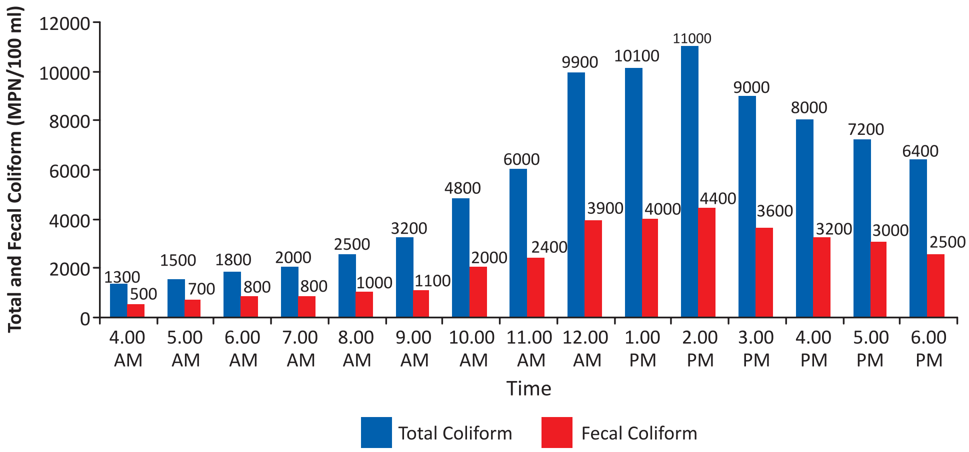


Fig-2.1.
Bacteriological load in Ganga River during Mahakumbh Snan on 14 April 2010 in Haridwar (from 4.00am to 6.00pm)[19].

Salient Features of Yamuna River in Uttarakhand[20]

Origin		Yamunotri Glacier (Saptrishi Kund near Bander punch peaks, 38° 59' N 78°27'E) in Mussoorie range of lower Himalaya, Uttarkashi district, Uttarakhnad.
Total length		1376 km upto Allahabad
Main tributaries in Uttarakhand		Rishi Ganga, Unta and Hanuman Ganga, Kamal, Giri, Tons, Asan
Total length upto Dak Patthar barrage		160 km
Dam / Barrage in Uttarakhand		Dak Patthar Barrage, Asan Barrage
Canal in Uttarakhand		Dak Patthar Canal, Asan Canal
Total catchment area in Uttarakhand (km^2)		3771 km^2
Total catchment area in Uttarakhand (%)		1.1 %
Land use pattern in Uttarakhand	Non-arable land	5.0 %
	Forest land	22.0 %
	Cuntivable land	23 %
Land actually cultivated		14.3 %
Land under habitational use		1.6 %

classes (Table 2.17)[22]. The water quality of Nainital (Table 2.18), Sat Tal (Table 2.19) and Naukuchiatal (Table 2.20) lakes during 2005-2006[15] was well below the permissible limits of BIS for drinking purposes and were slightly alkaline in nature.

2.4.3. Ground Water Sources of Uttarakhand

The ground water is a renewable resource of our planet which is recharged annually by precipitation in hydrological cycle. The behaviour of ground water in Indian sub-continent specially in Uttarakhand is highly complicated because of diversified geological formations, complex tectonic framework, different climatic and hydro-chemical conditions.

Drastic changes have occurred in rainfall behaviour during last three-four decades and the snowfall process in the Lesser Himalyan part has decreased significantly. The reduction in ground water recharge has been reported due to change in rainfall (refer chapter Climate Change). The state-wise estimates of dynamic ground water (fresh) resource was done by the Central Ground Water Board (Table 2.21)[23].

Table-2.15. Water quality statistics for Yamuna River during 1999-2005 at four sampling sites of Uttarakhand[20]

Location	pH		COD (mg/L)	BOD (mg/L)	Ammonia (mg/L)	TKN (mg/L)	DO (mg/L)	Cond. (µmhos/cm)	TC (No. /100 ml)	FC (No. /100 ml)
	Min	Max	Aver.	Aver.	Aver.	Aver.	Aver.	Aver.	Aver.	Aver.
Yamunotri	6.11	7.75	3	1.0	0.40	1.29	8.1	89	12669	361
Shyanachatti	7.06	7.90	7	1.0	0.40	1.27	8.5	122	23307	1254
Lakhwar dam	6.94	8.62	4	1.0	0.31	1.17	9.0	195	181858	587
Dak Patthar	6.95	8.61	5	1.1	0.32	1.49	9.2	207	102151	1367

Table-2.16. Altitude-wise and size-wise statistics of lakes of Uttarakhand[21]

Category/Class	Altitude Range (m) / Size Range (ha)	No. of lakes	Area (ha)
High Altitude	3000 – 4000 m	7	9
Steep Altitude	4000 – 5000 m	67	158
Very Steep Altitude	>5000 m	44	64
Total		**118**	**231**
Very Large	> 500 ha	-	-
Large	100-500 ha	-	-
Medium	25 – 100 ha	-	-
Small	10 – 25 ha	1	17
Very Small	< 10 ha	28	125
< 2.25 ha	< 2.25 ha	89	89
Total		**118**	**231**

Table-2.17.
Surface water quality criteria[22]

S. No.	Designated-Best-Use	Class of Water	Criteria
1.	Drinking water source without conventional treatment but after disinfection	A	Total coliform organisms (MPN/100 ml) shall be 50 or less pH between 6.5 to 8.5 Dissolved Oxygen (DO) 6 mg/l or more Biochemical Oxygen Demand (BOD) 5 days 20˚C 3 mg/l or less
2.	Outdoor bathing (Organised)	B	Total coliform organisms (MPN/100 ml) shall be 500 or less pH between 6.5 to 8.5 Dissolved Oxygen (DO) 5 mg/l or more Biochemical Oxygen Demand (BOD) 5 days 20˚C 2 mg/l or less
3.	Drinking water source after conventional treatment and disinfection	C	Total coliform organisms (MPN/100 ml) shall be 5000 or less pH between 6 to 9 Dissolved Oxygen (DO) 4 mg/l or more Biochemical Oxygen Demand (BOD) 5 days 20˚C 3 mg/l or less
4.	Propagation of wild life and fisheries	D	pH between 6.5 to 8.5 Dissolved Oxygen (DO) 4 mg/l or more Free Ammonia (as N) 1.2 mg/l or less
5.	Irrigation, industrial cooling, controlled waste disposal	E	pH between 6.0 to 8.5 Electrical Conductivity at 25 ˚C µmhos/cm maximum 2250 Sodium absorption ratio maximum 26 Boron maximum 2 mg/l
		Below E	Not meeting A, B, C, D & E Criteria

Table-2.18.
Water quality characteristics of Nainital Lake (Tallital) during 2005-2006[15]

Parameter	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Color	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL
Odour	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL
TDS	390	350	375	345	320	330	340	345	350	340	370	380
EC	596	537	574	533	498	505	560	510	515	510	545	580
pH	8.94	8.75	8.66	8.10	8.16	8.08	7.68	7.54	7.49	7.50	7.50	8.20
DO	9.4	8.6	3	5.8	6.2	10.8	8.2	8.4	3.2	6.3	6.8	8.9
BOD	2.2	3.0	2.4	2.6	3.6	3.0	1.5	1.4	1.8	2.8	2.0	2.0
T.Hardness (as $CaCO_3$)	308	224	214	210	202	288	284	270	276	276	288	316
Calcium (as Ca)	36.1	21.6	24.0	24.0	24.8	31.3	30.0	29.2	30.1	36.1	52.0	34.0
Magnesium (as Mg)	52.9	41.9	37.4	36.5	34.0	51.0	48.0	47.7	48.8	45.2	38.4	53.0
Alkalinity (as $CaCO_3$)	218	184	190	186	182	164	190	185	188.9	205	210	225
Chloride	20	18.0	20.0	20.0	18.0	16.0	21.0	22.7	23.0	18.5	21.0	18.5

** CLL- Colorless, ODL- Odorless and EC- Electrical Conductivity, except pH and conductivity all the results are in mg/l and conductivity is in µmhos/cm.*

Table-2.19.
Water quality characteristics of Sat Tal Lake during 2005-2006[15]

Parameter	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Color	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL
Odour	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL
TDS	70	80	100	100	70	70	80	120	115	90	100	90
EC	121	126	161	157	108.0	100	135	210	114	190	175	140
pH	8.72	8.34	9.30	8.81	8.04	8.00	8.50	8.40	8.15	7.4	7.5	8.2
DO	7.2	7.4	6.8	7.6	7.4	8.4	7.6	9.2	7.2	8.1	8.5	9.6
BOD	1.0	1.0	1.0	1.5	1.0	3.0	2.0	1.0	1.3	1.1	1.2	1.4
T. Hardness (as $CaCO_3$)	62	58	56	38	58	46	62	53	52.9	64	96	102
Calcium (as Mg)	11	10.4	10	12.8	3.6	11.2	14.4	20.4	23	22.4	32.9	32
Magnesium (as Mg)	8.4	7.8	7.5	1.5	8.3	4.4	6.0	6.2	6.9	3.8	3.4	5.3
Alkalinity (as $CaCO_3$)	68	81	72	46	52	49	58	65	64	80	85	80
Chloride	9	8.0	9.0	10.0	8.0	11.0	8.0	11.4	10.1	11.4	12.8	8.5

** CLL- Colorless, ODL- Odorless and EC- Electrical Conductivity, except pH and conductivity all the results are in mg/l and conductivity is in µmhos/cm.*

Table-2.20.
Water quality characteristics of Lake Naukuchiatal during 2005-2006[15]

Parameter	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Color	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL
Odour	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL	ODL
TDS	90	110	105	95	90	80	80	105	98	120	130	120
EC	161	169	168	149	136	129	145.5	181	181	190	240	150
pH	9.60	8.86	9.29	8.76	8.45	8.50	8.50	8.42	7.95	7.2	7.2	8.20
DO	8	7.6	7.2	6.2	6.8	9.8	6.8	8.8	9.0	8.5	9.2	9.8
BOD	1	1.1	1.4	1.6	1.8	2.6	2.0	0.8	1.5	1.8	1.2	1.2
T. Hardness (as $CaCO_3$)	88	70	62	40	70	63	72	65	68	80	116	116
Calcium (as Ca)	16.8	16.0	15.0	14.0	15.2	13.6	16.0	21.2	22.8	26.4	36.0	32.9
Magnesium (as Mg)	11.2	7.3	6.0	1.5	7.8	7.0	8.2	7.0	7.8	30.4	6.3	8.2
Alkalinity (as $CaCO_3$)	80	60	58	76	68	61	70	85	81.5	90	105	90
Chloride	10	10.0	10.0	10.0	9.0	12.0	10.0	9.2	10.0	15.8	12.8	8.2

** CLL- Colorless, ODL- Odorless and EC- Electrical Conductivity, except pH and conductivity all the results are in mg/l and conductivity is in µmhos/cm.*

Table-2.21.
Profile of ground water scenario in hilly states of India including Uttarakhand[23]

State	Annual Rain fall (mm)	Dynamic Ground Water Resources			
		Annual Replenishable Ground water Resource (BCM)	Net Annual Ground Water Availability (BCM)	Annual Ground Water Draft (BCM)	Stage of Ground Water Development (%)
Uttarakhand	1606	2.27	2.10	1.39	66
Himachal Pradesh	1340	0.43	0.39	0.12	30
Jammu & Kashmir	998	2.70	2.43	0.33	14
Arunachal Pradesh	3000 mm in 200 rainy days	2.56	2.30	0.0008	0.04
Manipur	1927	0.38	0.34	0.002	0.65
Meghalaya	2050 mm in 200 rainy days	1.15	1.04	0.002	0.18
Mizoram	1927	0.04	0.04	0.0004	0.90
Sikkim	3494	0.08	0.08	0.01	16
Tripura	1927	2.19	1.97	0.17	9
Nagaland	1927	0.36	0.32	0.009	3

2.4.3.1. Scenario of Ground Water Quality

The natural chemical contents of ground water are influenced by depth and sub-surface geological formations through which ground water remains in contact. In general, major part of the Uttarakhand, ground water from both shallow and deeper aquifiers is of good quality and suitable for drinking, agricultural or industrial purposes. Nitrate due to anthropogenic activities is a very common constituent in shallow aquifers and its higher concentration beyond the permissible limit of 45 mg/l causes severe health problems. During pre monsoon, higher concentration of nitrate in ground water of Uttarakhand has been found[24]. CGWB is periodically monitoring the chemical quality of ground water through a network of about 15000 observation wells located all over the country. Apart from these, it is also being monitored through various studies like ground water management studies, ground water exploration etc[1].

CGWB during 2009 – 2010, monitored 93 ground water monitoring wells in Dehradun, Haridwar, Udham Singh Nagar, Nainital and Almora districts and eight springs of Dehradun, Nainital and Almora districts (Table 2.22)[1].

The fluctuation of depth to water level data (March 2009 to January 2010) shows that percentage of 0-5 and 10-15 ranges of depth to water level have increased while ranges 5-10 and >15 depth wells have decreased during this period (Table 2.23)[1]. Table 2.24 and 2.25 presents the fluctuation pattern of ground water level during the periods August 2009, November 2009 (post monsoon) and January 2010 as compared to May 2009 (pre monsoon)[1].

The ground water occurs in multi aquifer systems in the plain areas of the state. Perched water bodies lying above the main water bearing formations are frequently encountered in Bhabar region and Doon Valley while in the hilly areas of the state the occurrence of ground water is limited to small, localised aquifers with limited ground water potential. In

Ground Water Scenario of Uttarakhand[1,8]	
Area (Sq. km)	53,484
Phisiography	Ganga Plain, Shiwalik Hills, Lesser Himalayas, Central Himalayas
Drainage	By major perennial rivers like Ganga, Yamuna, Ramganga, Sarda and Kali and their tributaries
Rainfall	1606 mm
Total Districts / Tehsils	13 districts / 78 Tehsils
Dynamic Ground Water Resources in Uttarakhand	
Annual Replenishable Ground Water Resources	2.27 BCM
Net annual Ground water Availability	2.10 BCM
Annual Ground Water Draft	1.39 BCM
Stage of Ground Water Development	66 %
Yield of Tube Wells in Uttarakhand	
Zone / Belt	**Yield per hour**
Shivalik	50.4 – 79.2 m^3
Bhabar	Upto 332.4 m^3
Tarai	36 – 144 m^3
Indo-Gangetic	90 – 198 m^3

Table-2.22.
District wise active ground water monitoring wells and springs under the study of CGWB, Dehradun[1]

District Name	No. of GW Monitoring Wells			
	May 2009	August 2009	November 2009	January 2010
Dehradun	28	28	28	28
Haridwar	*15	20	20	20
US Nagar	**29	29	29	29
Champawat	3	3	3	3
Nainital	13	13	13	13
Total	**88**	**93**	**93**	**93**
No. of Springs				
Dehradun	01	01	01	01
Almora	03	03	03	03
Nainital	04	04	04	04
Total	**08**	**08**	**08**	**08**

**Six new monitoring wells (3 hand pumps and 3 dug wells) in Haridwar district were established in August 2009;*
***Six hand pumps were established as replacement monitoring wells in US Nagar district.*

Table-2.23.
Overall summary of the depth to water level data in Uttarakhand during 2009-2010[1]

Range of depth to water level (mbgl)	% of wells analyzed			
	May 2009	August 2009	November 2009	January 2010
0-5	30.49	38.10	40.00	35.23
5-10	28.05	27.38	27.06	23.86
10-15	10.97	10.71	8.24	12.50
>15	30.49	23.81	24.70	28.41

Table-2.24. Fluctuation of water level in Uttarakhand during 2009-2010 (Compared to decadal average)[1]

Fluctuation (meter)	% of wells analyzed (Average)							
	May 2009		August 2009		November 2009		January 2010	
	Rise	Decline	Rise	Decline	Rise	Decline	Rise	Decline
0-2	50.0	30.0	10.0	45.0	22.22	77.78	30.0	55.0
2-4	10.0	5.0	5.0	30.0	0	0	0	15.0
>4	5.0	0	0	10.0	0	0	0	0

Table-2.25.
Fluctuation of water level during the period 2009-2010 (compared to May 2009)[1]

Fluctuation (meter)	% of wells analyzed					
	August 2009		November 2009		January 2010	
	Rise	Decline	Rise	Decline	Rise	Decline
0-2	60.00	13.85	52.17	11.59	56.52	15.94
2-4	7.69	3.08	20.29	2.90	17.39	4.35
>4	10.77	4.62	11.59	1.45	4.35	1.45

hilly terrains, the ground water remains in the secondary igneous and metamorphic rocks in the form of fractures, joints and fissures. Low to moderate ground water potential occurs in different parts of the state where ground water is located in valley filled with deposits of the alluvial plains and piedmont zones. Generally, the quality of ground water is good and water is safe for drinking, domestic and irrigation purposes.

CGWB, Dehradun has also studied the water quality of ground water monitoring wells of Dehradun, Haridwar, Nainital, Udham Singh Nagar, Almora and Champawat districts for the parameters like pH, electrical conductivity, total hardness (as $CaCO_3$), carbonate, bicarbonate, chloride, nitrate, sulphate, fluoride, calcium, magnesium, sodium and potassium in pre-monsoon 2009. The higher values of electrical conductivity (> 750-1000 µS/cm) was found in the central and west central parts of district Haridwar and Bhabar Zone in Udham Singh Nagar district. Nitrate values of 11.76% wells were more than the limit of BIS. Magnesium concentration was found more than limit in 27.06% samples of Doon Valley. Some samples of Haridwar, Nainital and Udham Singh Nagar Districts also represent the higher values of magnesium. Spring water samples were also found suitable in terms of ground water quality during pre-monsoon (2009). The water level data of GWMW of Uttarakhand, measured during 2009 – 2010, is given (Table 2.26)[1].

10 years mean of change in ground water level of various stations of Dehradun, Haridwar, Udham Singh Nagar and Nainital districts is given in Table 2.27 and its fluctuation during 2009 and 2010 and depth of water level data in GWMW in 5 districts of Uttarakhand in 2010 are depicted in Figure 2.2 and 2.3[1].

Table-2.26.
Water levels of ground water monitoring wells (GWMW) in 2009-2010[1]

Location of GWMW	Depth to Water Level (m bgl)			
	May 2009	August 2009	November 2009	January 2010
		Dehradun District		
Rishikesh	16.57	13.87	12.77	13.59
Rampura	10.66	10.52	12.24	14.35
Kuanwala	14.85	9.85	6.77	11.50
Herbertpur	10.52	8.63	9.24	10.35
Lal Tappar	18.37	18.65	18.34	17.5
Motichur	10.30	4.29	9.15	10.17
Nanda Ki Chowki	16.42	9.30	9.18	13.19
Selakui	Well Dry	9.26	9.08	10.21
Redapur	NA	NA	NA	NA
Dharmawala	3.60	3.35	3.60	3.68
Sabhawala	9.15	8.28	9.40	8.02
Singhniwala	8.91	8.84	8.98	9.25
Ramgarh	7.53	6.20	6.65	7.25
Kanwali	15.98	11.40	12.30	15.7
Chharba	18.36	18.20	18.15	18.2
Shankarpur	22.90	22.86	23.52	20.8
Judli	13.82	13.27	13.65	16.52
Chharba-Pz	74.92	Well Dry	83.45	73.45
Jhajra	13.40	7.30	NA	13.1
Redapur	10.73	9.39	NA	10.09
Majra	13.33	13.21	NA	NA
Bhaniawala	30.30	31.40	30.17	32.12

Location of GWMW	Depth to Water Level (m bgl)			
	May 2009	August 2009	November 2009	January 2010
Balliwala	59.02	64.64	55.70	55.43
Harbanswala	39.91	50.38	NA	49.04
Tarla Nagal	78.62	70.85	69.28	72.05
Nanurkhera	67.40	69.68	67.48	67.58
Haridwar District				
Bahadrabad	4.31	4.87	4.97	5.1
Missarpur	4.72	4.72	5.70	5.67
Dhanpura	6.10	4.44	4.12	4.88
Hussainpur	3.81	1.67	2.00	2.17
Shahidwala Grant	13.24	13.50	13.08	13.39
Bandarjud	NA	9.44	9.78	8.62
Rathaura	NA	6.05	5.53	4.25
Sarai	NA	11.16	10.27	11.16
Roorkee-Pz	7.74	6.71	6.36	6.1
Chudiala-Pz	19.02	19.94	18.32	18.5
Landhaura (1)	Well Dry	NA	NA	NA
Landhaura (2)	NA	NA	NA	NA
Bhagwanpur	21.73	22.43	19.82	15.74
Bahabalpur	3.89	3.58	3.88	4.12
Jhabrera	9.51	10.38	9.13	8.62
Iqbalpur	17.66	21.00	17.07	15.69
Bugawala	8.20	7.19	6.31	7.47
Shahpur Shitlakhera	NA	3.44	3.34	3.6
Khanpur	NA	1.77	2.18	2.06
Lakhnauta	NA	7.34	6.98	5.53
Udham Singh Nagar District				
Kashipur	5.79	4.87	2.93	3.53
Khatima	3.64	1.01	1.47	2.3
Bazpur	2.63	1.53	1.18	1.39
Kichha	7.01	6.19	6.55	5.53
Bara	2.35	1.10	1.25	1.45
Jaspur	Well Abandoned			
Angadpur	4.94	4.50	3.85	4.05
Patrampur	7.77	Well Dry	7.47	7.48
Bharatpur	Well Abandoned			
Barkhare Pande	Well Abandoned			
Barhini	1.73	0.50	0.29	1.48
Thanda Banjara	Well Abandoned			
Banna Khera	4.74	3.45	3.63	3.72

Location of GWMW	Depth to Water Level (m bgl)			
	May 2009	August 2009	November 2009	January 2010
Shantipuri	1.90	0.73	1.00	1.5
Nanak Mata	5.49	2.45	2.62	2.29
Chakarpur	5.00	4.83	3.80	4.14
Kamaria Pakki	7.37	6.82	3.07	5.94
Gangapur	3.23	8.57	2.14	2.94
Bhagwanpur	5.31	4.87	3.02	3.7
Beria Daulat	3.26	2.86	2.39	2.66
Mahabir Nagar	2.24	1.51	1.73	3.63
Jogipura	8.53	5.71	1.82	6.16
Jhagarpuri	1.97	1.71	1.93	1.72
Majhola	3.88	3.36	3.15	3.93
Dhanauri Patti	4.58	2.80	2.36	3.51
Kalyanpur	2.80	1.41	1.26	2.50
Patthar Chatta	2.70	2.34	2.30	2.60
Barkhare Pande	6.77	6.52	4.47	6.97
Jaspur	5.55	16.48	14.42	15.48
Bharatpur	9.05	8.94	7.89	6.15
Patrampur	8.77	8.43	7.12	7.69
Sultanpur Patti	1.12	0.54	0.21	0.24
Sitarganj	2.82	1.25	2.94	1.6
Kichha	7.46	6.19	6.55	6.87
Nainital District				
Lalkuan	6.71	7.89	6.89	6.32
Garjiya	3.92	3.03	2.28	3.99
Maldhan Colony	4.76	3.88	3.51	2.87
Ramnagar	6.63	6.38	6.50	7.53
Belparao	55.87	55.52	53.12	52.46
Dhela	59.86	63.66	63.05	63.62
Peeru Madara	23.05	23.53	18.53	20.04
Dhoniya	69.51	70.34	58.06	62.53
Lamachaur	32.17	38.23	35.39	39.01
Kaladhungi	27.59	26.73	27.00	27.54
Kathgodham	19.46	14.82	17.16	19.08
Sitapur	50.77	56.03	48.56	47.56
Khat Baas	33.83	27.18	25.84	22.80
Champawat District				
Tanakpur	9.92	NA	7.69	9.68
Banbasa	6.43	NA	2.65	3.23
Bastia	29.47	NA	20.29	25.65

Table-2.27.
Change in ground water levels of 04 districts of Uttarakhand – 10 Years Mean[1]

District	No. of stations analysed	Fluctuation (m)				Rise (m)				Decline (m)			
		Rise		Decline		0-2		2-4		0-2		2-4	
		Min.	Max.	Min.	Max.	No.	%	No.	%	No.	%	No.	%
During May 1999 to May 2008 vs. May 2009													
Dehradun	11	0.03	4.60	0.16	1.64	5	45.45	1	9.09	4	36.36	0	0
Haridwar	01	0.91	--	--	--	1	100	0	0	0	0	0	0
US Nagar	07	0.06	1.02	0.81	2.21	4	57.14	0	0	2	28.57	1	14.29
Nainital	01	--	2.58	--	--	0	0	1	100	0	0	0	0
Total	**20**	**0.03**	**4.60**	**0.16**	**2.21**	**10**	**50.0**	**2**	**10.0**	**6**	**30.0**	**1**	**5.0**
During August 1999 to August 2008 vs. August 2009													
Dehradun	12	0.33	--	0.50	6.66	1	8.33	0	0	4	33.33	5	41.67
Haridwar	01	--	--	--	1.38	0	0	0	0	1	100	0	0
US Nagar	06	0.28	--	0.14	2.98	1	16.67	0	0	4	66.67	1	16.67
Nainital	01	--	0.81	--	--	0	0	1	100	0	0	0	0
Total	**20**	**0.33**	**0.81**	**0.14**	**6.66**	**2**	**10.0**	**1**	**5.0**	**9**	**45.0**	**6**	**30.0**
During November 1999 to November 2008 vs. November 2009													
Dehradun	10	--	--	0.22	5.51	0	0	0	0	10	100	0	0
Haridwar	1	--	--	--	1.51	0	0	0	0	1	100	0	0
US Nagar	6	0.13	0.95	0.40	1.31	3	50.0	0	0	3	50.0	0	0
Nainital	1	--	0.73	--	--	1	100	0	0	0	0	0	0
Total	**18**	**0.13**	**0.95**	**0.22**	**5.51**	**4**	**22.22**	**0**	**0**	**14**	**77.78**	**0**	**0**
During January 2000 to January 2009 vs. January 2010													
Dehradun	12	--	1.70	0.13	3.79	1	8.33	0	0	8	66.67	3	25.0
Haridwar	1	--	--	0.71	--	0	0	0	0	1	100	0	0
U.S. Nagar	6	0.22	1.59	0.30	0.73	4	66.67	0	0	2	33.33	0	0
Nainital	1	--	1.02	--	--	1	100	0	0	0	0	0	0
Total	**20**	**0.22**	**1.70**	**0.13**	**3.79**	**6**	**30.0**	**0**	**0**	**11**	**55.0**	**3**	**15.0**

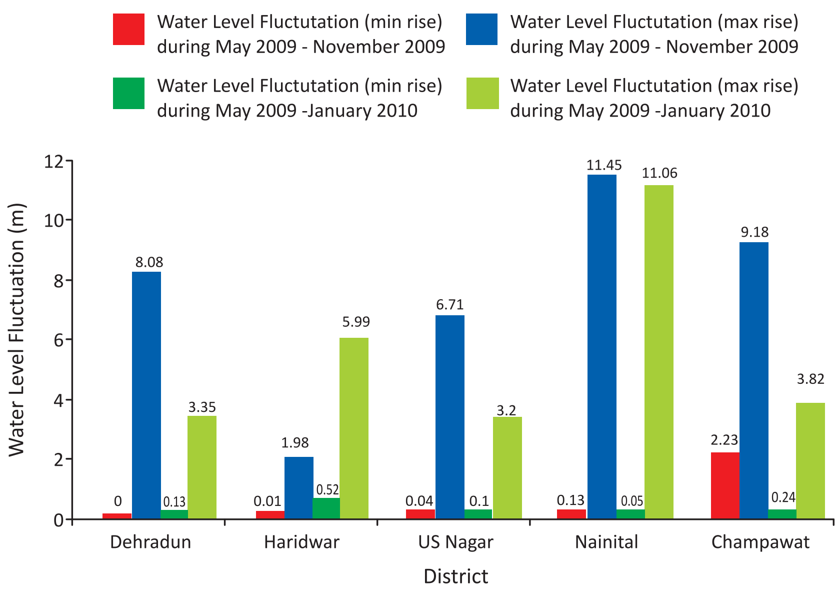
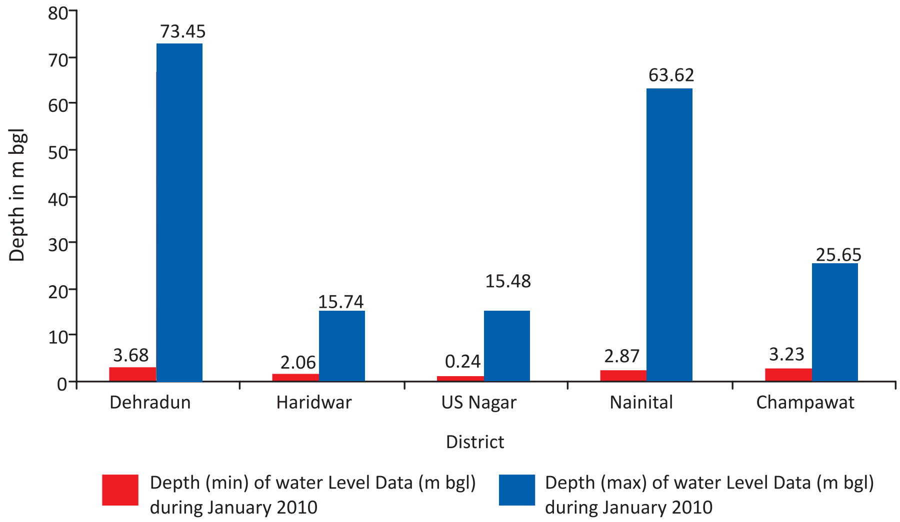
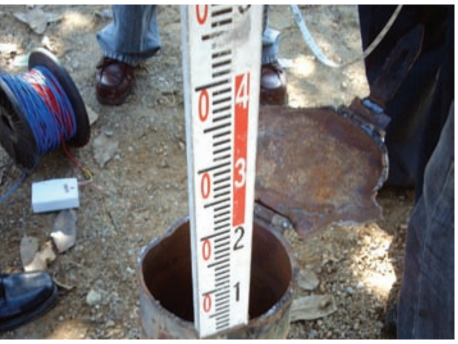


Fig-2.2.
Water Level Fluctuation of Ground Water of 05 districts in Uttarakhand[1]

Fig-2.3.
Depth of water level data in ground water monitoring wells of 05 districts of Uttarakhand[1]





The discharge of springs (Table 2.28) for Dehradun, Almora and Nainital districts in pre-monsoon and post-monsoon seasons clearly indicates that the rainfall is the main factor for variation in spring discharges. Data of water sample analysis collected during pre-monsoon (May 2009) from different locations of the state is given in Table 2.29[1].

2.4.3.1.1. Ground Water Quality Status of Dehradun City

Three solutions are recommended[25] for Doon city firstly the GWMW like piezometers should be constructed to tap the entire aquifer layer secondly, study the seasonal water level fluctuation of production wells in central and thirdly, western part of Dun Valley and RBF projects should be started along the Asan, Song and Tons rivers. The City Development Plan (CDP) of NIUA shows that the city receives more than 75% supply from ground water sources and remaining amount from surface water sources. Only 50% population of city is covered with a sewerage system and the city lacks the proper sewage treatment plants. The city generates more than 62.6 million litres per day (MLD) of waste water of which only 32.1 MLD is collected. Remaining population of the city uses soakpits and septic tanks for sanitation purposes[26].

Table-2.28.
Discharge of springs (in lpm)[1]

Spring Location	Discharge of the Spring (lpm)			
	May 2009	August 2009	November 2009	January 2010
Dehradun District				
Bhatta	1.80	12	5	10
Almora District				
Patali Talla	20	25	24	16.47
Patali Malla	16	17.14	36	4.29
Katarmal	34	22.22	NA	30.00
Nainital District				
Dogaon	14	41.86	48	20.60
Sipahidhara	120	442.97	800	235.45
Garampani	30	NA	36	20.00
Salari	14	141.42	148	25.00

Table-2.29.
Data of water sample analysis collected during pre-monsoon (May 2009) from different locations of Uttarakhand[1]

Site	pH	E.C. (µS/cm)	Concentration (mg/L)										
			CO_3	HCO_3	Cl	SO_4	NO_3	F	Ca	Mg	Na	K	Total Hardness (as $CaCO_3$)
District Dehradun													
Rishikesh	8.15	380	--	184	20	38	1	0.20	31	25	17	1	181
Motichur	7.85	300	--	171	10	7	12	0.17	46	6	14	2	142
Lal Tappar	7.70	350	--	108	10	92	19	0.11	34	28	6	1	200
Bhaniawala	7.60	445	--	114	15	132	8	0.07	44	33	4	1	245
Majra	7.65	490	--	127	15	116	34	0.06	41	33	13	1	239
Bhatta	7.92	355	--	171	15	56	8	0.06	23	39	3	1	220
Tarla Nagal	7.95	300	--	165	15	15	8	0.07	21	28	3	1	168
Nanurkhera	7.93	320	--	153	10	17	31	0.06	18	33	4	1	181
Harbanswala	7.75	435	--	127	15	95	24	0.05	34	36	7	1	232
Kanwali	7.90	490	--	133	40	56	90	0.04	23	44	24	1	239
Ramgarh	7.98	440	--	140	30	28	70	0.12	49	16	20	8	187
Singhniwala	7.88	440	--	108	15	120	28	0.06	46	30	7	1	239
Sabhawala	8.10	490	--	153	20	19	130	0.10	60	17	19	13	220
Jhajra	7.95	260	--	127	25	1	10	0.08	31	13	9	1	129
Selakui	6.95	175	--	82	10	3	18	0.07	18	5	14	2	65
Rampura	6.92	175	--	76	15	15	5	0.08	21	8	8	1	84
Shankarpur	6.95	120	--	70	10	3	nd	0.06	15	5	8	1	58
Redapur	7.00	80	--	38	15	nd	2	0.06	8	2	12	1	26
Dharmawala	7.25	375	--	153	30	6	55	0.09	28	13	28	23	123
Judli	7.30	310	--	82	25	10	80	0.08	36	11	18	2	136
Herbertpur	7.25	190	--	89	15	14	17	0.07	31	3	12	1	91
Chharba	7.20	110	--	51	15	2	1	0.06	15	2	9	1	45
Nanda Ki Chowki	7.35	260	--	108	20	11	31	0.07	36	5	21	1	110
District Haridwar													
Missarpur	7.50	365	--	133	20	26	47	0.10	31	20	18	6	162
Dhanpura	7.40	1090	--	336	101	100	84	0.10	54	53	61	81	355
Hussainpur	8.00	320	--	204	10	1	2	0.09	15	20	25	4	123
Chudiala	7.95	335	--	196	15	nd	2	0.67	15	24	22	2	136
Bahabalpur	7.92	395	--	248	15	nd	5	0.22	26	25	27	2	168
Bugawala	7.90	305	--	108	15	10	52	0.14	28	19	8	2	149
Shahidwala Grant	7.95	340	--	101	30	14	58	0.08	34	22	6	2	174
Bhagwanpur	8.20	340	--	184	20	3	3	0.54	15	16	38	2	103
Jhaberara	7.93	870	--	95	217	90	1	0.2	52	44	73	8	310
Iqbalpur	8.15	340	--	171	25	20	3	0.43	18	27	21	2	155
Bahadrabad	8.00	270	--	140	10	18	8	0.24	41	11	5	0.4	149
District Nainital													
Lalkuan	6.74	395	--	139	15	36	38	0.17	22	32	7	3	185
Maldhan Colony	7.25	480	--	240	30	14	3	0.44	13	32	41	1	163
Garjiya	7.33	250	--	114	15	24	6	0.16	17	18	10	3	119
Ramnagar	7.73	350	--	189	23	1	5	0.12	13	32	12	3	163

Site	pH	E.C. (μS/cm)	Concentration (mg/L)										
			CO_3	HCO_3	Cl	SO_4	NO_3	F	Ca	Mg	Na	K	Total Hardness (as $CaCO_3$)
Belparao	7.96	395	--	189	15	31	8	0.13	9	42	8	2	195
Dhela	8.00	210	--	88	15	1	32	0.08	26	8	10	1	98
Peeru Madara	7.97	290	--	101	15	36	23	0.11	17	24	8	2	141
Dhoniya	8.04	380	--	126	23	73	13	0.12	22	37	7	1	206
Lamachaur	8.17	240	--	132	15	nd	8	0.07	17	18	7	1	119
Kaladhungi	8.25	390	--	152	15	87	7	0.10	13	47	6	1	228
Kathgodam	8.28	300	--	126	15	22	30	0.08	13	24	17	4	130
Sitapur	8.20	270	--	114	15	12	26	0.26	26	16	8	1	130
Khaat Baas	8.06	200	--	101	8	7	18	0.08	22	11	8	1	98
Dogaon	8.15	200	--	101	15	7	nd	0.10	22	8	11	1	87
Sipahidhara	8.33	490	25	126	23	88	18	0.09	22	50	9	3	261
Garampani	8.33	175	12	73	8	nd	nd	0.08	22	8	2	1	87
Salari	8.18	210	--	112	15	nd	6	0.09	35	5	3	2	109
District Udham Singh Nagar													
Kashipur	8.14	710	--	88	189	37	1	0.26	48	48	28	2	314
Khatima	7.14	474	--	168	56	40	0.8	0.24	30	14	55	1.0	132
Bazpur	7.32	494	--	297	17	24	0.8	0.22	13	48	31	1.5	227
Sitarganj	7.44	263	--	152	7.1	1.6	nd	0.16	23	9	17	1.7	95
Kichha	7.54	978	--	289	94	64	90	0.42	11	55	87	53	253
Bara	7.80	298	--	160	7.1	15	3.3	0.09	25	12	20	1.5	111
Jaspur	7.89	683	--	417	7.1	nd	nd	0.22	30	7.7	114	1.2	106
Angadpur	7.87	213	--	136	7.1	nd	nd	0.10	21	10	12	0.8	95
Patrampur	7.82	367	--	217	7.1	nd	nd	0.16	17	19	32	0.9	122
Bharatpur	8.00	498	--	305	7.1	nd	nd	0.20	23	18	56	6.0	132
Barkhare Pande	8.01	363	--	209	7.1	4.0	nd	0.08	32	10	26	1.8	122
Barhini	6.85	625	--	321	21	39	1.8	0.18	32	51	17	6.7	290
Thanda Banzara	7.01	316	--	96	39	23	3.3	0.12	25	18	9.3	1.1	137
Banna Khera	7.09	571	--	233	21	57	9.2	0.18	68	15	17	12	232
Shantipuri	7.29	433	--	209	7.1	29	2.9	0.28	42	15	21	1.3	169
Nanak Mata	7.48	418	--	249	7.1	6.4	nd	0.22	17	21	44	0.8	127
Chakarpur	7.57	246	--	152	3.5	nd	nd	0.12	34	6.4	6.9	2.8	111
Kamaria Pakki	7.56	369	--	209	7.1	13	2.5	0.18	46	12	14	1.7	164
Gangapur	7.66	275	--	128	7.1	16	7.0	0.12	30	10	9.2	2.3	116
Bhagwanpur	7.60	354	--	217	7.1	7.6	nd	0.22	53	7.7	12	2.2	164
Beria Daulat	7.86	483	--	241	14	43	nd	0.24	34	35	16	1.9	227
Mahabir Nagar	7.98	486	--	225	3.5	70	5.0	0.31	13	53	7.3	1.6	248
Jogipura	7.95	447	--	193	7.1	52	nd	0.18	10	41	11	1.9	195
Jhagarpuri	8.01	478	--	225	14	44	nd	0.21	19	40	16	1.7	478
Majhola	8.10	208	--	120	11	2.0	nd	0.10	25	7.7	6.6	2.2	95
Dhanauri Patti	7.99	436	--	193	32	25	9.8	0.12	30	20	30	9.8	158

Site	pH	E.C. (µS/cm)	Concentration (mg/L)										
			CO_3	HCO_3	Cl	SO_4	NO_3	F	Ca	Mg	Na	K	Total Hardness (as $CaCO_3$)
Kalyanpur	8.05	207	--	80	32	2.8	3.0	0.08	27	6.4	8.6	1.3	95
Patthar Chatta	7.99	281	--	136	3.5	12	11	0.11	30	12	7.1	2.3	122
District Champawat													
Tanakpur	7.97	228	--	112	3.5	6.0	16	0.09	21	10	8.6	0.9	95
Banbasa	8.00	291	--	112	21	12	14	0.18	30	7.7	13	10	106
Bastia	8.05	203	--	96	7.1	4.4	13	0.18	17	12	7.9	0.9	89
District Almora													
Patali Thalla	8.16	250	--	101	15	15	27	0.12	35	8	10	1	119
Patali Malla	8.17	230	--	101	23	8	10	0.11	22	13	9	2	109
Katarmal	8.17	250	--	76	30	6	38	0.11	35	5	13	4	109

nd: not detectable

A ground water quality monitoring network in Dehradun was established during October to December 2009 by Cooperation Centre for Riverbank Filtration (CCRBF) with the support of Uttarakhand Jal Sansthan, Dehradun under UCOST and U-SERC sponsored project. In this study, 172 handpumps of the city were surveyed and their working status (Table 2.30) and seven new GWMW were installed to observe the water levels and water quality (Table 2.31). The results of ground water quality analysis for the samples obtained from different handpumps during this period are given in the Table 2.32. These results clearly shows the higher calcium and magnicium concentrations than desirable limits of BIS and the absence of faecal coliforms (FC). The total coliforms range from 60 – 400 MPN/100ml which may be due to the contamination of ground water through leaky sewers and/or septic tanks[27]. The results of water quality analysis of the 7 monitoring wells in October 2011 are given in Table 2.33. Only turbidity of MW1, MW5, MW6 and MW7 was found more than permissible limit of BIS and the remaining parameters were below and within the limits[27].

2.4.3.1.2. Water Quality Status of Haridwar

Haridwar is one of the holiest places of India, situated on bank of river Ganga and is a district of Uttarakhand State. It is ringed by the district Pauri Garhwal in east and Dehradun in north, Muzaffarnagar and Bijnor of UP in south and Saharanpur of UP in the west. The ground water and surface water quality of Haridwar has been studied for various water quality parameters of BIS in different seasons by Pollution Control Research Institute (PCRI). The ground water quality of SIDCUL area of Haridwar during 2010 is described in Table 2.34[17].

Table-2.30.
Working status of 172 handpumps surveyed in Dehradun city[27]

Hand Pump's Detail	Number
Total number of handpumps surveyed	172
Total number of working handpumps	125
Total number of not functioning handpumps	47

Table-2.31.
Detail of seven ground water monitoring wells installed during September – December 2009 in Dehradun city[27]

Well No.	Locality	Discharge (m^3/s)	Depth (m)	Ground Level (m a.s.l.)	Ground Water Level (m a.s.l.)
MW1	Hathi Barkala (near Survey of India)	0.007	140.24	711.822	596.792
MW2	Ahir Mandi Kalidas Road	0.010	131.09	691.166	595.516
MW3	Mall Road (near Bindal Bridge)	0.015	105.18	663.115	593.895
MW4	Durga Vihar (near Ballupur Chowk)	0.017	106.70	666.115	595.450
MW5	Chandar Mahadev GMS Road (near HP Petrol Station)	0.015	134.45	657.439	590.769
MW6	Vasant Vihar Phase I (Park No. 8)	0.013	76.21	643.992	585.122
MW7	Bhagirathi Purams	0.015	108.23	756.076	693.876

Table-2.32.
Water quality analysis for ground water samples of Dehradun city during November – December 2009[27]

*Sampled Handpump	Water Quality Parameter & BIS Desirable Limit							
	pH (6.5 – 8.5)	Total Dissolved Solids (TDS), 500 mg/L	Calcium (as Ca), 75 mg/L	Magnesium (as Mg), 30 mg/L	HCO_3^- mg/L	Chloride (as Cl), 250 mg/L	Fecal Coliform (FC), Zero MPN/100 mL	Total Coliform (TC), 10 MPN/100 mL
HP32	7.2	380.0	176.3	34.3	6.1	6.9	NIL	60
HP19	7.1	308.0	160.3	28.1	6.3	3.2	NIL	150
HP95	7.2	416.0	172.3	41.7	7.3	14.0	NIL	80
HP84	7.2	464.0	192.4	45.6	7.6	26.2	NIL	110
HP98	7.2	377.0	180.3	35.4	7.0	13.6	NIL	70
HP104	7.1	354.0	156.3	43.7	6.5	15.6	NIL	110
HP62	7.1	599.0	248.5	60.2	8.9	51.0	NIL	130
HP72	7.2	575.0	236.45	58.2	9.3	52.0	NIL	ND
HP11	7.1	534.0	236.5	47.5	8.3	40.0	NIL	120
HP13	7.3	358.0	116.2	49.5	5.7	5.1	NIL	400
HP136	7.1	433.0	224.4	36.8	7.2	14.0	NIL	ND
HP12	7.2	418.0	200.4	44.6	8.0	18.2	NIL	120
HP15	7.2	454.0	208.4	47.5	8.4	17.7	NIL	160
HP3	7.2	391.0	168.3	42.7	5.7	8.7	NIL	120

**Sampled handpump- HP32: Canal Road near Gasgowon; HP19: Doon Vihar near Park; HP95: Race-course Mallin Basti; HP84: Chander Nagar Tiraha Palika Quarter; HP98: Araghar Model Colony; HP104: Nehru Colony, G-Block; HP62: Bhandari Bagh; HP72: Sanjay Colony; HP11: Lohiya Nagar; HP13: Niranjanpur; HP136: Maharanibagh near lane no.13; HP12: Kanchi Mohalla; HP15: Bapu nagar near OST green valley; HP3: Nathanpur*

In another study, the ground water quality of Haridwar district was also monitored for 51 sites by PCRI, Haridwar in UCOST and U-SERC sponsored research project. The list of 51 ground water sampling locations is given in Table 2.35. In this study, it was found that the ground water quality of Haridwar district was suitable for drinking purpose except some places where higher values of iron and coliform bacteria were observed (Table 2.36)[28].

Table-2.33.
Water quality analysis results of the 7 monitoring wells in October 2011[27]

Parameter	BIS Limits	*Monitoring Wells						
		MW1	MW2	MW3	MW4	MW5	MW6	MW7
pH	6.5-8.5	7.15	7.19	7.25	7.04	7.22	7.21	7.46
Conductivity	-	778	688	632	776	704	885	731
TDS	500 – 2000 mg/L	514	455	418	512	464	584	481
Alkalinity	200 – 600 mg/L	344	312	280	340	292	284	272
Turbidity	5 – 10 NTU	14.1	8.8	9.8	8.8	10.1	13.3	11.5
Fluoride	1.0 – 1.5 mg/L	0.18	0.54	0.39	0.31	0.27	0.51	0.42
Nitrate	45 – 100 mg/L	3.5	4.1	5.6	6.6	4.1	5.5	4.4
Chloride	250 – 1000 mg/L	9.6	7.9	8.2	16.1	5.4	14.5	10.7
Iron	0.3 – 1.0 mg/L	0.1	0.04	0.89	0.79	0.13	0.78	0.25
Calcium	75 – 200 mg/L	129.9	89.8	78.6	93	97.8	80.2	76.9
Magnesium	30 – 100 mg/L	27.7	36.4	44.1	52.7	39.3	83.4	58.5
Sulphate	200 – 400 mg/L	76	53	37	40	69	132	80
Total *E. coli*	0 – 10 MPN/100 mL	NIL	NIL	NIL	NIL	NIL	NIL	20
Fecal *E. coli*	0 – 0 MPN/100 mL		NIL	NIL	NIL	NIL	NIL	NIL

**Monitoring Wells- the details are given in table 2.31*

Table-2.34.
Ground water quality status at SIDCUL in Haridwar during 2010[17]

Parameters	Seasons					BIS 10500, Limits of DW	
	Post Mon	Winter	Summer	S.W. Mon	Aver.	Desirable	Permissible
pH	7.5	7.4	7.7	7.3	7.4	6.5-8.5	NR
Color (Hazan)	<5	<5	<5	<5	<5	5	25
Alkalinity (mg/l)	308	298	315	290	302.75	200	600
Hardness (mg/l)	284	280	292	275	282.8	300	600
Boron (mg/l)	ND	ND	ND	ND	ND	1	5
Calcium (mg/l)	101.0	98	107	93	99.75	75	200
TDS (mg/l)	386	381	394	366	381.8	500	2000
Res. Chlorine (mg/l)	0.1	0.1	0.15	0.1	0.1	0.2	--
Copper (mg/l)	0.11	0.11	0.14	0.11	0.12	0.05	NR
Cyanide (mg/l)	ND	ND	ND	ND	ND	0.05	NR
Chloride (mg/l)	13	10	19	7	12.3	250	1000
Arsenic (mg/l)	ND	ND	ND	ND	ND	0.01	NR
Iron (mg/l)	0.09	0.08	0.11	0.07	0.09	0.3	1
Lead (mg/l)	0.01	0.01	0.01	0.01	0.01	0.05	NR
Fluoride (mg/l)	0.36	0.34	0.38	0.04	0.28	1	1.5
Manganese (mg/l)	ND	ND	ND	ND	ND	0.1	0.3
Mercury (mg/l)	ND	ND	ND	ND	ND	0.0001	NR
Nitrate (mg/l)	2.2	2.1	2.4	1.1	1.95	45	NR
Aluminum (mg/l)	0.01	0.01	0.01	0.01	0.01	0.03	0.2
Phenol (mg/l)	ND	ND	ND	ND	ND	0.001	0.002
Selenium (mg/l)	ND	ND	ND	ND	ND	0.01	NR
Sulphate (mg/l)	21.0	19.0	24.0	16.0	20.0	200	400.0
Cadmium (mg/l)	ND	ND	ND	ND	ND	0.01	NR

Parameters	Seasons					BIS 10500, Limits of DW	
	Post Mon	Winter	Summer	S.W. Mon	Aver.	Desirable	Permissible
Chromium+6 (mg/l)	ND	ND	ND	ND	ND	0.05	NR
Turbidity (NTU)	0.32	0.27	0.38	0.22	0.3	5	10
Zinc (mg/l)	0.02	ND	0.08	ND	0.06	5	15
Magnesium (mg/l)	7.6	5.6	11.6	3.6	7.1	30	100
Total Coliform (CFU/100 ml)	Absent	Absent	Absent	Absent	Absent	10	NR
Fecal Coliform (CFU/100 ml)	Absent	Absent	Absent	Absent	Absent	NR	NR

NR: No Relaxation; ND: Not Detected.

Table-2.35.
Site details of water quality sampling stations of Haridwar district[28]

Monitoring Stations	Site	Site code
Haridwar Industrial Area	Tube well near income tax building	W 1
	Tube well near Shakumbari auto	W 2
	Handpump near Hanuman mandir	W 3
SIDCUL - Integrated Industrial Estate	Tube well in District Judge House	W 4
	Tube well in Roshanabad	W 5
	Tube well in Hemantpur	W 6
	Hand pump in District Judge House	W 7
Roorkee Industrial Estate	Tube well in Shadipur near Omega Pharmaceuticals	W 8
	Tube well village Puhana near REC	W 9
	Tube well village Kishnapur	W 10
	Hand pump village Kishnapur	W 11
Bhagwanpur Industrial Area	Tube well from Shivganga Industrial estate	W 12
	Hand pump near Unitec machine	W 13
	Hand pump in village Lakeshwari, Sikandarpur	W 14
	Hand pump in village Raipur	W 15
	Tube well in Raipur	W 16
Laksar	Tube well from Mubarakpur	W 17
	Tube well in village Ranjeetpur	W 18
	Hand pump in village Ranjeetpur	W 19
	Tube well from village Gangnouli	W 20
Narsan	Tube well KIE Industrial Estate	W 21
Roorkee	Tube well near Titan Industry	W 22
Dev Bhoomi Industrial Estate	Hand pump village Karondi	W 23
	Tube well village Bentakhedi	W 24
	Hand pump village Bentakhedi	W 25
M/s AIS Industrial Estate	Tube well village Khanpur Kasauli	W 26

Monitoring Stations	Site	Site code
Haridwar	Tube well Bopatwala	W 27
	Tube well Jwalapur	W 28
	Tube well Ranipur	W 29
	Tube well Bahadarabad	W 30
	Hand pump Bahadarabad	W 31
	Tube well Kankhal	W 32
Roorkee	Tube well Ramnagar	W 33
	Hand pump Ramnagar	W 34
	Tube well Sabje Mandi	W 35
	Tube well Gandhi Vatika	W 36
	Hand pump Sabje Mandi	W 37
Municipal Landfill Haridwar	Hand pump North of Land fill site	W 38
	Hand pump Chandi ghat	W 39
Rural areas	Tube well village Baditeep, Laksar	W 40
	Hand pump village Batiteep, Laksar	W 41
	Tube well Mohamadpur, Bahadarabad	W 42
	Hand pump Puhana chowk, Roorkee	W 43
	Tube well Roorkee Institute of Technology	W 44
	Hand pump village Sissona	W 45
	Hand pump village Khumbpur	W 46
	Tube well village Shyampur	W 47
	Tube well Jagjeetpur	W 48
	Hand pump village Badsahapur, Bahadarabad	W 49
	Hand pump village Nangala Kurd	W 50
	Hand pump Akberpur, Laksar	W 51

2.4.3.1.3. Ground Water Quality Status around Integrated Industrial Estate (IIE) of Pantnagar

On monitoring of ground water quality (Table 2.37) around IIE of Pantnagar, high values of magnesium, fluoride and total dissolved solids (TDS) were reported. The ground water was highly polluted and not fit for drinking purposes. Heavy metal pollution specially of iron and copper, was seen in most of the sampling sites[29].

2.4.3.1.4. Water Quality of Almora District w.r.t. Temperature

To evaluate the effect of temperature on some water quality parameters like pH, dissolved oxygen (DO) and total dissolved solids (TDS) during pre-monsoon, monsoon and post-monsoon, 54 ground water sources of Almora district have been analysed in 2007. The results reported that pH, DO, TDS, cations and anions concentrations have direct relationship with temperature[30].

2.5. Uttaranchal Koop

Uttarakhand Jal Sansthan has developed "Uttaranchal Koop" which is a useful indegenious device to tap the sub-surface flow of a stream in Uttarakhand. In this method water is

Table-2.36.
Average physico-chemical parameters of pre- and post-monsoon seasons in ground water of Haridwar district[28]

Site	pH	TDS (mg/L)	Cond. (µmhos/cm)	BOD (mg/L)	COD (mg/L)	HD (mg/L)	Fluoride (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Alk. (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Cr (VI), (mg/L)	Cu (mg/L)	Fe (mg/L)	TC (MPN/100mL)	FC (MPN/100mL)
Industrial Area																	
W 1	7.3	177	395	0.25	1.1	194	0.78	36	23	264	18	4.19	ND	0.01	0.12	<2	<2
W 2	7.5	165	320	0.15	1.1	256	0.8	39	30	334	12	8.02	ND	0.01	0.045	2	<2
W 3	7.7	215	357	0.35	1.15	256	0.845	33	29	306	22	4.40	ND	0.01	0.06	<2	<2
W 4	7.5	410	659	0.45	1.1	310	0.505	72	31	301	11	1.00	ND	0.135	2.425	2	<2
W 5	7.4	339	795	0.15	1.05	236	1.085	67	31	238	11	2.35	ND	ND	0.3	18	4
W 6	7.5	257	422	0.3	1.1	230	0.965	47	26	227.5	4	1.30	ND	ND	0.055	20	6
W 7	7.4	451	659	0.45	1.1	228	1.035	98	33	357.5	13	2.85	ND	ND	0.23	28	7
W 8	7.2	404	449	0.1	1.0	176	0.885	84	19	318.5	17	4.00	ND	0.01	0.055	2	<2
W 9	7.3	423	653	0.4	1.1	200	1.105	71	26	416.5	15	5.00	ND	0.01	0.54	5	<2
W 10	7.6	349	521	0.1	1.0	153	1.15	66	23	258	12	5.25	ND	0.01	0.295	8	3
W 11	7.4	400	674	0.2	1.0	236	0.68	154	29	286	100	3.05	ND	0.02	0.1	7	<2
W12	7.5	228	386	0.45	1.1	238	0.86	36	25	266	13	3.75	ND	ND	0.225	2	<2
W 13	7.3	703	1053	0.55	1.1	242	1.28	155.5	11.85	248.5	102	4.65	ND	0.01	0.59	3	<2
W 14	7.4	282	422	0.65	1.65	176	0.77	55.1	9.0	258	11	6.00	ND	0.015	1.095	5	2
W 15	7.4	369	611	0.5	1.1	307	1.37	51.7	30.3	326	9	3.95	ND	ND	1.25	38	14
W 16	7.4	250	357	0.25	1.0	236	1.09	53.1	28.6	376	13	1.15	ND	ND	0.435	8	3
W 17	7.4	378	612	0.15	1.0	158	0.755	39.5	28.6	286	19	2.60	ND	ND	0.045	3	<2

Site	pH	TDS (mg/L)	Cond. (µmhos/cm)	BOD (mg/L)	COD (mg/L)	HD (mg/L)	Fluoride (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Alk. (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Cr (VI), (mg/L)	Cu (mg/L)	Fe (mg/L)	TC (MPN/100mL)	FC (MPN/100mL)
W 18	7.4	353	579	0.15	1.0	230	0.72	39.3	21.7	278	12	7.49	ND	ND	0.08	<2	2
W 19	7.6	327	509	0.15	1.0	244	0.715	44.1	30.2	300	17	5.84	ND	ND	0.085	<2	3
W 20	7.5	257	422	0.3	1.1	230	0.89	44.5	31.2	326	25	12.69	ND	0.01	0.065	<2	<2
W 21	7.3	341	659	0.2	1.0	208	0.24	53.5	29.0	324	20	15.13	ND	0.01	0.06	4	<2
W 22	7.6	569	479	0.45	1.1	228	1.195	34.0	28.2	276	20	13.81	ND	0.01	0.07	<2	<2
W 23	7.5	366	528	0.15	1.0	244	0.475	93.1	24.6	408	20	12.34	ND	0.01	0.065	34	12
W 24	7.2	461	624	0.15	1.0	153	0.51	99.2	36.2	417.5	7	35.80	ND	0.02	0.06	2	<2
W 25	7.4	445	375	ND	1.0	239	0.715	38.4	31.1	326	12	12.60	ND	0.01	0.04	6	<2
W 26	7.4	291	396	1.0	1.0	228	0.77	65.7	25.8	276	17	4.78	ND	ND	0.045	6	2
Residential Area																	
W 27	7.5	163	359	0.2	1.0	149	0.42	38.4	6.5	145	35	11	ND	ND	0.06	<2	<2
W 28	7.3	398	691	0.65	1.6	314	0.96	62.3	27.6	227	39	6	ND	0.02	0.06	3	<2
W 29	7.55	288	583	0.25	1.0	206	0.51	39.2	23.1	219	20	6	ND	0.02	0.06	<2	<2
W 30	7.6	195	718	0.15	1.0	174	0.97	43.3	14.2	230	20	6	ND	0.02	0.07	<2	<2
W 31	7.55	271	579	0.15	1.0	152	0.55	53.2	30.3	264	64	15	ND	0.03	0.05	<2	<2
W 32	7.55	327	509	0.15	1.0	194	0.73	39.9	3.1	246	20	10	ND	0.04	0.08	<2	<2
W 33	7.6	361	565	0.1	1.0	211	0.75	29.7	21.7	270	26	8	ND	0.02	0.06	4	<2
W 34	7.45	420	630	0.3	1.05	228	0.63	39.3	30.2	300	36	2	ND	0.03	0.05	<2	<2

Site	pH	TDS (mg/L)	Cond. (µmhos/cm)	BOD (mg/L)	COD (mg/L)	HD (mg/L)	Fluoride (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Alk. (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Cr (VI), (mg/L)	Cu (mg/L)	Fe (mg/L)	TC (MPN/100mL)	FC (MPN/100mL)
W 35	7.55	527	982	0.45	1.6	239	0.99	44.1	31.2	326	28	1	ND	0.04	0.09	8	<2
W 36	7.4	513	938	0.35	1.0	241	0.74	44.5	31.1	306	23	1	ND	0.03	0.06	2	<2
W 37	7.4	353	579	0.15	1.0	140	0.73	29.9	23.1	326	11	6	ND	0.02	0.32	<2	<2
Landfill Site																	
W 38	7.4	393	659	0.2	1.0	228	0.71	36.2	24.7	276	35	11	ND	0.03	0.06	<2	<2
W 39	7.2	444	691	0.65	1.6	204	0.73	43.3	32.7	326	39	6	ND	ND	0.05	<2	<2
Rural Area																	
W 40	7.4	422	718	0.15	1.0	218	0.85	50.7	30.7	276	20	5.8	ND	0.02	0.09	<2	<2
W 41	7.4	353	579	0.15	1.0	261	0.77	37.4	25.1	284	20	5.9	ND	0.02	0.06	<2	<2
W 42	7.6	327	509	0.15	1.0	292	0.78	64.55	20.3	264	64	15.0	ND	0.02	0.05	<2	<2
W 43	7.6	361	575	0.1	1.0	210	0.58	46.2	18	246	7	9.9	ND	0.03	0.10	9	5
W 44	7.5	420	630	0.3	1.05	208	1.05	56.6	30.75	270	7	7.9	ND	0.02	0.08	14	6
W 45	7.6	527	982	0.45	1.6	224	1.00	43.8	28.35	300	7	4.7	ND	0.02	0.07	47	5
W 46	7.4	513	938	0.35	1.0	213	0.59	57.05	22.5	326	31	12.4	ND	0.02	0.09	2	<2
W 47	7.5	444	661	0.35	1.0	199	0.60	97.15	26.15	306	26	12.4	ND	0.02	0.07	<2	<2
W 48	7.4	453	751	0.35	1.0	198	0.97	47.35	17.3	304	22	8.2	ND	0.04	0.61	2	<2
W 49	7.55	271	579	0.15	1.0	231	0.59	38.4	12.25	296	6	13.2	ND	0.03	0.05	21	<2
W 50	7.2	461	624	0.15	1.0	240	0.52	47.65	26.95	286	17	5.8	ND	ND	0.02	41	<2
W 51	7.4	445	375	ND	1.0	249	0.78	41.65	26.6	314	25	12.7	ND	0.02	1.82	<2	<2

Table-2.37.
Ground water quality near integrated industrial estate of Pantnagar[29]

Water Quality Parameters, DW Standard IS : 10500 Values	Lalkuan Near Petrol Pump	Kichha Dam	Kichha Raliway Station	Tinpani, Rudrapur	Rudrapur city	Bengali Colony Near SIDCUL	Haldi Market	Sanjay-Nagar Lalkuan	SIDCUL-1 (Near ESCORT Inds.)	SIDCUL-2 (Near Dabur Inds.)
Colour, 5 Hazen	CLL	Yellow	CLL	CLL	CLL	CLL	CLL	CLL	CLL	CLL
TSS (mg/L), -	120	620	160	160	340	180	520	280	260	240
pH, 6.5-8.5	6.98	7.96	8.00	7.65	7.20	6.72	7.27	7.65	7.74	7.40
TDS (mg/L), 500	456	547	640	895	313	616	431	256	320	626
Hardness (mg/L), 300	200	194	212	364	168	190	190	156	182	200
Conductivity (µs/cm)	712	868	1066	517	453	977	663	371	517	1009
Ca (mg/L), 75	48	24	24	97.6	28	32	52	22.4	20.8	30.4
Mg (mg/L), 30	80	134	152	120	98	92	60	100	130	124
Alkalinity (mg/L), 200	35	30	35	31	16	25	21	20	22	25
Chloride (mg/L), 250	20	36	40	74	18	48	38	28	56	40
Sulphate (mg/L), 200	119.2	71.0	23.0	61.4	26.9	26.8	36.5	46.1	51.8	65.3
Nitrate (mg/L), 45	14.7	6.3	14.5	8.0	6.2	4.1	4.0	9.7	12.5	6.2
Fluoride (mg/L), 1.0	1.41	1.45	1.40	ND	1.48	3.0	2.72	ND	1.42	0.925
Phosphate (mg/L), -	2.6	3.3	6.3	2.1	3.5	0.7	1.5	2.2	2.1	0.7
Lead as Pb (mg/L), 0.05	0.08	0.003	0.003	0.001	0.04	0.002	0.004	0.003	0.005	0.03
Zinc as Zn (mg/L), 5.0	0.55	0.55	0.19	0.49	0.46	1.37	1.615	1.09	1.56	1.04
Iron as Fe (mg/L), 0.3	0.42	1.60	0.55	2.08	0.40	0.17	0.73	0.22	0.06	0.25
Cu (mg/L), 0.05	0.27	0.42	0.13	0.32	0.32	0.04	0.27	0.23	0.21	0.14
Cd (mg/L), 0.01	0.002	0.003	0.004	0.010	0.001	0.003	0.003	0.03	0.001	0.001

ND – Not Detectable, CLL-Colour less

obtained from aquifers, which have the direct connection with the surface water source. The Gadheras i.e. stream or small rivulet flowing in hilly area of Uttarakhand State, normally have a permeable strata just below the bed, saturated with water and having continuous sub-surface flow by gravity. Uttaranchal Koop has been designed to tap this continuous sub-surface flow through saturated strata. The flatter section of a Gadhera has been found to be the most suitable site for establishing an Uttaranchal Koop. It is found useful due to less construction cost, negligible maintenance cost, better earth quake resistance, less chances of getting damaged during monsoon, lower turbidity, less suspended particles and removal of coliform etc. The quality of water obtained from Uttaranchal Koop was found suitable for drinking purposes as per Indian and WHO standard.

Basically, Uttaranchal Koop is a hollow cylindrical mild steel pipe which has radial perforated pipes of suitable lengths at the bottom and is kept open at the bottom and closed at the top with a plate by nut and bolts. It is connected with a welded outlet socket at the middle of the cylinder for joining outlet pipe. This 1 to 1.5m long hollow cylindrical pipe is placed vertically 2 - 3 m below the bed of the stream with open end at the bottom and closed end at the top. Further, it is placed over impermeable strata of so called Gadhera. The dug space

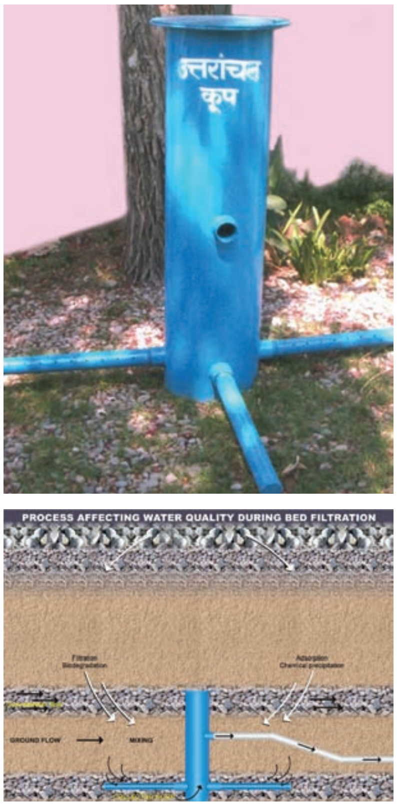


Fig-2.4A and 2.4B. Uttaranchal Koop[7]

is filled up with graded filter media enveloping the Koop up to the natural bed level of stream after fixing the Uttaranchal Koop. Now the sub-surface water from the stream rises inside the cylindrical pipe through its open end and perforated radial pipes by hydraulic pressure of the submerged surface and maintains a static level in the cylindrical pipe. The outlet socket which is placed almost at the middle of the koop is connected to gravity main of water supply scheme. This device is designed considering the minimum discharge of the stream during the summer (Fig. 2.4 A&B). The design of the device is approved by IIT Roorkee[31]. In 2009-10, UJS has installed total 1381 Uttaranchal Koop[8].

2.6. River Bank Filtration (RBF) in Uttarakhand

River bank filtration is a natural process of filtration along the banks of rivers in which the abstraction of water occurs from the wells located near river banks. In the light of current domestic water supply scenario, the use of RBF has much importance due to favourable hydrogeological conditions in Uttarakhand and is a good solution to save large investments. Infiltration well is a simple hydraulic and a large diameter structure which receives the naturally filtered water from the adjacent water body either lake or river. A filtration well primarily derives water from the river or lake seepage. The discharge of a filtration well mainly depends on the hydraulic conductivity and thickness of tapped aquifer. The distance of a well from water body should be such that the aquifer is able to filter the stream water. One of the main advantage of an infiltration well is the quality of water which we receive because it has inbuilt infiltration system and only disinfection is required after the well discharge. Such type of infiltration wells have been installed in the foothill parts of Rishikesh and Haridwar adjacent to River Ganga and in Nainital adjacent to Nainital lake[32,33]. A lot of energy can be saved for pumping and supplying of water. The water quality of seven tube wells, which are installed at a distance of less than 100m from the lake and the depths of 22.6 to 36.7m, was studied in monsoon and non-monsoon seasons during 1997 to 2006 and found suitable for domestic and drinking purposes. Coliform bacteria were not detected in any samples of these wells[34].

In Haridwar, more than 5,30,000 people reside permanently and temporarily in the city because Haridwar is a religious place of Hindus. Thus, the supply of good quantity and quality of water for Haridwar is an important issue. The current drinking water production of Haridwar is about 60,000m^3/day. Out of which 38% (Fig 2.5) of the drinking water supply is produced by 16 large diameter (about 10m) vertical caisson wells having 6.5 – 10.7m depth below ground level (Fig 2.6). The RBF wells and Tube wells of Haridwar are given in the Table 2.38 with their location and production capacities. Besides the good results obtained for water quality for physical and chemical parameters of RBF, the results of water quality monitoring programme (November 2005 to September 2006) showed the maximum removal of faecal coliforms by more than 99%. Furthermore, 62% of total water supply in Muni Ki Reti of Rishikesh is abstracted through two infiltration wells situated on the bank

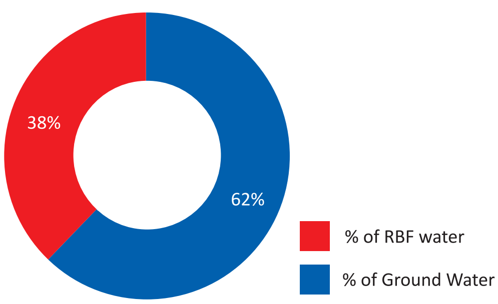


Fig-2.5. Percentage of river bank filtrate and ground water supply in Haridwar[35]

Fig-2.6. Monitoring wells at Haridwar[7] of River Ganga. Finally, it can be constitute that RBF technique is much useful as it is[32,33,35]

- Natural, sustainable and low cost method
- Effective elimination of pathogens and other organics
- Disinfection is sufficient in most cases

Table-2.38. RBF wells in Uttarakhand Jal Sansthan, Haridwar[33]

TW No.	Location of TW	Discharge (LPM)
TW No. 21	Tourist Banglow	1400
TW No. 28	Mahila Milan	1600
TW No. 29	Bairagi Camp	1500
TW No. 31	Sapat Sarowar	1700
TW No. 27	Parmarth Ashram	1650
TW No. 16	Bhopatwala	600
TW No. 26	Bhopatwala Office	1700
TW No. 40	Bhimgoda Pul	1500
TW No. 18	Pant Dweep	1200
TW No. 24	Roribelwala	1700
TW No. 25	Roribelwala	1700
TW No. 17	Laltarao	1800
TW No. 42	Ban Samadhi	1800
TW No. 43	Ban Samadhi	1800
TW No. 44	Vishnu Ghat	1600
TW No. 49	Bairagi Camp New	1800
	Total	25050

TW: Tube Well

2.6.1. *Cooperation Centre for River Bank Filtration (CCRBF)*

Cooperation Centre for River Bank Filtration has been established in Haridwar to assist the transfer of technology and knowledge between India and Germany in the area of RBF. The main functions of CCRBF are:

- Development of RBF technology for sustainable water resource management
- As a resource centre for quick dissemination of information at Haridwar
- Establishment of international collaboration for research purposes
- Technical support to Indian RBF projects

2.7. Departments Dealing with Water Resources in Uttarakhand

The State has three main Government departments, dealing with the management of water resources (Table 2.39).

Table-2.39. Departments dealing with water resources and concerned organizations in Uttarakhand[36]

Department	Concern Organization
Department of Drinking Water	1. Uttarakhand Jal Sansthan (UJS) 2. Peyjal Vikas Evam Nirman Nigam (UPJN) 3. Swajal Project
Department of Irrigation and Energy	4. Irrigation Department 5. Minor Irrigation 6. Uttarakhand Jal Vidyut Nigam Ltd.
Department of Rural Development	7. Watershed Management

UPJN is responsible for proper planning and construction of water supply and sewerage system in rural and urban areas. It also maintains few piped water supply schemes of rural areas of the state. On the other hand, UJS is in charge to operate and maintain water supply facilities as well as severage in rural and urban areas. SWAJAL is a Project Management Unit (PMU), registered under the Society Registration Act, 1860. It works to promote community based operation and maintenance of water supply schemes in rural areas. Currently, there are 13 PMU's i.e. one in each district to monitor and facilitate various project activities[36].

Water supply schemes of UJS in Garhwal and Kumaun regions are given in Table 2.40 and 2.41 while Table 2.42 depicts the decrease in discharge of rural drinking water schemes[7].

2.8. Recharge of Sources of Springs in Uttarakhand

Springs, which are the major available sources of water supply for agricultural, domestic and other purposes in Uttarakhand state, are meagre and have low discharge during summer season. The springs in hilly region originate from seepage waters which flow through the shallow weathered and fractured zones. The characteristics and existence of these springs has been changed significantly in last few decades due to natural and anthropogenic activities. However, the knowledge of the recharge area and recharge sources of the springs has become essential for their longer sustainability. The radioactive isotopes of hydrogen (H-3) and carbon (C-14) in conjugation with environmental stable isotopes of oxygen (O-18) and hydrogen (D) are being used to understand the recharge source or sources of a spring because environmental isotopes have some unique characteristic. The most frequently used natural isotopes in hydrological studies include isotopes of elements of the water molecule [^{1}H (Protium), ^{2}H or ^{2}D (deuterium), ^{3}H (tritium), ^{16}O and ^{18}O] and that of the element carbon [^{12}C, ^{13}C and ^{14}C] which occur in water as constituents of dissolved organic and inorganic compounds. The radioactive isotopes originated from cosmogenic nuclear reactions, are

Table-2.40. Water supply schemes of Uttarakhand Jal Sansthan in Garhwal Region[7]

Scheme	District Name								
	Uttarkashi	Chamoli	Tehri	Pauri	Rudraprayag	Dehradun Hilly	Dehradun Plain	Dehradun Total	Haridwar (Plain)
Maintained Drinking Water Sch. (Urban)	02	07	05	04	02	01	06	07	07
Maintained Drinking Water Sch. (Rural)	464	505	696	786	329	96	153	249	12
Tube Well	00	00	00	14	00	00	179	179	105
Mini Tube Well	00	00	00	06	00	00	100	100	02
Automatic Tube Well/Mini Tube Well	00	00	00	10	00	00	219	219	53
Hand Pump	647	521	999	1313	290	02	120	122	41
Uttaranchal Koop	98	71	110	123	72	39	21	60	00
Chal-Khal	294	125	528	454	232	13	10	23	00
Leakage Wells	00	03	10	09	23	00	00	00	00
Ponds	881	601	950	831	404	109	323	432	33
Water Connection	17867	12671	16564	35410	8899	2051	213081	215132	56077
Standpost	1187	4645	4621	6873	3370	108	2571	2679	954

Table-2.41.
Water supply schemes of Uttarakhand Jal Sansthan in Kumaun region[7]

Scheme	Pithoragarh	Almora	Nainital Hilly	Nainital Plain	Nainital Total	Bageshwar	Champawat	Udham Singh Nagar (Plain)
Drinking Water (Urban)	03	02	03	08	11	01	03	09
Drinking Water (Rural)	646	688	398	49	447	228	328	30
Working Tube well	00	00	49	26	75	00	07	124
Mini Tube well	00	03	00	06	06	01	03	00
Automatic Tube well/Mini Tube well	00	03	13	58	71	00	06	107
Hand Pump	721	1023	443	498	941	452	660	00
Uttaranchal Koop	229	330	78	20	98	83	184	00
Chal-Khal	274	636	54	12	66	123	59	00
Leakage well	04	32	14	00	14	08	02	00
Ponds	1061	1660	682	74	756	442	602	74
Water Connection	16166	17032	12521	62339	74860	3427	8779	23981
Stand Post	6696	10533	3063	1382	4445	4413	4372	1855

Table-2.42.
Decrease in discharge of rural drinking water schemes of Uttarakhand[7]

District	Rural Drinking Water Schemes in Maintenance	No. of Schemes /Details: 50 to 75% Decrease in Discharge	76 to 90% Decrease in Discharge	Decrease in Discharge More than 90%	Total	% of 2009	% of 2005-06	% of 2003
Nainital	421	141	9	0	150	35.63	55.33	9.44
Almora	667	151	36	19	206	30.88	49.42	20.07
Bageshwar	239	45	8	2	55	23.01	4.42	0.00
Pithoragarh	688	87	49	16	152	22.09	20.80	9.61
Champawat	338	70	26	10	106	31.36	55.36	0.00
Dehradun	269	30	5	3	38	14.13	18.22	3.10
Pauri	737	248	78	39	365	49.53	74.93	48.03
Chamoli	491	17	8	4	29	5.91	14.50	2.06
Rudraprayag	333	77	11	3	91	27.33	26.76	0.00
Tehri	691	282	143	40	465	67.29	40.84	32.97
Uttarkashi	461	6	30	6	42	9.11	0.00	0.00
Total	**5335**	**1154**	**403**	**142**	**1699**	**28.75**	**38.62**	**17.06**

useful for age or residence time determination of groundwater. Environmental isotop techniques are much helpful to understand the source and mechanism[37,38], recharge areas and transit times of the aquifer[39,40] and ground water circulation and its renewability[41].

National Institute of Hydrology, Roorkee has completed a case study in Uttarakhand State along the Bhagirathi River to identify the recharge areas and source of springs. The spatial distribution of $\delta\ ^{18}O$ for river water, hand pump (ground water) and spring water samples collected from Goumukh to Devprayag and a local meteoric water line (LMWL) was developed for Bhagirathi river catchment. Table 2.43 shows that the environmental tritium (^{3}H) contents in groundwater ranged from 7.5 to 13.0 TU. This was almost similar to tritium contents which were observed in precipitation, proving that the ground water was of recent age. Due to this reason, most of the hand pumps and springs do not sustain throughout the year[42].

The snow, ice, river discharge and rainfall samples for stable isotope ($\delta\ ^{18}O$) were studied along with other hydrometeorological data during May to October in 2004 and 2005 at Bhojwasa, which is 3 km downstream of Gaumukh[43]. The variation in river isotopic composition ($\delta\ ^{18}O$) with time shows the varied % of snow, glacier and rain contribution in the flow of the Bhagirathi River during the ablation period. The isotopic signatures of fresh snow and surface ice samples from Gomukh are given in Table 2.44 which were collected from different altitudes. The results showed that the melting rate of snow and glacier decreases due to decrease in temperature during the rainy period. This fact clearly explains the phenomenon of decrease in overall discharge of snow and glacier-fed rivers during the rainfall period at higher altitudes or near the snout.

Table-2.43.
Altitude of recharge zones of springs and environmental tritium contents in water bodies[42]

Altitude of recharge zones of springs whose isotopic values fall on LMWL					
Spring Name (altitude in m)	Spring $\delta\ ^{18}O$ (‰)	Precipitation $\delta\ ^{18}O$ (‰)	Difference $\Delta\ \delta\ ^{18}O$	Projected altitude of recharge area above the location of springs (m)	Altitude of recharge area (m)
Siyansu (752)	-7.76	-4.76	-3.0	748	1500
Bhinu (1256)	-7.1	-6.78	-0.32	244	1500
Koti (1450)	-8.6	-7.55	-1.05	260	1710
Altitude of recharge zones of springs whose isotopic values fall on Evaporation Lines					
Tehri (640)	-9.3	-4.3	-5.0	1245	1885
Sirai (658)	-9.2	-4.4	-4.8	1202	1860
Maldewal (755)	-8.45	-4.8	-3.65	917	1672
Environmental ^{3}H values (in TU) in ground water, river and rainfall in study area					
Ground water	Uttarkashi	Syanshu	Devprayag	Rishikesh	Range
	13	10.7	12.4	7.5	7.5-13.0
River	Gangotri	Uttarkashi	Devprayag		
	14	12	11		11-14
Rainfall	Uttarkashi	Devprayag			
	13	12			12-13

Table-2.44.
δ ^{18}O values of snow and ice/glacier samples[43]

Location	Altitude (m)	δ ^{18}O (‰)
Gaumukh, near Bhojwasa	3800	-11.6
	3800	-13.9
	3800	-9.7
	3800	-10.1
	3800	-11.7
	3800	-4.0
	3800	-14.0
Gaumukh	4000	-18.5
	4000	-13.37
	4000	-18.1
	4000	-14.5
	4000	-13.5
	4000	-15.0
	4000	-14.4

On the demand of UJS, NIH Roorkee has identified the recharge areas of Moli, Ratoli, Gothiyara and Kandha Dhangi springs in Chandrabhaga watershed in Jakhanidhar Block of Tehri Garhwal using environmental isotopes, particularly stable isotopes of oxygen and hydrogen including environmental tritium. About 300 water samples of springs, rain water and ground water have been collected. Out of which, 230 samples have been analysed for O-18 and deuterium and the discharge of all the 4 springs is being measured at 15 days interval since June-2010. The recharge area would be identified this year on the basis of exact altitude identification, ground water survey of the area and hydro-geological data of the area[18].

Recently, NIH Roorkee has completed a study for δD, δ^{18}O and ^{3}H analysis in samples of atmospheric moisture, precipitation and underground water of Roorkee and river Ganga (from upper Ganga Canal) at Roorkee. It is reported that the isotopic index of local vapours composition during mid-summer was about -5‰ for δ^{18}O, positive correlation occurred between the isotopic variation in air moisture and the absolute humidity, total vapour of the region replaced by monsoon vapour in monsoon periods. The impact of canal seepage was upto 1.5 Km across the canal length in isotopic variation study of ground water composition[18].

HESCO (Himalayan Environment Studies and Conservation) is also working for the recharging of drying springs in mountain regions using isotope hydro-geochemical techniques. HESCO has recharged 16 springs of Uttarakhand in association with BARC, Mumbai[44].

2.9. Watershed Management

Watershed means geographic boundaries of a particular water body including its ecosystem. Watershed development is essential for sustainable development in Uttarakhand to increase the rainfall based agricultural production in ecologically fragile and erosion prone hills of the state. Uttarakhand has 1110 total micro-watersheds (MWSs) which cover about 51.12 lakh ha area of the state (Table 2.45). Among which 948 MWSs are treatable and 641 MWSs of the treatable MWSs are covered under different schemes[45].

Watershed Management Directorate, Dehradun is currently implementing the following programmes/schemes in the state.

- Uttarakhand Decentralized Watershed Development Project (GRAMYA)
- Global Environment Facility (GEF) funded SLEM project (a sub-project of Gramya)
- IFAD assisted Integrated Livelihood Support Project (ILSP)
- CSS funded Integrated Watershed Management Programme (IWMP)

Himalayan region in Uttarakhand is characterized by distinct and contrasting qualities relating to landuse, physiographic, biodiversity, livelihood production systems and socio-economic conditions. Though, the state is rich with vast water resources but it suffers from scarcity amidst plenty especially during lean periods. The Springs, Gadheras or Khals frequently found on hill slopes and in the valleys constitute the major source of water supply in hilly watersheds. Uttarakhand receives on an average annual 1606 mm of rainfall, more than the national average but its major part flows down the slopes as runoff and hardly 10% of cultivated area is irrigated in the hilly districts. The shrinking glaciers feeding the major rivers, mismanagement of catchment areas of natural springs, high erosion rates and hydrological disasters are the major land degradation and environmental problems confronting the hilly areas. Sustainability of surface and sub-surface water resources can be ensured by integrated watershed management programmes to improve the productivity and environmental security. In the eastern Himalayas, the contribution of snow to major rivers is about 10% while it is more than 60 percent in the western Himalayas[46]. In the recent years, the hydrological characteristics of watersheds in Uttarakhand Himalayan region have undergone significant changes due to land use transformations leading to more repeated hydrological disasters, enhanced variable rainfall and runoff, pollution of lakes and extensive sedimentation in reservoirs. Increased temperatures and enhanced seasonal variability in precipitation is expected to result in glacier's recession and increasing danger from in peak flow; and sediment yield would have a major impact on hydropower generation, urban water supply and agriculture. The largest number of glaciers (3538) are located in Indus basin followed by 1020 in the Ganga basin and 662 in the Brahmaputra basin. However, the glaciers are retreating at a faster rate in comparison to last century. The recession of Uttarakhand glaciers which feed the Ganga River has been estimated to vary from 7 to 21 m per year. Consequently, the landslides, avalanches, low flows in lean periods and floods in monsoon season have been accelerated. In Uttarakhand, 35% of the area is suffering from potential erosion rates of more than 40 t/ha/yr while 88 percent of the area has erosion rates more than 10 t/ha/yr, which is an alarming situation. The flow in natural springs and streams of Himalayan watersheds has declined sharply in recent years due to accelerated deforestation, construction and mining. In Kumaun Himalayan region, Gaula river catchment is an example of declining discharge where 40% of the villages, spring discharge has declined by 25 to 75% during the last 10 to 50 years. Therefore, the river flow reduced from 12000 m^3/day to 5000 m^3/day in last 15 years due to over exploitation[47]. The average annual runoff in the Himalayan watersheds is estimated to vary from 15 to 20% in the valleys and up to 50% in the high hilly areas. Due to mismanagement of catchment areas and other development activities, it has been estimated that the dry weather flow in

Table-2.45.
Classification of Micro-watersheds (MWSs) of Uttarakhand[45]

S. No.	Detail of Micro-watershed (MWS)	MWS No.	MWS Area (lakh ha)
1	Total MWS in Uttarakhand	1110	51.12
2	Total untreatable MWS	162	11.82
3	Total treatable MWS	948	39.30 + 1.20
4	Total MWS covered under pre-IWMP schemes of DoLR	256	7.28
5	Total MWS covered under schemes of other Ministries	283	12.65
6	Total MWS covered under IWMP 2010-11 of DoLR	102	2.03
7	Balance MWS not covered till date	307	17.14
8	Plan for covering balance MWS		
	11th Plan (2011-12)	27	1.18
	12th Plan	101	4.3
	13th Plan	84	4.64
	14th Plan	95	7.02
	Total	307	17.14
9	No. of projects (clusters) proposed for 2011-12	18	

the springs of Uttarakhand vary from 2 to 20 Ipm in Kumaun Himalayas[48] and from 1 Ips to 15 Ips in Tehri Garhwal region[47].

2.9.1. Impact and Analysis of Climatic Variability on Himalayan Watershed in Uttarakhand

A study has been started by NIH, Roorkee, for long term climatic variability analysis of rainfall, temperature and stream flow, broad scale hydrological monitoring, data collection at watershed scale, a centralised database for watershed for users etc. in Chandrabhaga (4.34 Km^2) and Danda watershed (4.42 Km^2) at the elevation of 720m to 2350m in Tehri Garhwal district. For the Integrated Hydrological Study for sustainable development of these two hilly watersheds, a database of spatial and non-spatial data has been prepared using hydrological instrumentation, remote sensing and GIS technologies at Anjanisain observatory. Under the second phase of this project, rainfall monitoring was done with automated rain gauges. On the basis of ten and four year's data, the average runoff coefficient and sediment flow was 0.22 & 7 to 34 t/ha/yr and 0.21 & 71 to 197 t/ha/yr for Chandrabhaga and Danda watersheds, respectively[18].

2.10. Diminishing of Perennial Streams in Uttarakhand

The perennial streams of Uttarakhand state are diminishing at a faster rate due to the reduction in groundwater recharge and converting into non-perennial streams. The total lengths of perennial streams of Kosi watershed was about 225.6 km about four decades back but at present their length is about only 41.5 km. These streams are drying up at the rate of about 5.43 km per year. The rate of diminishing of the length of perennial streams is more in non-glacial fed river watersheds[10].

The 18 years data of minimum water discharge of Kosi river in Almora district clearly indicates that the river is dwindling speedily and if regenerative actions are not taken immediately then it may become non-perennial river in near future. Same condition is seem for other non-glacial fed rivers, which can be better understood by their minimum summer discharge rates[10].

2.11. Development of Water Resources in Uttarakhand

The major perennial rivers of north India originate from 917 glaciers which are spread over 3550 sq. Km in Uttarakhand. The average annual precipitation in Uttarakhand is

Drinking water standards of BIS (IS: 10500: 1991)[49]

Parameter	Unit	Standard Limit	
		Desirable Limit	Permissible Limit
pH value	--	6.5 to 8.5	No Relaxation
Residual Free Chlorine	mg/l	0.2	--
Odour	--	Unobjectionable	--
Taste	--	Agreeable	--
Alkalinity	mg/l	200	600
Turbidity	NTU	5	10
Total Coliform	MPN / 100 ml	0	10
Fecal Coliform	MPN / 100 ml	0	0
Colour	Hazen	5	25
Nitrate	mg/l	45	100
Total Dissolved Solids	mg/l	500	2000
Chloride	mg/l	250	1000
Fluoride	mg/l	1.0	1.5
Sulfate	mg/l	200	400
Total Hardness	mg/l	300	600
Phenolic Compound	mg/l	0.001	0.002
Arsenic	mg/l	0.05	No Relaxation
Aluminium	mg/l	0.03	0.2
Calcium	mg/l	75	200
Cadmium	mg/l	0.01	No Relaxation
Hexavalent Chromium	mg/l	0.05	No Relaxation
Copper	mg/l	0.05	1.5
Iron	mg/l	0.3	1.0
Magnesium	mg/l	30	100
Manganese	mg/l	0.10	0.30
Lead	mg/l	0.05	No Relaxation
Zinc	mg/l	5	15
Mercury	mg/l	0.001	No Relaxation
Selenium	mg/l	0.01	No Relaxation
Cyanide	mg/l	0.05	No Relaxation
Boron	mg/l	1.0	5.0
Pesticides	mg/l	Absent	0.001

higher than the National average and the total water requirement for the human and animal population, agriculture and industry of state has been estimated at only 3% of the annual precipitation received. The irrigated area in the hilly districts of state has been estimated at only 10-12% of the total cultivated area because most of the water available through rainfall flows down the hill slopes into the plains[47].

More than 86% of the total water demand of the rural areas is met from the natural resources. Out of which 50 to 60 percent of the drinking water supply systems have become non-functional (Table 2.7). It is also important to mention here that a major part of runoff which flows unutilized needs to be suitably harvested through water harvesting techniques following the concept of integrated watershed management. This would be helpful not only in checking the threat of land degradation but in increasing the productivity, moderating floods in downstream areas and to mitigate the harmful effects of drought. The conservation of rain water along with surface and sub surface water resources with efficient water application techniques, ground water recharge, spring rejuvenation methods needs due emphasis for sustainable management of water resources. Besides this, community participation and institutional participation with modern techniques to develop cost effective and sustainable water resource systems is also required.

2.12. State Level Water Quality Analysis Laboratory

A "State Level Water Quality Analysis Laboratory" has been established in Dehradun jointly by UCOST, UJS, and DAV (PG) College, Dehradun under Water Technology Initiative (WTI) programme of Department of Science and Technology (DST), New Delhi. The laboratory through advanced and modern analytical instruments is involved in analysing 32 water quality parameters by BIS and APHA procedures. Table 2.46 and 2.47 list out the method/ instruments used.

2.13. National Water Policy

Water is an essential natural resource for basic requirement of humans. According to an assessment done in year 1993, the availability of surface and replenishable ground water is about 1869 billion cubic metres in the country with rainfall, river waters, ponds, lakes and ground water being a part of this indivisible resource. Indian "National Water Policy" was adopted in September 1987 and has been reviewed and updated for a number of issues in the development and proper management of this resource in the country. Later an amended National Water Policy, 2002 was postulated which emphasized on a well developed information system for water quantity and quality related data, water resources planning, water allocation priorities such as drinking water, irrigation, ecology, agro-industries, non-agricultural industries, hydropower etc. It also proclaims development of ground water, proper resettlement and rehabilitation, participation of private sector, water conservation, flood control and management, monitoring of projects, water sharing and distribution among the states using science and technology interventions[50].

2.14. Irrigation in Uttarakhand

Irrigated agriculture is confined to the productive valleys in the hills. Constructed irrigation facilities are limited to plain areas of Uttarakhand (refer chapter Agriculture and Horticulture). As per the statistics of 2009-10, Hauj and Gools are the major sources of water supply for cultivation purposes. Gool travails a distance of 23715 Km in the State while, 29507 hauj's are distributing water for irrigation.

2.15. Sanitation in Uttarakhand

Individual's health and hygiene is mainly depends on the availability of potable drinking water and proper sanitation due to the direct relationship between water quality, sanitation

Irrigation in Uttarakhand[8]

A. Net and Gross Irrigated Area		
Canals	2008-09	95922 Hectare
Tube Wells	2008-09	198193 Hectare
Other Wells	2008-09	15587 Hectare
Tanks	2008-09	770 Hectare
Other Sources	2008-09	29657 Hectare
Net Irrigated Area (NIA)	2008-09	340129 Hectare
Gross Irrigated Area (GIA)	2008-09	569769 Hectare
B. Irrigation Infrastructure		
Length of Canal	2009-10	11081 Km
Length of Lift Canals	2009-10	201 Km
Tube Wells (State)	2009-10	981 No.
Pump Sets (Boring/Free Boring)	2009-10	54361 No.
Hauj	2009-10	29507 No.
Gool	2009-10	23715 Km
Hydrum	2009-10	1493 No.
CCA Under State Canal	2009-10	3.18 Lakh Hect.
Revenue Collection by Irrigation	2009-10	Rs. 243.61 Lakh

Table-2.46. Details of water quality parameters presently being analysed and analytical/ instrumental methods being used for analyses.

By Volumetric Method	By Instrumental Technique/ Manually	By UV-VIS Spectro-photometer	By Atomic Absorption Spectro-photometer	By Gas Chromatography
Alkalinity	Odour	Anionic Detergents	Aluminium	Chlorinated Pesticides
Total Hardness	Taste	Colour	Arsenic	
	Turbidity	Chloride	Calcium	
	Dissolved Solids	Res. Free Chlorine	Cadmium	
	pH value	Sulfate	Chromium	
	Coliform Bacteria	Phenolic compounds	Copper	
		Fluoride	Iron	
		Nitrate	Lead	
			Magnesium	
			Manganese	
			Mercury	
			Potassium	
			Selenium	
			Sodium	
			Zinc	
02	06	08	15	01

Table-2.47.
Details of equipments presently working in laboratory

Name of Equipment in Lab	Make and Model
High Quality Water Field Testing Kit with Bar Coded Water Testing Kits	Merck, Germany; Pharo 300 Spectrophotometer
Atomic Absorption Spectrophotometer (AAS) with Accessories	Varian, Australia; AA-240
pH Meter	Toshniwal, India; CL46
Turbidity Meter	Aqualytic Germany; Turbi Check
Portable Conductivity/TDS meter	Hach, U.S.A.; SensIon5
Millipore Ultra Pure Water Purification System for Analytical Grade Pure Water	Millipore; ELIX with Synergy and Surepro
COD Digester	Hach, U.S.A.; DRB200
Digital Titrator	Hach, U.S.A.; 16900-01
Vapour Generation Accessory i.e. Hydride Generator for AAS (VGA 77)	Agilent / Varian; 10051900
Auto Sampler for AAS (SPS 3)	Agilent / Varian; 10082200

and health. Urban sewerage facilities are available only to a small fraction of urban population and lack of proper sewerage system to a major part of population possesses adverse effects on environment and local water bodies. Therefore, the drinking water sources sometimes become unfit for use due to health related issues. The state water and sanitation mission for Uttarakhand have been constituted with the participation of all UPJN, UJS and Swajal. The Project Management Unit has implemented the World Bank assisted Uttarakhand Rural Water Supply and Environmental Sanitation (Swajal) Project in 857 villages of Uttarakhand state. After the encouraging results of Swajal Project Phase-I, Swajal Phase-II is under preparation[51]. Uttarakhand Government is following identical policy and practice under Sector Wide Approach (SWAP) for the implementation of water and sanitation programmes all over the state. The "Total Sanitation Campaign (TSC)" program along with Central Rural Sanitation Programme (CRSP) is being implemented by the department of Drinking Water Supply, Ministry of Rural Development, Government of India. Its mandate is to improve the quality of life of the rural individuals, to accelerate sanitation exposure in rural areas to access to toilets for all by 2012, to provide privacy and dignity to women, to encourage cost effective and appropriate technologies for ecologically safe and sustainable sanitation and to develop community managed environmental sanitation systems focusing on solid and liquid waste management[52]. The coordination of the TSC programme with other departments like Watershed Department, Health Department and Education Department has also been developed to provide the synergistic motion for TSC in state.

According to Uttarakhand Development Report 2009[5], the sewerage system in towns of the state is quite inadequate and only 20 towns of the state have the partial sewerage system cover (Table 2.48). Other than these towns, only Haridwar and Rishikesh have the sewage treatment plants (STPs) and require the upgradation in capacity for the increasing population accordingly (Table 2.49). Among the towns where sewerage system is absent, Rudrapur generates the maximum quantity followed by Jaspur and Kichha (Table 2.50).

Sewerage system was provided in Dehradun in 1921 with surface drains water flush toilets and short length intercepting sewers. Since, then it has been extended to different parts

Table-2.48.
Status of sewage system in Uttarakhand[5]

Total no. of Towns	63
No. of towns having partial sewage system (but requiring reorganization and extension)	20
No. of towns having no sewage system	43
No. of towns in which sewage system is under execution	8

Table-2.49.
Towns of Uttarakhand having partial sewerage system[5]

District	Town	Population of Town			Rate of Water Supply	Quantity of Sewage Developed
		2001 Census	Base Year 2005	Design Year 2035		
Garhwal Zone						
Uttarkashi	Uttarkashi#	16218	17191	26922	135	2.73
Chamoli	Joshimath#	13204	13996	21919	135	2.22
	Chamoli-Gopeshwar#	19833	21023	32923	135	3.33
	Badrinath#	1682	1783	2792	135	0.28
Tehri Garhwal	New Tehri	25423	26948	42202	135	4.27
	Muni-Ki- Reti	7880	8353	13081	135	1.32
Dehradun	Mussoorie	26075	27640	43285	135	4.38
	Rishikesh#	59540	63112	98836	135	10.01
	Dehradun	426674	452274	708279	135	71.71
	Vikas Nagar	12486	13235	20727	135	2.10
Pauri Garhwal	Kotdwar	24947	26444	41412	135	4.19
Haridwar	Haridwar#	175340	185860	291064	135	29.47
	Roorkee	97516	103367	161877	135	16.39
Total Garhwal		**906818**	**961227**	**1505318**	**1755**	**152.41**
Kumaun Zone						
Pithoragarh	Pithoragarh	44964	47662	74640	135	7.56
Almora	Almora	30154	31963	50056	135	5.07
Nainital	Haldwani cum Kathgodam	129015	136756	214165	135	21.68
	Nainital	38630	40948	64126	135	6.49
	Ramnagar	46205	48977	76700	135	7.77
Udham Singh Nagar	Kashipur	92967	98545	154325	135	15.63
Total Kumaun		**381935**	**404851**	**634012**	**810**	**64.19**
Total Uttarakhand		**1288753**	**1366078**	**2139330**	**2565**	**216.61**

Table-2.50.
Towns of Uttarakhand having no sewerage system[5]

District	Town	Population of Town			Rate of Water Supply	Quantity of Sewage Developed
		2001 Census	Base Year 2005	Design Year 2035		
Garhwal Zone						
Uttarkashi	Barkot	6095	6461	10118	135	1.02
	Gangotri	605	641	1004	135	0.10
Chamoli	Karanprayag#	6977	7396	11582	135	1.17
	Gauchar	7303	7741	12123	135	1.23
Rudraprayag	Rudraprayag#	2250	2385	3735	135	0.38
	Kedarnath	482	511	800	135	0.08
Tehri Garhwal	Devprayag#	2175	2306	3611	135	0.37
	Kirti Nagar	1040	1102	1726	135	0.17
	Narendra Nagar	5304	5622	8805	135	0.89
Dehradun	Herbertpur	9243	9798	15343	135	1.55
Pauri Garhwal	Pauri	24743	26228	41073	135	4.16
	Srinagar#	19658	20837	32632	135	3.30
Total Garhwal		**85875**	**91028**	**142553**	**1620**	**14.43**
Kumaun Zone						
Champawat	Tanakpur	15811	16760	26246	135	2.66
	Champawat	3959	4197	6572	135	0.67
	Lohaghat	5829	6179	9676	135	0.98
Bageshwar	Bageshwar	7803	8271	12953	135	1.31
Udham Singh Nagar	Rudrapur	88676	93997	147202	135	14.90
	Jaspur	38937	41273	64635	135	6.54
	Kichha	30503	32333	50635	135	5.13
Total Kumaun		**191518**	**203009**	**317920**	**945**	**32.19**
Total Uttarakhand		**277393**	**294037**	**460472**	**2565**	**46.62**

#: Towns situated along the Ganga are to be covered by GAP II.

of the city and presently covers about 50% population of the city. But there is no sewage treatment facility, collected sewage is disposed directly into Bindal and Rispana Rivers. Remaining 50% population depend on individual septic tank based waste disposal systems. The UPJN and UJS are involved in sewerage service provision in the city[53].

2.16. References

1. Ground Water Year Book (2009-2010) Uttarakhand, Central Ground Water Board, Uttaranchal Region, Ministry of Water Resource, Government of India, 2011.
2. Census of India, 2011.
3. Uttarakhand Vision 2022, Report of Confederation of Indian Industries (CII); http://www.indiaat75.in/vision.../Final_Uttarakhand_Vision_Document.pdf
4. IS1172: 1993, (Reaffirmed 1998), Code of Basic Requirements for water supply, Drainage and Sanitation (Fourth Revision) Bureau of Indian Standard.
5. Urban Area Development, Uttarakhand Development Report, Planning Commission, Government of India, 2009.

6. Chal-Khal: Parampra Ka Punarjivan, Book, Uttarakhand Jal Sansthan.

7. Uttarakhand Jal Sansthan, Dehradun.

8. Uttarakhand at a Glance (2010-2011), Directorate of Economics and Statistics, Dehradun, Uttarakhand; http://des.uk.gov.in/files/pdf/uttarakhand at a glance english.pdf; accessed on 20/04/2012.

9. Gupta, A., Ground water scenario and management options in Uttaranchal State. *Bhu-Jal News,* 2006, **21**, 1-5.

10. Rawat, J.S., Arora V.P.S., Dobhal, R., Gahlot, N. and Anand, A., Signature of climate change in Uttarakhand state, Interim Report, Uttarakhand Centre on Climate Change, Kumaun University, Nainital, 2011.

11. National Commission for Integrated Water Resources Development, Integrated Water Resources Development – A Plan for Action. Report of the National Commission for Integrated Water Resources Development. Ministry of Water Resources, Government of India, New Delhi, 1999.

12. IWRS, Theme Paper "Five Decades of Water Resources Development in India". Indian Water Resources Society, Roorkee, 1998.

13. Geological Survey of India, Sp. Pub. 34, 2009.

14. Semwal, N. and Akolkar, P., Water quality assessment of sacred Himalayan Rivers of Uttaranchal, ***Curr. Sci.,*** 2006, **91**(4) 486-496.

15. Uttaranchal Environment Protection and Pollution Control Board Annual Report (2005-06) Dehradun.

16. Monitoring of Indian Aquatic Resources, Series: MINARS/31/2009-2010, Ganga Water Quality Trend, Central Pollution Control Board, Ministry of Environment and Forests, Government of India.

17. Srivastava, N.G., Progress Report on Preparation of action plan for pollution control for Haridwar City, PCRI, Haridwar, Uttarakhand, 2011, (Unpublished).

18. Annual Report (2010-11) National Institute of Hydrology, Roorkee.

19. Srivastava, N.G., Progress Report on Preparation of action plan for pollution control for Haridwar City, PCRI, Haridwar, Uttarakhand, 2010, (Unpublished).

20. Water quality status of Yamuna River (1999-2005), Central Pollution Control Board, Ministry of Environment and Forests, Government of India, 2006.

21. National Wetland Inventory and Assessment, High Altitude Himalayan Lakes, Space Application Centre, ISRO, Ahmedabad, 2011.

22. Central Pollution Control Board, Environmental standards, water quality criteria, http://cpcb.nic.in/Water_Quality_Criteria.php; accessed on 25/02/2012.

23. State Profile, Central Ground Water Board, Ministry of Water Resources, Govt. of India, 2012; http://cgwb.gov.in/ accessed on 22/02/2012.

24. Srivastava, S.K., Ground water quality in parts of Uttaranchal. ***Bhu-jal News***, 2006, **21**(1-4), 56-62.

25. Gopikrishna, K., Ground water management studies, Dehradun district, Uttarakhand, Central Ground Water Board, Uttaranchal Region, Ministry of Water Resources, Government of India, 2009.

26. NIUA, Appraisal of city development plan Dehradun, National Institute of Urban Affairs, Core 4B, India Habitat Centre, Lodhi Road, New Delhi, 2007.

27. Report on Establishment of a ground water monitoring network in Dehradun, CCRBF Report, 2011 (Unpublished).

28. Kesav, K., Report on Assessment of ground water quality in Haridwar district, Pollution Control Research Institute, BHEL Haridwar, 2010, (Unpublished).

29. Benerjee, T., Pandey, A. and Srivastava, R. K., Study on variable nature of some ground water pollutants at surroundings of Integrated Industrial Estate – Pantnagar. ***J. Ecophysiol. Occup. Hlth.,*** 2009, **9**, 31-36.

30. Bhandari, N.S. and Joshi, H.K., Summary of the UCOST sponsored project report, Govt. of Uttarakhand, pp. 35-36 (Unpublished).

31. Uniyal, H.P., Uttaranchal Koop- a device to tap the sub-surface flow of stream in Uttaranchal state. *Bhu-jal News*, 2006, **21**(1-4), 44-47.

32. Uniyal, H.P. and Jamloki, D., River bank filtration: study of infiltration wells in Uttaranchal state. *Bhu-jal News*, 2006, **21**(1-4), 6-13.

33. Uniyal, H.P., River Bank Filtration in India: Existing efforts and future prospects: in Drinking Water, Source, Treatment and Distribution, Bishen Singh Mahindra Pal Singh Pub. Dehradun, 2011, 9-24.

34. Dash, R.R., Mehrotra, I., Kumar, P. and Grischek, T., Lake bank filtration at Nainital, India: water quality evaluation. *Hydrogeo. J.,* 2008, **16**, 1089 – 1099.

35. Sandhu, C.S.S., Grischek, T., Thakur, A.K. and Schoenheinz, D., Bank filtration in India. Proc. 10th Young Scientists Conference, Merseburg, 16.04.2009.

36. Water Resources, Uttarakhand Development Report, Planning Commission, Government of India, 2009.

37. Shivana, K., Kulkarni, U.P., Joseph, T.B. and Navada, S.V., Contribution of storms to ground water recharge in the semi-arid region of Karnataka, India. *Hydrol. Process.,* 2004, **18**, 478-485.

38. Sukhija, B.S., Reddy, D.V., Nagabhushanam, P., Hussain, S., Giri, V.Y. and Patil, D.J., Environmental and injected tracers methodology to estimate direct precipitation recharge to a confined aquifer. *J. Hydrol.,* 1996, **177**, 77-97.

39. Agarwal, M., Gupta, S.K., Deshpande, R.D. and Yadava, M.G., Helium, radon and radiocarbon studies on a regional aquifer system of the North Gujrat-Cambay region, *India. Chem. Geol.,* 2006, **228**, 209-232.

40. Sukhija, B.S., Reddy, D.V. and Nagabhushanam, P., Isotopic fingerprint of palaeoclimates during the last 30,000 years in deep confined ground waters of Southern India. *Quat. Res.,* 1998, **50**, 252-260.

41. Rao, S.M. and Kulkarni, K.M., Isotope hydrology studies on water resources in western Rajasthan**.** *Curr. Sci.,* 1997, **72**, 55-61.

42. Bhishm Kumar, Paper in Indo-German International Workshop on "Source, Treatment and Distribution of Drinking Water" at Indian Council of Forestry Research and Education (ICFRE), Dehradun, September 14-15 (2009).

43. Rai, S.P., Kumar, B. and Singh, P., Estimation of contribution of southwest monsoon rain to Bhagirathi River near Gaumukh, western Himalayas, India, using oxygen-18 isotope, *Curr. Sci.,* 2009, **97**, 240-245.

44. Annual Report (2010-2011). Himalayan Environment Studies and Conservation.

45. Watershed Management Directorate, Dehradun, Uttarakhand.

46. Vohra, C.P., The climate of the Himalayas. The Himalaya: aspects of change (ed, Lall, J.S.), Oxford University Press, New Delhi, India, 1981, pp. 138-151.

47. Sharda, V.N., Watershed management for water resources development in Himalayas with special reference to Uttarakhand, *Bhu-Jal News*, 2006, **21**, 14-20.

48. Srivastava, R.C., Film lined tanks for hilly regions. *Indian Farming*, 1983, XXXIII (II): 27-31.

49. Bureau of Indian Standards, *Specification for drinking water.* IS: 10500, New Delhi, India, 1991.

50. National Water Policy, Ministry of Water Resources, Govt. of India, 2002.

51. http://swajal.uk.gov.in/pages/display/77-about-ccdu; accessed on 08/04/2012.

52. http://swajal.uk.gov.in/pages/view/14/21-total-sanitation-campaign; accessed on 08/04/2012.

53. Initial Environmental Examination, June 2011, IND: Uttarakhand Urban Sector Investment Program—Dehradun, Water Supply Subproject Tranche II, Prepared by Government of Uttarakhand for the Asian Development Bank; http://www2.adb.org/Documents/IEES/IND/38272/38272-033-ind-iee-03.pdf; accessed on 12/04/2012

Section II

GEO-RESOURCES

Energy Resources

Chapter

THREE

ENERGY RESOURCES

(Sarita Khandka)

3.1. Introduction

Availability of energy is at the centre of all developmental processes and hence the economic well being of the state. The National Electricity Policy (NEP) under eleventh plan stipulates power for all and annual per capita consumption of electricity to rise to 1000 units by 2012. The all India installed capacity as on January 2011 is 170228 MW with centre share of 31%, state share of 48% and private share of 21%. In order to fulfill the objectives of NEP an addition of 78700 MW capacity has been proposed in eleventh plan. As per the proposal this addition will come from thermal (76%) followed by hydro (20%) and nuclear (4%). At present world wide among the various sources of energy, Oil remains the largest source (33.5%) although it is decreasing over the time, followed by coal (26.8%), gas (20.8%), renewable (hydro, solar, wind, geothermal power and biofuels) (12.9%), nuclear (5.8%) and others (4%). However in India coal is the main source of energy (55%).

While fossil fuel concerns related to CO_2 emissions and global warming are inherent, the increasing industrialization and development now is searching for the sustainable ways of energy production. In the present scenario the renewable and clean energy resources present an alternative. If we look at the potential of renewable energy worldwide, solar energy has the maximum potential followed by geothermal, biomass, hydro and ocean energy. In terms of solar energy, India's position is enviable as tropic of cancer passes through it making it amenable for receiving large amount of sunshine. However its present contribution to the total power generation is meager and efforts in this direction are needed.

India is blessed with immense amount of hydro-electric potential and ranks 5th in terms of exploitable hydro-potential on global scenario. As per assessment made by CEA, India is endowed with economically exploitable hydro-power potential to the tune of 149 GW of installed capacity. The potential basins in India are Indus basin, Ganga basin, Central Indian river system, western and eastern flowing rivers of southern India and Brahmaputra basin.

Uttarakhand lies in the northern part of Ganga basin and has the identified capacity of hydropower potential of around 18 GW. Out of this the state has developed 2980 MW capacity and there is still scope of 15 GW generation. The requirement of power till 2011 of the state was 3725 MW, which is only 745 MW more than the power produced through hydropower plants. Therefore, the state nevertheless can become self sufficient in power generation by means of hydropower only and can also further utilize this for SGDP growth of the state. In addition to this clean source of energy, Uttarakhand is also endowed with capacity of wind power, solar power, geothermal energy and biomass.

3.2. Energy Needs

3.2.1. National Status

During the year 2010–11, demand for electricity in India far outstripped availability, both in terms of base load energy and peak availability. Base load requirement was 861,591 MU against availability of 788,355 MU, a 8.5% deficit[1]. During peak loads, the demand was for 122 GW against availability of 110 GW, a 9.8% shortfall[1]. The energy needs of the country is mostly met by thermal (65%) followed by hydropower (21%), other renewable resources (11%) and nuclear power(3%).

The climate change issues have repeatedly stressed on reducing carbon foot prints and reducing the emissions. Although the per capita emission of India and other developing countries are less than the emissions of developed countries, post 2020 imposition of emission cut target, needs planning and execution from now itself. The adoption of climate friendly policies to lower the overall carbon footprint could then be effectively used as a green cover on the GDP growth, which is essentially required for the development of the nation. In this

endeavor the encouragement and support for renewable means of energy generation will become very important.

3.2.2. State Status

During the year 2010–11, the base load requirement of the state was 9,850 MU against availability of 9,255 MU, a 6.0% deficit. During peak loads, the demand was for 1520 MW against availability of 1520 MW, without any deficit[1]. The energy needs of the state is mostly met by hydropower. Fig. 3.1 provides the per capita electricity consumption of first eighteen states for the year 2005-06[2]. Dadar and Nagar Haveli ranks first with per capita power consumption of 11567.67 KW followed by Daman & Diu, Pudducherry, Goa and Delhi. Uttarakhand ranks eighteenth in this list with per capita power consumption of 654.84 KWh.

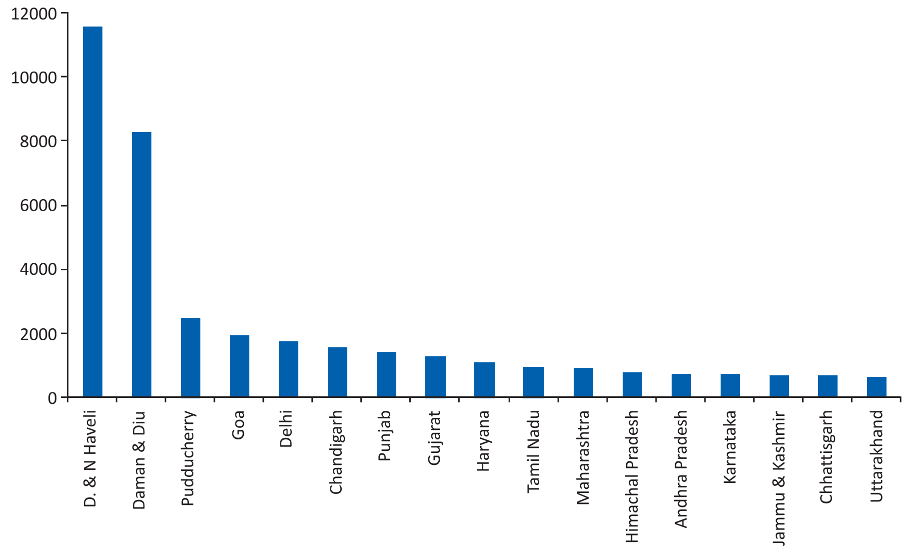


Fig-3.1.
Per Capita Electricity consumption in KWh of some states[2].

As per the projections of Uttarakhand Power Corporation Limited (UPCL), the demand will rise by 5% for the year 2012-13[3]. This additional requirement of energy can be generated from small hydro power plants. Besides this the state has capacity of wind power, watermills, geothermal, solar power and biogas which needs to be explored. The Table 3.1 shows the capacity of various resources in the state and its comparison with national status. Table 3.2 gives the demand and availability of power in India and Uttarakhand.

Table-3.1.
Resources of power generation[4]

Items	Uttarakhand	India
	Hydropower (MW)	
Identified capacity	18,175	1,48,701.00
Capacity developed	2,980	38,848.40
	Wind power (MW)	
Identified capacity	2	45,195
Capacity developed	Nil	13,183.59
	Solar power	
Identified capacity for PV power	4077 MWh/Yr	5 trilion KWh/Yr
	Total thermal (MW)	
Capacity developed	NA	1,23,758.98
	Nuclear (MW)	
Capacity developed	NA	4,780.00
	Geothermal (MW)	
Identified capacity	23.70	NA

Table-3.2.
Power supply position[5]

Item	Uttarakhand	India
Available base load supply (MU)	9,255	7,88,355
Available peak load supply (GW)	1.52	110.256
Demand base load (MU)	9,850	8,61,591
Demand peak load (GW)	1.52	122.287

3.2.3. Installed Capacity

The installed capacity of power in India are under various categories: state owned, private owned and centre owned. The Table 3.3 gives detail of installed power in India and Uttarakhand.

It is clear from the Table 3.3 that in Uttarakhand the maximum power generation is from Hydropower, however in the country as a whole, thermal power generation is maximum followed by hydropower.

3.3. Energy Resources

The country's annual electricity generation capacity has increased in last 20 years by about 120 GW, from about 66 GW in 1991 to over 185 GW in 2011. Another addition of about 100 GW of installed capacity between 2012 and 2017 is also expected. This growth makes India one of the fastest growing markets for electricity infrastructure but still the country is short of fulfilling the energy needs. The focus therefore should be to accelerate the

Table-3.3.
Installed capacity of Power in MW[6]

Ownership	Thermal	Nuclear	Hydro	RES*	Total
			Uttarakhand		
State	0.0	0.0	1252.15	132.92	**1385.07**
Private	0.0	0.0	400.00	0.5	**400.05**
Centre	330.61	22.28	272.03	0.00	**624.92**
Total	330.61	22.28	1,924.18	132.97	**2,410.04**
			India		
State	52,156.73	0.0	27,257.00	2,822.32	**82,236.05**
Private	19,755.25	0.0	1,425.00	13,964.66	**35,145.18**
Centre	1,11,034.48	4,560.00	37,367.40	16,786.98	**1,69,748.86**
Total	**1,11,034.48**	**4,560**	**37,367.40**	**16,786.98**	**1,69,748.86**

growth further to achieve the target of power for all. Some of the states (Fig. 3.1) and Union Territories of India with surplus power are Dadra and Nagar Haveli, Daman & Diu, Goa, Delhi, Himachal Pradesh, Sikkim, Tripura, and Gujarat.

In India unlike other countries, coal fired plants account for 55% of installed electricity capacity, followed by hydropower (21%), natural gas (10%) and others (14%). Uttarakhand however, fulfils its requirement of energy mostly from hydropower and still the potential of the hydropower are untapped. Besides the hydropower which is also a clean source of energy, the state has potential of other clean resources as well. This includes wind power, solar power, geothermal power and biogas. These are the areas which needs to be explored in the state for fulfilling the needs of the state.

3.3.1. Hydropower Projects

Hydropower projects are divided into small hydropower projects (SHP) and large hydropower projects (LHP) depending upon their power generating capacity. In India hydro projects upto 25 MW are considered small hydropower projects and above 25 MW are considered large hydropower projects. Unlike large hydropower projects which displaces large population, affects faunal and floral biodiversity of the water bodies, evoking resistance of local people and environmental groups, SHP are considered to be environment friendly and suitable for the state. Moreover, the SHP can provide employment to the local youth

and can be a source of generating Clean Development Mechanism (CDM) revenue for the state. In the face of resistance for the large hydropower projects the state can utilize this decentralized approach for fulfilling the energy needs of the rural population.

The country has an estimated SHP potential of about 15000 MW. So far 495 SHP projects with an aggregate installed capacity of 1603 MW has been installed. A database has been created for most potential sites by collecting information from various sources. As a part of the UNDP-GEF Hilly Hydro project, a detailed exercise was undertaken to prepare zonal plans for 13 participating states of the Himalaya and sub-Himalayan region. Models have been developed that take into account the regional flow duration curves, geological and seismological data, vegetation cover etc. In this regard a software package has been developed at Alternate Hydro Energy Centre, IIT Roorkee which incorporates regional hydrological models that enable users to rapidly estimate the hydropower potential and other salient features of potential sites[7]. The database for SHP projects created by New and Renewable Energy sources now includes 4233 potential sites with an aggregate capacity of 10,324 MW. Of these Uttarakhand has 354 identified SHP sites with the aggregate potential of 1478.24 MW[8]. Details of some SHP's in Uttarakhand with CO_2 reduction are given in Table 3.4[7].

Table-3.4. Small Hydropower Projects In Uttarakhand[7]

Project	Scale	Location of Project	Implementing Agency	Annual tCO_2e reduction	Total tCO_2e reduction till 2012
3 MW 21 Energy Project Hydro Power Generation pvt. Ltd.	Small	Ghansalitaluka	M/s Gunsola Northern region in Tehri	11650	23300
Vanala Small Scale Hydro Power Project (15 MW)	Small	Village- Vanala, District- Chamoli	M/s Him Urja Private Limited	45914	137742
Badyar Hydro (4.90 MW) Plant	Small	Village- Nagangaon Town- Barkot, District- Uttarkashi,	M/s Regency Yamuna Energy Ltd.	23.824	95296
Hanuman Ganga Hydro (4.95 MW) Plant	Small	Village- Hanuman Chatti, Town- Barkot, District Uttarkashi	M/s Regency Aquaelectro & Motelresorts Ltd	23717	118585
Bundled Microhydel Projects (3.115 MW)	Small	District- Bageshwar, Pithoragarh, Chamoli, Uttarkashi, Almora and Tehri	M/s Uttaranchal 21 Energy Development Agency (UREDA)	8668	17336
Kalinga Small Hydroelectric Projects n Uttaranchal- 10 MW bundled Small CDM Project	Small	District Rudraprayag	M/s Uttaranchal Jal Vidyut Nigam Limited (UJVNL)	55742	195097

Project	Scale	Location of Project	Implementing Agency	Annual tCO_2e reduction	Total tCO_2e reduction till 2012
10 MW Madhyamaheswar Ganga Grid-connected Small Hydroelectric Project	Small	Village Chuni and Mansura, District Rudraprayag	M/s Uttaranchal Jal Vidyut Nigam Limited (UJVNL)	50711	177489
5 MW Debal Grid- connected Hydroelectric Project	Small	Village Debal, Taluk-Narainbagar, District Chamoli	M/s Chamoli Hydro Power Pvt. Ltd.	23880	95520
Madkini Hydro Power (13.5 MW)	Small	Village Madkot Munsiyari Block, District Pithoragarh	M/s Madkini Hydro Power Pvt. Ltd.	68460	273840
4.8 MW Loharkhet Hydro Electric Project	Small	--	M/s Parvatiya Power Pvt. Ltd.	17928	12550

Among the large hydropower projects, Tehri project on Bhagirathi river, is the largest with an installed capacity of 2000 MW. Other includes Maneri Bhali I (90 MW) and Maneri Bhali II (304 MW). However, some projects like Lohari Nagpala, Pala Maneri and Bhairongathi projects of Bhagirathi river has been suspended due to environmental concerns[4]. Table 3.5 shows the identified potential of small hydro power in the states of India[9] and Fig. 3.2 shows a comparison between Uttarakhand, J&K and Himachal Pradesh with respect to Hydropower development[4].

3.3.2. *Wind Power*

India is one of the leaders in the Wind power generation but in the state it is in the exploratory phase. The wind power density map of India (Fig 3.3) shows that Uttarakhand has the capacity of generation of wind power. The Centre of Energy Technology (CWET) has found one site

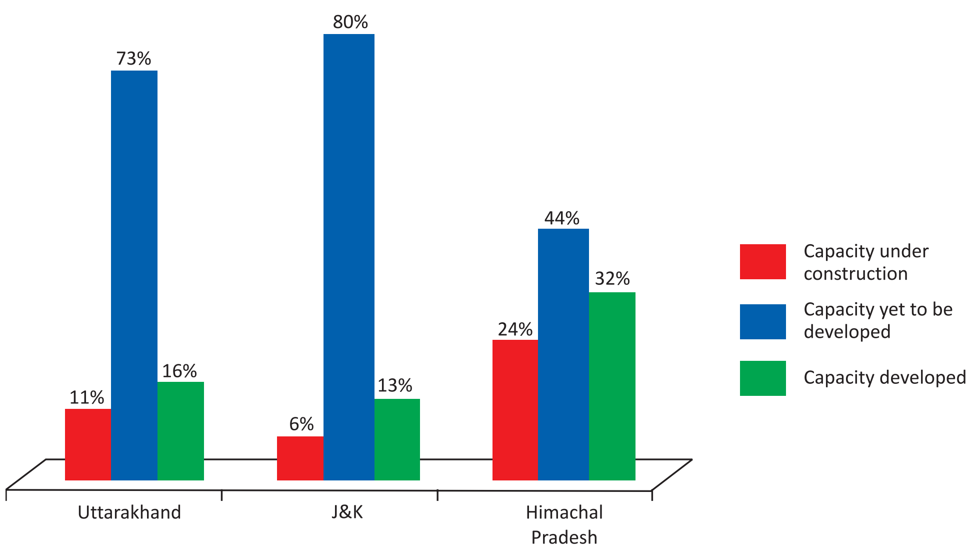


Fig-3.2.
Hydropower Development of some Hill States[2].

Table-3.5.
State Wise status of SHP projects as on 31.01.2011[9]

State	Potential		Projects Installed		Projects under Implementation	
	Nos.	Total Capacity (MW)	Nos.	Capacity (MW)	Nos.	Capacity (MW)
Andhra Pradesh	497	560.18	62	189.83	18	61.75
Arunachal Pradesh	550	1328.68	101	78.835	28	38.71
Assam	119	238.69	4	27.11	4	15
Bihar	95	213.25	18	58.3	11	36.31
Chhattisgarh	184	993.11	6	19.05	1	1.2
Goa	6	6.5	1	0.05	-	-
Gujarat	292	196.97	4	12.6	-	-
Haryana	33	110.05	7	70.1	2	3.4
Himachal Pradesh	536	2267.81	112	375.385	40	132.2
J&K	246	1417.8	34	129.33	5	5.91
Jharkhand	103	208.95	6	4.05	8	34.85
Karnataka	138	747.59	111	725.05	18	107.5
Kerala	245	704.1	20	136.87	7	23.8
Madhya Pradesh	299	803.64	11	86.16	4	19.9
Maharashtra	255	732.63	39	263.825	15	51.7
Manipur	114	109.13	8	5.45	3	2.75
Meghalaya	101	229.8	4	31.03	3	1.7
Mizoram	75	166.93	18	36.47	1	0.5
Nagaland	99	188.98	10	28.67	4	4.2
Orissa	222	295.47	10	79.625	5	3.93
Punjab	237	393.23	43	133.2	15	21.4
Rajasthan	66	57.17	10	23.85	-	-
Sikkim	91	265.55	16	47.11	2	5.2
Tamil Nadu	197	659.51	16	94.05	6	33
Tripura	13	46.86	3	16.01	-	-
Uttar Pradesh	251	460.75	7	23.3	-	-
Uttarakhand	444	1577.44	95	134.12	55	230.65
West Bengal	203	396.11	24	98.9	16	79.25
A&N Islands	7	7.27	1	5.25	-	-
Total	**5718**	**15384.15**	**801**	**2933.58**	**271**	**914.81**

suitable for tapping the wind energy in the state. Uttarakhand government has approved a wind energy farm on hill top in Tehri district, which is also the first Himalayan site. In collaboration with UREDA, CWET has established 11 wind monitoring station in Uttarakhand. As on March 2009, India is generating 59208 MU of electricity through wind. Tamilnadu is leader in the production followed by Maharashtra, Gujarat and Karnataka (Table 3.6).

Table-3.6. Status of Wind Power in India 2010-11[10]

States	Potential	Capacity installed during 2010-11 (upto Jan. 2011)	Cumulative capacity upto Jan 2011
Andhra Pradesh	8968	44.80	180.90
Gujarat	10645	172.18	2035.81
Karnataka	11531	121.30	1594.10
Kerala	1171	0	27.750
Madhya Pradesh	1019	7.80	237.200
Maharashtra	4584	125.05	2202.80
Rajasthan	4858	292.70	1381.00
Tamil Nadu	5530	613.00	5519.72
Others	255	0	4.30
Total	**48561**	**1376.83**	**13183.58**

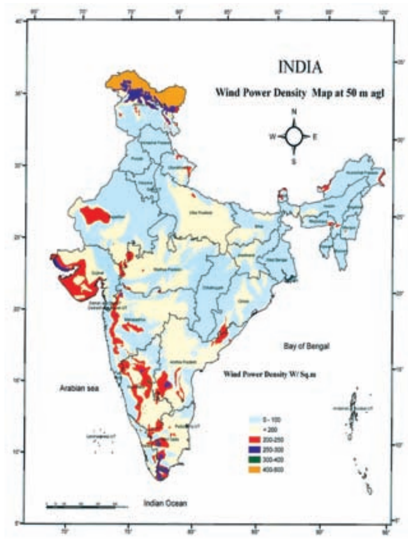


Fig-3.3. Wind power density map of India

A package of incentives which includes fiscal concessions such as 80% accelerated depreciation, concessionary custom duty for specific critical components, excise duty exemption, income tax exemption on profits for power generation, etc. are available for wind power projects. The State Electricity Regulatory Commissions (SERCs) in Andhra Pradesh, Haryana, Punjab, Madhya Pradesh, Maharashtra, Rajasthan, Tamilnadu, Gujarat, Kerala, Punjab and West Bengal have announced preferential tariff for purchase of power from wind power projects. Many States have also announced renewable energy purchase obligations, which catalyses the growth in the wind power generation. Similar effort can also be initiated in the State as well for growth of renewable energy sector.

3.3.3. Solar Power

Although among the renewable resources, solar power has the maximum potential, the generation of solar power in the country is at fourth position after wind power, small hydro power and biomass power. The problem seems to be the high cost of solar power generation. In order to address the problem "The Jawaharlal Nehru National Solar Mission" was launched on the 11th January, 2010 by the Prime Minister. The Mission has set the ambitious target of deploying 20,000 MW of grid connected solar power by 2022 and aims to reduce the cost of solar power generation in the country through (i) long term policy; (ii) large scale deployment goals; (iii) aggressive R&D; and (iv) domestic production of critical raw materials, components and products, as a result to achieve grid tariff parity by 2022.

Solar Units

The state has the following installed units for solar power generation (Jan, 2011):

1. Lanterns: 64023
2. Home lights: 91307
3. Street lights: 7673
4. Pumps: 26
5. Stand alone power plant: 80 KWp.
6. Grid connected power plant: 50 KWp

The National Solar Mission is a major initiative of the Government of India and the State Governments to promote ecologically sustainable growth while addressing India's energy security challenge. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change. Solar is currently high on absolute costs compared to other sources of power such as coal. The objective of the Solar Mission is to create conditions, through rapid scale-up of capacity and technological innovation to drive down costs towards grid parity. The Mission anticipates achieving grid parity by 2022 and parity with coal-based thermal power by 2030.

Uttarakhand has the capacity of generation of solar power to the tune of 4077 KWh/yr and as on Jan. 2011 only 50 KW of grid connected and 80 KW of off-grid power is generated. It is ranked 15th in the country. Other solar photovoltaic installations in the state (Table 3.7) are lantern (64023), home light (91307), Street lights (7673) and pumps (26)[9].

3.3.4. Biomass

Biomass power programme is implemented with the main objective of promoting technologies for optimum use of country's biomass resources for grid power generation. Biomass materials used for power generation include bagasse, rice husk, straw, cotton stalk, coconut shells, soya husk, de-oiled cakes, coffee waste, jute wastes, groundnut shells, saw dust etc. In addition to agro-residues that are available, it is possible to have dedicated plantations on waste land or degraded lands that are not normally used for agriculture. The benefits from biomass include its renewable nature, wide availability, being carbon neutral and the potential to provide large productive employment in rural areas. The constraints are competitive uses of biomass leading to possible non-availability or rise in costs.

The current availability of biomass in India is estimated at about 500 millions metric tonnes per year. Studies sponsored by the Ministry has estimated surplus biomass availability at about 120 – 150 million metric tonnes per annum covering agricultural and forestry residues corresponding to a potential of about 18,000 MW. In Uttarakhand, the potential for biomass power generation is around 270 MWh.

Table-3.7.
State-wise Cumulative Installation of SPV Systems (31.1.2011)[9]

State/UT	Solar Photovoltaic Systems				Power Plants	
	Lanterns	Home Lights	Street Lights	Pumps	Stand alone	Grid Connected
	Nos.				(KWp)	
Andaman & Nicobar	6296	405	358	5	167	100
Andhra Pradesh	35799	1958	4044	613	238.94	100
Arunachal Pradesh	13937	9120	1071	15	17.1	25
Assam	1211	5870	98	45	9	0
Bihar	50297	3170	955	139	0	0
Chandigarh	1675	275	229	12	0	0
Chhattisgarh	3192	7211	1889	166	371.72	0
Delhi	4753	0	301	89	80	2143
Goa	1027	362	463	15	1.72	5000
Gujarat	31603	9231	2004	85	336	0
Haryana	73116	37416	10858	469	434.4	0
Himachal Pradesh	22970	16848	2994	6	1.5	0
Jammu & Kashmir	28672	23083	5596	39	175.6	0
Jharkhand	16374	4905	620	0	0	0
Karnataka	7334	29894	2694	551	29.41	6000
Kerala	41181	32326	1090	810	44.7	25
Lakshadweep	0	0	0	0	85	750
Madhya Pradesh	9444	2651	6054	87	22.4	100
Maharashtra	68683	2072	5471	228	6.44	1000
Manipur	4787	3500	490	40	28	0
Meghalaya	24875	7840	1273	19	50.5	0
Mizoram	8331	5395	431	37	109	0
Nagaland	6317	720	271	3	6	0
Orissa	9882	5156	5819	56	74.515	0
Pudducherry	1637	25	417	21	0	25
Punjab	17495	8620	4737	1857	121	1325
Rajasthan	4716	91754	6722	283	990	7450
Sikkim	2470	3890	212	0	16.7	5000
Tamil Nadu	16818	1557	5885	829	39.5	50
Tripura	42360	26066	1199	151	24.57	0
Uttar Pradesh	52815	102041	4117	751	129.2	375
Uttarakhand	64023	91307	7673	26	80.03	50
West Bengal	17662	111090	27512	48	675	1150
Others	125797	24047	9150	0	58	790
Total	**817549**	**669805**	**122697**	**7495**	**4422.95**	**31458**

Watermills (Gharat)[11-12]

The watermills are traditionally used for grinding grains using energy of moving water. Uttarakhand being a hill state, can effectively use its gradient in watermills or traditionally called Gharats. The survey funded by Asian Development Bank in 2003 revealed that there are total of 15,449 waremills in the state of which 7000 are defunct. UREDA under took the process of reviving the defunt watermills and upgrading them as well. It has successfully revived more than 750 watermills in the state. The centre also provides a subsidy of Rs. 1.00 Lakhs for electric generation from a watermill. In another estimate, UREDA found that the power generation capacity from improved watermills in Uttarakhand is 24 MW. HESCO is another NGO which is working for reviving and upgrading the traditional eco-friendly devices of energy generation by water.

During the year i.e. April 2010 to January 2011, 143.50 MW capacity biomass power projects have been achieved in the States of Chhattisgarh, Maharashtra, Punjab, Rajasthan and Tamilnadu against a target of 150 MW. The cumulative biomass power generation capacity has reached to 997 MW from 130 projects in the country. In Uttarakhand, 5 MW captive Power Plant based on Rice Husk at Sidharth Paper Mill, Kashipur, U.S. Nagar, 250 KW Biomass Gasifier at MKU Industry, Lal Tappar, Dehradun and 19 MW Co-generation Power Plant at RBNS Sugar Mill, Laksar, Haridwar has been installed under the biomass power generation[9].

3.4. Policies

3.4.1. Policy For Renewable Energy Sources With Private Sector and Community Participation[13]

- The policy is notified by order No. 263/I(2)/2008-04(8)-96/2001, dated 29th Jan, 2008, entitled "Policy for Promoting Generation of Electricity through Renewable Energy Sources with Private Sector & Community Participation".
- Energy auditing to be made mandatory for industrial units where load exceeds 25 KW
- UPCL to have first right of purchase of electricity, UERC to determine price of electricity, Government of Uttarakhand to provide guarantee for payments to be made by UPCL for purchase.

- UPCL/PTCUL to transmit the power generated through its grid for captive use or third party sale within/outside the state. Wheeling charges applicable and to be announced in advance
- T&D lines from generation site to be provided by UPCL/PTCUL
- Not more than three projects in each category to be allotted to a developer
- Preference to be accorded to industrial units located in Uttarakhand in the open competitive bidding process, provided the bid is not less than 80% of the highest bid.
- State Government reserves its rights to allot a project to a State owned Enterprise
- In case Micro/Mini hydro projects remains un-allocated, the same to be allotted to any developer through open competitive bidding
- If the developer does not restrict to the prescribed time schedule of completion of project, premium to be forfeited and allotment canceled
- Projects allotted before notification of this policy shall be governed by the policy under which the allotment was made.
- In case of augmentation of the capacity of self identified projects, the developer to pay additional premium of Rs. 1 lakh per MW or fraction thereof up to 5 MW and ₹ 5 lakh per MW or fraction thereof above 5 MW along with requisite amount to take into effect the inflation from the date of payment of premium.
- In case the developer sells his projects before commissioning, he has to pay an additional amount equal to the bid premium
- Projects to be offered for a period of 40 years from the date of award, thereafter they shall revert to the State Government or extended further on mutually agreed terms
- No royalty on micro, mini and other RE projects
- Royalty @ 18% of energy generated to be charged from 16th year of operation of small hydro projects which are governed by this policy

3.5. Challenges and Concluding Remarks

The increasing pressure of population and increasing use of energy in different sectors of the economy is an area of concern for India. With a targeted GDP growth rate of 9% during the eleventh five year plan, the energy demand is expected to grow around 5%. For Uttarakhand also the growth of energy demand is put at 5%. Economic Survey 2011-12 has suggested that post Kyoto protocol and Durban climate change submit, India will adopt a low carbon growth path in the 12th five year plan to meet the national target of lowering the emission intensity of its gross domestic product (GDP) by 20-25% by 2020. With increasing energy demand, adoption of low carbon growth path is a challenge for the country. As per the state is concerned, it is already on this path and has to further make inroads for exploring other renewable resources. The challenges are now for enhancing skills and faster generation of employment, efficiency of energy usage, rural transformation, managing urbanization with respect to the energy sector. For sustaining high GDP growth of the state, besides other things, it should generate more power. If the path adopted by state in past has any indication, renewable energy generation can ease out the power scarcity of the state as it has still untapped resources of hydro, solar, wind and geothermal. Like the state of Himachal Pradesh the state also can achieve the target of producing surplus energy in a sustainable way.

In case of Hydropower generation, challenges related to clearance from forest and environment departments, environmental implications, financing, political priority and displacement of population are the major hindrance. In order to address and mitigate the

problems, path for decentralized small hydropower plants can be taken as is also suggested by Task force 2010. This will also be an appropriate approach for remote villages with small population as the case in Uttarakhand and has smaller environment footprint as well. As far as tapping of solar power is concerned, although the state has potential for it but large portion (64%) of the state is covered by forest. Therefore, population pressure on the land will make it difficult for installation of big solar power plants in the state. However, solar panels on roof top and again decentralized plan, coupled with hybrid systems will be suitable as an alternative for urban areas of the state.

Another challenge faced by the state is its capability for distribution of energy to rural areas and to improve the livelihood and productive capacity in these areas. This will have cumulative effect on economy, development and environment as this will help create new market opportunities where currently these are very limited. At the same time renewable resources of energy can offer large investment opportunities to the private sector not only in generation of power, but also in manufacturing. Some of this would also be foreign investment. This will help create a substantial number of jobs and create demand for skilled workforce contributing to the overall economic growth.

In the end, the losses in transmission, distribution and at consumer level which accounts to 30% also needs to be addressed appropriately. Time has come when we should give it a serious thought as these losses are not affordable by country like us. In view of all above, clean, efficient ways and conservation are the key word for treading on a path of sustainable development for the state and country as a whole.

3.6. References

1. Load generation balance report 2011-12, Central Electricity Authority, Ministry of Power, Govt. of India.
2. http://www.orissalinks.com/orissagrowth/archives/465
3. www.upcl.org
4. Tolia, R.S., *A planning frame-work for the mountain states of India*, Doon University, Uttarakhand, 2012.
5. www.powermin.nic.in
6. Annual Report 2010-11, Ministry of Power, Govt. of India.
7. *Opportunities for carbon trading and co-benefits in the Uttarakhand Himalaya*, Centre for Ecology Development and Research, Uttarakhand, 2012.
8. Verma, C.V.J. and Gupta, N.D., Non Conventional Energy Development in India – An Overview, 2008, http://www.indiapower.org/images/finalpaper.pdf
9. www.mnre.in
10. Annual Report 2009-10, Centre for Wind Energy Technology.
11. Uttarakhand diagnostic study of building a mountain state 2000-2012, *giz* and Doon University.
12. Report of Task Force 2010, India.
13. Compendium of State Government Policies on Renewable Energy Sector in India, http://www.ireda.gov.in

Section II

GEO-RESOURCES

Glaciers

Chapter

FOUR

GLACIERS

(Om Prakash Nautiyal)

4.1. Introduction

A glacier is a large, accumulation of snow, ice, rock, sediment and liquid water, originating on land and moving down slope under the influence of its own weight and gravity. As it begins to move down the valley, its front makes a giant wall of ice called the snout, which is the terminal point of a glacier. Due to the dynamic and fragile characteristics of the glaciers and their sensitivity to environment, these constantly change their shape and size.

Presently 10% of land area on earth is covered with glacial ice, including glaciers, ice caps, and the ice sheets of Greenland and Antarctica. Glaciers store about 75% of the world's freshwater. Glacierized areas cover over 15 million square kilometers. Antarctic ice is over 4.2 kilometers thick in some areas. In the United States, glaciers cover over 75,000 square kilometers, with most of the glaciers located in Alaska. If all land ice melted, sea level would rise approximately 70 meters worldwide.

In India, glaciers are restricted to Himalaya within the latitude 27^0 to 36^0 N and longitude 72^0 to 96^0 E. An Inventory compiled by Geological Survey of India[1] has revealed the existence of 9,575 glaciers in the Indian administered part of the Himalayas comprising the territories of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh. Total glacier cover within these states is less than 40,000 km^2 with an approximate volume of ice of the order about 2,000 km^3. Upper reaches of Ganga basin falls within the Uttarakhand Himalayas, which includes Yamuna, Bhagirathi, Alaknanda, Kaliganga (Ghaghra) etc. Total number of glaciers identified in this part is 968 with 213.74 km^3. Total ice volume and the glacier covered area coming to about 2,883 km^2, which is 9% of the basin area. Largest number of glaciers totalling 407 has been identified in the Alaknanda basin, that occupies 1,255 km^2, which account for almost 11% of total basin area. Yamuna basin has the least number of glaciers, numbering 52, occupying 143.43 km^2 as the glacier covered area, which comes to just about 2% of the total basin area. Mean glaciations level varies from 5,154 masl (Alaknanda basin) to 5,189 masl (Yamuna basin).

4.2. Himalayan Glaciers

All the major north Indian rivers owe their origin to thousands of glaciers in the Himalayas. There are 9575 glaciers in the Indian Himalayas as per the latest updating of the glacier

inventory maintained by the GSI[1]. The GSI had started glaciological studies in 1840 and systematic studies involving demarcation of the glacier snout were undertaken since, beginning of the last century. Compilation of glacier inventory was initiated in 1977 immediately after the constitution of the world glacier inventory body at Zurich. The Himalaya is a large mountain system, influencing the interaction between climate, hydrology and environment. The total spread of Himalayas between latitude 25° and 35° N and longitude 60° to 105° E covers an area of 84.4 lakh km^2 (Table 4.1).

Indian part of the Himalayas above 1060m covers an area of 3.5 lakh km^2 out of which 1.9 lakh km^2 forms a part of Jammu & Kashmir, Uttarakhand & Himachal Pradesh and the rest is covered by eastern Himalayas. Distribution of glaciers is controlled by the altitude, orientation, slope and climatic zone in which they fall. A detailed basin-wise inventory of 9575 Indian glaciers[2] is tabulated in Table 4.2.

Table-4.1.
Distribution of areas at different Altitudes in the Himalaya[2]

Above 5400 M	5.6 lakh km^2
Above 3000 M	32.8 lakh km^2
Above 1500 M	46.0 lakh km^2
Total	**84.4 lakh km^2**

Table-4.2.
Basin-wise inventory, areas and volumes of Indian glaciers[2]

Basin	No. of glaciers	Area (km^2)	Volume (km^3)
Indus Basin			
Ravi	172	192.74	8.038
Chenab	1278	3058.99	206.15
Jhelum	133	94.18	3.3
Beas	277	599.06	36.94
Satluj	926	1250.86	60.99
Indus	1796	2165.46	104.6
Shyok	2658	7105.66	601.71
Kishanganga	222	174.28	5.93
Gilgit	535	8240	N.D.
Total	**7997**	**22881.23**	**1027.658**
Ganga Basin			
Yamuna	52	144.47	12.21
Bhagirathi	238	755.43	67.02
Alaknanda	407	854.59	90.72
Ghagra	271	729.42	43.77
Total	**968**	**2483.91**	**213.72**
Brahmaputra Basin			
Teesta	449	705.54	39.61
Arunachal	161	223.37	9.96
Total	**610**	**928.91**	**49.57**
Grand Total	**9575**	**26294.05**	**1290.95**

4.2.1. State Wise Distribution of Glaciers in Indian Himalaya

Indian Himalayan Glacier System is shown in Fig. 4.1. In Indian Himalaya, Jammu and Kashmir state have maximum 5262 glaciers with 29163 km^2 glacierised area followed by Himachal Pradesh 2735 glacier with 4516 km^2 area and Uttarakhand 968 glacier with 2857 km^2 glacierised area. Sikkim and Arunachal Pradesh have 449 and 161 glaciers with 706 km^2 and 223 km^2 glacierised area respectively. 77.84% of total area is covered by glaciers in J&K, 12.05% in Himachal, 7.63% in Uttarakhand, 1.88% in Sikkim, while Arunachal Pradesh is covered only 0.6% of its total area by glaciers. State wise descriptions of glaciers in Indian Himalaya[1] are shown in Fig. 4.2-4.5.

Fig-4.1.
Indian Himalayan Glacier System

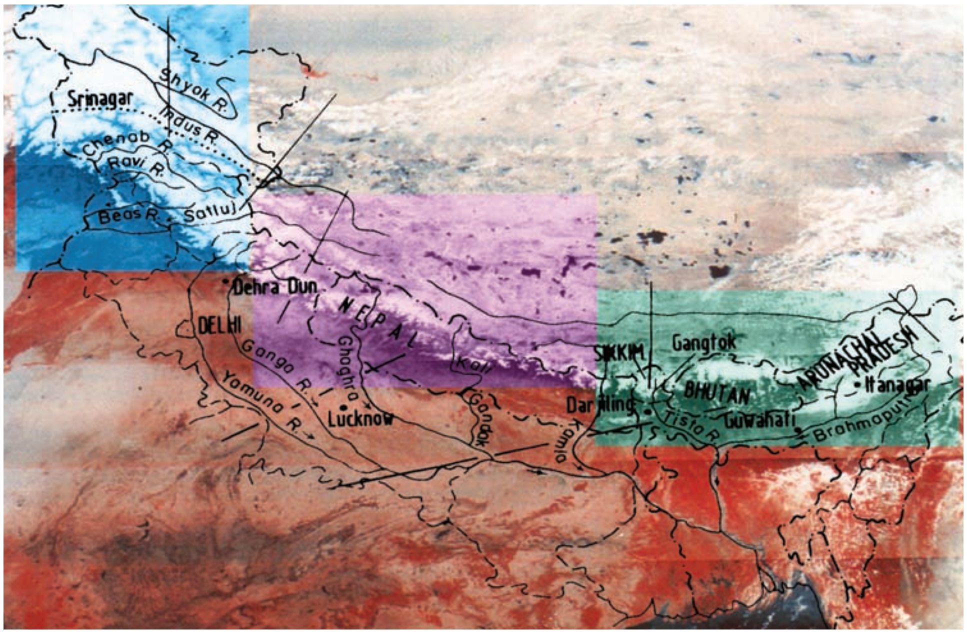
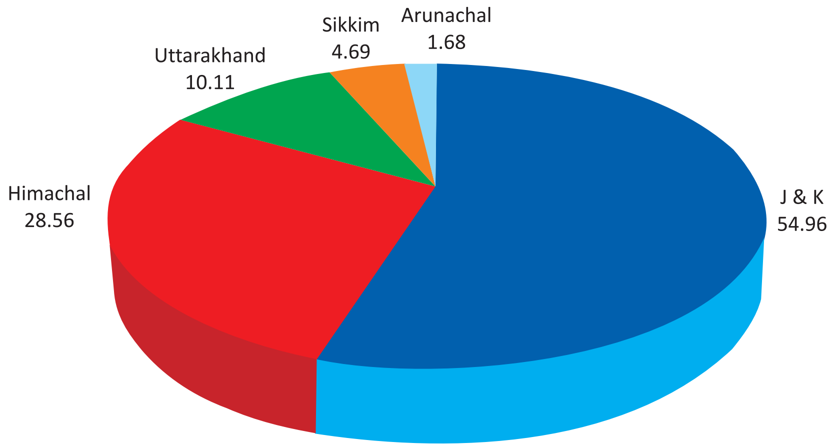


Fig-4.2.
Distribution of glaciers (percentage) in Indian Himalaya



4.3. Uttarakhand Glaciers

One of the most important features of Uttarakhand's topography is its glaciers. The Uttarakhand Himalaya, consisting of one of the most important snow cover and glacier regimes, stretches for about 325 km between Kali Ganga in the east and Tons-Yamuna valley in the west. As per the data published in 'Inventory of the Himalayan Glaciers'[1], there are 968 glaciers in the four sub-basins of the river Ganga, followed by 52 in the Yamuna basin with 12.2 Km^3 ice volume, 238 in the Bhagirathi basin with 67.02 Km^3 ice volume,

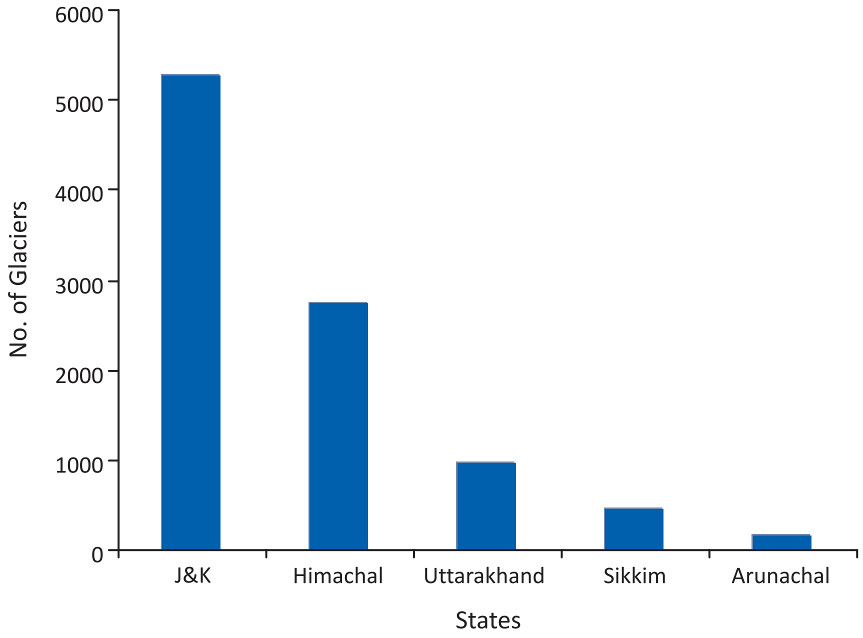


Fig-4.3.
Distribution of glaciers (No.) in Indian Himalaya

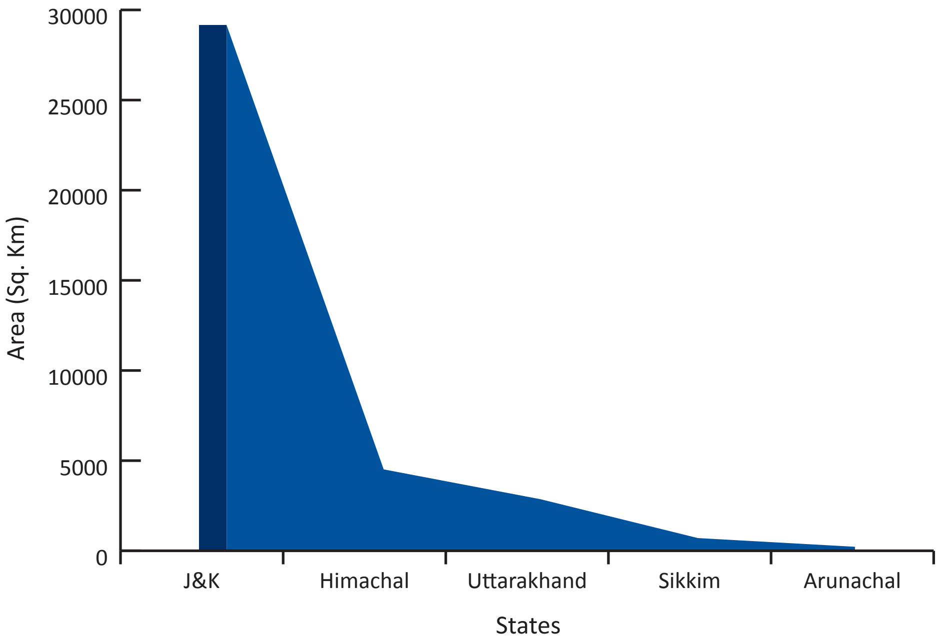


Fig-4.4.
State wise area of glaciers in Indian Himalaya

407 glaciers with 90.75 Km^3 ice in the Alaknanda and 271 Glaciers in the Kaliganga basins with 43.77 Km^3 ice covering a total basin area of 31449.3 km^2 and 2883.37 km^2 glacierised area. These glaciers can be further sub-divided in the following basins: Yamuna basin: Tons, Yamuna; Bhagirathi basin: Bhilangna, Pilang, Jalandhri, Jahnvi, Bhagirathi; Alaknanda basin: Mandakini, Pindar, Nandakini, Vishnuganga, Rishiganga, Dhauliganga, Girthiganga and Ghaghra (Kaliganga) basin: Ramganga, Goriganga, Dhauliganga, Kuthi (Yankti) etc. Glacierised area of Ganga basin, Uttarakhand is shown in the map[1] (Fig. 4.6) and basin wise descriptions of Uttarakhand glaciers are plotted in (Figs. 4.7-4.11)[1].

Fig-4.5.
State wise average size of glacier in Indian Himalaya

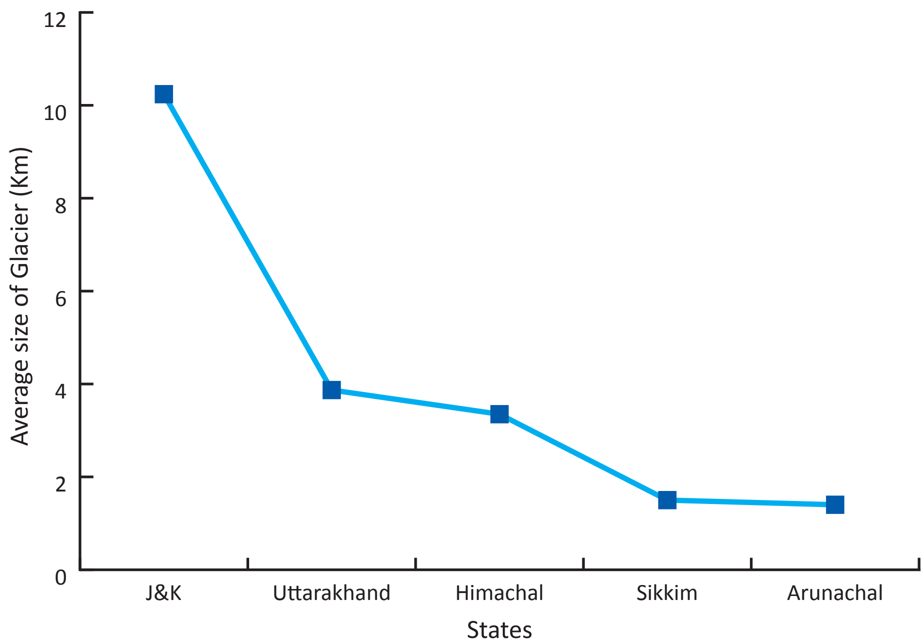
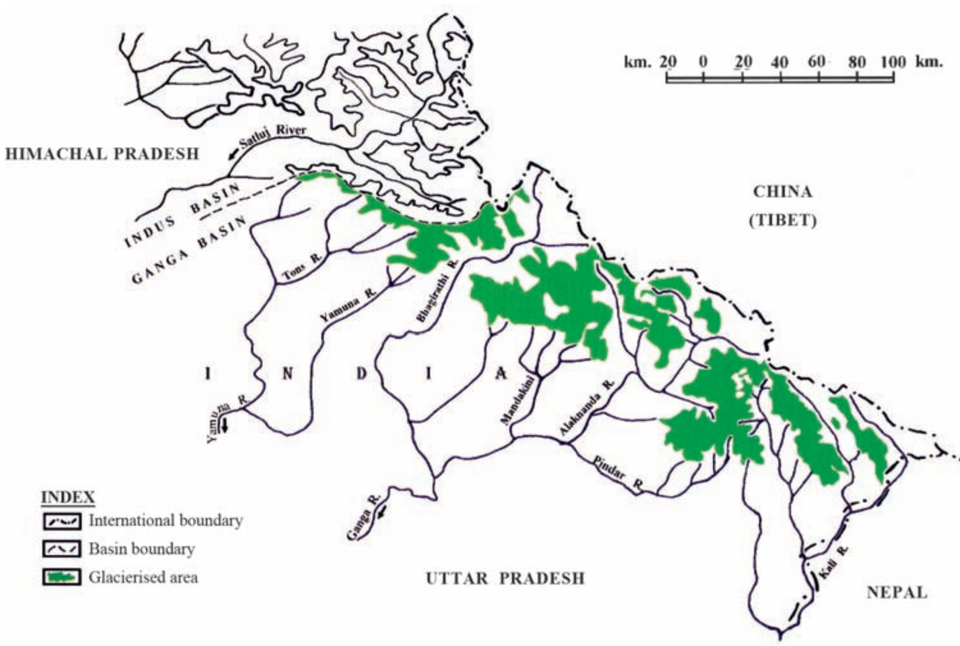


Fig-4.6.
Glacierised area of Ganga basin, Uttarakhand[1]



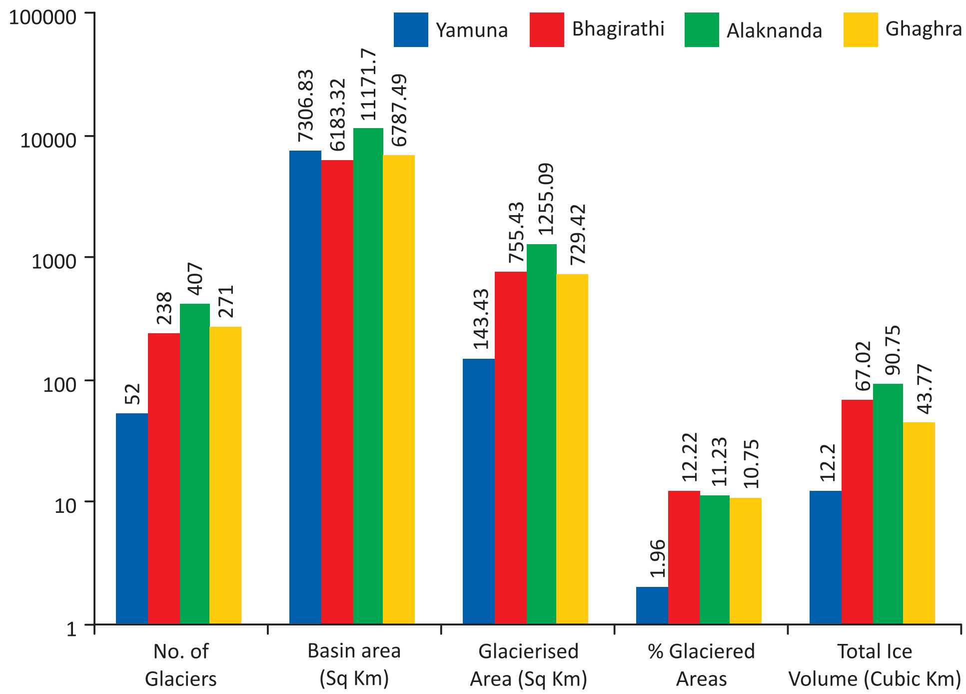


Fig-4.7.
Basin wise descriptions of Uttarakhand glaciers[1]

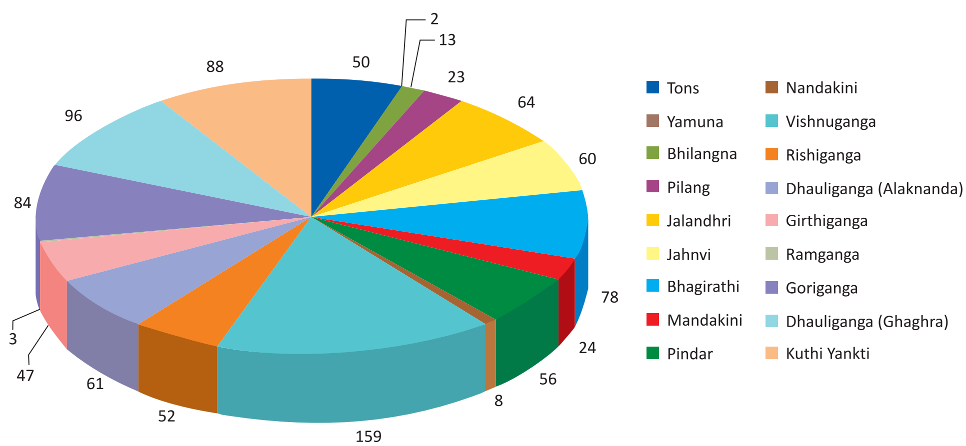


Fig-4.8.
Basin wise distributions of Uttarakhand glaciers[1]

4.3.1. *Status of Uttarakhand Glaciers*

The status of Uttarakhand glaciers is shown in Table 4.3. with the values in brackets showing the position of Uttarakhand in Indian Himalaya scenario[1,4].

Table-4.3.
Ranking of Uttarakhand Glaciers

Description	Value (Ranking)
No. of Glaciers	968 (3rd)
Area of Glaciers (Km^2)	2883 (3rd)
Glacier %	10.11 (3rd)
Average Size (Km)	3. 87 (2nd)

4.3.2. *District-Wise Distribution of Uttarakhand Glaciers*

District-wise descriptions of glaciers of Uttarakhand[8] are shown in Fig. 4.12-4.14. Out of the 968 glaciers, 310 glaciers are found in Chamoli district while, Tehri Garhwal district has only

Fig-4.9.
Glacierised area of basins of Uttarakhand[1]

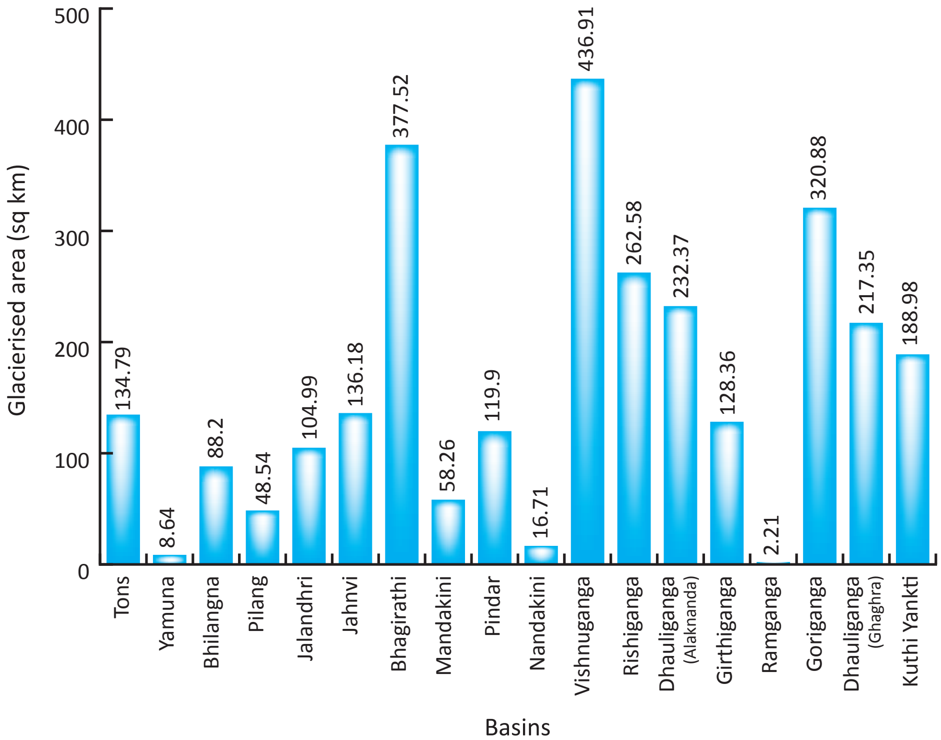
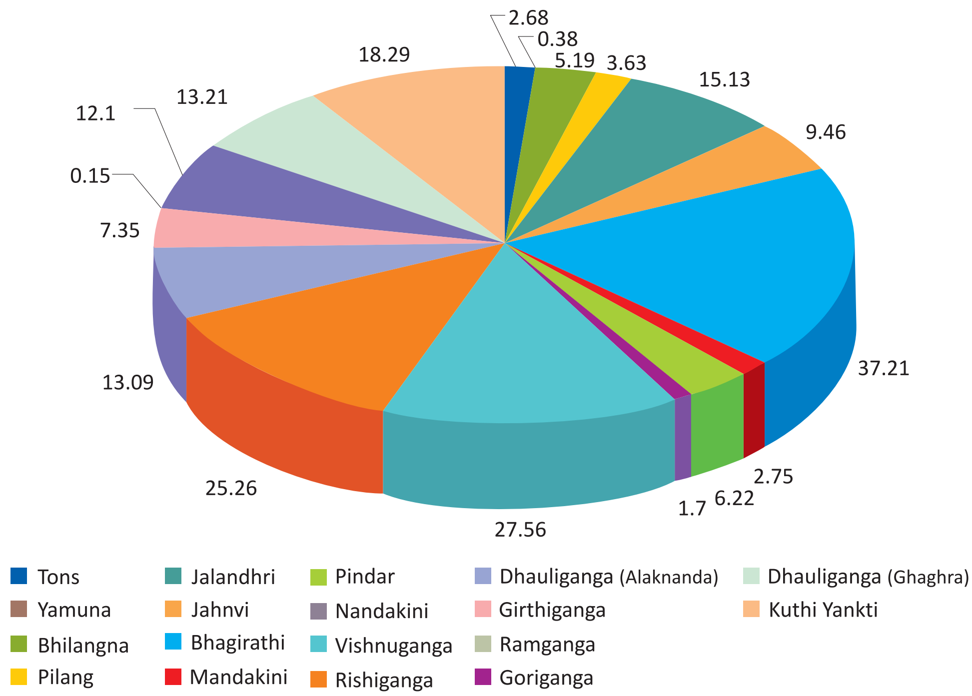


Fig-4.10.
Percentage Glaciered areas of basins of Uttarakhand[1]



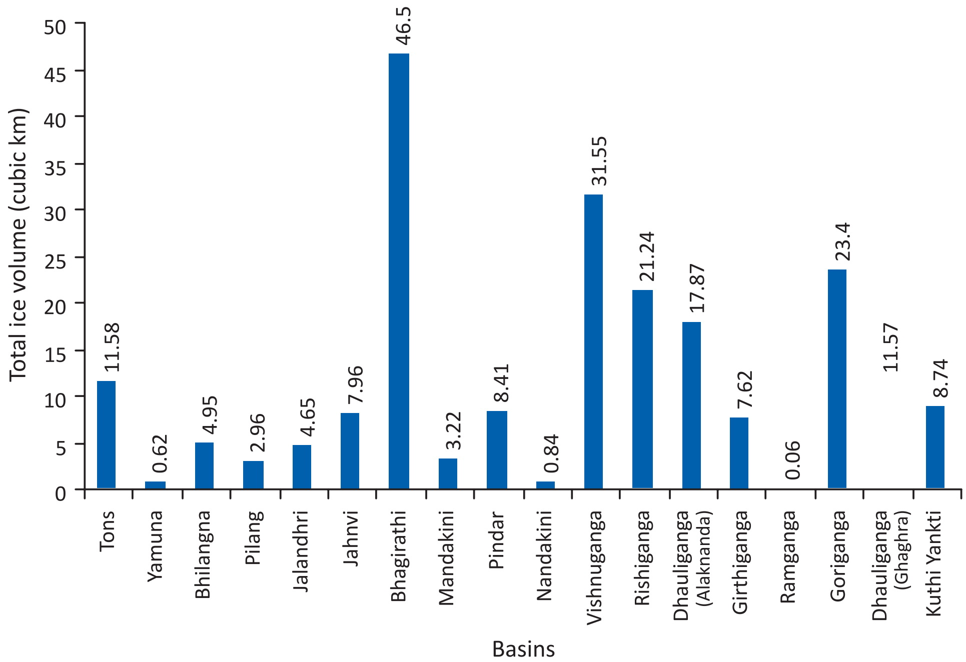


Fig- 4.11.
Total ice volume of basins of Uttarakhand[1]

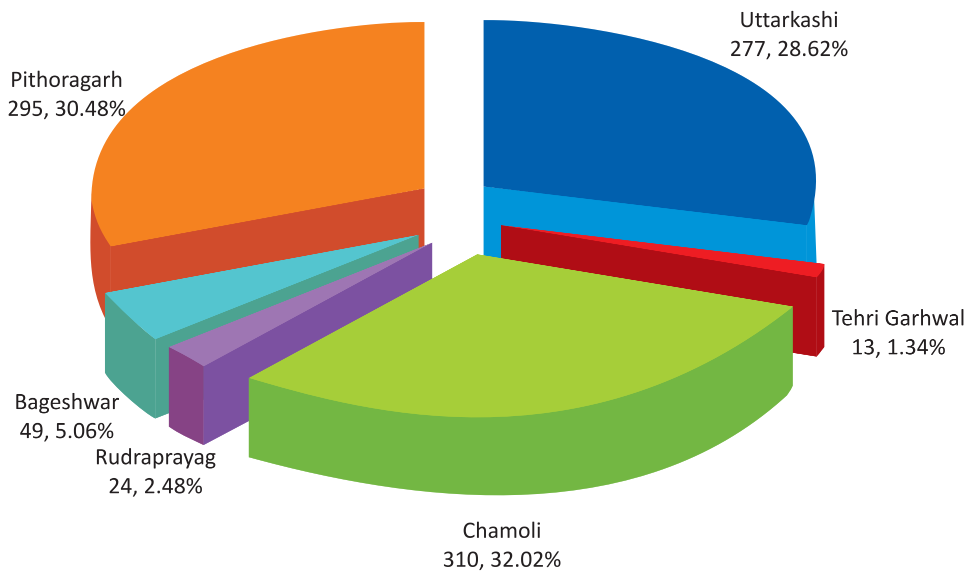


Fig-4.12.
Distribution of glaciers in Uttarakhand (District- wise)

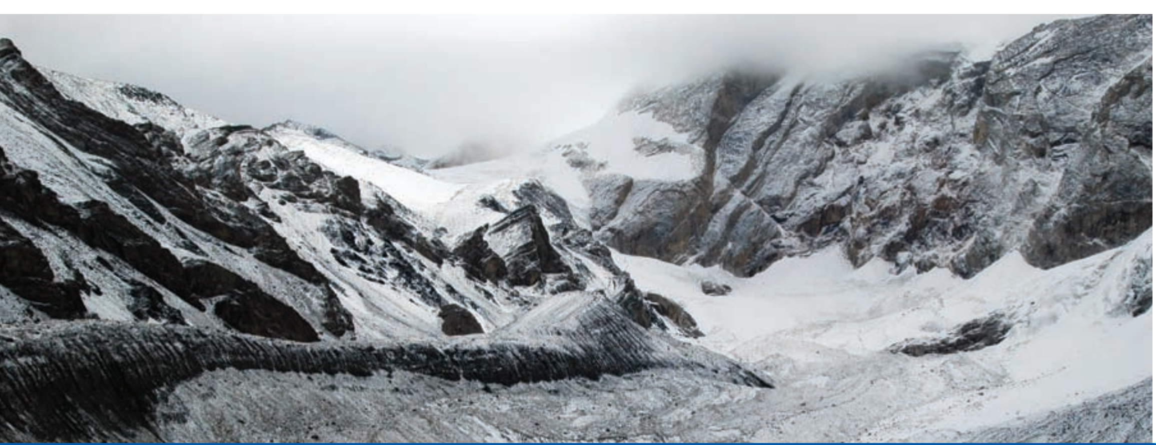


Fig-4.13.
Percentage glacierised area of districts of Uttarakhand

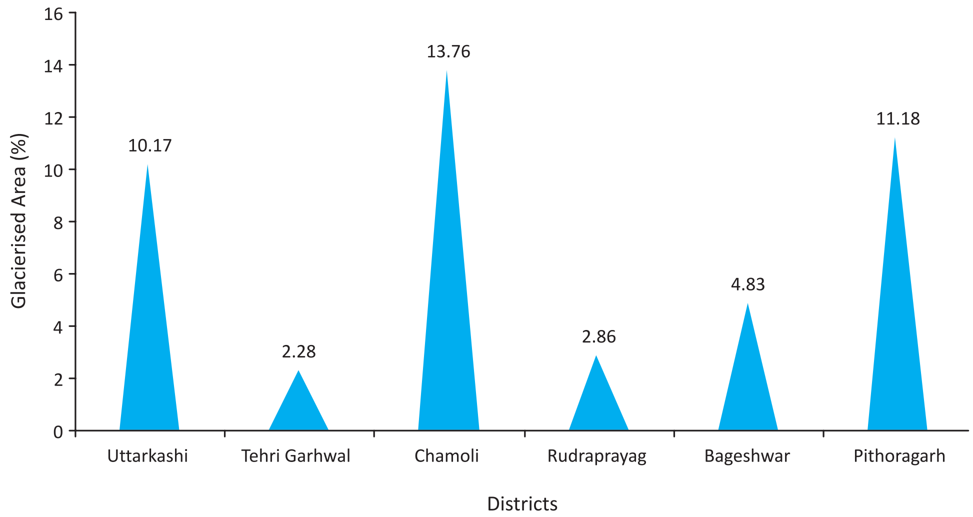
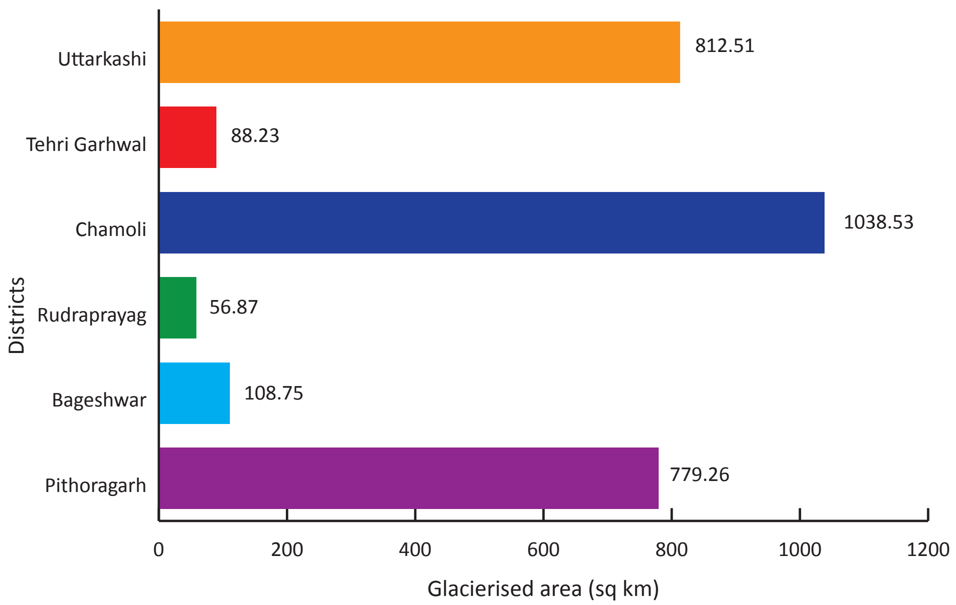


Fig-4.14.
Glacierised area of districts of Uttarakhand



13 glaciers[8]. Chamoli, Uttarkashi and Pithoragarh districts jointly account for 91% of glaciers, 92% of the glacier cover and 94.5% of glacier ice volume.

4.3.3. Some Well Known Glaciers in Uttarakhand

Feeding the perennial rivers of Himalaya, the glaciers of Uttarakhand have a life and beauty of their own. Glaciers here are very popular for researchers tourists trekkers. Some of these mighty glaciers are considered holy while some are visited just because of their sheer magnificence.

Details of some famous glaciers which fall in Uttarakhand Himalaya[1] is given in the Table 4.4.

4.4. Recession of Glaciers

Recession of Glaciers is not a present day phenomena. The process of advancement and recession of glaciers results of the occupation or evacuation of an area by the glacier. It is

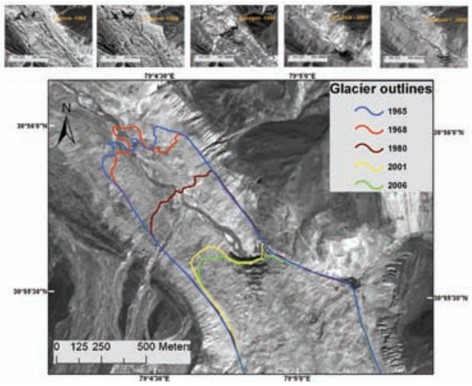
Gangotri Glacier

Gangotri Glacier is located in Uttarkashi District, Uttarakhand, a region bordering China. **Gomukh,** is the terminus or snout of the Gangotri Glacier, from where Ganga (Bhagirathi) river originates. Gomukh is also referred as 'Gaumukh' or 'Gomukhi'. The word Gomukh (go + mukh) literally means 'Mouth of a Cow'. According to some sayings, earlier the snout exactly looked like "Mouth of a Cow". The Gangotri glacier is one of the largest in the Himalayas with an estimated volume of about 28.72 cubic kilometers. The glacier is about 30.20 kilometres long and 143.58 square km area. Gomukh is 18 km from Gangotri in the foot hills of Bhagirathi at a height of 4255m. It is the snout of the Gangotri Glacier. Around the snout, nature presents a wild topography. There are bolders scattered here and there with some pieces of broken snow. This glacier has been constantly receding since measurements began in 1780. Data for 61 years (1936–96) showed that the total recession of Gangotri glacier is 1147m, with the average rate of 19m/year[3]. However, over the last 25 years of the 20th century, it has retreated more than 850 meters (34 meters/year)[5] and over 1519 meters between 1935 and 2004 (22.02 meters per year)[6].

Gangotri glacier inventory[3,7]

Glacier Coordinates	30043'22"-30055'49" N 79004'41"-79016'34" E
GSI identification number	50131 06029
Highest elevation	7138 masl
Lowest elevation	4000 masl
Surface area	143.58 km^2
Ablation	92.48 km^2
Accumulation	51.11 km^2
Mean width	1.50 km
Maximum length	30.20 km
Ablation zone length	26 km
Accumulation zone length	4.20 km
Mean depth	0.20 km
Ice volume	28.716 km^3
Tributaries: Chaturangi Glacier Raktvarn Glacier Kirti Glacier	 Length 22.45 km; area 67.70 (km^2) Length 15.90 km; area 55.30 (km^2) Length 11.05 km; area 33.14 (km^2)

a)



b)

Fig.
a. Gangotri Glacier[30]
b. Retreat in Gangotri Glacier[31]

Table 4.4.
Some well known Glaciers in Uttarakhand

Name of Glacier	River Basin	District	Height (m)	Length (km)
Tilku	(Tons) Yamuna	Uttarkashi	4,200 - 5,720	4.5
Jhajju	(Tons) Yamuna	Uttarkashi	3,880 - 5,600	4.5
Jaundar	(Tons) Yamuna	Uttarkashi	3,880 - 5,840	19.0
Bandar Punch	(Tons) Yamuna	Uttarkashi	5,080 - 5,600	12.0
Gangotri	Bhagirathi	Uttarkashi	4,120 - 7,000	30.2
Dokriani	Bhagirathi	Uttarkashi	3,800 - 6,000	5.5
Kedar Glacier	Bhagirathi	Uttarkashi	4,300 - 6,600	9.7
Khatling	(Bhilangna) Bhagirathi	Tehri	3,840 - 6,632	11.7
Chorbari Glacier	(Mandakini) Alaknanda	Rudraprayag	3,900 - 6,500	6.0
Bhagirathi Khark	Alaknanda	Chamoli	3,820 - 6,600	18.0
Satopanth	Alaknanda	Chamoli	3,810 - 7,000	16.0
Arwa	(Sarswati) Alaknanda	Chamoli	5,000 - 6,640	8.2
Tipra Bamak	Alaknanda	Chamoli	3,865 - 5,133	7.0
Jumma	(Dhauliganga) Alaknanda	Chamoli	4,700 - 5,640	4.2
Kosa	(Dhauliganga) Alaknanda	Chamoli	4,200 - 6,100	11.0
Girathi	(Dhauliganga) Alaknanda	Chamoli	4,900 - 6,000	3.8
Nandadevi N	(Dhauliganga) Alaknanda	Chamoli	3,800 - 6,500	17.0
Nandadevi S	(Dhauliganga) Alaknanda	Chamoli	4,000 - 6,300	16.0
Doonagiri	(Dhauliganga) Alaknanda	Chamoli	4,200 - 6,400	6.0
Kafni	(Dhauliganga) Alaknanda	Bageshwar	3,930 - 5,447	3.21
Pindari	(Pindar) Alaknanda	Bageshwar	3,900-5,800	5.0
Milam	(Gauriganga) Kaliganga-Ghaghara	Pithoragarh	3,500 - 6,500	18.0
Burphu	(Gauriganga) Kaliganga-Ghaghara	Pithoragarh	4,000-6,000	5.0
Meola	(Kaliganga) Ghaghara	Pithoragarh	3,500-6,800	10.3
Sona	(Kaliganga) Ghaghara	Pithoragarh	4,200-6,500	6.0
Ralam	(Kaliganga) Ghaghara	Pithoragarh	3,800-6,400	16.0
Kalabaland	(Kaliganga) Ghaghara	Pithoragarh	5983 - 6,559	15.0

a self-regulating mechanism which is control by the glaciers shape, geometry, bedrock topography and climate of the area. Results of the spot studies from Uttarakhand (Table 4.5) reveal that the glaciers are retreating at different rates in different time periods.

4.4.1. Status of Glacier in Different Basins in Uttarakhand Based on Satellite Images

On the basis of report published by Space Applications Centre ISRO, Ahmedabad[25] status of glacier advance or retreat in different basins in Uttarakhand based on Survey of India (SOI) maps and satellite images is presented Table 4.6.

Salient Feature Of Uttarakhand Glaciers (Central Himalaya)[1,8,9]

Source/ Basin : Ganga
Climate : Semi-arid & Semi-humid
Latitudes : 29^0 -32^0 N
No. of Glaciers : 968
Glacierised Area : 2883.37 km^2
Ice volume : 213.74 km^3
Permanent Snowline : 4950-5200 masl
Snout Altitude : 3800-4200 m
Glacier Surface : Partially debris covered
Av. Discharge : 488 km^3/yr
Largest Glacier : Gangotri

- Uttarakhand glaciers are the source of 51 important rivers and of three major rivers Ganga, Yamuna and Kali Ganga
- Out of the 968 glaciers in Uttarakhand, maximum numbers of glacier are in Alaknanda river basin (407) followed by Kaliganga (271), Bhagirathi (238) and Yamuna (52).
- Out of the 968 glaciers, 310 glaciers are found in Chamoli district, followed by 295 in Pithorgarh, 277 in Uttarkashi, 49 in Bageshwar, 24 in Rudrapryag and 13 in Tehri Garhwal district.
- Glaciers extended between altitude 3800 and 6400m.
- Snow line (ELA) fluctuates between 4950-5200m.

Table-4.5.
Retreat trends of glacier snouts of Uttarakhand glaciers, surveyed and monitored in different time periods[17,24]

Name of glacier	Period of Observation	Period (years)	Recession (m)	Average rate (m/year)	Ref.
Gangotri Glacier	1936-1996	61	1147	19.00	3
	1935–2004	69	1519.13	22.02	6, 10
Dokriani Glacier	1962-1995	33	550	16.60	11
	1991-1995	04	69.90	17.40	11
	1962–2007	45	751.35	16.70	12
Milam Glacier	1849–1997	148	2471	16.69	13
Bandarpunch	1960–1999	39	995	25.51	14
Jaundar Bamak	1960–1999	39	1455	37.31	14
Jhajju Bamak	1960–1999	39	1075	27.56	14
Chorabari Glacier	1992–1997	05	55	11.00	15
Satopanth	1962–2006	44	1163.65	26.45	16
Tipra Glacier	1962–2008	46	663	14.41	17
Dunagiri	1992–1997	5	15	3.00	15
Shankulpa	1881–1957	76	518	6.80	10
Pindari Glacier	1845-1906	61	1600	26.22	18, 19
	1906-1958	52	1040	20.00	20
	1958-1966	8	200	25.00	21, 22
	1845-1966	121	2840	23.47	10
Tributary Glaciers:					
Chhanguch	1958-1966	8	680	85.00	22
Thelu	1962-2004	42	1248	30.66	23
Raktvarna	1962-2004	42	1585	37.73	23

Table-4.6.
Status of glacier advance or retreat in different basins in Uttarakhand[25]

Sub-Basin	No. of glaciers monitored	Retreat	Advance	No Change	Area in 1962 (km²)	Area in 2004-05 (km²)	Loss in area %
Alaknanda	274	243	27	4	1047	905	14
Bhagirathi	183	117	27	39	1218	1074	11
Dhauliganga	104	65	-	39	429	362	16
Gauriganga	29	20	-	9	272 (1990)	261 (2005)	4

4.5. Hazards Associated with Glaciers

Glaciers are perennial sources of fresh water. Snow and glacier melt guarantee certain amount of base flow throughout the year to Himalayan rivers. With fast recession of glaciers, base flow of Himalayan rivers would be adversely affected. Knowledge of glaciers is essential for formulating suitable future programs for development and management of environment and Himalayan rivers. For this, it is essential to know the total number of glaciers; their volume and the volume of melt water they generate in different climatic regions of the Himalaya, along with the probable risks associated with glaciers.

In the Himalayas, a large section of people live in the valleys formed by the glaciers. Understanding of glaciers assume importance when difficult scientific and ethical questions need to be answered about sustainable development of mountain ranges and adjoining plains, especially with regard to hydropower, water supply and environmental quality, which has direct bearing on the national growth. In this regard the fluctuation of glaciers, change in runoff, annual balance, sediment transportation and their roles in controlling the climate of the subcontinents are of great significance.

Another important aspect is glacial hazards. Of these, glacial lake outburst floods (GLOF), avalanches and flash floods can be considered to be primary hazards, while rock fall, debris fall and landslides can be considered secondary hazard. Such events can affect the storage capacity of dams and disrupt the smooth functioning of the turbines in the power stations. However, our knowledge of GLOF is very limited and advanced research needs to be undertaken to predict and reduce their effects.

4.5.1. Glacial Lake Outburst Floods (GLOF) / Flash Floods

Valley glaciers generally have supra-glacial ponds and moraine dam lakes. As the glacier retreats it leaves a large void behind. Ponds occupy the depression earlier occupied by glacial ice. The moraine walls that act as dam are structurally weak and unstable and undergo constant changes due to slope failures and slumping and there exists the danger of catastrophic failure, causing glacial lake outburst floods (GLOFs). GLOF is characterized by sudden release of huge amount of lake water that rushes along the stream channel downstream in the form of dangerous flood waves. The propagation of GLOF surges trigger landslides and bank erosion that temporarily block the surge waves and result in a series of surges as the landslide dam breach. Earthquakes may also be one of the triggering factors depending upon its magnitude, location and other characteristics. Discharge rates of such floods are typically several thousand cubic meters per second. In Uttarakhand Himalayas there are 127 glacial lakes of varying sizes[26], the total area of which is around 75 km^2. Therefore, the possibility of the state being affected by GLOF cannot be ruled out.

As per the report published by ISRO in 2011, the summarized glacier inventory data with Permanent Snow Field, Supra-Glacier Lake, De-Glaciated valley, Moraine Dam Lake for seven sub-basins of Ganga basin are given in Table 4.7.

Table-4.7.
Sub-basin wise summarized Glacier Inventory data for Ganga Basin[25]

Sub-Basin	Area (sq km)			Glaciated Area		Permanent Snow Field		Supra-Glacier Lake		De-Glaciated valley		Moraine Dam Lake	
	Accumulation	Ablation Debris	Ablation Exposed	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
Yamuna	87.1	37.6	41.8	59	166.63	27	4.99	Nil	Nil	Nil	Nil	Nil	Nil
Bhagirathi	617.7	237.0	137.9	172	992.67	61	16.51	2	0.16	Nil	Nil	Nil	Nil
Alaknanda	783.0	349.8	193.0	253	1325.94	186	24.51	12	0.65	6	2.63	Nil	Nil
Ghagra	624.2	285.5	199.4	355	1109.28	113	44.35	9	2.31	8	4.19	Nil	Nil
Karnali	2620.0	1394.7	261.2	1705	4276.04	158	31.38	27	3.29	9	12.27	14	2.51
Narayani	3397.4	904.7	822.0	1756	5124.15	17	39.75	13	0.90	13	24.93	12	2.35
Koshi	2754.9	1635.2	1007.9	1937	5398.18	79	42.20	24	7.93	48	167.73	168	59.33
Total	**10797.20**	**4806.90**	**2621.4**	**6178**	**18226.26**	**614**	**198.7**	**87**	**15.24**	**84**	**211.75**	**194**	**64.19**

4.5.2. Avalanches

Avalanche is a sudden downward movement of snow, ice blocks and rock mass when internal cohesion decreases or with intrusion of liquid water. The factors that govern the generation of an avalanche are weather conditions, snow fall, slope steepness, slope orientation, wind direction, terrain conditions, vegetation cover and snow peak conditions. Most of the avalanches occur on 30-45^0 slopes. A large avalanche might release 300,000 cubic yards of snow that is equivalent to 200 football fields under 10 feet of snow[26]. Avalanche can reach up to a speed of 394 m/hr.

In Uttarakhand, there has so far been no report on the occurrence of avalanche. However, the high Himalayan valleys close to glaciers and which receive winter snow are susceptible to avalanches.

4.5.3. Damage to Hydropower Stations

The discharge during a GLOF event is laden with large amount of sediments that cause acute toe erosion leading to landslides along the valley slopes. The sediment-saturated discharge can cause destruction of the dam, fill the dam or damage the turbines besides reducing the power generation capacity. Uttarakhand has the identified capacity of hydropower generation potential of around 18 GW. Out of which the state has developed 2980 MW capacity and there is still scope of 15 GW generations[27]. Regular monitoring of glacial lakes and glacial retreat is therefore, utmost necessary to safeguard the power projects in the State.

4.6. List of Government Agencies, Institutes and Universities involved in Glaciological Studies in the Uttarakhand

- The Director, Wadia Institute of Himalayan Geology, Dehradun, Uttarakhand
- The Vice Chancellor, H.N.B., Garhwal University, Srinagar, Uttarakhand
- The Director, G.B. Pant Institute of Himalayan Environment and Development, Almora, Uttarakhand
- The Director, Indian Institute of Remote Sensing, Dehradun, Uttarakhand
- The Director, Geological survey of India, Dehradun, Uttarakhand
- The Director, Indian Institute of Technology, Roorkee, Uttarakhand
- The Director, National Institute of Hydrology, Roorkee, Uttarakhand
- The Director, Uttarakhand Space Application Centre, Dehradun, Uttarakhand

4.7. Key Findings

On the basis of discussion with the subject experts, researchers and social workers engaged in the related field and suggestions & recommendations from various reports[28,29] the following recommendations for Uttarakhand glaciers are drawn:

- The receding trend of the glaciers is a global phenomenon; a very limited data base is available for glaciers of Uttarakhand. It is recommended that creation of data base for recession of UK glaciers be taken up on priority basis.
- To assess the impact of glaciers recession on local population, agriculture, forest and land use pattern data base for all above parameters be created.
- Monitoring of climate and snow precipitation is of outmost importance. It is recommended to establish AWS network in glacier valleys. A long term data series is required to assess impact of climate on glacier and also the anthropogenic impact on climate.
- As the glaciers vacate more areas, the fragile areas are prone to glacier related hazards like avalanche and glacial lakes etc. monitoring of potential hazards in these areas is very essential. An early warning system may be considered.
- Risk assessment to understand the impacts of glaciers on safety of dams, reservoirs and power projects in important. It should be made mandatory for hydel projects in the state to have discharge gauging, suspended sediments load and meteorological stations in the upstream catchment areas and the information made available to concerned department for their assessment.
- The glacier inventory map and glacial hazards map be superimposed on habitat map of UK to identify most glacial hazards prone areas requiring immediate redressal
- To develop human resource programme, Universities in Himalayan region may be encouraged to have special summer training schools on glaciers. Incentives may be given trainees as well as to universities for encouragement.
- Awareness programme and general guidance may be prepared and school and collages may be involved to disseminate the knowledge.
- All the data base generated may be integrated under Geographical Information System (GIS) environment. This will help in effective planning, management and monitoring eventually.
- Glacier research (including the related study in high altitude and snow bound areas) is tough and hazardness involving lot of efforts both in terms of men and material. A suitable mechanism has to be evolved for this purpose which could interalia includes the following steps:
    - Sufficient funding for glacier research
    - Creation of appropriate institutional structure including a model institution and regional centre and net work.
    - Man power generation with suitable incentive.
    - Fast Track programs at Graduate and Post Graduate Level e.g. Short term training courses, Study tour/ Expedition to snow bound and glacier areas.

4.8. References

1. Sangewar, C.V. and Shukla, S.P., Inventory of the Himalayan Glaciers, A Contribution to the International Hydrological Programme, Geological Survey of India, 2009, Special Publication No. 34
2. Report on 'India: Country Paper on Water Security', Central Water Commission, Ministry of Water Resources Government of India, New Delhi, June 2011.
3. Naithani, Ajay K., Nainwal, H.C., Sati, K.K. and Prasad, C. Geomorphological evidences of retreat of the Gangotri glacier and its characteristics. *Current Science*, 2001, **80(1)**, 87-94.
4. Raina, V.K. and Srivastava, D., Glacier Atlas of India: Geological Society of India, Bangalore, 2008.
5. Sharma, M.C. and Owen, L.A., *J. Quat. Sci. Rev.*, 1996, **15**, 335–365.
6. Kumar, K. Dumka, R.K., Miral, M.S., Satyal, G.S. and Pant, M., Estimation of retreat rate of Gangotri glacier using rapid static and kinematic GPS survey. *Current Science* 2008, **94(2)**, 258–262.
7. Singh, P., Haritashya, U.K., Kumar, N. and Singh, Y., Hydrological characteristics of the Gangotri Glacier, Central Himalayas, India. *Journal of Hydrology*, 2006, **327**, 55– 67.

8. Srivastava, D., 2009. Himalayan ecosystem and glacier regime–implications and manifestations, Abstract of the Geomatics 2009 National Conference, Dehradun, Feb. 4-6, 2009.
9. Dobhal, D.P., Climate Change at the Third Pole: The Impact of Climate Instability on Himalayan Ecosystems and Himalayan Communities; (eds. Vandanashiva & Vinod Kumar Bhatt), Navdanya, Research Foundation for Science, Technology and Ecology, New Delhi, 2009.
10. Vohra, CP., Himalayan Glaciers. (Eds. Lall, J.S. and Maddie, A.D. Himalayan Aspects of Change. Delhi: Oxford University Press, 1981, 138–151.
11. Dobhal, D.P., Gergan, J.T. and Thayyen, R.J., Recession and morpho-geometrical changes of Dokriani glacier (1962–1995) Garhwal Himalaya, India. *Current Science,* 2004, **86 (5)**.
12. Dobhal, D.P. and Mehta, M., Surface morphology elevation changes and terminus retreat of Dokriani glacier, Garhwal Himalaya: Implication of climate change. *Himalayan Geology*, 2010, **31(1)**, 71–78.
13. Shukla, S.P. and Siddiqui, M.A., Recession of snout front of Milam glacier, Goriganga valley, Pithoragarh district, Uttar Pradesh. In: Symposium on Snow, Ice and Glaciers – A Himalayan Perspective, Lucknow, 2001 9–11 March 1999, 71–75.
14. Shukla, S.P., Siddiqui, M.A., Hampaiash, P., and Swaroop, S., Secular movement studies of selected glaciers of Yamuna and Ghagra Basins, Dehradun and Tehri, Uttarkashi and Pithoragarh Districts, U.P. *Geological Survey India Records*, 2001, **133,** 161–165.
15. Swaroop, S., Oberoi, L.K., Srivastava, D. and Gautam, C.K., Recent fluctuation in snout front of Dunagiri and Chaurabari glaciers, Dhauliganga and Mandakini – Alaknanda basins, Chamoli district, Uttar Pradesh. In: Symposium on Snow, Ice and Glaciers – A Himalayan Perspective, Lucknow, 2011 9–11 March 1999, 53: 77–81.
16. Nainwal, H.C., Negi, B.D.S., Chaudhary, M., Sajwan, K.S., and Gaurav, A., Temporal changes in rate of recession: Evidence from Satopanth and Bhagirathi Kharak Glacier, Uttarakhand, using total station survey. *Current Science*, 2008, **94(5),** 653–660.
17. Mehta, M., Dobhal, D.P. and Bisht, M.P.S., Change of Tipra Glacier in the Garhwal Himalaya, India, between 1962 and 2008. *Progress in Physical Geography*, 2011, **35(6),** 721–738.
18. Holland, T.H., A preliminary survey of certain glaciers in northwest Himalaya, *Rec.Geol. Surv.Ind,* 1906, **35(3)**, 124-126.
19. Cotter, G.de P., Notes on certain glaciers in Kumaun, ***Rec. Geol. Suv. Ind.*** 1906, **35(4),** 148-152.
20. Strachey, R., A description of glaciers of the Pindari and Kaphnee rivers in the Kumaun Himalaya, *Journal Asiatic Soc. Bengal*, 1947, **16(2)**, 203.
21. Tewari, A.P. and Jangpangi, B.C., The retreat of the snout of the Pindari Glacier, *Proc. Symp. of Obsergurgle Intern. Assoc. Sci. Hydrol.*, 1962, **58**, 245-248.
22. Tewari, A.P., Recent changes in the position of the sout of the Pindari Glacier, Kumaun Himalaya, Almora district, U.P., India, Proc. Symp. Role of Snow and Ice in Hydrology, UNESCO-WMO-IAIS, Canada, 1972, **2**, 1144-1149.
23. Kotlia, B.S., Rakesh, K, Dunka, M.S., Miral, L.M., Joshi, Recession rate of tributary glaciers of Gangotri glacier system, Garhwal Himalaya, India, Bio-Nano-Geo Science the future challenges (eds Srivastava and Roy), Ane Books Pvt. Ltd. New Delhi, 2009, 141-148.
24. CSSIHR, Compendium of Statics for the States of Himalayan Region, GBPIHED, Katarmal, 2010, 1-130.
25. Snow and Glaciers of the Himalayas prepared by the Space Applications Centre (SAC), ISRO, Ahmedabad, 2011
26. Report of the expert committee on Glaciers, 2007, DMMC, Govt. of Uttarakhand
27. Tolia, R.S., A planning frame – Work for the Mountain States of India.
28. Summary and recommendations of the workshop on 'Recent developmental activity and its impact on the environment and people of the higher Himalaya', organized by Dasoli Swarajya Mandal & UCOST during 2-3 June 2011.
29. Report of the study group on Himalayan glaciers. Prepared by the study group on Himalayan glaciers, for the office of the Principal Scientific Adviser to the Govt. of India, 2011).
30. http://www.indianetzone.com/photos_gallery/31/gangotri-glacier_21738.jpg
31. Bhambri, R., Bloch, T., Chaujar, R.K., Frontal recession of Gangotri Glacier, Garhwal Himalayas from 1965 to 2006, measured through high resolution Remote Sensing data, *Current Science*, 2012, **102(3)**, 489-494.

Section III

CLIMATE CHANGE

Climate Change

Chapter

ONE

CLIMATE CHANGE

(JS Rawat, Rajendra Dobhal
and VPS Arora)

1.1. Introduction

Uttarakhand having a complex geographic personality is miniature of the earth as it has almost all the climatic and vegetation regions of the world. Uttarakhand mountain system delivers a wide array of goods and services to humanity such as fresh water, carbon storages, biodiversity, forest products, agricultural and horticultural products, minerals, electricity, recreation opportunities and many others. All these services are exposed to climate change on multiple fronts. The functioning of fragile mountain system is threatened today by global warming accelerated alarmingly by various anthropogenic and technogenic activities. It is not an easy task to define the impact of climate change on different resource sectors without understanding anthropogenic and technogenic impacts in different systems. It is a challenging task for the scientists and Uttarakhand is an excellent state to assess the various impacts of climate change because it has still some virgin or anthropogenically least affected alpine and snow cover area in its high altitudinal zone, and has a good amount of anthropogenically least affected forest area.

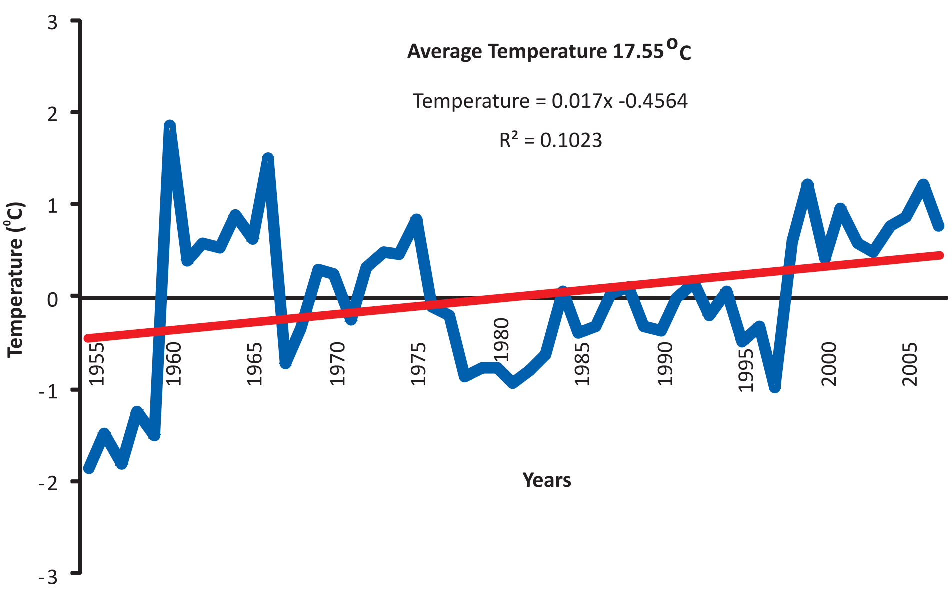
This paper provides preliminary results of climate change impact studies on temperature and rainfall, snow cover and glaciers, biodiversity, streams and rivers, agriculture and other sectors conducted by UCCC in Uttarakhand and also embraces an overview of long term action plan initiated by UCCC for climate change impacts mitigation in association with villagers, government departments and scientists.

1.2. Temperature and Rainfall

1.2.1. Increase in Temperature

Global warming is a universal phenomenon but how much a particular region or place has warmed actually, it has to be determined region to region and place to place. The observations of available temperature data reveal that since the last 53 years (1955 to 2007) average temperature of a Lesser Himalayan Hill station, viz., Almora -located at 29⁰35′ and 79⁰35″E at an elevation of 1640m from the m.s.l. has an increasing trend (Fig. 1.1) due to anthropogenically accelerated global warming. These data indicate that the average temperature of Almora, i.e., 17.55 ºC (1955-2007) has increased up to 0.46ºC during the last 53 years. This preliminary observation suggests that the average temperature is rising in hills. The amount of temperature rise may vary from place to place which has to be

Fig-1.1.
Variation in average annual temperature and its trend at Almora[2].



determined by further studies. Similar temperature study in Changbaishan Natural Reserve in the neighboring country China has also reported the increasing trend in the average annual temperature from 1982 to 2002[1].

1.2.2. Reduction in Annual Rainfall

Rainfall records of two places, i.e., Almora and Manora Peak (Nainital) were examined. There results have indicated that annual rainfall has decreasing trend. The rainfall record of 53 years (1955 to 2007) of a Hill Station of Uttarakhand, viz., the Almora, postulates the fact that the average annual rainfall has a decreasing trend (Fig. 1.2). At present, on an average, the Almora Hill Station is receiving 23% or 244 mm less annual rain compared to its 53 years annual average rainfall, i.e., 1060 mm. The rainfall records of 40 years (1964-2003) of the Manora Peak near the Nainital town also reveal that the annual rainfall has decreasing trend (Fig.1.3). The average rainfall (1964-2003) of the Manora is 2324 mm. At present this area is receiving about 16% (or 232 mm) less rainfall from its annual rain (i.e., 2324 mm).

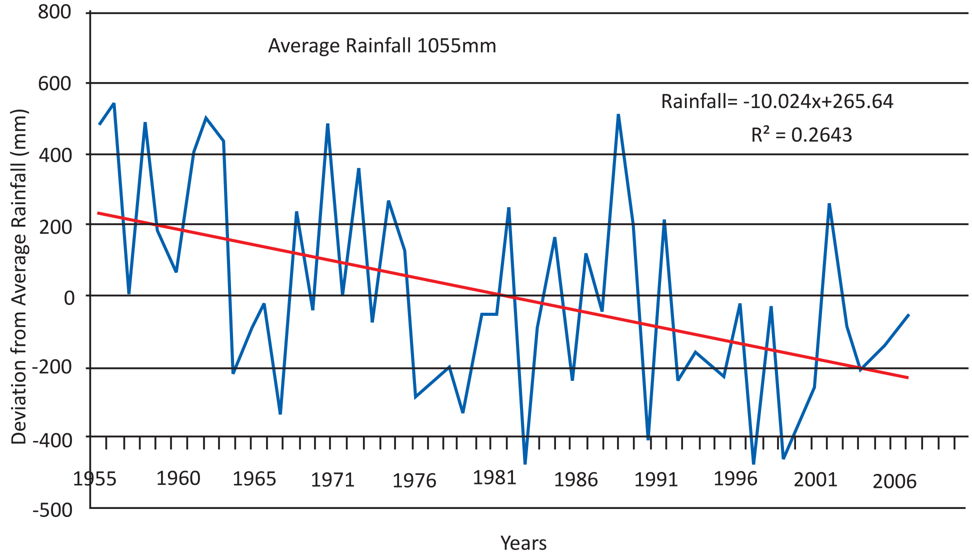


Fig-1.2.
Variation from average rainfall and its trend at Almora[2].

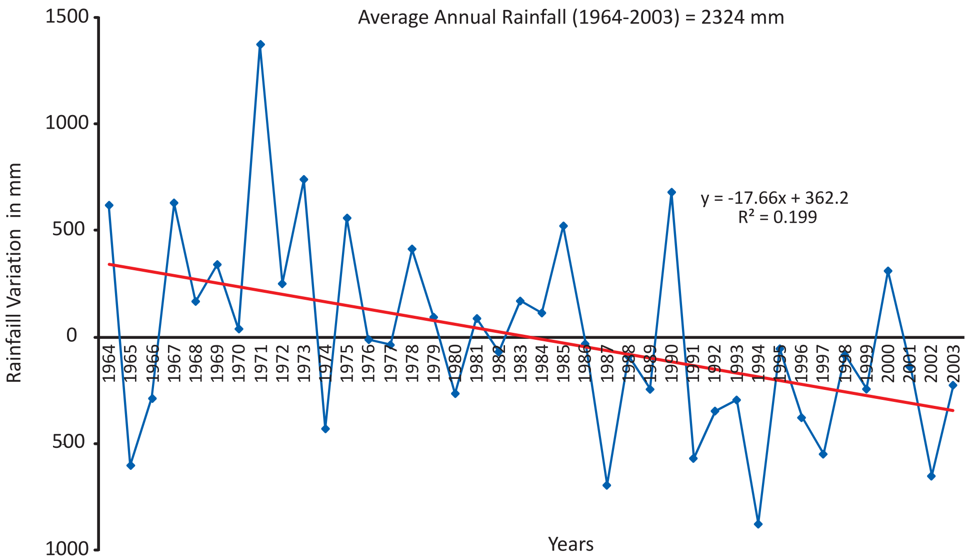


Fig-1.3.
Variation from average rainfall and its trend at Manora Peak[2].

1.2.3. Reduction in Annual Rainy Hours

The latest available rainfall duration records on hour by basis of village Sall Rautela (Fig. 1.4) in district Almora reveal that average annual rainfall duration stands at about 251 hours/ year which varies between 0.66 hours in October to 42.33 hours in August. Although such hourly basis records of rainfall are not available of the past for comparison but most of the natives of the state having age of more than about 50 to 60 years would have not forgotten the popular geographic phenomenon which used to occur in the recent past normally in mid July, viz., *Satzhar*, i.e., rain of continuous seven days. This rainfall duration of seven days (i.e., 168 hours) is more than the present entire rainy season (June to September) rainfall duration, i.e.,147.99 hours (Fig. 1.4).

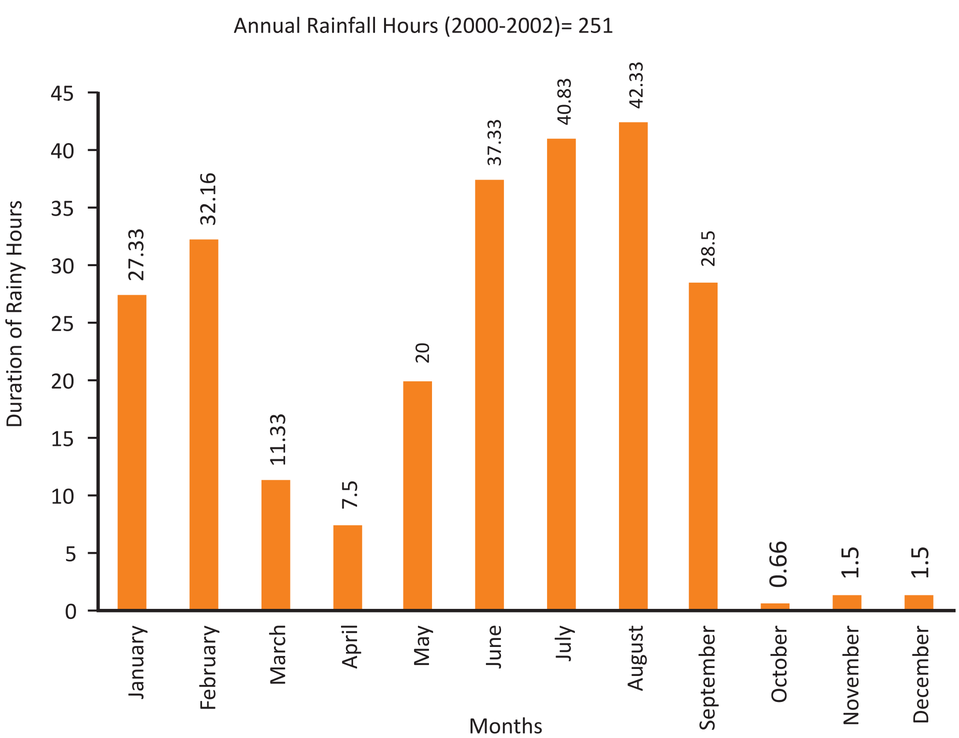


Fig-1.4.
Average monthly rainfall hours (2002-2003) at Village Salla Rautela, District Almora[2].

State Climate Change Council

As concluded in the 'Shimla Conclave' held in Oct 2009, Uttarakhand state has crafted its own State Climate Change Council under the chairmanship of the Chief Secretary, Government of Uttarakhand and additional PCCF as a member Secretary (Order No. 37/X-3-2010-13(12)/2009 dated 19 Jan 2011)

The council has members belonging to 27 different departments. The departments are Forest, Climate Change and Forest Influence Division, Forest Research Institute, Rajaji National Park, H N B Garhwal University, Agriculture Department, Industries, Urban Development, Watershed Management Directorate, Animal Husbandry, Power Transmission Corporation of Uttaranchal Ltd (PTCUL), Planning Department, Uttarakhand State Council for Science and Technology, SIDCUL, Uttarakhand Jal Sansthan, Disaster Mitigation and Management Centre (DMMC), Uttarakhand Peyjal Sansadhan Evam Nirman Nigam, State Water and Sanitation Mission, Uttarakhand Renewable Energy Development Agency (UREDA), Uttarakhand Power Corporation Limited, Transport, Directorate General of Health Services, NRHM, Biodiversity Board, Tourism, Uttarakhand Jal Vidyut Nigam, SWAJAL and PWD.

The mandate of the council is to approve, implement and monitor the state level work plan for climate change. It will also update the state about the various programmes initiated globally as well as in the domestic level and contextually implement the ones relevant for the state.

These data suggests that the actual rainfall duration has been reduced to 75% less in the month of July alone. The situation is similar in case of the other months also but no hourly basis rainfall records of past are available to compare. The automatic rain gauge record of the Salla Rautela village is symbolic which advocates that the actual annual rainfall duration has been drastically reduced due to climate change.

1.2.4. Changes in Rainfall Rhythm

The normal monthly distribution of rainfall in the region reveals that the maximum rainfall occurs in the month of July which constitutes the peak of the annual hyetograph and the months August and September constitute the recession segment of the hyetograph. The recent rainfall records (2000-2002) suggest that the peak of annual hyetograph has been shifted from July to August (Fig. 1.5) and since the last two decades there are incidences when the peak of the annual hyetograph is being formed in the month of September (Fig. 1.6). This indicates that in future the peak of the annual hyetograph may be shifted from August to September. The shifting of rainfall peak in the annual hyetograph reveals that the rainfall rhythm is gradually changing due to climate change.

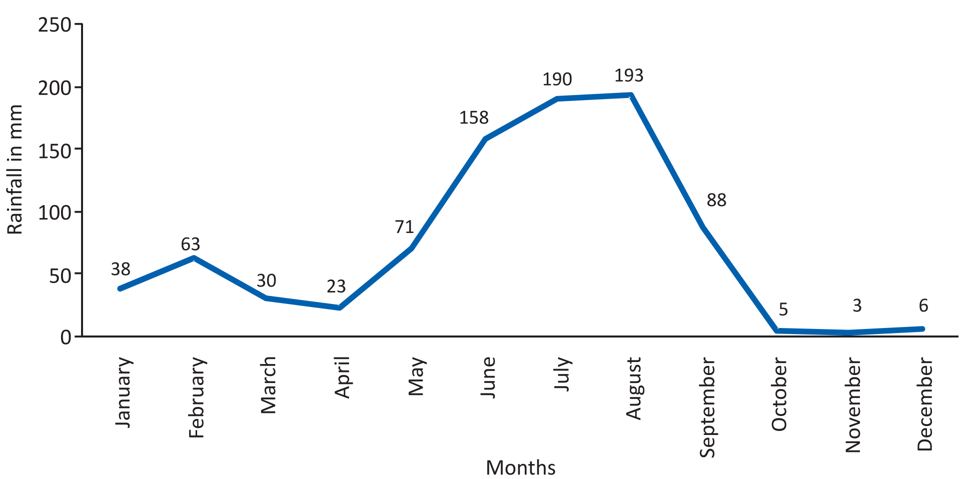
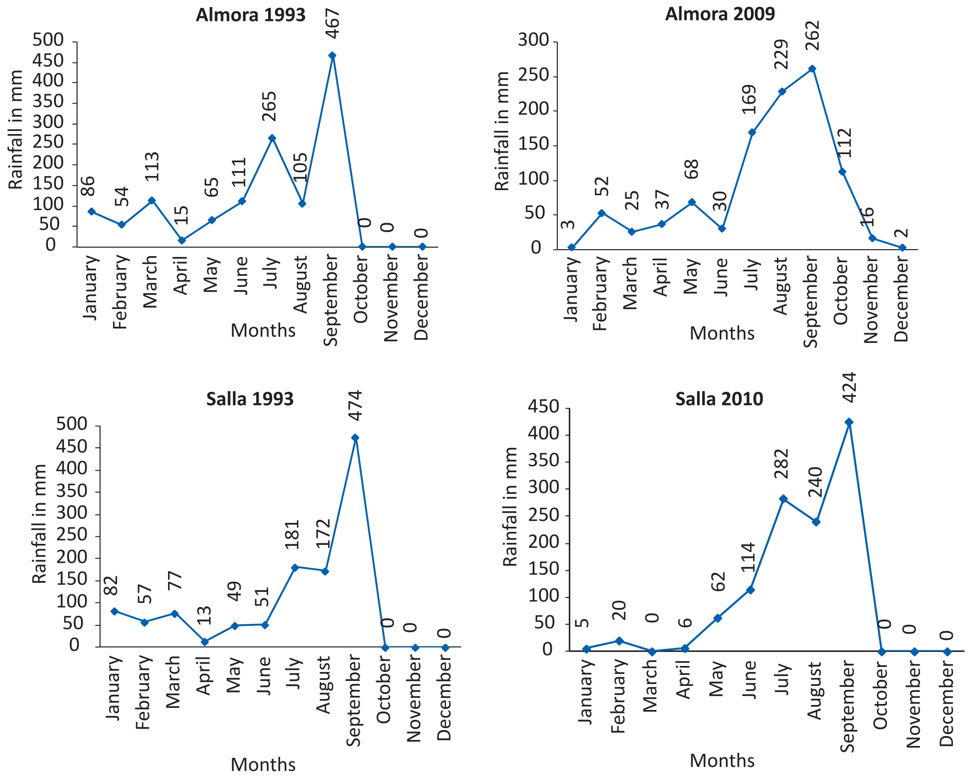


Fig-1.5.
Average annual hyetograph (2002-2003) of Village Salla Rautela showing the peak of hyetograph in month of August[2].

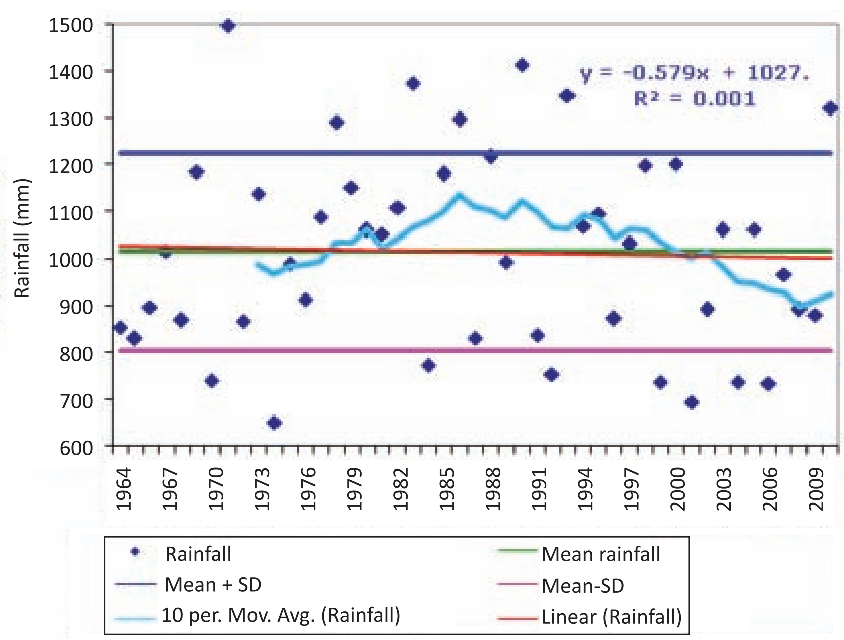
Fig-1.6.
Annual hyetograps of the Almora town (data after VPKAS Almora) and village Salla Rautela[2] showing the peak of hyetographs in the month of September.



1.2.5. *Increasing Trend of Draught Years*

Due to climate change there has been increasing trend of occurrence of draught incidences in the recent past. The Hawalbagh rainfall record postulates this fact revealing that during 1964 to 2000 the total incidences of draught were 16, out of which 5 were severe but during 2001-2009 within 8 years, 7 draughts occurred out of which 3 were severe (Fig. 1.7).

Fig-1.7.
Rainfall pattern at Hawalbagh, district Almora (*After Pandey, VPKAS Almora*).



1.3. Snow and Glaciers

1.3.1. Snow Cover

Snow cover is highly sensitive for climate change impact. Geographical distribution of snow cover area on different dates in different watersheds (Table 1.1) and in the entire state of Uttarakhand was worked out from the available remote sensing data. Fig. 1.8 depicts example of distribution of snow cover area in different years in one of the watersheds of Uttarakhand, viz, the Kuthiyangti while Fig. 1.9 depicts status of change in snow cover area in Uttarakhand from 1990 to 1999, i.e., a period of about one decade.

Table-1.1.
Geographical area under snow cover on different dates in different watersheds and in the Uttarakhand state (based on MSS and LANDSAT TM and ETM Data)

Name of Watershed	Area of Watershed in km^2	Area under Snow Cover Area	
		Year	In %
1. Kuthiyangtai	639.89	October, 1972	69.8
		15th October, 1990	64.4
		15th October, 1999	56.7
		15th October, 2010	44.5
2. Dhauliganga (E)	1432.36	October, 1972	62.4
		15th October, 1990	40.0
3. Goriganga	2279.71	15th October, 1990	27.6
		15th October, 1999	25.9
4. Ramganga (E)	1282.32	October, 1972	1.7
		15th October, 1990	1.3
5. Pindar Watershed	1872.98	October, 1972	12.5
		15th October, 1999	8.6
6. Dhauli Ganga (W)	3210.67	15th October, 1990	63
		15th October, 1999	42
7. Dhauli Ganga (E)	1432.36	October, 1972	62.4
		15th October, 1990	40.0
8. Alaknanda	3414.64	October, 1972	38.0
		15th October, 1999	34.1
9. Bhagirathi	6073.25	October, 1972	45.8
		15th October, 1999	22.6
10. Mandakini	1667.75	October, 1972	14.2
		15th October, 1990	12.8
11. Yamuna	5165.21	October, 1972	16.9
		15th October, 2010	10.6

Table 1.1 reveals that the snow covered area in different watersheds of Uttarakhand varies maximum 56.7 to 69.8% in Kuthiyangti watershed to minimum 1.3 to 1.7% in the Eastern Ramganga watershed. The geographical distribution of snow reveals that on 15th and 21st October 1990, about 4884.29 km^2 area of the Uttarakhand state was under snow cover while on the same dates and month in 1999, the snow cover was found in 4145.95 km^2 area. This reveals that the snow cover area was about 17.98% (or 738.34 km^2 - Fig. 1.9) less in Uttarakhand in October 1999 as compared to October 1990, i.e., within a period of about one decade.

Fig-1.8. Geographical distribution of snow cover area and NDVI based vegetation line in different years in the Kuthiyangti Watershed[2] (*based on MSS, LANDSAT TM and ETM+ data of October 1972, 15th October 1990,15th October 1999 and 15th October 2010*).

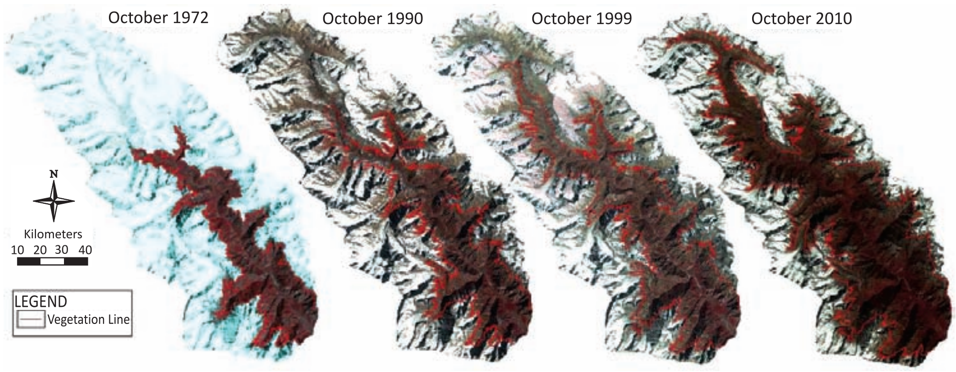
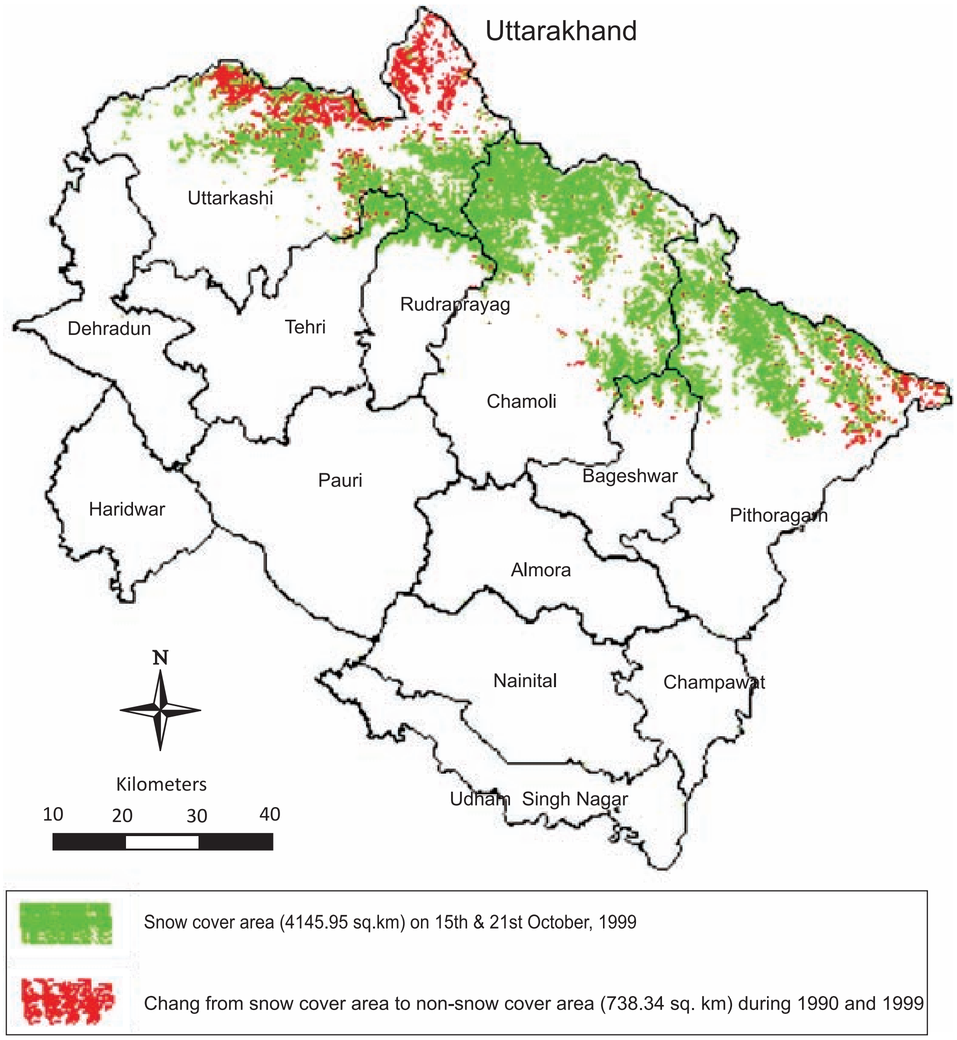


Fig-1.9. Difference in snow cover area between October 1990 and October 1999 in the Uttarakhand State[2] (*based on of 15th and 21st October 1990 LANDSAT TM data and 15th and 21st October 1999 LANDSAT ETM+ data.*)



1.3.2. Glaciers

Snow is very sensitive for global warming. Results of studies from Uttarakhand (Table-1.2) reveal that the glaciers of Uttarakhand are retreating at different rates in different time periods depending on their different geographic position, aspect and altutude. The Pindari glacier has retreated about 2840 m since the last 121 years at an average rate of 23.47 m/

year. It retreated at the rate of 26.22 m/year during 1845 to 1906, 20 m/year during 1906 to 1958 and 25 m/year during 1958 to 1966 (Table-1.2). The Raktvarna and Thelu glaciers (Plate-1.1 and 1.2) have retreated 1248 m (at the rate of 30.66 m/year) and 1585 m (at the rate of 37.73 m/year) during the last 42 years between 1962 to 2004. A glacier is a system of many smaller glaciers. For example the Gangotri glacier is system of as many as 32 tributary glaciers ranging from 1.05 km^2 to 17.70 km^2 in area[4]. The tiny and small glaciers are retreating relatively at faster rate. For example, Chhanguch, a tributary glacier of the Pindari, retreated at more than 10 times higher rate (i.e., 85 m/year) during 1958 to 1966 as compared to the retreat rate (i.e., 25 m/year) of its master Pindari glacier (Table-1.2). Similarly the rate of retreat of the two tributary glaciers, viz.,the Raktvarna (Plate-1.1) and Thelu (Plate-1.2) is near about two times higher as compared to the retreat rate (19 m/year) of their master glacier, viz., the Gangotri (Plate-1.3). Numbers of tiny and small glaciers have completely disappeared from the region which is not documented.

Table-1.2.
Rate of recession of different glaciers of Uttarakhand

S. No.	Name of Glacier	Period	Duration	Recession	Rate of Retreat
1	Gangotri	1936-1996[3]	61 years	1147m	19m/year
2	Pindari	1845-1906[4,5] 1906-1958[6] 1958-1966[7]	61 years 52 years 8 years	1600m 1040m 200m	26.22m/year 20.0m/year 25.0m/year
		1885-1966[8]	121years	2840m	23.47m/year
3	Milam	1849-1957[9]	108 years	1350m	12.5m/year
4.	Dokriani	1962-1991[9] 1991-2000[9]	29 years 9 years	480m 161.15m	16.5m/year 18.0m/year
Tributary Glaciers					
1	Chhanguch	1958-1966[8]	8 years	680m	85m/year
2	Thelu	1962-2004[10]	42 years	1248m	30.66m/year
3	Raktvarna	1962-2004[10]	42 years	1585m	37.73m/year

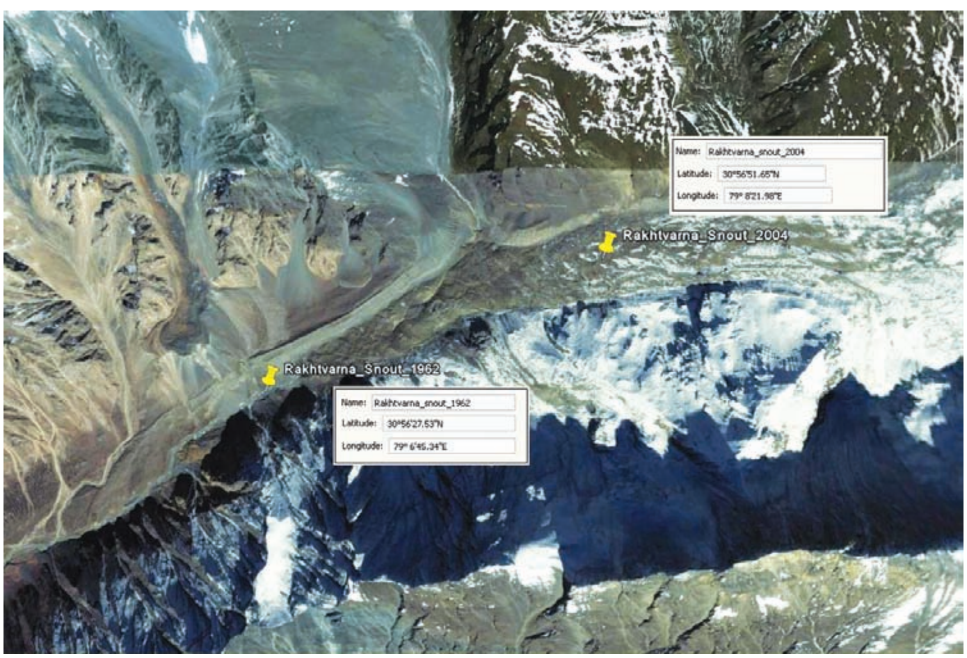


Plate-1.1.
Geographic position of Raktvarna (above) glacier snouts in 1962 and 2004.

(Source of Coordinates[10]: image from Google Earth).

Plate-1.2.
Geographic position of Thelu glacier snouts in 1962 and 2004

(Source of Coordinates[10]: image from Google Earth).

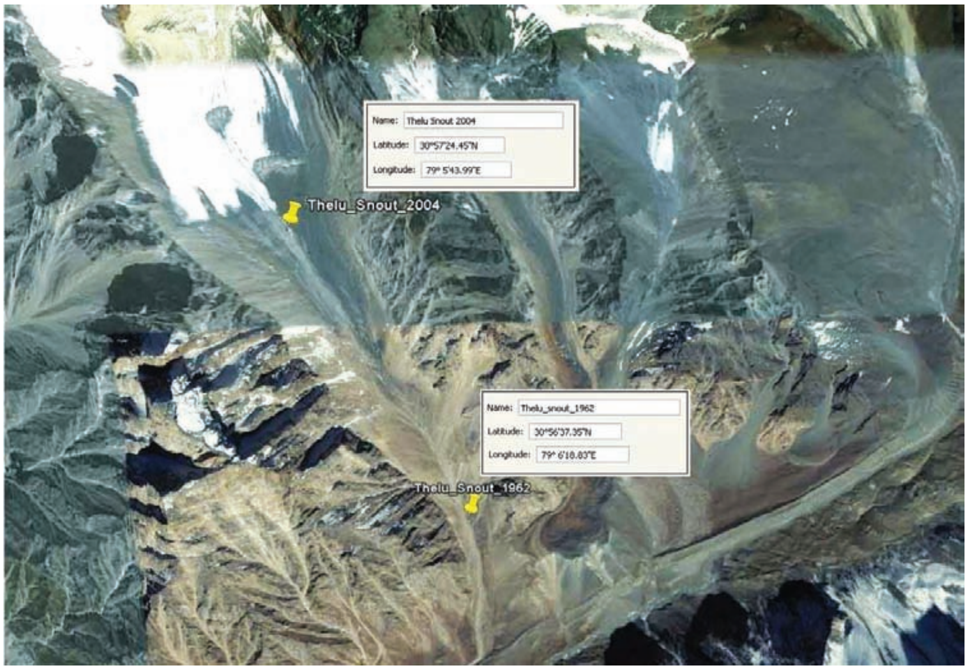


Plate-1.3.
Geographic position of snout of the Gangotri Glacier in 1935, 1971 and 2004

(Source of Coordinates[13]: image from Google Earth).

The snow cover is depleting at different rate in different regions. In Colombia, "Since the end of the Small Ice Age (1850), the glacier regions of Colombia lost 80 per cent of their area, considering current climate change trends in Colombia, an analysis of this process suggests that the glaciers will disappear completely within the next century, as has already happened to other glaciers in the country"[11]. According to Fagre[12], "Small alpine glaciers are rapidly disappearing in the Glacier MBR (Rocky Mountain USA). Historic data on recession have been produced that show over 72 per cent of the largest glaciers have disappeared over the past century. Geospatial modeling techniques were applied that suggest that all glaciers will disappear by 2030".

1.3.3. Changes in Snow Period

Although studies are not yet available from the Uttarakhand region that due to global warming the snow period is changing but a study[14] from Changbaishan Natural Reserve in the neighboring country China reports, "During the early 1970s, we observed that the snow period usually began in mid-September, ending in July of the following year. However, we now observe the snow period beginning in October and ending earlier; the period when snow is seen on the mountain summit has also diminished. Twenty years ago there were perennial scattered snow patches in the valleys throughout the year above 2300 m elevation. Today no snow patches are found during the hot summer months." The situation may be similar in the Uttarakhand region but the documents or reports of such changes are not available.

1.3.4. Transformation of Glacial Fed Rivers

The mighty glacial fed rivers of Uttarakhand are gradually leading towards non-glacial fed rivers due to reduction in snow cover area and recession of glaciers. One of the major glacial fed rivers of the State, viz., the Saryu has been completely transformed into non-glacial river (Plate-1.4). Glacial fed rivers like the eastern. Ramganga and Pindar are on the top of the

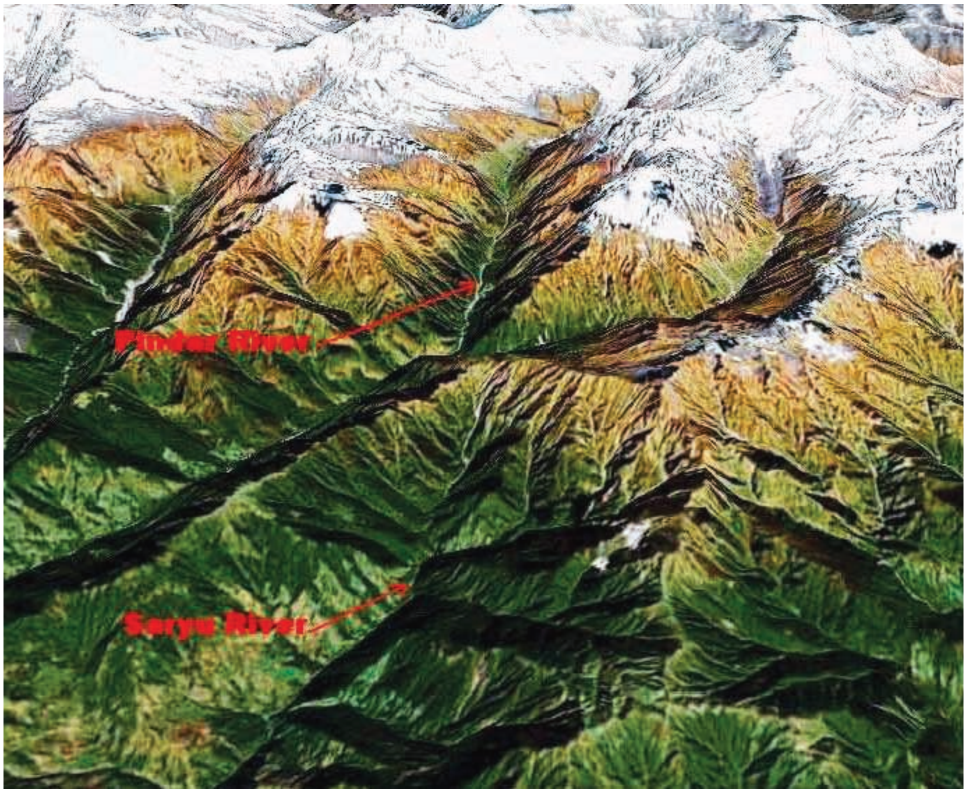


Plate-1.4.
Origin of Saryu River, a non-glacial fed river

(image from Google Earth).

queue in the process of transformation of glacial fed to non-glacial fed rivers as the snow cover area in these watersheds remains only in 1.3% and 8.6%, respectively.

1.3.5. Development of Pro-Glacial Lakes

Signatures of development of pro-glacial lakes (Fig. 1.10 and 1.11) have started coming up in the region which is another sharp evidence of impact of global warming in the region. Apart from these two tiny pro-glacial lakes another important example of pro-glacial lake is the Gorikund located in the neighboring region Tibet (Plate-1.5). A brief account of these pro-glacial lakes is given below.

Example 1: Pro-Glacial Unnamed Lake in Dhauli Ganga Valley -North of the village Niti (in Dhauli Ganga Valley) in district Pithoragarh, a pro-glacial lake (30^{0}54'4"N Latitude and 79^{0} 45'21" E Longitude) at the height of 4720m from m.s.l. has been developed at the mouth of the terminal moraine of the Kamet Glacier (Fig. 1.10A). Due to warming, the size of this lake is gradually increasing. In October 1990 the aerial extent of this lake was about 0.0864 km^2 which was found 1.1751 km^2 after 9 years, i.e., in October 1999 (Fig. 1.10B). During this period (1990-1999) the aerial extent of this lake has been increased about 0.09 km^2 at the rate of 0.01 km^2/year.

Example 2: Pro-Glacial Unnamed Lake in the Bhagirathi Watershed -In the Bhagirathi watershed (31^{0}16'12"N Latitude and 78^{0}56'22"E Longitude) at an elevation of 4700m, a small new lake has been developed due to global warming which can be seen in 1999 image (Fig. 1.11B). The image (Fig. 1.11A) depicts that there was no lake at that place in 1990. In October 1999 the aerial extent of this lake was about 0.0254 km^2 which was found 0.031 km^2 after 11 years, i.e., in October 2010 (Fig. 1.11C). During this period (1999-2010) the aerial extent of the lake has increased about 0.0056 km^2.

Example-3: Melting of the Gorikund - "Situated on the eastern side of the Kailash peak is Gauri Kund (Plate-1.5, left),…..a small beautiful, oval-shaped lake about ¾ mile long and

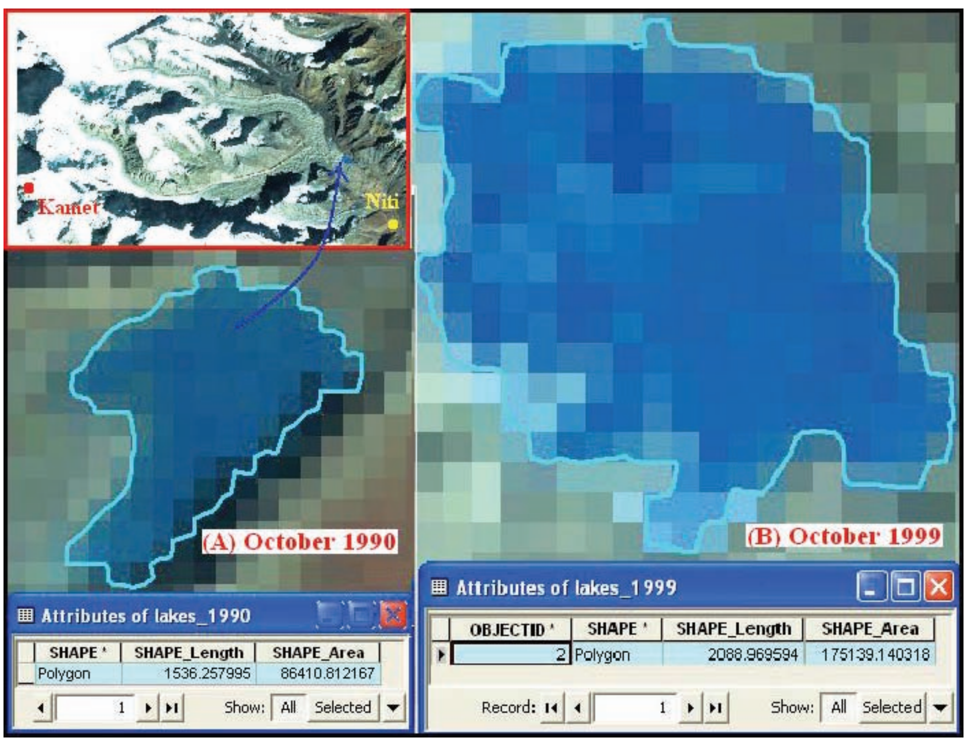


Fig-1.10.
A pro-glacial lake developed by global warming at north of village Niti at the Kamet terminal moraine (*based on Oct.1990 TM and Oct.1999 ETM data*).

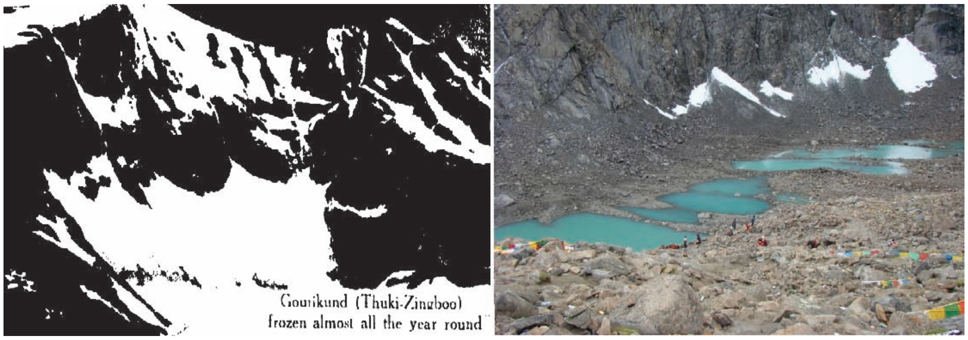


Plate-1.5.
Gorikund -*Photo by Swami Purnanand 1946* (left); and Gorikund as witnessed in August 2010, *Photo by Prof. N.C. Dhoundiyal* (right).

½ mile broad covered with sheets of ice almost all the year round...... Pilgrims usually take bath in this lake, for doing so they often have to break ice on its surface; sometime the ice is so thick that they desperately hurl number of stones on it and yet cannot reach the water. No Tibetan has ever seen or heard this lake to have been completely free from ice" ….. "But in 1946, 47 and 48 it completely melted away[15]. The present picture (Plate-1.5, right) of the glacial lake Gorikund depicts that the Gori Kund has been completely melted due to warming in the region.

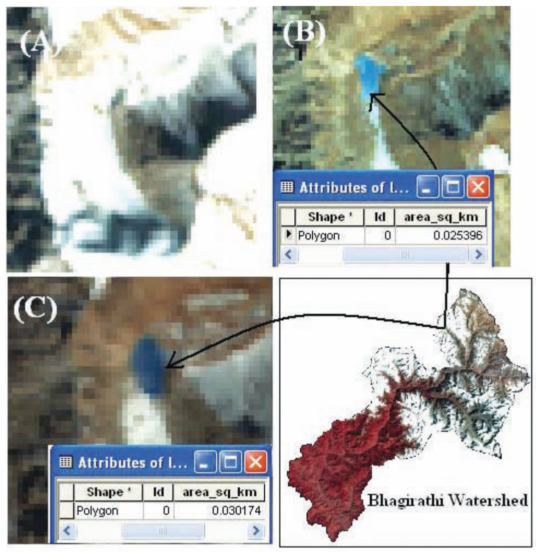


Fig-1.11.
A pro-glacial lake developed by global warming in the Bhagirathi watershed: (A) 1990 there was no lake, (B) in 1999 a tiny lake developed and (C) its size increased in 2010.

1.4. Biodiversity

The general effect of projected human –induced climate change is that the habitat of many species will move pole ward from their current locations. Disturbances can increase the rate of species loss and create opportunities for establishment of new species. The abrupt changes in climatic conditions in the mountainous part of the Himalaya are directly or indirectly affecting the vegetation development and regeneration of important species. Singh *et al.*[16] studied the impact of climate change in the Himalayan region and reported that the Himalaya is warming more than the global average rate. Alpine ecosystems are particularly vulnerable to warming, as species occurring near the mountain tops will have no space for their upward march. The regeneration of many species is dependent on the monsoon rainfall especially the dominant sal, banj oak and telonj oak. The variation in such condition may adversely affect the regeneration and growth of these species. Long term data base is required on species composition, life cycle pattern of important species, monitoring of regeneration and species adaptation to climate change. This section attempts to understand the impact of climate change in shifting of few vegetation species, in particular, such as ***Phoenix humilis,Euphorbia royleana*** and ***lichens,*** and shifting of the vegetation line, in general in Uttarakhand.

1.4.1. Upward Shifting of Vegetation Species

Upward Shift of xerophytic Plant Royleana - The xerophytic plant *Euphorbia royleana* is gradually invading upward specifically in the tectonic valleys, for example, the Kakarighat valley in district Nainital (Plate-1.6). The upward growth of this plant is an indication of increasing aridity due to gradual temperature rise.

Plate-1.6. Development of xerophytic plant *Royleana* in the Kakarighat valley in district Nainital

(photo taken on 8th March 2011 by Naresh Pant).

Plate-1.7. Palm trees developing their colony in the southern part of the Almora Town in the Kosi Valley

(image based on Google Earth, inset photo by Naresh Pant taken on 1st March 2010)

Plate-1.8. Development of palm tree colonies near Kakarighat in district Nainital (*photo taken by Naresh Pant on 8th March 2010*)

Plate-1.9. *Oroxylum indicum* (L.) Vent. with its capsules

Upward Shift of Palm Tree Colonies -The Palm tree *(Phoenix humilis)* a native flora is gradually invading towards higher altitude and has started developing colonies specifically on steep fault scarps constituted of highly deformed rocks having very thin and biologically poor soils. Such growing palm colonies are particularly discernible in the southern part of the Almora Town along a fault (Plate-1.7) and in Kakarighat valley near the South Almora Fault in district Nainital (Plate-1.8). Upward invasion of such colonies of palm trees is a sharp signature of aridity and beginning of the process of desertification in the region being accelerated by the climate change.

Upward Shift of Oroxylum indicum - Recent survey conducted by Joshi Pande[17] reveals that *Oroxylum indicum* (L.) Vent. a meditational plant (Plate-1.9), is gradually shifting towards higher altitude due to warming. As per studies of Atkension[18], Hooker[19], Duthie[20] and Osmaston[21], *O. indicum* (L.) Vent. grows in Kumaun region up to the height of about 914 m. Study conducted during 2010-2011 by Joshi Pandey reveals that a number of plants of *O.indicum* are growing above 914 m at many places in Kumaun and noticed its maximum altitude up to 1301 m at Sirauli and Kaseree (Gangolihat) in Kumaun Himalaya. A comparison of altitudinal range with that of Atkinson, Hooker, Duthie and Osmaston shows upward movement in order to approximately 387 m of *O. indicum* in Kumaun Himalaya within the last 83 years. This might be due to the climatic change in the Uttarakhand hills.

Upward Shift of lichens – Lichens are also gradually shifting towards higher elevation due to warming. In the Chopta-Tunganath landscape, which comes under Kedarnath wildlife sanctuary protected area, Upreti and Negi[22] found distribution of 92 lichen species in between 2500 to 3500 m about two and half decade back, i.e., in 1988. Recent study in the same area conducted in 2009 by Kumar[23] has reported that lichens diversity has increased because apart from already existing 92 lichens, 14 new species of lichens of lower altitude have come up in the Chota-Tungnath landscape area.

1.4.2. Shifting of Vegetation Line

Due to global warming shifting of vegetation line is an universal phenomenon in the alpine zones of the world. Recent study by Yang[1] in the neighboring country China has reported, "The greatest impact of climate warming observed in nature can be seen in the response of vegetation. Many annual observations and interviews with local people show that alpine *ermannii* birch has moved toward the tundra ecosystem over the last twenty years (Table-1.3)."

Table-1.3.
Average height of vegetation line in different watersheds of Uttarakhand[2].

Watershed	Year	Average Height of Vegetation Line
Kuthiyangti	1972	4700m
	1990	5000m
	1999	5160m
	2010	5330m
Gori Ganga	1990	4900m
	1999	5040m
Dhauli Ganga E	1972	4600m
	1990	4880m
	1999	5040m
Ramganga E	1972	4200m
	1990	4580m
	1999	4670m
	2010	4840m
Pindar	1972	4200m
	1990	4500m
	1999	4700m
Dhauli Ganga W	1990	4980m
	1999	5190m
Alaknanda	1972	4600m
	1990	4980m
	1999	5200m
Mandakini	1972	4400m
	1990	4780m
	1999	4980m
Bhagirathi	1972	4620m
	1990	5000m
	2010	5350m
Yamuna	1972	3940m
	1990	4200m
	2010	4500m

To examine above fact, the glacial fed river watersheds of the Uttarakhand state were studied using MSS October 1972, LANDSAT TM 15th and 21st October 1990, LANDSAT ETM+ 15th and 21st October 1999 and LANDSAT ETM+ 15th and 21st October 2010 satellite data. Vegetation lines uncovered by snow of different watersheds in different years were determined. The Average height of vegetation line was determined using Cartosat 1 data (Table-1.3) and then the amount and rate of shift of vegetation line in different watersheds were worked out (Table-1.4). A brief account of the status of vegetation line in the watershed is presented.

Table-1.4.
Amount and rate of vegetation line shift during different periods in different watersheds of Uttarakhand State[2].

Watershed	Years	Duration in Years	Shift of vegetation line	
			Amount	Rate in m/yr
Kuthiyangti	1972-1990	18	300m	16.69
	1990-1999	9	160m	17.78
	1999-2010	11	170m	15.45
	1972-2010	38	630m	16.58
Gori Ganga	1990-1999	9	140m	15.56
Dhauli Ganga E	1972-1990	18	280m	15.56
	1990-1999	9	160m	17.78
	1972-1999	27	440m	16.30
Ramganga E	1972-1990	18	280m	16.67
	1990-1999	9	190m	21.11
	1999-2010	11	170m	15.45
	1972-2010	38	640m	16.84
Pindar	1972-1990	18	300m	16.67
	1990-1999	9	200m	22.22
	1972-1999	27	500m	18.52
Dhauli Ganga W	1990-1999	9	210m	23.33
Alaknanda	1972-1990	18	380m	21.11
	1990-1999	9	220m	24.44
	1972-1999	27	600m	22.22
Mandakini	1972-1990	18	380m	21.11
	1990-1999	9	200m	22.22
	1972-1999	27	580m	21.48
Bhagirathi	1972-1990	18	380m	21.11
	1990-2010	20	350m	17.50
	1972-2010	38	730m	19.21
Yamuna	1972-1990	18	260m	14.74
	1990-2010	20	300m	15.00
	1972-2010	38	560m	14.74

The Kuthiyangti Watershed: Kuthiyangti is a northwest to south east flowing Tributary River of the Kali River system. The NDVI (Fig. 1.12) and Cartosat –1 data reveal that at present the average height of vegetation line in the Kuthiyangti watershed stands at 5330 m which was 5160 m in 1999, 5000 m in 1990 and 4700 m in 1972 (Table-1.3).These data suggest that the vegetation line in the watershed has been shifted about 630 m towards higher elevation within the last 38 years, i.e., between 1972 to 2010 (Fig. 1.13) at an average rate of 16.58 m/year (Table-1.4). During 1972-1990, 1990-1999 and 1999-2010 the rate of vegetation line shift in this watershed was at 16.69 m/year, 17.78 m/year and 15.45 m/year, respectively.

The Dhauli Ganga E Watershed: For Dhauli Ganga E, a tributary system of the Kali, three years data are available to examine the vegetation line shift. The results of these data reveal that the average height of vegetation line in the Dhauliganga E watershed was at 5040 m in 1972, 4880 m in 1999 and 4600 m in 1990 (Table-1.3). These data indicate that the vegetation line uncovered by snow in the watershed has been shifted about 440 m towards higher elevation within the last 27 years (i.e. from 1972 to 1999) at an average rate of 16.30 m/year (Table-1.4). During 1972-1990 and 1990-1999, the rate of vegetation line shift in this watershed was found at 15.56 m/year and 17.78 m/year, respectively.

The Gori Ganga Watershed: For the Gori Ganga, a north to south flowing tributary of the Kali River, only two years data are available which reveal that the average height of vegetation

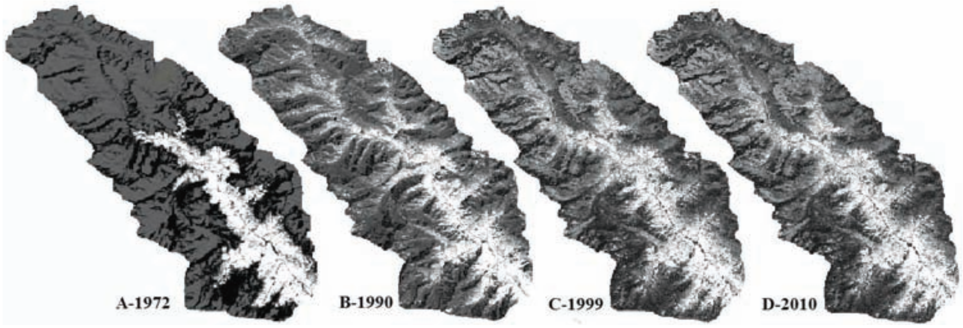


Fig-1.12.
NDVI in different years in the Kuthiyangti Watershed (*based on MSS, LANDSAT TM and ETM+ data of October 1972,15th October 1990, 15th October 1999 and 15th October 2010*).

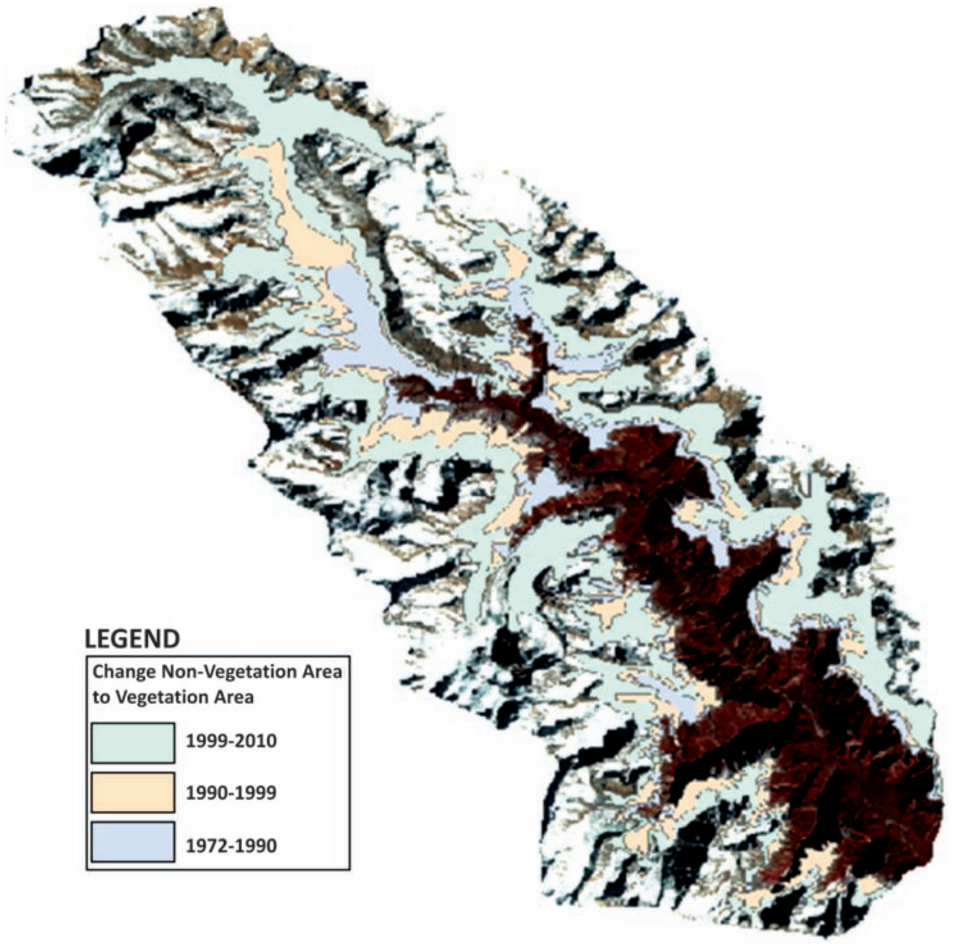


Fig-1.13.
Change from non-vegetative area to vegetative area in different periods in the Kuthiyangti watershed.

line in this watershed was 4900 m in 1990 which was shifted up to 5040 m till 1999 indicating a shift of about 140 m within the last 9 years at the rate of 15.56m/year (Table-1.4).

The E Ramganga Watershed: The Eastern Ramganga is a north to south flowing tributary of the Kali River system. At present the average height of vegetation line in the Ramganga stands at 4840 m which was at 4670 m in 1999, 4580 m in 1990 and 4200 m in 1972 (Table-1.3). Thus, the vegetation line in the watershed has shifted about 640 m towards higher elevation within the last 38 years (i.e. between 1972 to 2010) at an average rate of 16.84 m/year (Table-1.4). During 1972-1990, 1990-1999 and 1999-2010 the rate of

vegetation line shift in this watershed was at 16.67 m/year, 21.11 m/year and 15.45 m/year, respectively.

The Pindar Watershed: In the Pindar watershed, a east-west flowing tributary of the Ganga river, the average height of vegetation line was found at 4200 m in 1972, 4500 m in 1990 and, 4700 m in 1999 (Table-1.3). These data indicate that the vegetation line in the watershed has been shifted about 500 m towards higher elevation within the last 27 years (i.e. from 1972 to 1999) at an average rate of 18.52 m/year (Table-1.4). During 1972-1990 and 1990-1999, the rate of vegetation line shift in this watershed was found at 16.67 m/year and 22.22 m/year, respectively.

The Dhauli Ganga (W) Watershed: In the Dhauli Ganga West, a tributary of the Ganga River, the average height of vegetation line was 4980 m in 1990 which shifted up to 5190 m till 1999 indicating a shift of about 210 m within the last 9 years at the rate of 23.33 m/year (Table-1.4).

The Alaknanda Watershed: In the Alakhnanda watershed, a tributary of the Ganga river, the average height of vegetation line was at 4600 m in 1972, 4980 m in 1990 and 5200 m in 1999 (Table-1.3). These data indicate that the vegetation line in the watershed has shifted about 600 m towards higher elevation within the last 27 years (i.e. from 1972 to 1999) at an average rate of 22.22 m/year (Table-1.4). During 1972-1990 and 1990-1999, the rate of vegetation line shift in this watershed was found at 16.67 m/year and 22.22 m/year, respectively.

The Mandakini Watershed: In the Mandakini watershed the average height of vegetation line was at 4400 m in 1972, 4780 m in 1990 and, 4980 m in 1999 (Table-1.3). In this watershed, the vegetation line has been shifted to 580 m towards higher elevation within the last 27 years (i.e. between 1972 to 1999) at an average rate of 21.48 m/year (Table-1.4). During 1972-1990 and 1990-1999, the rate of vegetation line shift in this watershed was found at 21.11m/year and 22.22 m/year, respectively.

The Bhagirathi Watershed: In the Bhagirathi watershed, at present the average height of vegetation line stands at 5350 m which was at 5000 m in 1990 and at 4620 m in 1972 (Table-1.3). These data indicate that the vegetation line in the watershed has shifted to about 720 m towards higher elevation within the last 38 years (i.e. between 1972 to 2010) at an average rate of 19.21 m/year (Table-1.4). During 1972-1990 and 1990-2010, the rate of vegetation line shift in this watershed was found at 21.11 m/year and 17.50 m/year, respectively.

The Yamuna Watershed: In the Yamuna (including Tons) watershed at present the average height of vegetation line stands at 5000 m which was at 4200 m in 1990 and at 3940 m in 1972 (Table-1.3).These data suggest that the vegetation line in the watershed has been shifted to about 560 m towards higher elevation within the last 38 years (i.e. between 1972 to 2010) at an average rate of 14.74 m/year (Table-1.4). During 1972-1990 and 1990-2010, the rate of vegetation line shift in this watershed was found at 14.74m/year and 15.0 m/year, respectively.

Status in Uttarakhand: The NDVI (Fig. 1.14) and Cartosat 1 based data reveal that in October 1990, the average height of the vegetation line in Uttarakhand was about 4770 m (Fig.1.15) which ranged between 4200 m in the Yamuna watershed to 5000 m in the Bhagirathi watershed. In October 1999, the average height of vegetation line was found at 4970 m (Fig. 1.15). These data suggest that the vegetation line has shifted on an average of 200 m

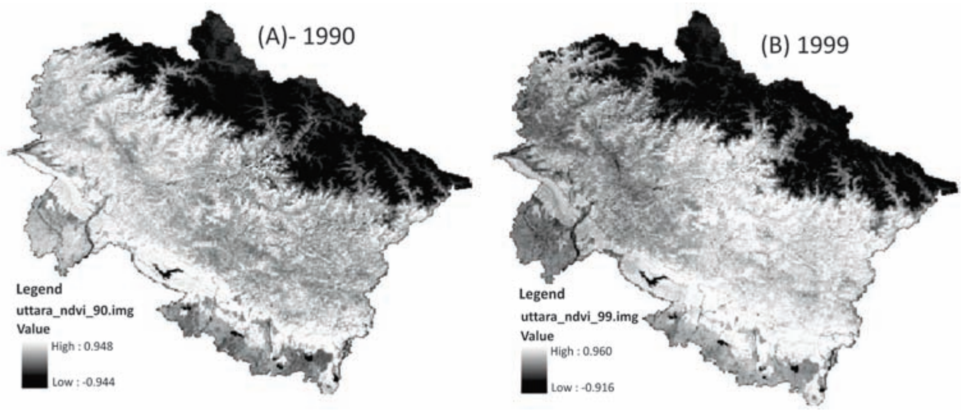


Fig-1.14.
NDVI in different years in Uttarakhand (*based on TM and ETM+ data of 15th October 1990 and 15th October 1999*).

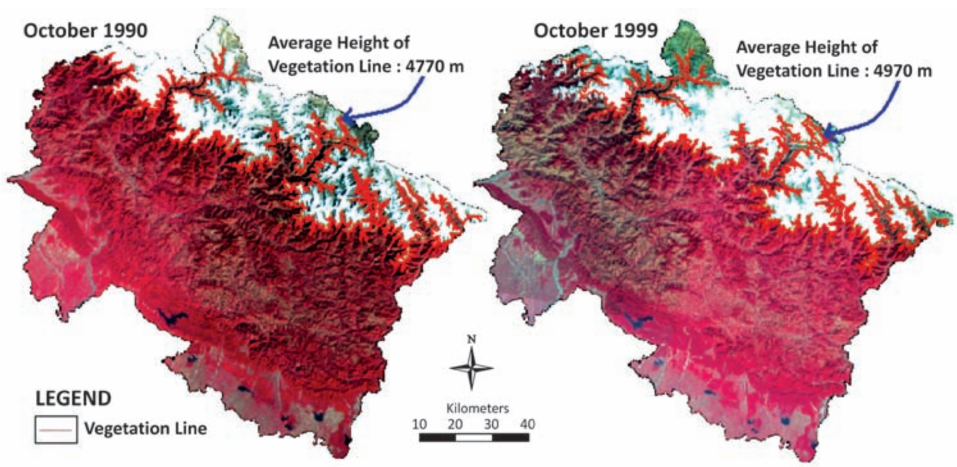


Fig-1.15.
Geographic Location of Vegetation line in Uttarakhand (*based on 15th and 21st October 1990 LANDSAT TM data and 15th and 21st October 1999 LANDSAT ETM+ data*[2]).

towards higher elevation within one decade (i.e. between 1990 to 1999) at an average rate of 22.22 m/year which varied between 15.56 m/yr in Gori Ganga to 24.44 m/yr in Alaknanda watershed (Table-1.4).

1.4.3. Phonological Changes

Variation in rainfall and temperature may lead to variations in phonological events of many species particularly the dominant oaks. The phonological changes in plant species have given clear signal that climate of the region is changing rapidly. Some of the incidences of phonological changes in plants are early ripping of kafal fruit with change in their taste and early flowering in *Rhododendron* trees[24]. The phonological changes in tree and shrubs are also reported[25,26,27,28]. These base line data would be helpful to predict the vegetation – climate change response and adaptation of species in such conditions. The phonological calendar should be developed especially for the evergreen species like oaks, *Rhododendron* and some important shrubs. Very few studies have been made on these aspects. Therefore, vegetation- climate change response should be investigated for the conservation and management of many important species of this region.

1.5. Streams and Rivers

Uttarakhand which lies on the highest water tower of the earth, viz., the Himalaya, is one of the most vulnerable regions of the world with respect to climate change genetic water stress. Evidences of shrinking of snow cover area, reduction in groundwater recharge, drying up of perennial streams and dwindling of summer flows in rivers have demonstrated that climate change, and anthropogenic and technogenic activities[29] have alarmingly perturbed the hydrological cycle in Uttarakhand. Perturbation in hydrological cycle may result in adverse impact in near future on water availability for out-of-stream and in-stream uses in Uttarakhand. Out-of-stream uses include domestic, municipal, irrigation and industrial withdrawals. Water availability for withdrawal is a function of surface runoff and groundwater flow and aquifer storage. In near future, the goal of improved safe access to drinking water will be harder to achieve in non-glacial fed as well as glacial fed river watersheds in Uttarakhand because groundwater runoff has given clear signals of fast depletion as a result of anthropogenically accelerated climate change. People living in glacial fed river watersheds of Pindar, Alaknanda, Dhauli (W), Bhagirathi, Bhilangana, Yamuna and Kali which are experiencing decreasing snow storage in winter may be negatively affected by decreased river flows in the summer and winter seasons. In-stream uses of water include hydropower, navigation, fisheries and recreation. All these in-stream uses of water shall be adversely affected by global warming. The electricity production potential of hydropower plants will decrease considerably. Indications of this fact have started to come. Low summer flow conditions will restrict the recreation use of rivers such as rafting etc and shall adversely affect electricity production, and high flash floods may effect fishery production. If decreasing trend of precipitation continues, domestic and irrigation water demands, which dominate water use in throughout the region, would increase, and it may become very difficult to satisfy all demands.

1.5.1. Glacial Fed Streams and Rivers

Diminishing Regulatory Effect of Glaciers -There is a repeated common complaint of the local people that despite of melting of glaciers due to global warming why the discharge of the snow fed rivers is decreasing year by year? This is happening because of three reasons. Firstly, there has been significant reduction in the snow cover in the catchment areas of snow fed rivers since the last 3 to 4 decades and numbers of unnamed tiny glaciers have been completely disappeared which used to contribute water to the main rivers. Secondly, due to the decreasing length of time that snow remains on the mountain. Thirdly, in the glacial fed river system network, there are thousands of tributary streams which are groundwater fed and the groundwater storage has been drastically reduced due to change in rainfall behavior. Due to cumulative effect of these three factors, the flow of water into the major glacial fed rivers during the dry session has declined. Yang[1] through his study from Changbaishan Biosphere Reserve (China) has also reported that due to decreasing length of time that snow remains on the mountain, the flow of water into the river during the dry season has declined. Reduction in summer water discharge in glacial fed rivers is a warning for the production of hydroelectricity projects and also for irrigation facility for crops in hills as well as plains.

1.5.2. Non-Glacial Streams and Rivers

Reduction in Groundwater Recharge: The groundwater storage is a renewable resource which is recharged annually by the hydrological cycle through precipitation. Since the last three four decades drastic changes in the behavior of rainfall are noticed. The most important change is very rare or absence of snowfall events in the Lesser Himalayan region and complete absence of the popular geographic phenomenon, viz., *Satzhar*, i.e., low intensity rain of continuous seven days in mid of July when the *Herela* festival is celebrated. These two geographic phenomenons were responsible for sufficient recharge of the perched and deep groundwater storages in hills. Now in place of these two geographic phenomenon, the entire region is characterized by high intensity rain events and the frequent events of cloud burst followed by very high surface runoff resulting in drastic reduction in groundwater recharge.

Two hydrologic studies conducted under natural conditions in the Sall Raulela Pine Reserved Forest watershed (Fig. 1.16) and in the Dharpani Dhar spring sanctuary in Bhatkot Reserved Forest (Fig. 1.17) in the Central part of the Uttarakhand postulate the fact that due to change in rainfall behavior, groundwater recharge has been drastically reduced since the last three to four decades. A brief account of these case studies is presented below.

Case Study from the Salla Rautela Pine Watershed -The Salla Rautela (29^0 35'19.37"N-29^0 35'44.08"N Latitudes and 79^0 33'3.25"E- 79^0 35'20.66"E Longitudes), a non-glacial fed pine forest watershed in Syahi Devi Reserve Forest in Kumaun Lesser Himalaya (Fig. 1.16) was employed as a natural laboratory in 1992 to keep an eye on its hydrologic response to rain input[30]. Attempts were made to maintain monitoring of these parameters till date[31,32,33]. Water is tapped for drinking purpose from this watershed from two sites at the average rate of 0.07 l/sec, and 0.035 l/sec since 1970 and 1994, respectively. The site-I is a spring located at the height of 1840 m on northwestern middle part of the watershed and site-II is the stream itself at the height of 1800 m within the watershed. Table 1.5 contains the average discharge pattern and extreme conditions of water flow of the Salla Rautela stream. The extreme minimum water discharge records reveal that this stream was perennial in nature in 1992 when its minimum annual discharge rate was 0.038 l/sec. This minimum annual flow dropped down to 0.009 l/sec in 1999 and then since June 2000 this stream was transformed first time in its history to non-perennial stream (Fig.

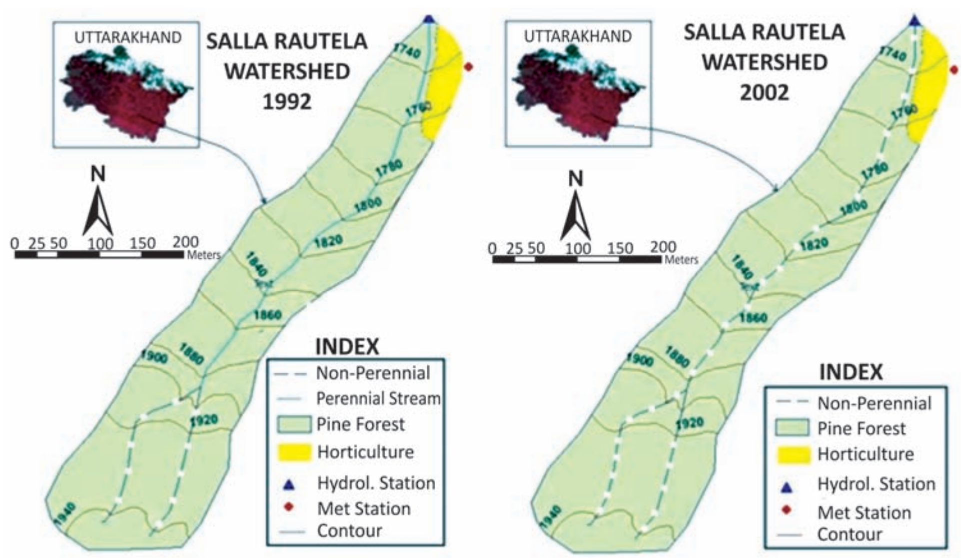


Fig-1.16.
The Salla Rautela watershed in the Syahi Devi Reserved Forest, district Almora drained by a perennial stream in 1992 (left). Since June 2000 this Salla Rautela stream has been transformed into non-perennial stream[2].

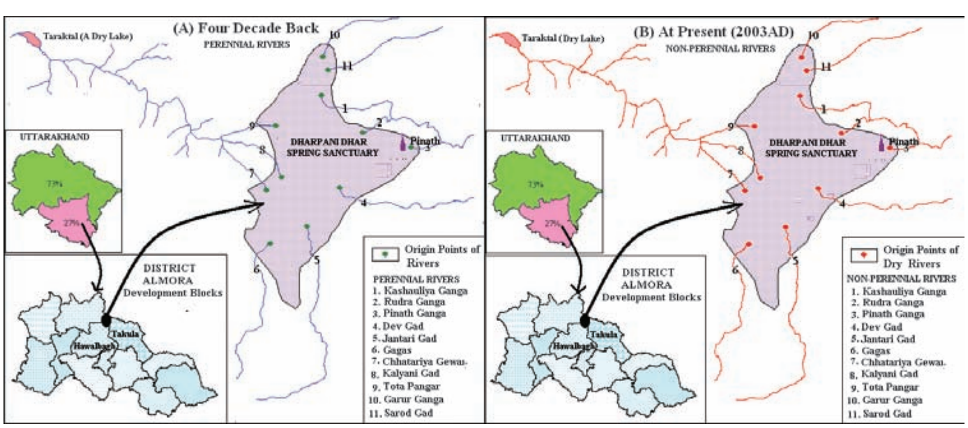


Fig-1.17.
The distribution of perennial streams in the Dharpani Dhar Reserve Forest about 4 decade back (A) based on Survey of India Topographic Map; and the present (2003AD) condition of these streams (B), i.e., all streams have been transformed into non-perennial streams due to depletion of groundwater storage in the Dharpani Dhar aquifer[34].

1.16, right) when it was completely dried up for 64 days during summer season of that year. Since then the extreme minimum discharge of this stream was always found zero (Table-1.5). This is the sharp indicator that the groundwater level of the aquifer from which this stream originates, now goes below the origin point of this stream during summer due to low recharge of rainwater into the aquifer. The another important noticeable fact is increasing number of dry days of this stream which has reached up to 187 days, i.e., more than 6 months period in 2010 (Table 1.5 column 4). This is a hydrologic signal that ground water storage has gone drastically down in the watershed.

Table-1.5: Characteristics of water discharge flow of the Salla Rautela Stream[2]

Year	Average Discharge (l/sec)	Ex. Max. Discharge (l/sec)	Ex. Min. Discharge (l/sec)	No of zero discharge days
1992	0.601	13.49	0.038	0
1993	5.481	361.51	0.022	0
1994	0.625	9.251	0.020	0
1995	0.310	7.35	0.018	0
1996	0.181	7.78	0.015	0
1997	1.420	25.89	0.012	0
1998	1.552	24.67	0.011	0
1999	0.340	10.12	0.009	0
2000	1.223	47.59	0.000	64
2001	0.316	22.29	0.000	79
2002	0.359	33.13	0.000	99
2003	0.228	27.93	0.000	88
2004	1.590	62.25	0.000	71
2005	3.817	119.4	0.000	140
2006	1.190	60.4	0.000	143
2007	1.350	155.2	0.000	120
2008	0.510	62.5	0.000	135
2009	0.321	8.21	0.000	175
2010	8.596	910.11	0.000	187

Case Study From Dharpani Dhar Spring Sanctuary - The Dharpani Dhar Spring Sanctuary (29°48'56"N to 29°53'33"N Latitudes and 79°30'4"E to 79o30'13"E Longitudes; area 17.23 km^2), is located in the Bhatkot Reserved Forest, predominantly of pine trees in district Almora (Fig. 1.17). The groundwater storage (aquifer) of this hill gives birth to eleven perennial tributary streams (Fig. 1.17A) of three major rivers of Uttarakhand, i.e., Kosi, Gomati and Western Ramganga. The names of streams which originate from this spring sanctuary are - Kaushalya Ganga (or Kosi River), Rudra Ganga, Pinath Ganga, Dev Gad, Janatari Gad, Gagas River, Kalanyani Gad, Totapangar and Garur Ganga (or Gomati River). These rivers originate at 2000 m to 2240 m altitudes from the Dharpani Dhar Hill. The recent hydrometric survey shows that all these eleven perennial streams become dry during summer season due to depletion of groundwater in their aquifer (Fig. 1.17B). This study demonstrates that drying of perennial streams in forest system during summer is a sharp indicator that groundwater recharge has been reduced due to changes in amount and behavior of rainfall. The situation is similar in other forest systems of the region.

1.5.3. Transformation of Perennial Streams

Hydrologic studies of the Salla Rautela reserve forest watershed (Fig. 1.16) and the Dharpani Dhar reserved forest spring sanctuary (Fig. 1.17) demonstrate that due to reduction in groundwater recharge the perennial streams are being transformed from their perennial nature to the non-perennial nature. Thus, the perennial streams are being rapidly transformed into intermittent nature which are further gradually leading towards their ephemeral stage. This process of transformation of most of the perennial streams to seasonal streams is common phenomenon throughout the non-glacial river catchment areas even under the forest system. Apart from the streams, some of the mighty rivers and lifeline of major towns and villages have also transformed into seasonal rivers. For example the life line of Almora and Ranikhet towns, viz., the Kosi (Fig. 1.18 and 1.19) and the Gagas Rivers have been transformed into non-perennial rivers first time in their history of life since June 2003 and 2005, respectively.

1.5.4. Diminishing Length of Perennial Streams

The process of transformation of perennial streams in to non-perennial streams is resulting in reduction of the total length of perennial stream network. A case study of the Kosi watershed in district Almora (Fig. 1.18A) reveals that about four decade back the total length of perennial streams in the watershed was about 225.6 km and at present their length is only 41.5 km (Fig.1.18B) due to the disappearance of perennial streams from the headwater regions. These data indicate that the perennial streams in the region are drying up at the rate of about 5.43 km/year in the Kosi watershed in district Almora due to anthropogenically accelerated processes of climate change. The process of diminishing length of perennial streams is relatively faster in the watersheds of non-glacial fed river catchments (Fig. 1.19) compared to the glacial fed river catchments because all the perennial streams of this region are groundwater fed.

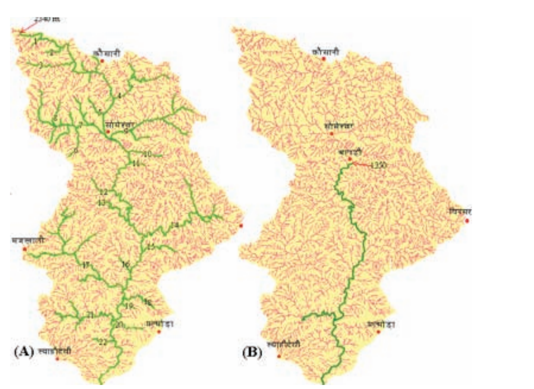


Fig-1.18.
Distribution of perennial streams (in green colour) and non-perennial streams(in red colour) in the Kosi watershed in district Almora; (A) about 40 years back total length of perennial streams was 225.6 km and (B) at present (2003 AD) it is only 41.5 km[35].

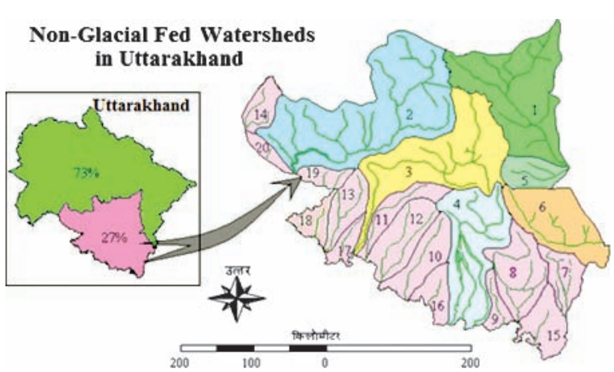


Fig-1.19.
Spatial distribution of non-glacial fed river watersheds in Uttarakhand[35];

1-Saryu, 2-W.Ramganga, 3-Kosi, 4-Gaula, 5-Panar, 6-Ladhiya, 7-Kirola, 8-Nandhor, 9-Dihowa, 10-Bhakar, 11-Dabka, 12-Baur, 13-Dhaila, 14-Kotdwar Stream, 15-Khatima Stream, 16-Rudrapur Stream, 17-Kashipur Stream, 18-Jaspur Stream, 19-Jhirana, 20-Barahapura.

1.5.5. Dwindling Summer Discharges of Rivers

As it is evident from the Salla Rautela and Dharpani Dhar case studies that the perennial streams of reserved forest are being gradually transformed into non-perennial stream in the region. This is resulting not only in reduction in length of perennial streams network but also cumulatively affecting the summer discharges of major rivers. Gradually the major rivers are dwindling in summer season due to disappearance of perennial streams in massive scale in the headwater regions and partially by increasing rate of water extraction from river for different uses. Records of the last 18 years minimum water discharge of the Kosi River (Fig. 1.20) in district Almora postulate that the Kosi river dwindled very fast which was converted into non-perennial river on 22nd June 2009 (Fig. 1.20) about 50 m downstream of the Almora Pump house. Although no long term data of water discharge are yet available with UCCC but the point measurements of the Saryu, Panar, Western Ramganga and Kosi (Fig. 1.21) reveal that the summer flows of these non-glacial fed rivers is dwindling steadily due to anthropogenically accelerated climate change. The minimum summer flow of Saryu and Panar at their confluence, W.Ramganga at Marchula and Kosi at Mohan was 3324 l/sec, 251 l/sec, 2282 l/sec and 175 l/sec, respectively in June 2005. After three years, i.e., in June 2008, the minimum discharge of these rivers was found at 2431 l/sec, 175l /sec, 1928 l/sec and 1170 l/sec, respectively (Fig. 1.21).

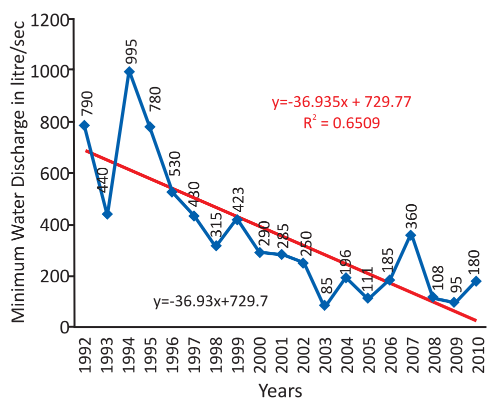
1.5.6. Water Quality

Higher water temperature and variations in runoff due to climate change in geologically weak and ecologically fragile region like Uttarakhand may produce adverse changes in water quality. Lowering of the water levels in rivers and lakes will lead to the re-suspension of bottom sediments and liberating compounds, with negative effects on water supplies. Cloud burst or high intensity rainfall will lead to an increase in suspended solids (turbidity) due to soil erosion, and pollutants will be introduced. Higher surface water temperature will promote algal blooms and increase the bacteria and fungi content. This may lead to a bad odor and taste in chlorinated drinking water and the occurrence of toxins. Moreover, even with enhanced phosphorus removal in wastewater treatment plants, algal growth may increase with warming over the long term. Due to the high cost and the intermittent nature of algal blooms, water utilities will be unable to solve this with the available technology. Increasing nutrients and sediments due to higher runoff, coupled with lower water levels, will negatively affect water quality, possibly rendering a source unusable unless special treatment is introduced. Furthermore, higher water temperatures will enhance the transfer of volatile and semi-volatile compounds, e.g., ammonia, mercury, dioxins, pesticides from surface water bodies to the atmosphere.

Fig-1.20.
Transformation of the lifeline of Almora, viz., the Kosi River in to non-perennial river (left) and its minimum annual water discharge rates near Almora pump house at Kosi[35].

Transformation of Perennial Rivers into Non-Perennial Rivers e.g. the life line of the Almora and its environs. viz. the Kosi River

22 June 2009, Discharge=0 litre/sec



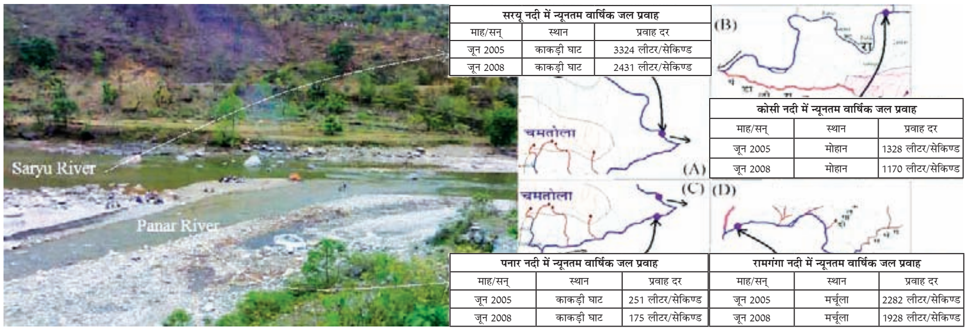


Fig-1.21.
Minimum annual discharge rates of Saryu and Panar at their confluence, W. Ramganga at Marchula and Kisi at Mohan in 2005 and 2008.

In regions like Uttarakhand, where cloud burst and high intensity rainfall is expected to increase, pollutants (pesticides, organic matter, heavy metals etc) will be increasingly washed from soil to water bodies. Researches elsewhere have suggested that increasing water temperature affects the self-purification capacity of rivers by reducing the amount of oxygen that can be dissolved and use for biodegradation[36]; increase nitrogen loads from rivers of up to 50% due to enhanced precipitation[37]; numerous diseases linked to climate variations can be transmitted via water, either by drinking it or by consuming crops irrigated with polluted water. The presence of pathogens in water supplies has been related to extreme rainfall events[38,39]; and in aquifers, a possible relation between virus content and extreme rainfall can be developed[40].

Higher water temperature and variations in runoff due to climate change are likely to produce adverse changes in water quality. Chemistry of water greatly depends upon the temperature. Although specific data is not yet available from Uttarakhand that how much the water quality is being or will be effected by temperature rise but a study of 54 ground water resources (i.e., springs and hand pumps) of district Almora carried out in 2007[41] has demonstrated that the water quality parameters like pH, Dissolve Oxygen (DO), Total Dissolve Solids (TDS) (Fig. 1.22) and cations and anions concentrations have direct relationship with temperature. These base line data shall be useful to define the impact of climate change in water quality parameters (pH, TDS and DO) by re-examining these parameters in future.

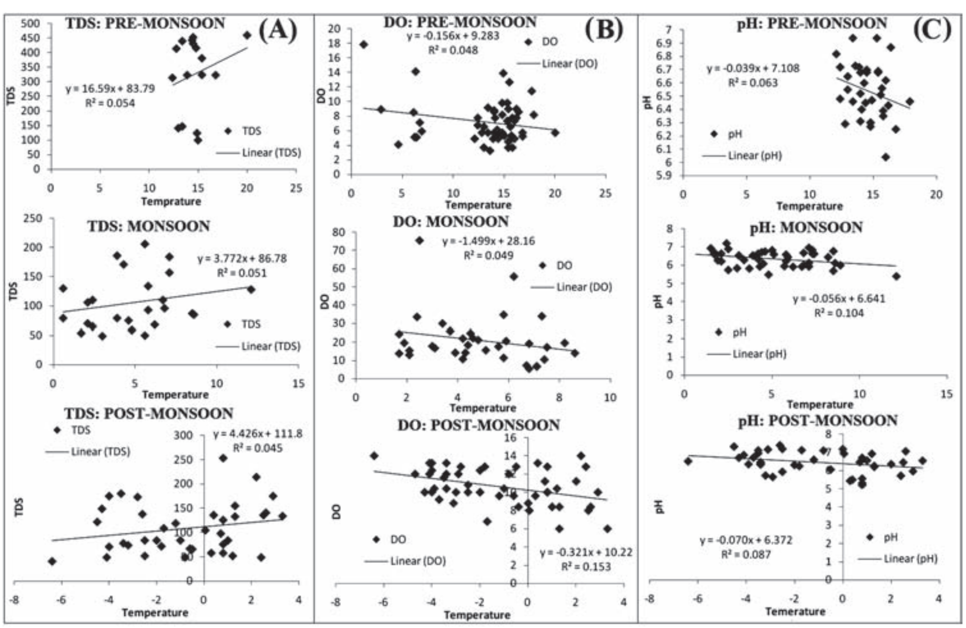


Fig-1.22.
Variation in concentration of TDS (A), DO (B) and pH (C) with temperature, based on the study of 54 groundwater sources, i.e., springs and hand pumps carried out in 2007[41].

1.6. Agriculture

1.6.1. Reduction in Crop Production

Recent study and surveys indicate that production of different crops is being affected by two major reasons related with climate change. First, delay in rainfall onset, and second, drying up of irrigation water sources, i.e., streams and rivers. A brief account of these two reasons is given below.

Delay Onset in Rainfall- According to Bhatt[24] due to changes in rainfall rhythm, delay in onset, rainfall during maturity period of crops and erratic behavior of rainfall have caused significant crop loss and delayed crop leads to yield reduction. Recent study advocates about 19.7% reduction in wheat, 48.5% in soybean, 28.6% in lentil, 45.2% in garden pen and 36.7% in pea production due to late shown caused by delayed onset of rain (Table-1.6). Early ripping of wheat crop (i.e. in March in place of April) due temperature rise is another sharp indicator of climate change.

Table-1.6.
Reduction in crop yield due to delay showing because of delay in rainfall[24].

Crop	Yield/Q/hec		Production in %
	Normal Shown	Late Shown	
Wheat	49.8	40.0	19.7
Soyabeen	13.0	6.7	48.5
Lentil	19.2	13.7	28.6
Garden Pen	25.9	14.2	45.2
Field Pea	31.9	20.0	36.7

Drying up of Irrigation Water Sources- The production of crops from irrigated land is directly related with water available for irrigation. Due to very high intensity rainfall and incidences of cloudburst, a large part of the rain input runs off as overland flow from hills and a little part percolates deep into the rocks to recharge groundwater storage, consequently there is very little or no water flow in most of the hill streams during the summer season. Due to this reason the irrigation guls and canals remain dry due to lack of water. Hence, the irrigated land in hills is being transformed gradually into non-irrigated land by which the production of crops is drastically reducing year by year. Recent survey of paddy production (Table-1.7) from irrigated land conducted in one of the micro-watersheds of district Bageshwar, viz., the Mahogad (Fig. 1.23) reveals that due to lack of water for irrigation in the Mahogad stream during summer season, production of paddy crop has decreased considerably (Fig. 1.24) during the last decade. Table 1.7 suggests that in the Pokhari and Naogoan villages the production of paddy has reduced down to 53% while in villages Silingtoli and Ghirtoli it was found 52% and 41% less in 2010 as compared to 2001.

Table-1.7.
Production of paddy crop in villages of Mahogad Watershed in district Bageshwar[2].

Village	Area in hec	Production in Q/hec										Average Q/hec
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Shilingtoli	7.70	66.12	69.10	65.72	59.80	65.32	51.62	46.48	41.68	40.90	34.93	54.17
Pokhari	6.90	61.72	69.31	62.08	60.55	58.28	46.97	43.24	60.31	39.01	33.00	53.45
Naogaon	12.26	64.32	67.64	64.29	59.53	63.40	50.48	45.04	39.88	39.33	34.52	52.84
Ghirtoli	14.17	59.78	62.85	57.21	50.21	40.22	44.51	29.98	29.95	20.29	24.95	41.99

1.6.2. Shifting of Horticulture Belts

Due to temperature rise, the temperate horticultural belts have started shifting towards higher altitude. Although such changes have yet not documented scientifically from Uttarakhand but in the neighboring state of Himachal Pradesh, it has been recently reported that the apple cultivation belt is shifting towards higher altitude[42].

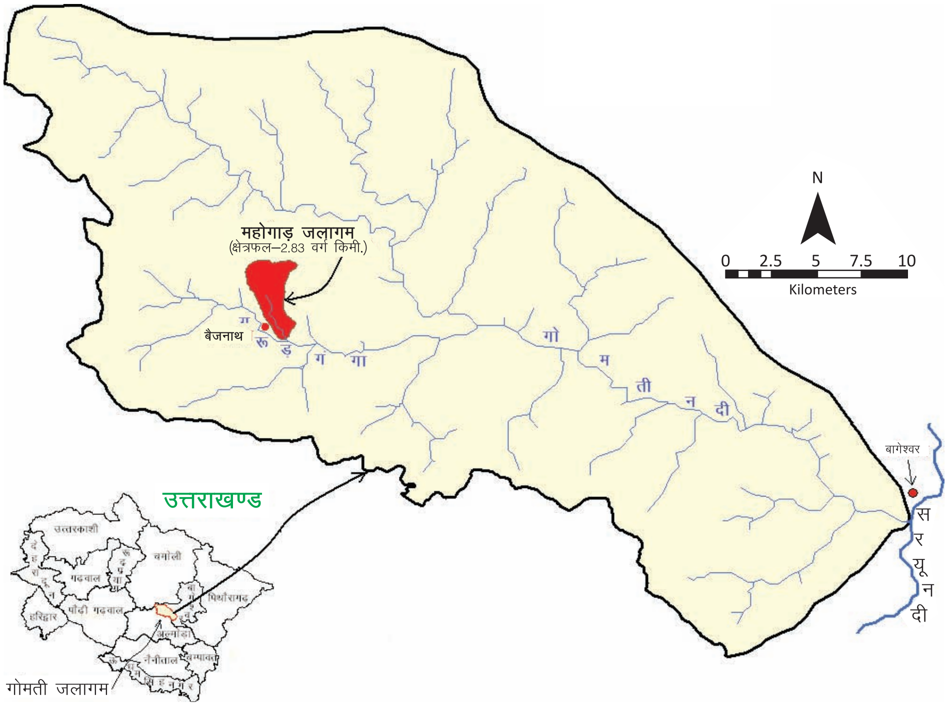


Fig-1.23.
Location map of the Gomti watershed, district Bageshwar

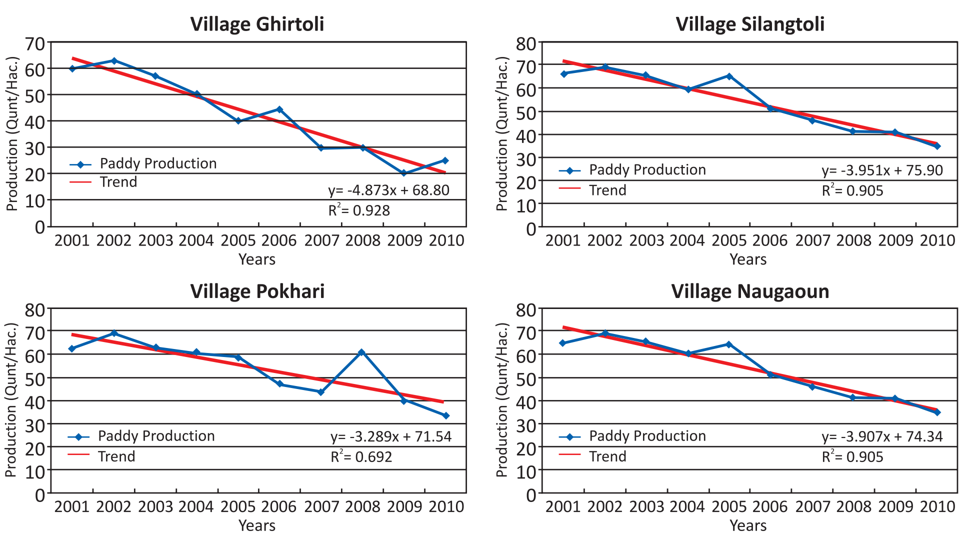


Fig-1.24.
Production and trend of paddy crop in the villages of the Mahogad watershed in district Bageshwar[2].

1.6.3. Reduction in Production of Fruits

Mango which is cultivated in many warm valleys of Uttarakhand such as Bageshwar and Bhikiasain is being threatened due to the impact of climate change. Apple is another important fruit whose production is highly vulnerable for climate change impact.

1.6.4. Impact on Pest Spectrum

Recent study of Bhatt[24] has indicated that climate change has started to impact the pest spectrum in hills. He has observed few incidents of Broun Plant Hopper in mid hills, increasing incidences of white grubs in May and June due to temperature increase, and positive effect of rice-leaf folder in the month of August due to change in rainfall rhythm.

1.7. Tourism

Climate is a major factor for tourists when choosing a destination both for tourists and tourism. Stakeholders are sensitive to fluctuations in the weather and climate. Likely effects of climate change on tourism vary widely according to location, including both direct and indirect efforts. Incase of climate change in temperate and Alpine mountain in Uttarakhand seems to have shifted towards higher altitudes due to many forms of tourism. This might for instance, lead to more domestic tourism in higher altitudinal zones. Due to climate change, if winters turnout to be milder the gains are obvious. Tourism sector dependent on the availability of snow are among those most vulnerable to global warming. In summer, destinations which are already warm could become more uncomfortable. Tropical destinations might not suffer as much as from an increase in temperatures, since tourists might expect warm climate as long as indoor comfort is assured - with implications for greenhouse gas emissions. Extreme climate events, such as tropical events, could have substantial efforts on tourist infrastructure and the economies. Indirect efforts include changes in the availability of water and cost of space cooling, but at least as significant could be changes in landscape of areas of tourist interest, which could be positive or negative. Warmer climates open up the possibility of growing or extending exotic environment which could be considered by some tourists as positive. Draughts and extension of arid environment and the effects of extreme weather events might discourage tourists. One indirect factor of considerable importance is energy prices, which affect both the cost of providing comfort in tourist areas and the cost of travelling to them. The environmental context in which tourism will operate in the future involves considerable uncertainties. Nature based tourism is one of the booming industries in Uttarakhand, specially ski resorts, snow, hill, lake and valley, mountain and snow view resorts, wild life sanctuaries, waterfall picnic spots and ecotourism destinations which are likely vulnerable to climate change[43].

1.8. Health

Uttarakhand has complex climate environment. Climate change impacts show significant increase in respiratory-related diseases and hospitalization. Besides heat stress and respiratory distress from air quality, changes in temperature, precipitation and/or humidity effect environment for water-and vector-borne diseases and create conditions for disease outbreaks. Climate-change related exposures are likely to affect the health status of people particularly to those with low adaptive capacity, through: increase in malnutrition and consequent disorders, with implications for child growth and development; increase in deaths, disease and injury due to heat waves, floods, storms, fires and draughts; the increased burden of diarrheal diseases; in increased frequency of cardio - respiratory diseases due to higher concentrations of ground level ozone related to climate change; and the altered spatial distribution of some of infectious disease vectors. Climate change is expected to have some mixed effects, such as a decrease or increase in range and transmission potential of different diseases. Studies have shown that climate change is projected to bring some benefits, such as fewer deaths from cold exposure. Overall it is expected that these benefits will be outweighed by the negative health efforts of rising temperatures. The balance of positive and negative health impacts will vary from one location to another, and will alter over time as temperatures continue to rise. Critically important will be factors that directly shape the health of populations such as education care, public health initiatives and infrastructure, and economic development.

Climate change is likely to alter social environment resulting in important impact on activities. The climate change may affect environment in three different ways. First, it provides a context for climate-sensitive human activities ranging from agriculture to tourism, For instance, rivers fed by rainfall enable irrigation and transportation and can enrich or damage landscape. Second, climate affect the cost of maintaining climate controlled internal environments for human life and activity; clearly higher temperatures increase costs of cooling and reduce cost of heating. Third, climate interacts with other types of stresses on human systems, in some cases reducing stresses but in other cases exacerbating them. For example, draught or landslides caused by high intensity rain can contribute to rural urban migration, which combine with population growth, increases stress on urban infrastructures and socio-economic environment. In all of these ways, effects can be positive as well as negative; but extreme climate events and other abrupt changes tend to affect social environment more severely than gradual change, because they offer less time for adaptation, although gradual changes may also reach thresholds at which effects are notable[44].

1.9. Electricity

Due to climate change net electricity demand is very likely to change[45]. Demand for air conditioning is highly likely to increase, whereas demand for heating is likely to decrease. Climate change is likely to affect both electricity use and electricity production. Some of the possible impacts of climate change in electricity in the mountainous region like Uttarakhand are rather obvious. Due to global warming less heat will be needed for industrial, commercial and residential buildings, but the cooling demands will increase with changes varying from the Outer to the Greater Himalayan region of the Uttarakhand state, and by season. The main source of cooling is electricity, while coal, oil, gas, biomass and electricity are used for space heating. Regions with substantial requirements for both cooling and heating could find the net annual electricity demand increase while demand for other heating energy sources decline. In addition to demand side impacts, electricity production is also likely to be affected by climate change. Policies for reducing greenhouse gas emission are required to increase the production of electricity[46]. Limited studies on the impacts of climate change on the electricity sector suggest that this sector will be affected by climate change. In particular, South Asia (including India) is expected to account for one fifth of the world's total electricity consumption by the end of 21st century. An increase in the energy consumption of industry, residential and transport sector could be significant as population, urbanization and industrialization rise. It is likely that climate change will influence the pattern of change in electricity consumption that could have significant efforts on CO_2 emission.

1.10. Industry Trade, Retail, Commerce and Human Settlements

The economy of Uttarakhand is diverse along with adverse geographical conditions ranging from the subsistence agriculture, allied activities and small concentration of industries. Other activities include traditional crafts and skills, casual labour, employment in the fruit processing industries, tea gardens and tourism. Corn, wheat, millet, barley, sugarcane, tea, oilseeds, and potatoes are some of the major crops. A wide variety of fruits are grown in the state. Gradually tourism has emerged as a major growth industry in the state ranging from eco-tourism, pilgrimages, adventure sports and mountain climbing are major attractions of the area. The state is gifted with rich ecosystem which is responsible for the tremendous biodiversity of the region. However, the State has undergone major changes in the last century because of global warming and climate change. The conditions range from a critical situation in the Himalayas of Sikkim, Uttarakhand, and Kashmir to a moderately serious situation in Bhutan and the Eastern Himalayas.

The industrial infrastructure in Uttarakhand is mainly concentrated in plains (Haridwar, Dehradun and Udham Singh Nagar). These areas accommodate a large chunk of rural out migrated population who mainly work there as semi-skilled and unskilled laborers. The other commercial activities include fruit production and processing, floriculture, tea-estates, tourism etc. All the commercial operations are vulnerable to climate change as the perishable commodities are most climate sensitive. Extreme climatic events will

adversely affect the productivity and sometimes as a consequence of frequent blockage of transportation routes the whole produce may get destroyed.

Vulnerability of industry, infrastructures and human settlements to climate change are generally greater in certain high risk locations, particularly in hill state like the Uttarakhand having fragile ecosystem, landslides and areas where economics are closely linked with climate-sensitive resources, such as agricultural and forest product industries, water demands and tourism. These vulnerabilities tend to be localized but are often large and growing. Industry includes manufacturing, transport, energy supply, and demand, mining, construction and related informal production activities. Climate change is almost certain to affect human settlements (urban and rural both) large and small, in a variety of significant ways. Settlements are important because they are where most of the population live, often in concentrations that imply vulnerabilities to location specific events and processes and, like industry and certain other sectors of concern, they are distinctive in the presence of physical capital (buildings, infrastructures) that may be slow to change. Case studies of larger settlements indicate that climate change is likely to increase heat stress in summers while reducing cold-weather stresses in winter. It is likely to change precipitation patterns and water availability, to lead to increase risk of extreme weather events, such as severe storms causing massive landslides and flooding.

Extreme weather events associated with climate change pose particular challenges to human settlements, because assets and populations are increasingly located in mountain slopes and other risk prone zones. Settlements within urban areas specifically in the hills are especially vulnerable, as they tend to built on hazardous sites and to be susceptible to landslides and other climate related disasters. Several recent assessments have considered vulnerabilities of rapidly growing and/or large urban areas to climate change.

Possible impact on climate change on inter-regional trade is still rather speculative. Climate change could affect trade by reshaping regional comparative advantage related to general climate-related influences such as on agricultural production. Climate change may also disrupt transport activities that are important to national supplies and travellers as well as international trade. For instance, extreme events may temporarily close transport route and damage infrastructure critical to trade. Increases in the frequency and magnitude of extreme weather events could amplify the cost to transport companies and state authorities from closed roads, train/truck delays and cancellations and other interruptions of activities. It appears that there could be linkage between climate-change scenarios and different scales of trade scenarios, such as a number of regional and sub-regional free trade agreements, although research on this topic is lacking.

Climate change is likely to interact with and possibly exacerbate ongoing environmental change and environmental pressure in settlements. In region like the Uttarakhand, for example, mass wasting (i.e., landslides, rock fall, slumping and creeping) is expected to add to irreparable settlement damage. With growing urbanization and development of modern industries, air quality and hazard has become more salient issues in urban areas. How climate change might interact with these problems is not clear as a general rule, although temperature increases would be expected to aggravate the problems. In sum, settlements are vulnerable to impacts that can be exacerbated by direct climate changes. Retail and other commercial services have been often neglected in climate-change impact studies. Climate change has the potential to affect every link in supply chain, including the efficiency of the distribution network, the health and comfort of the workforce and pattern of consumption. In addition, climate change policies could raise industrial and transportation costs, alter trade patterns, and necessitate change in infrastructure and design technology. As one example, distribution network of commercial activities would be affected in a variety of ways by changing rainy season road conditions and negatively affected by an increase in hazardous weather events. Strong wind can unbalance high sided vehicles on roads and bridges and may delay the passage of goods. Mountain infrastructure and distribution facilities are highly vulnerable for mass-wasting. Further climate variation creates short-term shifts in pattern of consumption within specific retail markets, such as the clothing and footwear market. Perishable commodities are one of the most climate-sensitive retail markets. It is possible that climate change will alter the sources and processing of agricultural produce, and climate change policies, e.g., a carbon tax or an emission offset payment, may further alter the geographical distribution of raw materials and product market[46].

1.11. Policy and Governance

To cope up with the impacts of climate change, there is an urgent need of new policies and some effective changes in our existing policies. Some of the vulnerable areas of policies which need urgent intervention are policy on forestry, water policy and policy on hydro-power. A brief description of these policy areas is given in the following paragraphs[47].

1.11.1. Policy on Forestry

Recently, sixteenth session of Conference of Parties of United Nations Framework Convention on Climate Change (UNFCC) was held at Cancun, Mexico. In this session, immense stress was given for adopting the scheme Reducing Emission from Deforestation and Forest Degradation (REDD+) and Enhancing the Carbon Stock in Developing Countries. Core idea behind underlying REDD+ is to make performance-based payments, that is, to pay forest owners and users to reduce emissions and increase removals. India is a party to REDD+. There is vast scope for attracting REDD+ scheme in Uttarakhand. Under the REDD+, Deforestation means forest area is reduced, Degradation means carbon density is reduced and Regeneration and Rehabilitation means carbon density is increased. The existing policies need urgent intervention in order to evolve a socially just and environmentally sustainable policy for the following sectors of the forestry, which at the same time may be eligible to attract REDD+ incentives in Uttarakhand. The forests can further be distributed in *van panchayats, protected areas, reserved forests and private tree cover* categories for the purposes of formulating policies.

1.11.2. Water Policy

One of the consequences of the climate change is the speedy depletion in water availability. In near future, the State is going to face water scarcity. In order to deal with the situation, intervention is needed in *groundwater policy, surface water policy, drinking water policy and irrigation water policy* sectors.

1.11.3. Policy on Hydropower

In International climate regime incentives under Clean Development Mechanism are provided. In the State, three private sector hydropower projects are receiving incentives and Uttarakhand Renewable Energy Development Agency (UREDA) has been enlisted for Clean Development Mechanism in UNFCC in its 16th session held in Cancun, Mexico. A policy on hydropower is needed to be in tune with the international climate regimes in order to receive incentives of Clean Development Mechanism.

1.12. Towards Mitigation of Climate Change Impacts: The UCCC Efforts

UCCC aims to develop action projects for mitigation of climate change impacts. For this purpose UCCC has employed the Mahogad (Fig. 1.23) - a representative watershed of the Lesser Himalayan non-glaciated watersheds, as its first natural field laboratory. The Mahugad is a non-glacial fed perennial tributary of Gomati river which joins Saryu at Bageshwar. It provides drinking and irrigation water to the highly fertile land of clay soil of Pokhari, Naogaon, Ghirtoli, Shilingtoli villages. Since June 2010, the Mahogad river has been transformed into non-perennial river by which there has become water scarcity for irrigation as well as drinking water in the surrounding villages. Study indicates that due to depletion of water resources, production of paddy in the villages of Mahogad watershed (Fig. 1.24) has gone drastically down (50% to 70%) during the last one decade. Changes in the resource pattern occurred during the last 5 decades in the villages of the Mahogad watershed were studied in detailed on Cadestral maps using GIS and GPS technologies. For example, figure 1.25 and 1.26 depict the resource pattern in one of the villages of the Mahogad watershed, viz., Naogaun about 5 decade back and at present. These resource maps of village Naogoun reveal that the water resources have depleted drastically and the large part of irrigated land of the village has been converted into non-irrigated land generating problem of agriculture and livelihood sustenance in the village. The condition of other villages of the Mahogad watershed is also similar to the Naogaun village.

For mitigation of climate change impacts, the most important work to be done is regeneration of drying and dead rivers in the non-glacial fed watersheds through both, mechanical and biological treatment measures of groundwater augmentation. This work cannot be done in isolation neither by the scientists and villagers nor by the government alone. It needs a coordinated action programme of scientists, villagers and government

Fig-1.25.
Status of resources during 1958-59 in one of the villages of Mahogad watershed, viz, Naogaun, Block - Garud, District Bageshwar (*prepared through GIS and based on Cadestral Maps*)

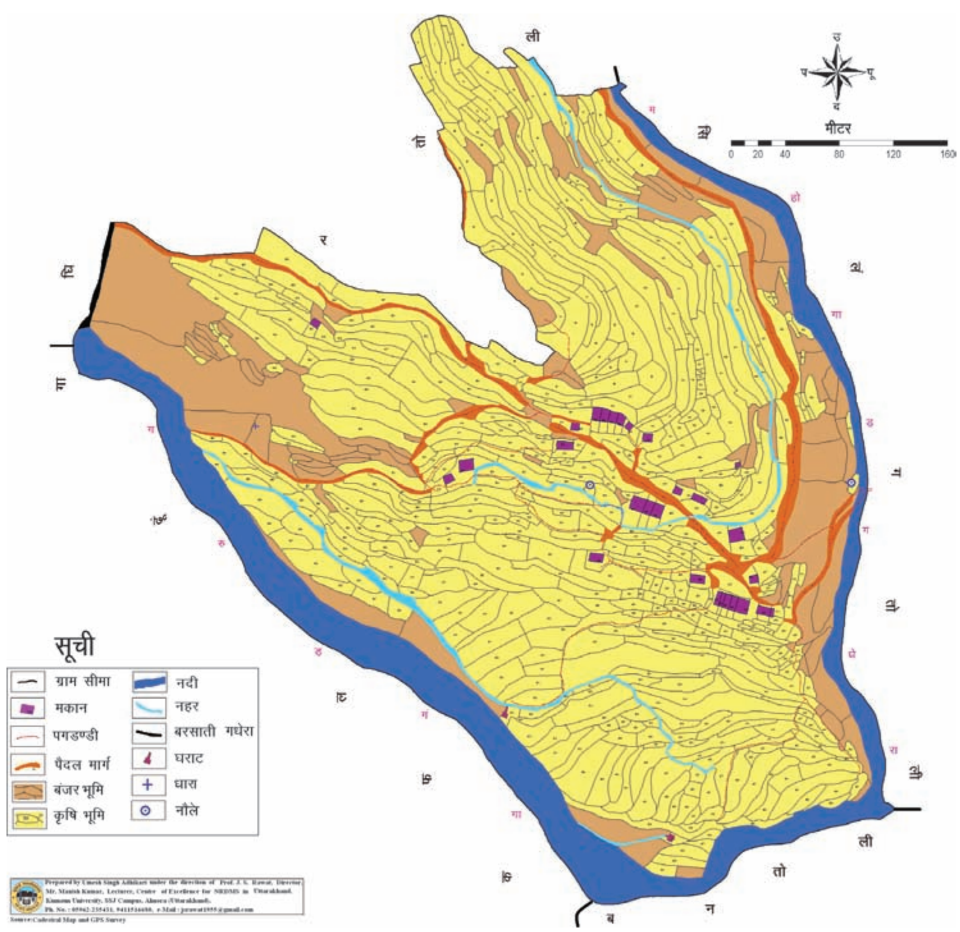


Plate-1.10.
Participants (Scientists/villagers/ Officers of Government Departments) of UCCC workshop organized at village Naogoun on 7th December 2011.

Fig-1.26.
Status of present resources (2012) in one of the villages of Mahogad watershed, viz, Naogaun, Block - Garud, District Bageshwar

departments. For developing a coordinated action plan for mitigation of climate change impacts in the Mahogad watershed, the UCCC organized a one day workshop at village Naogoun in the Mahogad watershed on 7th December 2011 in which 110 (i.e., 13 scientists, 74 villagers and 33 government officials) participants actively participated in the workshop (Plate-1.10).

After discussions, a detail action plan for mitigation of climate change impacts was worked out in this workshop[48]. Past (Fig. 1.25) and present (Fig. 1.26) resources pattern of the villages was worked out. Two types of action plan were developed in the workshop. First, at village level in which development plans of each village were drawn by the villagers (Fig. 1.27) in case of the Naogaun village, and second watershed level, in which sites and area were identified for various mechanical and biological treatments for groundwater augmentation to regenerate dead and dying rivers. Fig. 1.28 depict the proposed sites/areas for Mahogad watershed treatment through the concerned government departments involving villagers and scientists advices. The implementation work of the Mahogad watershed action project is in progress through different government departments and the villagers. It is hoped that within next 3-4 years we shall have a concrete model for mitigation of climate change impacts in the highly fragile ecosystem and very sensitive environmental systems in Uttarakhand.

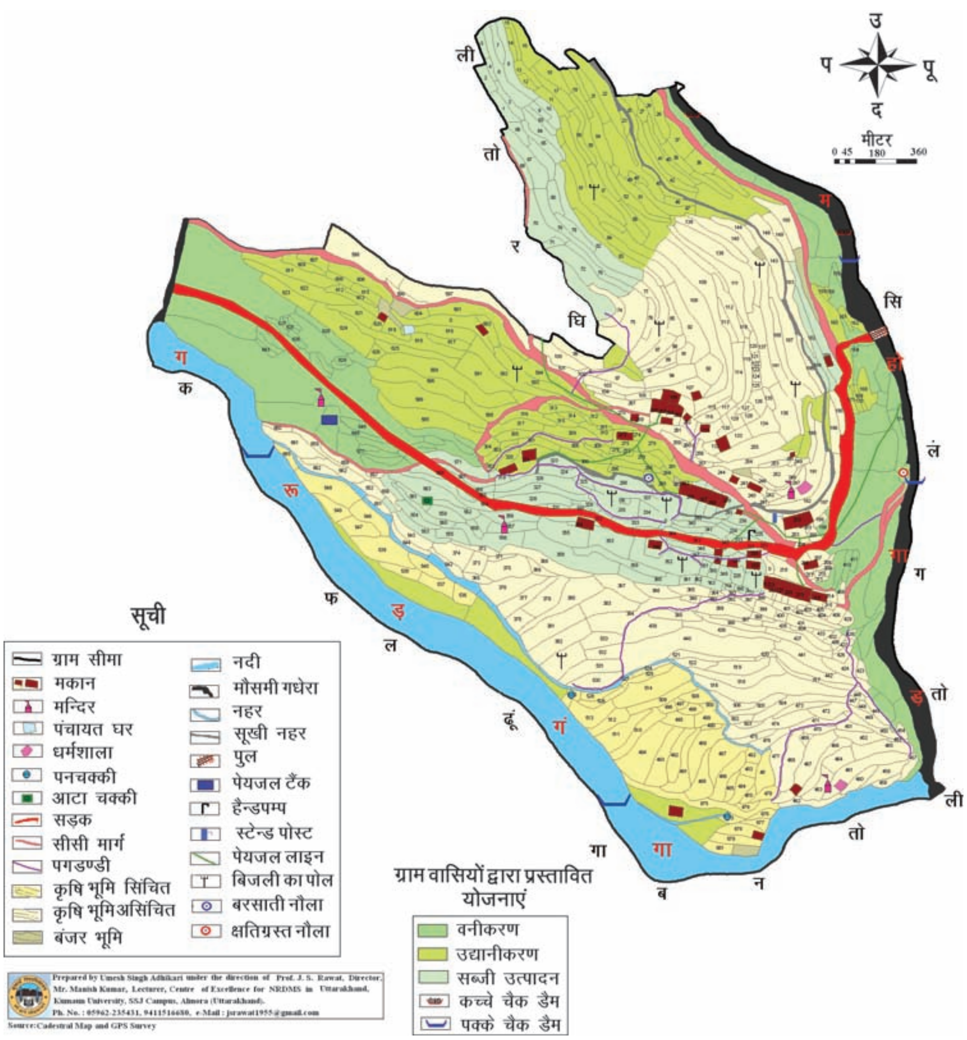


Fig-1.27. Proposed development plans (2012) of village Naogaun proposed by the villagers for sustenance of water, agriculture and livelihood.

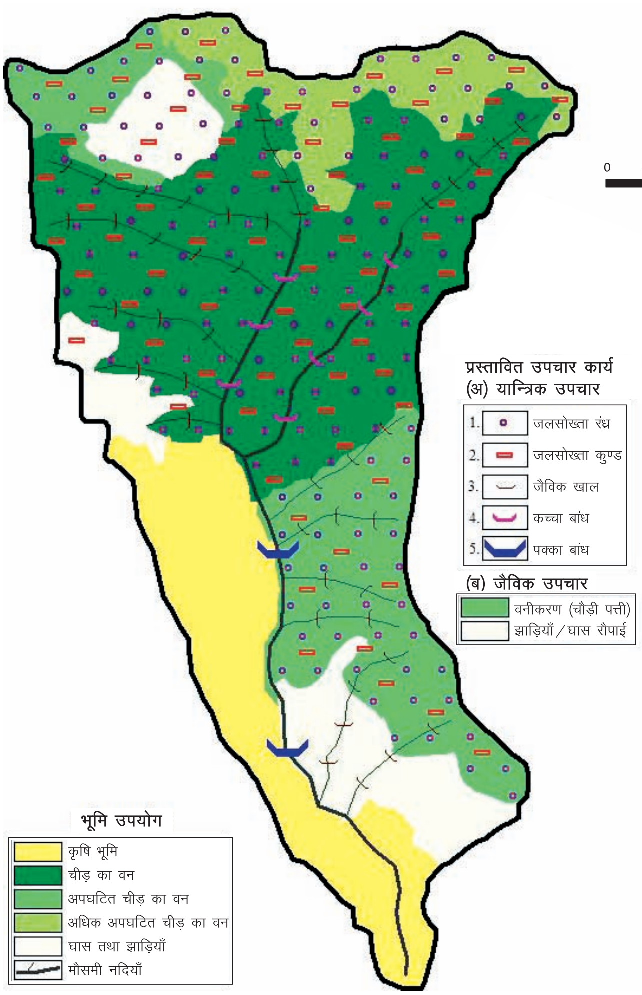


Fig-1.28.
Proposed sites/areas for mechanical and biological treatments in the Mahogad watershed for regeneration of dead/dying rivers of the through groundwater augmentation for sustenance of water, agriculture and livelihood.

1.13. References

1. Yang, L., Global change monitoring activities in Changbaishan Biosphere Reserve, in Global Change Research in Mountain Biosphere Reserves, Proceedings of the International Launching Workshop, Entlebuch Biosphere Reserve, China, 2003, pp. 12-16.
2. Rawat, J.S. *et al.*, Uttarakhand Centre on Climate Change, 1at Interim Report, Issued by USERC, UCOST, UCCC and COE NRDMS in Uttarakhand, 2011, 9-35,
3. Naithani, A.K., Nainwal, H.C., Sati, K.K. and Prasad, C., Geomorphological evidences of retreat of Gangotri glacier and its characteristics. *Curr. Sci.*, 2001**,** **80**, 87-94.
4. Holland, T.H., A preliminary survey of certain glaciers in northwest Himalaya. *Rec. Geol. Surv. Ind,* 1906, **35**, 124-126.
5. Cotter, G. de P., Notes on certain glaciers in Kumaun. *Rec. Geol. Suv. Ind.* 1906, **35**, 148-152.
6. Strachey, R., A description of glaciers of the Pindari and Kaphnee rivers in the Kumaun Himalaya. *Journal Asiatic Soc. Bengal*, 1845, **16**, 203.
7. Tewari, A.P. and Jangpangi, B.C., The retreat of the snout of the Pindari Glacier. Proceeding Symposium of Obsergurgle Intern. *Assoc. Sci. Hydrol.*, 1962, 58, 245-248.
8. Tewari, A.P., Recent changes in the position of the snout of the Pindari Glacier, Kumaun Himalaya, Almora district, U.P., India. Proceeding Symposium of Role of Snow and Ice in Hydrology, Canada, UNESCO-WMO-IAIS, 1972, 1144-1149.

9. Compendium of Statics for the States of Himalayan Region (CSSIHR), GBPIHED, Katarmal, 2010, 1-130.
10. Kotlia, B.S., Rakesh, K.D., Miral, M.S., Joshi, L.M., Recession rate of tributary glaciers of Gangotri glacier system, Garhwal Himalaya, India**.** *Bio-Nano-Geo Science the future challenges* (ed. Srivastava and Roy), Ane Books Pvt. Ltd. New Delhi, 2009, 141-148.
11. Canon, M.A., Colombian Case, Cinturon Andino Biosphere Reserve, Proceedings of the International Launching Workshop, Entlebuch Biosphere Reserve, 2003, 17-31.
12. Fagre, D.B., Glacier National Park, Biosphere Reserved and GLORIA site, Proceedings International Launching Workshop, USA, Entlebuch Biosphere Reserve, 2003, 99-108.
13. Kumar Kireet, Rakesh K. Dumka, M.S. Miral, and G.S. Satyal, *Curr.Sc.,* 2008, **94**(2), 258-261.
14. Yang, L., Proceedings of the International Launching Workshop held in Entlebuch Biosphere Reserve, 10-13 Nov, 2003, 12-16.
15. Swami Pravanand, Writing on the basis of his journeys to Kailash-Mansarovar, between 1928 to 1946, 1950.
16. Singh, S.P., Singh, V. and Margaret, S., Rapid warming in the Himalayas: Ecosystem responses and development options. *Climate and Development*, 2010, **2**, 1- 13.
17. Joshi Pandey, Bhawana, 1st Interim Report, UCCC, USERC,UCOST,NRDMS, 2011,32
18. Atkinson, E.T., The Himalayan Gazetteer. Vol. 1 (I & II); Cosmo Publications, New Delhi. (First published under the title 'THE HIMALAYAN DISTRICTS of the North Western Provinces of India' (forming Vol. X of the Gazetteer N.W.P.) Allahabad- 1882.
19. Hooker, J.D., The flora of British India (Asclepiadaceae to Amaranthaceae). (Reprinted by Singh B. S. M. P., Dehra Dun), Reere Co., London, 1884.
20. Duthie, J.F., Catelogue of plants of Kumaon and adjacent portion of Garhwal and Tibbat (Catelogue originally prepared by Strachey in 1852 on collections made by Strachey and Winterbottom between the years 1846-49), Lovell Reeva & Co. Ltd. London, 1906.
21. Osmaston, A.E., A Forest Flora for Kumaon, Allahabad, 1927.
22. Upreti, D.K. and Negi, H.R., *J. Econ. Tax. Bot.* 1998, **22**:, 266-273.
23. Kumar, B., *The Journal of American Science.* **5**(4), 2009, 107-112.
24. Bhatt, J.C., Impact of Climate Change on Hill Farming, International Workshop on Mountain biodiversity and impacts of climate change with special reference to Himalayan biodiversity hotspot, GBPIHED, Almora, 2010, 5-8.
25. Ralhan, P.K., Khanna, R.K., Singh, S.P. and Singh, J.S., Phenological characters of the shrub layer of Kumaun Himalayan forests. *Vegetation*, 1985, **60**, 191-201.
26. Ralhan, P.K., Khanna, R.K., Singh, S.P. and Singh, J. S., Certain Phenological characteristics of the tree layer of Kumaun Himalayan forests. *Vegetation*, 1985, **63**, 113-119.
27. Negi, G.C.S. and Singh, S.P., Leaf growth pattern in evergreen and deciduous species of the Central Himalaya, India. *Int. Jour. Biometeorol*, 1992, **36**, 233-242.
28. Negi, G.C.S. and Singh, S.P., Leaf nitrogen dynamics with particular reference to re-translocation in evergreen and deciduous tree species of Kumaun Himalaya. *Can. Jour. For. Res,* 1993, **23**, 349-357.
29. Rawat, J.S., Rawat, G. and Rai, S.P., Impact of human activities on geomorphic processes in the Almora region, Central Himalaya, India. *Geomorphology, Human Activity and Global Change* (ed. Slymaker, O.), John Wiley and Sons, New York, 2000, 285-297.
30. Valdiya, K.S., Rawat, J.S. and Rai, S.P., Response of hydrologic cycle to environmental degradation, Technical Report, Submitted to the Ministry of Environment and Forest, Department of Geology, Kumaun University, Nainital, 1993.
31. Rawat, J.S. and Rawat, G., Environmental Hydrology of the Almora Region. Technical Report submitted to DST, New Delhi, Department of Geography, Kumaun University, SSJ Campus, Almora, 1998, 1-332.

32. Rawat, J.S., Kaur, R. and Rawat, G., Watershed Monitoring and Modelling in the Central Himalaya, Technical Report submitted to DST, New Delhi, Department of Geography Kumaun University SSJ Campus Almora, 2002, pp. 1-47.

33. Rawat, J.S., Application of geohydro- meteorological informatics in groundwater augmentation and water conservation in the Kosi watershed, DST, New Delhi ongoing project, Centre of Excellence for Natural Resources Data Management System in Uttarakhand, Department of Geography, Kumaun University, SSJ Campus Almora, 2011.

34. Rawat, J.S., Dharpani dhar sukhe jal abhyaran ke punarjanan hetu eak jal begyanik vishlesan. *Quest*, 2009, **1**, 34-39.

35. Rawat, J.S., Khoo Na Jai Kahi Kosi, Gyanodaya Prakashan Nainital, 2007, 1-60.

36. Morrison, J.M.Q., and Foreman, M., Climate change in the fresher river watershed: flow and temperature projections. *Jour. Hydrol*, 2002, **263**, 230-244.

37. Chang, Evans, H. B. and Esterling, D., The effect of climate in stream flow and nutrient loading. *Jour. Amer. Water Resour. Assoc.*, 2001, **37**, 937-985.

38. Yarze, J.C. and Chase, M.P., E coli O157; H7-another waterborn outbreak!. *Amer. Jour. Gastroenterol*, 2000, **95**, 1096.

39. Cox, P.I. F., Castl, G., Jagatheesan, V., Warneck, M., Angle, M., Bustamante, H., Chiffing, T. and Hawkins, P.R., Sydney 1998-lessons from a drinking water crises. *Jour. Amer. Water Works Assoc.*, 2003, **95**, 147-161.

40. Hunter, P., Climate change and water born and vector born diseases. *Jour. Appl. Microboil,* 2003, **94**, 37-46.

41. Bhandari, N.S. and Joshi, H.K., Summary of the project report (File No. USC&T/R&D/CHEL-3/06-07), submitted to UCOST, Govt. of Uttarakhand, 2011,35-36.

42. Ranbir, R.S., Bhagat R.M., Kalia, Vaibhav and Lal Harban, ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture.

43. Arora, A. and Kumar, A, 1st Interim Report of UCCC, Issued by USER, UCOST, UCCC and COE NRDMS in Uttarakhand, 2011,47.

44. Pandey, G., 1st Interim Report of UCCC, Issued by USER, UCOST, UCCC and COE NRDMS in Uttarakhand, 2011,44.

45. Rawat, G., 1st Interim Report of UCCC, Issued by USER, UCOST, UCCC and COE NRDMS in Uttarakhand, 2011,46.

46. Joshi, K.C., 1st Interim Report of UCCC, Issued by USER, UCOST, UCCC and COE NRDMS in Uttarakhand, 2011,48.

47. Pant, A., 1st Interim Report of UCCC, Issued by USER, UCOST, UCCC and COE NRDMS in Uttarakhand, 2011.50.

48. Arora, V.P.S. and Rawat, J.S., Report on workshop on impact of climate change in water, agriculture and livelihood in the Mahogad watershed (in Hindi), organized by UCCC at village Naogaun on 7th December 2011, 1-16.

Section IV

DISASTER

Disaster Scenario and Management

Chapter

ONE

DISASTER SCENARIO AND MANAGEMENT

(Namita Karki, Om Prakash Nautiyal and Ashutosh Mishra)

1.1. Introduction

Uttarakhand's complex geography and geomorphology has made it more prone to various kind of disasters. Disaster is not a once in a blue moon event for a state like Uttarakhand, it has become a regular feature in the life of its natives. Disaster in general can be classified broadly into two types-*natural disaster and man-made disaster*. There is no country, no state which is immune to disaster, though vulnerability to disaster varies. Landslide, cloud burst and earthquakes are the natural disasters which are the main concern of the state at the moment.

A disaster refers to a catastrophe, mishap, calamity or grave occurrence from natural or man-made causes, which is beyond the coping capacity of the affected community. Fig. 1.1 shows the human losses due to natural disasters in Uttarakhand during 2005-2011.

Table-1.1.
List of various Disasters faced by Uttarakhand[1]

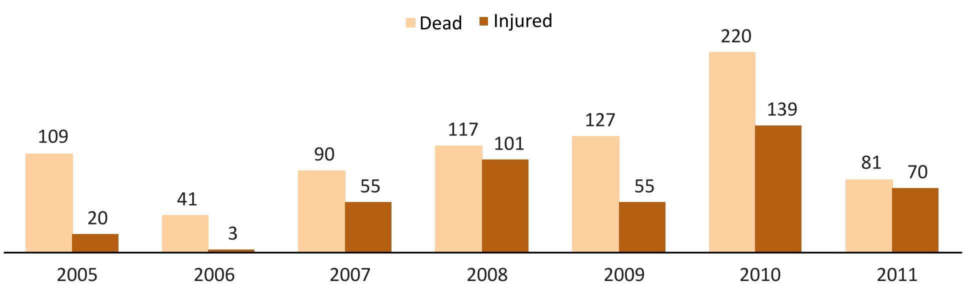
i. Water and climate related disasters	a) Floods and drainage management b) Hailstorm c) Cloud burst d) Snow avalanches and cold wave e) Droughts
ii. Geological related disasters	a) Landslides and mudflows
	b) Earthquakes
	c) Dam failures/ Dam bursts
	d) Minor fires
iii. Accident related disasters	a) Forest fires
	b) Urban fires/Village Fire
	c) Festival related disasters
	d) Electrical disasters and fires
	e) Air, road or rail accidents
	f) Stampede
v. Biological related disasters	a) Epidemics
	b) Pest attacks
	c) Cattle epidemics
	d) Food poisoning

1.2. Major Natural Disasters

1.2.1. Landslides

Landslides are catastrophic mass wasting events that can create devastating consequences for communities. It is one of the unique natural hazard which is mostly area specific and effects at least 15% of land area of our country[2]. Himalayan mountains are the youngest and most dominating mountain system in the world and are not a single long landmass but

Fig-1.1.
Human losses due to Natural Disasters in Uttarakhand State Since 2005 to 2011[1].



comprise a series of seven curvilinear parallel folds running along a grand arc. Uttarakhand hills are in this geodynamically active domains of Himalaya and thus has faced very disastrous consequences of landslides in recent years. It constitute a major natural hazard in our state, which accounts for considerable loss of life and damage to communication routes, human settlements, agricultural fields and forest lands. Fig. 1.2 depicts the human losses due to landslides in Uttarakhand. High risk landslide map of the state is shown in Fig. 1.3. In recent years landslide activities has increased drastically, proclaiming to be a major killer.

1.2.1.1. Landslide Causes[3]

The causes of Landslide in the state can be attributed to the following causative factors solely or in combination with:

i. Geology of the area.

ii. Geo-technical condition.

iii. Heavy rainfall/Snowfall.

iv. Slope angle and slope formation materials.

v. Hydrological condition of the area.

Fig-1.2.
Human losses in Uttarakhand due to landslide/flash floods[1].

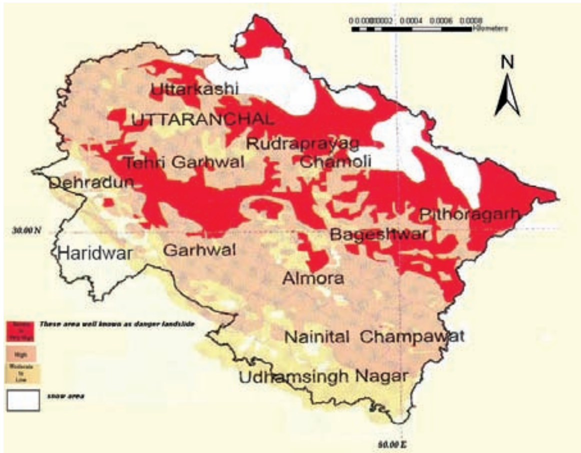


Fig-1.3. Landslide hazard map of Uttarakhand[1].

Causes may be considered to be factors that made the slope vulnerable to failure, that predispose the slope to becoming unstable. The trigger is the single events that finally initiate the landslide. Thus, causes combine to make a slope vulnerable to failure, whilst the trigger finally initiates the movement. Landslide can have many causes, but can only have one trigger. Usually, it is relatively easy to determine the trigger after the landslide has occurred. Cloud burst and prolong precipitation has come out to be the main cause of the landslide in Uttarakhand. Human activities like road widening has also emerged out as a trigger in the region. Different types of landslides are shown in the Fig. 1.4.

Table-1.2. Classification of Landslides[4]

Type of Movement			Type of Material		
			Bedrock	Engineering Soil	
				Predominantly	Predominantly fine
Falls			Rock fall	Debris fall	Earth fall
Topples			Rock Topples	Debris Topples	Earth Topples
Slides	Rotation	Few units	Rock Slump	Debri Slump	Earth Slump
	Translations	Many units	Rock Block Slide	Debris Block Slide	Earth Block Slide
			Rock slide	Debris Slide	Earth Slide
Lateral Spread			Rock Spread	Debris Spread	Earth Spread
Flows			Rock Flow	Debris Flow	Earth Flow
			(Deep Creep)	(Soil Creep)	
Complex			Combination of two or more principal types of movement		

Table-1.3. List of landslides occurred after 2002 in the state[1,7].

S. No.	District	Date	Place	No. of Casualties	Reason of Incident
1	Pithoragarh	12.07.2002	Khatgaun, Pithoragarh	4	Heavy rain/cloud burst
2	Pithoragarh	21.07.2003	DDHat, Pithoragarh	4	Land Slide
3	Uttarkashi	25.09.2003	Varunavat mountain, Uttarkashi	-	Land Slide
4	Chamoli	06.07.2004	Lambagarh, Chamoli	7	Land Slide

S. No.	District	Date	Place	No. of Casualties	Reason of Incident
5	Chamoli	17-18.07.2004	Joshimath, Chamoli	1	Land Slide
6	Uttarkashi	29.07.2004	Kalandi mountain, Uttarkashi	6	Land Slide
7	Tehri	02.08.2004	Tehridam, Tehri	29	Land Slide
8	Chamoli	08.08.2004	Paatal ganga, Chamoli	1	Land Slide
9	Chamoli	12.08.2004	Peepalkoti, Chamoli	1	Land Slide
10	Almora	14.08.2004	Ranikhat, Almora	1	Land Slide/Heavy rain
11	Rudraprayag	15.08.2004	Jungle chatee, Rudraprayag	2	Land Slide
12	Nainital	23.08.2004	Aampadav, Nainital	3	Land Slide
13	Chamoli	07.08.2005	Gaun Tangri, Chamoli	2	Land Slide
14	Rudraprayag	12.07.2005	Mannsuna Rudraprayag	1	Land Slide
15	Tehri Garhwal	21.07.2005	Dhanolati, Tehri	4	Land Slide
16	Uttarkashi	02.09.2005	Pali Tehsil Badkot	1	Land Slide
17	Pithoragarh	14.07.2006	Tehsil Dharchula	3	Land Slide
18	Tehri Garhwal	09.07.2006	Tehsil Ghanseyali	1	Land Slide
19	Almora	26.09.2007	Lohaar gaun, Salt, Almora	3	Land Slide
20	Bageshwar	25.08.2007	Tehsil Kanda Gaun kedae	2	Land Slide
21	Pithoragarh	14.08.2007	Jorashi Tehsil DD haat	1	Land Slide
22	Pithoragarh	16.08.2007	Khala k tok raple Tehsil Dharchula	1	Land Slide
23	Pithoragarh	05.09.2007	Baram, Tehsil Dharchula	10	Land Slide/Heavy rainfall
24	Pithoragarh	06.09.2007	Seyaldhar, Tehsil Dharchula	5	Land Slide/ Heavy rainfall
25	Pithoragarh	07.09.2007	Tehsil Dharchula	2	Land Slide
26	Nainital	25.09.2007	Nainital	1	Land Slide
27	Pauri Garhwal	15.08.2007	Kasan block Yamkasver	4	Land Slide
28	Chamoli	12.07.2008	Devpuri Tehsil Gharsan	8	Land Slide/ Heavy rain
29	Champawat	17.07.2008	Amru band, Sukhidhang	17	Land Slide
30	Pithoragarh	3.07.2008	Galati, Tehsil Dharchula	1	Land Slide
31	Pithoragarh	22.07.2008	Patee samkot	1	Land Slide
32	Pithoragarh	04.09.2008	Gothidhura, Tehsil Dharchula	1	Land Slide/ Heavy rain
33	Pithoragarh	20.09.2008	Badabay	1	Land Slide
34	U.S. Nagar	16.05.2008	Tehsil Khatema	1	Land Slide
35	Haridwar	18.08.2008	Talpura, Tehsil Roorkee	1	Land Slide/
36	Uttarkashi	27.07.2008	Nag mandir, Tehsil Bhattvare	1	Land Slide

S. No.	District	Date	Place	No. of Casualties	Reason of Incident
37	Uttarkashi	09.08.2008	Jarda khad, Tehsil Badkot	1	Land Slide
38	Uttarkashi	18.08.2008	Barnegard, Purala	1	Land Slide
39	Chamoli	11.07.2008	Lambagarh, Joshimath	3	/Land Slide
40	Chamoli	26.07.2008	Chamoli, Joshimath, Motor marg, Patalganga	9	Land Slide
41	Chamoli	20.08.2008	Mokhmalla, Mokh, Tehsil Ghat	6	Land Slide
42	Tehri	04.06.2008	Kadhi, Tehsil Devprayag	1	Land Slide
43	Tehri	19.06.2008	Rishikesh-Srinagar, Shivpuri marg	2	Land Slide
44	Tehri	15.07.2008	Noghar lambgaun, Tehsil Pratapnagar	1	Land Slide/
45	Tehri	17.08.2008	Kandikhal, Suleyadhar, Chamba	1	Land Slide/
46	Rudraprayag	24.07.2008	Chomashi & Jaal talla, Tehsil Ukhimath	1	Land Slide
47	Chamoli	04.01.2009	Saliyana band, Tehsil Garhsan	1	Land Slide
48	Nainital	14.02.09	Malla Koshiyakotole, Nainital	2	Land Slide
49	Pauri Garhwal	16.02.09	Pauri Thalesan	1	Land Slide
50	Pithoragarh	08.04.09	Chataldhar, Tehsil Dharchula	1	Land Slide
51	Almora	18.05.2009	Lala bazaar, Tehsil Almora	1	Land Slide
52	Tehri	04.06.09	Tehsil Ghansaale	1	Land Slide
53	Rudraprayag	30.06.09	Gourikund, Rudraprayag	2	Land Slide
54	Nainital	10.07.2009	Barapathar, Nainital	3	Land Slide
55	Chamoli	12.07.2009	Harisankar, Tehsil Pokhari	1	Land Slide
56	Uttarkashi	13.07.2009	Near Hanuman chatee	1	Land Slide
57	Pithoragarh	20.07.2009	Hokara Gaun Seyada Thok, Munsyari	3	Land Slide
58	Dehradun	26.07.2009	Sanstradhara, Chamasari	1	Land Slide
59	Pithoragarh	29.07.2009	Gunji, Pithoragarh	4	Land Slide
60	Tehri	31.07.2009	Kalfari, Shivpuri Narandranagar	1	Land Slide
61	Pithoragarh	08.08.2009	Nachani, la Jhkala, Chacna & Badue mahar ka Rumi Dola Tehsil-Munsyari	43	Cloud burst
62	Almora	18.09.2010	Pelakha, Balta, Tehsil Almora	36	Cloud burst

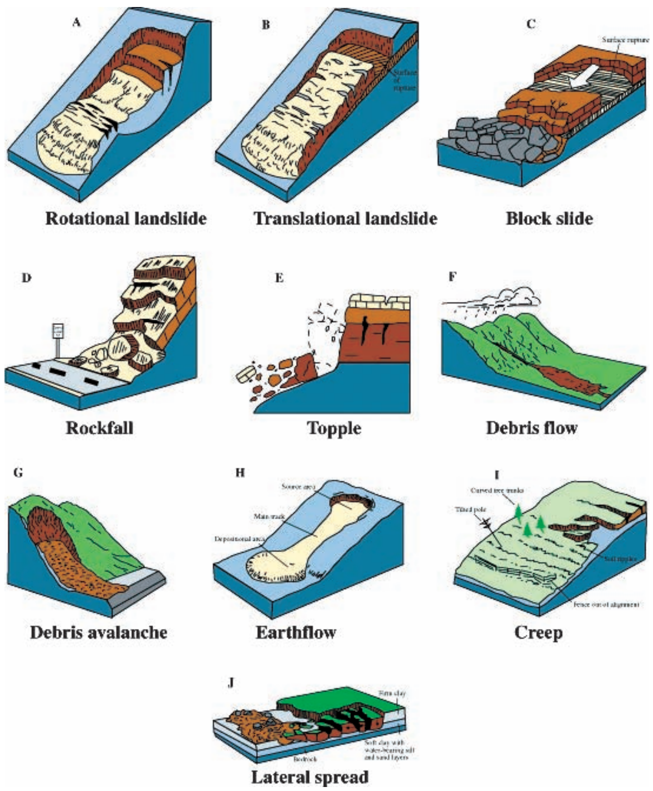


Fig-1.4.
Types of Landslides[5]

Fig-1.5.
A major landslide about 1 Km north of Gopeshwar after Chamoli Earthquake[6].

1.2.1.2. Landslide Mitigation[3]

The hazard from landslides can be reduced by avoiding construction on steep slopes and existing landslides, or by stabilizing the slopes. Stability increases when ground water is prevented from rising in the landslide mass by (i) covering the landslide with an impermeable membrane, (ii) directing surface water away from the landslide, (iii) draining ground water away from the landslide, and (iv) minimizing surface irrigation. Slope stability is also increased when a retaining structure and/or the weight of a soil/rock beam are placed at the toe of the landslide or when mass is removed from the top of the slope.

1.2.2. Earthquakes

The state of Uttarakhand is among the most seismically active parts of India. Many events of M5.5 or more have struck the region since 1900. The state straddles several active parallel thrust faults that form the ranges of the Himalayan mountain range. These faults have been formed in the highly folded strata of these mountains. The Main Boundary Thrust (MBT) and the Main Frontal Thrust (MFT) are the main active features in Uttarakhand. Slippage on these faults and their counterparts has in the part generated great earthquakes. Since the last earthquake of this magnitude range in this region, occurred more than 200 years ago, this section of the Himalayan thrust zone is believed to have the greatest potential for a future great earthquake. The region of potential danger is known as the Central Seismic Gap, and underlies Uttarakhand and western Nepal. Smaller faults such as the Yamuna Fault near Haridwar and Alaknanda Fault near Rudraprayag have been active during the Holocene period. The plate boundary between the Indian and Eurasian plates lies in southern Xizang (or Tibet) and is known as the Indus-Tsangpo Suture Zone. However, it must be stated that proximity to faults does not necessarily translate into a higher hazard as compared to areas located further away, as damage from earthquakes depends on numerous factors such as subsurface geology as well as adherence to the building codes.

1.2.2.1. Seismic Hazard[8]

In seismic hazard map of Uttarakhand, districts along the borders with Nepal and China lie in Zone V. MSK intensities in excess of IX can be expected in these districts. The rest of the state, including the city of Dehra Dun lie in Zone IV, where the maximum intensity expected could reach MSK VIII. Since the earthquake database in India is still incomplete, especially with regards to earthquakes prior to the historical period (before 1800 A.D.), these zones offer a rough guide of the earthquake hazard in any particular region and need to be regularly updated. Earthquake hazard map of Uttarakhand is shown in Fig. 1.6.

1.2.2.2. Significant Earthquakes in Uttarakhand

The following list (Table 1.4) briefly outlines known earthquakes in this region which either had observed intensities of VII or higher (historical events) or had known magnitudes of 6.0 or more (instrumented events). General locations are provided for historical events for which "generalized" epicentral co-ordinates are available (Fig. 1.8). Some events which were significant for other reasons are also included.

Fig-1.6. Earthquake hazard map of Uttarakhand[1]

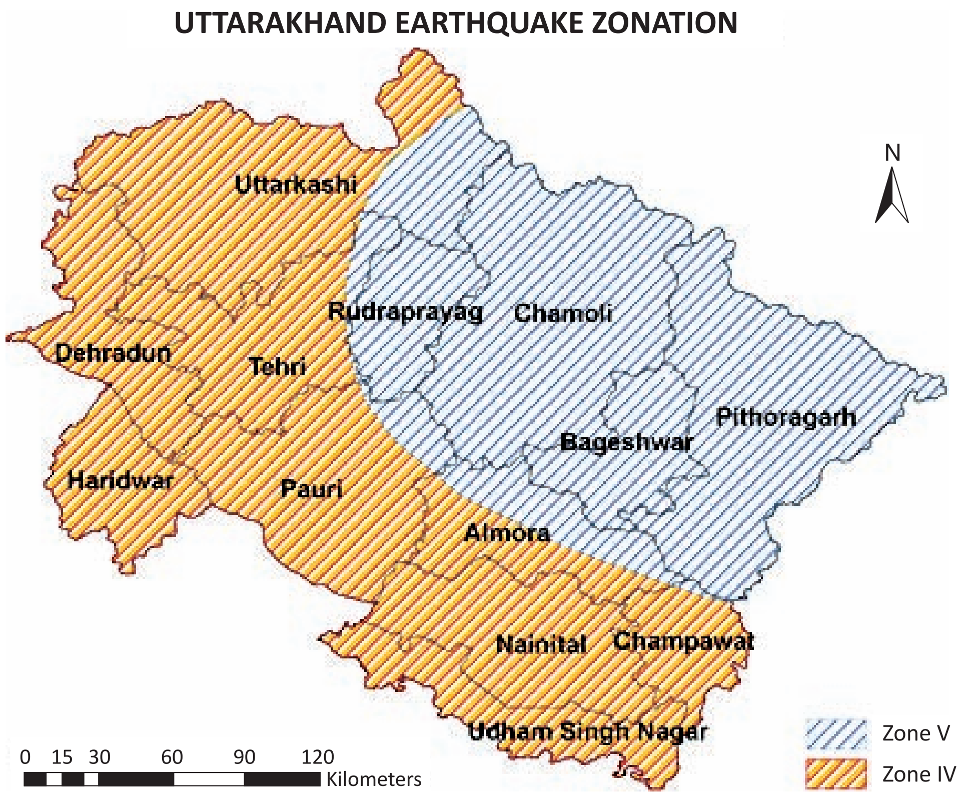


Table-1.4.
List of earthquakes occurred in Uttarakhand[8]

Date	Magnitude	Epicentre	Area/Location
01-09-1803	7	Not available	Kumaon-Gharwal area
26-05-1816	6.5	30.9^0 N, 79.0^0 E	Gangotri area
16-06-1902	6	30.0^0 N, 79.0^0 E	Pokhra-Kainur area
13-06-1906	6.1	31.0^0 N, 79.0^0 E	Gangotri area
27-07-1926	6.5	30.5^0 N, 80.0^0 E	Near Changabang Peak
08-10-1927	6.1	Not available	Dakar, Indo China border
04-06-1945	6.5	30.3^0 N, 80.0^0 E	Near Nanda Devi Peak
28-12-1958	6.1	29.5^0 N, 80.0^0 E	Rameshwar-Devi Dhura area
27-06-1966	6.2	29.6^0 N, 80.8^0 E	Athpali-Dhung area
19-10-1991	6.8	30.7^0 N, 78.8^0 E	Pilang-Bhatwari, Uttarkashi
05-01-1997	5.6	29.8^0 N, 80.5^0 E	Dharchula area,
28-03-1999	6.4	30.4^0 N, 79.4^0 E	Chamoli-Pipalkoti area
30-03-1999	4.9	30.4^0 N, 79.4^0 E	Chamoli-Pipalkoti area,
27-05-2003	5	30.6^0 N, 79.3^0 E	Bangina region
14-12-2005	5	30.4^0 N, 79.2^0 E	Pokhri-Gopeshwar region
05-08-2006	4.4	29.7^0 N, 80.2^0 E	Thal area, eastern Uttarakhand
19-01-2007	3.5	30.5^0 N, 80.0^0 E	Joshimath, Chamoli
27-01-2007	3.2	31.1^0 N, 78.2^0 E	Purola, Badkot, Uttarkashi
05-02-2007	3.5	29.9^0 N, 80.5^0 E	Dharchula, Pithoragarh
08-04-2007	2.6	30.0^0 N, 80.4^0 E	Dharchula, Pithoragarh
12-06-2007	3.0	29.8^0 N, 78.0^0 E	Laksar, Haridwar
22.07.2007	5	30.9^0 N, 78.3^0 E	Surka Ridge, Uttarakhand
27-07-2007	5.0	31.2^0 N, 78.2^0 E	Uttarkashi
07-08-2007	3.5	31.0^0 N, 78.3^0 E	Purola, Uttarkashi
03-10-2007	2.7	30.7^0 N, 78.4^0 E	Badkot, Uttarkashi
25-01-2008	3.5	30.6^0 N, 79.2^0 E	Rudraprayag
11-03-2008	2.5	30.1^0 N, 80.5^0 E	Dharchula, Pithoragarh
29-03-2008	3.2	29.9^0 N, 80.5^0 E	Dharchula, Pithoragarh
28-05-2008	3.2	30.4^0 N, 80.3^0 E	Dharchula, Pithoragarh
15-06-2008	4.5	29.6^0 N, 80.2^0 E	Dharchula, Pithoragarh-Nepal Border
27-01-2009	2.6	Not available	Bageshwar
25-02-2009	3.7	Not available	Rudraprayag/ Ukhimath
02-03-2009	2.7	Not available	Rudraprayag/ Ukhimath
18-03-2009	3.3	Not available	Uttarkashi
16-05-2009	4.1	Not available	Chamoli/Dasholi
16-05-2009	4.5	Not available	Rudraprayag
28-06-2009	Small tremmors	Not available	Dharchula
27-08-2009	3.9	Not available	Bageshwar

Fig-1.7.
Ground fissure at Telecom Hill near Gopeshwar after Chamoli Earthquake of 29 March 1999[6]

Date	Magnitude	Epicentre	Area/Location
18-09-2009	3.4	Not available	Rudraprayag
21-09-2009	4.7	Not available	Uttarkashi
03-10-2009	4.3	Not available	Bageshwar
21-10-2009	3.4	Not available	Uttarkashi, Purola
08-12-2009	4.1	Not available	Munsyari-Pithoragarh
11-01-2010	3.9	Not available	Matoli Vikaskhand-Gangolihat Pithoragarh
22-02-2010]	4.7	Not available	Munsyari, Pithoragarh
02-05-2010	4.6	Not available	Bageshwar
03-05-2010	3.5	Not available	Tehri-Uttarkashi
31-05-2010	3.6	Not available	Almora
23-06-2010	4.5	Not available	Haulbagh, Almora
07-07-2010	5.1	Not available	Jaoljivi-Pithoragarh
10--07-2010	4.1	Not available	Almora/Bageshwar
14-03-2011	3.3	30.5^0 N, 79.1^0 E	Chamoli/Rudraprayag
16-03-2011	2.5	29.6^0 N, 80.1^0 E	Dharchula
04-04-2011	5.7	29.6^0 N, 80.8^0 E	Indo-Nepal Border
05-05-2011	5.0	30.2^0 N, 80.4^0 E	Dharchula-Munsyari, Pithoragarh
13-05-2011	2.9	30.5^0 N,78.4^0 E	Uttarkashi
15-06-2011	3.4	30.6^0 N, 80.4^0 E	Milam & Munsyari, Pithoragarh
20-06-2011	4.6	$30\text{-}5^0$ N, 79.4^0E	Vikaskhand-Dasholi, Chamoli
24-06-2011	3.2	30.0^0 N, 80.5^0 N	Dharchula, Pithoragarh
04-07-2011	3.4	29.9^0 N, 79.3^0 E	Vikaskhand-Chaukhatiya, Almora
12-07-2011	3.1	29.6^0 N, 80.4^0 E	Munakot, Pithoragarh
28-08-2011	2.8	30.9^o N, 78.5^0 E	Uttarkashi

Table-1.5.
List of districts located in Seismic Zones III, IV and V.

States	DISTRICTS		
	Zone III	Zone IV	Zone V
Uttarakhand		Nainital, Udham Singh Nagar, Haridwar, Dehradun, Uttarkashi, Pauri Garhwal, Tehri-Garhwal, Champawat	Almora, Bageshwar, Chamoli, Pithoragarh, Rudraprayag

1.2.2.3. Earthquake Mitigation

Since the earthquake risk in the region is very high and with regard to the socio-economic condition, mitigation alternatives must be very critical. Decision making at the time of the disaster should include the collective efforts from geosciences, engineering, disaster planning and response, techno-legal, insurance and economics. In the case of an earthquake, casualties are caused primarily due to the collapse of the buildings that have usually no earthquake-resistant features. This emphasizes the need for strict compliance of town planning bye-laws and earthquake-resistant building codes in India. The following (Table 1.6) are the Indian standards providing a guideline in designing and repairing of buildings under seismic forces.

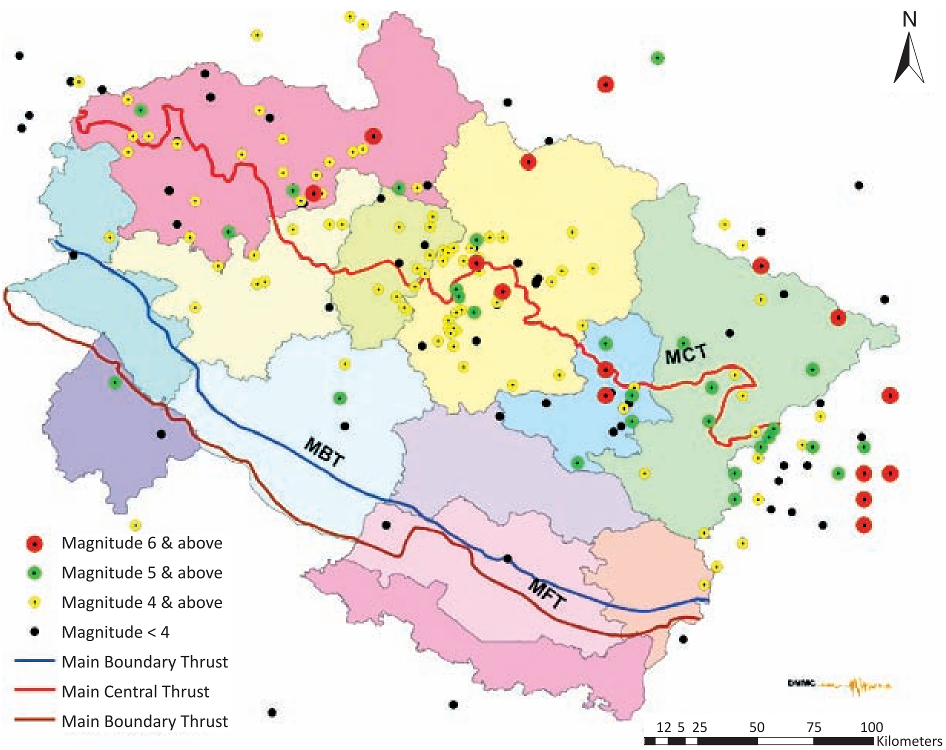


Fig-1.8.
Map showing epicenters of earthquakes in Uttarakhand[1]

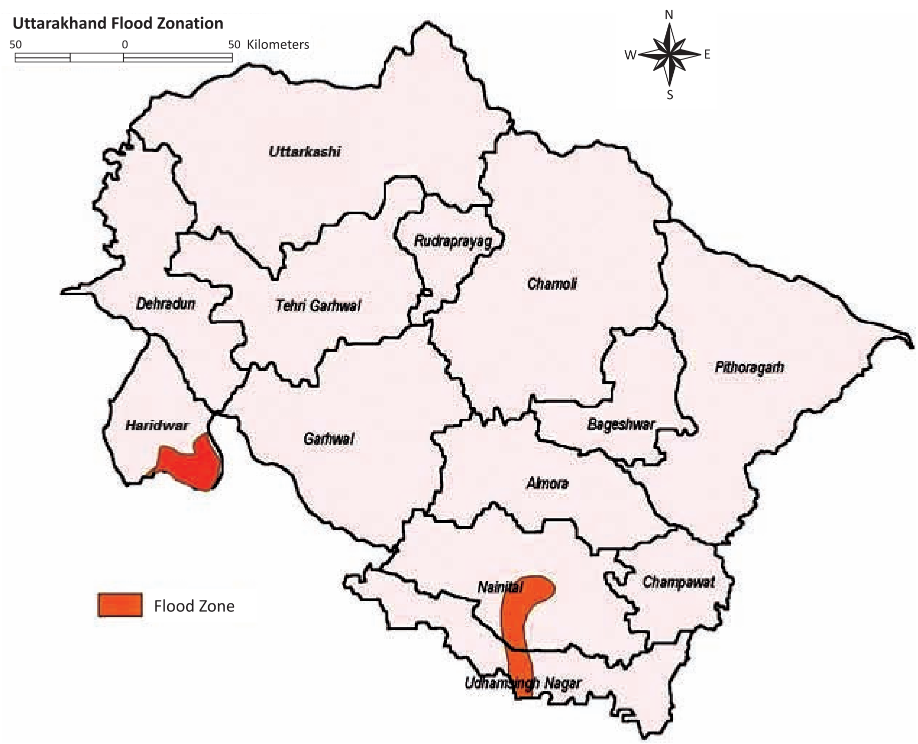


Fig-1.9.
Flood hazard map of Uttarakhand[1]

Table-1.6.
List of Indian Standards for Earthquake resistant structure[9].

1	IS 1893:1984 Criteria for Earthquake Resistant Design of Structures
2	IS 1893(Part 1):2002 `Criteria for Earthquake Resistant Design of Structures :Part 1 General provisions and Buildings'
3	IS 1893(Part 4):2005 `Criteria for Earthquake Resistant Design of Structures: Part 4 Industrial Structures Including Stack Like Structures
4	IS 4326:1993 Earthquake Resistant Design and Construction of Buildings - Code of Practice
5	IS 13827:1993 Improving Earthquake Resistance of Earthen Buildings – Guidelines
6	IS 13828:1993 Improving Earthquake Resistance of Low Strength Masonry Buildings-Guidelines
7	IS 13920:1993 Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces – Code of Practice
8	IS 13935:1993 Repair and Seismic Strengthening of Buildings – Guidelines
9	IS 6922:1973 Criteria for Safety and Design of Structures Subject to Underground Blasts
10	IS 4991:1968 Criteria for Blast Resistant Design of Structures for Explosions Above Ground
11	IS 4967:1968 Recommendations for Seismic Instrumentation for River Valley Projects

1.3. Man-Made Disasters

Man made disasters cover a wide range of events created largely due to road accidents, negligence or sometimes even by human design, which result in huge loss of lives and property every year in our state. In the state, road accidents and building & bridge collapse are the main man made disasters. The problem of road safety is acute in state. At present there is no organized system for collecting data on all man made disasters. Though DMMC collects road accident data in the state. In the year 2008 alone, number of deaths in Uttarakhand due to road accidents were 543 and 1163 were injured, many of whom are disabled for rest of their lives.

1.3.1. Road Accidents

The rapid expansion of road transport has brought with it the challenge of addressing adverse factors such as the increase in road accidents. Road accidents are a human tragedy. It involves high human suffering and monetary costs in terms of premature deaths, injuries, loss of productivity etc. Most deaths and injuries due to road accidents are invisible to society. They are a hidden epidemic. In India, motor vehicles including two wheelers are growing at a faster rate then the economic and population growth[10].

During the year 2009, there were around 4.9 lakh road accidents, which resulted in deaths of 1,25,660 people and injured more than 5 lakh persons in India[11]. These numbers translate into one road accident every minute, and one road accident death every four minutes, for India.

In Uttarakhand also the deaths due to Road accidents are far ahead then the deaths due to natural calamities. Deaths due to road accidents have increased to five fold from 2005 to 2008. The deaths/injured during 2005 to 2011 in the state are shown in Fig. 1.10.

1.4. Disaster Management[12]

Disaster management involves a continuous and integrated process of planning, organizing, coordinating and implementing measures which are necessary for prevention, mitigation, capacity building, preparedness rescue and relief and finally rehabilitation and reconstruction in case of disaster. A typical DM continuum comprises six elements;

the pre-disaster phase includes prevention, mitigation and preparedness, while the post-disaster phase includes response, rehabilitation, reconstruction and recovery. A legal and institutional framework binds all these elements together (Fig. 1.11).

1.4.1. Disaster Prevention, Preparedness, Relief and Recovery

Disaster prevention, mitigation and preparedness are better than disaster response in achieving the goals and objectives of vulnerability reduction. Unlike man-made disasters, natural hazards like floods, earthquakes and cyclones cannot be avoided. However, with mitigation measures along with proper planning of developmental work in the risk prone area, these hazards can be prevented from turning into disasters. A multi-pronged approach needs to be adopted to undertake mitigation measures:

a. Building mitigation measures into all development projects.

b. Initiating of National level mitigation projects by the NDMA, in high priority areas, with the help of the Central Ministries and Departments concerned and the States.

c. Encouraging and assisting state level mitigation projects in accordance with the guidelines.

d. Indigenous knowledge on disaster and coping mechanisms adopted by various States will be given due weightage with special focus on protection of heritage structures.

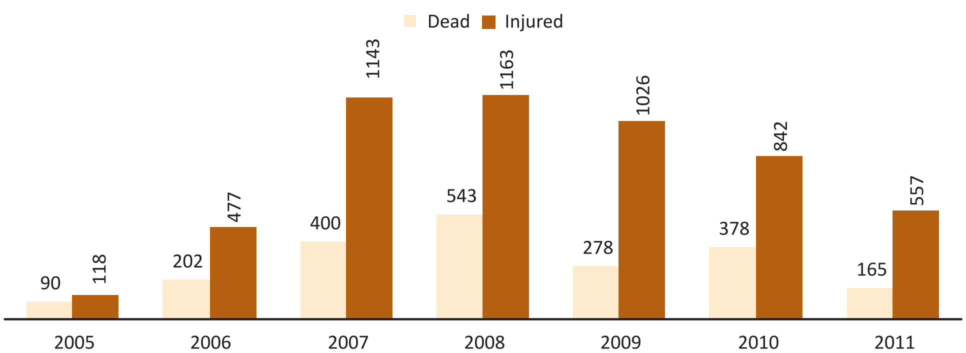


Fig-1.10.
Losses of human lives due to road accidents.

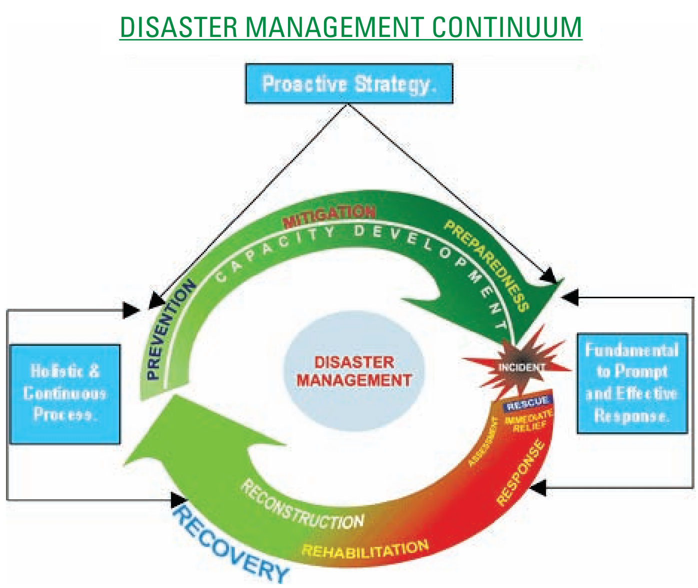


Fig-1.11.
Disaster management Continuum[12]

Hazard zonation, mapping and vulnerability analysis in a multi-hazard framework should be done for analyzing the risk in the area.

The concept of disaster preparedness is quite straight forward. Its objective is to ensure that in times of disasters, appropriate systems, procedures and resources are in place to assist those afflicted by the disaster and enable them to help themselves. The aims of disaster preparedness are to minimize the adverse effects of a hazard through effective precautionary actions, and to ensure timely, appropriate and efficient organization and delivery of emergency response following the impact of a disaster.
States/UTs have to accord the highest priority to building up their own DM capabilities. Plans at all levels should be made in consonance with the guidelines and provisions in the DM Act, 2005. While the National Plan will be prepared by the NEC, the disaster and domain-specific plans will be made by the respective Central Ministries and Departments. State and District plans will be prepared for their specific disaster related vulnerabilities in accordance with the guidelines issued by the NDMA. New institutional mechanisms may have to be built specifically in those sectors of DM where none of the existing agencies are working towards the building of required capacities.

Medical preparedness is a crucial component of any DM Plan. The NDMA, in close coordination with the Ministry of Health and Family Welfare, States and premier medical research institutes formulate policy guidelines to enhance capacity in emergency medical response and mass casualty management. DM plans for hospitals will include developing and training of medical teams and paramedics, capacity building, trauma and psycho-social care, mass casualty management and triage. The surge and casualty handling capacity of all hospitals at the time of disasters, will be worked out and recorded through a consultative process, by all the States/UTs in the pre-disaster phase. The State and District authorities will be encouraged to formulate appropriate procedures for treatment of casualties by private hospitals during disasters. These plans will also address post-disaster disease surveillance systems, networking with hospitals, referral institutions and accessing services and facilities such as availability of ambulances and blood banks.

The approach to the reconstruction process has to be comprehensive so as to convert adversity into opportunity. Incorporating disaster resilient features to 'build back better' will be the guiding principle. This phase requires the most patient and painstaking effort by all concerned. The administration, the stakeholders and the communities need to stay focused on the needs of this phase, as, with the passage of time, the sense of urgency gets diluted. The appropriate choice of technology and project impact assessment needs to be

Guidelines on Preparedness/Response- (Checklist for preparedness by state/district agency)	
• Vulnerability assessment	• Pre- Contract
• Dissemination of warning	• Evacuation Plan
• Emergency Response activities	• Activating Control Rooms
• Coordination	• Search & Rescue Team
• Rapid Damage Assessment	• Communication
• Maintenance of essential services	• Identification of Nodal Officer
• Stocking of essential commodities	• Status of SDRF
• Medicines	• Preparedness Drill
• Drinking water	
• Shelter/Camps	

carried out to establish that the projects contemplated do not create any side effects on the physical, socio-cultural or economic environment of the communities in the affected areas or in their neighbourhood. Systems for providing psychosocial support and trauma counselling need to be developed for implementation during the reconstruction and recovery phase. The year-wise breakup of the State Disaster Response Fund for Uttarakhand is shown in Table 1.7.

Table-1.7.
Year-wise breakup of the State Disaster Response Fund for Uttarakhand[13]

Year 2010-11	Year 2011-12	Year 2012-13	Year 2013-2014	Year 2014-15	Total
Rs. In Crores					
Grant Allocation for Capacity Building for Disaster Response					
4	4	4	4	4	20
Grant Allocation of State Disaster Response Fund					
117.66	123.54	129.72	136.21	143.02	650.15

1.5. DM Structure in India

Government of India enacted The Disaster Management Act on 23rd December 2005 after Indian Ocean Tsunami of December 2004[14]. One of the provisions of this Act included creation of National Disaster Management Authority (NDMA) headed by the Prime Minister, to spearhead and implement a holistic and integrated approach to disaster management in the country. The DM Act 2005 provides for establishment of Disaster Mitigation and Disaster Response Fund at National, State and District Levels. Disaster Management structure[15] is shown in the hierarchal form in the Fig. 1.12 which shows the role of centre and state in Disaster Management.

1.6. Policies

1.6.1. Disaster Management Act 2005[15]

The Act lays down institutional, legal, financial and coordination mechanisms at the National, State, District and Local levels. These institutions are not parallel structures and will work in close harmony. The new institutional framework is expected to usher in a paradigm shift in DM from relief-centric approach to a proactive regime that lays greater emphasis on preparedness, prevention and mitigation.

1.6.2. National Policy on Disaster Management 2009[16]

The National Policy on Disaster Management was approved by the Government in November 2009. This comprehensive policy document lays down policies on every aspect of holistic management of disasters in the country. The policy has thirteen chapters as under:

- Preamble
- Approach and Objectives
- Institutional and Legal Arrangements
- Financial Arrangements
- Disaster Prevention, Mitigation and Preparedness
- Techno-Legal Regime
- Response
- Relief and Rehabilitation
- Reconstruction and Recovery

Fig-1.12.
Disaster Management Structure in India[17]

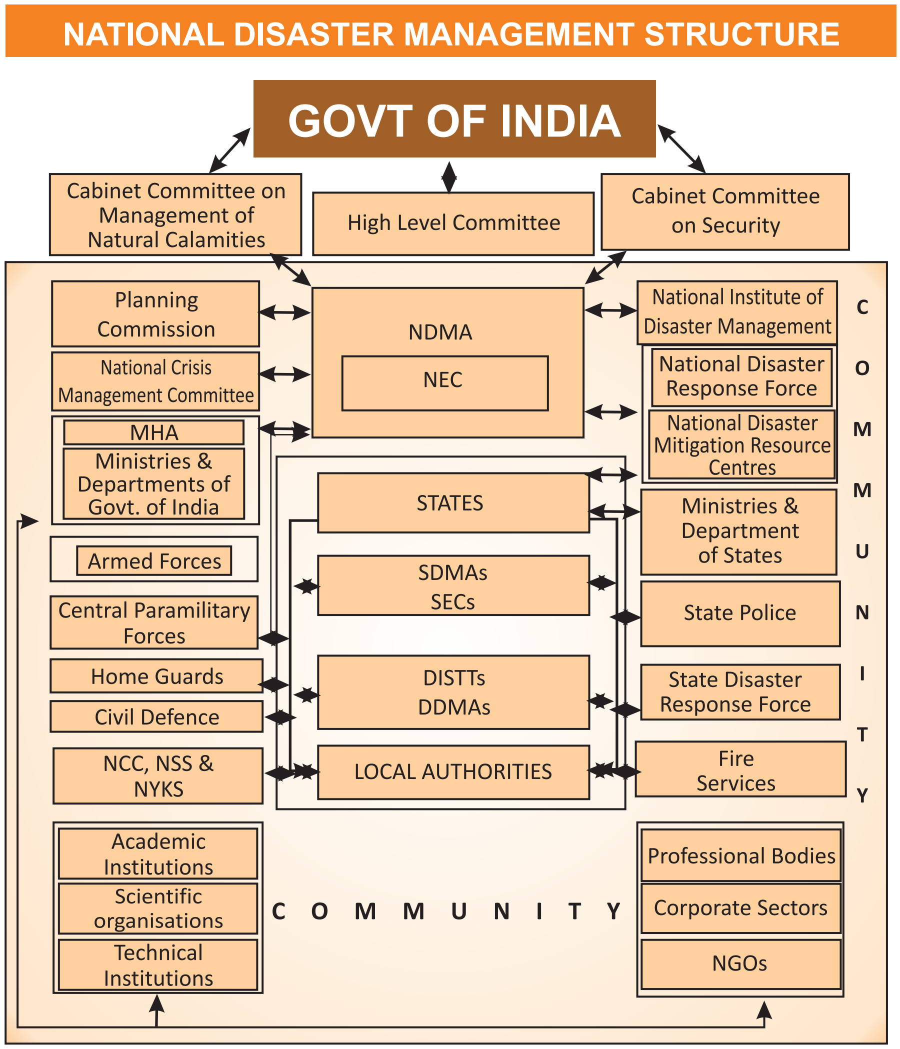
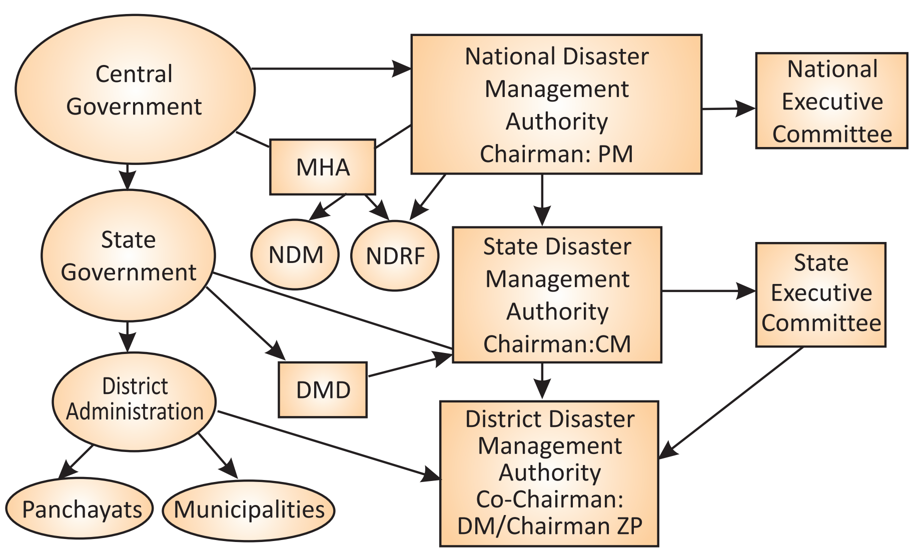


Fig-1.13.
Institutional framework for disaster management under the DM Act 2005[18].



- Capacity Development
- Knowledge Management
- Research and development
- Road Ahead

1.6.3. State Policies on Disaster Management[16]

The States of Madhya Pradesh, Gujarat, Kerala have formulated State Disaster Management Policies. Uttarakhand with few more states has prepared draft policies.

1.7. Institutional and Legal Arrangements

The Disaster Management Act, 2005 has created new institutions at the national, state, district and local levels. The new institutional framework for disaster management in the country is shown in the Fig. 1.13.

Uttarakhand is having a separate Disaster Mitigation & Management Centre (DMMC), which is an autonomous institute under Department of Disaster Management Government of Uttarakhand. Its mandate is to protect the community and the environment from the over whelming obliteration caused by disasters and to generate the sense of worth amongst common people and the government authorities in formulating appropriate policies and strengthening their capabilities to cope up with all aspects of disaster management[19]. DMMC offers various training programs, provide advance information about likely disaster through latest technologies available and maintaining a network of experienced experts working in the field and institutions of excellence. DMMC also provides consultancy services to all levels of government, international agencies and non-government organizations. DMMC is in the process of developing a regional knowledge base towards disaster policy, prevention mechanisms, mitigation measures, preparedness, and response plans.

1.7.1. Institutions and Resource Persons Involved in DM Activities in the State[20].

Institutions and resource people involved in the various disaster management activities are listed in Table 1.8.

Table-1.8.
List of institutions and resource people involved in the various disaster management activities.

1	Director, Disaster Management Cell, Uttarakhand Academy of Administration, Ardwell Camp, Mallital Nainital - 263001, Uttarakhand, India. Tel: 05942 - 235011/236068/236149 Fax: 05942 - 237642
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akw1954@gmail.com

1.8. References

1. Disaster Mitigation & Management Centre, Govt. of Uttarakhand, Dehradun.
2. National Disaster Management Guidelines, Management of Landslides and Snow Avalanches, National Disaster Management Authority, Government of India, 2009.
3. http://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html
4. http://en.wikipedia.org/wiki/Landslide_classification
5. http://pubs.usgs.gov/fs/2004/3072/images/Fig3grouping-2LG.jpg
6. http://www.iitk.ac.in/nicee/IITK-GSDMA/
7. Sah, M.P., Asthana, A.K.L. and Rawat, B.S., *Him. Geol.*, 2003, **24** (2), 87-101.
8. http://asc-india.org/seismi/seis-uttaranchal.htm
9. http://www.bis.org.in/other/quake.htm
10. SDMC, South Asia Disaster Report 2007. SARC Disaster Management Centre, New Delhi
11. http://www.unescap.org/ttdw/common/Meetings/TIS/EGM-Roadsafety-2011/Status/Countries/India-2010-Status.pdf
12. National Policy on Disaster Management, National Disaster Management Authority, Government of India, Ministry of Home Affairs, Government of India, 2009
13. State Level Programmes for Strengthening Disaster Management In India by Ministry of Home Affairs, GoI
14. Sharda, Y.P., Landslide Studies in India. *Glimpses of Geoscience Research in India, GSI,* 98-101
15. Disaster Management In India, Ministry of Home Affairs, Government of India by UNDP, 2011
16. National Policy on Disaster Management, National Disaster Management Authority, Government of India, Ministry of Home Affairs, Government of India, 2009
17. http://www.saarc-sadkn.org/countries/india/act.aspx
18. http://www.saarc-sadkn.org/countries/india/institution.aspx
19. http://dmmc.uk.gov.in
20. Directory of Institutions and Resource Persons, In Disaster Management, NIDM, Ministry of Home Affairs, Govt. of India.

Section V

HEALTH

Health Status

Chapter

ONE

HEALTH STATUS

(Sarita Khandka)

1.1. Introduction

Over the years of human development, it has been recognized that a healthy society can lead to overall growth and self fulfillment of the individuals. Therefore, health must take centre stage of all developmental agenda. The environment and the changes in it are also reflected in the health of the people. Therefore, review of the health status of the population is an integral part of any environmental report.

If we talk of the approach towards health, it has undergone various stages of change: from curative to preventive, preventive to social and social to community based, where the whole community is involved in the process. It has now been recognized that the community as a whole should be mobilized and involved in order to attain the goal of "Health for all" set up by WHO[1-2]. Public Health care originated from this concept and is considered the key strategy to achieve the goal. In India, we have a network of primary health centres and community health centers across the country which has seen a tremendous growth in the last 5 decades. Around 70% of the country's population in rural India gets the health care access through PHC system.

In Uttarakhand, the government has established network of hospitals in the form of sub-centers of health care, primary health care centers, combined health care centers and district hospitals and the basic medical facilities are provided by this network of hospitals throughout the state. Besides this the state government works in synchronous with center for implementing the various national programs of health within the state.

1.2. Health Indicators

The state has a population of 10116752 (census 2011), constituting 0.8% population of India. The literacy rate, female literacy rate and male literacy rate of the state is higher than the national values. The crude birth rate(CBR), crude death rate (CDR), total fertility rate (TFR) and Infant mortality rate(IMR) of the state are less than the national values. This is a clear indicator that the state's efforts towards population control and achieving replacement level of population has been bearing fruits. Immunization percentage of children below 23 months is also higher than the National value. However maternal mortality ratio is higher then the national value and percentage of institutional deliveries are also less than the

national average. Therefore these two areas need attention of the Health department of Uttarakhand. The Health indicators of the state and its comparison with National status is shown in Table 1.1.

1.3. Health Infrastructure

In order to provide benefit of the various programs started by the government, the delivery system is the utmost important requirement. In Uttarakhand there are total of 2593 government Allopathic hospital/dispensary/clinics, 545 government Ayurvedic and Yunani hospitals and clinics, 107 government Homeopathic hospitals/clinics/dispensaries and 4 medical colleges (two are government medical colleges). In terms of number of various health facilities, there are 1765 Sub-Centers (SCs), 239 Primary Health Centers (PHCs) and 55 Community Health Centers (CHCs) in the state. Their number is sufficient in the state and rather they are more than required. However, there is shortage of doctors, specialists, health workers, ANMs, laboratory technicians and nurses in the health department. Since Uttarakhand is a hill state and the population is scattered, the shortage of health workers in rural areas can become one of the major constraint in achieving the targets set for the various programs of the government. Therefore, the human resource development for taking care of the primary health of the people in rural areas should be emphasized in all planning and implementation projects.

It is evident from Table 1.2 and Table 1.3 that number of sub-centers, PHC and CHC are sufficient but there is a shortage of health workers. On calculation of availability of health workers and health facility per lakh population in each district of the state from district health action plan (2006-07) found that Pauri Garhwal has maximum number of government health facilities per lakh of population followed by Chamoli, Tehri Garhwal and Pithoragarh (Table 1.4 & 1.5)[5]. However, Chamoli has maximum number of health workers per lakh population followed by Uttarkashi, Rudraprayag, Tehri Garhwal and Pauri Garhwal. It has been observed from Table 1.4 that the plain districts of the state which are considered to be well equipped with the health facility and infrastructure, are very low on this scale. It seems that since these are the district having maximum population also, the number of health facilities and health workers per lakh population is low. Therefore, in contradiction

Table-1.1.
Health Indicators

Item	Uttarakhand	India
Population	10116752 (census 2011)	1210193422 (census 2011)
Population Density	189 (census 2011)	382 (census 2011)
sex ratio	963 (census 2011)	940 (census 2011)
Literacy rate	79.63 (census 2011)	74.04 (census 2011)
Female literacy	70.70 (census 2011)	65.46 (census 2011)
Male Literacy	88.33 (census 2011)	82.14 (census 2011)
Crude Birth Rate (CBR)	18.6 (Annual Health Survey 2011)	22.5 (SRS 2009)
Crude Death Rate (CDR)	6.6 (Annual Health Survey 2011)	7.3 (census 2011)
Total Fertility rate	2.6 (NFHS-3, 2005-06)	2.7 (SRS 2007)
Infant Mortality rate (IMR)	43 (census 2011)	50 (SRS 2007-09)
Maternal Mortality ratio	359 (SRS 2007-09)	212 (SRS 07-09)
Immunization (%)	62.9 (DLHS–3 (2007–08))	54.1 (DLHS–3 (2007–08)) provisional
Institutional delivery (%)	30.0 (DLHS–3 (2007–08))	47.0 (DLHS–3 (2007–08)) provisional

1.3.1. *Government Facility and Medical Colleges*

Table-1.2.
Status of Health Infrastructure[3]

Particulars	Required	In position	Shortfall
Sub-centre	1294	1765	-
Primary Health Centre	214	239	-
Community Health Centre	53	55	-
Multipurpose worker (Female)/ANM at Sub Centres & PHCs	2004	1903	101
Health Worker (Male) MPW(M) at Sub Centres	1765	616	1149
Health Assistant (Female)/LHV at PHCs	239	340	-
Health Assistant (Male) at PHCs	239	417	-
Doctor at PHCs	239	866	-
Obstetricians & Gynaecologists at CHCs	55	30	25
Physicians at CHCs	55	4	51
Paediatricians at CHCs	55	18	37
Total specialists at CHCs	220	67	153
Radiographers	55	30	25
Pharmacist	294	294	0
Laboratory Technicians	294	132	162
Nurse/Midwife	624	292	332
Total	**7699**	**7068**	**2035**

Table-1.3.
Health Institutions[4]

S. No.	Items		Statistics
(A)	State Allopathic Hospitals and Dispensaries		
	(i)	District Level Hospitals	12
	(ii)	District Female Hospitals	7
	(iii)	Base Hospitals	3
	(iv)	P.H.C./Additional P.H.C.	250
	(v)	Community Health Centres	55
	(vi)	State Allopathic Hospitals	322
	(vii)	Joint/ Women Hospitals	39
	(viii)	Tehsil/ Distt. Level Post Portem Centres	24
	(ix)	Health Posts	9
	(x)	Tuberculosis Hospitals/Clinics	18
	(xi)	Leprosy Hospitals	3
	(xii)	Beds in Govt. Hospitals	8075
(B)	Family Welfare Services		
	(i)	Women & Child Welfare Centres	2
	(ii)	Main Centres	84
	(iii)	Women & Child Welfare Sub-Centres	1765
(C)	Ayurvedic & Unani Hospitals		
	(i)	Ayurvedic Hospitals	540
	(ii)	Unani Hospitals	5
(D)	Homeopathic Hospitals/Dispensaries		107
(E)	Medical Colleges		2

District	Population (2011 census)	No. of health facilities	No. of Health workers	Health facility/ Lakh population	No. of Health workers/lakh population
Almora	621927	325	421	52.25693691	67.69283212
Bageshwar	259840	106	150	40.79433498	57.72783251
Chamoli	391114	222	725	56.76094438	185.367949
Champawat	259315	105	126	40.49129437	48.58955325
Dehradun	1698560	275	570	16.19018463	33.55783723
Haridwar	1927029	206	295	10.69003113	15.30853973
Nainital	955128	248	383	25.96510625	40.09933747
Pauri Garhwal	686527	413	572	60.15786706	83.31791758
Pithoragarh	485993	264	307	54.32177007	63.16963413
Rudraprayag	236857	115	217	48.55250214	91.61646056
Tehri Garhwal	616409	336	559	54.50926252	90.68654092
U.S. Nagar	1648367	226	436	13.71053898	26.45042033
Uttarkashi	329686	172	339	52.17085348	102.8251124

(Constructed from reference no. 5)

Table-1.4.
Status of health facility and health workers [5]

to the wide perception that the plain districts of the state are well equipped with health infrastructure, our report suggest that the plain districts of the state also need attention and widening of the health support system.

In order to further get insight related to availability of allopathic doctors per lakh of population in various districts of the state, we collected and constructed the data from the district health action plan (Table 1.5). Rudraprayag has maximum number of doctors per lakh population followed by Almora, Bageshwar and Tehri Garhwal. Haridwar has the minimum number of government doctors per lakh of population. Here also, it is found that the plain districts of the state are having less number of doctors per lakh of population compared to the hill districts.

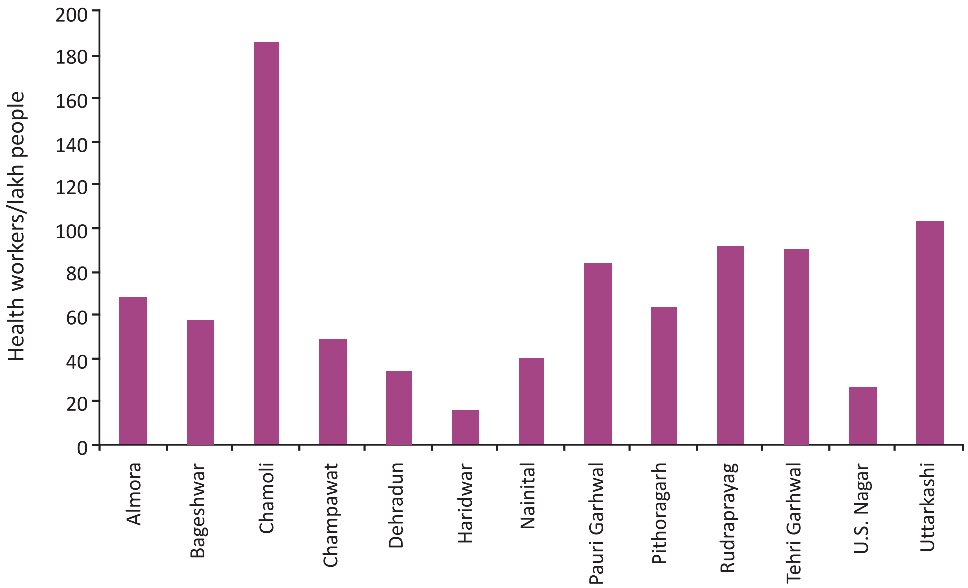


Fig-1.1.
Health workers per lakh population.

Table-1.5.
District wise distribution of Allopathic doctors per lakh population[5]

District	Population (2011 census)	No. of Doctors (2006-07)	Doctors/lakhs population
Almora	621927	88	14.14957061
Bageshwar	259840	36	13.8546798
Chamoli	391114	46	11.76127676
Champawat	259315	34	13.11146675
Dehradun	1698560	183	10.77383195
Haridwar	1927029	45	2.335200975
Nainital	955128	29	3.036242263
Pauri Garhwal	686527	69	10.05058796
Pithoragarh	485993	56	11.52279971
Rudraprayag	236857	34	14.35465281
Tehri Garhwal	616409	84	13.62731563
Udham Singh Nagar	1648367	123	7.461930505
Uttarkashi	329686	33	10.00952421

(Constructed from reference 5)

1.3.2. Private Facility

In addition to the health infrastructure of government, private sector also has good infrastructure in the state. However the private sector setup are predominantly located in plain areas of the state and the remote hill area of the state lacks the infrastructure of private sector. It is also important to note here that although the private sector has some facility for basic health care, the state is not able to attract the super speciality health care facilities for the people even in private sector. Upcoming AIIMS at Rishikesh, HIHT (Jolly Grant Hospital) and few other private hospitals like Max and Synergy Hospital may provide the people of Uttarakhand with the latest expertise of the fast advancing field of medical science.

Table 1.6. Provides the overview of the district wise private health care facility available in the state. The data has been compiled from the district health action plan of 13 districts of Uttarakhand for the year 2006-07, available at the site of Uttarakhand state Health and Family Welfare Society.[5]

1.4. National Programs

In order to develop a comprehensive strategy to combat the diseases in the country and cover the whole population, various programs are started at the National level. The aim of these programs is to adopt and provide uniform strategies either to eradicate or control the spread of the diseases.

1.4.1. National Rural Health Mission (NRHM)

Recognizing the importance of health in the process of economic and social development and improving the quality of life of our citizens, the Government of India has resolved to launch a very ambitious program - National Rural Health Mission (NRHM). The main component of the program is to provide decentralized management of health programs with convergence of all health programs under one umbrella. Thus NRHM has components of disease control programs, infrastructure development, strengthening of human resource and development of local body committees for decentralization of health management at rural level. The selection of ASHAs, ANMs, establishment of First Referral Units (FRUs) in district hospitals, Village Health Sanitation Committees (VHSCs), Rogi Kalyan Samitis (RKS), starting 24 x 7 health facilities, posting of AYUSH doctors in district hospitals, Janani Suraksha Yojna (JSY), Rashtriya Swasthya Bima Yojna (RSBY) and strengthening of sub-centers, PHCs, CHCs are some of the novel and first time approach initiated by the program. With these innovative networking, the program hopes to bring about some of the major architectural corrections in the basic health care delivery system and improvement in the availability of quality health care for the people.

Since health is a state subject, Ministry of health and family welfare, Government of India, is working in synchronous with states to implement the program agenda. In Uttarakhand, the mission was launched on 27th October 2005. In the state Maternal and child health care programs are taken on priority since the Maternal Mortality Ratio of the state is above the national value. Uttarakhand has performed better than the national average under immunization program (71.5%)[7] and disease control programs. The Infant Mortality Rate (43, census 2011) of the state is also less than the national average (50, SRS 2007-09). The areas where it is lacking behind are Anti Natal Care (ANC) and institutional deliveries. Therefore, Maternal Mortality Ratio (MMR) (359, SRS 2007 -09) of the state is more than the national average (212, SRS 07-09). While implementing the schemes, it has to be kept in mind that due to difficult geographic terrain and scattered population in hill regions, the percentage of institutional deliveries can be increased by proper back up from the local health workers working in the field, like ASHAs and ANMs.

The status of infrastructure, human resource developed in the state under NRHM is given in Table 1.7.

In addition to this, Urban Health Centres (UHCs) for the health services to urban slums, which have become an integral part of the developing economy in india, are also being established under NRHM. These centers help strengthening community-provider linkages through community mobilization and demand generation for primary reproductive and child health services. Table 1.8 provides the status of UHCs in four districts and the NGOs involved.

Table-1.6.
Private health facility[5]

District	Multi-Specialty Nursing Homes	Qualified Practitioners	Practitioners from AYUSH	Approved MTP centres	RMPs
Almora	6	16	73	NA	167
Bageshwar	2	10	3	NA	15
Chamoli	Nil	1	3	Nil	Nil
Champawat	06	16	73	NA	167
Dehradun	58	NA	247	NA	NA
Haridwar	2	NA	30	40	700-800
Nainital	3	NA	NA	NA	NA
Pauri Garhwal	NA	15	1	7	NA
Pithoragarh	5	25	4	NA	187
Rudraprayag	NA	NA	247	NA	NA
Tehri Garhwal	NA	NA	247	NA	NA
Udham Singh Nagar	NA	NA	NA	NA	NA
Uttarkashi	NA	27	15	NA	NA

(Constructed from reference no. 5)

Table-1.7.
NRHM achievements[8]

Component	Uttarakhand	India
Rogi Kalyan Samitis (RKS)	124	29223
ASHA	9873	7.49 Lakhs
ANM	177	46,690
Village Health and Sanitation Committees (VHSC)	14646	451,473
24 x 7 Health facilities	292	23520
First Referral Units	72	2,463
Mobile Medical Units under NRHM	17	1031 (NRHM, Meating people's health needs in partnership with states), Mins. Of health & family welfare
Sub-Centers til 2010	1765	146036
PHC till 2010 under NRHM	239	23458
CHC till 2010 under NRHM	55	4276
Doctors under NRHM		8624
Short fall of allopathic doctors under NRHM	-	10.3%
Specialist doctors under NRHM	0	2450
Increase of Pharmacist in CHC and PHC		3980
Increase of Laboratory Technician		2810
Nurses under NRHM	175	26793
AYUSH Doctors under NRHM	140	7692
Increase in Paramedical staff		14,490
Malaria mortality reduction rate (2006-08), 100%reduction by 2010 and elimination by 2012	-	45.23%
Kala-Azar reduction rate(2006-08), 100% reduction by 2010 and elimination by 2012	-	21.93%
Filaria/Microfilaria reduction rate-70% by 2010, 80% by 2012 and elimination by 2015	-	26.74%(2006-08)
Dengue reduction rate-50% by 2010 sustaining at that level till 2012	-	56.52%(2006-08)
Cataract operations increasing to 46 lakhs until 2012	-	Already being achieved every year
Leprosy prevalence rate- reduce from 1.8/10000 in 2005 to less than 1 per 10000 thereafter	achieved	Achieved in Dec. 2005 and maintained thereafter.
Tuberculosis – maintain 85% cure rate through out the mission period	achieved	87% cure rate has been maintained.

In order to attain the replacement level of Total Fertility Rate (TFR), family planning strategies and their implementation plays very important role. The country has seen a continuous decrease in fertility rate in last 20 years and remained stationary at 2.6 during 2008-09. Achievements under the family planning scheme in Uttarakhand is tabulated in Table 1.9. NRHM has been successful in addressing problems related to shortage of health workers by involving innovative methods like employing ANMs, ASHAs and others.

Name of City	No. of UHC's	Starting Month	NGO's Engaged
Haridwar	6	February 2010	2 (SPD-3, DGUS-3)
Haldwani	3	February 2010	1 (ASTHA SEWA SANSTHAN)
Dehradun	9	August 2010	2 (SPD-3, CMI & SAMARPAN-6)
Roorkee	3	August 2010	2 (DGUS-2, FRIENDS-1)
Total UHC's	21		

Table-1.8.
Status of Urban Health Programme[9]

Key Demographic Health Indicators and Relationship to Poverty and Wealth[6]

States	Life Expectancy at Birth (2002-06)	IMR (2008)	MMR (2004-06)	TFR (2008)	Poverty Level (2004-05)	Per capita NSDP 2008-09 (in ₹)	Per capita Health Expenditure (NHA-04-05)
Bihar	61.6	56	312	3.9	41.4	10206	513
Chhattisgarh	-	57	-	3.0	40.9	19521	772
Jharkhand	-	46	-	3.2	40.3	16294	500
Madhya Pradesh	58.0	70	335	3.3	38.3	13299*	789
Orissa	59.6	69	303	2.4	46.4	18212	902
Rajasthan	62.0	63	388	3.3	22.1	19708	761
Uttar Pradesh	60.0	67	440	3.8	32.8	12481	974
Uttarakhand	-	44	359	2.6	39.6	25114	818
Arunachal Pradesh	-	32	-	-	17.6	22475	1454
Assam	-	64	480	2.6	19.7	16272	774
Manipur	-	14	-	-	17.3	16508	673
Meghalaya	-	58	-	-	18.5	23069	894
Mizoram	-	37	-	-	12.6	20483	1133
Nagaland	-	26	-	-	19.0	17129*	819
Sikkim	-	33	-	-	20.1	30652	1507
Tripura	-	34	-	-	18.9	12481	1486
Himachal Pradesh	67.0	44	-	1.9	10.0	32343	1511
Jammu & Kashmir	-	49	-	2.2	5.4	17590*	1001
Andhra Pradesh	64.4	52	154	1.8	15.8	27262	1061
Goa	-	10	-	-	13.8	60232*	2298
Gujarat	64.1	50	160	2.5	16.8	31780*	953
Haryana	66.2	54	186	2.5	14.0	41896	1078
Karnataka	65.3	45	213	2.0	25.0	27385	830
Kerala	74.0	12	95	1.7	15.0	35457	2950
Maharashtra	67.2	33	130	2.0	30.7	33302*	1212
Punjab	69.4	41	192	1.9	8.4	33198	1359
Tamil Nadu	66.2	31	111	1.7	22.5	30652	1256
West Bengal	64.9	35	141	1.9	24.7	24720	1259
INDIA	63.5	53	254	2.6	27.5	25494	1201

Table-1.9.
Achievements of IFPS schemes in Uttarakhand[9].

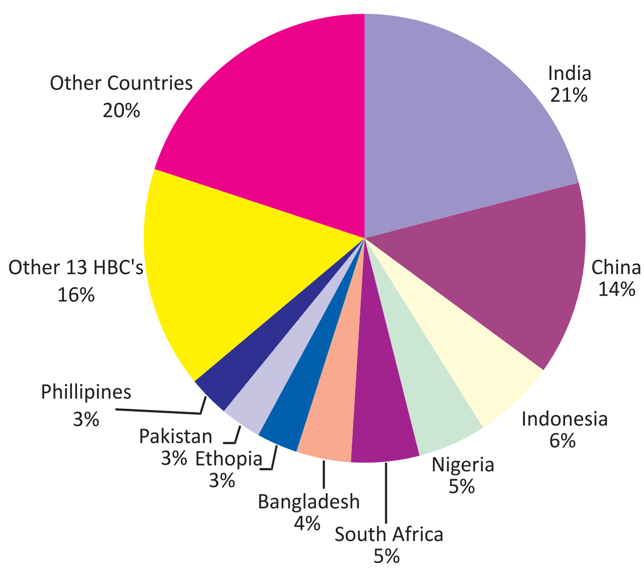
S.No.	Indicators	Achievements(no. of Beneficiaries)			
		2005-06	2006-07	2007-08	2008-09
1	Janani Suraksha Yojna	1,360	23,873	69,679	66,202
2	Total Sterilisation	34,980	32,767	34,799	NA
3	IUD Insertions	1,30,447	1,40,899	1,40,932	NA

1.4.2. Revised National TB Control Programme (RNTCP)

Tuberculosis (TB) is an infectious disease caused by the bacillus *Mycobacterium tuberculosis* and spreads through air by a person suffering from TB. It is one of the major public health problems not only in India but globally. In terms of percentage of mortality, TB is ranked seventh in the world accounting for 2.5% of all deaths as per the WHO global burden of disease estimates for the year 2004. As per the WHO report 2009, out of the annual global incidence of 9.4 million new TB cases, 2 million cases are in India, thus contributing to a fifth of the global burden of TB (Fig. 1.2). It is estimated that about 40% of Indian population is infected with TB bacillus.

The treatment regimens for TB are for long duration, therefore, a strategy is needed to keep the track of patients till the treatment is complete. For this WHO has launched "Stop TB Strategy". Under this strategy in India, Revised National TB Control Program (RNTCP) was initiated in 1997 and thus originated Directly Observed Treatment, Short-course (DOTS). After registering a good progress in the program, action has been initiated to address the challenges of Multi Drug Resistance –TB (MDR-TB) and TB-HIV co-infection. In Uttarakhand RNTCP has shown a good progress and the next phase of MDR-TB is also started recently. HIHT hospital, Jolly grant has been identified as a nodal site for DOTS PLUS treatment. The progress of RNTCP from 2003-2011 in the state and comparison with national status is shown in Table 1.10. The figure of annualized new smear positive case detection rate for Uttarakhand and India clearly shows that the state is behind the national detection rate and has to work towards increasing it (Fig 1.3). However, initially the success rate of smear positive patients was more than the national value but fell below the national value in 2008 (Fig 1.4). From 2009, an upward trend is again registered but it is still below the national mark.

Fig-1.2.
TB burden worldwide[10].



Year	Uttarakhand		India	
	Annualized New Smear +ve case detection rate in %	Success rate %	Annualized New Smear +ve case detection rate in %	Success rate in %
2000	-	-	56	84
2001	-	-	57	85
2002	-	-	60	86
2003	44	95	69	87
2004	61	92	64	87
2005	51	87	66	86
2006	52	88	66	86
2007	61	89	70	86
2008	57	86	72	87
2009	58	84	72	87
2010	56	85	-	-

Table-1.10.
Comparative data of RNTCP for Uttarakhand and India[11]

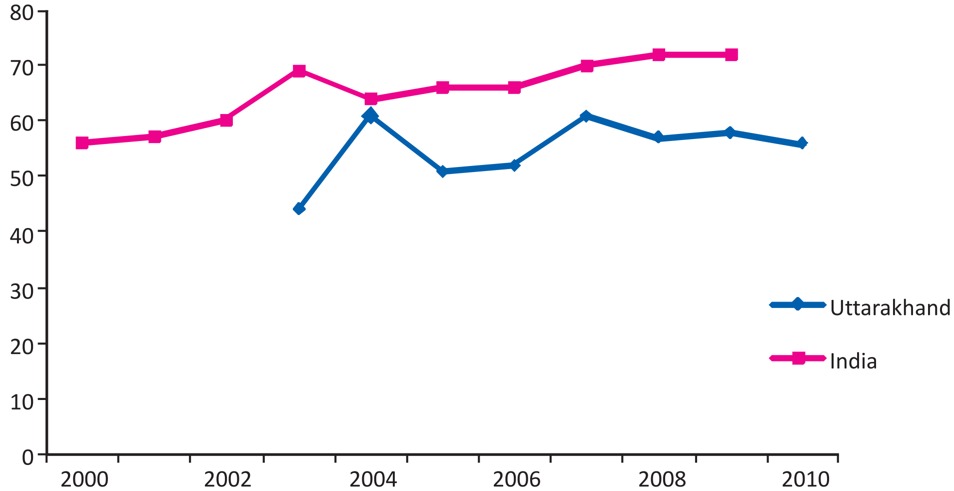


Fig-1.3.
Annualized New Smear +ve case detection rate

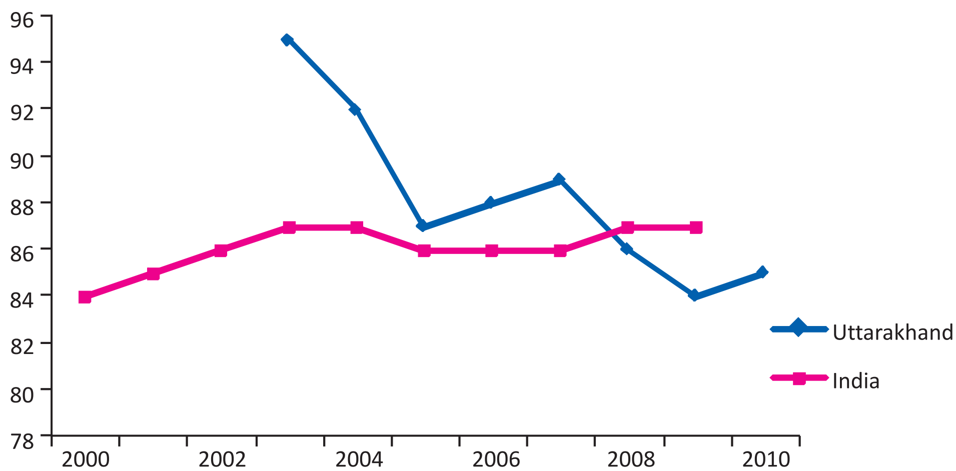


Fig-1.4.
Success rate of new smear positive patients

1.4.3. *Reproductive & Child Health (RCH)*

Since independence, the life expectancy has increased, IMR, MMR & TFR have shown a declining trend, but India is still far behind the Millennium goal of 2015. It has been suggested that literacy rate of female and GDP is closely linked with TFR & other health indicators. Not surprisingly, the states with poorest health indicators also have lowest GDP & economic wealth. The same correlation of health indicators with per capita health expenditure is found to hold good. If we consider the Hill states of India and compare their per capita health expenditure[6], Himachal Pradesh tops the list followed by Sikkim, Tripura and Arunachal Pradesh. The position of Uttarakhand is 9th. The same is shown in Fig. 1.5. However, on the same scale Uttarakhand tops the list among the newly formed states i.e. Uttarakhand, Chhattisgarh & Jharkhand.

IMR and MMR directly reflects the status and functioning of health system and therefore in the health policy it has been accorded high priority. RCH program of centre also encompass the same philosophy and approach (Fig. 1.6. & Table 1.11.). This program is started in a mission mode, with an objective of bridging the spatial variations and achieving the goals set out in the national policies and the state policies, by improving accessibility to quality services and strengthened infrastructure facilities, a comprehensive approach through partnerships with private and civil society organizations, increasing public health

Fig-1.5.
Per capita Health expenditure of Hill States[6]

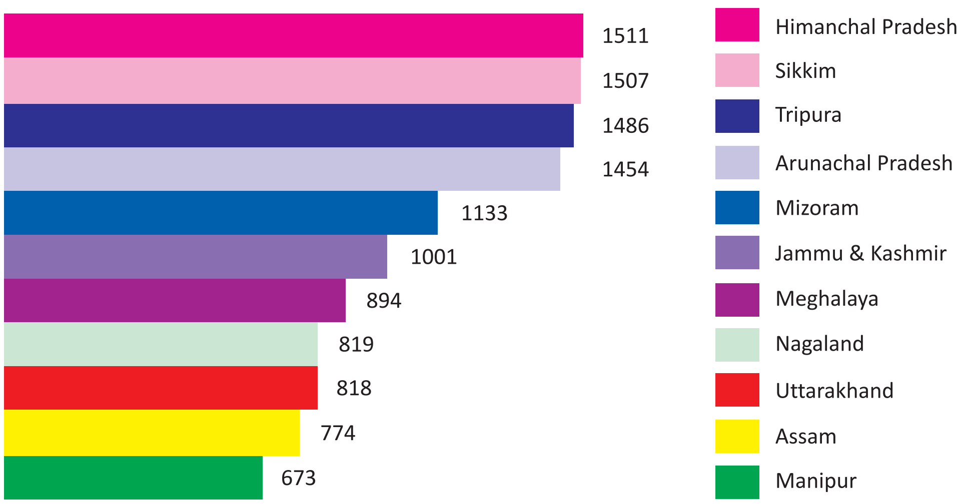


Fig-1.6.
Comparative fact sheet of RCH[12] in%

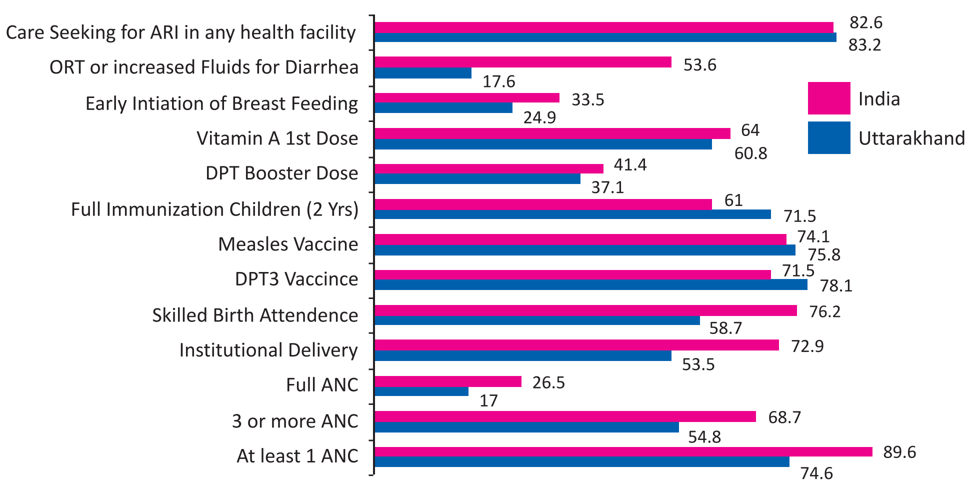


Table-1.11.
Vaccination status[4]

Indicator	2006-07	2007-08	2008-09	2009-10	2010-11(P)
BCG Coverage (%)	110.9	100%	100%	100%	100%
DPT-1 Coverage (%)	99.8	100%	100%	100%	100%
DPT-3 Coverage (%)	97.7	100%	100%	100%	100%
Districts with over 80% DPT-3 Coverage No. (%)	13 (100%)	100%	100%	100%	100%
Measles Coverage (%)	92.8	100%	100%	100%	100%
Vit A Coverage (% 2+ doses)	41.5	-	-	-	-
Districts with over 70% Vit A Coverage No. (%)	4 (30.8%)	-	-	-	-
Drop-out rate BCG – Measles (%)	8.1	-	-	-	-
Districts with under 15% BCG Measles Drop Out – No. (%)	-	-	-	-	-
Children fully vaccinated by 12 months of age (%)	92.8	-	-	-	-

investments, reducing gender discrimination and involving elected representatives and community at large.

The program strives to reduce IMR from present level to 30, MMR to 100/Lakh, TFR to 2.1 by 2015. For this RCH camps are considered effective tool for the state of Uttarakhand, as the population is sparse in remote and hill areas. It is proposed to organize one camp in every two months per block. However for thickly populated districts like Haridwar, Dehradun and U.S. Nagar there are proposals for organizing 12 camps per month. The camps provide ante-natal, post-natal checkups, TT vaccination, IFA distribution, RTI/STI treatment and services related to child health and family planning[4].

1.4.4. National Vector Borne Disease Control Programme (NVBDCP)

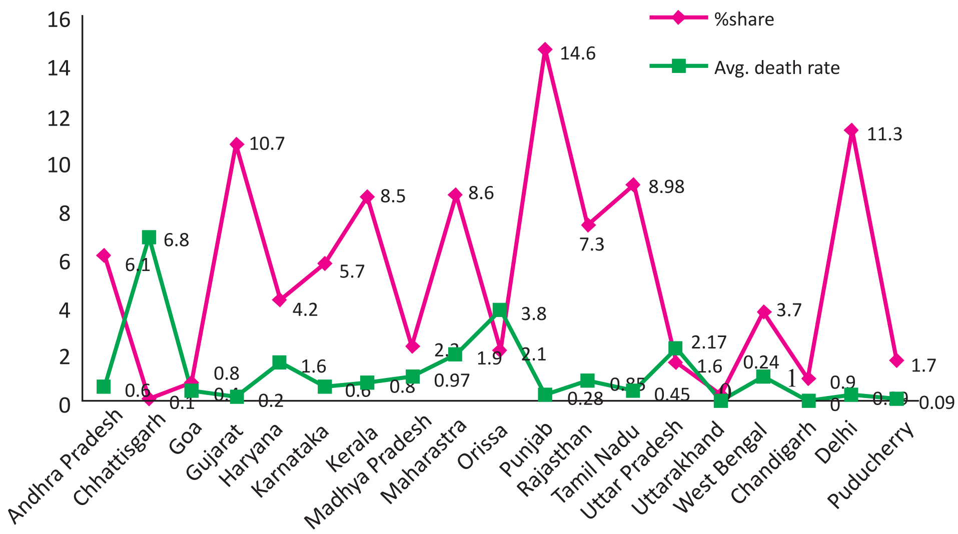
The National Vector Borne Disease Control Programme has been started as an initiative for prevention and control of the vector borne diseases i.e. Malaria, Dengue, Lymphatic Filariasis, Kala-azar, Japanese Encephalitis and Chikungunya in India. These are the diseases which many time spread alarmingly and can become an epidemic with serious threat to the life of people. In Uttarakhand, only 4 Districts i.e. Haridwar, Dehradun, Udham Singh Nagar & Nainital are in plains and the rest of the districts are in high altitude. Therefore, most of these diseases are found in these plain areas only and the hill districts doesn't face the wrath. The Figures 1.7-1.9 show the state wise prevalence and effect of these diseases in the Country. The project had a goal to reduce the mortality due to Malaria, Dengu and Japanese Encephalitis by 70% by the year 2011.

The status of vector born diseases in Uttarakhand is tabulated in Table 1.12. Among the four diseases tabulated below, Malaria is most prevalent followed by Dengue, Japanese Encephalitis and Kala-Azar. The average cases of Malaria in the state are 1297 per year with a mortality rate of 0.031 (calculated for the period of 2007-11 from reference 13). The state registered an average of 53 cases of Dengue per year in last three years with no mortality. Japanese Encephalitis and Kala-Azar both show a meager presence in the state with an average value of 4 and 1 respectively in the last five years with out any mortality.

Table-1.12.
Fact-sheet of Vector born diseases in Uttarakhand for last five years[13]

Disease	2007		2008		2009		2010		2011	
	cases	deaths	cases	deaths	cases	deaths	cases	deaths	cases	deaths
Dengue	0	0	20	0	0	0	178	0	68	0
Malaria	955	0	1106	0	1307	0	1855	0	1263	2
Japanese Encephalitis	0	0	12	0	0	0	7	0	0	0
Kala-Azar	2	0	0	0	2	0	1	0	0	0

Fig-1.7.
Dengue status in some major affected states



Comparison with the national status reveals that Uttarakhand ranks very low on the scale of number of cases and mortality due to these four diseases[13], which otherwise are major health problem. The results consolidate the point mentioned above regarding the hilly landscape of the state and hence less occurrence of these diseases. On the national level, Punjab followed by Delhi, Gujarat and Maharashtra witness the maximum cases of Dengue, but owing to the effective medical facility available, mortality rate is low (Fig. 1.7). However, in Chhattisgarh, Orissa and Uttar Pradesh, the number of cases are not high but the mortality rate is high. This is indicative of lack of infrastructure in these states to tackle the Dengue outbreak. In case of Malaria, Orissa followed by Jharkhand, Chhattisgarh, Assam and West Bengal are the states with maximum number of reported cases but the mortality rate is highest in north eastern states like Mizoram, Nagaland and Sikkim. In case of Japanese Encephalitis, skewed situation exist. Uttar Pradesh where maximum number of cases are registered, the mortality is not high but in states like Haryana, Maharashtra, Bihar, Assam and Nagaland the mortality rate is very high, surpassing Uttar Pradesh (Fig. 1.8). The states dominantly affected by Kala-Azar are Bihar, Jharkhand and West Bengal. However, mortality rates are low and other states like Gujarat and Sikkim have high mortality rates (Fig. 1.9). The fact-sheet of states provides an interesting picture that the states with history of these diseases are well equipped and are capable of fighting against them effectively and hence register low mortality rate. On the other hand, states without the history of these diseases fare badly and end up with high mortality rate due to lack of preparedness. From all above cases, it is inferred that these vector diseases can be handled effectively with proper infrastructure and integrated approach.

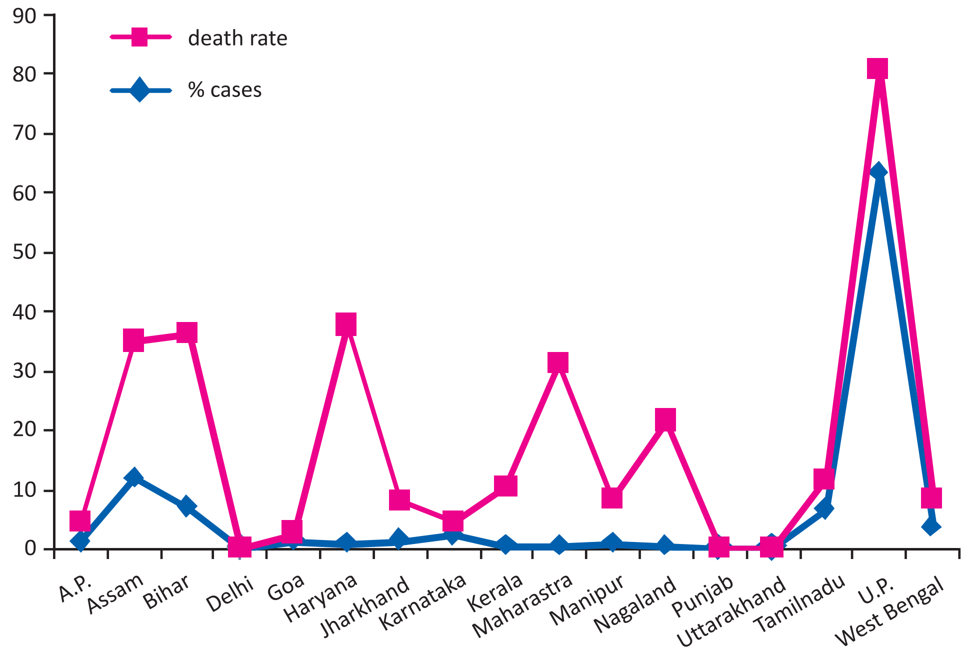


Fig-1.8.
Japanese Encephalitis status in some affected states

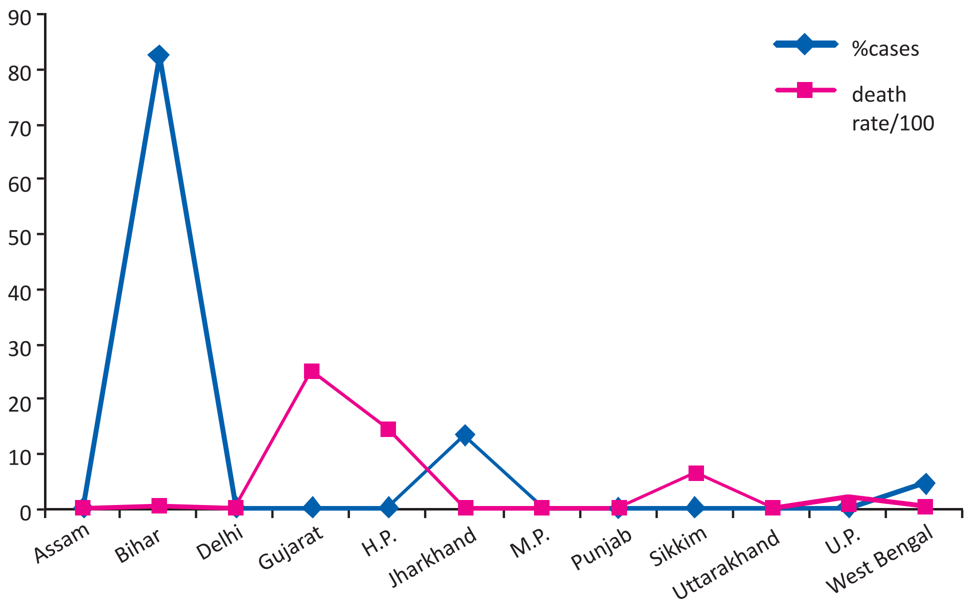


Fig-1.9.
Kala-Azar status in some affected states

1.4.5. National Programme for Control of Blindness (NPCB)

National Program for Control of Blindness was launched in the year 1976 with an aim of reducing the prevalence of blindness to 0.3% by 2020. In addition, the program aims to provide high quality eye care to the affected population, expand coverage of eye care services to the underserved areas, develop institutional capacity for eye care services and training personnel. This is a 100% centrally funded program.

As it is known that among the causes of blindness, Cataract is the main culprit (62.6%), followed by refractive error (19.7%), Glucoma (5.8%), surgical complications (1.2%), Corneal blindness (0.9%) and others. The cataract and corneal operations have been taken up under this program extensively[14]. The data of various states reveal that achievement rate for Cataract operations is maximum in Dadar and Nagar Haveli followed by Jammu and Kashmir and Goa. It is also found that seventeen states have achieved the target of cataract operations and beyond. 25 states have achieved upto 90% of the target. Uttarakhand is ranked 10th in this list (Fig. 1.10). Corneal operations have also been successfully done in the country with seven states having more than 100% of achievement rate and 17 states have either achieved 50% or more. Tripura tops the list with 242 % of corneal operations and Uttarakhand is at 22nd position with 17% of achievement rate (Fig. 1.11). The school students screening for refractive errors also is one of the important activities under this program which has been taken up in all states. The average detection rate of

Fig-1.10.
Achievement rate of Cataract operations (%)

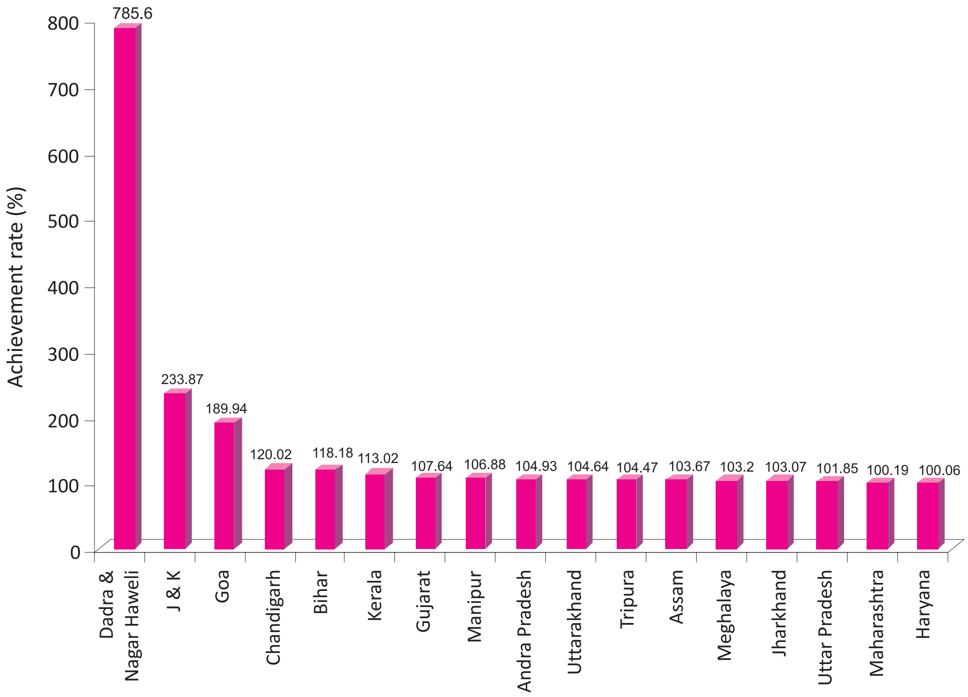
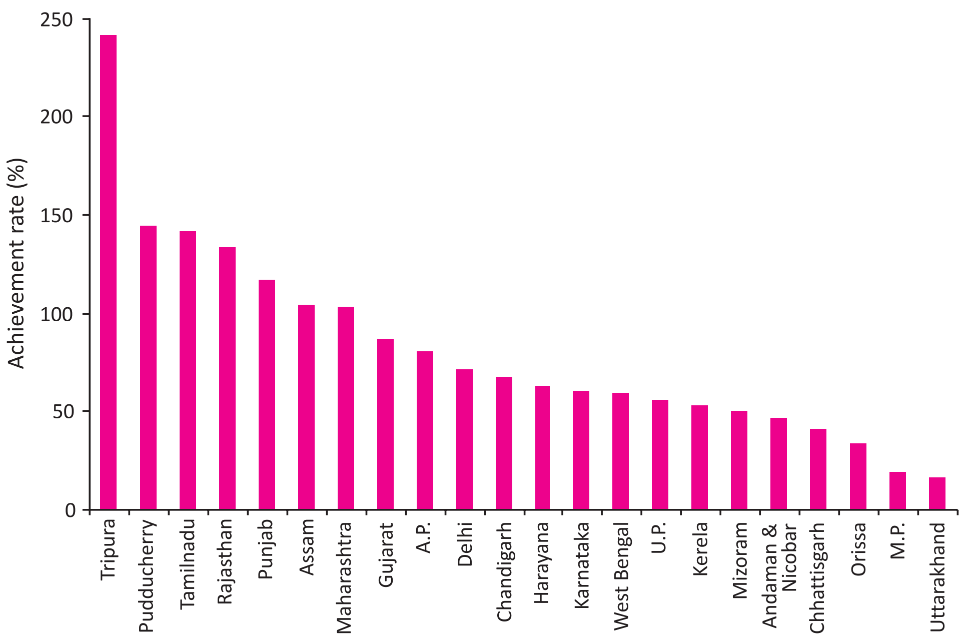


Fig-1.11.
Achievement rate of Cornea operations (%)



refractive error among students and percentage of distribution of free glasses is plotted in (Fig. 1.12). Meghalaya has the highest detection rate followed by jammu and Kashmir and Manipur. Gujarat has a small detection rate of 2% but the state provides around 90% of students detected with the refractive error with the glasses (Fig. 1.12). Uttarakhand's detection rate is only 4% and provides only 15% of the students with the glasses.

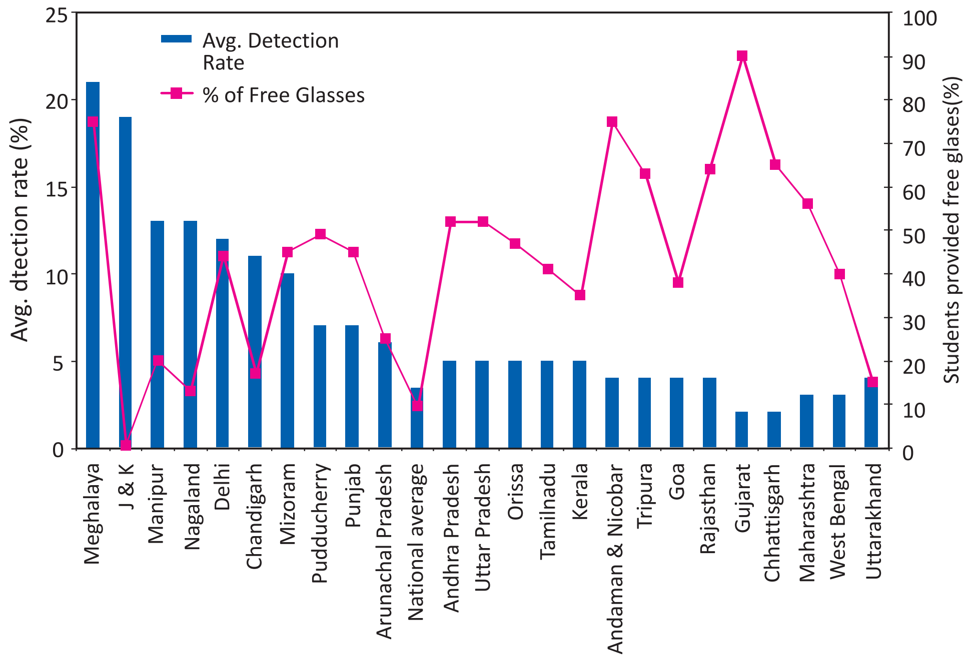


Fig-1.12.
School eye screening program

1.4.6. National Leprosy Eradication Programme (NLEP)

National Leprosy Eradication programme phase II is running from April 2001. The main objective of the project is to achieve the targets set by the GOI of bringing down the leprosy prevalence rate to 1 or below 1 per 10000 populations. The prevalence rate of leprosy in Uttarakhand state was 28.77/10000 in the year 1986, which has been brought down to 0.38/10000, as of March 2010 and hence the state has achieved the target of leprosy elimination program.

1.4.7. Rastriya Swasthya Bima Yojna (RSBY)

Rastriya Swasthya Bima Yojna has been launched by Ministry of Labour and Employment, Government of India in April 2008 to provide health insurance coverage for Below Poverty Line (BPL) families. The objective of the program is to provide protection to BPL households from financial liabilities arising out of health shocks that involve hospitalization. The scheme provides hospitalization coverage up to ₹ 30,000 for most of the diseases. The scheme will cover at most five members of BPL family including the head of the family, spouse and up to three dependents. The benefits of the scheme can be availed by registering with a meager amount of ₹ 30. In the year 2010-11 maternity benefits were also covered under RSBY Scheme. In Uttarakhand, RSBY Scheme was launched on 1st December 2008 and the Nodal Agency was Uttarakhand State Labour Department. However the scheme was transferred to Uttarakhand Health & Family Welfare Department in September 2009.

It has been now three years of implementation of the scheme and around 42% of BPL families of Uttarakhand are covered under the scheme of RSBY. Still there are 58% of BPL households which are not covered under the scheme. The districts having largest gap between RSBY card holders and no. of BPL families is Haridwar followed by Almora and Tehri (Fig. 1.13). Maximum number of claims till now have been made in Dehradun followed by Udham Singh Nagar. The same is true for the amount of insurance claimed with 89% of total amount claimed in Dehradun and Udham Singh Nagar itself[4] (Fig. 1.14).

Fig-1.13.
District wise RSBY card holders

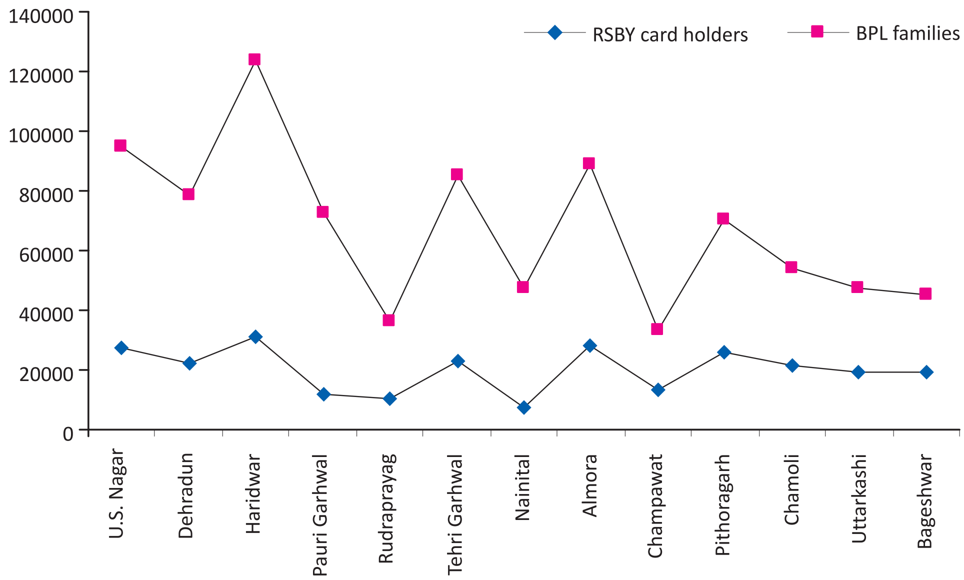
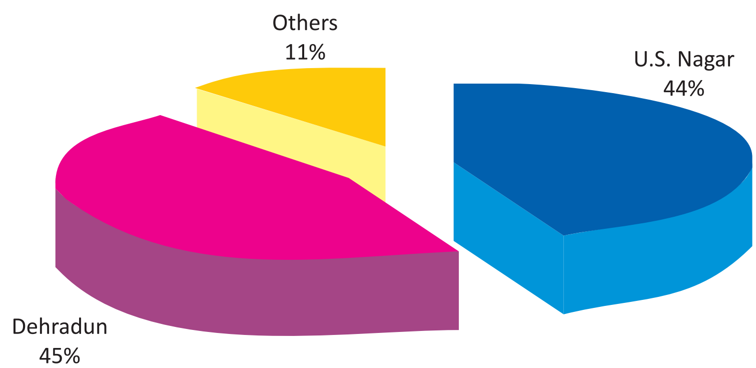


Fig-1.14.
Insurance amount claimed under RSBY



1.4.8. Integrated Disease Surveillance Project (IDSP)

The project aims to detect early warning signals of impending outbreak and help initiate an effective response in a timely manner. It is also expected to provide essential data to monitor progress of on going disease control programme and help allocate health resources more optimally. In Uttarakhand the Integrated Disease Surveillance Project was launched on 5th July 2005 with World Bank Assistance. The project covers communicable and non communicable disease. Table 1.13 shows the epidemic attended during 2009-10 under the IDSP.

1.4.9. AIDS

AIDS (Acquired Immuno Deficiency Syndrome) is caused by HIV (Human Immuno Deficiency Virus). The virus gradually destroys the immunity of the body to fight infections and certain cancers. The people suffering from AIDS may get life threatening diseases which ultimately become the cause of the death of the person. As per the World Health Organization (WHO)

Table-1.13.
Epidemic reported and attended 2009-10[4]

District	Disease	Affected/ Death
Rudraprayag	Food Poisoning	31/0
	PUO	5
	Chorine Gas Poisoning	60
	Dysentery	20/0
	Food Poisoning (Trichinolysis)	85
Nainital	Unknown Disease	4
	Influenza	1
	Jaundice	10
	Jaundice	13
	Food Poisoning	16
	PUO	125
Dehradun	Paratyphoid and Typoid	77
	Measles	6
	Dengue	00
	Measles	00
Haridwar	Chickenpox	25/0
	Measles	00
	Food Poisoning	1
	Chickenpox	19/0
	Acute Diarrhoeal Disease	30/0
	Diarrhoea	134
U.S. Nagar	Dog bite	60
	Chicken Pox	20
	Typhoid	35
Pithoragarh	Acute Diarrhoel Disease	21
	Diarrhoea	25
	Acute Diarrhoel Disease	16
	Jaundice	132
Bageshwar	Acute Diarrhoel Disease	20
Chamoli	Typhoid	13
	Chickenpox	14/0
Pauri Garhwal	Diarrhoea	134
	PUO	17
Almora	Acute Diarrhoel Disease	16
	Acute Diarrhoel Disease	24
	AC. Diarrhoel Disease	24/2
Uttarkashi	Acute Diarrhoel Disease	7
	Acute Diarrhoel Disease	11
	Acute Diarrhoel Disease	7

report "AIDS epidemic update-2009", there are 33.4 million people worldwide living with HIV/AIDS, with 2.7 million new HIV infections per year and 2.0 million annual deaths due to AIDS .

In order to combat the deadly spread of the HIV virus and provide necessary medical facility and counselling, the National AIDS Control Organisation (NACO) has established Uttarakhand State AIDS Control Society (USACS) in 2001. The society is working with the goal to halt and reverse the epidemic in the state through integration of prevention, care, treatment and support programs.

The society has established 48 Integrated Counselling and Testing Centers (ICTCs) (Fig. 1.15), ten Sexually Transmitted Infection (STI) centers and two Antiretroviral therapy (ART) centers in the state. Table 1.14 shows the number of HIV positive patients detected by the

Fig-1.15.
Distribution of ICTC centers in Uttarakhand[16]

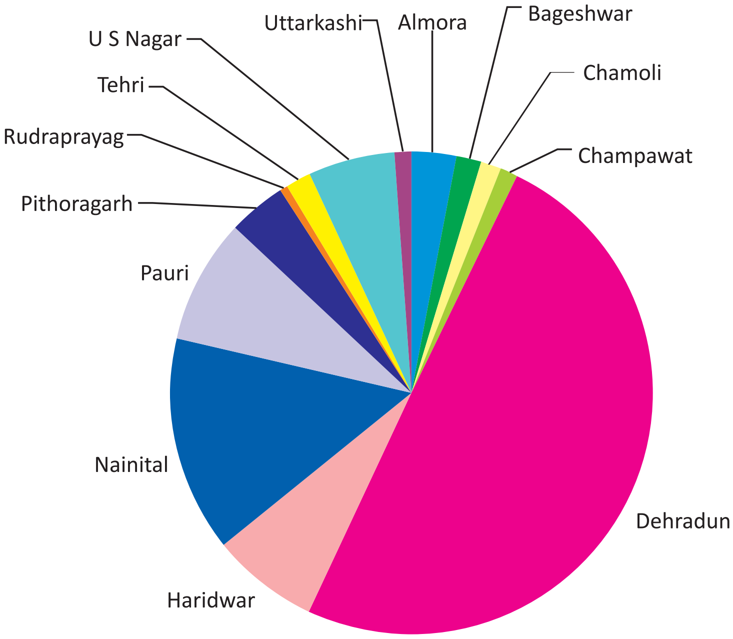


Table-1.14.
HIV status[15]

District	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Almora	0	3	5	5	6	8	20	28	17	17	109
Bageshwar	0	0	0	0	0	17	9	15	16	27	84
Chamoli	0	4	4	1	5	6	5	11	11	18	65
Champawat	0	0	2	6	3	4	10	6	10	16	57
Dehradun	15	46	74	122	177	262	268	290	343	329	1926
Haridwar	0	0	3	18	20	29	44	70	52	83	319
Nainital	8	22	28	30	38	74	64	104	180	145	693
Pauri Garhwal	0	0	5	14	24	40	70	53	51	49	306
Pithoragarh	0	2	1	4	14	29	13	36	32	22	153
Rudraprayag	0	0	0	0	0	0	14	2	23	27	66
Tehri Garhwal	0	0	1	5	8	2	15	13	10	10	64
U.S. Nagar	0	2	8	21	10	29	32	44	52	72	270
Uttarkashi	0	4	0	3	8	4	3	4	3	9	38
Total	23	83	131	229	313	504	567	676	800	824	4150

ICTC centers in Uttarakhand. The maximum number of HIV positive patients are detected at Dehradun (46%) followed by Nainital (16.7%), Haridwar (7.7%), Pauri Garhwal (7.4%) and Udham Singh Nagar (6.5%) in last ten years.

1.4.10. National Polio Surveillance Project

The goal of the Global Polio Eradication Initiative is to ensure that no child will ever again know the crippling effects of polio. Polio is a highly infectious disease caused by a virus poliovirus. It invades the nervous system and can cause total paralysis in a matter of hours. It can strike at any age, but affects mainly children under three. Polio is mainly passed through person-to-person (i.e., fecal-oral) contact, and infects persons who do not have immunity against the disease. There is no cure for polio, but the disease can be prevented by immunization with polio vaccine.

Since 1995, the Ministry of Health and Family Welfare, Government of India has been conducting intensive immunization and surveillance activities aimed at the complete elimination of poliovirus and paralytic polio. The National Polio Surveillance Project, which was launched in 1997, provides technical and logistic assistance to the GoI, and works closely with state governments and a broad array of partner agencies to achieve the goal of polio eradication in India.

Regions that have been certified as polio-free are the Americas (last case in 1991), Peru (Region certified polio-free in 1994), the Western Pacific Region (last case in 1997), Cambodia (Region certified in 2000), and the European Region (last case in 1998), Turkey (Region certified 2001). After intensive surveillance of Polio drive, India achieved the milestone of having no polio case for more than one year since 13 January 2011 and has been removed from the list of endemic countries[17].

Plasma Pyrolyser system for safe & eco-friendly disposal of bio-medical waste[21]

To deal with the growing bio-medical waste and hazards, Uttarakhand State council for Science & Technology (UCOST) with the financial support of Department of Science & Technology, New Delhi installed the Plasma Pyrolyser machine in the Doon Hospital at Dehradun to dispose off the biomedical waste generated in the hospital. The Pyrolyser was designed by Facilitation Centre for Industrial Plasma Technologies, Gujarat and it works on thermal plasma application i.e it integrates the thermo-chemical properties of plasma with the pyrolysis process to dispose the biomedical waste safely, in which, extreme high temperature of plasma arc in oxygen starved environment is used to completely decompose waste material into simple molecules.

The machine is successfully working in Doon hospital and data of waste disposal is being registered in the log book. In the last one year, 4070.5 Kg of hospital waste has been disposed off by the machine. The data reveals that maximum waste is generated during August month and minimum during July month.

Accomplishments

- ♦ Successful installation of the Plasma Pyrolyser machine in the Doon Hospital, Dehradun. Manpower is trained for proper handling and operationalizing of the machines of the Plasma Pyrolysis System. The training was conducted by the Facilitation Centre for Plasma Research, Dept. of Atomic Energy, Govt. of India.
- ♦ The data is collected regularly and maintained in the proper format (Log Sheets).
- ♦ The machine is successfully disposing the solid waste of the hospital.

1.5. Ayush

Ayurveda, Homoeopathy, Siddha, Unani, Yoga and Naturopathy offer a wide range of preventive, promotive and curative treatments that are both cost effective and efficacious. In addition to this the country has a vast existing infrastructure of these system of medicine but they are underutilized. Recognizing this, Government of India created Department of Indian Systems of Medicine and Homoeopathy (ISM & H) in 1995, which was renamed as Department of Ayurveda, Yoga, Naturopathy, Unani, Siddha and Homoeopathy (AYUSH). The main objective of this is to utilize the neglected health care facility and improve the educational standard, strengthen the existing research institution, promotion for cultivation of medicinal plants used in these systems and to evolve pharmacological standards of drugs in AYUSH. The status of AYUSH hospitals and colleges in Uttarakhand and comparison with country is given in Table 1.15.

1.6. Bio-Medical Waste

The density of population varies greatly in different parts of the State. The minimum density of population is 37 people per squire Kilometre in district Uttarkashi to 613 people per square Kilometer in district Haridwar. The State is divided into three zones, namely High Hills, Mid Hills and Foothills/Plains. With these wide variations, the quantity of waste generated in the healthcare facilities of the state is likely to vary from the standard norms prescribed for bio-medical waste generation. A bio-medical waste audit was conducted and submitted to Uttaranchal Health Systems Development Project, Dehradun[18]. As per the audit report the average value of the waste generated in various hospital is tabulated in Table 1.16.

The Yellow, Blue and Red bins are used for the disposal of the hospital waste and collected by the respective agency but there is no mean to dispose the waste by the hospitals itself except at Doon Hospital, Dehradun, where plasma Pyrolyser system is installed for disposal of Bio-medical waste.

1.7. Challenges and Key Issues

The geographical terrain with huge variation in the population density makes it difficult to have uniform access of the health facilities. Providing the health facilities in the remote areas of the state is a challenge. The overall development of hill regions with good facilities of education, connectivity by means of road and telephony can attract more qualified health workers in remote areas. Awareness regarding sanitation and safe drinking water is poor in remote areas. The policy adopted in NRHM for additional health workers is welcome step in the direction. Environment friendly waste disposal methods should be adopted by the hospitals of the state. Proper training for segregation of waste is required for the staff handling the bio-medical waste.

Table-1.15.
Comparison of AYUSH facility[18]

States/UT's	Branch of AYUSH	Hospitals	Beds	Clinics	Regd. Doctors	Colleges		Licensed Pharmacies
						UG	PG	
Uttarakhand	Ayurveda	7	319	467	2060	5	1	237
	Homeopathy	1	50	60		50	-	0
	Unani	2	8	3	91	-	-	3
	Amchi	-	-	3	-	--	--	-
India	Ayurveda	2434	43914	15131	478750	254	64	7494
	Homeopathy	240	9466	6732	246772	12371	1073	100
	Unani	258	4562	1127	51067	39	6	414
	Amchi	2	32	134	-	-	-	-

Table-1.16.
Status of Bio-medical waste generation[19]

Type of Health Facility	Gen Waste (Kg) per day/ Hospitals	% of Gen Waste	Total BMW (Kg) per day/ Hospitals	% of BMW
Combined Hospital	25.85	64%	12.8	36%
District Hospital	16.4	64%	9.75	36%
Community Health Centre	6.8	67.20%	2.82	32.80%
Primary Health Centre	1.1	52.80%	1.28	47.20%
Additional Primary Health Centre	0.55	61%	0.605	39%

UCOST sponsored study on enteric diseases[20]

Under a UCOST sponsored project a study has been conducted to find the hotspots of enteric diseases using GIS in Almora and Nainital district. During the study five enteric diseases were considered: (i) Diarrhoea (ii) Dysentery (iii) Hepatitis (iv) Typhoid (v) Gastro-enteritis.

After collecting the secondary data from Almora and Nainital district, the hotspots of enteric diseases in both the districts have been obtained with the help of SatScan software and they have been depicted in geographical maps using GIS software Arc View 9.3. It has been found that in Almora, hotspots are at Dwarahat, Tarikhet and Chaukhutiya blocks and in Nainital district, the hotspots are in Motahaldu block.

In the long run the results of the project can be used by public health department of the state to control enteric diseases and check the water pollution and immediate action can be taken by the local authorities in the hotspots of enteric diseases by providing better sanitation facilities and potable water to the residents of Almora and Nainital districts of Uttarakhand.

1.8. References

1. Beauscolcil E.G., Technical discussions at World health Assembly 1977. Geneva: 34th World Health Assembly 1981.
2. Lahariya, C., Khanna, R. and Nandan, D., ***Indian Journal of Pediatrics,*** 2010, 77, 283-290.
3. RHS Bulletin, M/O Health & F.W., GOI, March 2008.
4. http://ukhfws.org/
5. http://mohfw.nic.in/NRHM/DHAP/DHAP.htm#UT
6. Annual Report on Health, Ministry of Health and Family Welfare, Govt. of India, Sept. 2010.
7. UNICEF survey, 2009
8. NRHM, Meating people's health needs in partnership with states, The journey so far, 2005-2010, Ministry of health & family welfare.
9. http://ukhfws.org as on 21/02/2012.
10. WHO Report 2009: Global Tuberculosis Control; surveillance, Planning and Financing.
11. RNTCP ***Annual status report***, 2000-2010
12. National Fact Sheet: Coverage Evaluation Survey, UNICEF,2009.
13. http://nvbdcp.gov.in/
14. http://npcb.nic.in/
15. Office of Uttarakhand state AIDS control society.
16. http://www.uasacs.org/
17. http://www.npspindia.org/index.asp
18. http://indianmedicine.nic.in/index2.asp?slid=46&sublinkid=31&lang=1

19. Bio-medical waste audit report, AMS consulting private Ltd., submitted to Uttaranchal Health System Development Project, Chandan Nagar, Dehradun.

20. *Detection of geo-spatial hotspots for enteric diseases using GIS and spatial scan statistic and to study the effect of water pollution on physical and mental health of residence of Almora and Nainital district of Uttarakhand,* UCOST sponsored project.

21. Data Generation and Analysis of Emission from plasma system for safe & eco-friendly disposal of bio-medical and plastic waste at different locations across India (Plasma Pyrolyser System), UCOST coordinated project.

Section VI

INDUSTRY

Landscape of Industries

Chapter

ONE

LANDSCAPE OF INDUSTRIES

(Sarita Khandka and Manoj Kumar Singh)

1.1. Introduction

Around two hundred years back, the industrial revolution has brought a turning point in the ecology of the Earth and life style of human beings. In one hand if it has brought the economic prosperity, it also is the cause of the concerns related to environment degradation. After two hundred years of this revolution, concerns of climate change and human's relationship with the environment have received huge attention. The industries are formidable part of a country's economy and without it developmental activities will be difficult to progress therefore emphasis has been laid for ways of sustainable development. The present report will focus of the present scenario of industries in Uttarakhand, policies for industries, contribution of industries in the economy of the state, future of industries in the state and finally their environmental assessment.

When Uttarakhand came to existence in 2000 as a separate state, agriculture dominated the state and 64% of the area covered with forest. The state had few resources for up-liftment of its economy. The state was then known as "zero industry region". Banking on the strength of the state in terms of good connectivity, perfect location, cheap and abundant power and highly educated human resource, the state was able to develop the industrial infrastructure in a very short span of time. SIDCUL successfully developed Haridwar, Pantnagar, Selaqui industrial areas. All this had a direct effect on the state GDP with an increase of more than 9% from 2000 to 2007. During this period the industrial sector growth rate was 17.2%. Afterwards also the growth of GDP was upward with 33.9% in 2007-08. The unprecedented growth of industries in the state is due to cumulative effect of conducive environment for industries and favorable policies special promotional package. The growth of industry in the state has resulted in growth of GDP of the state, which is highest among the three newly formed states i.e. Uttarakhand, Jharkhand and Chhattisgarh.

1.2. Status of Industries

1.2.1. Heavy Industries

The state has 206 heavy industries in the state (till 2010) and has registered an increase of 318% in heavy industries after the formation of state[1]. The maximum heavy industries are registered in Udham Singh Nagar followed by Haridwar and Dehradun.

1.2.2. *Micro Small and Medium Enterprises (MSMEs)*

According to the newly enacted Micro, Small and Medium Enterprises Development Act 2006, which has come into effect from October 2, 2006, the enterprises are classified according to Table 1.1.

The state has 37,780 registered Micro, Small and Medium Enterprises (till 2010). The state registered an increase of 211% in MSMEs after the formation of state[1]. The table below shows the district wise distribution of MSMEs (Fig. 1.1 and Fig. 1.2) and heavy industries in the state[1]. The number of MSMEs are maximum in Haridwar followed by Dehradun, Udham Singh Nagar and Pauri Garhwal. Table 1.2 shows the distribution of MSMEs in various districts of Uttarakhand.

The investment of MSMEs in the state before and after creation is depicted in Table 1.3, which shows that the Haridwar and Udham Singh Nagar district has the highest investment in the state. The classification of MSMEs of three major industrial districts as per the Trademark classification of India is shown in Table 1.4.

Table 1.5 shows the survey of industries in Himalayan states of India. It reveals that among them, Uttarakhand industries employs maximum number of people and has maximum

Table-1.1.
Classification of MSMEs, according to Micro, Small and Medium Enterprises Development Act 2006.

Type of enterprise	Engaged in manufacture or production of goods	Engaged in providing or rendering of services
	Investment in plant and machinery	Investment in equipment
Micro enterprise	Does not exceed 25 Lakh rupees	Does not exceed 10 Lakh rupees
Small enterprise	More than 25 Lakh rupees, but does not exceed 5 Crore rupees	More than 10 Lakh rupees, but does not exceed 2 Crore rupees
Medium enterprise	More than 5 Crore rupees but does not exceed 10 Crore rupees	More than 2 Crore rupees but does not exceed 5 Crore rupees

Table-1.2.
Distribution of industries in the State.

District Name	No. of MSME Before Nov-2000	No. of MSME After Nov-2000 to Feb-2011	Total No. of MSME till Feb-2011	No. of Heavy industries till Feb-2011
Almora	904	1911	2815	Nil
Bageshwar	387	563	950	01
Chamoli	844	1423	2267	Nil
Champawat	147	600	747	Nil
Dehradun	2321	3239	5560	12
Haridwar	2533	3564	6097	75
Nainital	816	1665	2481	4
Pauri Garhwal	1720	2127	3847	02
Pithoragarh	534	1416	1950	Nil
Rudraprayag	394	676	1070	Nil
Tehri Garhwal	1025	1941	2966	Nil
U.S. Nagar	804	3133	3937	112
Uttarkashi	1734	1359	3093	Nil
Total	**14163**	**23617**	**37780**	**206**

Fig-1.1.
Distribution of Heavy industries in Uttarakhand.

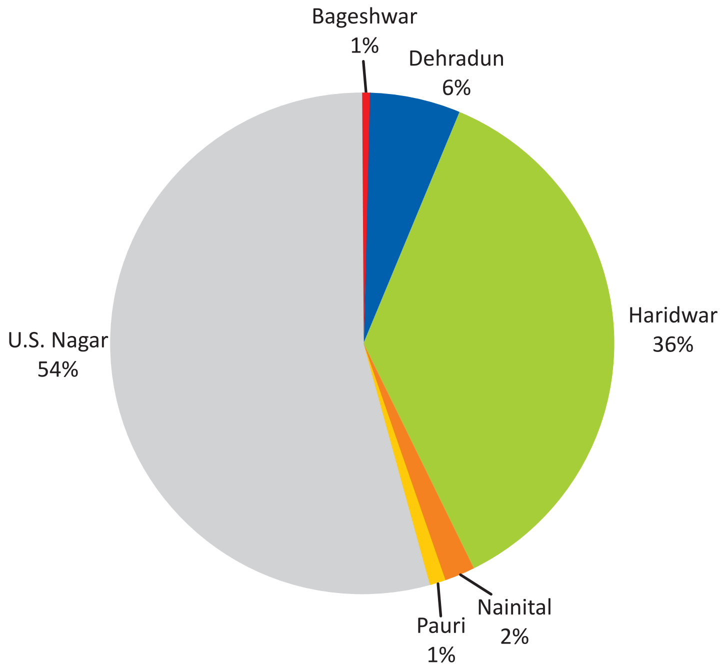
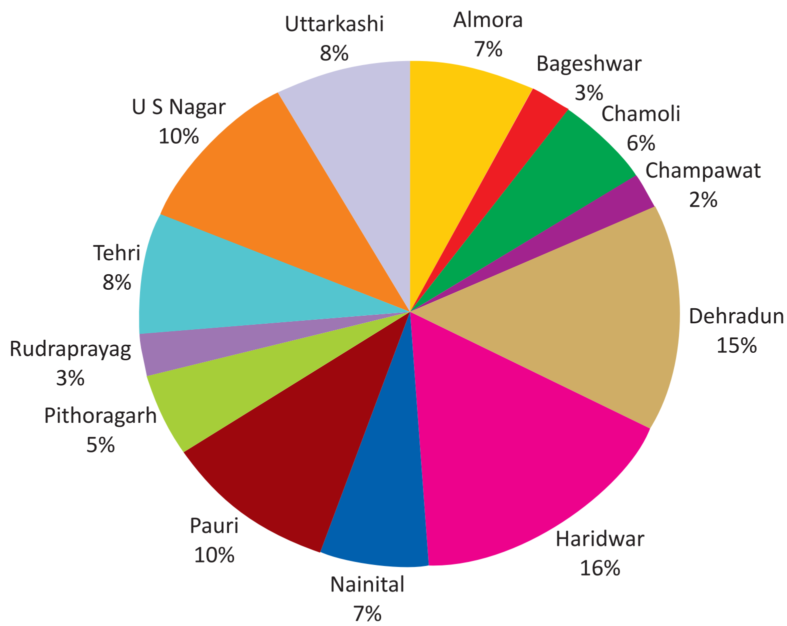


Fig-1.2.
Distribution of MSMEs in Uttarakhand.



number of factories. As per the Annual survey of industries (2008-09), Tamilnadu (16.87%) has the maximum share of factories followed by Maharashtra (13.17%), Andhra Pradesh (10.8%). In this list Uttarakhand is ranked at 17th position. Since after its inception in 2000, the state registered an unprecedented increase in industries in a short span of 5 years, the resulting environmental footprints also needs to be examined and necessary action for sustainable development should be taken.

1.3. Industrial Policies

The industrial policy adopted by the state after receiving special category state status in 2003 (New industrial policy 2003) is for encouraging Industrial Development in Uttarakhand and

Table-1.3.
Investment in MSMEs

District Name	Before Nov-2000		After Nov-2000 to Feb-2011		Total up to Feb-2011	
	No. of MSME	Investment (in Crore)	No. of MSME	Investment (in Crore)	No. of MSME	Investment (in Crore)
Almora	904	17.78	1911	17.72	2815	35
Bageshwar	387	2.04	563	8.54	950	10.58
Chamoli	844	5.45	1423	26.54	2267	31.99
Champawat	147	4.95	600	10.25	747	15.20
Dehradun	2321	88.01	3239	645.82	5560	733.83
Haridwar	2533	123.51	3564	2387.14	6097	2510.65
Nainital	816	158.36	1665	144.23	2481	302.59
Pauri Garhwal	1720	28.23	2127	97.02	3847	125.41
Pithoragarh	534	5.85	1416	19.08	1950	24.93
Rudraprayag	394	7.20	676	11.75	1070	18.95
Tehri Garhwal	1025	14.44	1941	50.26	2966	64.70
U.S. Nagar	804	233.71	3133	2072.14	3937	2305.85
Uttarkashi	1734	10.60	1359	18.66	3093	29.26
	14163	**700.29**	**23617**	**5508.65**	**37780**	**6208.94**

Table-1.4.
Classification of MSMEs[3]

Class	Haridwar	Dehradun	U S Nagar	Total
Class 1. Chemical used in industry, photography, agriculture	0	16	7	23
Class 2. Paints, varnishes, lacquers	18	9	24	51
Class 3. Soaps; perfumery, essential oils, cosmetics, hair lotions, dentifrices	0	21	29	50
Class 5. Pharmaceutical	244	93	52	389
Class 6. Common metals and their alloys; metal building materials;	198	74	178	450
Class 7. Machines and machine tools; motors and engines (except for land vehicles	21	4	44	69
Class 9. Scientific, cinematographic, optical, weighing, measuring, signalling, checking.	16	80	81	177
Class 11. Electrical & Electronics	431	129	193	753
Class 12. Vehicles; apparatus for locomotion by land, air or water	120	38	19	177
Class 14. Jewellery, precious stones; chronometric instruments	16	25	19	60
Class 15. Musical instruments	1	14	6	21
Class 16. Stationary & Office equipment	72	131	141	344
Class 17. Rubber, packing, stopping and insulating materials; flexible pipes, not of metal	18	51	23	92
Class 18. Leather and imitations of leather	36	7	2	45

Class	Haridwar	Dehradun	U S Nagar	Total
Class 19. Building materials	20	68	69	157
Class 20. Furniture, mirrors, picture frames;	162	185	88	435
Class 21. Household or kitchen utensils	235	5	3	243
Class 23. Yarns and threads, for textile use	0	6	14	20
Class 25. Clothing, footwear, headgear	89	406	85	580
Class 27. Carpets, rugs, mats and matting	131	34	26	191
Class 29. Edible Oils	0	0	3	3
Class 30. Food Products	173	214	150	537
Class 31. Agricultural, horticultural and forestry	3	14	78	95
Class 33. Alcoholic beverages(except beers)	1	3	1	5
Class 34. Tobacco, smokers' articles, matches	1	2	1	4
Class 37. Building construction; repair; installation services.	871	764	404	2039
Class 38. Telecommunications.	110	30	34	174
Class 39. Transport; packaging and storage of goods; travel	302	5	52	359
Class 42. Computer hardware and software Services.	83	307	125	515
Class 43. Services for providing food and drink; temporary accommodation	167	29	672	868
Class 44. Medical services and beauty care.	101	134	43	278

Table-1.5.
State of Industries in the IHR. (Values in Lakhs, others in Numbers)

Item	All India	J & K	HP	UK	Nagaland	Manipur	Tripura	Meghalaya
Number of Factories	129074	342	530	679	120	45	269	47
Fixed Capital	47333140	38189	571383	218176	2768	579	4966	10691
Working Capital	11923101	18704	157138	89458	2835	246	6340	7647
Invested Capital	67959853	66566	697916	416974	6449	804	11805	15674
Outstanding Loans	28977564	36405	467984	84016	3835	415	4831	6278
Number of Workers	6086908	21993	27636	27592	2356	1090	13105	1773
Total Persons Engaged	7870081	26952	36753	41561	2802	1231	14508	2228
Wages to Workers	3047777	8562	12261	23868	401	182	2008	496
Total Emoluments	**5833675**	**12897**	**28170**	**46881**	**584**	**218**	**2701**	**919**

to offset the constraints that hampered this process. In light of this the aim of the policy is to provide a comprehensive framework to enable a facilitating, investor friendly environment for ensuring rapid and sustainable industrial development in Uttarakhand and, through this, to generate additional employment opportunities and to bring about a significant increase in the State Domestic Product and eventual widening of the resource base of the state.

A special integrated industrial promotion policy 2008, for hill and remote areas of Uttarakhand is also adopted by the state. The period of the policy is from 1st April 2008 to 31st March 2018[1]. The main objective of this policy is to accelerate the pace of industrial development in remote and backward hill region. The aim is to provide employment opportunities for the local people of the remote and hill areas so that the economic upliftment of the areas can be achieved. This will also have impact on the migration of the people from the hill and remote areas. In this policy following are the industrial activities identified in the manufacturing and service sectors :

1. The Manufacturing Industries classified under Green and Orange Categories which are of non-polluting in nature
2. The industrial activities included in the Thrust Industries declared by Government of India under the Special Industrial Promotion Package for the States.
3. The industrial activities having the status of Industry declared by the State Government such as the poultry farming and tourism
4. The following industrial activities are included in the Service Sector and other sector industries declared under the Special Package Scheme 2007 for the North Eastern States;
   (a) Service Sector-
      i) Hotel, adventurous and leisure sports including the ropeways
      ii) Medical and health services in the nature of Nursing homes
      iii) Vocational training institutes such as institutes of hotel management, catering and food craft, and entrepreneurship development training, nursing and paramedical civil aviation related training, fashion designing, and industrial and skill development training.
   b) Bio-technology Industry
5. Protected Agriculture and Poly House, cold storage and like activities
6. Petrol Diesel pumping and filling, gas go-downs

The areas which will be benefited from the policy are:

Category- A

The remote hill and border districts of the State including the newly created districts comprising of the hill territories of the district Uttarkashi, Pithoragarh, Chamoli, Champawat and Rudraprayag.

Category- B

The territories of district Pauri Garhwal, Tehri, Almora and Bageshwar including the Development Blocks forming the hill areas in district Dehradun and Nainital except the territories comprising the Doiwala, Sahaspur and Raipur Blocks in district Dehradun and the territories comprising the Haldwani and Ram Nagar Blocks in district Nainital.

1.3.1. Fiscal Incentives to new Industrial Units and existing units

a) New industrial units and existing industrial units on their substantial expansion, set up in Growth Centres, Industrial Infrastructure Development Centres (IIDCs), Industrial Estates, Export Processing Zones, Theme Parks (Food Processing Parks, Software Technology Parks, etc.) and other areas as notified from time to time by the Central Government, are entitled to :

- ✦ 100% (hundred percent) outright excise duty exemption for a period of 10 years from the date of commencement of commercial production.
- ✦ 100% income tax exemption for initial period of five years and thereafter 30% for companies and 25% for other than companies for a further period of five years for the entire states of Uttarakhand and Himachal Pradesh from the date of commencement of commercial production.

b) All New industries in the notified location would be eligible for capital investment subsidy @ 15% of their investment in plant & machinery, subject to a ceiling of ₹ 30 Lakhs. The existing units will also be entitled to this subsidy on their substantial expansion, as defined.

c) Thrust Sector Industries are entitled to similar concessions as mentioned in (a) & (b) above in the entire state of Uttarakhand without any area restrictions.

1.3.2. Schemes for Small Industries

1.3.2.1. Deen dayal Hathkargha Protsahan Yojna and other incentives of Ministry of Textiles

The funding pattern between Government of India and the States is 50:50 to 90:10 under this Scheme.

1.3.2.2. Ministry of Food Processing Industries

It include Uttarakhand in difficult areas category and all schemes thereof are applicable to the state.

1.3.2.3. Pradhan Mantri Rozgar Yojana (PMRY)

Ministry of Agro & Rural Industries would provide for the state relaxation under PMRY with respect to Age (i.e. 18-40 years from 18-35 years) and Subsidy (@ 15% of the project cost subject to a ceiling of ₹ 15,000/- per entrepreneur).

1.3.2.4. Uttarakhand Woolen Scheme or Uttarakhand Woolen Bank

The main aim of this scheme is to increase the woolen business and to create the employment in the rural & hilly areas of Uttarakhand. The headquarter of the woolen bank

General Standards For Discharge Of Environmental Pollutants (Effluents)[1,4]

Parameter	Inland Surface Water	Public Sewers	Land for Irrigation
Suspended solids mg/l, max	100	600	200
Particle size of suspended solids	Shall pass 850 micron IS Sieve	-	-
pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
Temperature	Shall not exceed 5^0C above the receiving water temperature		
Oil and grease, mg/l max,	10	20	10
Total residual chlorine, mg/l max	1.0	-	-
Ammonical nitrogen (as N), mg/l, max	50	50	-
Total kjeldahl nitrogen (as N); mg/l, max, mg/l, max	100	-	-
Free ammonia (as NH_3), mg/l, max	5.0	-	-
Biochemical oxygen demand (3 days at 27^0C), mg/l, max	30	350	100
Chemical oxygen demand, mg/l, max	250	-	-
Arsenic (as As)	0.2	0.2	0.2
Mercury (As Hg), mg/l, max	0.01	0.01	-
Lead (As Pb), mg/l, max	0.1	1.0	-
Cadmium (As Cd), mg/l, max	2.0	1.0	-
Hexavalent chro-mium (As Cr + 6), mg/l, max	0.1	2.0	-
Total chromium (As Cr), mg/l, max	2.0	2.0	-
Copper (As Cu), mg/l, max	3.0	3.0	-
Zinc (As Zn), mg/l, max	5.0	15	-
Selenium (as Se)	0.05	0.05	-
Nickel (As Ni), mg/l, max	3.0	3.0	-
Cyanide (As CN), mg/l, max	0.2	2.0	0.2
Fluoride (As F), mg/l, max	2.0	15	-
Dissolved phos- phates (as P), mg/l, max	5.0	-	-
Sulphide (As S), mg/l, max	2.0	-	-
Phenolic compounds (as C_6H_5OH) mg/l, max	1.0	5.0	-
Radioactive materials: (a) Alpha emitters micro curie mg/l, max (b) Beta emittermicro curie, mg/l	10 -7 10 -6	10 -7 10 -6	10 -8 10 -7
Bio-assay test	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent
Manganese	2 mg/l	2 mg/l	-
Iron (as Fe)	3 mg/l	3 mg/l	-
Vanadium (as V)	0.2 mg/l	0.2 mg/l	-
Nitrate Nitrogen	10 mg/l	-	-

Wastewater Generation Standards[1,4]

Industry	Quantum
Integrated Iron and Steel	16 m^3/tonne of finished steel
Sugar	0.4 m^3/tonne of cane crushed
Pulp & Paper Industries (a) Large Pulp and Paper (i) Pulp & Paper (ii) Rayon Grade Pulp (b) Small Pulp & Paper (i) Agro-Residue based (ii) Waste Paper based	 175 m^3/tonne of paper produced 150 m^3/tonne of paper 150 m^3/tonne of paper produced 50 m^3/tonne of paper produced
Fermentation Industries (a) Maltry (b) Brewer (c) Distillery	 3.5 m^3/tonne of grain processed 0.25 m^3/KL of beer produced 12 m^3/KL of alcohol produced
Caustic Soda (a) Membrane Cell process (b) Mercury Cell process	 1 m^3/tonne of caustic soda produced excluding cooling tower blowdown 4 m^3/tonne of caustic soda produced (mercury bearing). 10% below down permitted for cooling tower.
Textile, Industries: Man-made fibre (i) Nylon & Polyester (ii) Viscose Staple Fibre (iii) Viscose Filament Yarn	 120 m^3/tonne of fibre produced 150 m^3/tonne of product 500 m^3/tonne of product
Tanneries	28 m^3/tonne of raw hide
Starch Glucose and related products	8 m^3/tonne of maize crushed
Dairy	3 m^3/kl of Milk
Natural rubber processing industry fertilizer (a) Straight nitrogenous fertiliser (b) Straight phosphatic fertilizer (SSP & TSP) excluding manufacture of any acid (c) Complex Fertilizer	4 m^3/tonne of rubber
Biochemical oxygen demand (3 days at 27°C), mg/l, max (a) Straight nitrogenous fertilizer (b) Straight phosphatic fertilizer (SSP & TSP) excluding manufacture of any acid (c) Complex Fertilizer	 5 m^3/tonne of urea or equivalent produced 0.5 m^3/tonne of SSP/TSP Standards of nitrogenous and phospathic fertilizers are applicable depending on the primary product

Environmental Impact Assessment Study of Sidcul Integrated Industrial Estate – Pantnagar[5]

UCOST, Dehradun sanctioned a project to G.B. Pant University of Agriculture & Technology, Pantnagar (U.S. Nagar) regarding Environmental Impact Assessment Study of SIDCUL integrated industrial estate, Pantnagar. The study reveals that the ambient air quality at various locations is deteriorating. The first year study of monitoring locations inside the industrial estate reveals that, SO_2 and NO_2 concentrations are lower than the annual permissible limit of industrial zone. Following are the outcome of the study[5] :

- Maximum concentration of SO_2 & NO_2 is found to be 36.5 µg/m^3 and 35.0g/m^3, respectively and average concentrations of SO_2 & NO_2 are lesser than the annual prescribed permissible limit for industrial zone.
- Maximum concentration of SPM and RPM is 372.7 µg/m^3 and 198.4 µg/m^3, respectively. Average concentration of SPM is also less than the annual permissible limit prescribed for industrial area (360 µg/m^3), but average RPM concentration exceeds annual industrial permissible limit (60g/m^3).
- Observations reveal that level of monitored air pollutants in surrounding areas are increasing with time.
- Water quality (surface and ground water samples) are found with significant pollution loads.
- Surface water reveals higher BOD & COD values in winter months at most of the sampling locations.
- Common Effluent Treatment Plant (CETP) is non- functioning. There is no official dumping sites for solid waste disposal inside the industrial estate. Most of industries dumpe their waste material within their premises.
- In case of Shantipuri, annual average COD concentrations are found to increase from 4400 to 5200 mg/l. At sampling location of Kichha Dam, the annual average concentrations are found between 3254 to 4320 mg/l.
- Concentration of sulfate is found alarming both in case with ground and surface water samples.
- In most of the sampling locations, concentrations of Phosphate was found to be increasing gradually from year 2007 onwards and were in a range of 1 to 15 mg/l.
- Both surface and ground water samples are also found highly contaminated with heavy metals especially with Fluoride, Lead, Copper and Cadmium over the baseline data collection period.
- During the study period traffic densities have been found to increase with annual growth rate of 86.5%.
- The study period (2005-2011) revealed the consumptions of diesel and gasoline increased to 80% and 89%, respectively

will be at Almora and its sub - center will be at Srinagar and Chamba. The main aim of the woolen bank is to provide the wool to the weavers in time.

1.3.3. Bunkar Schemes

1.3.3.1. Integrated Handicraft Development Scheme

Govt. of India started Integrated Handicraft Development Scheme to help the weavers (Bunkars) to provide different facilities. The financial help to the Bunkars is provided under this scheme under following component:

- Formation of self-help group
- Setting of Yarn Depots
- Design Development
- Common facility Center/ Dye House
- Publicity & Marketing

- Basic Inputs
- Skill up- Graduation
- Construction of Workshed

There are Six Handicraft Clusters registered in the state:

1. Chinka, Chamoli
2. Manglor, Haridwar
3. Dunda, Uttarakhashi
4. Munsyari, Pithoragarh
5. Dharchula, Pithoragarh
6. Kalasi, Dehradun

1.3.3.1. Health Insurance Scheme

This Health Scheme is for Bunkars and their families (upto 4 Members) provided by Govt. of India. Under the scheme 15000 Yearly health Insurance is provided to the Bunkers according to following share:

Govt. of India Share	:	₹ 631.19
State Govt. Share	:	₹ 89.80
Bunkar Share	:	₹ 50.00
Total	:	₹ 770.99

1.3.3.2. Mahatma Gandhi Bunkar Yojana

Govt. of India and Life Corporation of India Jointly launched an Insurance Scheme for Bunkars. A premium of ₹ 330 per person is deposited annually as per the following share:

Govt. of India Share	:	₹ 150.00
State Govt. Share	:	₹ 80.00
Bunkar Share	:	₹ 100.00
Total	:	₹ 330.00

Benefits of Insurance Policy:

Natural Death	:	₹ 60,000.00
Accidental Death	:	₹ 1,50,000.00
Fully Injured	:	₹ 1,50,000.00
Nominal Injured	:	₹ 75,000.0

1.4. Waste Management

The industries are crucial for the development of economy and well being of the state, on the flip side, the emissions and effluents from them are of environmental concerns. For sustainable development proper treatment of industrial waste should be done. The government of India has laid down the standard for safe disposal of the waste generated from the industries. Uttarakhand Environment Protection and Pollution Control Board (UEPPCB) has also laid down the standard as per the central guidelines[4].

1.5. References

1. http://www.doiuk.org/
2. Report of Task force 2010, India and Central Statistical Organization
3. Intellectual Property Facilitation Centre (IPFC) for MSMEs, UCOST study.
4. GSR 801 (E), EPA, 1986, dated Dec. 31, 1993
5. Srivastava R.K., Environmental impact assessment study of SIDCUL integrated industrial estate - Pantnagar, 2009, (Unpublished).

Section VII

TOURISM

Tourism and Ecotourism

Chapter ONE

TOURISM AND ECOTOURISM

(Abhinav Dubey)

1.1. Introduction

Tourism has been a major social phenomenon of all societies all over the world. Zeal of human mind to explore, experience and entertain has led to the development of Tourism. Right from the ancient times travelling across the political, social and cultural borders has been the major urge of mankind to be both educated and entertained. As the civilisations grew across the globe the motivation for travelling came up more and more through economic, political and religious reasons. The growth in number of travellers and activities related to them has transformed tourism from an activity to an organised industry.

Over the years countries have realised the potential of tourism as an industry and its potential to attract foreign capital and eventually prosperity. The industry of tourism has been taken very seriously by all major nations like U.S.A. and members of European Union especially Switzerland, France and Spain. Tourism has been a major source for foreign currency in flow in India as well. India being located in the sub-tropical and temperate regions of the globe possess all possible popular natural land forms and features like mountains ranges & peaks, seacoasts & beaches and deserts, thus having every prospect for natural tourism.

Moreover, India is the land of diversity having many religions, languages and culture thus making it more apt for the purpose of inland and foreign tourism. Foreign Tourist Arrival (FTA) in India in 2010-11 has recorded an increase of 8.1% than 2009-2010. The tourist as an industry is an important sector as the revenue generated in the financial year of 2010-11 is ₹ 64,889[1].

Uttarakhand popularly known as *'Dev Bhoomi'* for possessing major Hindu pilgrimages is one of the primate states as far as tourism is concerned. Moreover, located in the foothills of Himalaya and among the shiwaliks the state is well decorated with renowned hill stations and India's biggest river system i.e. Ganga River System. Apart from this, the state possess 64% of forest cover of its total area, making it viable for wildlife and ecotourism.

In comparison with the total nationwide tourist influx Uttarakhand hosts about 4% of the total tourist visiting the country. Table 1.1 shows the Uttarakhand's share percentage for domestic tourist arrivals in 2010. The state annually hosts more than 4% of total tourist of India, but in the year 2009 there is significant decline in the percentage share although the number of tourists were increased by 0.11 million[2] (Table 1.1). Uttarakhand usually hosts a consistent number of visitors as the major tourism factors are constant year along heavily marked by religious reasons e.g. the Chardham Yatra is a constant annual practise within India or the bathing days in Ganges.

Moreover, in 2010 the enhancement in the tourist arrivals was significant due to the super events of Mahakumbh - 2010 and SAIF Games - 2010. Besides these two reasons the tourist arrivals especially FTA was on the higher side all across the country.

Tourism in India[1]

- In the year 2010-11 India noted 5.58 million Foreign Tourist Arrivals (FTA) 8.1% more than the last year
- The increase in FTA this year is significant as the growth rate of previous year was -2.2%
- Revenue generated from Tourism is ₹ 64,889 crore which has observed 18.1% growth
- Share of tourism in country's GDP and jobs is 5.92% and 9.24% respectively,

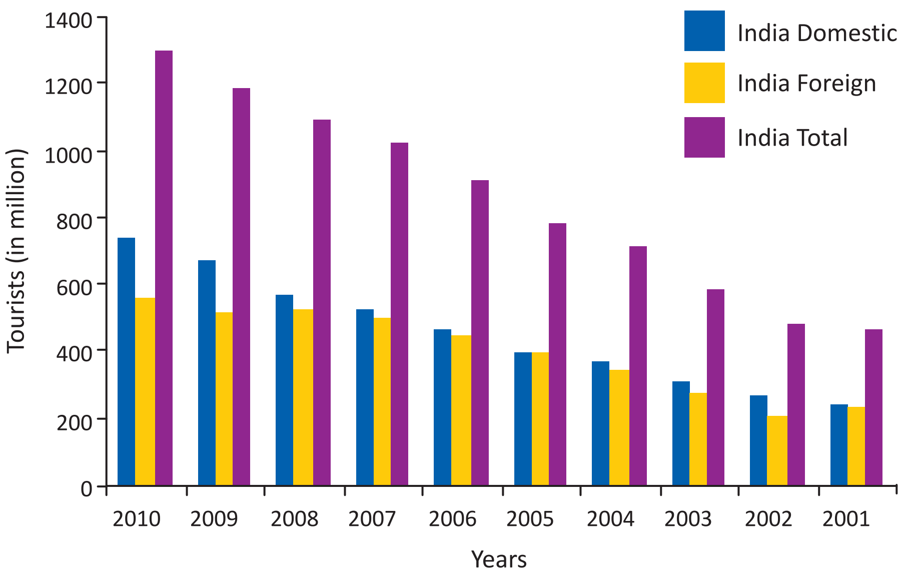


Fig-1.1.
Tourists statistics India (2001-2010)

Tourism in Uttarakhand

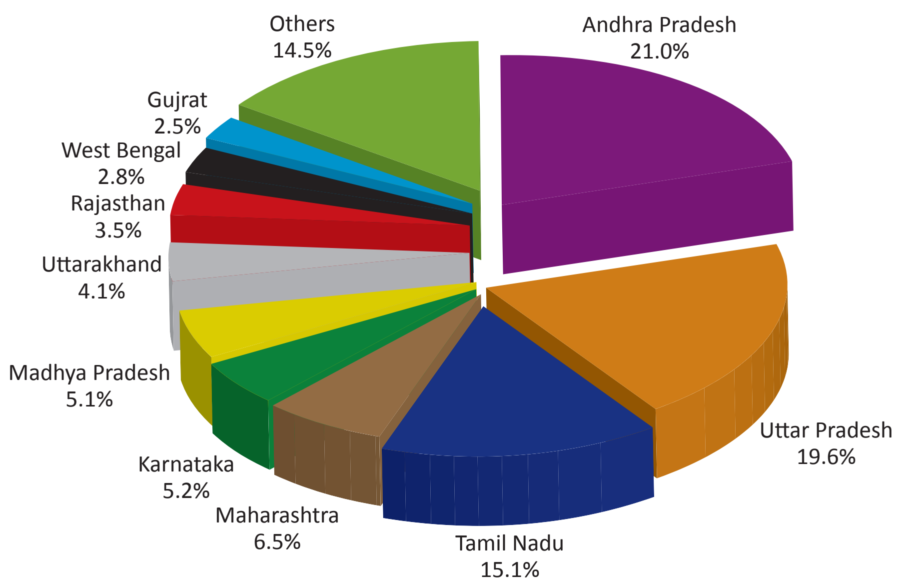
- In the year 2010, the state observed 3.11 million of Tourist Arrivals which is 34% more than the last year
- The increase in FTA this year is significant with a growth of about 15%
- In the financial year of 2010-11, ₹ 55.51 million were spent on the development of Tourism in the state

If we talk about the comparison of Uttarakhand with other states, Uttarakhand stands among the *Top-10 states* as far as domestic tourism is concerned. According to the Economic State of Tourism, Ministry of Tourism, Govt. of India in 2010 Uttarakhand stands at 7th position with a percentage share of 4.1% total tourist counting[3]. As shown in Fig. 1.2, Uttarakhand is

Table-1.1.
Domestic tourist percentage share of Uttarakhand in comparison to India in the last decade

Year	India	Uttarakhand	
	Number (In millions)	Number (In millions)	Percentage (%)
2010	740.21	30.97	4.18
2009	668.80	23.15	3.46
2008	563.03	23.06	4.10
2007	526.43	22.15	4.21
2006	462.31	19.34	4.18
2005	391.95	16.28	4.15
2004	366.27	13.80	3.77
2003	309.04	12.93	4.18
2002	269.60	11.65	4.32
2001	236.47	10.55	4.46

Fig-1.2.
Percentage share of top ten States/UTs in Domestic Tourist visits in 2010



way behind the leading states of Andhra Pradesh (21%) and its parental state Uttar Pradesh (19.6%). Unexpectedly, Uttarakhand is found behind the states of Maharashtra and Madhya Pradesh by a substantial margin even when the year 2010 had noticed the mega event of Mahakumbh in Haridwar which is characterised by heavy influx of Hindu pilgrims from across the world and also by the media reporters from all across the globe. Having said that, the decadal growth of state in domestic tourist influx has been impressive, observing a continuous rise in the percentage share of total domestic tourist counting of India in last five years (from 2005-10)[3].

Coming to foreign tourist influx, it is found that the state is not even among the *Top-10 states* of India. In this area Maharashtra is the clear leader with a toping percentage share of 28.5% way ahead of its immediate successor Tamilnadu (15.7%), being the economic and trade capital it experiences the most number of FTA. Noticeably, Himachal Pradesh, the neighbour of Uttarakhand and having a similar terrain observes 2.5% of FTA in India equalling the famous holiday capital of India 'Goa' (Fig. 1.3).

Year	India	Uttarakhand	
	Number (In millions)	Number (In millions)	Percentage (%)
2010	5.5837	0.14	2.57
2009	5.1677	0.12	2.32
2008	5.27.71	0.12	2.27
2007	4.9771	0.11	2.21
2006	4.44.71	0.097	2.18
2005	3.9186	0.092	2.35
2004	3.4575	0.075	2.17
2003	2.72.62	0.063	2.31
2002	2.0730	0.56	2.70
2001	2.2827	0.55	2.41

Table-1.2.
Foreign tourist percentage share of Uttarakhand in comparison to India in the last decade

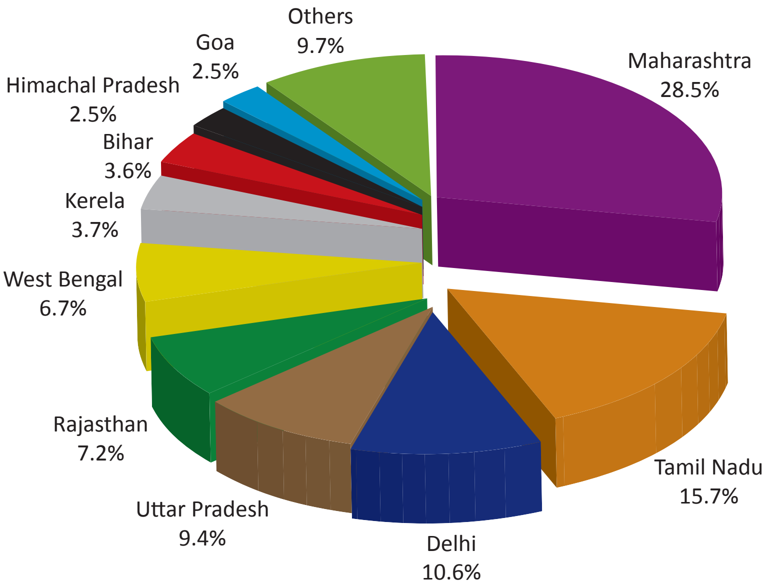


Fig-1.3.
Percentage share of top ten States/UTs in Foreign Tourist visits in 2010

1.2. Landscape

Uttarakhand situated among the rising peaks of Himalayas, patronizing the source glaciers of river Ganga and Yamuna, known as *Dev Bhoomi* is god's own land in true sense. The presence of exotic natural beauty, remote areas virgin from human interference, locations preserving scenic sites are featuring the tourism of resources of the state. The state enriched with Bhabar and Terai lands has total area of 53,566 km^2, of which 93% is mountainous. Situated in the slopes of Himalaya the state has peaks of Greater Himalayas in north and Shiwaliks standing southwards. The state in itself is reserve of geographical resources having all major relief features from mountains to glaciers, Bugyals and plain agricultural lands of Haridwar, major river systems of Ganga and Yamuna, highland lakes like Roopkund, Nainital, Nakuchiatal & Chhatrakund, Bio-diversity rich valleys like Valley of Flowers etc.

Along the geographical relief the state is also blessed with a rich forest cover and bio-diversity. It is evident from the fact that the state is the birth place of historical *Chipko Environmental Movement* and houses 6 National parks, 6 Sanctuaries and 1 Biosphere Reserve[4].

Uttarakhand lies on the southern slope of the Himalaya range, and the climate and vegetation vary greatly with elevation, from glaciers at the highest elevations to subtropical forests at the lower elevations. The highest elevations are covered by ice and bare rock. Below them, between 3,000 and 5,000 metres (9,800 and 16,000 ft) are montane grasslands and shrublands: the western Himalayan alpine shrub and meadows. Temperate coniferous forests, the western Himalayan sub-alpine conifer forests, grow just below the tree line. At 3,000 to 2,600 metres (9,800 to 8,500 ft) elevation they transit to the temperate western Himalayan broadleaf forests, which lie in a belt from 2,600 to 1,500 metres (8,500 to 4,900 ft) elevation. Below 1,500 metres (4,900 ft) elevation lie the Himalayan subtropical pine forests. The Upper Gangetic Plains moist deciduous forests and the drier Terai-Duar savanna and grasslands cover the lowlands along the Uttar Pradesh border. This belt is locally known as Bhabhar. These lowland forests have mostly been cleared for agriculture, but a few pockets remain[4].

Together the two (topography and wildlife) makes the state a paradise for adventure lovers and caters them with the facilities to experience the rare. Having said that the real jewel in the crown is the spiritual essence of the state. Uttarakhand has a pleasure to have the presence of few of the major holy towns, pilgrimages and temples of Northern India. Every year devotees

Uttarakhand tourism facts

- Total Geographic Area: 53, 566 sq km
- Mountainous Area : 93%
- Forest Area : 64%
- Capital : Dehradun
- Major Mountain Ranges: Nanda Devi Peak,
- Highest Peak: Nand Devi
- Major River Systems: Ganga and Yamuna
- Major Hill Stations: Dehradun, Mussoorie, Dhanolti, Nainital, Ranikhet, Almora, Kausani and Auli
- Religious Towns: Haridwar, Rishikesh, Badrinath, Kedarnath

Forest Research Institute

- Established in 1906, is the premier institute in the field of forest research
- Built in the traditional *Greeko-Roman* architectural style is an exceptional man-made structure
- Landmark building in Dehradun
- Institute has a museum on forestry, a herbarium and arboreta

from across the country and from the world visits these places in search of peace with belief of experiencing then spiritual side. The sacredness and holiness of the State is by virtue of its being mentioned in the mythologies of the country. With all these exotic locations, geographical landforms, rivers, forest and wildlife the state is the destination for all.

1.3. Types of Tourism

Tourism as a practise has many forms based on the purpose of the travelling, including exploring, experiencing, attainment of knowledge, adventure, religion and business. Uttarakhand due to its topographical location, temporal existence and cultural heritage provides reasons to all possible forms of tourism which is rare in its own. It is so because even the most popular tourist destination states like Rajasthan, Goa and National Capital Territory-Delhi are devoid of such rich diversity in types of tourism.

1.3.1. Natural Tourism (Ecotourism)

The topographical location of the state attracts tourists, ecologists and nature lovers from all across the globe to experience the rich natural beauty and sight-seeing activities. The rich bio-diversity and hilly culture is worth experiencing. The presence of lesser Himalayan Ranges with southward situated Shiwaliks is a prominent natural feature. Adding to it is the major river system of holy Ganga the lifeline of Northern India and major reason for the great alluvial planes of India. In the presence of all possible landforms occurring due to geological and aggregation processes, the state is enriched with wealth of nature. Having three of the major vegetation i.e. temperate, tundra and montane vegetations, the ecological diversity of the region could be imagined with no hardship.

Uttarakhand houses few of the renowned hill stations of the country that includes Dehradun, Mussoorie, Almora, Nainital, Ranikhet, Kausani, Pauri, Lansdowne, Auli and Chopta. All these hills station are posses exotic scenery views to attract tourist[5].

Dehradun: The capital city situated in the Garhwal division of the state is a famous hill station. The city is popular among the Indians from the time of British rule. Having major scientific and research institutions like Survey of India, Forest Research Institute and Wadia Institute of Himalayan Geology etc. the city also patronizes some of the finest and renowned schools of India e.g. Doon School. Famous Buddha Temple and Assan Barrage are some of the places of interest from tourism point of view.

Mussoorie : Famous Hill station situated in the Garhwal Himalayas at an altitude of 1, 876 mt., popularly known as *'Queen of Hills'*. The highest point in Mussoorie is *'Lal Tibba'* (7000 ft. asl) and following it is Gunhill, another tourist spot accessible via famous Mall Road of Mussoorie. Above Mall road there is the St. Mary's Church, oldest church in the Himalayas[4].

Sir George's Peak

- Is the old house of Sir Everest George, Former Surveyor General of India after whom Mt. Everest is named
- Situated in the Park Estate is the place from where Sir Everest George, measured the height of Mt. Everest under the Great Trignometric Survey project.

Dhanaulti

- Situated at Chamba-Mussoorie Road at an altitude of 2,250m asl.
- It is among the thick forest cover of Deodars, Oak and Rhododendrons
- Preferential site for natural and adventure tourism with trekking as popular activity
- Most popular treks are to Surkanda Devi, Chandrabadani and Kunjapuri, all three being the sacred shaktipeeths

Lal Bahadur Shastri National Administrative Academy

- Established in 1959 at Mussoorie, acquiring Charleville Hotel by Govt. of India
- Academy imparts training to the Civil Servants and other administration and management trainings to personnel's of various streams

Valley of Flowers

- Valley of Flowers was discovered by British Botanist and mountaineer Frank S. Smith in 1937
- It is an alpine U-shaped valley formed by retreating glaciers
- The valley houses some of the rarest flora and fauna, being one of the most attractive National Natural Parks. Pushpawati river emerging from deposits of Ratanban and Nilgiri Ranges divides the valley into two.
- Valley remains under snow blanket from December-May and as the white blanket melts appears alpine vegetation.
- Few important species of flower found in the Valley are: *Anemos, Geranium*, Marsh, Marigold, Primula, Himalayan blue poppy, *Aconite delphinium* etc.

Centres of Eco- Tourism in Uttarakhand

Centre for Ecotourism : Centre for Ecotourism and Sustainable Livelihoods (CESL) was established by Govt. of Uttarakhand in 2003 as the nodal institution for promotion of ecotourism and community based tourism. The CESL promotes awareness training and research on ecotourism so as to assist communities and indigenous people in addressing livelihood issues. Barati Rau, a series of three waterfalls, and Laduwagar waterfall are situated close to the centre.

Agora : Agora Rural Tourism Village, having its connectivity with Dodital, a high altitude lake situated at an elevation 3188m, is the source of river Asi Ganga. The surroundings are featured with gurgling streams and dense alpine forests make this an ideal trek for beginners. WWFs Green Hiker Campaign has been launched in Agora and Dodital as part of WWF's Saving Wetlands Sky-High (SWSH) initiative to minimize the negative environmental impacts of tourism.

Bhyundar : Bhyundar Village lies on the trek path along the Pushpavati river from Govindgarh to Hemkund Saheb. The Eco Development Committee of Bhyundar provides camping and trekking facilities for tourists. The EDC played a pivotal role in removing more than 200 tons of trail through community participation.

Bugyal Sarai : Barsu village situated close to Dayara Bugyal, one of the Uttarakhand's largest and easily accessible meadows. Featured with serene pine forests and green meadows as surrounding which are covered with flowers and ice in monsoon and winters, respectively. Camping is a most common activity in this place packaged along with trekking, hike and skiing.

Choti Haldwani : Resting in the foothills of Nainital is the quiet little village of Choti Haldwani. This village was once owned by the famous hunter turned conservationist of British India, Jim Corbett. His Irish cottage is now maintained as a museum by Forest Department. With the co-operation of the local people, homestays and souvenir by the Corbett Gram Vikas Samiti. Corbett's Jungle Studio and Corbett Waterfall are some of the places of interest nearby.

Dalar : Surrounded by pine forest, Dalar has an eco-lodge, guesthouse and home stays. All 5 villages of Binsar have an elected committee to co-ordinate tourism activities. The area has populated with dense forests of Oak and *Rhododendron.*

Eco Camp, Binsar : Eco Camp Binsar is situated on the boundary of Binsar WLS at Dhaulchhina at an altitude of 2100m. The camp falls on way while trekking from Binsar to Jageshwar temple. Initiated as a part of the World Bank aided Uttarakhand Forestry Project's Eco-Development Programme. The camp is facilitated with trekking, rock climbing, rappelling, river surfing, bird watching, yoga and local food served with herbal tea. The site is also marked with the presence of barking deer and occasional sighting of Leopard.

Eco Park, Dhanaulti : Situated on Mussoorie-Chamba Road at an elevation of 2286m above sea level, Dhanaulti is a small and serene hill town. Surrounded by the forest of Deodar, green meadows with a view of Himalayan Peaks. Two adjacent eco-parks namely "Amber" and "Dhara" have been developed by the Forest Department with the help of Local Youth. The eco parks are marked with bamboo huts, herbal gardens and children's park. The parks also facilities of recreation and adventure.

Marchula : Situated on the banks of river Ramganga is a hamlet, marked with stream, rapids and pools containing fishes in them. Mahseer Convention organizes angling activities in Ramganga with the help of gillies. Vanghat riverine Woods provides lodging facilities and Van Gaon Athitya offers homestay at Baluli, Sakar, Jameria and Bakhroti.

Sari : Sari Rural Tourism Village, situated on the route to Deoriatal at a distance of 3 km, is a camping and trekking site managed by Sari Eco Development Committee. Deoriatal is a high altitude lake located in Kedarnath at an elevation of 2443m above sea level. The site is marked with high altitudes surrounding the lake potraying a pleasing scenery.

Supi : Located in the foothills of Himalayas in the Pindari valley. The habitation is featured with white washed two story buildings called Berklays. Gram Paryatan Samiti formed by villagers run homestays and organizes walks along the Kumauni Heritage Trail. A Development Resource Centre at Supi showcases local bio-diversity.

Tolma : Situated at an altitude of 2740m above sea level, is the habitation of 17 families belonging to Bhotiya community, provides the easiest access to Nanda Devi National Park. The site is featured with forests of Deodar, Birch and Cypress and surrounded by snow capped mountain peaks including the famous Dronagiri Glacier. Home stays in this village provide an amazingly unique cultural experience.

Another famous tourist spot Dhanaulti is at distance of 32km from Mussoorie. Other tourist spots near to this place are Kempty Fall, Mist Lake, Bhatta Fall and Sir Everest George's House.

Nainital: Most famous hill station in Kumaun Himalayas located at $29^{0}22'48''$ N $79^{0}27'$ E, at an altitude of 2, 084m featured with a pear shaped lake surrounded by mountains with Naina (2615m) being the highest on the north, Deopatha (2,438m) on the west, Ayarpatha (2,278m) on the south. Nainital has temperate climate with annual temperature ranging from 27^{0}C - -7^{0}C. As per tourism point of view Nainital and its surrounding areas has many scenic spots like, Naini lake owing to which the city got it's name, Bhimtal, Nakuchiatal i.e. lake having nine corners, Naina peak (2611m), Nainadevi temple, Governor House-heritage of Victorian Gothic architecture and Snow View Point[4].

Almora: Located at $29^{0}37'12''$ N $79^{0}40'12''$ E at an elevation of 1651m on the southern edge of Kumaun Himalayas. The city derived its name from a local plant called "Kilmora" used to clean utensils of 'Katarmal Temple'[4].

Kausani

- Situated at an altitude of 1890m, 52 km north of Almora in Bageshwar district
- Birth place of legendry poet Sumitranandan Pant
- Perfect Scenic Spot for Himalayan Peaks like Nanda Devi, Trisul and Panchulli
- Mahatma Gandhi gave Kausani it the title of 'Switzerland of India'

Ranikhet

- Renowned hill station and cantonment in the Almora district
- Located at an altitude of 1869m in the Kumaun Himalayas
- Divided in Ranikhet and Chaubatia ridges, receive snowfall in winter season and temperate climatic conditions for the rest of the year
- Having a forest of Oak, Deodar and Pine, Ranikhet is rich in scenic beauty
- G.D. Birla Memorial School is situated here

City is the hometown of Sh. Govind Vallabh Pant, first Chief Minister of Uttar Pradesh and former Union Cabinet Minister Sh. Murali Manohar Joshi. Moreover, the renowned Nobel Laureate Sir Ronal Ross was born here[4].

The city has Alpine and temperate climatic conditions, with temperature ranging from 15^{0}C - 2^{0}C in winter and 28^{0}C – 12^{0}C.

Other tourist attraction in the nearby areas of Almora includes Golu Devta Temple, Kausani, Nanda Devi Temple etc.

1.3.2. Wildlife Tourism

Forest and Wildlife are the most important components of the nature, portraying the beauty of it in the most real and original sense. Uttarakhand has 3.53% of total forest cover of India and in terms of spatial coverage 64% of the area of the state is covered by forest. State being rich in Bio-diversity, posses a rich flora and fauna kingdom and thus, found apt for wildlife tourism. With the presence of 6 National parks out of the total 80 National parks of India, including Corbett National Park the first National park of India[7].

Corbett National Park: The Park is an abode to 448 species of plants and 585 of permanent and migratory species of animals and birds. Corbett national park, the oldest national park has celebrated its platinum jubilee year in 2010. Spreaded in the area of 580 sq. km at an average altitude of 1210m a.s.l. it is home to all the famous animals like Royal Bengal Tiger, Elephant, one horn Rhinocerous, Crocodiles, leopards, Black and Sloth Bear.

Uttarakhand parks & sanctuaries

- The state has 6 National Parks including Corbett National Park, Rajaji National Park, Nanda Devi National Park, Govind National Park and Valley of Flowers National Park
- Nanda Devi National Park is also Biosphere reserve under UNESCO
- 6 Sanctuaries are situated within states namely, Govind Wildlife Sanctuary, Assan Barrage Bird Sanctuary, Mussoorie Wildlife Sanctuary, Kedarnath Sanctuary, Malan Sanctuary and Motichur Sanctuary

Corbett National Park

- Oldest National Park in India recently marked its Platinum Jubilee
- Established in 1921 as Hailey National Park
- Area : 520.8 km^2
- Altitude: 1210m
- Temperature range : 5^0C-34^0C
- Situated in Nainital District
- A total of 400 plant species has been recorded in the park
- Rare Species: Bengal Tiger, Rhinoceros
- 585 Bird Species were recorded
- Reptiles: 33 species
- Amphibians: 7 species
- Fishes: 7 species
- Dragonflies: 34 species
- Corbett National Park is the most gifted habitat for royal Bengal Tiger, as per Govt. estimates of 2009 there are 162 tigers in the reserve.
- In 2009, the park has seen death of 11 tigers
- According to a study conducted by Institute of Hotel Management, Pusa, New Delhi, the growing anthropogenic activities in the area are causing disturbance to wildlife[8].
- The report indicated too much of construction, organisation of camps, noise enhancement and illegal angling in the hotels.

The park located at 29°25' to 29°39'N and 78°44' to 79°07'E, is featured with various rivers, ridges, minor streams and small plateaus. Ramganga river forms a valley in the park named *Patli dun*. The park has humid subtropical and highland climate. With the presence of tall grasses and Ramganga River it is a perfect adobe for Bengal tigers. The temperature may vary from 5^0C (41^0F) to 30^0C (86^0F) during the winter and some mornings are foggy. Summer temperatures normally do not rise above 40^0C (104^0F). The main raining season is monsoon and highest precipitation it receives is about 2800 mm[4].

Corbett National Park is one of the 13 protected areas covered by World Wildlife Fund under the Terai Arc Landscape Programme. The programme aims to preserve the important terrestrial species of Tiger, Elephant and Rhinoceros. Moreover, the Corbett National Park is the launching site of Project Tiger of Govt. of India initiated in 1974[4].

Rajaji National Park: Situated in the foothills of Shivaliks the park possess scenic beauty and rich bio-diversity. Originally being a sanctuary,the park got its present shape with the merger of Rajaji, Motichur and Chila Wildlife sanctuaries in 1983. Rajaji National Park named after Sh. C. Rajagopalchari, first Indian Governor General of India, is spreaded over Pauri, Dehradun and Saharanpur districts of Uttarakhand and Uttar Pradesh, respectively. According to Rajaji National Park authorities 324 species of animal are surviving in the park which includes bird like Greater Scaup, White Naped Woodpecker, Great Hornbill, and Black-bellied Tern. The park experiences all three seasons i.e. winter, summer and monsoon with annual temperature range of 12^0C – 38^0C. The rainy season is from July - September with annual precipitation range of 1200-1500mm.

Vegetation of the park is of mixed type with broad leaf deciduous forest, ravine vegetation, scrubland, Sal forest and grassland. The park covers an area of 820 sq km.

The park is home to the Cheetal, hog deer, barking deer, Sambar deer, wild boar, antelopes such as the Nilgai, Goral and of course the Asian Elephant. The park also has the privilege of having presence of mighty Ganga flowing to a span of 24 km. The rivers which flow through the Park harbour species of fish such as trout and mahseer[9].

Nanda Devi National Park: Is a National Park situated around the peak of Nanda Devi established in 1982, park along with Valley of Flowers has been conferred with the status of *World Heritage Site* of UNESCO. Nanda Devi National Park covers an area of 630.33 km^2 (243.37 sq mile) and together with Valley of Flowers National Park is encompassed in the **Nanda Devi Biosphere Reserve** totaling a protected area of 2,236.74 km^2 (863.61 sq mile), which is surrounded by a buffer zone of 5,148.57 km^2 (1,987.87 sq mile)[4].

Nanda Devi Biosphere

- It is one of the 17 Biosphere reserves in India
- It is a World Heritage site declared by UNESCO in 1987
- The area covered by National Park is 630.33 km^2 but the total protected area of biosphere is 5,148.57 km^2
- Altitude: 3,500m (average)

This Reserve is part of the UNESCO World Network of Biosphere Reserves since 2004. Nanda Devi National Park is the only Biosphere within Uttarakhand. There are about 84 species of animals reported in the National Park along with 114 bird species[7].

Asan Barrage Bird Sanctuary: Located at 40 km from Dehradun is a famous bird watching site popularly known as Dhalipur Lake. Established in 1963, on the confluence of river Yamuna and Asan, is known for habitating local as well as international birds on seasonal basis. The Asan reservoir attracts about 53 species of birds; of them 19 are migratory species from Eurasia. The prime migratory species are Brahmini Duck, Pintail, Red Chrested Pockard, Wigeon and Tufted Duck. The reservoir enjoys temperate climate with average rainfall of 250cm. The Barrage is 287.5 km long, having the river bed 389m above sea level[7].

1.3.3. Religious Tourism

In India religion is not just an activity or belief, it is actually a driving force of life. It has become an integral part of life to such an extent that the Indians who aren't fond of travelling do it for the sake of their faith. The sacred travelling, locally known as *'Teerth Yatra',* is enshrined in the Hinduism as an important activity. In Uttarakhand, religious tourism hogs the major share in different tourism types. Uttarakhand possess the mighty presence of Himalayas and river Ganges, two pillars of Hindu mythology The state patronizes *'Badrinath Dham',* a major pilgrimage out of the one established in all four directions of country. Moreover, the state also has the privilege of having Gaumukh and Yamunotri glaciers, the origins of river Ganges and Yamuna respectively. In recent times, due to increasing tourism, a religious square has emerged consisting of four centres religious importance i.e. Badrinath, Kedarnath, Gangotri and Yamunotri, being popularised as 'Chardham'. Religious tourism is the backbone of tourism industry in Uttarakhand as it accounts majority of total share of tourism within the state.

Badrinath: Located at $39^{0}44'24''$ N & $79^{0}23'24''$ E, it is a hill town in the Himalayas honoured with the presence of *Badrinath Shrine* or *'Sri Badrinarayan Temple'* alongside the Alaknanda River. Having its roots way back in 9th Century the temple is of *'Lord Vishnu'* one of the most popular gods and thus observes a huge number of pilgrims every year. Due to its

topographical location the temple is covered with snow all through out the winters and is opened for the public from April to October every month.

Kedarnath: It is a holy town situated in Rudraprayag district, at 3553m at $30^{0}26'24"$N & $79^{0}2'24"$ E. Situated alongside the River Mandakini it is remotest of the four shrines. The city is named after an ancient ruler *King Kedar* and hosts the holy temple of *Kedarnath*, known from the times of pandavas. The temple opens on *'Akshaya Tritiya'* (Third Week of April to First week of May) and closes on *'Bhai Dooj'* (Last of October to First week of Nov.)[4].

Gangotri: It is a glacier located in Uttarkashi district of Uttarakhand. The glacier has a holy place related to it called *Gaumukh,* which is the origin of river Ganges. The total volume of Gangotri glacier is expected to be 27 km^3, one of the largest in Himalayas and located between 30°43'22"–30°55'49" (lat.) and 79°4'41"–79°16'34" (long.), extending in height from 4120 to 7000m a.s.l. This area is situated north of the Main Central Thrust (MCT) and is made up of bedrocks of granites, garnet mica schist, quartz biotite schist, kyanite schist, augen gneiss and banded augen gneiss. The glacier is composed of a variety of depositional features such as talus cones, snow-avalanche fans, snow-bridges, and dead ice mounds, and erosional features like pyramidal and conical peaks, serrated ridge crests, glacial troughs, smooth rock walls, crags and tails, waterfalls, rock basins, gullies and glacial lakes. All along the Gangotri glacier, several longitudinal and transverse crevasses are formed along which ice blocks have broken down. The ablation zone of the Gangotri glacier is covered by a thick pile of supraglacial moraines and is characterized by several ice sections, melting into pools of supraglacial lakes[4].

Yamunotri: It is also a glacier in the lesser Himalayas near the *Bandar Poonch Peak,* the source of river Yamuna, located at $31^{0}36"$ N $78^{0}27'$ E and has an average elevation of 3,955m in the Uttarkashi district. The actual source, a frozen lake of ice and glacier (Champasar Glacier) located on the Kalind Mountain at a height of 4,421m above sea level, about 1 km further up, is not frequented generally as it is not accessible; hence the shrine has been located on the foot of the hill. The main attraction is the temple of Yamuna goddess on the bank of river Yamuna and Janki Chatti a thermal spring[4].

Haridwar: As a holy city and district Haridwar is one of the prime cities of Uttarakhand. The city is as ancient as the Hindu mythologies i.e. Haridwar has her presence in most of the mythological stories. The city is blessed with the mighty presence of river Ganges which flows here at rapid pace in a considerable volume. Haridwar could be taken as the starting land of the Indo-Gangetic alluvial plains which plays an important part in the economy of the country. A large part of the district is forested, and Rajaji National Park is within the bounds of the district, making it an ideal destination for wildlife and adventure lovers. Rajaji is accessible through different gates; the Ramgarh Gate and Mohand Gate are within 25 km of Dehradun, while the Motichur, Ranipur and Chilla Gates are just about 9 km from Haridwar. Other places of interest are Har ki Pauri, Chandi Devi Temple, Mansa Devi Temple, Maya Devi Temple, Daksheshwar Mahadev Temple, Piran Kaliyar, Neel Dhara Pakshi Vihar, Shantikunj and Patanjali Yogpeeth. But the biggest attraction of Haridwar is the Mahakumbh organised in every 12 years[4].

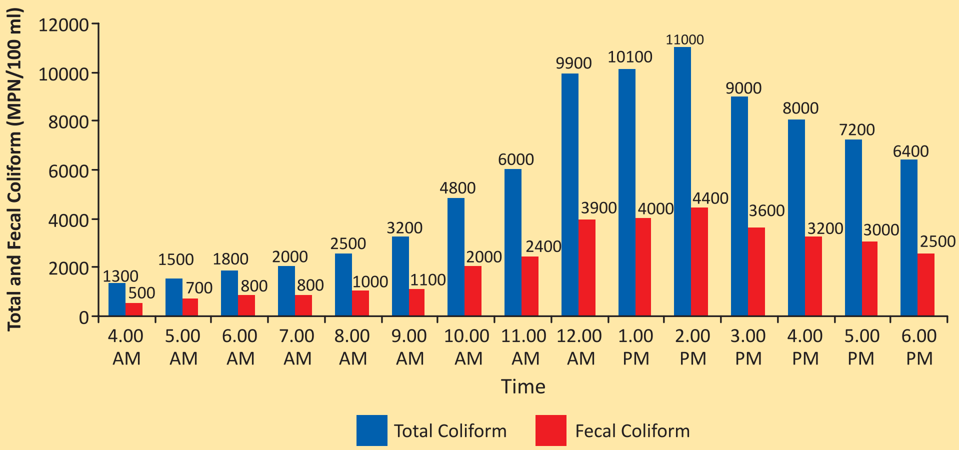
Rishikesh: It is a holy city located at foot hills of Himalayas, situated in Dehradun district. Popularly known as *Gateway of Himalayas,* Rishikesh is the entry port for Chardham yatra. The city is marked with the presence of river Ganges flowing through the middle of the city and settlements are located on each sides of it. The city is located between 30°06'12" N 78°17'41" E with an average elevation of 372m.

The city patronizes many temples, spiritual centres and ashrams, which are a major attraction for tourists, especially foreign tourists. Moreover, the famous Lakshman Jhula stands tall

Mahakumbh

Mahakumbh also known as Kumbh Mela is a mega event of Hindus where followers from across the country gather in Haridwar for sacred bathing. Mahakumbh is organised at four places i.e. Haridwar, Nasik, Allahabad and Ujjain. It repeats itself in every 12 years. Meanwhile, Ardh-Kumbh is organised in every four years at same places. Selection of places is based on the astrological calculations depending on the positioning of Sun. Kumbh Mela is one of the largest pilgrim gathering in world.

Last Kumbh Mela was organised in Haridwar in 2010 starting from Makar Sankranti (14th January) and ended on Shakti Purnima (28th April). As per the estimation of local administration more than 50 million people attended the Mahakumbh of which about 10 million people attended in the last week of April. The event was success on administrative and managerial grounds but as far as environment is concerned it raised a few concerns. As per a study done by Pollution Control Research Institute, BHEL sponsored by Uttarakhand Council for Science & Technology (refer chapter Water) the water was tested during Mahakumbh Snan on 14 April 2010 in Haridwar from 4.00 AM to 6.00 PM when about 14.5 lacs people took the holy dip in Ganga. The total coliform and fecal coliform bacterial count was found very high on that day. The water quality was monitored at equal time duration of 1 hour and the observations are shown in the Fig. below[10].



Graph.
Bacteriological load in Ganga River during Mahakumbh Snan on 14 April 2010 in Haridwar (from 4.00am to 6.00pm).

joining the two banks of the river Ganga, built in 1939 by britishers is an suspension bridge and on similar lines Ramjhula was constructed in 1980. The Tehri dam is just 80 km uphill on the way to Gangotri.

1.3.4. Health Tourism

This type of tourism is an important and most rapidly growing sector in tourism industry. According to a general estimate the health tourism sector is expected to grow at an annual growth of 30% i.e. $ 200 Billion. Health tourism in Uttarakhand is not confined to traditional ways of healing e.g. Ayurveda only but there are also Hospitals established in the state which renders patients with modern day technologies. However, predominantly this sector in the state is represented by Yoga, meditation and Ayurveda techniques of medicine.

In Uttarakhand, health tourism is present as a sub activity of Religious tourism as yoga and meditation preachings and healing activities are often carried by spiritual gurus in their ashrams. However, organised private sector is not yet come out in its full colours. Haridwar and Rishikesh are the primate centres of Health tourism in the state. The state also has few resorts in Hill stations like Kausani, Ranikhet and outskirts of Dehradun[4].

1.3.5. Adventure Tourism

This form of tourism has evolved in recent times in the form of sports. Like all other types this is also a great source for relieving stress by experiencing the rare. Adventure tourism has got popular among the youth at quick pace; with the increasing exposure to international activities adventure sports have gained popularity in India. Due to its topographical positioning and featured with all possible landforms Uttarakhand is a paradise for adventure savvys. The state has mountains, snow covered slopes, rapids, waterfalls, rivers, lakes and forest which makes it the premium destination for adventure experiences.

Patanjali Yogpeeth

- Named after renowned Yog guru Patanjali is the flagship project of Baba Ramdev
- Located in Kankhal, 20 km away from Haridwar is a prominent medicare centre in the State
- Yogpeeth has facilities of O.P.D, Library, Yog Training Centre, Nursery of Medicinal Plants, Food Court and accommodation facilities for patients

Jageshwar Temple

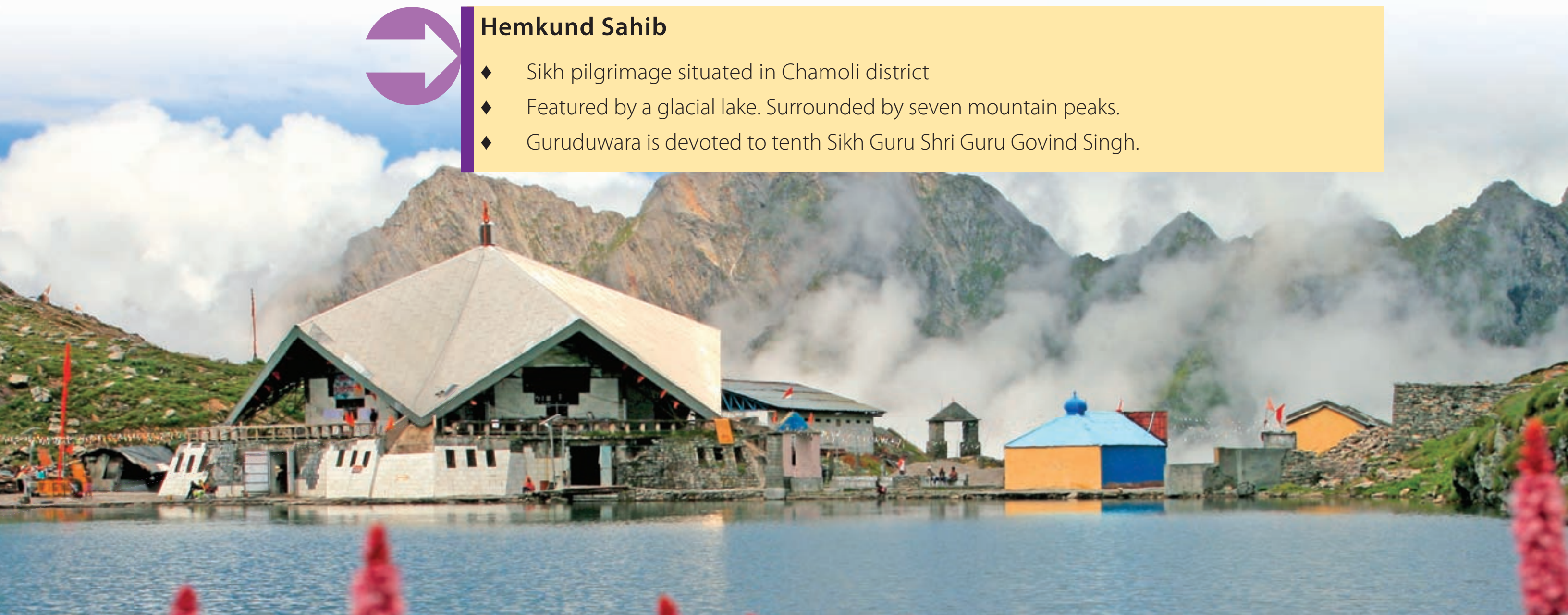
- Located at an altitude of 1870m Jageshwar is one of the 12 Jyotirlings
- Dedicated to Lord Shiva the temple is situated 36 km away from Almora
- Jageshwar is believed to be first among the 12 Jyotirlings
- The temple is complex of 200 temples made up of carved stones and is an example of exquisite craftsmanship
- The main temple of the complex is of Bal Jageshwar and also a temple of Vrihidh Jageshwar

Goludev Temple

- Temple of a local lord ***Goludev***, who is believed to be the lord of Justice in Hills
- Temple is situated in Kumaun Ranges at Chitai
- Locals have immense faith on the deity and take it as Justice Seat of God
- People tie & hang their written complaints on judicial papers in the temple

Hemkund Sahib

- Sikh pilgrimage situated in Chamoli district
- Featured by a glacial lake. Surrounded by seven mountain peaks.
- Guruduwara is devoted to tenth Sikh Guru Shri Guru Govind Singh.



Auli

- Snow Ski destination in Uttarakhand with finest snow covered slopes in winter.
- Auli is also known for its Bugyals (meadow), mainly Gorson Bugyal
- Located in the Chamoli district, surrounded by peaks of Mt. Mana, Mt. Kamet and Mt. Nanda Devi
- Chattrakund, World's Highest artificial lake is located in Auli

Various adventure sports are being organised in the state, prime among them is trekking, river rafting, rock climbing and skiing. Among these, river rafting is most popular among the Indian masses and is the biggest tourist attraction. River rafting camps are regularly being organised in Rishikesh. Moreover, government has issued 235 licences to private companies for conducting rafting activities The activity is carried out in Bhagirathi and Alakhnanda streams with different stretches for amateurs and professional. In fact, for professional rafting the stretch of Ghansali to Gadolia in Bhilganga stream and strech of Chandrapuri to Rudraprayag in Mandakini stream is apt.

Trekking is another popular activity along with mountaineering. There are several trekking trails like Pindari Glacier trek, Hemkund Sahib trek, Gangotri trek, Valley of Flower, Milam Glacier trek, Har-ki-Dun etc. Activities like Bunjee-jumping and rock climbing are also being organised in Mussoorie and other hill stations. Other than these kia-king, Cannoning, para-gliding, artificial wall climbing are some of the adventure sports which government is planning to develop. For the purposes, Training programmes and Adventure foundation courses are being conducted for the unemployed youth who are interested to pursue these games as profession[4].

1.3.6. Cultural/Rural Tourism

In India, culture is given prime importance, just after religion. Infact, it is interwoven with mythologies. According to mythologies hills are the favourite adobe of God and Goddesses and Uttarakhand is not an exception to this, with plenty of pilgrimages. It is also called Dev Bhoomi by virtue of this. If we talk of the culture of the state, it is distinctively different from other hill regions and consists of Garhwal and Kumaon cultures. Besides them, the various tribes of the state also contribute to the richness of the cultural heritage. The major tribes of the state are Bhotias, Tharus, Buxas, Jaunsaris and Rajis. The cultural heritage includes the folk dances, music, paintings, art and craft of the state.

The various form of folk dances like Chholia, Thadya, Chauphula, Jhora, Chanchari, Chhapeli and Jaagar are popular. These folk dances are performed on any ceremonial occasion. Among the musical instruments Dhol is the most popular. Other are Damama, Hurka, Turturi, Binaee, Mushak Been and Murali.

The state also witnesses many varieties of folk songs like Nyoli, Phag, Bair, Barahmasa, Saiddhali, Pawada, Hurakiya Bol and Pandava Songs. The art of the region has a distinct feature. Aipan Bar Boond, Patta, Rangwali, form of wood carving are some of them.

The cultural attraction of the state is also displayed in various fairs and festivals. Nanda Devi Raj Jat Yatra is at the forefront in this list. Another major attraction of the region is the Kumbh Mela. Besides them Bagwal, Hiljatra, Deolang fair are the showcase of the cultural diversity and heritage of the state.

1.4. Economic Aspect - Tourism as an Industry

Though tourism is officially not given the status of industry, but its significance in economy and its share in employment generation requires it to be looked upon as an industry. It is an important activity within the service sector of our economy. Like all other service sector industries tourism has also recorded impressive growth after liberalisation of economy. The industry covers many economic activities prime among them are hospitality, transportation, mart, festive and trade fairs and there is a big unorganised sector which depends on tourism for earning its living. Tourism is one of the largest service industry in India and an important source for providing foreign currency.

Like other industries tourism industry also requires quality infrastructure and skilled manpower but these are not the only requisites for the industry there are some other constraints as well like proper sanitation and municipal facilities, civilised local community and efficient administrative set up of the region and lastly but most importantly publicity.

Uttarakhand is a small but prominent state in the country as far as tourism is concerned. As discussed earlier, the State renders all possible forms of tourism and thus has great scope for the development of this industry. The share of industry in the state domestic product is substantial. According to Directorate of Economics and Statistics the Net State Domestic Product (NSDP) at current prices of Hotel, Restaurant and Trade sector in 2008-09 is 637957 lakhs which is about 18% of total NSDP. Moreover, the indirect contribution to transport and other related sectors will make the figure go even higher. If we see the share of tertiary sector as a whole in NSDP it is 1686500 lakhs i.e. 48% and tourism industry has a very large say in the tertiary sector of the state[11].

In cognizance to the importance of the industry, government has also initiated various development projects to make this industry flourish in the state. The ***Inclusive Tourism Infrastructure Development Project*** with financial assistance from Asian Development Bank is the step in the same direction, agreed outlay of which in 2011-12 is 28 crore. Moreover, development of infrastructure has been given prime importance as a result of centrally sponsored schemes of Rs. 4452.22 Lakhs were implemented to improve the ***Haridwar-Rishikesh-Muni Ki Reti-Swargashram*** Circuit. Moreover, to improve sanitation facilities for the tourists 28 toilets are being prepared and 50 are being renewed at important sites[2].

A study on Uttarakhand tourism was conducted by AC Neilson ORG MARG Ltd. with the financial support of Ministry of Tourism, Govt. of India in 2005-06. The study very well showed the prevailing conditions of commercial accommodation arrangements in the state. As per Table 1.3. which depicts the number of starred, unstarred and unorganised sector active in Hospitality business.

It is clearly evident that the unorganised sector dominates the hospitality business one of the reasons can be that domestic tourists visit the State more due to religious and family reasons. Speculating that they tend to spend less on accommodation. The unorganised

Table-1.3.
No. of starred, unstarred and unorganised sector in Hospitality business

Location	Type of Accommodation			
	Starred	Unstarred	Others	Total
Dehradun	6	94	31	131
Haridwar	0	37	791	828
Rishikesh	0	30	34	64
Mussoorie	9	162	33	204
Badrinath	0	4	27	31
Gangotri	0	9	52	61
Yamunotri	0	7	70	77
Nainital	1	110	24	135
Joshimath	0	30	17	47
Kotdwar	0	7	6	13
Corbett National Park	5	0	0	5
Pithoragarh	0	7	5	12
Almora	0	3	34	37
Ranikhet	2	1	11	14
Pauri Garhwal	0	15	3	18
Bageshwar	1	2	1	4
Kausani	1	12	0	13
Uttarkashi	0	18	56	74
Total	**25**	**548**	**1195**	**1768**

being the cheapest therefore, caters to the largest mass. This inference is well supported by the fact that Corbett National Park has only starred hotels because arrival of generally elite of tourists. However, in case of Haridwar where there is no starred accommodation available only reason for this could be the presence of large number of ashrams to reside. **Table 1.4 shows the total available Hotels in the premium tourist places of Uttarakhand12.**

The study also found out the monthwise pattern of tourist influx in the state and it was found that the tourist arrivals of domestic (Fig. 1.4) as well as foreign (Fig. 1.5) tourists is maximum in summers i.e. May, June and July which is understandable in case of hilly places.

Moreover, foreign tourist arrival could be improved with involvement of more organisations providing winter activities. Equally the domestic tourist arrival can be enhanced with increase recreation events and activities like fun parks, cultural and trade fairs etc.

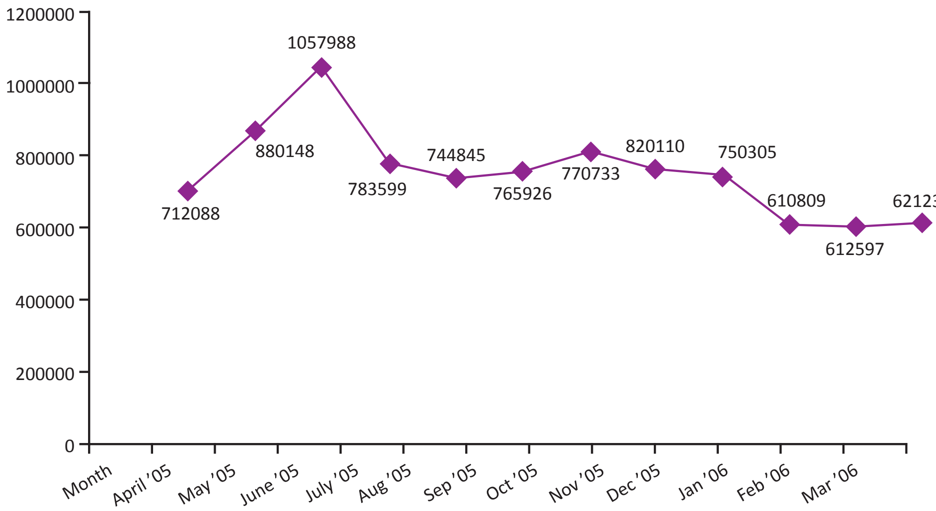
1.5. Environmental Aspects

Considering the importance of tourism as an industry came out shining but the environmental aspect related to it could not be undermined either. The growth is necessary but environment cannot be overlooked infact, both should go hand in hand. Over construction, encroachment of human settlements in the forest for and growing urbanisation is leading to many problems like weather change, deforestation, pollution of rivers & lakes and man-animal conflict. As discussed in the earlier chapters about the degradation of forest, melting of glaciers and pollution of water resources, they are some of the serious issues emerging as the cost of development. However as State is still in its infancy, development is high on priority. At

Table-1.4.
Total available Hotels in Prime Tourists places in Uttarakhand.

Location	Total Hotels	Total Rooms	Total Beds
Dehradun	131	2309	4574
Haridwar	828	17546	36252
Rishikesh	64	1310	2619
Mussoorie	204	2387	5700
Badrinath	31	439	1575
Gangotri	61	478	1539
Yamunotri	77	542	1798
Nainital	135	3076	6488
Joshimath	47	447	1348
Kotdwar	13	122	278
Corbett National Park	5	100	200
Pithoragarh	12	245	433
Almora	37	458	1010
Ranikhet	14	190	397
Pauri Garhwal	18	154	369
Bageshwar	4	73	135
Kausani	13	158	322
Uttarkashi	74	1031	2936
Total	**1768**	**31065**	**67973**

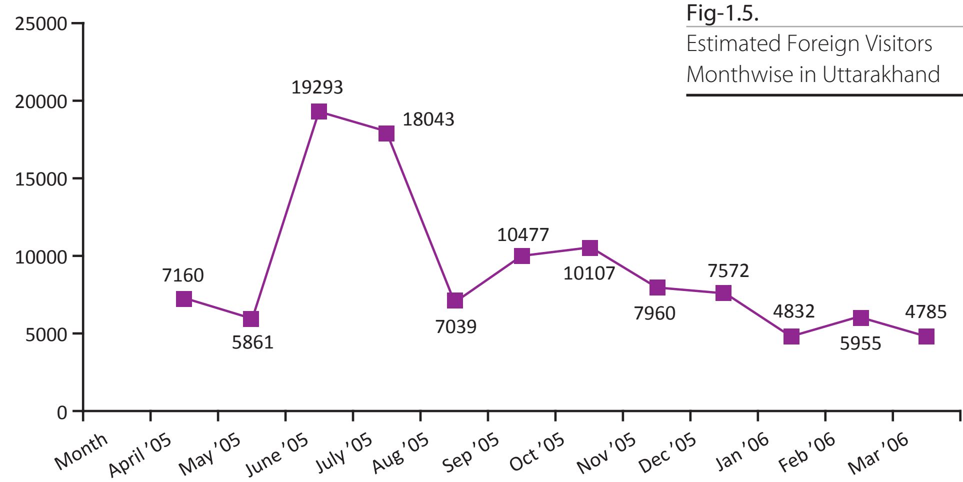
Fig-1.4.
Estimated Domestic Visitors Monthwise in Uttarakhand



the same time it is necessary to ensure sustainability of this development in a manner that resources are sensibly utilised rather than exploited.

Moreover, natural and scenic beauty is the backbone of natural tourism and thus requires a conscious effort to maintain it. Degradation of environment affects all forms of life by means of weather change, disaster and erratic climatic conditions. Most of the environmental degradation activities are anthropogenic and thus can be controlled.

Fig-1.5.
Estimated Foreign Visitors Monthwise in Uttarakhand



First among them is the pollution of rivers specifically Ganga. The religious activities especially the sacred bathing in Ganga has been the immense cause for its degradation. River Ganges considered as the holy river and worshiped as a goddess by locals and comes in contact to several human activities of faith and religious belief thereby being the cause pollution of the river. The number is so large that even small amount of pollutant discharged by one person becomes a huge amount when seen collectively.

Moreover, growing industrialisation in Haridwar district is also raising concerns. Accordingly, the tributaries of Ganga also face the same problem in hills. Thus it becomes important to tackle the situation in congruence to the problem i.e. the problem is generated with religious faiths and beliefs and thus can be cured by the same. On the same node the Sparsh Ganga Board came into being in 2010. The main objective of the board is to keep the tributaries of Ganga pollution free eventually making the mighty Ganga clean.

Moreover, the environmental issues are not just confined to rivers but wildlife has also been under some retrogressive affect. According to a study conducted by Institute of Hotel Management, Pusa, New Delhi, in Corbett National Park the growing anthropogenic activities in the area are causing disturbance to wildlife. The report indicated too much of construction, organisation of camps, noise enhancement and illegal angling in the hotels. Apart from this the growing cases of human animal conflict is also an issue of concern. To avoid this two villages situated on the southern boundary were shifted to the Firozpur–Manpur area situated on Ramnagar–Kashipur highway during 1990–93; the vacated areas were designated as buffer zones. The families in these villages were mostly dependent on forest products. Apart from this the Wildlife of Rajaji National Park has also been adversely affected by the growing industrial area of Haridwar[13].

Too much of tourism promotion has exposed remote and naturally virgin areas for the anthropogenic activities which should be controlled if not avoided. It is because growing human presence mostly of visitors shall pave way for the commercial activities. If it gets overdone then there is a potent threat of destroying the original essence.

1.6. Programmes and Policies

(a) Institutionalisation: According to the provisions of tourism policy of Uttarakhand, a statutory body called *Uttarakhand Tourism Development Board* has been established. The Minister of Tourism, Govt. of Uttarakhand is the ex-officio Chairman of the board, Chief Secretary, Govt. of Uttarakhand is the ex-officio Vice Chairman and Secretary, Tourism, Govt.

of Uttarakhand is the ex-officio Executive Officer. The board acts as a consultancy body regarding all matters concerned with the development and promotion of tourism in the state. Moreover, the board also functions as the authority for regulations and licensing in the same area[2].

(b) Infrastructure: It plays a vital role in the development of tourism. The connectivity comes first in all the infrastructural requisites followed with issues of equal importance like communication facilities, boarding and lodging facilities, availability of water, power and other useful resources. In Uttarakhand, following measures have been taken in order to ensure enhanced infrastructural shape of tourism industry:

(i) Establishment of Inter State Bus Terminal in Dehradun to connect the state with its neighbouring states of Uttar Pradesh, Haryana, Himachal Pradesh, Punjab and to the states of Jammu & Kashmir, Rajasthan and National Capital Territory, New Delhi.

(ii) Deptt. of Tourism, Govt. of Uttarakhand in association with GMVN and private organisations Prabhatam & Pavanhansa is facilitating the pilgrims with the helicopter from Phata and Augustmuni to Kedarnath shrine[2].

(iii) Establishment of 44 Tourist Convention Centres/Tourist Information Centres on the way of Chardham Pilgrimage. It is proposed that after their complete establishment and functioning will be handed over to private organisations.

(iv) Application of Project Management System to ensure proper implementation of projects

(v) Establishment of 25 'Rain Basera' traveller lodges for the low income tourist. These Rain Basera lodges will be managed by the Diploma holders in tourism from Garhwal University. Two units of the same project will also be established in Kumaun Division[2].

(c) Private Investments: Encouragement of private investment in infrastructure developmental projects majorly in PPP mode by attracting the investors in the areas of hospitality, transportation and adventure tourism. Moreover, under the Vir Chandra Singh Gharhwali Tourism Swarozgar

Yojna a total of 3373 beneficiaries were transformed into entrepreneurs. The scheme has been introduced with the aim of improving the employment scenario within the state at the same time to build a competent human resource and infrastructure related to tourism[2].

Moreover, investment from various other sources has been invited via means of IL & FS, a joint venture of Uttarakhand, including foreign and NRI investment[2].

(d) Capacity Building: State Institute of Hotel Management and Catering are established at Almora and Dehradun where 97 students are enrolled for the year 2010-11. In addition an Indian Institute of Hotel Management (IHM) has been established at Dehradun wherein 88 students undergone the training in the year 2010-11. Moreover, Diploma Courses in Food Production of 18 months is instrumented for youth to pursue hospitality. Along with it a professional training course in F&B management is also being executed at the same institutes[2].

(e) Endorsement: Tourism as an industry majorly depends on two major components i.e. infrastructure and popularisation. Publicity is the backbone of this industry as you have to expose your services and create a market for you. Uttarakhand Tourism Board has taken many initiatives which include advertisements in newspaper and magazines. Programmes on remote areas and adventure sports sites are being relayed on local channels along with programmes on culture of Hills (Garhwal & Kumaun). Moreover, programmes on SAIF Games-2011 were prepared and was relayed on channels namely, TV-100, ETV (U.P./Uttarakhand), Sahara (U.P./ Uttarakhand). Under the same persuasion, to publicise Uttarakhand at the international level, Board participated in various international travel & tourism fairs among which World Travel Mart, London, I.T.B. - Berlin, I.T.B. - Asia, and Pata Travel Mart, Macau are prime[2].

1.7. References

1. Annual Report, Ministry of Tourism, Govt. of India, 2011, pp.132.
2. Annual Report, Department of Tourism, Govt. of Uttarakhand, 2011, pp.18.
3. Tourism Stats, Statictical Report-I on Tourism, Govt. of India, 2010, pp.20.
4. www.wikipedia.com
5. www.euttaranchal.com
6. Ecotourism map of Uttarakhand, Ecotourism wing, Deptt. of Forest, Govt. of Uttarakhand.
7. www.indiawildlifeportal.com
8. Study report on Corbett National Park by Institute of Hotel Management, Pusa, New Delhi.
9. www.rajajinationalpark.com
10. Srivastava, N.G., Progress Report on Preparation of action plan for pollution control for Haridwar City, PCRI, Haridwar, Uttarakhand, 2010, (Unpublished).
11. www.uttarakhand.nic.in
12. Study report on Uttarakhand Tourism, AC Neilson ORG Marg Pvt. Ltd., 2005-06, pp.239.
13. Chandola, S., Proceedings of 3rd Environment Summit, 2011, pp.12.

Uttarakhand State Council for Science and Technology
Department of Science and Technology
Govt. of Uttarakhand

M/s Bishen Singh Mahendra Pal Singh
Publishers & Distributors of Scientific Books
23-A, New Connaught Place, P.O. Box 137
Dehra Dun -248001, Uttarakhand, INDIA

ISBN-13 : 978-81-211-0845-4
9 788121 108454