The Economics of Ecosystems and Biodiversity - TEEBAgriFood initiative in Uttar Pradesh, India

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Contents

List of Figures

List of Tables

List of Acronyms

APEDA	Agricultural and Processed Food Products Export Development Authority
BAU	Business as Usual
BAU	Business as Usual
BMI	Body Mass Index
BSI	Botanical Survey of India
Ca	Calcium
CAFRI	Central Agroforestry Research Institute
CHC	Community Helath Centre
CPCB	Central Pollution Control Board
Cu	Copper
DAC	Department of Agriculture and Coorperation
DEM	Digital Elevation Model
ENVIS	Environment Information System
ESIPL	Eldeco SIDCUL Industrial Park
FAO	Food and Agriculture Organisation
GHG	Greenhouse Gas
GSDP	Gross State Domestic Product
ha	Hectare
HEP	Hydroelectric Projects
ICAR	Indian Council for Agriculture Research
ICMR	Indian Council of Medical Research
IFAD	International Fund for Agricultural Development
IHM	Institute of Hotel Management
IIFSR	Indian Institute of Farming Systems Research
InVEST	Integrated Value of Ecosystem Servicesand Tradeoffs
IPCC	Intergovernmental Panel on Climate Change
ISFR	Indian State of Forest Report
Kt	Kilo tonne
LTF	Littoral Forest
LULC	Land Use and Land Cover
masl	Metres above sea level
MDF	Moderately Dense Forest
Mg	Magnesium
NABARD	National Bank for Agriculture and Rural Development
NAEB	The Afforestation and Eco-development Board
NAP	National Agroforestry Policy
NBM	National Bamboo Mission
NDR	Nutrient Delivery Ratio

NHM	National Horticulture Mission
NMSA	National Mission on Sustainable Agriculture
NPOF	National Project on Organic Farming
NPOP	National Programme for Organic Production
NPV	Net Present Value
OF	Open Forest
PGS	Participatory Guarantee System
PHC	Public Helath Centre
PHFI	Public Health Foundation India
PKVY	Paramparagat Krishi Vikas Yojana
PRA	Participatory Rural Appraisal
PSC	Project Steering Committee
R&D	Research and Development
RCP	Representative Concentration Pathways
RFA	Recorded Forest Areas
RKVY	Rashtriya Krishi Vikas Yojana
RUSLE	Revised Universal Soil Loss Equation
S	Sulphur
SDR	Sediment Delivery Ratio
SIDCUL	State Industrial Development Corporation of Uttarakhand Limited
ST	Scheduled Tribe
SWAT	Soil Water Analysis Tool
TCCW	Total Cardiac Cost of Work
TEEB	The Economics of Ecosystems and Biodiversity
TOF	Trees Outside Forests
UKFDC	Uttarakhand Forest Development Corporation
UKHDR	Uttakhand Health Development Report
UOCP	Uttarakhand Organic Commodity Board
USLE	Universal Soil Loss Equation
VDF	Very Dense Forest
Zn	Zinc

1. Executive Summary

The Economics of Ecosystems and Biodiversity (TEEB) is a global initiative aimed at recognizing, valuing, demonstrating, and capturing the value of ecosystem and biodiversity services in both monetary and non-monetary terms. In 2020, the TEEB initiative launched the TEEBAgrifood project, titled "The Economics of Ecosystems and Biodiversity: Promoting Sustainable Agriculture and Food Systems" in India. The project established a Project Steering Committee (PSC) to conceptualize, design, and steer the TEEBAgriFood application throughout the project's duration focusing on promoting organic farming and agroforestry in the Ganga basin region of India with the objective of informing decision-making in both public and private sectors involved in the agri-food sector. By making visible the invisible benefits of nature and highlighting the associated trade-offs of policy choices through scientific evidence, the project seeks to assess the impacts of decisions on natural, social, human, and produced capital.

This report serves as the scoping and scenario-setting document for the TEEBAgriFood project in Uttarakhand state, India. The project aims to increase the utilization of organic farming and agroforestry in Uttarakhand by analysing various scenarios and making predictions until 2050. The analysis will involve comparing the current state of affairs with different possible future scenarios, including a business as usual (BAU) scenario, an optimistic scenario, and a pessimistic scenario. The project's objective is to determine how different interventions might impact the four capitals - natural, human, social, and produced - throughout the food value chain in agricultural systems. The report outlines the scope of work required to identify gaps in existing policies that could promote organic farming and agroforestry in Uttarakhand through policy modification.

Selection of Study Area

The state of Uttarakhand is spread across a total area of 53,484 km^2 of which, 86% falls under hilly terrain, and only 14% of the area lies under the plain region. Geographically, it covers, 1.63% of the total land area of India, 15.5% of the western Himalayas and is home to 8.5 million people. There are 13 districts in the state and each district is subsequently divided into administrative units.

The TEEBAgriFood Project Steering Committee meetings held on October 2020 identified districts of Tehri Garhwal, Haridwar, Nainital, and Udham Singh Nagar in the Indian state of Uttarakhand for the implementation of the study, based on the rationale of evaluating both plain and hilly areas under the framework. However, following the refinement of the scope with G.B Pant University of Agriculture and Technology, Pant Nagar, the Tehri Garhwal and Haridwar region were later excluded from the study area due to limitations concerning watershed delineation such as – overlap boundaries with neighbouring countries', and not being able to evaluate large geographical area over the given time period. In addition. the Kosi and Kailash watersheds were

finalized as representative sites for biophysical modelling and scenario analysis using the TEEBAgriFood framework.

Aim and objectives of the study

The TEEBAgriFood project in Uttarakhand will evaluate components of the eco-agri-food system. Ecosystem services in the Kosi and Kailash watersheds will be valued in economic terms – namely for water yield and water quality amelioration, soil erosion and sediment yield, soil health, crop provisioning (based on the primary and secondary cropping systems in the study area), fuelwood and fodder, carbon sequestration, and climate change regulation services. Elements of human and social capital that have been prioritized for assessment include human health (nutrition and reduction in the burden of disease), women empowerment, education and skill development, livelihoods and enhancement of income of farmers.

The study process will be guided by the objectives outlined in the small-scale funding agreement (SSFA) between G.B. Pant University of Agriculture & Technology, Pantnagar, and TEEBAgriFood, United Nations Environment Programme (UNEP).

- Inform policy about the overtime impact of organic farming on ecosystem services
- Inform policy, institutional, and governance solutions that take a food systems approach, endorsing coherence across different policy areas (e.g., agriculture, health, trade, food).
- Support spatial planning of agricultural production to maximize ecosystem services.
- Evaluate the economic case for scaling up organic farming and agroforestry.
  Inform sustainable food production policy interventions, such as policies related to pollution, pesticide and fertilizer use, sustainable value chains, market linkages, and certifications.

Expected Outcomes

The proposed theme for the study is to conduct an overall evaluation of sustainable options in the agriculture sector and technologies/interventions supporting the ecosystem services and biodiversity all over the region. As the TEEBAgriFood initiative is dedicated to the economic evaluation of agricultural and ecosystem services, the following outcomes are expected from the TEEBAgriFood Uttarakhand project:

- Economic evaluation of ecosystem services of organic farming, agroforestry and conventional farming practices across natural, human, social and produced capitals
- Technical outputs and demonstration plot study results that can support future scaling of agroforestry and organic farming measures in the state
- Identification of positive and negative impacts and externalities across the entire agri-food value chain that can support future decision support system and policy planning.

2. Project Area

2.1. Overview of Study Area

The Indian state of Uttarakhand covers a total area of 53,484 km^2, out of which, 86% falls under hilly terrain, and only 14% of the area lies under the plain region. Geographically, it covers, 1.63% of the total land area of India, 15.5% of the western Himalayas and is home to 8.5 million people. There are 13 districts in the state and each district is subsequently divided into administrative units. Uttarakhand's terrain varies significantly, with Nanda Devi being the State's highest elevated peak (7,816 meters), whereas Sardar Sagar Reservoir has the lowest altitude at 187 meters.

Given the vast altitudinal range in the state, from 187 masl to 7000 masl the districts covered under the study captures variation in agroecological zones and demographic factors. For this study, the Kosi and Kailash watersheds were defined as the study regions as they thoroughly represent the state profile (Figure 1).

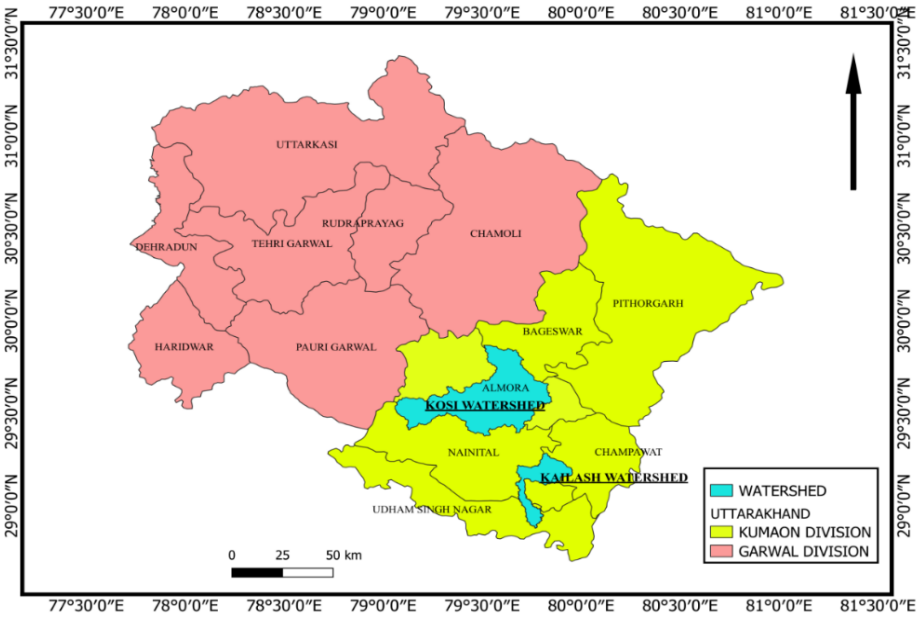


Figure 1: Location of watersheds in Uttarakhand

Located within the boundaries of Nainital and Almora district, Kosi is a gauged watershed encompassing an area of approximately 2,101 km^2. With 6 order streams, the watershed has elevations ranging between 365 meters to 2,622 meters (Annex 1: Digital elevation maps). Kosi river originates in Dharpanidhar and flows into the Ramganga river covering 4 towns and 897 villages in the state. The Land Use and Land Cover map below (Figure 2) shows that 50% of the watershed area is covered by forests. The water that flows through the Kosi river is widely used

for drinking and irrigation purposes. The Kosi River's water yields will be studied using biophysical models such as SWAT.

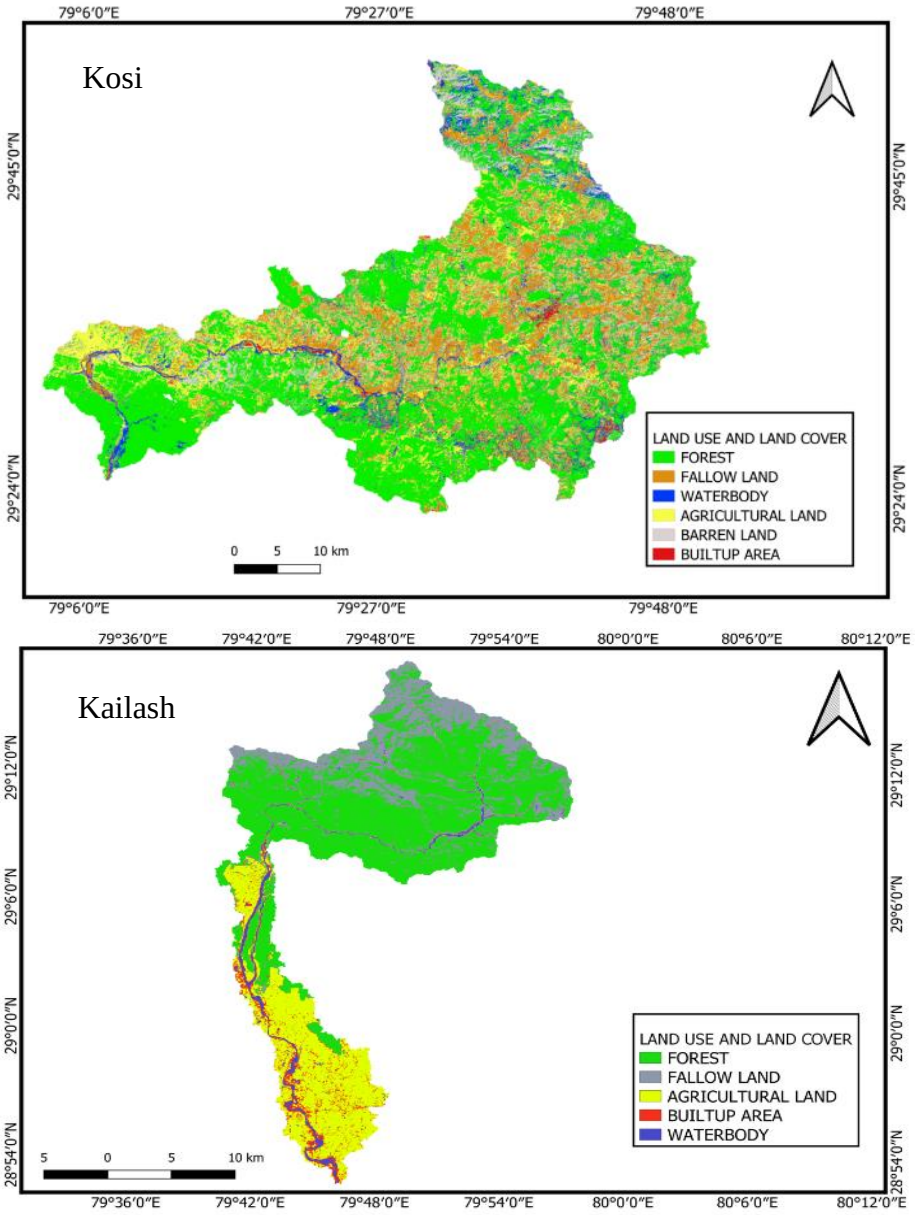


Figure 2: Land use and land cover map of Kosi and Kailash watersheds

The Champawat, Nainital, and Udham Singh Nagar districts of Uttarakhand share a border with the Kailash watershed, which is the other part of the research area. The extent of Kailash watershed is 41,585 km^2 with elevation ranging between 204 - 2129 meters. The ungauged watershed is predominantly drained by four order steams (Annex 1) and covers 92 villages in Uttarakhand. The river Kailash originates from Pangoot, Nainital, and runs down along the Eldeco SIDCUL Industrial Park (ESIPL), Sitarganj, through the Sitarganj town in Uttarakhand. Within the confines

of this watershed, the Nandhaur wildlife sanctuary was established in 2012 that extends into the Nepal territory with majority of its area being covered by dense forest.

2.2. State's physiography

The state of Uttarakhand can be physio-graphically divided into two zones: montane and non-montane regions:

Non-Montane: This zone can be further categorized into two terrains i.e., Bhabhar and Terai. The Bhabhar zone is located at the foothills of the Himalayas. The 34km wide area, where the Himalayan deluge rushes down from the steep slopes and disappears under boulders and gravels due to the extremely porous soil types. Due to its formation, this zone creates fan piedmont which are a collection of numerous coalescent fans occupying a narrow tract and form a floor of sediment-like structures between the mountains and the Bbabhar zone. The debris from the torrential streams descending from the higher Himalayan altitudes creates the piedmont fans. Consisting of poorly sorted, unconsolidated sediments of varying sized fractions. The presence of thick clay layers over coarser sediments with the abrupt reduction of slopes marks the southern limit of this zone. The Terai zone on the other hand is situated below the Bhabhar zone and runs parallels to it. It is a marshy and damp track (about 80–90km wide) containing fertile soils with a high level of water retention capacity. The Tarai zone merges with the Central Ganga Plains. This zone is characterized by moist, waterlogged areas that gently slope southwards, considered best suited for agriculture.

Montane: This area is characterized by zones extending between 60–90km with an abrupt rise in elevation between 1,200m and 2,400m and is known as the Lesser Himalayas. It contains two types of physiographic sub-units: the Himachal ranges and valleys and lake basins. It also includes the Sub-Himalaya, which has the fewest recognisable Himalayan features. The Shivaliks, the youngest of the Himalayan ranges and the Doon (flat longitudinal structural valleys) to the north of Shivaliks, make up this region. The Shivaliks have a restricted range with width between 6-30 km. The width of another region, the Greater Himalayas ranges from 40–60km. This zone is perpetually covered with snow; hence it is called 'The Himadri'.

2.3. Soil Profile

According to FAO soil world map, there are seven different soil orders in Uttarakhand (Figure 3). Fine loamy soil makes up nearly 46.29% of measured area, and 9%of the surveyed area has fine textural class. These soils offer excellent biomass production potential. Additionally, the analysed region has moderate to low potential for biomass production in coarse loamy soils (6.22%) and loamy soils (2.80%), respectively.

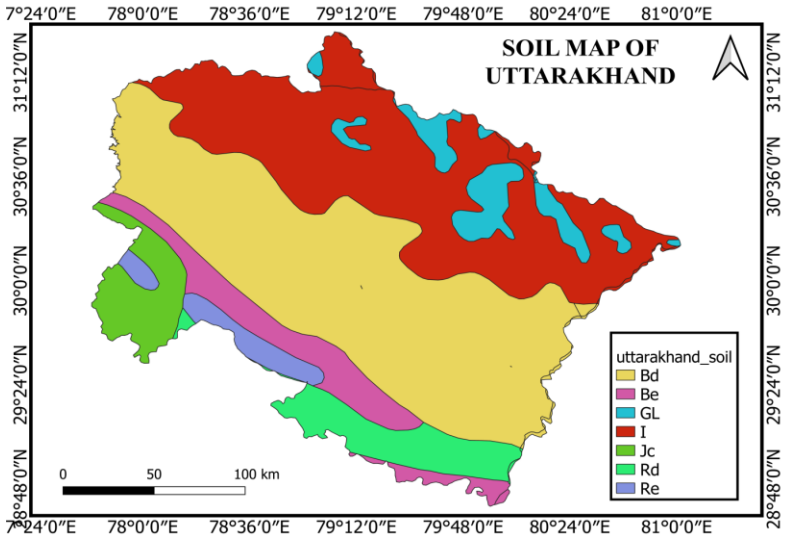


Figure 3: Soil map of Uttarakhand

Due to heavy rainfall, fragile geological formations, active seismicity, and uncontrolled deforestation, the state suffers from significant soil erosion issues. Steep to very steep slopes, deforestation, burning, clearing, and dibbling of seeds alone cause around 4.1-tonne ha^{-1} $year^{-1}$ of soil material to roll down towards foothills. Different researchers have indicated that soil erosion from hill slopes (60–70%) is 146.6, 170.2, and 30.2-tonne ha^{-1} $year^{-1}$, during the first, second and third years.

The highest amount of soil erosion that can allow agricultural productivity to be sustained economically and indefinitely is known as soil tolerance. According to Mannering (1981) tolerance levels can range from 4.5 to 11.2-tonne ha^{-1} $year^{-1}$. Water conservation structures perform less effectively when there is soil loss more than 11.2-tonne ha^{-1} $year^{-1}$. This stage results in the creation of gullies formation which in turn obstructs cultivation activities. Analysis of soil loss in the state reveals that classes of moderate, moderately severe, severe, and very severe soil erosion surpass the tolerance level of 11.2-tonne ha^{-1} $year^{-1}$ and cover an area of 394,000 ha (7.39%), 359,000 ha (6.71%), 473,000 ha (8.84%), and 1,750,000 ha (32.72%) of the state's total geographical area, respectively. Therefore, to preserve the soil, considerable policy action is required.

The soil loss in different districts of Uttarakhand is shown in Annex 2: Soil loss in different districts of Uttarakhand. It depicts areas affected by moderate to slightly severe loss are primarily districts of Pauri Garhwal, Champawat, Nainital and Udham Singh Nagar covering 10.53%, 3.22%, 7.22% and 5.71% of the total area respectively. The severe and very severe erosion classes are primarily found in the districts of Dehradun, Uttarkashi, Tehri Garhwal, Rudraprayag, and Bageshwar districts. The primary objective of agronomic measures on cultivated lands is to maximise the in-situ conservation for sustained and increased production in slightly sloping areas (1-6%). Farmers often engage in contour farming, out of convenience, which encourages run-off water to reach higher velocities, resulting in more run-off and soil erosion.

2.4. Climate Profile

Uttarakhand's climate ranges from hot and humid subtropical in the south to chilly alpine in the north. The dominating hilly terrain and the minor plain region, make up Uttarakhand's two distinct climate regions. Higher elevations have a cold alpine environment, with cool summers and extreme winters. At elevations above 4800m, temperatures are continuously below the freezing point of water, and the terrain is perpetually coated in snow and ice. The area can be divided into three agroclimatic zones based on elevation, and 12 agroclimatic zones based on temperature and precipitation (Annex 3: Agro-climatic zones of Uttarakhand). Along the gradient of elevation, three distinct agroclimatic zones are: lower altitude (500-1000 masl), middle altitude (1000-1800 masl), and higher altitude (1800 masl and above). The state's rainfall and monsoon patterns are influenced by the mountain range itself.

Changing climate conditions have significant impacts on Uttarakhand. Some of these include: Increased temperatures, changes in precipitation patterns, glacier retreat and biodiversity loss According to Krishna Kumar et al. (2011), temperature will rise by 1-4 Degree Celsius and precipitation is projected to increase by 9-16%. The Himalayan range is expected to experience a 3 degree Celsius rise in temperature as per IPCC (IPCC, 2007).

Predictions and data analysis for the time period 2021-2050 relative to 1961-1990 (provided in Annex 4 – changes in rainfall and temperature related agri-variables) show changes in variables associated with rainfall that are relevant from an agriculture perspective. The state's annual maximum temperature increased by 0.42 degrees Celsius between 1951 to 2013, while the annual minimum temperature decreased by -0.25 degrees Celsius, consistent with the evidence of receding snowlines and glacier melt. In addition, vulnerability assessments show that Udham Singh Nagar and Nainital districts have high vulnerability score of 10 and 11 respectively (Annex 5: District-wise vulnerability index). The results depict, Almora, Chamoli, Pithoragarh, and Bageshwar are evidently the most sensitive areas, whereas, Udham Singh Nagar, Dehradun, Haridwar, and Nainital districts are found to have higher adaptive capacities for agriculturally significant factors.

The pre-monsoon season (March-May) is predicted to have the largest fluctuations in maximum and minimum temperatures going forward, which will have a variety of effects on crop development. There has been significant inter-annual variability in rainfall over the century, with the number of wet days dropping since the 1990s. Particularly, state's steep regions, have become drier. However, overall rainfall has not reduced significantly, meaning that fewer but more severe rainstorm events have occurred in recent decades.

2.5. Water Resources

The main rivers in Uttarakhand's inner Himalayan region are Ganga, Yamuna, Bhagirathi, Alaknanda, Kosi and Mandakini. Notable glaciers include Gangotri, Nandadevi, Maiktoli, and Chorbani. The central Himalayan region of Uttarakhand is nourished by over 900 glaciers through rivers such as the Yamuna, Ganga, and Kali, and its tributaries such as the Tons, Bhagirathi, Bhilangana, Dhaulaganga, Mandakini, Alakananda, and Pindar. The Shivaliks' rivers mostly ger their start from monsoon torrents, with relatively little flow during the rest of the year. Numerous springs on the Himalayan slopes support life and livelihoods while Uttarakhand's rivers are vital for agriculture and the production of hydroelectric power. But the decline in broadleaf trees on the slopes has caused the water to dry up.

After Arunachal Pradesh, Uttarakhand has the second-highest hydropower potential among the Himalayan states. The leadership of Uttarakhand regards hydropower sales as a crucial source of revenue, when power shortages are at peak, melting of summertime glaciers allows Uttarakhand to export electricity to other states. The state has a lot of potential for hydropower, which is used to meet its business energy needs. In addition, Uttarakhand has established an ambitious plan to construct 450 hydroelectric projects (HEPs) with a capacity of 2,7039 MW[1] .

2.6. Biodiversity

Uttarakhand holds several wetlands due to its large geographical extent. Numerous faunal species, ranging from microorganisms to mammals, call these wetlands home. These wetlands are among the most productive and threatened ecosystems on the planet. Numerous migratory and resident birds call these wetlands home at various times of the year; 743 bird species have been reported in Uttarakhand out of an estimated 1300 in India.

Floral Biodiversity

The state's flora is diverse, ranging from subtropical, temperate, subalpine, and alpine varieties through tropical deciduous to alpine vegetation types. Pine, Oak, and Rhododendron are the three primary natural species. Below the snowline there are Forest of Spruce, Fir, Cypress, Juniper, and Birch. Above the snowline, you can find Alpine vegetation, including mosses, lichen, and a diversity of wildflowers such as blue poppies and Edelweiss. Angiosperms and gymnosperms account for about 6390 species in Uttarakhand. The flora of Uttarakhand includes; 352 species of algae, 560 species of bryophytes, 541 species of lichens, 365 species of pteridophytes, 35 species

[1] Expert Body (EB) Report (2014): Assessment of environmental degradation and impact of Hydroelectric Projects during June 2013 disaster in Uttarakhand, (Part1 – Main Report, Mins of Env & Forests, GoI, New Delhi, pp 29-30.1

of gymnosperm, 1268 species of monocotyledons, 237 species of orchids, and 3572 species of dicotyledons were found in Uttarakhand's flora.

Faunal Diversity

3748 species of vertebrates and invertebrates from 1848 genera and 427 family's makeup Uttarakhand's diverse Wildlife. There are 499 genera with 1060 vertebrates and 1349 genera with 2688 species of invertebrates. According to Uttarakhand Biodiversity Board, 451 species have been reported for the first time in Uttarakhand making new records for the state and 22 new records for India. 35 species reported from Uttarakhand are endemic to the state, one being endemic to India.[2] Uttarakhand's flora and fauna comprises 100 mammalian species, 743 bird species, 142 fish species, 75 reptile species, and 20 amphibian species. Highly endangered animals like the snow leopard, musk deer, tiger, Asiatic elephant and others have ample habitat in Uttarakhand's forest (Tripathi and Lakhera, 2019).

Causes of Biodiversity loss

The research wing of Uttarakhand's Forest Department has successfully preserved 1145 species through in-situ and ex-situ conservation efforts. According to International Union for Conservation of Nature (IUCN), eight of these species among these are critically endangered, twenty-three species are endangered, fourteen are vulnerable, and twelve are near-threatened. Whereas, Environment Information System (ENVIS) of the Ministry of Environment, Forest and Climate Change classifies one species as endangered, two species as vulnerable, three species as rare, and one species as threatened. Furthermore, Botanical Survey of India (BSI) classifies five species as critically endangered, seven species are endangered, five species are vulnerable and eleven species are threatened as per Uttarakhand Biodiversity Board. Out of 1145 total conserved species, 46 species are endemic, with 25 being near-endemic, 10 species being unique to Uttarakhand, and 10 being endemic to Indian Himalayan Region (Forest Research, Uttarakhand Report). Detailed list of threatened species of plants, mammals, birds, reptiles, amphibians and wild animals is provided in Annex 6 – Biodiversity of Uttarakhand.

- Given that a huge number of manmade factors (mainly) are causing biodiversity loss in the state, Uttarakhand's rich biological variety and high number of distinct species make conservation efforts there imperative. A few of these are:**Poaching and hunting:** One of the biggest hazards to wildlife in the state is illegal poaching, hunting, and killing of wildlife. Poachers and crashes with large vehicles are responsible for the deaths of porcupines, rats, snakes, birds, and occasionally tigers and leopards. For instance, a leopard was discovered dead in 2016 after colliding with a bus close to Bhiri NH 109. It is also usual practise to extract therapeutic plants illegally.
- **Forest fires:** The state's forest, wildlife, medicinal plants and human livelihoods have all suffered significant harm as a result of forest fires. Some local people create fires in the

[2] Book on threatened species of India. Available at: https://sbb.uk.gov.in/files/books/Threatened_Species_Book-CTP.pdf

near forest intentionally. Forest fires harm young plants as well as mammals, reptiles, amphibians, and butterflies, who may flee the area or suffer burns of their own.

- **Human-wildlife conflicts** - The common leopard, black bear, and monkey are the common animals that have involved in conflicts with humans. Livestock (buffalos, sheep, goats, horses, and mules) are killed by the common leopard, while the black bear has been reported to attack humans. Two women were killed by a black bear in 2017 in Rampur Nyalsu. Maheswari and Sharma (2010) reported that there is a depredation of livestock (sheep and goats) during summers when the shepherds visit the higher ranges of Snow Leopard habitats in Uttarakhand.
- **Biotic interferences** - Due to the abundance of religious and tourism attractions in Uttarakhand, the animal variety may be under threat from factors including the huge number of pilgrims, tourists, buses, and trekkers. Additionally, environmental deterioration and the depletion of natural resources are caused by these biotic interferences.
- **Concretization and urbanization activities** – One of the critical anthropogenic factors contributing to environmental degradation and the depletion of natural resources is road construction and its widening. Road dust resuspension, traffic delays, freshwater spring contamination, severe soil erosion, landslides and increase impermeable area causing obstruction of natural water seepages are all effects of road building. In Uttarakhand specifically, the Indo-China war compelled construction of roads, which have a significant impact on the biodiversity of the entire Himalayan region.

  Similarly, diversity of animals and flora is threatened by construction of hydroelectric power generation plants. Sometimes, behaviour of the wild animals is impacted by the blastings done during road building and tunnel dug work for hydroelectric plants.

Loss of natural resources which were based on subsistence agriculture, forest resources, artisanal crafts, some mining, and cross-border trade with Tibet by the Bhotiya communities, has resulted in the hampering of the traditional economy of Uttarakhand. The disaster in terms of bank bursts of big and small rivers and mountain streams throughout the state is creating an unpleasant atmosphere in nearby villages. Heavy rains destabilizing mountain slopes are causing landslides at thousands of locations more specifically in fragile high ranges. Human tragedy is therefore a major concern and hence, people who are homeless, landless and without rural populace will become a major challenge.

Agricultural Biodiversity

The state has a diverse range of agricultural crops and major commercial food crops. Including six types of cereals, five types of pseudocereals, six types of millets, 16 types of pulses, four types of oilseeds, five types of condiments, and eight types of vegetables. (Refer to Annex7: Agricultural Biodiversity for details on crops grown in Rabi and Kharif season) Traditional farming practices are still prevalent in the region, with crop production, animal husbandry and forestry being interlinked. Modern agriculture has been slow to penetrate the area due to inaccessibility, environmental heterogeneity, and ecological fragility, leading to a subsistence production system that can sustain organic matter and nutrients derived from forests. Basmati rice of the Doon Valley, Ogal-Phapahar (buckwheat), Mandua (finger millet,) Jhangora (foxtail millet,) and a variety of traditional legumes are grown in the high mountains that are unique to the region.

Despite the challenges of scarcity of arable land and scanty irrigation, agriculture remains the mainstay of the rural population, with pulses being the most important crop, especially in the hilly regions. Although the average productivity of pulses in Uttarakhand is around 6.68 quintals per hectare, the economic potential of diverse crops, including pulses, is high due to their nutraceutical and pharmaceutical importance. Cereal, millets and mustard, soybeans are other important crops cultivated in the hills. Vegetables are cultivated mostly during the off-season (apart from Rabi and Kharif seasons), mostly in greenhouses to obtain better yields. However, growing crops in controlled environments with optimal fertilization and irrigation increases their vulnerability to various insect pests, including white grubs, which are the most harmful in the Indian Himalayan region. Over 80 species of white grub have been recorded infesting crops in Uttarakhand, including major vegetables such as tomato, capsicum, chili, brinjal, cabbage, cauliflower, and green leafy vegetables.

The state has also been affected by the effects of climate change, resulting in unpredictable weather and erratic precipitation. Traditional practices such as mixed cropping and intercropping, crop rotation, maintenance of crop fallow periods, and interspersing of trees and other non-crop species are used for conserving agro-diversity in the system. However, the introduction of exotic pests and locally available low-grade chemicals has made the scenario more vulnerable. Furthermore, changing climatic conditions have caused a shift in insect pest populations towards temperate regions, and sucking pests such as aphids, thrips, mites, and whiteflies have become hard to manage. Exotic pests such as the tomato pinworm, fall armyworm, and eriophyid mite are also causing severe threats to hill agriculture. (Refer to Annex 7: correlation between insect population density for different commodities v/s climatic conditions of Kharif from 2015 to 2020)

Pollinators

Pollinators are essential for the survival of over 180,000 plant species and support 87 of the world's top food crops. Insects, which are a significant part of terrestrial biodiversity, play multiple roles in ecosystems, such as herbivores, pollinators, seed dispersers, and more (Weisser and Siemann, 2008). The use of pesticides has led to poor pollination and lower yields of crops like apples and radishes in Uttarakhand (VSPC reports). There is a need for policy intervention to determine the economic value of pollinators and to raise awareness among local communities to conserve them. Agricultural machinery needs to be improved to promote better practices for pollinator conservation.

2.7. Agriculture

Although it contributes very little to the overall Gross State Domestic Product (GSDP), Uttarakhand is predominantly an agricultural state. In the past 20 years, Uttarakhand's GSDP has experienced remarkable increase. Despite its steadily diminishing percentage, the primary sector's economy has witnessed a significant role in the state economy. When it came to the state's gross domestic product (GSDP), the primary sector, which includes agriculture, livestock, forestry, fisheries, and mining, contributed 31.49% in 1999–2000 but just 10.2% in 2019–2020. Despite losing relevance for Uttarakhand's GSDP, the primary sector still employs close to 70% of the state's workers.

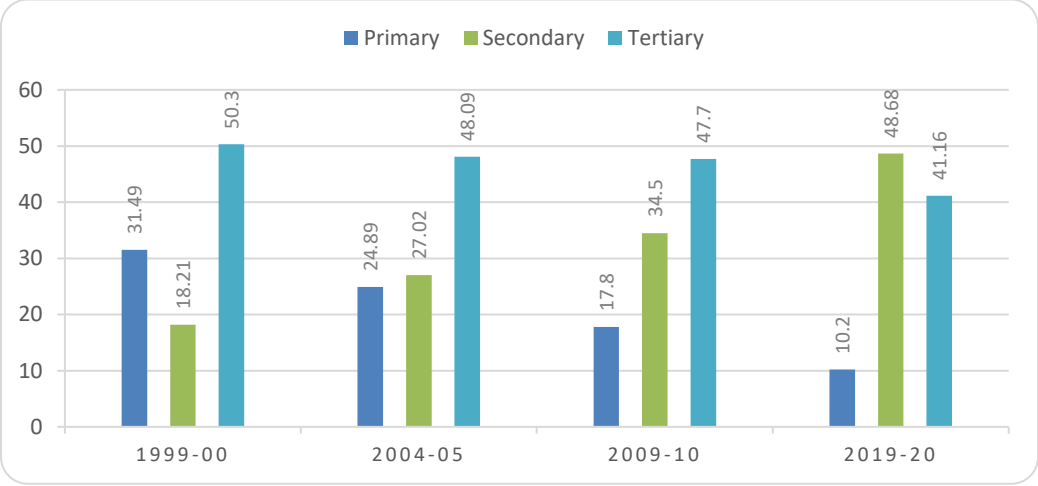


Figure 4: Percent share of different sectors to GDP in Uttarakhand
Source: Directorate of Economics & Statistics of Uttarakhand

The structural composition of the state economy has witnessed a significant change in recent years. While the primary sector contribution has declined, the secondary sector covering manufacturing, construction, electricity, gas, and water supply sector contribution to GSDP increased from 18.21% in 1999-2000 to 48.68% during 2019-20. Implying that the state's economy is transitioning

from one based on agricultural to one based on manufacturing, with the service sector continuing to hold a strong position.

Table 1: Pattern of land use in the gross sown area, net sown area, and area covered under different agriculture seasons in Uttarakhand (Area-Hectares)

Agriculture Area	**1990-91**	**2000-01**	**2010-11**	**2018-19**
Kharif	753315	732571	678469	606661
Rabi	497982	467003	453934	385009
Zaid	20225	24144	36631	37137
Net Shown Area	789865	769944	723164	647788
Gross Crop Area	1274629	1225556	1169697	1029014
Area Shown more than once	484764	455612	446533	381226
Cropping Intensity (%)	161.37	159.17	161.75	158.85

In 1990-91, the net sown area in the state was 753,315ha which decreased to 606,661ha in 2018–19. It decreased by 18% and 23% during the Kharif and Rabi season, respectively. However, during the Zaid season, the area increased by 83% during this time period. Likewise, the gross sown area has decreased from 1274 (000' ha) in 1990-91 to 1029 (000' ha) in 2018-19 and the area sown more than once has also decreased from 482 (000' ha) to 381 (000' ha) in 2018-19.
A large part of Uttarakhand is hilly; the average size of operational holdings is less than one hectare. Out of the total, approximately 92% are classified as small and marginal.

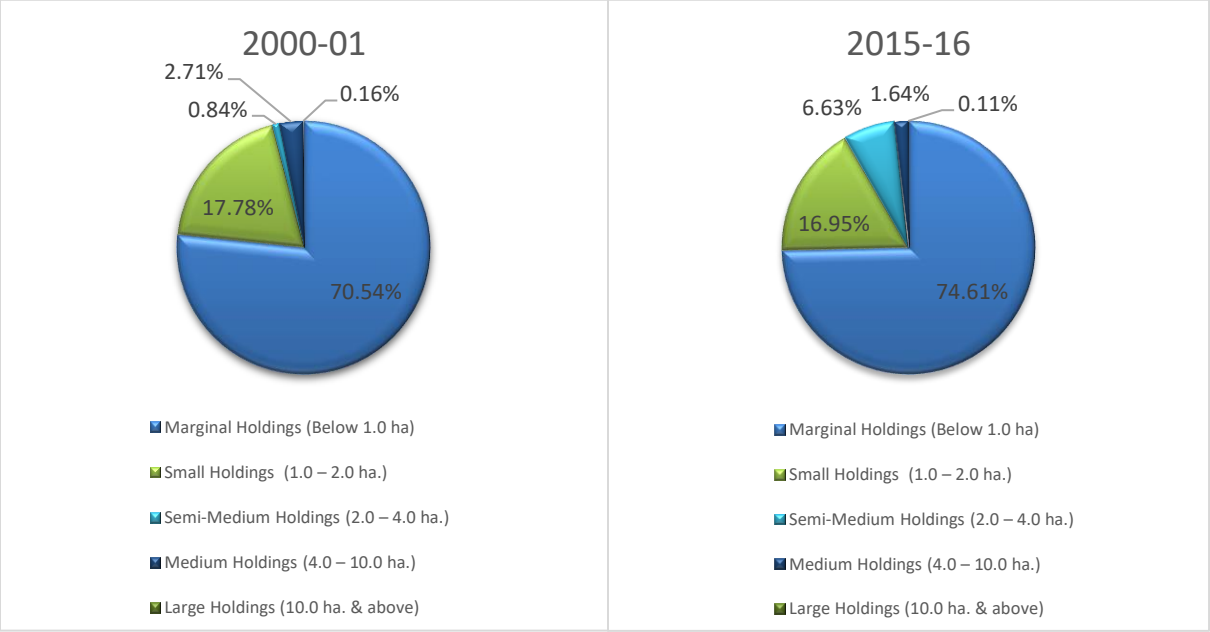


Figure 5: Percentage of operational land holdings in Uttarakhand for 2000-01 and 2015-15

According to their various categories, Figure 5 above breaks down the percentage of operational holdings in Uttarakhand. According to the figure, in the last 15 years the percentage contribution of Marginal and semi-medium land holdings has increased from 70.54% to 74.61% and 0.85% to 6.63%, respectively. Meanwhile, contribution by medium and large land holdings has decreased from 0.16% and 2.71% to 0.11% and 1.64%, respectively.

Cropping Pattern and Agricultural Production

The proportion of a region's total cropped land that is used for each crop throughout the course of an agricultural year is known as the cropping pattern. The three major crops grown in the state's gross cultivated lands are finger millet (10%), rice (23%) and wheat (31%). In addition, the state's diverse agro-climatic circumstances give it a distinct advantage over the other states in production of off-season fruits and vegetables which have a high market value.

One of the most significant economic industries in Uttarakhand is horticulture. It offers the state, where the possibility of a high rate of growth in conventional agriculture is somewhat limited due to unusual geography and the majority of scattered and marginal holdings, a much-needed chance for diversification and expanded employment. According to the data that is shown in the chart below, around 5% of the area that is used for crop production is being utilized for horticulture (Figure 6).

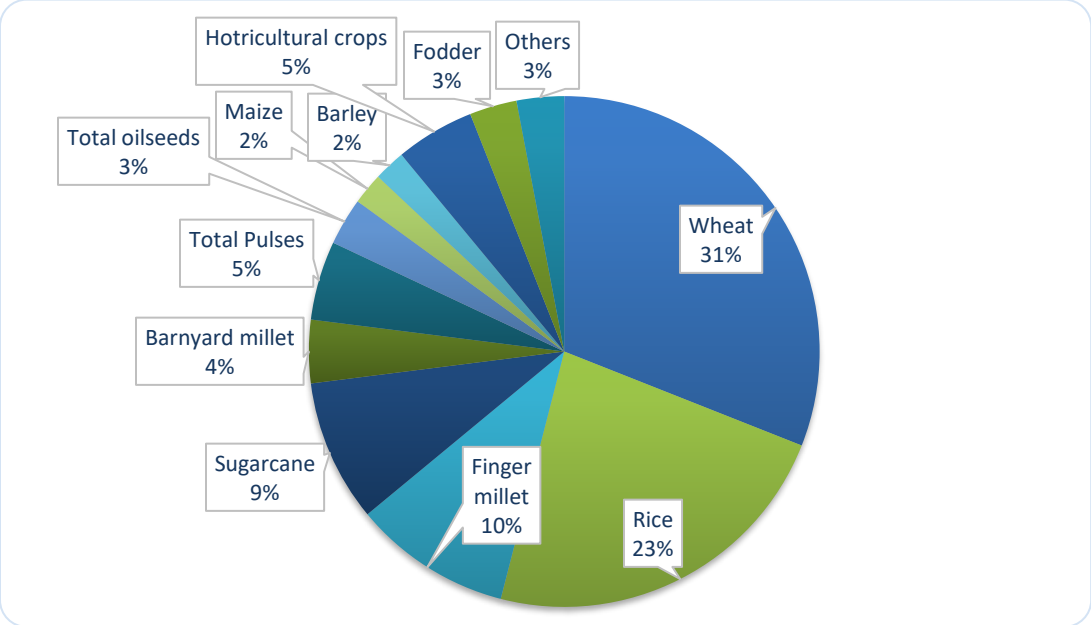
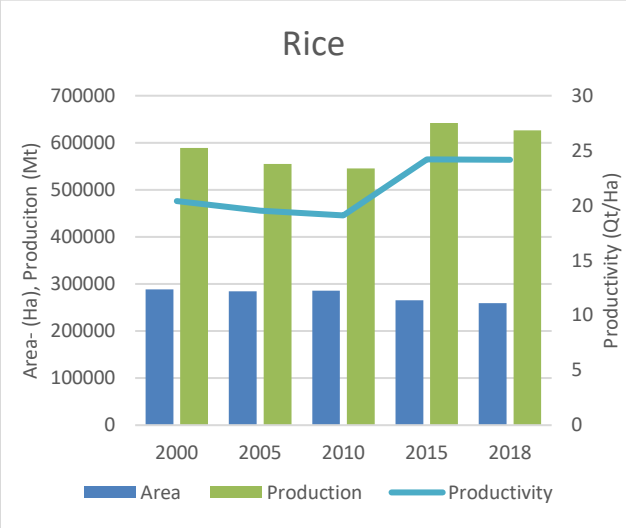
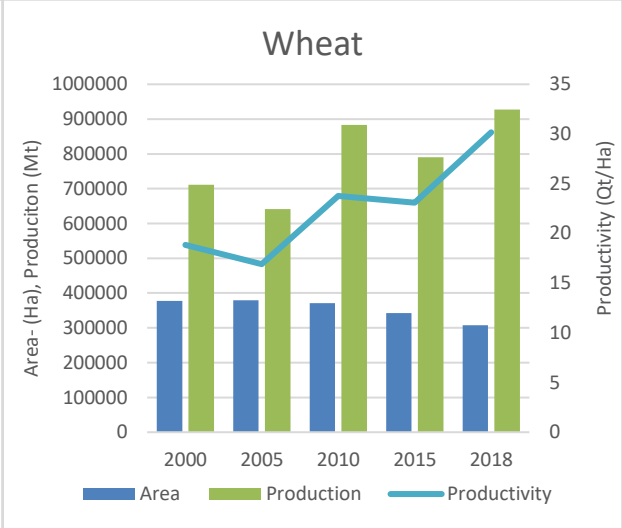


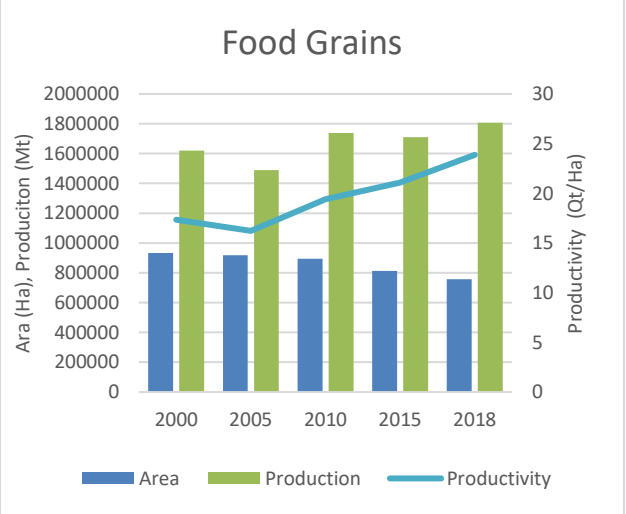
Figure 6: The cropping pattern of Uttarakhand (2018-19)

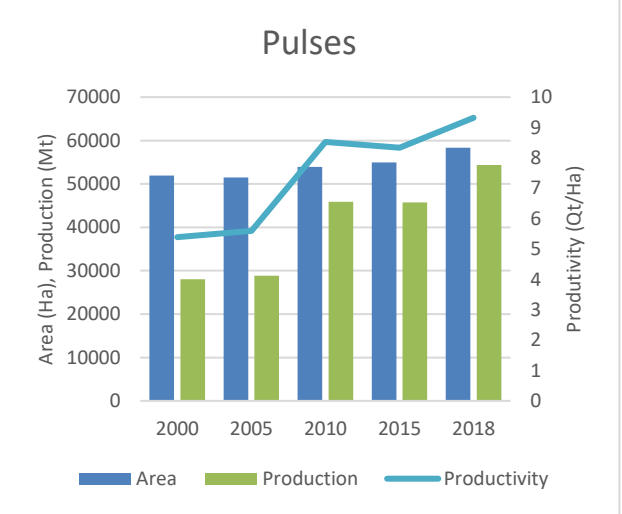
The graphs below, displays the area, output and yields of various agricultural commodities in the state between 2000-2018. As per the trends, while the area under wheat, rice and grains has decreased over time, the productivity has increased considering the rise in production between

2000-2018. Meanwhile, the area and production of pulses in Uttarakhand have increased depicting a significant rise in productivity. The trends in productivity vary remarkably in different area. Productivity of districts Udham Singh Nagar, Haridwar, Nainital and Dehradun is very high, compared to hilly areas. The details of the physiographic zones and farming situation of the state are given in Annex 8.









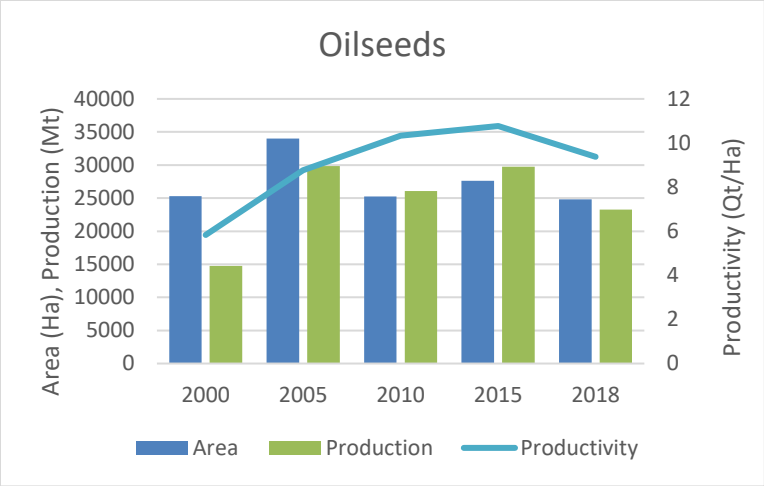


Figure 7: Area, production and productivity of rice, wheat, grain, pulses and oilseeds in Uttarakhand

Irrigation

In Uttarakhand, agriculture is rainfed due to limitations in access to irrigation. The state's hilly geography poses challenges for constructing irrigation facilities, resulting in only 10% of the hilly area getting irrigated compared to 90% of the state's plain districts. As a result, only 48% of the state's net area planted is irrigated. However, the availability of irrigation facilities varies by district.

Fertilizer consumption

The implementation of the Green Revolution led to a significant increase in the use of chemical fertilizers, particularly in certain regions. Despite the positive effects of the Green Revolution on crop yields, the excessive use of chemical fertilizers deteriorated the soil quality. In Uttarakhand, the consumption of fertilizers is comparatively low, and it is mainly used in the agricultural areas of the plains. However, there is a considerable disparity in the use of agricultural inputs between the hills and plains of Uttarakhand, leading to differences in crop production and productivity.

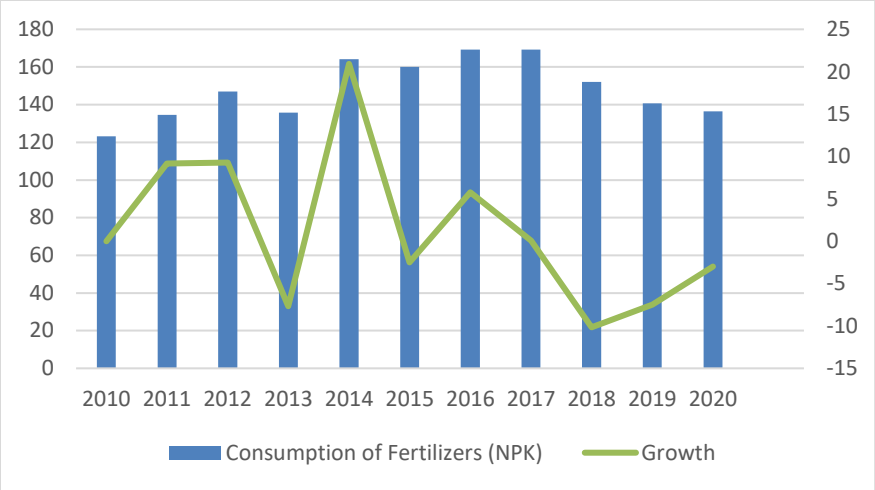


Figure 8: Fertilizer consumption patterns per hectare of consumption of fertilizer (NPK) in Kg per ha

Source: Ministry of Agriculture and Farmers Welfare, Government of India

The consumption patterns of nitrogen (N), phosphorus (P), and potassium (K) per hectare presented in Figure 8 illustrate variable trends from 2010 to 2020. Trends suggest, the consumption peaked in 2016 and 2017 at 169.2 and 169.3kg per hectare, respectively, before declining to 152.1kg per hectare in 2018; 140.7kg per hectare in 2019; and 136.5kg per hectare in 2020. An important question here is, whether the agricultural production in the state remain sustainable in the long run given the deteriorating state of the soil. Studies suggest the amount of humus in the soil has decreased in the plains due to extensive chemical use. Additionally, excessive fertilizer use is costly beyond a certain level of input use, returns to scale begin to decline and yields stop increasing proportional to the input use. Micronutrient status (Ca, Mg, S, Zn, and Cu) is also extremely poor. Phosphate fixation can occasionally become problematic if active iron and aluminium levels are high.

Gender Aspects of Agriculture

According to the Human Development Report from 2017, a large proportion of female workers in the rural India, particularly in the hilly regions of Uttarakhand. Women are engaged in a number of agricultural activities from land preparation to post harvest activities. A study by Indu Pathak (2016) suggests that the work share for agricultural activities such as land preparation (85%), sowing and transplanting (72%), Gap filling (100%), intercultural operations (68%), and weeding consisted of 94% women participation in the hilly region of Uttarakhand. In addition, women are responsible for livestock activities such as collecting fodder, cleaning cattle shade, milking cattle, and preparation of milk products.

In Uttarakhand, various departments and projects promote community-based organizations among the farmers and women. Since women in Uttarakhand play a vital role in agriculture, the state government has launched different schemes.

- **Aajivika (Women's Livelihood Scheme):** The Aajeevika project in Uttarakhand, under the Rural Development Department, is funded by the International Fund for Agricultural Development (IFAD) covering 5 districts and 17 development blocks from October 2004 which has been extended to 618 villages by March 2007. The project focuses on community mobilization and their empowerment. The project strives to work for the livelihood's enhancement of vulnerable and poor households through the approach of convergence and collaboration, especially in the field of livelihood support through enterprise and business promotion. In order to improve productivity, 20 women, in groups of 5 people, are provided training by the Department on improved practices, methods, and techniques. Special attention is provided to women belonging to the SC/ST communities.
- **Sampoorna Grameen Rojgar Yojana (Total Rural Employment Scheme):** The scheme is focused on the problem of unemployment/under-employment and is aimed to tackle the issues of poverty and chronic hunger. The share of the Central Government and that of the State Government is 75:25.
- **Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGA):** A national level scheme extended to Uttarakhand first phase Tehri, Champawat and Chamoli regions ensuring 100 days of employment under the first phase of the project. Women and men are equally paid in this scheme showing enthusiastic participation by women. In addition to this, the Department of Horticulture, Sericulture, and Dairy have also launched different schemes ensuring the participation of women.

In the hilly agro-based economy, land primarily belongs to men although the majority of them work outside their villages, while women are involved in land tillage activities. Not owning the land prevents women from accessing many government programs and schemes as these accrue to landowners rather than to farm workers. In the wake of climate change, this also prevents women from taking quick decisions on even basic matters such as what crops to sow and what farming practices to adopt in order to adapt to climate change.

Agricultural Market Linkages

When assessing the product's commercial potential, it is important to consider scarcity and surplus. In the hilly areas of Uttarakhand, farmers have historically exchanged traditional crops like Chaulai, Oggal, and various types of soybean for other goods like wheat, rice, and commodities not produced locally due to small surpluses and poor market connections. Recently, this tradition has changed, with Chauli being exchanged for sugar, clothes, and money. However, the exchange rates are still highly unfavourable to farmers due to poor market linkages.

The Uttarakhand Integrated Horticulture Development Project reported that postharvest losses of fruits and vegetables in the state range from 10-40%, and producers receive a low share of consumer prices due to an inefficient supply chain. There are several large-scale and medium-

small industries operating in the agriculture sector, including food processing, but they are mostly located in areas (Dehradun, Haridwar, Udham Singh Nagar, and Nainital) with a good road network, water and electricity supply, and human resources, leaving the hilly regions with limited industries.

Agrobiodiversity loss is not caused by a single factor, but rather by a combination of several factors, such as the degradation of natural forests, the belief in coarse and fine grains, the perception that traditional crops are backward, migration for off-farm employment leading to the abandonment of agricultural land, the supply of subsidized high-yielding seed varieties by the government, the trend towards maximizing profits through monocropping of cash crops, and the lack of marketing for traditional crops. Cropping patterns are influenced by social, ecological, and policy factors. Traditional millets and pseudo-cereals are often considered food for the poor, and government policies encouraging monocropping of selected crops have further reduced the diversity and specificity of mountain agriculture. Per capita consumption of traditional crops, along with altitude, reflects the dietary habits of the people. Around 70% of the region's population depend on agriculture and its allied activities. Native communities have developed and followed several traditional and indigenous farming strategies over hundreds of years to conserve and promote agro-diversity in synergy with religious and cultural practices. Agro-diversity acts as a shield against disease, helps to sustain extreme climatic fluctuations, is a coping mechanism during times of scarcity, and is a source of critical nutrition and medicine for the Himalayan population.

Scope of bioprospecting

Uttarakhand state comprised of Kumaun and Garhwal and a part of Himanchal Pradesh, has unique characteristics of three provinces – the Tibetan in the north, the Upper Gangetic plain in the south, and the eastern Himalayan provinces in the east. Out of the total identified floral species in the Himalayas, around 50% are identified from the Garhwal region. It would be interesting to investigate the history of this region to relate this study to social and cultural wealth. Based on the evidence, human civilization was found during the Mesolithic age (5000BC) or Megalithic age (2600 BC). The first race of Garhwal is Kole, which descended from Munda. Subsequently, Kirata, Khasas, Sakas, and many other races like Tangana, Partagana, Naga, Huns, and Bhotia intermixed and settled down in Garhwal Himalaya. These races prospected the bioresources traditionally. Bioprospecting of the available floral diversity may be good for plant-based industries. Some of the wild edibles of Garhwal Himalaya include vegetables, fruits, seeds, grains, spices, condiments, oil and beverages, fibre yield plants, plants with prospects for use in handicrafts and dyes insecticides, piscicides. Detailed list of commodities having potential for bioprospecting is provided in Annex 9.

2.8. Livestock

Livestock Distribution

In Uttarakhand, there are various kind of livestock; cattle, buffalo, goats, sheep, pigs, horses, etc. Small and marginal farmers including agricultural labourers frequently engage in animal husbandry for supplemental income. However, the productivity of these animals is low. Each household keeps a small amount of cattle of a variety of species. Compared to cattle in the plains, animals like cows and buffalo in the state are quite small and of an unremarkable breed.

According to the 20th Livestock census, there are 2.713 million cattle in the state, consisting of 47% local cows and 21% cross bred varieties and 32% buffalos. Trends suggest, the number of native cow (Hariana, Red Sindhi and Sahiwal) and buffalo (Bhadawari and Murrah) breeds have decreased between 2012 to 2019 by 15%. This has contributed to an increase in the milk production of the state; 53.84% higher in 2016-17 (1.6 Million tonnes) compared to 2001-02 (1.066 Million tonnes). While the milk production from native varieties remained constant appreciable increase in milk production was achieved mainly due to an increase in crossbred milk production (from 1.9 litre in 2005-06 to 5.76 litre in 2015-16)

Fodder Availability and Climate

While mountain regions have high potential for sustainable livestock farming Uttarakhand could not get to an impressive position. The various sources of fodder in the state are – public forest, agricultural residue, leaf litter, pasture and grazing lands, shrubs. The most significant source of fodder and leaf fodder is the public forests. Degradation of forests in the mid slopes in population dense areas has reduced the fodder and leaf litter with implications both for livestock productivity and productivity of the agricultural lands. In addition, inadequate fodder supply is also attributed to poor irrigation facilities, lack of awareness regarding the importance of quality fodder, and less acreage under forage crops. Furthermore, seasonal availability of green fodder becomes a major problem except in the monsoon season, there is an acute shortage of green fodder during other seasons.

2.9. Health and Nutrition

Results of a survey conducted by the state health department in 2018 suggest that the high proportion of non-communicable diseases in Uttarakhand is a cause for concern. Non-communicable diseases are responsible for almost 56%of the total disease burden in the state, followed by communicable diseases, maternal diseases, neo-natal diseases, and nutritional diseases, all of which account for 32% together. Ischemic Heart Diseases (IHD, 7.8%), Chronic

Obstructive Pulmonary Disease (COPD, 6.8%), diabetes (2.2%), stroke (2.2%), and iron deficiency anaemia (2.2%) were among the leading causes of Disability-Adjusted Life Years (DALYs) in Uttarakhand, according to a report compiled by ICMR, PHFI, and IHM.

Table 2: The Nutritional Status of Adults and Children in Uttarakhand from 2005-06 to 2020-21

S. No	Indicators	2005-06	2015-16	2020-21
Nutritional Status of Adults (Age 15-49 years)				
1	Women whose Body Mass Index (BMI) is below normal (BMI < 18.5 kg/m^2)	30.0	18.4	13.9
2	Men whose Body Mass Index (BMI) is below normal (BMI < 18.5 kg/m^2)	28.4	16.1	16.2
3	Women who are overweight or obese (BMI > 25.0 kg/m^2)	12.8	20.4	29.7
4	Men who are overweight or obese (BMI > 25.0 kg/m^2)	7.9	17.7	27.1
Nutritional Status of Children				
1	The Children aged 6-23 months receive an adequate diet	NA	8.5	12.5
2	Children under 5 years who are stunted (Height-for-age)	44.4	33.5	27.0
3	Children under 5 years who are Wasted (Weight-for- Height)	18.8	19.5	13.2
4	Children under 5 years who are severely Wasted (Weight-for- Height)	5.3	9.0	4.7
5	Children under 5 years who are Underweight (Weight-for-Height)	38.0	26.6	21.0

Malnutrition in children and mothers remains one of the most important risk factors that are responsible for most of the morbidity in the state. However, the comparative results of the NFHS (III, IV, and V) also demonstrate that the state has been able to achieve a marked improvement in the nutritional status of adults and children older than 5 years within 15 years (2005-06 to 2020-21). There is an increase in the percentage of overweight women in every district with district Dehradun showing the best results.

Children with a haemoglobin level of 11 and below mg/dl (decilitre of blood) are categorized as anaemic. It may be noted that a healthy child (who is not stunted, wasted or underweight) or adult may be anaemic. Currently, the percentage of anaemic persons in the country stands at around 50%. Anaemia is also a major health problem in Uttarakhand, especially among women and children. Among children between the ages of 6 and 59 months, more than half (55%) are anaemic.

This includes 26%who are mildly anaemic, 27%who are moderately anaemic, and 2%who suffer from severe anaemia. Girls are slightly more likely than boys to have anaemia. Although anaemia levels vary somewhat according to background characteristics, anaemia among children is widespread in every group. Almost half of the children (49%) are anaemic even if their mother has 12 or more years of schooling. The prevalence of anaemia among children decreased from 61% in NFHS-3 to 55%in NFHS-4. In the last 5 years, most of the districts have managed to reduce the prevalence of anaemia. However, anaemia among children has increased in Almora, Dehradun, and Chamoli districts. Relative to the national prevalence of anaemia among women, the status of pregnant women in Uttarakhand is better, except for the Haridwar district where the percentage has increased in the last five years.

2.10. Tribes of Uttarakhand

The tribes of Uttarakhand are various ethnic groups in the state, of which schedule tribes (STs) constitute 2.9% of the total population. Other major tribes include - the Jaunsari tribe, Tharu tribe, Raji tribe, Buksa tribe and Bhotiyas. As per Census 2011, Tharu is the largest of the five schedule tribes of Uttarakhand constituting 31.3% of the population of the state, followed by Jaunsari, Buksa and Bhotiya constituting 30.4%, 18.5% and 13.4% respectively. All thirteen districts of the state have a moderate tribal population and the majority of the population is concentrated in four districts, namely, Udham Singh Nagar (43.3%), Dehradun (38.78%), Pithoragarh (7.53%), and Chamoli (4.09%). These tribes are predominantly rural (around 90.7%).

The diversity of tribes in Uttarakhand makes are significant cultural heritage and contribute to unique handicrafts prevalent in the state. Agriculture is the main source of income for these tribes. The tribal communities of the state have remained the weakest section in the state from an ecological, economic and educational point of view (Raghav et al. 2013)**.** These tribes are basically an agricultural-cum-pastoral community whose economy has been based on a crude type of cultivation, animal husbandry and livestock. These tribes have their traditional way of living and represent the distinctive culture and traits of primitive life. Their traditional norms and socio-cultural practices determine their ethnicity.

In the Himalayas of Uttarakhand, two communities, the Gujars and Bhotiyas, are known for practicing transhumance and depending entirely on their livestock for their livelihoods. The Van Gujjars, a pastoral nomadic community, have been living inside the Rajaji National Park, which was declared a wildlife sanctuary in 1983 and later a tiger reserve in 2015, for many years. They migrate to hills and plains every season. These communities have been classified as de-notified tribes and considered criminal tribes under the Criminal Tribes Act of 1945. Unlike those belonging to the Scheduled Caste and Scheduled Tribe communities, they have little protection in terms of land rights. Currently, there are about 1,610 Van Gujjar families living in the Rajaji

National Park, while 1,393 families have been relocated in the last 15 years on the pretext of wildlife conservation and encroachment.

Tribes and Government Concerns

Education

The National Policy on Education, 1986 (revised in 1992) to improve the educational status of STs is a major step taken by the government to improve the accessibility for the tribes who live in far-flung remote areas and remain isolated. Sarva Shiksha Abhiyan at the primary level is one such intervention. This scheme involves parents/guardians for ensuring ownership of the program, even the most disadvantaged. The supply of mid-day meals is one support service for instance.

Reservation of seats, relaxation in minimum qualifying cut-off percentages, remedial coaching, and scholarships are some important steps that have been taken in the field of higher and technical education for improving the overall education standard in India, especially for the weaker section or the socially backward section. Similar concessions were also given to ST students for improving their skills in the upcoming/modern trades which have better employability.

Health

The National Health Policy, 1983, categorically emphasizes the urgent need for improving tribal health, especially through the detection and treatment of endemic and other diseases specific to tribals. In pursuance of the policy commitments, the Ministry of Health and Family Welfare continued to give focused attention to improving the health conditions of STs by implementing various health care programs besides relaxing norms with a major objective to attend to the health needs of STs. Keeping in view that most of the tribal habitations are concentrated in far-flung areas, forest land, hills, and remote villages, the population coverage norms have been relaxed as – i) for a Sub-Centre, the average norm for Hilly/Tribal areas has been fixed at 3,000 compared to 5,000 for plains; ii) for Primary Health Centre (PHC) 20,000 coverage norm is fixed for Hill/Tribal areas compared to 30,000 for plains, and iii) the norm of Community Health Centres (CHCs) is fixed at 80,000 for Hilly/ Tribal areas compared to 1,20,000 for plains. Similarly, Multipurpose Workers are appointed for 3,000 population in tribal areas compared to the norm of 5,000 population for general.

3. Organic Farming

3.1. Overview

Organic farming is a system of sustainable agriculture production that has been followed since ancient times. The main objective of this method is to promote eco-friendly and pollution free agricultural production using naturally available resources such as organic wastes (crop, animal, farm wastes) and other biological materials as inputs. The government of India has taken several steps to promote organic agriculture. The National Programme on organic production by the Agricultural and Processed Food Products Export Development Authority (APEDA) of the Ministry of Commerce and Industry, Government of India, helped advance organic farming in the country. Through an expert focussed strategy supported by a third-party certification system, it was largely promoted at the national level (Bhardwaj & Dhiman, 2019).

In addition to NPOP, organic farming is promoted through various initiates under the National Mission on Sustainable Agriculture. Pradhan Mantri Krishi Vikar Yojana and Rashtriya Krishi Vikas Yojana are also prominent schemes that provide financial and technical assistance to farmers to adopt agriculture practices. Furthermore, nine of India's 29 states have developed rules on organic farming with the goal of accelerating the practise. Hill states of Uttarakhand, Sikkim, Mizoram, and Nagaland have stated their goal to adopt a 100% organic diet. Sikkim was designated as the nation's first state to be entirely organic.

The promotion of organic farming will have a significant positive impact on Uttarakhand, both in terms of the long-term sustainability of the state's agriculture and in terms of increased revenue from the sale of the state's premium organic produce on the national and international markets. On the social front, not only does organic farming contribute to rural jobs and growthcan significantly lower state migration.

Horticulture and its connection with other industries are mostly covered by organic agriculture. The majority of mountain villages rely mostly on agriculture for their food. There are five main farming systems used are:

- Cereal based cropping system
- Horticulture or agri-horti based production system
- Vegetable and floriculture-based production system
- Integrated livestock-based production system
- Integrated horti-silvi-pastoral based production system

In the past three years, implementation of initiatives such as the ones listed below have increased the organic farming area in Uttarakhand by 23%. In 2016-17, organic farming was done on 10%

of the total agriculture area of the state. As of 2020-21, 0.218 million hectares of land was being used for organic farming by approximately 0.459 million farmers (Agriculture Today, 2021). In 2021, the aggregate farm production was 46645.41 metric tons, comprising 420.98 metric tons of organic produce harvested via wild collection and 261.62 metric tons of organic produce exported to other regions (Seshia, 2018).

The hilly terrain and traditional farming practices in Uttarakhand focusing low chemical consumption make it a conducive state for promoting environmentally friendly organic farming that provides a better market value. 33% of the land is already certified for organic farming. The Uttarakhand government has taken steps to declare the state as an organic state through the Organic Agriculture Act, which regulates the sale of chemicals in ten notified regions. (namely- Dunda, Pratapnagar, Jaiharikhal, Jakholi, Augustmuni, Ukhimath, Dewal, Salt, Betalghat, Munsyari) (Agriculture Today, 2021).

3.2. Organic Farming Policies and Schemes

The following policies have been introduced by the Government of India and are being implemented in the state (Figure 9):

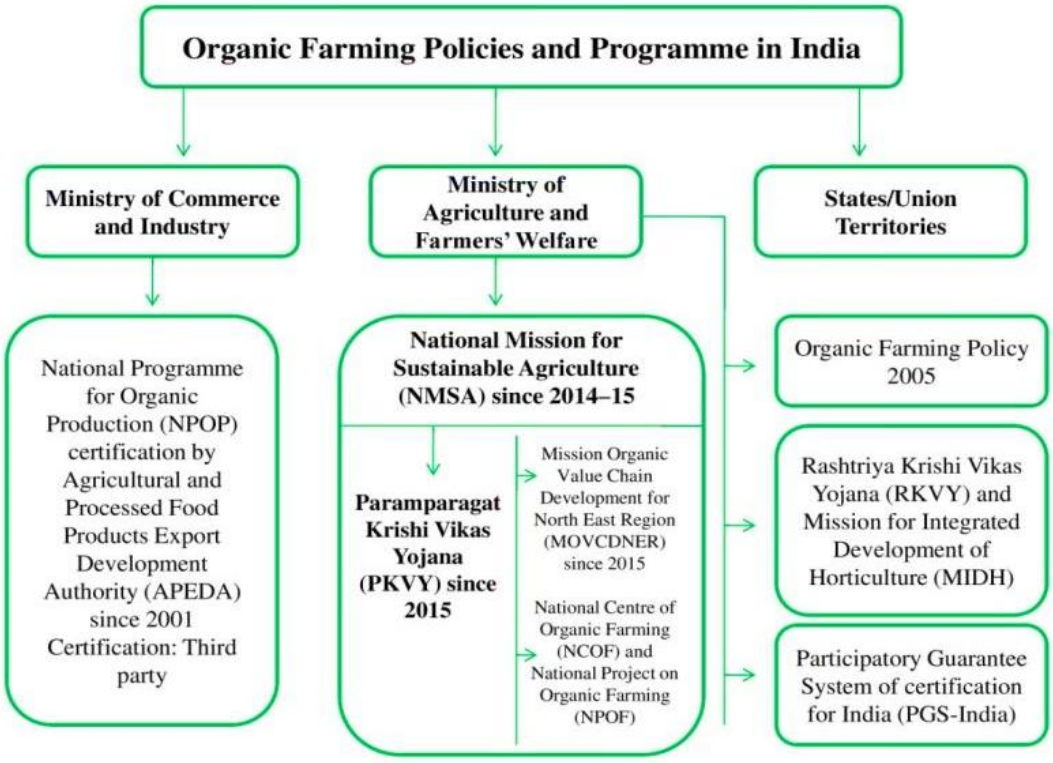


Figure 9: Organic farming policies and programmes in India

- The National Programme for Organic Production (NPOP)

The National Program for Organic Production (NPOP) began in 2001, is a quality control initiative that manages certification programmes and offers a legal framework for the accreditation of certifying agencies. Under this programme, products that have received third-party certification may be exported in addition to being marketed domestically. The cost of accreditation is prohibitive for India's small farmers because it is industry-driven. Additionally, it has led to more expensive products on the market, which has lowered demand for organic goods.

- Organic Farming Policy, 2005

The Ministry of Agriculture's Organic Farming Policy was established in 2005 with the goals of fostering organic farming, preserving soil fertility, protecting bioresources, enhancing the rural economy, fostering value addition, accelerating the growth of agribusiness, and ensuring a respectable quality of life for farmers and employees. Despite being a great opportunity, the programme was unable to provide the required attention to the country's organic farming. It lacked ambition and couldn't raise sufficient funds.

- National Mission on Sustainable Agriculture

The National Mission on Sustainable Agriculture (NMSA), made operational in 2014–15, was one of the eight missions under the National Action Plan on Climate Change. By promoting area-specific integrated farming systems, soil and moisture conservation measures, comprehensive soil-health management, and efficient water-management practices, as well as mainstreaming rain-fed technologies, the Mission aimed to make agriculture more productive, sustainable, remunerative, and climate-resilient.

- National Project on Organic Farming (NPOF)

The National Project on Organic Farming (NPOF), which serves as a nodal quality-control laboratory for the examination of bio-fertilizers and organic fertilisers, was founded in 2004 to promote the development and use of biological and organic nutrient sources as well as alternative bio-pesticides for long-term soil health and fertility. Additionally, it maintains a national and regional culture collection bank for the design, acquisition, and effectiveness testing of bio-fertilizer strains and mother cultures as well as for the distribution of bio-fertilizers, bio-control agents, and waste decomposer organisms to manufacturing units.

- Organic farming certification (Participatory Guarantee System)

Participatory Guarantee System, PGS Organic India Council was formed in 2006 after various consultations initiated with various stakeholders by The Food and Agriculture Organization (FAO), International Federation of Organic Agriculture Movements (IFOAM) and Ministry of Agriculture. The goal was to identify certification systems that are inclusive of small farmers in the country. It functioned as an informal coalition of non-governmental organizations (NGOs) dedicated to the promotion of organic food production in India for domestic consumption. Participatory Guarantee Systems Organic India Council was formally registered as a society in Goa in April 2011.

PGS certify producers with active stakeholder participation and are based on mutual trust, social networks, and knowledge exchange. PGSs are locally focused quality assurance systems. Inspired by the PGS system run by civil society in India, the Ministry of Agriculture and Farmers' Welfare (MoAFW) adopted PGS-India certification in 2015–16. The National Centre of Organic Farming (NCOF) is the secretariat of PGS-India. Regional councils are organizations responsible for coordinating, monitoring, and approving PGS-India certification decisions. They can be a district agriculture department, existing NGOs, Central and state government organic-certification service providers, or any other organization. Farmers that meet all PGS-India standard requirements receive a ''PGS-India Organic'' certificate, while in-conversion products are labelled ''PGS-India Green''.

- Paramparagat Krishi Vikas Yojana (PKVY)

One of the eight missions included in the National Action Plan on Climate Change was the National Mission on Sustainable Agriculture (NMSA), made operational in 2014–15. By promoting area-specific integrated farming systems, soil and moisture conservation measures, comprehensive soil-health management, and efficient water-management practices, as well as mainstreaming rain-fed technologies, the mission aimed to make agriculture more productive, sustainable, remunerative, and climate-resilient. A dedicated scheme of Paramparagat Krishi Vikas Yojana (PKVY), a sub-component of the National Mission on Sustainable Agriculture is being implemented since 2015-16 to promote chemical-free organic farming in the country in cluster mode. PKVY aims to develop sustainable organic farming models using traditional wisdom and scientific knowledge to ensure long term fertility, conservation of natural resources and implementation of climate change adaptation and mitigation actions. The various components of PKVY are explained in Annex 9.

The mission promotes natural resource-based, integrated, and climate-resilient agricultural systems that ensure soil fertility, on-farm nutrient recycling, and natural resource conservation while reducing farmers' reliance on external inputs and producing chemical-free, nutrient-dense food for human consumption in a sustainable manner.

The PKVY scheme promotes organic farming in all states and union territories of India, particularly in hilly, tribal, and rain-fed areas, through a cluster-based approach of 500–1000 hectares. Under the scheme, the national government bears 60% of the costs while 40% is borne by the state. Furthermore, the ratio for the distribution of funds to north-eastern and Himalayan states is 90:10, while union territories receive 100% of central aid, given the development disabilities in these states. Cost-effective ways of using sustainable integrated organic farming methods thereby increase farmer's net income per unit of land.

As per the program guidelines, PKVY is implemented through farmer groups at the village or cluster level. A group has 20 farmers with a total area of at least 20ha in a contiguous patch within a cluster. Each of these groups can receive benefit for a maximum of 2 hectares. Over the course of three years, Rs 50,000 per hectare is spent on overall implementation, with Rs 31,000 going directly to farmers for the preparation/purchasing of organic inputs like bio/organic fertilizer, bio-pesticides, seeds, and so on. Moreover, at a national scale, between 2015–16 to 2017–18, the first phase of PKVY enrolled 0.59 million farmers covering an area of 0.24 million hectares. This was extended to 0.4 million hectares by the second year. During the first and second phases of the scheme, a total number of 29859 clusters adopted PGS certification in India, comprising of 1.493 million farmers, and covering a 5.9 million ha.

Progress of PKVY in Uttarakhand

Under the PKVY scheme in Uttarakhand, 4485 clusters comprising of 224250 farmers cover an area of 89700 ha under organic farming. A total amount of Rs. 1857.753 million has been released during the period of 2015-21 for the conversion of the area into organic farming. During the first phase of the scheme, 585 clusters adopted PGS certification during the period 2015-18, while 3900 clusters adopted PGS certification during the period 2018-21.

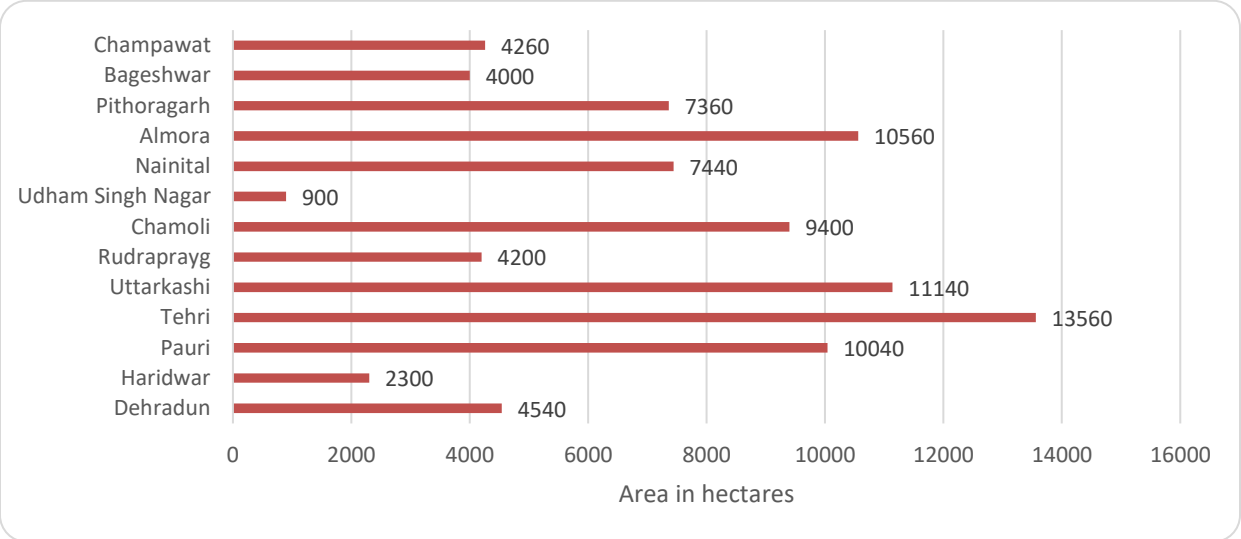


Figure 10: Area under PKVY in Uttarakhand

A total of 89700ha area converted under PKVY Scheme, where Tehri Garhwal has a maximum area contributing 15.12% followed by Uttarkashi, Almora, and Pauri contributing 12.42%, 11.77%, and 11.19%respectively. The area under the Nainital district is 7440ha contributing 8.29%of the total area (Figure 10) The plain districts of Uttarakhand, Udham Singh Nagar, and Haridwar have the lowest area under PKVY contributing respectively, 1% and 2.56% of the total area of the state.

3.3. Uttarakhand Organic Commodity Board (UOCB)

The Uttarakhand Organic Commodity Board (UOCB) was established in 2003 under the Societies Registration Act of 1860. Its role is to promote organic agriculture, horticulture, medicinal aromatic plants and herbs, and animal husbandry in Uttarakhand. As the state's nodal agency for promoting organic agriculture, the UOCB advises the state department on organic infrastructure development, supports backward and forward linkages for organic farming, conducts research, and collaborates with national and international agencies to promote organic agriculture. Rice, pulses, spices, and cereals are among the commodities currently farmed and sold organically.

The key objective of UPCB is to train farmers, extension workers from government line departments and NGOs, in the areas of production, certification and marketing. They organise seminars, exhibitions and other outreach events in the organic sector for farmers and officials working in this space. UOCB has also been successful in turning a few districts into bio-villages. This started with a pilot program demonstrating technology in 16 villages which was later scaled up to 212 villages.

The concept of “bio-village" evolved from demonstration villages to fully saturated villages with commodity production, certification, and market linkage. Currently, there are 1,200 bio-villages, under the organic initiatives and 20,000 farmers have been sensitized up to Haridwar, where the Ganga enters Uttar Pradesh from the north. Between the financial years 2018-19 and 2020-2021, around 3,900 organic farming clusters have been established, with organic farming being implemented on 50,000 hectares of land, benefiting over 0.125 million farmers.

3.4. Organic Produce Certification and Marketing

Uttarakhand Department of Agriculture promotes organic farming among farmers through two key programs: PGS standard certification through PKVY and Third-Party certification program as per NPOP & NOP (National Organic Program) standard through RKVY (Rashtriya Krishi Vikas Yojana**)** assistance. Since the first phase of PGS was established in the state under the PKVY program in 2016, there have been more than ten local organic outlets run by farmer/farmer groups

in various parts of the state. Following the successful deployment of the outlets and the farmer' satisfaction, it was decided to expand the number of outlets in other places. Regular Organic Outlets (10x15 sq. feet) and Exclusive Organic Outlets (10x15 sq. feet) will be the two types of outlets (15x30 sq. feet). In the state, tea has developed into a unique and lucrative cash crop model. In Ghorakhal (Nainital), Champavat and Nauti, the Uttarakhand Tea Development Board transformed 218 acres of the plantation into organic tea.

Farmers' Dairies

Farmers' diaries is a record through which the Organic board, which manages organic agriculture and certification for the state government, monitors the daily activities of the farmers who are certified under the organic norms as third-party requirements of the certification process. The Farmer's diary is not only a crucial document to look after farming activities but is also a connective link between the farmers of Uttarakhand and the organic standards of national and international markets. The diary plays the 'mirror of the field' through which the compliance standards can be monitored by the certifying inspectors. These diaries or other record lists from the farmers pass through the hands of various people such as trainers, farmer's federations, private sector buyers, etc. from third-party certifying agencies (Seshia, 2018). Despite all these documentation requirements from the farmers and stringent certification procedures, some organic produces still fail to match the international organic market standards nonetheless (Mathur, 2016).

4. Agroforestry

4.1. Overview

Agroforestry improves productivity, profitability, diversity, and ecosystem sustainability while also focusing on quantifiable benefits such as increasing tree coverage to enhance carbon sequestration, and soil organic matter enrichment. In the Himalayan region, the traditional agroforestry land-use system is an intrinsic element of society, and the local ecosystem since agriculture, animal husbandry, and forests form interconnected systems. The forest cover in the hill district of the country is 2,84,006 km^2 which is 40.30% of the total geographical area of the districts. Forest cover in tribal districts is 4,22,351 km^2, which is 37.54% of the geographical area of these districts. The total forest cover in the northeast region of India is 1,70,541 km^2, 65.05% of its geographical area (India State of Forest Report, 2019).

Trees Outside Forests (TOF) are defined as; trees growing outside the Recorded Forest Areas (RFA) found in diverse formations in the rural and urban landscapes such as small woodlots, block plantations, trees along linear features such as roads, canals, bunds, etc and scattered trees on farmlands, agricultural lands, homesteads, community lands, and urban areas. In the 1990s, FAO

recognized that TOF is typically splinted among the components of agroforestry, urban and rural forestry, and other disciplines.

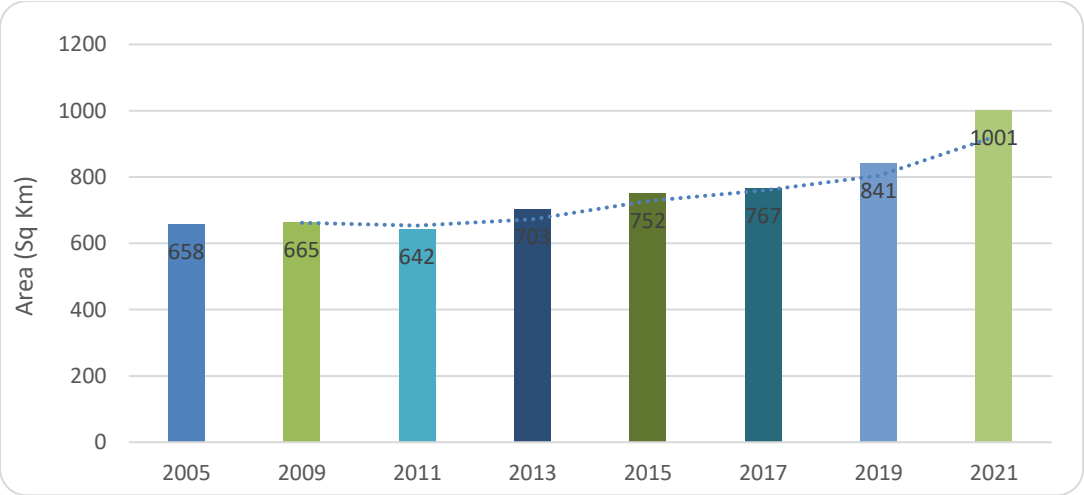


Figure 11: Trees Outside Forests in Uttarakhand

Source: Indian state of forest report 2005-2021

The area under Trees Outside Forest (extent of forest area outside the recorded forest area) increased from 658 sq. km in 2005 to 1001 sq. km in 2021 (Figure 11). Continuous growth in the area depicts the increase in the area under the Agroforestry area, Horticultural crops, woodlots, trees appearing near the house area, etc.

4.2. Agroforestry Policy and schemes

In the recent decade, agroforestry has received more attention due to diversified outputs, sustained agricultural productivity, diverse incomes, mitigation of climatic aberrations, and technical innovations led by research institutions and private organizations. The Government of India has launched several schemes/projects, including the National Bamboo Mission (NBM), Rashtriya Krishi Vikas Yojna (RKVY), National Horticulture Mission (NHM), and National Biofuel Policy, etc. under the Ministry of Agriculture, to integrate forestry components on farmlands. In addition, the National Bank for Agriculture and Rural Development (NABARD) provides financial and banking institutional support for farm forestry, social forestry, and afforestation of wastelands. Similarly, the AYUSH (Ayurveda, Yunani, Siddha, and Homeopathy) department's National Medicinal Plants Board (NMPB) has encouraged integrating medicinal plants and trees with agricultural goods. The Animal Husbandry Department’s many initiatives include establishing Silvi-pastoral systems and fodder blocks/banks. The National Afforestation and Eco-development Board (NAEB) of the Ministry of Environment, Forests, and Climate Change promotes agroforestry technologies on farms and wastelands. In addition to these schemes/programs, State

Governments also have agroforestry-related programs and initiatives. Thus, there have been some scattered efforts to focus on agroforestry practices (National Agroforestry policy, 2014).

National Agroforestry Policy, 2014

In 2014, the government of India introduced the National Agroforestry Policy to promote agroforestry and simplify regulations related to tree harvesting, feeling, and transportation on farmlands. The policy also aims at investing in research, extension and capacity building. The NAP designated 20 essential multifunctional tree species being free from all harvesting, transit and marketing restrictions. One of the core objectives of NAP 2014 is to bring different agroforestry schemes, policies and missions onto a single platform.
It is proposed that a National Agroforestry Mission/Board be established under the Department of Agriculture and Cooperation (DAC), Ministry of Agriculture, and that the Central Agroforestry Research Institute (CAFRI, Jhansi), be upgraded as a nodal centre with agro-ecology-based regional centres in various parts of the country. This will support value chain growth, climate-resilient technology development, and regional agroforestry commercial connections. The policy also recommends large-scale extension programs to disseminate the results of rigorous R&D in the field of agroforestry[3]**.**

However, the policy lacks state to state model development strategy to makes impact and requires a dedicated policy to coordinate different disciplines to institutions. Necessity brings the invention and this is very true especially in the Himalayan region as considering topography, vegetation, existing agriculture practices, and the necessity of society, agroforestry is one of the livelihoods which exists in the rural areas and more significantly, occupies the people living near forests. Agroforestry has not gained the impetus due to a lack of coordination and synergy among different disciplines and institutions, and hence a dedicated policy is needed. The growth and development of agroforestry are influenced by various economic policies such as credit, trade, taxation, power, and transport. These policies impact the agroforestry sector either directly or indirectly in addition to forest policies (Dhyani and Handa, 2013). The use of renewable energy to gain domestic energy security, offsets the energy demand and reduces global warming which is also caused by accelerating agroforestry. However, it needs to be tackled with technology interventions for providing better planting material and generating awareness amongst the farming community.

[3] http://aicrp.icar.gov.in/agroforetry/

5. TEEBAgriFood Evaluation

The TEEBagrifood evaluation in Uttarakhand is benefited from wide stakeholder consultations at the state and national level, guided by the Project Steering Committee, co-chaired by the Ministry of Agriculture and Farmer's Welfare and Ministry of Environment, Forest and Climate Change. During the consultations it was agreed that the scenarios for evaluation would be created based on current policies related to organic farming and agroforestry, such as PKVY, National Agroforestry Policy and the Namami Gange Programme.

According to Reganold and Wachter (2016), organic agriculture may have limitations, including a decrease in productivity and crop loss due to the exclusion of pesticides and insecticides. Before conventional agriculture became dominant, agroforestry was a widely practiced form of agrarianism (Dupraz et al., 2018). Despite being less common, the integration of agroforestry into organic production can offer significant opportunities if the linkages are strengthened. These opportunities include achieving a balance between productivity and environmental impact, reducing competition for resources, maximizing synergies, and complementarities, providing protection against unpredictable weather events, and obtaining premium prices for organically grown agroforestry products (Smith et al., 2013).

For Uttarakhand, scenarios developed represent both hilly and plain regions of Uttarakhand. These would be developed district wise as presented in chapter 1 to capture the distend physiographic features. These scenarios represent the alternative future scenarios for upscaling organic farming and agroforestry. The Kosi and Kailash watersheds, finalised as representative sites for scenario analysis are to be valued – namely for water yield and water quality amelioration, soil erosion and sediment yield, soil health, crop provisioning (based on the primary and secondary cropping systems in the study area), fuelwood and fodder, carbon sequestration, and climate change regulation services. Elements of human and social capital that have been prioritized for assessment include human health (nutrition and reduction in the burden of disease), women empowerment, education and skill development, livelihoods and enhancement of income of farmers. The Soil and Water Assessment Tool (SWAT), TerrSet, QGIS and InVEST modelling methodologies will be used for the biophysical modelling and valuation of ecosystem services.

Scenario Analysis

Six scenarios have been created, considering different policy interventions (BAU, optimistic, and pessimistic) and climate change projections (RCP4.5 and RCP8.5). The assessment period for these scenarios is until 2050. Decadal assessments will be presented for clarity. These scenarios have been created by combining the three policy scenarios (BAU, optimistic, and pessimistic) with

two climate change scenarios (medium and high greenhouse gas emission scenarios RCP4.5[4] and RCP8.5[5]).

The BAU scenarios represent the existing policies at the national and state level and their expected outcomes on organic farming and agroforestry, while the optimistic/pessimistic scenarios consider positive/negative changes in policy. Additionally, the scenarios for Study Area 1 (Udham Singh Nagar) and Study Area 2 (Nainital) are distinct because they are located in different regions of Uttarakhand with different prospects for the expansion of organic farming and agroforestry. Table 3 provide the specifics of the six scenarios for both study sites.

Table 3: Summary of Scenarios

Udham Singh Nagar District		
Scenario 1 (BAU Policy Intervention + RCP 4.5 Climate Scenario)	**Scenario 2 (Optimistic Policy Intervention + RCP4.5 Climate Scenario)**	**Scenario 3 (Pessimistic Policy Intervention + RCP4.5 Climate Scenario)**
- Increase in organic farming area to 38% of the net cultivated area[6] - Agroforestry continues to cover 12% of the cropped area	- 75% (103,273 ha out of 137,743 ha) of the net cultivated area brought under organic farming[7] - Area under agroforestry increases at a growth rate of 3.5% per year[8]	- Organic farming continues to cover 4% *(3.98% PKVY organic farming area/net sown area of the district)* of the net cultivated area - Agroforestry: Area under agroforestry reduces to 6% of the net cultivated area due to increasing urbanization and change from agricultural land to non-agricultural practices
Scenario 4 (BAU Policy Intervention + RCP8.5 Climate Scenario)	**Scenario 5 (Optimistic Policy Intervention + RCP8.5 Climate Scenario)**	**Scenario 6 (Pessimistic Policy Intervention + RCP8.5 Climate Scenario)**

[4] Representative Concentration Pathway 4.5 is a greenhouse gas concentration scenario that is used in climate modelling to project future impacts of climate change. RCP 4.5 represents a medium emissions scenario, assumes that the GHG emissions will peak around the year 2040 and then decline, leading to a stabilizing concentration level of around 4.5 watts per square meter by the end of the century

[5] Representative Concentration Pathway 8.5 is a greenhouse gas concentration scenario that is used in climate modelling to project future impacts of climate change. RCP 8.5 assumes that GHG emissions will continue to increase throughout the country, leading to a concentration level of around 8.5 watts per square meter by the end of the century. This represents a future with high greenhouse gas emissions and is considered a worst case scenario for climate change.

[6] As per the Uttarakhand Vision 2030 document (https://cppgg.uk.gov.in/wpcontent/uploads/2020/09/Uttarakhand_Vision_2030-Compress.pdf)

[7] As per*: Organic Farming Packages for Major Cropping Systems – ICAR-IIFSR*

[8] Based on an assessment of Trees outside Forests (India State of Forest biennial assessments)

- Increase in organic farming area to 38% of the net cultivated area[9] - Agroforestry continues to cover 12% of the cropped area	- 75% (103273 ha out of 137743 ha) of the total net cultivated area is brought under organic farming - Area under agroforestry increases at a growth rate of 3.5% per year[10]	- Organic farming continues to cover 4% (3.98% PKVY organic farming area/net sown area of the district) of the net cultivated area due to disincentives to shift to organic farming - Area under agroforestry reduces to 6% of the net cultivated area due to increasing urbanization and transition to non-agricultural practices
Nainital District		
Scenario 1 (BAU Policy Intervention + RCP 4.5 Climate Scenario)	**Scenario 2 (Optimistic Policy Intervention + RCP4.5 Climate Scenario)**	**Scenario 3 (Pessimistic Policy Intervention + RCP4.5 Climate Scenario)**
Organic farming increases from the current 36% of the net cultivated area under existing schemes to 65% of the net sown area[11] Area under agroforestry continues to cover 12% of the cropped area in Nainital as per current assessments because trees are rarely felled	- 95% of the net cultivated area is brought under organic farming considering targets set by the Government of Uttarakhand to accelerate the shift to organic farming in the hills and establish Uttarakhand as an organic state *(reference: UK Vision Document 2030)* - Area under agroforestry increases at a growth rate of 3.5% per year based on the assessment of Trees outside Forests (India State of Forest biennial assessments)	- Organic farming: Organic farming continues to cover 36% of the net cultivated area (*the current area under organic farming in the study area*) due to disincentives to shift to organic farming - Agroforestry: Area under agroforestry reduces to 6% of the net cultivated area due to increasing urbanization and change from agricultural land to non-agricultural practices
Scenario 4 (BAU Policy Intervention + RCP8.5 Climate Scenario)	**Scenario 5 (Optimistic Policy Intervention + RCP8.5 Climate Scenario)**	**Scenario 6 (Pessimistic Policy Intervention + RCP8.5 Climate Scenario)**
- Organic farming increases from the current 36% of the net	- 95% of the net cultivated area is brought under organic farming [12]	- Organic farming continues to cover 36% of the net

[9] As per the Uttarakhand Vision 2030 document (https://cppgg.uk.gov.in/wp-content/uploads/2020/09/Uttarakhand_Vision_2030-Compress.pdf)
[10] Based on an assessment of Trees outside Forests (India State of Forest biennial assessments)
[11] Given the scaling potential of organic farming in the district. *Reference – ICAR-IIFSR document*
[12] Considering targets set by the Government of Uttarakhand to accelerate the shift to organic farming in the hills and establish Uttarakhand as an organic state (reference: UK Vision Document 2030)

cultivated area under existing schemes to 65% of the net sown area given the scaling potential of organic farming in the district - Area under agroforestry continues to cover 12% of the cropped area in Nainital considering rate felling of trees	- Area under agroforestry increases at a growth rate of 3.5% per year [13]	cultivated area due to missing incentives to shift to organic farming - Agroforestry: Area under agroforestry reduces to 6% of the net cultivated area due to increasing urbanization and transition to non-agricultural practices

5.1. Scenario Setting

5.1.1. Udham Singh Nagar (Plains of Uttarakhand)

S.no.	Scenario/Parameters Considered
1.	Business as usual scenario
1.1.	Organic Farming
	The Uttarakhand Vision 2030 outlines the state's goals for expanding organic farming, with a target of 250,000 ha of land (38% of net sown area) by 2030. Currently, only 4% of the net cultivated area in the district is under organic farming, which amounts to 5,486 ha of land. To achieve the target, the BAU scenario relies on three national government organic promotion schemes; PKVY, RKVY and Namami Gange. However, due to limitations in access to resources and the need for modernization in the agriculture sector, and underdeveloped organic produce market, we postulate that the target may be achieved by 2050 instead of 2030.
1.2.	Agroforestry
	The Forest Survey of India estimates that Uttarakhand has a total area of 84100ha covered by trees Outside Forests (TOF), while the Central Agroforestry Research Institute (CAFRI) found the area under agroforestry to be 74000ha. Together, these data suggest that about 85% of the area under tree cover in the state is due to agroforestry. In the Udham Singh Nagar district, agroforestry covers roughly 12% of the cropped area, and it is expected to remain at that level in the BAU scenario. The state already has a tree cover of 65.84% of its total area under land utilization, which is well above the National Forest Policy's target of 33%. Incentives for expanding agroforestry are therefore weak, and any increase may be affected by

[13] based on the assessment of Trees outside Forests (India State of Forest biennial assessments)

	increasing Land Use Land Cover Change. Additionally, the BAU scenario considers RCP4.5 and RCP8.5 to evaluate changes in the capitals under different climate parameters.
2.	Optimistic Scenario
2.1.	Organic Farming
	In an optimistic scenario, it is envisioned that organic farming in U.S. Nagar, as assessed by ICAR-IIFSR on Organic Farming Packages for Major Cropping Systems, could scale up to cover an estimated 103,273 hectares. With robust policy support and market connections for organic produce, the goal is to increase the coverage of organic farming from the current 4% (5,846 hectares) to encompass 75% of the district's net sown area by 2050. Achieving this would involve converting conventional agricultural land into organic farmland, which aligns with Uttarakhand's Vision 2030 and various government schemes at the national and state levels. Notably, organic farming in Uttarakhand has already witnessed a significant upward trend, experiencing a 369% increase from 2015 to 2018 and a further 77% increase from 2018 to 2021.
2.2.	Agroforestry
	The National Agriculture Policy (2000) encourages farmers to engage in agroforestry for higher income generation. Several policy measures are introduced to support agroforestry, such as the Integrated Watershed Management Programme and the National Horticulture Mission. In addition, significant public sector finance has been made available for tree planting and agroforestry. The Forest Survey of India reports that the area under Trees Outside Forests (TOF) in the state has increased by 3.5% annually, and the demand for poplar timber from paper mills in the district could further encourage agroforestry. In the optimistic scenario, it is expected that the district will continue to see an increase in the area under agroforestry at a rate of 3.5% per year. The optimistic policy implementation scenarios also consider the expansion of organic farming and agroforestry under different climate scenarios.
3.	Pessimistic Scenario
3.1.	Organic Farming
	Currently, only 4% of the net sown area in the district is under organic agriculture. The use of pesticides and chemicals in U.S Nagar is higher than national estimates, with 91% of farmers in the Tarai belt using pesticides according to a 2011 study. Pesticide use in Uttarakhand has increased by over 5% from 2000 to 2013. Additionally, the introduction of new agricultural practices and chemicals could hinder the expansion of organic farming. Given the lack of policy support and market linkages for organic produce, the area under organic farming is likely to remain at 4% until 2050 under the pessimistic scenario.
3.2.	Agroforestry

	Udham Singh Nagar in Uttarakhand has experienced a decrease in forest area from 100,648ha to 93,837ha over the period 2008-2009 to 2018-19, but the area under trees remains steady. In 2021, 337 hectares of natural forest were lost, resulting in a decrease in carbon sequestration capacity by 190 kt of CO2 emissions. Considering the declining trend in forest and tree cover, under the pessimistic policy implementation scenario, the area under agroforestry is expected to decrease to 6% of the net sown area by 2050. The pessimistic policy scenarios will also consider the RCP4.5 and RCP8.5 climate scenarios to assess two potential climate pathways.

5.1.2. Nainital (Hills of Uttarakhand)

S.no.	Scenario/Parameters Considered
1.	Business as usual
1.1.	Organic Farming
	Currently, 36% of the Nainital district is engaged in organic farming. According to our predictions, if the business-as-usual (BAU) scenario continues, the entire area designated by the Government of India in the district will be practicing organic farming by 2050. There is potential for the district to expand its organic agricultural area to 11,505 hectares, which would account for 65% of the net cultivated area. Based on our projections, efforts will be made to scale up organic farming to cover the total potential area in the district by 2050, utilizing existing government policies that support this transition.
1.2.	Agroforestry
	Estimations suggest that agroforestry currently encompasses approximately 12% of the cultivated area in the Nainital district, equivalent to approximately 5,040 hectares. Despite the fact that the area under miscellaneous trees has remained consistent from 2008-09 to 2018-19, according to the Directorate of Agriculture, Uttarakhand (refer to Annex 11: LULC trends, section 11.1: Nainital), we anticipate that the area dedicated to agroforestry will continue to be 12% until 2050. This prediction considers the disincentives to expand this area and the fact that 73% of the district's total land area is already covered by forests and trees. Furthermore, in the business-as-usual (BAU) scenario, we will evaluate changes in the capitals by considering two climate scenarios: RCP4.5 and RCP8.5.
2.	Optimistic Scenario
2.1.	Organic Farming
	Currently, organic farming covers 36% of the net sown area in the Nainital district, which amounts to 14,830 hectares. According to the Organic Farming

	Packages for Major Cropping Systems by ICAR-IIFSR (2022), there is a potential to expand organic farming in the district by an additional 11,505 hectares. With robust policy measures, financial support, and active engagement of farmers in adopting organic farming schemes, it is projected that 95% of the net sown area in the district could be transitioned to organic agriculture by 2050 under this scenario.
2.2.	Agroforestry
	In the optimistic policy scenario, it is assumed that agroforestry in Nainital will experience an annual growth rate of 3.5% until 2050, mirroring the growth rate observed in the nearby district of Udham Singh Nagar. This projection is based on existing trends documented by the Forest Survey of India. Furthermore, Scenario 2 will consider climate scenarios, specifically RCP4.5 and RCP8.5, to assess the potential effects of these scenarios on agroforestry in Nainital.
3.	Pessimistic Scenario
3.1.	Organic Farming
	In the pessimistic scenario, we anticipate slow growth in the adoption of organic farming in the district due to various factors that could impede its expansion. One such factor is the trend of rural-urban migration in Uttarakhand, with a significant portion of the population migrating from the Nainital District, as indicated by the UKHDR Survey in 2017. The high rate of long-term migration from hilly areas is attributed to the lack of opportunities and the increasing unsustainability of hill agriculture, according to the UKHDR report. Additionally, the smaller landholdings and resulting lower income for farmers in the hilly districts of Uttarakhand may act as a disincentive for the adoption of organic farming practices, especially considering the potential initial reduction in yields during the conversion process. Furthermore, data from the Indian Space Research Organization (ISRO) Bhuvan LULC indicates an increase in built-up areas and a decrease in agricultural land in the district between 2005-06 and 2015-16 refer to (Annex 11: LULC trends, section 11.1: Nainital). Nainital is also experiencing a rapid growth in urban population, with more than 35% of the district's population classified as urban based on the 2011 Census. Considering these factors and the absence of policy support for organic farming, the pessimistic scenario suggests that the area dedicated to organic farming will remain at 36% of the total organic agricultural area until 2050.
3.2.	Agroforestry
	Given the increase in urbanization and the use of land for non-agricultural purposes being observed in the district and no growth observed in forest and tree cover in Nainital district for the period 2009-2019 - 238374ha (2009-10) to 238236ha (2018-19), the pessimistic policy implementation scenario assumes reduction in area under agroforestry to 6% of the net cultivated area by 2050.

	In addition to the policy considerations detailed above, Scenario 3 will also consider the climate scenario for RCP4.5 (Medium GHG emissions) and climatic scenario for RCP 8.5 for scenario 6 (high GHG emissions) to evaluate the variation in impacts on capital stocks.

5.2. Ecosystem Services

A summary of ecosystem services that are identified for evaluation/modelling for the current TEEBAgrifood evaluation across the four capitals and their linkages with organic farming and agroforestry are provided in Table 4 below

Table 4: Ecosystem services identified for evaluation

Capital	**Ecosystem Services identified for evaluation/modelling**	**Linkages with Organic farming and agroforestry**
Natural Capital	Water Quantity	- Perennial crops/tress have higher water retention capacity - Building up of crop/tree canopy reduces evapotranspiration - Improvements in soil water holding capacity due to build-up of organic matter
	Water Quality	- Reducing the porosity and binding properties of organic matter will enhance the filtering capacity of soil - Absorption of toxic metals by trees
	Soil Erosion	- Reduction in soil erosion due to binding properties of organic matter
	Soil Health	- Enrich the nutrient holding capacity of the soil - Increase in soil biodiversity and organic carbon content
	Carbon Sequestration	- Enhancement of carbon sequestration potential

Produced Capital	- Rice and wheat yield - Vegetable Yield - Millet yield	Initially, the yield might be compromised but eventually it will be sustained. Additional quality might be SOP for the intervention
	Timber provisioning services	An increase in the number of trees, especially in the plain region of the state will enhance water quality, and timber availability and intervention with horticultural plants will support by providing fruits and income
Social	- Women Empowerment	Women in hilly areas have significant contribution to agricultural activities, as discussed above. Organic farming and agroforestry will add to the quality of life not only in terms of health but also economy by getting the better price of their produce (Jhariya and Bargali,2015)
	- Increased employment opportunities	Organic farming and agroforestry will increase employment opportunities for both on farm and off farm activities
Human	- Education & Skill development	Knowledge dissemination through cultivation practices will enrich the present status of practices (Adnan et al. 2018)
	- Improved Livelihoods	Organic farming and agroforestry will ensure a high income which should be seen not only in terms of paper currency, but should also be seen from the health gain and expenditure made on health care issues (Rosati et al. 2021)
	- Human Health	Quality food for family consumption and marketing of surplus will add value to society. Rural and tribal families, not aware of the quality of food and its relationship with health will be benefitted (Meemken and Quaim, 2018)

5.3. Linkages to Natural, Produced, Human and Social Capitals

5.3.1. Natural Capital

In Uttarakhand, water quantity and quality are major concerns. The region experiences erratic rainfall. 49.05% of the net sown area in the district is covered under irrigation through water from spring-fed rivers. The water falls to be inadequate during the lean period and flooding during the monsoons. Rivers such as Kosi and Kailash are heavily used for irrigation and domestic purposes, resulting in diminished water flows due to low rainfall, deforestation, and changing rainfall patterns.

The quality of these rivers is also affected by natural, human, and industrial activities, leading to contamination downstream. The Central Pollution Control Board found high levels of coliforms, nitrates, and phosphates in the water samples. The Deolikhan spring in the Kosi watershed was found to have high iron content that can clog pipes and fixtures. Therefore, it is crucial to quantify and manage water resources in the region.

Water Quantity

Kosi watershed: Over the past two and a half decades, a large portion (82%) of the major non-glacial fed rivers have transformed from being perennial to non-perennial in nature, indicating the non-glacial master rivers are dwindling steadily (Alam & Bhardwaj, 2020). River Kosi, a spring fed river, is Western Ramganga's most important river. The unconsolidated and semi-consolidated fluvial and colluvial valley fill deposits along the river is highly permeable and can hold significant quantities of groundwater in unconfined conditions. This water is heavily extracted for irrigation and household purposes to nearby catchment areas such as Almora, Kausani, and Ramnagar, in addition to in-stream uses such as bathing, fishing, cremation on the banks, and waste dumping. Heavy water extraction in combination with low rainfall regime, extensive deforestation, and changing rainfall patterns, has severely reduced river flows, particularly during the lean periods, over the last four decades (Rawat, 2014). A study of the Kosi watershed suggests that only 19.6% of the upper Kosi basin possessing exceptional recharge potential. While 47% of the area has declining recharge potential and was deemed acceptable for the implementation of artificial recharge structures (Rani et. al 2022). Diminishing inflows and excessive pumping in the areas neighbouring to the settlements experience significantly lower summer season flows even beyond the Someshwar town area. In order to meet the water demand of Almora city, a barrage was constructed in 2016 across the Kosi River, but excessive siltation has caused operational issues with the pump (Chopra and Singh, 2016).

Kailash watershed: The Kailash River originates from Pangoot in the Nainital district and flows through Udham Singh Nagar. The river then passes through the Nandhaur reserve forest towards the Terai landscape downstream. This river, which is fed by springs, experiences a significant increase in water volume during the monsoon season, leading to riverbank erosion and flooding in the downstream area. As a result, the river's course changes over time. The Kailash watershed has not been monitored, and there is limited data available. To address this, the SWAT model will be used to quantify water in both the Kosi and Kailash watersheds, with inputs such as soil, land use and land cover, and climate parameters.

Water Quality

The water quality of rivers in Uttarakhand is poor due to various natural, human, and industrial factors. The Kosi and Kailash rivers originate from hilly regions where natural influences like leaching of minerals due to rainfall, changes in river flow, and spring elevations are the main factors affecting water quality. However, when these rivers reach the downstream plains, human and industrial activities become the major factors affecting water quality. Many point and non-point sources of pollution are found downstream of the watersheds where these rivers meet the plains, which are heavily occupied by intensive agricultural and industrial zones. The chemical constituents of irrigation water can have direct or indirect effects on plant growth by causing toxicity or deficiency or by changing nutrient availability (Ayres and Westcot, 1985).

As per the bio mapping results presented by the Central Pollution Control Board (CPCB) of the Kosi river for the period between 2000 and 2006, the river is found to be contaminated with coliforms mainly due to the untreated sewage discharge at Ramnagar. Assessment suggests, at Ramnagar, the water from Kosi and Kailash have alarming high levels of total coliform at 3683.2 MPN/100ml and 3945 MPN/100ml respectively. Near Kashipur, paper and pulp mills discharge untreated effluents into the Kosi River's outflow in Uttarakhand, leading to contamination. The Central Pollution Control Board found that in January 2022, the Kosi River samples from the Kashipur-Bajpur bridge had Nitrate levels of N 0.05 mg/l and Phosphate levels of 0.25 mg/l, while Kailash River samples from the Sitarganj industrial area had Nitrate levels of N 0.08 mg/l and Phosphate levels of 0.15 mg/l. This contamination is not only affecting the water quality, but also the geological structure of the river. For instance, the Deolikhan spring in the upper portion of the Kosi watershed in Almora district has high iron content due to Almandine Garnet present in Garnetiferous Mica Schist, which can clog pipes and fixtures if stored, produce color, taste, and rust flakes in the water, and promote the growth of undesirable microorganisms that form a sticky coating in water pipes. Therefore, a thorough investigation is needed to study the distribution of iron and other factors that impact the entire water quality of the springs.

According to the Bureau of Indian Standards (IS: 11624-1986), organic farming requires appropriate irrigation water quality. Implementing agroforestry practices in watersheds can also reduce soil erosion and prevent sediments from entering the water stream. A study of the Kosi

river's water quality in 2007 found that the water quality was good to very good up to Ramnagar, but then worsened downstream (Chopra and Singh, 2016). Almora town's population has grown rapidly outside the municipal limits, leading to untreated sewage from a large portion of the city entering the Suyal River, the main tributary of Kosi. The quality of the water in the Kosi and Kailash watersheds is also crucial for social and economic development. To examine the N and P exports of the Kosi and Kailash watersheds, the Nutrient Delivery Ratio method will be employed using land use data, precipitation data, and Digital Elevation Model (DEM) data in the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) model.

Soil Erosion

For centuries, terrace farming has been the most suitable agricultural technique in Uttarakhand's hilly regions. However, faulty farming techniques, such as ploughing parallel to the slope, furrowing across the contour of the hill slope, and poorly designed terraces with outward slopes and improper grades, have accelerated the erosion of fertile topsoil. As a result, eroded sediments are carried downstream by runoff and deposited on riverbeds and other bodies of water. In Uttarakhand, 6.71%, 8.84%, and 32.72% of the land area are categorized as having moderately severe soil loss, severe soil loss, and very severe soil loss, respectively. According to a study, 48.3% of the state's area exceeds the tolerance limit of 11.2 tonne/ha/year of soil loss (Mahapatra et al., 2018).

Trees and grasses play an essential role in preventing soil erosion by acting as a barrier to runoff and providing protective cover for the soil through their canopies and litter. Emphasizing soil conservation measures, agroforestry, and organic farming in cropped areas can help keep soil erosion to a minimum in the state. These conservation efforts can slow the rate of soil erosion, repair damaged ecosystems, and provide job opportunities for low-income individuals. The sediment yield and soil erosion of the Kosi and Kailash watersheds will be assessed in this study using the SWAT model and RUSLE.

Soil Health

Soil health is a major concern for the state, both in hilly and plain areas. The consumption patterns of nitrogen (N), phosphorus (P), and potassium (K) per hectare of land are presented in Figure 12 below depict an increasing pattern in the consumption of fertilizers between 2010 and 2020.

The declining condition of soil is a major concern for the long-term sustainability of agricultural production. In order to maintain crop yield, 91% of farmers in the Tarai belt and 47% of farmers in the hilly region use pesticides for agricultural production, with the highest use being in the Udham Singh Nagar district. The introduction of new agricultural practices and heavy doses of NPK fertilizers, as well as the use of various chemical compound-based formulations, pose a threat to organic farming (Miglani, et al., 2019). The excessive use of urea and poor nutrient management practices have led to a deficiency of multiple nutrients in the soil. The lack of organic manures and

uneven nutrient consumption over time have resulted in a multi-nutrient deficiency in many parts of the Udham Nagar district, as shown in Figure 12.

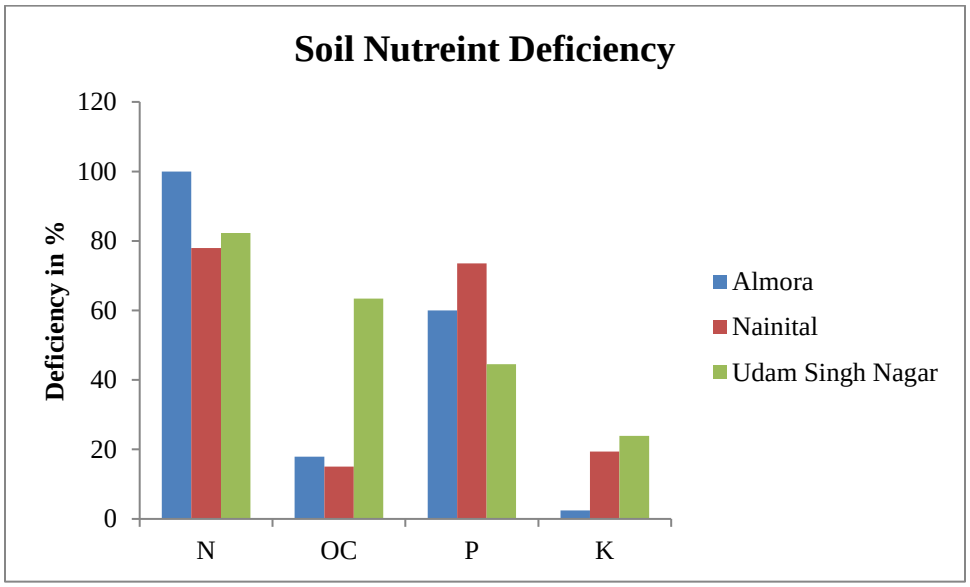


Figure 12: Soil nutrient deficiency in Nainital and Udham Singh Nagar districts

N - nitrogen, OC - organic carbon, P - phosphorus and K- potassium

Source: Soil Health Card, Cycle III

Agroforestry system involving *Populus deltoids* and *Eucalyptus* Spp. hybrid canopies, aid in enhancement of soil nutrients viz. organic carbon, nitrogen, and phosphorus. It is apparent from the studies that agroforestry systems, which promote the use of legumes as fertilizer or shade trees, may increase N_2O emissions compared to unfertilized systems. Assessments of soil health will be carried out using both assessments through biophysical modelling and through demonstration plots. Biophysical modelling will be used to determine soil loss through the Revised Universal Soil Loss Equation.

Carbon pools and Sequestration

Forests sequester CO_2 from the atmosphere and store it as biomass in different pools, namely above-ground biomass, below-ground biomass, leaf litter, dead wood, and soil carbon (IPCC 2014; Sahu et al. 2016). Uttarakhand has a massive 348.2 million metric tonne carbon pool (Singh et al. 2022 in press). The state has 65.70 thousand tonnes of above-ground mass, 17.65 thousand tonnes of below-ground mass, 1.46 thousand tonnes of dead wood, 2.13 thousand tonnes of litter, and 68.65 thousand tonnes of soil organic carbon (FSI, 2021).

As per 2021 ISFR assessment, total area under forest cover in Uttarakhand is 24,305.13 sq. km. Showing an increase of 2.09 sq, km with respect to 2019 assessment. However, forest cover for Udham Singh Nagar reported a decline of 3.71 sq.km compared to 2019 levels. While area under forest cover in Nainital reported an increase of 2.93 sq km. Capturing and storing atmospheric carbon dioxide not only reduces the amount of carbon dioxide in the atmosphere but also strengthens global warming mitigation efforts. Higher CO_2 sequestration is reflected by the plants' having higher quantity of biomass (Jana et al. 2011). Adaptation to agroforestry would not only supplement the existing forestry benefit but aid long term land restoration and increase the soil's organic carbon content. For instance, in drought years, organic yields may be more resilient, probably due to higher soil organic matter and water-holding capacity (Siegrist et al. 1998; Letter et al. 2003). Therefore, it is suggested as a measure to improve the overall greenhouse gas balance of agriculture (Leifeld & Fuhrer, 2010). With the help of the InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) model, this study will explain why carbon sequestration is important by looking at the change in total carbon in different scenarios in the Kosi and Kailash watersheds in the state of Uttarakhand.

5.3.2. Produced Capital

Rice and wheat yield

The area under agriculture in Uttarakhand experiences a wide range of climatic conditions and therefore processes rich agrobiodiversity including that of plant species. Wheat and rice are the major crops grown in the state covering 31% and 23% of the total gross cropped area (Agriculture Today, 2020).

The data chart above in Figure 7 shows a sharp decline in the total area under rice and wheat over the period from 2000 onwards. In 2018, the total area decreased to 259 thousand ha from 288 thousand ha in 2000 for rice; 377 thousand ha to 307 thousand ha in wheat. It is conceivable to meet the food security and environmental issues of the future decades, but it will necessitate significant adjustments in nutrient and water management practices suitable for current needs. Through the crop provisioning services this can be evaluated and can contribute towards analysing crop yield and nutrient status.

Timber provisioning services

While green felling has become regulated in India as a result of the Hon'ble Supreme Court's judgment, timber remains one of the most easily marketable benefits of forests. Although forests in India have not been specifically managed for timber production since the National Forest Policy

of 1952 and 1988, the economic value of timber output from Indian forests is enormous and crucial (Verma et al. 2014).

Table 4: Market-wise distribution of wood consuming units and market functionaries in the Tarai region

S. No	Wood-consuming units and market functionaries	Udham Singh Nagar	Nainital
1	Plywood	18	12
2	Paper and pulp unit	0	1
3	Sawmills	54	73
4	Wooden furniture units	473	265
5	Wooden crates and packing cases	11	30
6	Charcoal units	2	2
7	Brick kilns	30	0
8	Commission Agent	73	37
9	Misc. units	24	29
10	Total	685	449

In recent years, due to the establishment of the State Industrial Development Corporation of Uttarakhand Limited (SIDCUL) in Udham Singh Nagar district, and the emergence of additional plywood industries, has initiated a supply chain demand for timber-based products which indicates a huge scope for scaling up Agroforestry for farmers in the region. The main timber species traded in Tarai region include Sal, Shisham, Teak, Jamun, Tun, Kokat, Poplar, Eucalyptus, etc., and these are also supplied to other states across the country. The Jaspur block of Udham Singh Nagar is considered to be one of the biggest markets of sal timber in the country. However, with the increasing demand for timber, there is no mandi and market accessibility in the districts for the marketing of agroforestry produce and 65% of farmers sell their wood (standing trees) directly to the contractors, while 25% sell through commission agents. These districts relate to the reserved forest area, and as such permission for felling and transit of every tree product, including agroforestry such as poplar, is mandatory. The transit permit is valid only for 24 hours only. Most of the timber species like sal, shisham, teak, toon, chir, etc., are procured from the Uttarakhand Forest Development Corporation (UKFDC), and small timber traders deal in agroforestry species like eucalyptus, poplar, mango, jamun, etc. from farmers. Eucalyptus demand is met by 70% from Uttar Pradesh and 30% from Uttarakhand. However, Uttarakhand supplies 70% of the entire Poplar demand, with the remaining 30% coming from Uttar Pradesh. Moreover, agro-forestry is adopted only by a few large farmers of plain areas of the region (Panse and Kushwaha, 2016). Such a market situation demands an evaluation of timber provisioning services in the watershed area for reviewing the existing scope of upscaling agroforestry in the study region.

5.3.3. Social and Human Capital

Human health (nutrition & disease)

The region under study, specifically Udham Singh Nagar, is significantly impacted by the use of pesticides in agricultural practices, which has major implications for human health. While pesticides are designed to be relatively safe for human health and the environment, published research has not always confirmed this. Agricultural workers in open fields and homes, as well as exterminators, are exposed to pesticides through their occupation. The general population can also be exposed to pesticides by consuming contaminated food and water, and by living in close proximity to workplaces that use pesticides. Non-occupational exposure to pesticide residues in food, air, and water is typically chronic and involves low doses. To assess the impact of organic farming and agroforestry on health status indicators, a PRA survey will be conducted in selected villages in Udham Singh Nagar and Nainital districts. The intervention's impact on farmers' livelihoods will be studied on a small scale and evaluated using an appropriate assessment model.

Income enhancement

As mentioned in chapter 1, while majority of the workforce in the state was engaged in agriculture, its contribution to the state's income is only 11%. The cost-benefit ratio of organic farming intervention can be assessed using the data collection post-harvest.

Migration

The migration of people from rural to urban areas in the state poses a significant challenge, as evidenced by census data from 2001-2011, which shows an increased rate of migration in the hilly districts. During this period, a total of 383,726 people from 6,338 Gram panchayats migrated on a semi-permanent basis, and 1,898 people were permanent migrants from 3,946 Gram panchayats. Rural out-migration was 9.1%, which is three times higher than urban out-migration (about 3%). The primary reason for migration (50.16%) was employment opportunities, followed by migrants seeking quality education (15.21%). Long-term rural out-migration is more common than long-term urban out-migration in almost all districts of the state. Additionally, rural out-migration in hilly areas is more significant than in rural plain areas. The migration trends and patterns will be analyzed using census data and other relevant sources to assess the impact of these trends on the state's population and economy.

Women empowerment

Women suffer on a large scale in comparison to men in the state of Uttarakhand, where women's work participation is dominant. However, they remain behind in getting an education (female literacy rural 66.1% in 2011 according to census 2011 as compared to male literacy rural 86.6%) and toil hard to manage household chores and farm at the same time. Women suffer through drudgery-related issues which need to be addressed through a change in existing agriculture patterns and market accessibility through which income generation is enhanced. An extensive

study by Indian Agricultural Operators to assess the occupational workload based on individual capacity to perform work was conducted where it was found that the Total Cardiac Cost of Work (TCCW) was 1965 beats for the manual beating of paddy and 780.4 beats using paddy thresher (manually operated). The PRA from demonstration sites will cover the questions and data collection for analysis of existing women's drudgery in the region.

6. Proposed Methodology for Computations

6.1. Data sources and Tools

The bio-physical modelling will be conducted in the Kailash and Kosi watersheds. The selected ecosystem services - water quality, quantity, soil erosion, carbon sequestration, crop and timber provisioning services will be analysed through different tools and models that are listed in Table 5 below.

Table 5: Data sources and tools needed for Biophysical modelling

Capital Stocks	Modelling	Data Type	Source	Method
Natural Capital	Revised Universal Soil Loss Equation	Rainfall data, soil map, Digital Elevation Model, Land use, and Land cover	Indian Meteorological Department, National bureau of soil survey and land use planning (ICAR)/ DSMW of FAO soil data, Shuttle Radar Topography Mission/ Cartosat-1, LANDSAT8 image, and Future LULC	Based on Wischmeier and Smith, 1978 RUSLE model using QGIS/ArcGIS
	Sediment Delivery Ratio Model	Rainfall data, soil map, Digital Elevation Model, Land use and Land cover, Runoff Data	Indian Meteorological Department, National bureau of soil survey and land use planning (ICAR)/ DSMW of FAO soil data, Shuttle Radar Topography Mission/ Cartosat-1, LANDSAT8 image, Uttarakhand Irrigation department, and VPKAS Almora	Using SWAT and InVEST Software
	Water yield Model	Rainfall data, Reference Evaporation, Depth of the root restricting layer, Plant available water fraction, land use and land cover,	Indian Meteorological Department, Global Aridity and PET Database, Food and Agriculture Organization, ISRIC, LANDSAT8 image	Using the InVEST software

		Watershed, Biophysical table		
	Nutrient Delivery Ratio (NDR)	Digital Elevation Model, land use and land cover, Nutrient runoff proxy, Cover management, Practice management, load_p, eff_n/p, Crit_len_n/p,Root depth, K_C	Shuttle Radar Topography Mission/ Cartosat-1, LANDSAT8 image, and Future LULC,https://www.worldclim.org/ / Indian Meteorological Department/Quick flow index from water yield model, according to the InVEST data sources.	Using the InVEST software
	Carbon Pools and Carbon Sequestration	Land use and Land cover map of the different year (2020,2030,2040,2050), Markov chain model, Global market price for carbon	LANDSAT8 image for 2020	Using the InVEST software and TerrSet
	Land use and Land cover change for 2030,2040 and 2050	Land use and Land cover map of the different year (2000,2010,2020)	LANDSAT8, LANDSAT7, LANDSAT5 images	Using TerrSet by CA Markov chain model
	Scenario Projection CMIP5, RCP 4.5and RCP 8.5 IPCC	Daily precipitation, temperature, wind speed, solar radiation, and relative humidity data, Digital Elevation Model,	VPKAS Almora (ICAR) Irrigation Department, Uttarakhand, Kosi Barrage Observatory, Shuttle Radar Topography Mission (SRTM) DEM/ Cartosat-1.	SWAT IN ArcGIS
Produced	Crop Provisioning services	Crop production and fertilizer, Land use, and land cover map	Food and Agriculture Organization, Landsat8 Images	InVEST
	Timber Provisioning services	Forest Type, Forest Density, Forest Area, Forest Type Group / Value of timber (₹ /ha/yr)	Forest Survey of India, www.uttarakhandforest.org,	NPV (Net Present value)
Social	Human Health		Primary survey & Secondary data from govt. databases	Details of the methods are described in detail in Deliverable 6
	Women Empowerment			
Human	Education & Skill Development			
	Income generation			

6.2. Description of Methodology to be used for Biophysical modelling

Soil Erosion and Sediment Yield

Land degradation, a global environmental concern that decreases soil productivity and water quality, is caused mainly by soil erosion. Researchers and policymakers face a significant issue in assessing soil erosion in mountainous data-scarce terrain. Natural Capital Project's InVEST 3.6.0 software will be used to model present soil erosion by water (Sharp et al. 2018). InVEST models are "ready-to-use" spatially explicit models, meaning they run in a simple interface and provide the desired outputs once the user gathers and pre-processes the appropriate input data. The Sediment Delivery Ratio (SDR) model works with only a few parameters and is based on hydrological connectivity. The applied model uses the RUSLE (Revised Universal Soil Loss Equation) expression to calculate annual soil loss, with variables taken from multiple maps provided by other sources. The RUSLE (Universal Soil Loss Equation) is an improvement on the original USLE (Universal Soil Loss Equation) in terms of calculating the factors that control erosion (Renard et al 1997, Wischmeier et al 1978).

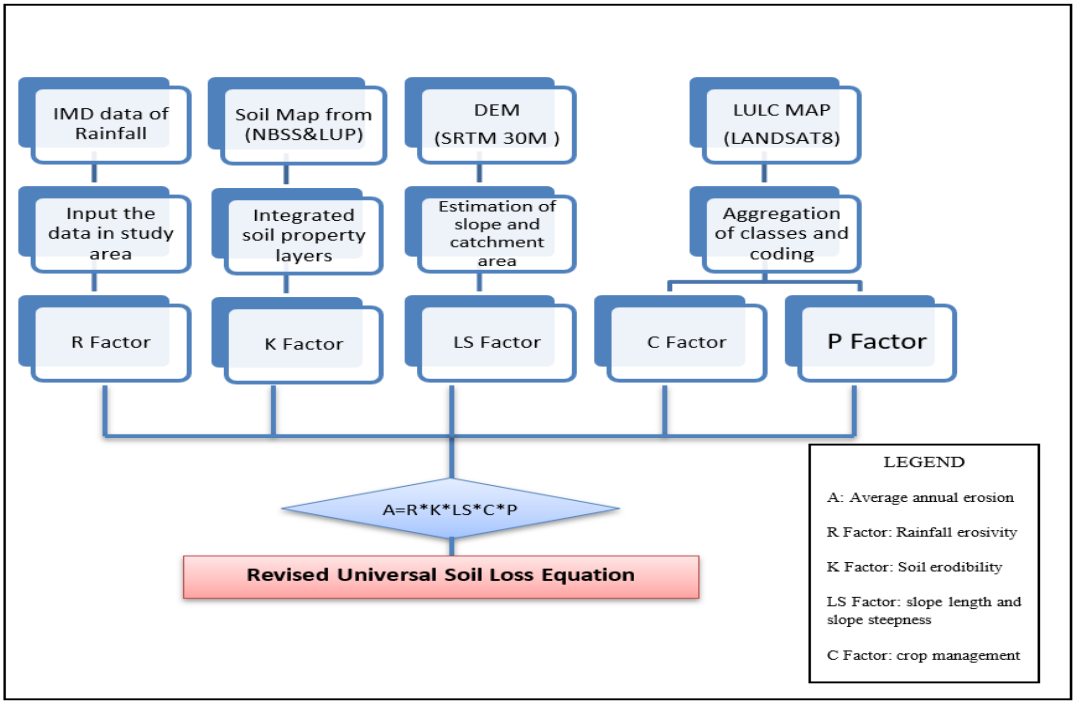


Figure 13: Data acquiring steps for RUSLE

The RUSLE model will be used to assess the average annual soil erosion in the Kosi and Kailash watersheds (Figure 13). Reliable data on the spatial extent and the magnitude of soil erosion rates are required for planning/implementation of control measures aimed at prudent management of

natural resources and to comprehend diverse erosion driven ecosystem responses. Many Indian rivers are sediment driven and need filtration by biological treatment.

The Sediment Delivery Ratio model in InVEST assesses water quality and analyses the necessity for filtration (Figure 14). The InVEST sediment delivery ratio model provides the sediment delivery map, which is vital for planning and policymaking concerning hydropower, Dam etc.

Figure 14: Process of Sediment Delivery Ratio

Water Yield

To obtain the runoff and water yield, the semi-distributed SWAT model and InVEST mode will be used, respectively. Hydrological routes have been the main focus of watershed modeling work. A SWAT model integrated with arc GIS was developed by Arnold at the USDA Agricultural Research Service (ARS) (Li et al. 2018, Arnold et al. 2012) to predict long-term effects of various soil, land, and water management circumstances, as well as sedimentation and farming constituents. The InVEST model will be used with input data such as Watershed Digital Elevation Model (DEM), LULC map, monthly precipitation, evaporation data, hydrological soil data, and climate zone data to estimate water yield in the watershed. The Water yield model shows the amount of water used for consumptive activities each year across the landscape per sub-watershed. (Ghosh et al. 2017) Inputs for the water yield model are provided in Figure 15 below Policymakers will utilize the results from these models to determine the available water.

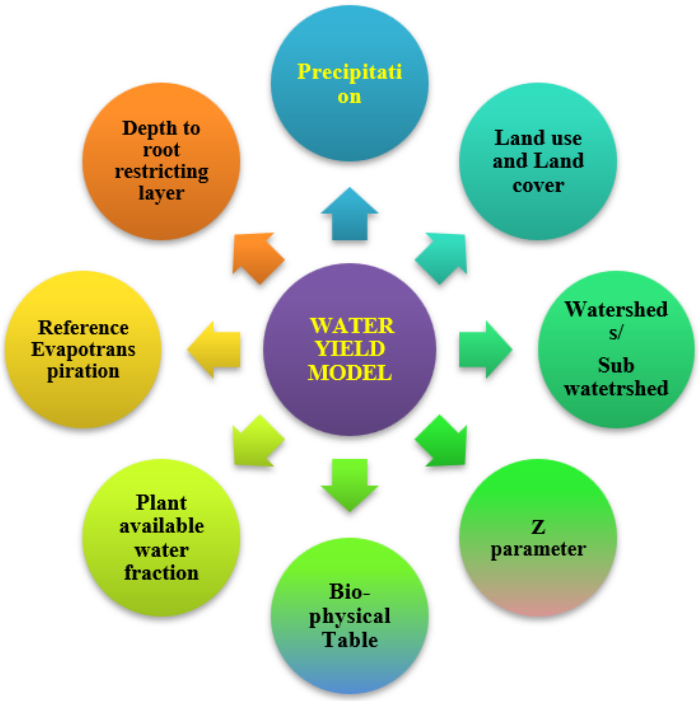


Figure 15: Inputs for the Water Yield Model

Nutrient Delivery Ratio (NDR)

Land use change, especially the conversion to agricultural lands, has a significant impact on the natural nutrient cycle. There are two types of anthropogenic nutrient sources: point sources such as industrial effluent or water treatment plant discharges, and non-point sources such as fertilizer use in agriculture and residential areas. When it rains or snows, water flows over these surfaces and carries pollutants into streams, rivers, lakes, and the ocean, which has negative consequences for human health and well-being. (Keeler et al., 2012). One way to decrease non-point source pollution is by managing fertilizer inputs. Ecosystems can also offer a purification service by retaining or degrading pollutants before they enter streams. Vegetation can remove pollutants by storing them in tissue or releasing them in another form, while soils can store and trap some soluble pollutants. Wetlands can slow the flow of water long enough for pollutants to be taken up by vegetation, and riparian vegetation serves as the last barrier before pollutants enter a stream.

Land-use planners need information on the contribution of ecosystems in mitigating water pollution. They require spatial information on nutrient export and areas with the highest filtration. The nutrient delivery and retention model provide this information for non-point source pollutants. This model was designed for nutrients like nitrogen and phosphorous, but its structure can be used for other contaminants such as persistent organics and pathogens, provided that data are available on the loading rates and filtration rates of the pollutant of interest. The model is based on the concept of Nutrient Delivery Ratio (NDR), which calculates the proportion of the nutrient load

that will reach the stream. (Drewry et al., 2011) Two delivery ratios are computed: one for nutrients transported by surface flow and the other for subsurface flow. The InVEST model will be used to evaluate the Kosi and Kailash watershed river according to the NDR process.

Carbon Sequestration

Carbon monitoring is required to watch the amount of carbon in our environment. Many industries now profit from carbon credits, adding a commercial value to it. Carbon storage and sequestration will be quantified using LULC data and InVEST model (Figure 16). To accomplish this, the LULC data from the study regions and the present quantity of carbon stored in a landscape will be used to calculate the amount of carbon sequestered over time. The global market price of carbon will be applied in this scenario.

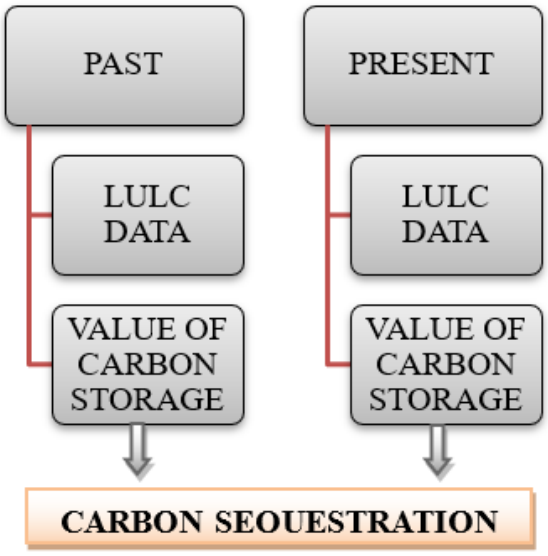


Figure 16: Carbon sequestration process and scenario analysis

Climatic Scenario Modelling

The climate change scenarios affect the natural environmental factors as a driving force, and they can be studied using the SWAT tool. For the current study, the following climate change scenarios will be assessed-

- RCP 4.5, a representative concentration pathway for radiative forcing 4.5 watts per m^2, represents the medium global emission of greenhouse gases and its effect on the natural capital.
  RCP 8.5, representative concentration pathway for radiative forcing 8.5 watts per m^2, representing the high-temperature rise scenario's effect on natural capital.

Land Use and Land Cover

The alteration of how land is used is a meaningful reflection of the interplay between people and the natural world. It is also a critical aspect of sustainable development, as it demonstrates the impact of human behavior on the environment. Meanwhile, climate change is a significant factor that influences how land is utilized. Among all global environmental factors, human activities have the most significant impact on climate change.

In India, forest cover grew from 20.55% in 2001 to 21.23% in 2013. This rise was 15.7% in the Himalayan region. Similarly, Uttarakhand saw a 9.7% rise in forest cover from 2004 to 2014 (Table 6) (FSI, Forest Survey of India, Dehradun, India, 2014). The forest covers over half of the state and is a crucial aspect of its land use, providing a livelihood for many people. While a significant portion of the region is rocky, barren, or snow-covered, there is a shortage of arable land. The fertility of the soil has declined, and the availability of arable land per acre has decreased in recent years. Nonetheless, the area has favourable agro-climatic conditions that allow for the long-term cultivation of various crops such as cereals, pulses, oilseeds, vegetables, and fruits, making farming the primary occupation. Rural-urban migration and climate change are the primary factors driving changes in land use and cover. Many changes in land use reduce soil fertility, resulting in low yield from arable land[14].

Table 6: Land use and land cover change in Uttarakhand

Category	**2004-05**		**2013-14**		**Change (%)**
	Area (ha)	**% Share of area**	**Area (ha)**	**% Share of area**	
Forest	3465057	56.7	3799953	59.4	9.7
Land not suitable for agriculture	311849	5.1	228016	3.6	-26.9
Land use other than agriculture	160649	2.6	222173	3.5	28.3
Wasteland suitable for agriculture	366713	6	316898	5	-13.6
Permanent pastureland	220286	3.6	192098	3	-12.8
Land under bushes and shrubs	269042	4.4	389183	6.1	44.7
Current fallow	44064	56760	56760	0.9	28.8

[14] Dynamics of Land Use/Cover Changes in the Uttarakhand Himalaya Vishwambhar Prasad Sati Department of Geography and Resource Management, School of Earth Sciences, Mizoram University, Aizawl – 796004, India

Fallow land other than current fallow	64068	1.1	86161	1.3	34.5
Actual area sown	765150	12.5	701030	11	-8.4
Area sown more than once	447159	7.3	398155	6.2	-11
Total area	6114037	100	6390427	100	4.5

Source: Office of the Principal Revenue Commissioner, Uttarakhand, 2004-05 and 2013-14

The overall land use and land cover change of the state are shown above in Table 6. The results show changes in several land use categories between 2004-05 and 2013-14. Land under bushes and shrubs increased the most (44.7%), followed by fallow land other than current fallow (34.5%). Current fallow and non-agricultural land use account for 28.8% and 28.3% of the total area, respectively. There was a 9.7% increase in the forest area. In 2017, the forest area of Uttarakhand was 71% of its total geographical area (ISFR, 2017). The land categories that experienced the most significant loss in terms of area were unsuitable land for agriculture (26.9%), followed by wasteland suitable for agriculture (13.6%), and permanent pastureland (12.8%). During the evaluation period, there was a decrease in both actual areas sown (8.4%) and areas sown multiple times (11%).

The land use and cover change patterns in major districts vary based on their location, whether they are in plains or mountains. Table 7 shows these patterns. Results show, both Kosi and Kailash watersheds have more forest area compared to other land use and land cover classes. In addition, due to ease of cultivation, agricultural land is abundant in plain regions compared to hilly terrain. For this study, future land use and land cover maps for these watersheds will be evaluated for 2030, 2040, and 2050, depicting decadal changes across the categories.

Table 7: Area under different land use and land cover categories for Kosi and Kailash watershed

Sr.no.	**LULC Classes**	**Area (km^2)**	**Area (%)**	**Area (km^2)**	**Area (%)**
		Kosi Watershed		**Kailash Watershed**	
1	Forest Area	816	44.85	214.635	51.62
2	Fallow land	384	21.11	85.2201	20.50
3	Waterbody	259	14.23	11.2635	2.71
4	Agricultural Land	169	9.29	88.7652	21.35
5	Barren land	156	8.57	-	-
6	Built-up area	35	1.92	15.9219	3.83

Crop Provisioning Services

Humans have intentionally created agricultural ecosystems to meet the fundamental need for food and support societal development (Nayak et al., 2019). In this study, the InVEST model is utilized to assess the crop provisioning services. Specifically, the InVEST Crop percentile Model is employed to estimate the yields of rice and wheat, which are the predominant crops in the study area. Two distinct land use and land cover (LULC) for different are generated to determine the spatial distribution of these crops. Given the extensive cultivation of wheat and paddy, which are the main crops in the region, conducting a comprehensive survey to assess the diversity among all crops would be challenging and time-consuming. However, if recommended, the inclusion of sugarcane cultivation in the plain region is considered. Rice cultivation occurs during the summer season, while wheat is grown in winter. Consequently, LANDSAT 8 images corresponding to the respective seasons will be utilized for the Crop percentile Model. The InVEST model offers a percentile-based approach for 175 crops worldwide, enabling the identification of yields within the 5th, 50th, 75th, and 95th percentiles based on climate characteristics. These models rely on data from the Food and Agriculture Organization (FAO) and global sources pertaining to climate and irrigation. The model outputs include yield maps, incorporating nutritional content, and incorporate information on climate, fertilization, and irrigation

Timber Provisioning

The Kosi watershed encompasses 9 forest divisions under 5 forest circles. (Figure 17). The total area of the reserve forest in the watershed is 860.68km^2 (ITGC report). The three forest types found in the Kosi watershed are: Tropical Moist Deciduous, Subtropical Pine/Broadleaved Hill Forests and Montane & Moist Temperate Forest (Kumar et al. 2019). However, these types vary in forest densities, there are very dense and medium dense forests.

Subsequently, as seen in Figure 18, the Kailash watershed has 4 forest divisions under 2 forest circles with. 331.68km^2 of reserve forest area. Having two forest types 1) Tropical moist deciduous forests, and 2) Subtropical Pine/Broadleaved Hill Forests, Kailash watershed has three kinds of forest density 1) Very dense Forest, 2) Medium Density Forest, and 3) Open Forest.

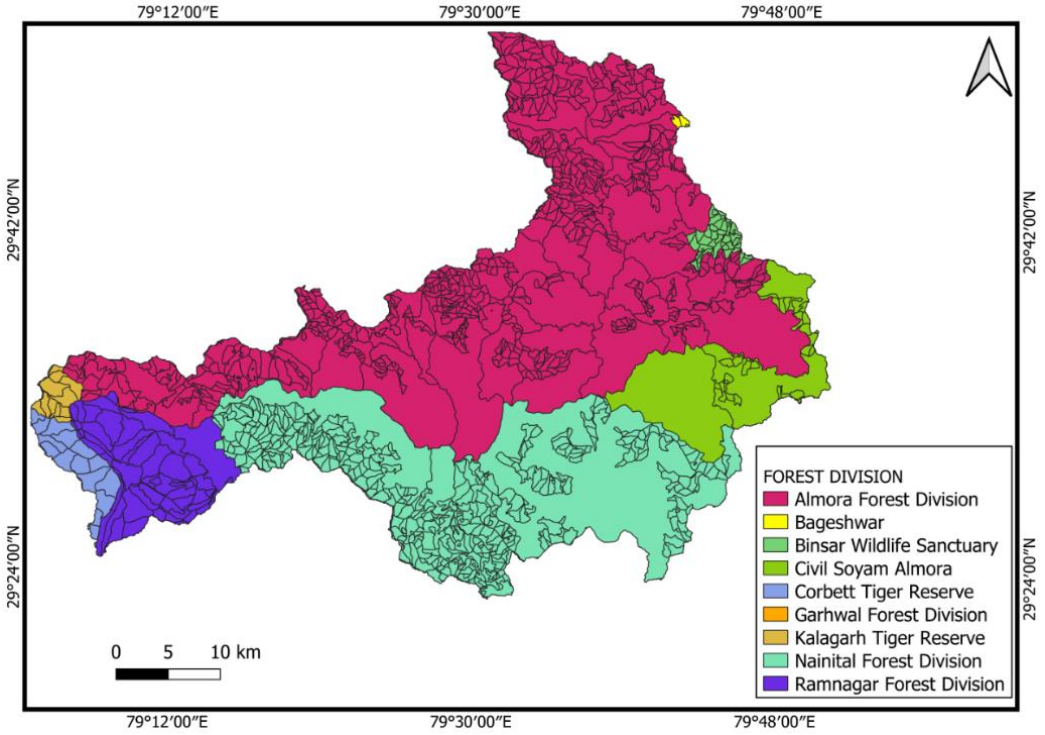


Figure 17: Forest divisions for the Kosi watershed

Source: ITGC, PCCF Office

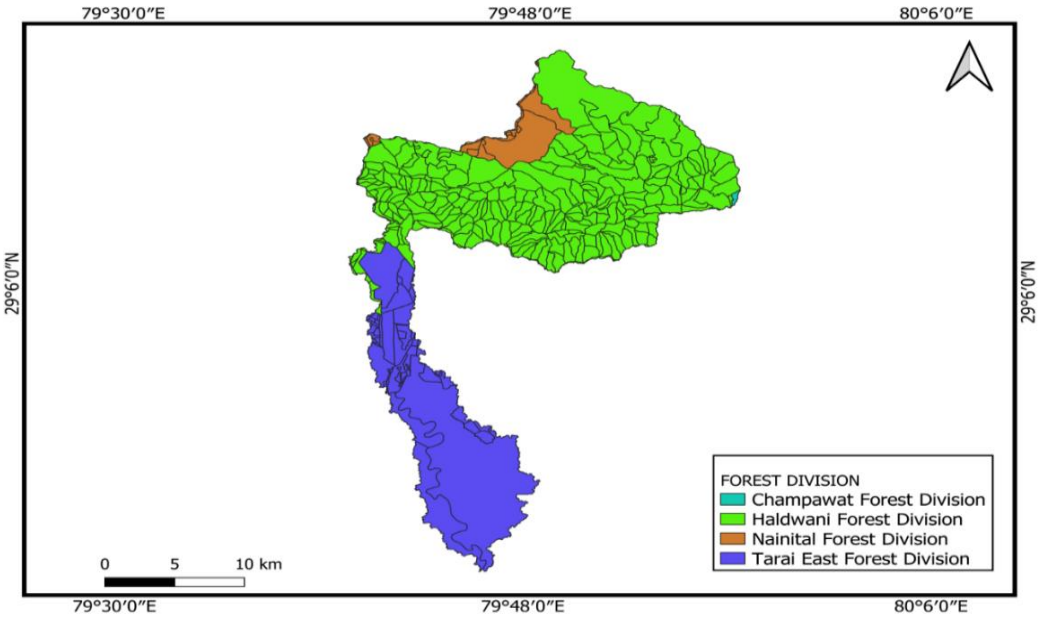


Figure 18: Forest divisions of Kailash watershed

Source: ITGC, PCCF Office

The final estimates of the economic value of timber presented by Forest Survey of India in 2014 are given in Table *8* below. The table presents the economic value of timber production by forest types for 4 forest types; very dense forest, medium dense forest, open forest and littoral forest. However, the proposed NPV (Net Present Value) rates differ from the currently existent NPV rates for various forest type groups and forest canopy cover density classes.

Table 8: The economic value of timber production

Forest Type Group / Value of timber (₹ /ha/yr)	**Very Dense Forest (VDF)**	**Medium Density Forest (MDF)**	**Open Forest (OF)**	**Littoral Forest (LTF)**
Tropical Wet Evergreen Forests – North-East	₹ 1,86,148	₹ 94,393	₹ 64,733	₹ 6,370
Tropical Wet Evergreen Forests – Western Ghats	₹ 2,40,183	₹ 1,56,800	₹ 36,061	₹ 6,688
Tropical Semi Evergreen Forests – North-East	₹ 77,299	₹ 66,394	₹ 26,604	₹ 11,022
Tropical Semi Evergreen Forests - Eastern Deccan	₹ 1,66,836	₹ 1,24,885	₹ 13,037	₹ 6,490
Tropical Semi-Evergreen Forests - Western Ghats	₹ 1,49,128	₹ 77,376	₹ 30,482	₹ 5,428
Tropical Moist Deciduous Forests	₹ 1,24,682	₹ 64,627	₹ 25,884	₹ 2,615
Littoral & Swamp Forests	₹ 1,84,491	₹ 1,01,498	₹ 29,997	₹ 4,849
Tropical Dry Deciduous Forests	₹ 60,058	₹ 41,198	₹ 15,346	₹ 1,707
Tropical Thorn Forests	₹ 35,367	₹ 12,637	₹ 13,223	₹ 1,727
Tropical & Subtropical Dry Evergreen Forests	₹ 1,17,247	₹ 82,836	₹ 31,992	₹ 717
Subtropical Pine/Broadleaved Hill Forests	₹ 96,794	₹ 70,688	₹ 32,170	₹ 1,237
Montane & Moist Temperate Forest	₹ 1,51,103	₹ 1,14,471	₹ 48,058	₹ 1,114
Sub Alpine & Dry Temperate Forest	₹ 1,13,507	₹ 95,347	₹ 39,892	₹ 1,008
Alpine Scrub	₹ 79,263	₹ 72,642	₹ 22,976	₹ 1,195

*forest under the study region
Source: FSI,2014

The proposed procedure to be used for timber provisioning services in depicted in Figure *19* below

Figure 19: Procedure for timber provisioning

7. Demonstration Plot Study

There have been observations of a significant decrease in agricultural production during the conversion from conventional (chemical-based) agriculture to organic agriculture, as documented by Meemken and Qaim in 2018. However, there are conflicting reports that support organic farming without major yield losses, leading to contradictory findings. The underlying issues primarily stem from a lack of knowledge and reliable input systems, particularly in India and specifically in Uttarakhand. Considering that hill agriculture relies on rainfall and generally yields are already low, considering topographical, soil-related, and environmental factors, organic agriculture could still enhance yields if implemented effectively. Apart from concerns about market viability, one of the main reasons' farmers are hesitant to adopt organic farming is the availability of quality inputs and timely support.

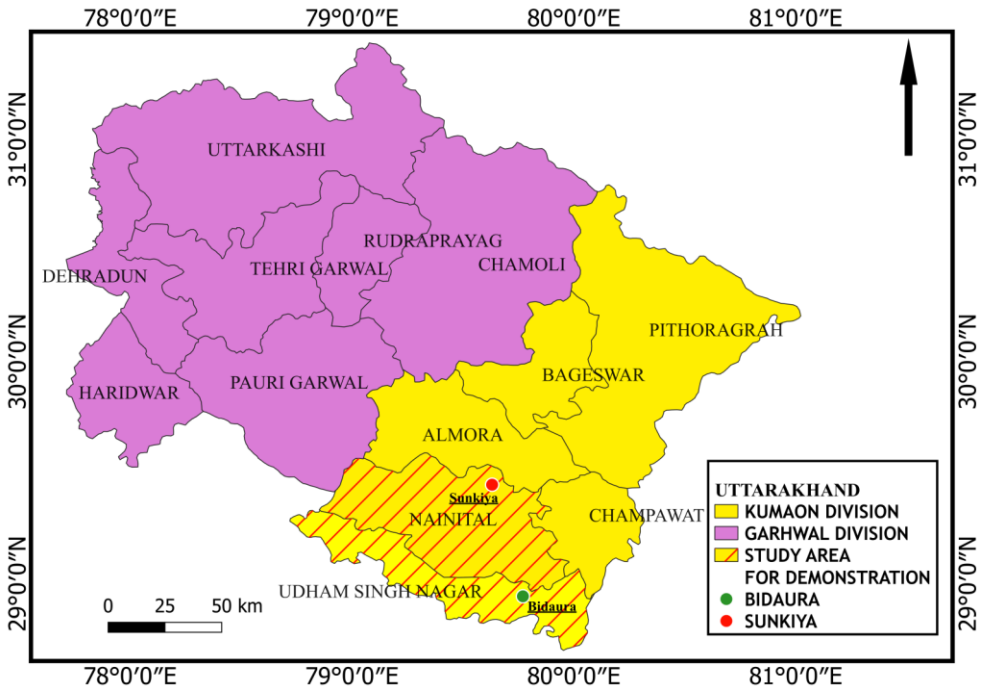


Figure 20: Demonstration plot study area

During the project initiation phase, it was initially proposed to have demonstration sites in four locations: Nainital, US Nagar, Haridwar, and Tehri. However, due to limitations in time and funding, the final decision, in agreement with the Steering Committee members, was to focus on

two sites: Nainital (representing hilly region) and US Nagar (representing plains) districts. Two village sites, Bidaura in Udham Singh Nagar district and Sunkiya in Nainital district, were selected for field assessment studies to evaluate the impact of organic farming inputs in both hilly and plain regions. The table below provides information of some of the field level assessments that will be undertaken for the demonstration plot study

Table 9: Field level estimations for demonstration plot study

Parameter	Assessment
Soil Health	Lab based soil health assessments will be undertaken using different pre and post-harvest crop trails from the rhizopheric soils. Considering organic farming plays a vital role in maintaining long term soil fertility and sustainability by finishing atmospheric nitrogen, Total microbial community enumeration in-vitro, physico-chemical, and functional microbial communities' assessment, and soil enzymes estimation will be conducted
Soil Carbon	Percentage of soil organic carbon will be assessed as part of the impact assessment on soil Physio-chemical properties, as a result of organic management of the farm through intervention
Social and Human Capital studies	Community participation techniques such as Participatory Rural Appraisal and questionnaire surveys will be carried out to capture information relevant for calculation of social and human capital impacts in the study plot.

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ANNEXURES TO THE TEEB-AGRIFOOD SCOPING AND SCENARIO SETTING REPORT FOR UTTARAKHAND

Contents of Annexures

Annexure 1: Digital Elevation Maps

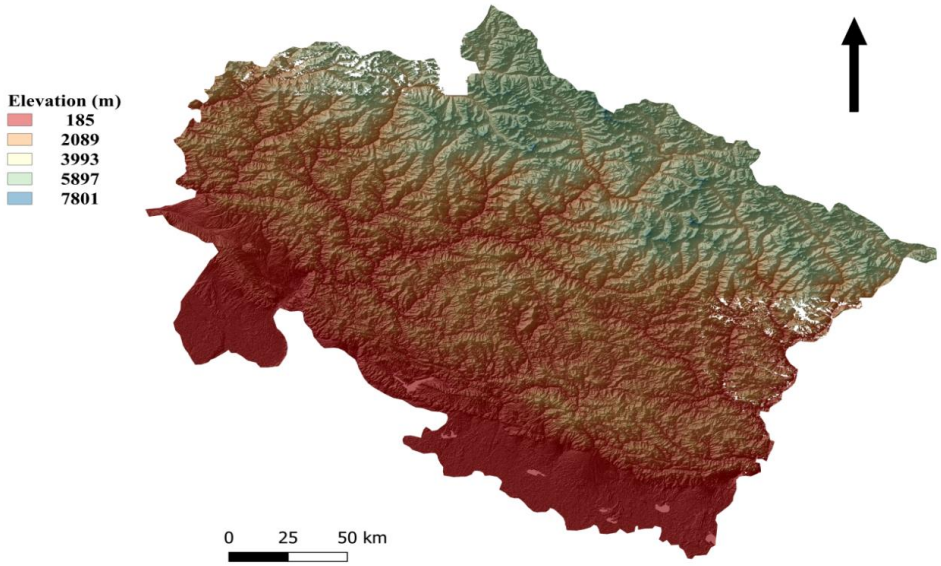


Figure 1: Digital Elevation Map of Uttarakhand

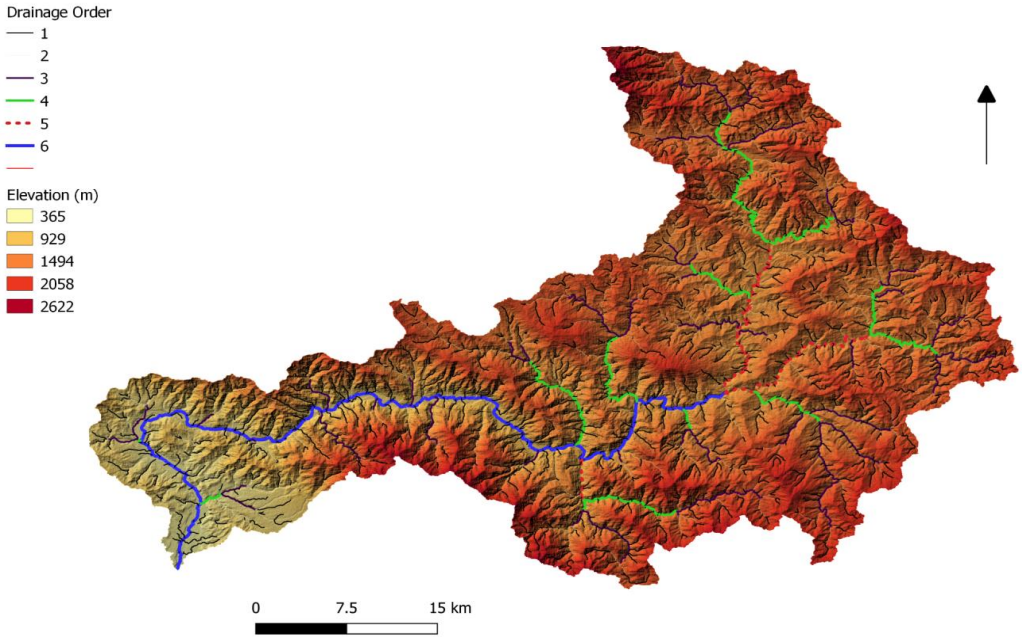


Figure 2: Digital elevation map of Kosi watershed

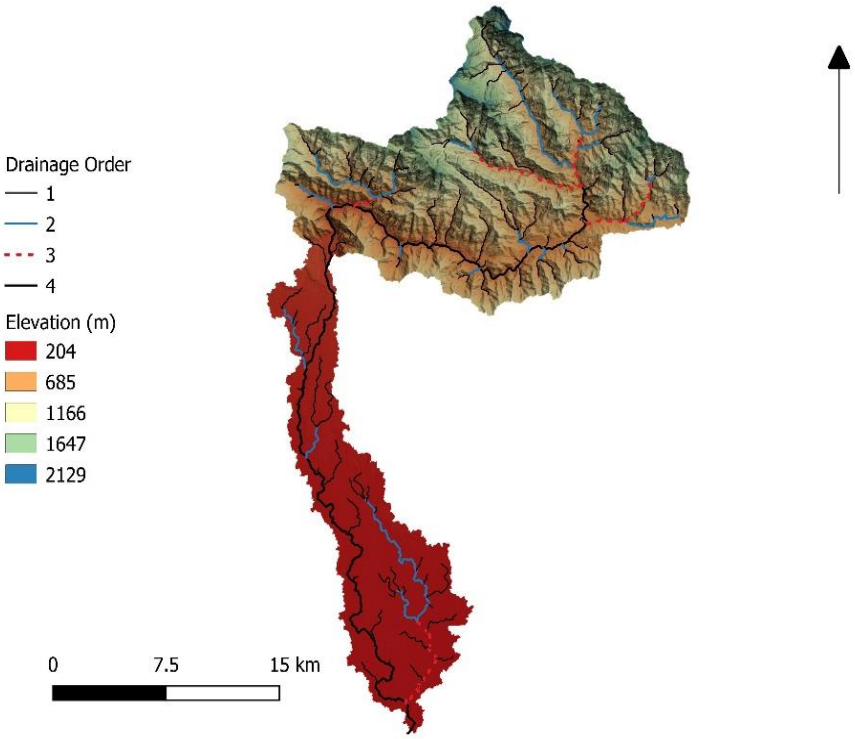


Figure 3: Digital elevation map of Kailash watershed

Annexure 2: District wise soil loss in Uttarakhand

Table A2.1: District wise soil loss in Uttarakhand

District	Area under different soil loss classes (tonne ha^{-1} $year^{-1}$) in '000 ha (%)							
	<5	5-10	10-15	15-20	20-40	>40	Area not surveyed	Total area
Almora	32.7(0.61)	12.1(0.23)	21.4(0.40)	51.2(0.96)	104.5(1.95)	78.1(1.46)	0.0(0.00)	300.1(5.61)
Bageshwar	48.9(0.91)	5.3(0.10)	10.1(0.19)	9.3(0.17)	8.0(0.15)	93.8(1.75)	55.0(1.03)	230.4(4.31)
Chamoli	72.8(1.36)	3.1(0.06)	4.9(0.09)	5.5(0.10)	6.8(0.13)	282.2(5.28)	386.9(7.23)	762.2(14.25)
Champawat	8.3(0.16)	12.5(0.23)	39.0(0.73)	38.5(0.72)	23.3(0.44)	50.4(0.94)	0.0(0.00)	172.0(3.22)
Dehradun	8.8(0.16)	2.6(0.05)	3.0(0.06)	6.0(0.11)	32.3(0.60)	244.4(4.57)	0.0(0.00)	297.1(5.56)
Haridwar	9.0(0.17)	13.7(0.26)	43.3(0.81)	51.8(0.97)	43.9(0.82)	69.8(1.30)	0.0(0.00)	231.5(4.33)
Nainital	31.5(0.59)	68.7(1.28)	81.7(1.53)	78.5(1.47)	47.9(0.90)	78.1(1.46)	0.0(0.00)	386.4(7.22)
Pauri Garhwal	157.5(2.95)	103.0(1.93)	87.9(1.64)	47.2(0.88)	41.6(0.78)	125.9(2.35)	0.0(0.00)	563.2(10.53)
Pithoragarh	2.0(0.04)	0.4(0.01)	0.5(0.01)	0.3(0.01)	0.3(0.01)	27.6(0.52)	693.9(12.97)	725.0(13.56)
Rudraprayag	8.7(0.16)	3.4(0.06)	5.2(0.10)	7.4(0.14)	15.6(0.29)	114.7(2.14)	27.3(0.51)	182.3(3.41)
Tehri Garhwal	2.7(0.05)	1.2(0.02)	5.5(0.10)	20.0(0.37)	74.1(1.39)	286.0(5.35)	0.0(0.00)	389.6(7.28)
Udham Singh Nagar	48.8(0.91)	78.3(1.46)	81.4(1.52)	28.7(0.54)	13.1(0.25)	54.8(1.03)	0.0(0.00)	305.2(5.71)
Uttarkashi	68.7(1.29)	4.9(0.09)	10.2(0.169)	15.4(0.29)	60.7(1.13)	243.6(4.56)	399.8(7.48)	803.3(15.02)
Total	500.8(9.36)	309.2(5.78)	394.0(7.37)	359.8(6.73)	472.2(8.83)	1749.4(32.71)	1562.8(29.22)	5348.3(100.00)

Annexure 3: Agro-climatic zones of Uttarakhand

Table A3.1: Agro-climatic zones of Uttarakhand

Agro-climatic Zone (ACZ)	Agro-climatic zones initials	Temperature (˚C)	Precipitation(mm)	% Area
1	T1P1	<0	<800	10.26
2	T2P1	0-10	<800	0.14
3	T3P1	10-20	<800	0.004
4	T4P1	>20	<800	0.18
5	T1P2	<0	800-1400	8.06
6	T1P3	<0	>1400	0.07
7	T2P2	0-10	800-1400	9.07
8	T2P3	0-10	>1400	2.66
9	T3P2	10-20	>800-1400	4.96
10	T3P3	10-20	1400	31.39
11	T4P2	>20	800-1400	7.116
12	T4P3	>20	>1400	26.09

T1P1: This zone accounts for 10.26% of the state's total geographical area. This zone's annual average temperature and precipitation are 0 0C and 800 mm, respectively. This zone is primarily located in the state's higher highlands, where temperatures remain below zero degrees Celsius all year. The land is perpetually snow-covered and unsuitable for agricultural activities of any type.

T2P1: This zone covers 0.14% of Uttarakhand's total geographical area. The yearly average temperature in this zone is between 0 and 100 degrees Celsius, and the annual precipitation total is 800 millimetres. This zone is present in Uttarakhand's high hills and serves as a transition zone between the snowbound region and Uttarakhand's mild temperature zones in some areas.

T3P1: The yearly average temperature in this zone ranges between 10 and 20 degrees Celsius, and the annual precipitation totals 800 millimetres. The zone is not very significant because it covers only 0.004% of the state's overall geographical area. Because it is dispersed throughout the state's mid hills, its presence is vividly noticeable.

T4P1: The temperature in this zone is above 20 degrees Celsius, and the precipitation total is 800 millimetres. This zone is limited to a small fraction of the state and covers 0.18% of Uttarakhand's total geographical area, which is spread across the lower hills and some areas of the western Tarai region.

T1P2: This agro-climatic zone covers 8.06% of Uttarakhand. This zone's annual average temperature is 0 0C, and precipitation ranges from 800-1400 mm. In most sections of Uttarakhand, these zones form the snowbound upper hills and the moderate temperature zones of the middle hills. Summer has very little forest potential because vegetation is not possible at temperatures below 0 0 C.

T1P3: This zone accounts for 0.07% of Uttarakhand's total geographical area. This zone's annual average temperature is 0 0 C, and the yearly precipitation totals more than 1400 mm. Because the zone's yearly temperature is below freezing, it is unsuitable for agricultural activity.

T2P2: The annual average temperature of this agroclimatic zone is 0-10 0C, with precipitation ranging from 800-1400. This zone covers 9.07% of the overall geographical area. This zone is found in Uttarakhand's mid-high hills. Because the temperature in winter is below freezing and the temperature in July is around 10 0C, crops can be produced for a limited time in summer.

T2P3: This agro-climatic zone covers 2.65% of the total geographical area. The temperature ranges from 0 to 10 degrees Celsius, and the yearly rainfall totals more than 1400 millimetres. This zone is restricted to the upper highlands of Uttarakhand, primarily in the districts of Rudraprayag and Chamoli. Summer crops with a short growing season can be grown in this zone.

T3P2: This agro-climatic zone covers 4.96% of Uttarakhand. The yearly average temperature in this zone is between 10 and 20 degrees Celsius, while the annual rainfall is between 800 and 1400 millimetres. This zone can be found primarily near rivers in valley sections of the Upper Hills, where rainfall is abundant and temperatures are moderate due to the lower elevation than the surrounding area. This region is ideal for growing a variety of crops because it receives a considerable quantity of precipitation throughout the year.

T3P3: This agro-climatic zone encompasses the majority of Uttarakhand. It accounts for 31.39% of Uttarakhand's overall geographical area. This zone's average annual temperature ranges between 10 and 20 degrees Celsius, while the yearly precipitation totals more than 1400 millimetres. This zone is primarily found in the mild to moderately high hills of Uttarakhand and is ideal for most crops that require a low temperature climate. This zone is ideal for growing vegetables in a protected setting.

T4P2: This agro-climatic zone covers 7.11% of Uttarakhand's total geographical area. This zone's average annual temperature range is >20 0C, while the annual precipitation range is 800-1400 mm. The zone is found in Uttarakhand's Tarai and Bhabar regions, as well as the lower hills.This zone is rich in soil and water availability, and it is home to some of the world's most fertile soils. In this region, any crop (depending on the season) can be grown.

T4P3: This agro-climatic zone covers 26.09% of the entire geographical area. This zone's typical annual temperature range is >20 0C, and annual precipitation is >1400 mm. This zone is primarily located in the Uttarakhand districts of Haridwar and Udham Singh Nagar, and it marks the state's southern boundary. The region's soils are extremely rich, and irrigation facilities abound. Different agricultural activities are carried out in this region, ranging from rice farming to sugarcane cultivation to agro-forestry, thanks to the availability of irrigation infrastructure.

Annexure 4: Changes in Rainfall and Temperature Trends

Table A4.1: Changes in rainfall-related agriculturally relevant variables during 2021-50 relative to 1961-90

District	June rainfall (%)	July rainfall (%)	Annual rainfall (%)	No. of rainy days (%)	Drought incidence	Dry spells	99 percentile rainfall (%)	Maximum rainfall event	Three-day maximum rainfall	Event with >100mm rainfall (%)
Uttarkashi	12.08	10.56	11.31	4.55	0.50	-0.23	19.70	0.39	1.03	43.88
Chamoli	-0.74	5.69	7.00	-0.52	0.50	-0.03	10.82	0.35	0.60	20.08
Rudrapraya g	3.98	10.88	7.89	-2.11	0.00	-0.07	15.15	0.29	0.65	20.85
Tehri Garhwal	10.69	17.89	11.93	0.27	-1.00	0.00	15.10	0.35	0.73	26.55
Dehradun	10.9	16.98	14.60	3.06	0.00	-0.10	20.97	-0.17	0.28	40.08
PauriGarhwal	7.50	14.97	10.48	1.49	0.00	-0.03	12.85	0.90	0.78	36.68
Pithoragarh	3.0	1.44	6.25	1.60	0.50	-0.03	11.06	0.35	0.50	15.15
Bageshwar	1.68	5.31	5.80	0.67	0.50	-0.07	13.43	0.78	0.93	13.07
Almora	2.30	6.48	4.80	-1.19	0.00	-0.07	14.70	1.37	1.87	24.28
Champawat	4.53	-4.60	-0.44	-2.00	-0.50	0.03	-3.69	0.72	0.54	-0.39
Nainital	7.65	1.25	3.77	-1.26	0.00	0.00	-0.58	0.97	0.98	13.11
Udham Singh Nagar	10.56	4.20	4.45	-1.50	-0.50	0.00	-0.52	0.55	0.29	12.93
Haridwar	5.21	7.42	5.64	0.58	0.00	0.00	4.66	0.11	-0.18	24.44

Table A4.2: Changes in temperature-related agriculturally relevant variables during 2021-50 relative to 1961-90

District	**Maximum Temperature (^{0}C)**	**Minimum Temperature (^{0}C)**	**Unusually hot days**	**Unusually cold days**	**Frost day frequency**
Uttarkashi	2.18	2.24	0.97	-1.77	-3.27
Chamoli	2.13	2.36	-0.27	-1.67	0.00
Rudraprayag	2.16	2.26	1.80	-0.20	-1.57
Tehri Garhwal	2.07	2.15	3.17	0.17	-12.17
Dehradun	1.75	2.04	3.40	-0.47	-19.43
PauriGarhwal	1.79	2.01	2.3	-1.00	-14.40
Pithoragarh	2.05	2.41	-0.73	-2.07	0.00
Bageshwar	2.09	2.7	1.40	-1.97	-4.53
Almora	1.92	2.03	2.60	-0.60	-19.40
Champawat	1.88	2.07	0.87	-0.37	-20.73
Nainital	1.77	1.95	1.17	-0.37	-8.20
Udham Singh Nagar	1.80	2.03	0.57	-1.33	-3.47
Haridwar	1.64	2.12	2.43	-3.00	-8.40

Annexure 5: Relative position of districts of Uttarakhand with respect to different components of vulnerability

Table A5.1: Changes in temperature-related agriculturally relevant variables during 2021-50 relative to 1961-90

District	**Rank based on**			
	Exposure	**Sensitivity**	**Adaptive Capacity**	**Vulnerability**
Uttarkashi	11	4	11	6
Chamoli	1	5	8	4
Rudraprayag	6	9	5	7
Tehri Garhwal	12	11	10	8
Dehradun	13	12	2	13
PauriGarhwal	10	7	6	9
Pithoragarh	3	1	12	1
Bageshwar	4	2	13	2
Almora	7	3	9	3
Champawat	2	6	7	5
Nainital	5	13	3	11
Udham Singh Nagar	8	8	1	10
Haridwar	9	10	4	12

Annexure 6: Biodiversity in Uttarakhand

Table A6.1: Threatened Species of Plants, compiled from the book released by Uttarakhand Biodiversity Board (5).

S. No.	Botanical Name	Local/Common Name	Endemism	Threats
1	*Aconitum balfourii*Stapf.	Mitha/Vish/Banwa	Uttarakhand and Western Nepal)	Over-exploitedspecies due to ready market for tubers.
2	*Aconitum heterophyllum*Wall.ex Royale	Atis/Patis/Ativish/Atvika	Himalayan Region	Due to over-exploitation for medicine use, it has become one of the most highly threatened medicinal plant species.
3	*Aconitum violaceum*Jacq. Ex Stapf	DoodhAtis, Chhota Atis.	Himalayan Region	Habitat degradation and overexploitation
4	*Eremostachyssuperba*Royle ex Benth.		Shiwaliks or North-Western India and Pakistan	Trampling and overgrazing.
5	*Gentiana kurroo*Royle	Karvi, Kamalphul, Nilkanth (Hindi), Trayaman (Sanskrit) Indian Gentian (English)	Western Himalaya	Excessively exploited till the 1960s. The existing habitats of this species are vulnerable to pilferage, degradation, road widening, etc.
6	*Nardostachys grandiflora* DC. (Nardostachys jatamansi DC.)	Masi, Jatamasi (Hindi and Sanskrit), Indian Spikenard (English)	Himalaya from Himachal Pradesh to SW China	There is excessive exploitation and trampling by sheep and goats

				in the alpine meadows.
7	*SchreberasweitenioidesRoxb*	Ghant (local), Banpalas or Banda (Hindi), Mokha (trade name), Weaver's Beam Tree (English)	The IndIan subcontinent, Central -South India	Decreasing numbers leads to species extinction due to restricted gene variability.
8	*Pinguicula alpine* Linn	Alpine butterwort	Himalaya and Eurasian Mountains	Habitat degradation
10	*Phaiustancarvilleae*(Banks et L. Herit.) Blume	Nun's Orchid, Nun's Cap Orchid, Chinese Ground Orchid, Red Crane Orchid	Himalaya and South East Asia	The Extraction of plants from the wild for ornamental purposes and trade
11	*Pecteilis gigantea* (J.E. Sm.) Rafi n.	Butterfly Orchid, Lady Susan's Orchid, Waghchora (Marathi)		i)Broad endemismHabit at degradation ii) Extraction from the wild for aesthetic value and trade.
12	*Diplomatichirsute*(Lindl.) Lindle	Snow Orchid	Eastern Himalaya and SW China	Habitat degradation
13	*Cyathea spinulosa* Wall.ex Hook.	Sala tree	Eastern Himalaya, China and SE Asia	Forest fires, habitat degradation, collection for ornamental use.
14	*TurpinianepalensisWall. ex W. & A*	Thali	Himalaya northeast India	Habitat degradation
15	*Indopiptadeniaoudhensis*(Brandis) Brenan	Genti (Avadhi-dialect of Hindi)	Awadh region of erstwhile United Province and footers on Nepal	Excessive loopingaffects seed production and regeneration
16	*Meizotropispellita* (Hook. f. ex Prain) Sanjappa	Patwa		i)Patwadangar near Nainital, Uttarakhand Forest fires ii) Trampling iii)Degradation of habitat.

17	*Trachycarpustakil*Becc	Thakal or Jhagerau	Uttarakhand and Western Nepal	Extremely poor regeneration and habitat degradation

Table 6.2: Mammals and their conservation status in Kedarnath Valley

SN	Zoological Name	Local Name	English Name	Conservation status		
				IUCN Category	ZSI	WPA (1972)
Bovidae						
1	*Hemitragusjemlahicus (Smith, 1826)*	Himalayan Thar	Himalayan Thar, Wild Goat	Near threatened	-	I
Hystricidae						
2	*Hystrixindica(Kerr, 1792)*	Solu	Indian Porcupine	Vulnerable	-	II
Cercopithecidae						
3	*Macaca mulatta (Zimmermann, 1780)*	Bandar	Monkey	Least Concern	-	II
4	*Semnopithecus entellus (dufresne, 1797)*	Goni	Hanuman Langoor	Least Concern	-	II
Cervidae						
5	*Muntiacusmuntjak (Zimmermann, 1780)*	Kakar	Barking Deer	Least Concern	Endangered	I
6	*Rucervus spp.*	Jaray	Barasinga	Vulnerable	-	-
Felidae						
7	*Panthera pardus (Linnaeus, 1758)*	Bagh, Tendua	Leopard	Vulnerable	Vulnerable	I
8	*Felis chaus (Schreber, 1777)*	Ban Biralu	Jungle Cat	Least Concern	-	I
9	*Panthera uncial (Schreber, 1775)*	Him Tendua	Snow Leopard	Least Concern	Endangered	I
10	*Felis bengalensis (Kerr 1792)*		Leopard Cat	Least Concern	-	I
Canidae						
11	*Canis aureus (Linnaeus, 1758)*	Syal	Jackal	Least Concern	-	II
12	*Vulpes vulpes (Linnaeus, 1758)*	Red Fox	Red Fox	Least Concern	-	II
Suidae						
13	*Sus scrofa (Linnaeus, 1758)*	JungaliSuwar	Wild Boar	Least Concern	Endangered	III
Muridae						
14	*Mus musculus (Linnaeus, 1758)*	Chuha	Indian Mouse	Least Concern	-	-
Pteropodidae						
15	*Pteropus giganteus (Brunnich, 1782)*	Chamgadar	Indian Flying Fox	Least Concern	-	-

16	*Rhinolophus ferrumequinum (Schreber. 1774)*	Chamgadar	House Shoe Bat	Least Concern	-	-
Mutellidae						
17	*Martes flavigula (Boddaert, 1785)*	Titriyal	yellow-throated marten	Least Concern	-	II
Bovidae						
18	*Moschus leucogaster (Hodgson, 1839)*	Kasturimrig	Himalayan Musk Deer	Least Concern	Endangered	I
19	*Nemorhaedus goral (Hamilton Smith, 1827)*	Ghwed	Deer ,Ghurad	Endangered	-	III
20	*Capricornissumatraensis (Bechstein, 1799)*	Serow	Serow	Least Concern	Vulnerable	I
Soricidae						
21	*Suncus murinus (Linnaeus, 1766)*	Chakchunder	House Shrew	Least Concern	-	-
Muridae						
22	*Rattus rattus (Linnaeus, 1758)*	Chuha	House Rat	Least Concern	-	-
23	*Mus musculus (Linnaeus, 1758*	Chuha	House Mouse	Least Concern	-	-
24	*Mus buduga*	Chuha	Indian Field Mouse	Least Concern	-	-
Oechotonidae						
25	*Ochotona roylei (Ogilby, 1839)*	Chuhatunanath	Royle's pika	Least Concern	-	IV
Ursidae						
26	*Selenarctos thibetanus (G. Cuvier, 1823)*	Bhalu, Richh	Black Bear	Vulnerable	-	I

Table A6.3: Birds and their conservation status in Kedarnath Valley

SN	Zoological Name	Local Name	English Name	Conservation status		
				IUCN Category	ZSI	WPA (1972)
Phasianidae						
1	*Arborophilatorqueola*(Valenciennes, 1826)	Titar	Hill Patridge	Least Concern	-	IV
2	*Lerwalerwa*(Hodgson, 1833)		Snow Partridge	Least Concern	-	IV
3	*Lophuraleucomelana* (Latham, 1790)	JugliMurga	White CreastedKaleej Pheasan	Least Concern	-	-
4	*Lophophorusimpejanus* (Latham, 1790)	Monal	Himalayan Monal	Least Concern	Endangered	IV
5	*Pucrasiamacrolopha* (Lesson, 1829)		Koklass	Least Concern	-	IV
Columbidae						

6	*Columba livia* (Gmelin, 1789)	Kabuter	Rock Pigeon	Least Concern	-	IV
7	*Steptopeliaorientalis* (Latham, 1790)	Ghuguti	Rufous Turtle Dove	Least Concern	-	IV
8	*Treronsphenurus*(Vigors, 1832)	Malyo	Wedge Tailed Green Pigeon	Least Concern	-	IV
Cettiidae						
9	*Horornisfortipes*(Hodson, 1845)		Brown-Flanked Bush Warble	Least Concern	-	IV
10	*Cettiacastaneocoronata* (Burton, 1836)		ChestnutHeadedTesia	Least Concern	-	IV
Dicruridae						
11	*Dicrurusleucophaeus* (Vieillot, 1817)	Kala Lampuchh	Ashy Drongo	Least Concern	-	IV
Accipitridae						
12	*Gyps himalayensis* (Hume, 1869)	Giddh	Griffin Vulture	Least Concern	-	I
13	*Aquila chrysaetos*	Garud	Himalayan Golden Eagle	Least Concern	-	I
Emberizidae						
14	*Emberizacia* (Linnaeus, 1766)		Rock Bunting	Least Concern	-	IV
15	*Melophuslathami* (Gray, 1831)		Crested Bunting	Least Concern	-	IV
Fringillidae						
16	*Carpodacus erythrinus* (Pallas, 1770)		Common Rose Finch	Least Concern	-	IV
17	*Procarduelisnipalensis* (Hodgson, 1836)		Dark-Breasted Rose Finch	Least Concern	-	IV
18	*Mycerobasicterioides* (Vigors, 1831)		Black-andYellow Grosbea	Least Concern	-	IV
Muscicapidae						
19	*Myophonus caeruleus* (Scopoli, 1786)		Blue Whistling Thrush	Least Concern	-	IV
20	*Phoenicurus frontalis* (Vigors, 1832)		Blue Fronted Redstart	Least Concern	-	IV
21	*Chaimorrornis leucocephalus* (Vigors, 1831)		White Caped Redstart	Least Concern	-	IV
22	*Eumyiasthalassinus*(Swainson, 1838)		Verditer Flycatcher	Least Concern	-	IV
23	*Enicurus maculates* (Vigors, 1831)		Spotted Forktail	Least Concern	-	IV
24	*Ficedulasuperciliaris* (Jerdon)		White-Browed Blue Flycatcher	Least Concern	-	IV

25	*Phoenicurusfuliginosus* (Vigors, 1831)		Plumbeous Water Redstart	Least Concern	-	IV
26	*Tarsigerchrysaeus* (Hodgson, 1845)		Golden Bush Robin	Least Concern	-	IV
27	*Niltavamacgrigoriae* (Burton, 1836)		Small Niltava	Least Concern	-	IV
Motacillidae						
28	*Motacillacaspica* (Tunstall, 1771)		Grey Wagtail	Least Concern	-	IV
29	*Motacilla alba* (Linnaeus, 1758)		White Wagtail	Least Concern	-	IV
30	*Anthusroseatus*(Blyth, 1847)		Vinaceous Breasted Pipit	Least Concern	-	IV
Nectariniidae						
31	*Aethopygasiparaja*(Raffles, 1822)		Crimson Sunbird	Least Concern	-	IV
Phylloscopidae						
32	*Phylloscopustrochiloides* (Sundevall, 1837)		Greenish Leaf Warbler	Least Concern	-	IV
Cerambycidae						
33	*Pseudhammus occipitalis* (Lameere, 1893)		Crowned Leaf Warbler	Least Concern	-	IV
Passeridae						
34	*Passer montanus* (Linnaeus, 1758)	Ghiduri	Tree Sparrow	Least Concern	-	IV
35	*Passer domesticus* (Linnaeus, 1758)		House Sparrow	Least Concern	-	IV
Prunellidae						
36	*Prunella collaris*(Scopoli, 1769)		Alpine Accentor	Least Concern	-	IV
Pycnonotidae						
37	*Pycnonotuscafer* (Linnaeus, 1766)	Bulbul	Red Vented Bulbul	Least Concern	-	IV
38	*Pycnonotusleucogenys* (Gray, JE, 1835)	Bulbul	White Checked Bulbul	Least Concern	-	IV
Psittacidae						
39	*Psittaculakrameri* (Scopoli, 1769)	Tota	Parrot, RoseRinged Parakeet	Least Concern	-	IV
Strigidae						
40	*Glaucidumcuculoides*(Vigors, 1831)	Ulloo	Himalayan Spotted Owl	Least Concern	-	IV
Laniidae						
41	*Laniusschach*(Linnaeus, 1758)		Long Tailed Shrike	Least Concern	-	IV

Leiothrichidae						
42	*Trochalopteronlineatum* (Vigors, 1831)	Musbhegur u	Streaked Laughing thrush	Least Concern	-	IV
43	*Trochalopteron erythrocephalum* (Vigors, 1831)		Chestnut-Crowned Laughing thrush	Least Concern	-	IV
Picidae						
44	*Dendrocoposhimalayensis* (Jardine & Selby, 1835)	Kathphorw a	Himlayan Wood Pecker	Least Concern	-	IV
Prunellidae						
45	*Prunella collaris*(Scopoli, 1769)	Burfili Ghinduri	Alpine Accentor	Least Concern	-	IV
Sturnidae						
46	*Acridotheres tristis* (Linnaeus, 1766)	Myana	Indian Myana	Least Concern	-	IV
Corvidae						
47	*Corvus macrorhynchos* (Wagler, 1827)	Kawwa	Jungle Crow	Least Concern	-	IV
48	*Garrulus glandarius*(Linnaeus, 1758)		Eurasian Jay	Least Concern	-	IV
49	*Urocissaerythroryncha* (Boddaert, 1783)	Lampuchh	Red Billed Blue Magpie	Least Concern	-	IV
50	*Dendrocittaformosae* (Swinhoe, 1863)	Brown, black color lambpuchh	Himalayan tree Pie	Least Concern	-	IV
51	*Nucifragacaryocatactes* (Linnaeus, 1758)		Nutcracker	Least Concern	-	IV
52	*Pyrrhocoraxgraculus* (Linnaeus, 1766)		Yellow Billed Chough	Least Concern	-	IV
Timaliidae						
53	*Pomatorhinuserythrogenys* (Vigors, 1832)		Rusty-Cheeked Scimitar Babbler	Least Concern	-	IV
54	*Heterophasiacapistrata* (Vigors, 1831)		Black-Caped Sibia	-	-	IV
Upupidae						
55	Upupa epops (Linnaeus, 1758)	Bulbul	Hoopoe	Least Concern	-	IV
Zosteropidae						
56	*Zosteropspalpebrosus* (Temminck, 1824)		Oriental WhiteEye	Least Concern	-	IV

Table A6.4: Reptiles and their conservation status in Kedarnath Vally

S.N.	Zoological Name	Local Name	English name	IUCN Category	WPA (1972)
Colubridae					
1	*Platycepsventhromaculatu*	Saanp	Gray Rat Snake	Least concern	-
2	*Ptyasmucosus (Linnaeus,1758)*	-	Oriental Rat Snake	Not evaluated	-
Natricidae					
3	*Herpetorisplatyceps (Blyth*	-	Himalayan Keelback	Not evaluated	-
4	*Xenochrophis piscator (Schneider, 1799)*	-	Checkered Keelback	Not evaluated	II
Viperidae					
5	*Trimeresurusalbolabris (Gray, 1842)*	saap	Green Pit Viper	Least concern	-
6	*Gloydiushimalayanus (Günther, 1864)*	-	Himalayan Pit Viper	Not evaluated	IV
Elapidae					
7	*Bungarus caeruleus (Schneider, 1801)*	saap	Common Krait	Least concern	-
8	*Najanaja (Linnaeus, 1758)*	naag	Indian Cobra	Least concern	-
Lumbricidae					
9	*Lumbricusterrestris (Linnaeus, 1758)*	Kechua	Common Earthworm	-	-
Agamidae					
10	*Agama tuberculata (Gray, 1827)*	Chhipkali	Common Lizard	Least concern	-
11	*Calotis versicolor (Daudin 1802)*	Chhipkali	Indian Garden Lizard	Least concern	-
12	*Japalura major (Jerdon, 1870)*	-	Garhwal Mountain Lizard	Not evaluated	-
Scincidae					
13	*Scincellahimalayanum (Greer 1974)*	-	Himalayan Ground Skink	Not evaluated	-

Table A6.5: Amphibians and their conservation status in Kedarnath Valley

S.N	Zoological Name	Local Name	English name	IUCN Category	WPA (1972)
Bufonidae					
1	*Duttaphrynushimalayanus*(Gunther, 1864)	Medhak	Himalayan Toad	Least Concern	IV
2	*Duttaphrynusmelanostictus*(Schneider, 1799)	Medhak	Asian Common Toad	Least Concern	IV
Ranidae					
3	*Amolopsspp Cope, 1865*	-	Cascade Frogs	-	IV
4	*Rana (Paa) annandolii*	-	Boulerger	-	IV
5	*Rana dhakuriensis*	-	Boulerger	-	IV

Table A6.6: Diversity of butterfly in Kedarnath Valley

S.N.	Zoological Name	English Name
Nymphalidae		
1	*Acreaeissoria*(Hubner, 1819)	Hubner
2	*Aglaiscashmerenisis*(Kollar, 1848)	-
3	*Argyreushyperbius*(Linnaeus, 1763)	Linnaeus
4	*Auloceraswaha*(Kollar, 1844)	Kollar
5	*Danaus genutia*Cramer, (1779)	Cramer
6	*Issorialathonia*(Linnaeus, 1758)	Linnaeus
7	*Junoniaiphita*(Cramer, 1779)	Cramer
8	*Neptiszaida*(Fabricius, 1807)	Doubleday
9	*Vanessa cardui*(Linnaeus, 1758)	Linnaeus
10	*Venessa indica* (Herbst, 1794)	Herbst
Papilionoidea		
11	*Callerebiaannada*(Moore 1857)	Moore
12	*Graphiumnomius*(Esper, 1793)	Esper
Pieradae		
13	*Catopsilia Pomona*	Fabricius
14	*Gonopteryxrhamni*(Linnaeus, 1758)	Linnaeus
15	*Pieris brassicae*(Linnaeus, 1758)	Linnaeus
Lycaenidae		
16	*Lycaenapavana*(Kollar 1848)	Kollar
17	*Udara akasa*(Horsfield, 1828)	Hoursefiels

Source: Prasad et al (2021)

Table A6.7: Threatened Species of Wild Animals, compiled from the book released by Uttarakhand Biodiversity Board

S. No.	Zoological Name	Local/Common Name	Threats
1	*Gyps bengalensis*	White-rumped Vulture, Asian White-backed Vulture, Oriental White-backed Vulture, White-backed Vulture	The anti-inflammatory veterinary drug diclofenac, used to treat domestic livestock, has been identified as the cause of mortality from renal failure resulting from visceral gout in the vast majority of vultures.
2	*Sarcogyps calvus*	The Red-headed Vulture (Sarcogyps calvus), Asian King Vulture, Indian Black Vulture or Pondicherry Vulture	The rapid decline over the last eight years is believed to have been driven by the pharmaceutical NSAID diclofenac used to treat livestock, which has proven highly toxic to vultures, causing mortality from renal failure resulting from visceral gout.

3	*Vanellus gregarious*	Grey-headed Lapwing	The cause of the recent decline in sociable lapwing numbers is unknown.
4	*Hyaena hyaena*	Striped Hyena	Decreasing natural and domestic sources of carrion due to declines in the populations of other large carnivores (wolf, leopard, lion, and tiger) and their prey.
5	*Tragopan melanocephalus*	Jujurana(Himachali-Kullu, mandi), Jyazi (Bushahr) Sonalu, Solalee (Kashmiri), Sing monal (N.W. Himalaya)	The degradation of the alpine habitat of the Western Tragopan as a result of intensive grazing by livestock has led to its decline in numbers
6	*Tragopan satyra*	Lungi (Hindi, Garhwali, Kumaoni), Bop (Bhotia), Tarrhyak (Sikkim)	Degradation of habitat is a serious threat to this species.
7	*Ophrysiasuperciliosa*	Himalayan Quail	
8	*Moschus chyrogaster*	Alpine Musk Deer, Kasturi Mrig	
9	*Uncia uncia*	Snow leopard	Poaching for musk and extensive habitat degradation20odellid to the decline of musk deer populations and local extinctions in many parts of its once continuous distribution range.
10	*Ursus arctos isabellinus*		1. Barhal he (Pahari), Barfani cheetah (Urdu), Shan (Ladakhi), Burhelhaye (Bhotia), Sheen-e-suh (Kashmiri)Poaching ii)Human-animal conflict
11	*Cervus duvaucelii*	Himalayan brown bear (English), Lal bhalu or Burra bhalu (Hindi)	Degradation of alpine habitats due to increasing anthropogenic pressures and habitat loss due to developmental activities and poaching for bear parts (gallbladder, bear paws) are major threats to brown bears.
12	*Melursus ursinus*		1. The sloth bear (English), Reech (Hindi).Habitat degradation and loss ii)Conflict with humans and retaliatory killings.
13	*Murina grisea*	Peter’s tube-nosed bat	The species has a highly restricted range. There has been extensive loss of habitat due to human interference, housing, and tourism
14	*Amblonyx cinereus*	Asian small-clawed otter	
15	*Panthera tigristigris*	Royal Bengal Tiger	Habitat losses and Poaching

Annexure 7: Agricultural Biodiversity

Table A7.1: Crop Diversity with altitude

Crop species	Common name	Vernacular name	Altitude range (MSL)				
			500	1000	1500	2000	2500
Allium cepa	Onion	Pyaz					
Amaranthus oleracea	Amaranth	Chaulai					
A. frumentaceus	Amaranth	Chuwa/Marcha/ Ramdana					
Avena sativa	Oat	Jai					
Brassica compestris	Mustard	Sarson					
Brassica spp.	Mustrad	Toria					
Cajanus cajan	Pigeon pea	Tor					
Canabis sativa	Hemp	Bhang					
Chenopodium album	Pig-weed	Bethu					
Clemoe viscose		Jakhiya					
Colocasia himalayensis	Taro	Pindalu/Kuchain					
Echinochloafrumentaces	Barnyard millet	Jhangora					
Elusine coracana	Finger millet	Mandua/Koda					
Fagopyrum esculentum	Buckwheat	Oggal					
F. tataricum	Buckwheat	Phaphar					
Glysine soja	Soybean	Bhatt					
Glysine spp.	Soybean	Kala bhatt					
Glysine max	Soybean	Soybean					
Hordeum himalayens	Nacked barley	Jowar					
Hordeum vulgare	Barley	Jau					
Hibiscus subdarifa	Roselle	Sun					
Lens esculenta	Lentil	Masoor					
Macrotyloma uniflorum	Horse gram	Gahat					
Oryza sativa	Paddy	Satti					
O. sativa	Paddy	Dhan					
Panicum miliaceum	Hog millet	Cheena/Bhangna					
Papaver somniferum	Popy	Post (Aphim)					
Penillafrutescense	Perilla	Bhangjeera					
Phaseolus vulgaris	Kidney bean	Razma					
Pisum sativum	Pea	Matar					
Pisum arvense		Kong					
Seasamom indicum	Seasame	Til					

Setariaitalica	Foxtail millet	Kauni					
Solanum tuberosum	Potato	Alu					
Triticum aestivum	Wheat	Gehun					
Vigna aconitifolia	Mat bean	Bhimga					
V. mungo	Black gram	Urd					
V. anfularis	Adjuki bean	Rains					
V. radiata	Green gram	Mung					
V. unguiculata	Cow pea	Sonta					
V. umbellate	Rice bean	Bhotia					
Zea mays	Maize	Mungri/Makka					

Table A7.2: Area in ha/village under different traditional crops in Kharif and Rabi seasons during 1970-74 and 1990-94 in Central Himalaya

Crops/cropping season	Area (ha/village)		Area declined in percentage	Probable reasons for decline
	1970-74	1990-94		
Kharif season crops				
Panicum miliaceum	14.2	4.9	65.5	Cultivation/introduction of high yielding rice varieties (HYVs)
Oryza sativa (irrigated)*	14.2	14.2	-	Cultivation/introduction of HYVs
Avena sativa	15.8	3.4	78.5	Cultivation/introduction of potato
Fagopyrum talatricum	8.6	1.5	82.5	Cultivation/introduction of potato+kidney bean
Fogopyrumesculenium	4.1	0.3	92.7	Cultivation/introduction of kidney bean
Parilla frutescense	1.3	-	100.0	Cultivation/introduction of soyabean
Setaria italic	2.3	0.8	65.2	Cultivation/introduction of soyabean
Oryza sativa (rainfed)*	11.2	11.2	-	Cultivation/introduction of HYVs
Eleusine coracana	9.6	6.1	36.5	Cultivation/introduction of soyabean+amaranth

Echinochloafrumentacea	2.5	0.7	72.0	Cultivation/introduction of pigeonpea
Vigna spp.	3.3	-	100.0	Cultivation/introduction of pigeonpea +amaranth
Rabi season crops				
Triticum aestivum*+Brassica spp.	14.2	14.2	-	Cultivation/introduction of HYVs
Hordeum himalayens	17.1	4.7	72.5	Cultivation/introduction of potato, amaranth+ kindey bean
Hordeum vulgare	7.0	1.1	84.3	Cultivation/introduction of HYVs
Brassica compestris	2.0	2.0	-	-

Table A7.3: Per capita annual consumption of traditional crops by the locals in relation to other food items along an altitudinal gradient of Central Himalaya in 1970-74 and 1990-94 (after Maikhuri et al. 1996)

Food items	**Lower altitude (500-1000m amsl) villages**			**Middle altitude (1000-1800 m amsl) villages**			**Higher altitude (1800-2400 m amsl) villages**		
	Quantity (kg)	Energy equivalent (MJ)	Protein equivalent (kg)	Quantity (kg)	Energy equivalent (MJ)	Protein equivalent (kg)	Quantity (kg)	Energy equivalent (MJ)	Protein equivalent (kg)
1970-74									
Common crops produced locally*	105.00	1637.60	12.00	92.00	1441.00	10.00	58.00	903.00	7.70
Traditional crops produced locally**	86.40	1170.40	9.35	90.40	1252.60	10.86	150.60	2085.00	17.70
Food grains imported from outside at village***	3.00	51.40	0.70	-	-	-	-	-	-
Animal products	97.20	295.30	4.90	127.20	384.30	6.20	206.80	627.00	10.50
Vegetables	16.00	248.80	1.32	26.0	404.30	2.15	85.00	1321.00	7.00

Total	307.60	3403.50	28.27	335.60	3482.20	29.21	500.40	4936.00	42.90
1990-94									
Common crops produced locally*	119.90	1942.50	11.70	103.70	1680.00	8.80	49.80	806.70	4.60
Traditional crops produced locally**	24.90	369.80	3.79	70.40	963.40	8.68	122.80	1730.20	15.70
Food grains imported from outside at village***	68.70	1119.70	7.28	54.40	885.10	5.83	56.10	908.80	4.60
Animal products	50.50	152.70	2.66	74.20	227.80	3.90	102.30	323.60	6.40
Vegetables	20.50	318.80	1.70	26.50	412.50	1.90	40.60	631.30	3.50
Total	284.50	3903.50	27.13	329.20	4168.80	29.10	371.60	4400.60	34.80

Table A7.4: Decadal variation in Population Since 1901

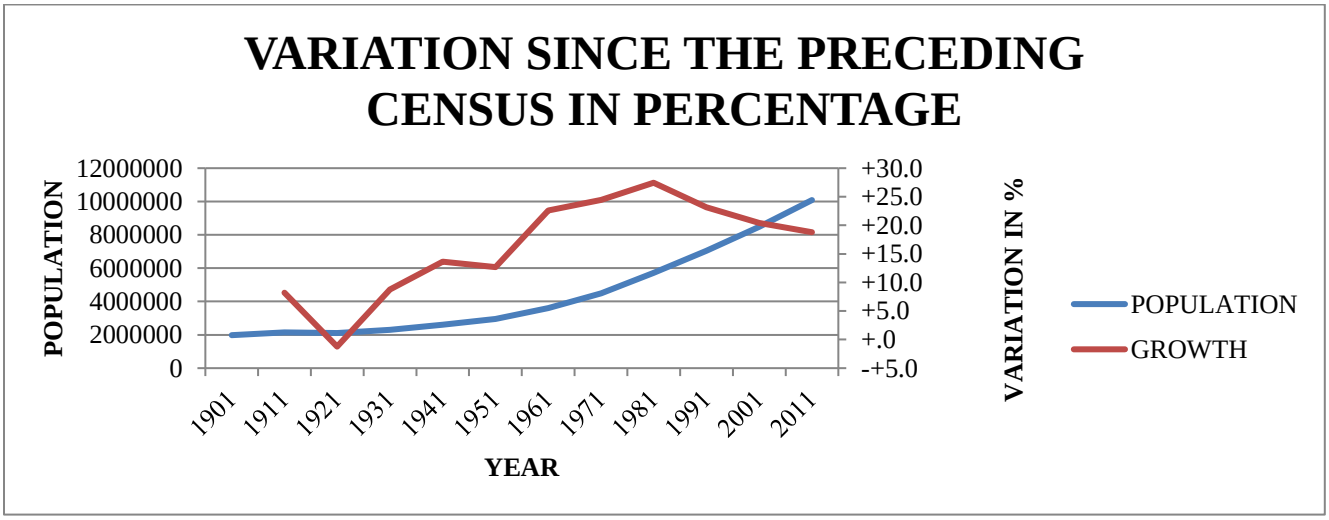


Table A7.5: Correlation between insect pest population density of different commodities v/s climatic conditions of kharif season from 2015 to 2020 (6 years)

Pest Type	Rainfall (mm)	Max Temp	Min Temp	Avg Temp	RH (%)
In Cereal					
Paddy grasshoppers	0.355	−0.18	0.30	0.22	0.32
Rice leaf roller	0.215	0.03	0.34	0.31	0.31
Brown plant hopper	0.482**	−0.030	0.398*	0.341	0.503**
Stem borer	0.063	−0.396*	0.162	0.026	0.335
Wheat shoot fly	−0.433**	−0.143	−0.395**	−0.281	0.027
Wheat aphids	0.258	0.613**	0.697**	0.682**	−0.330*
Helicoverpaarmigera	0.268	0.653**	0.738**	0.724**	−0.368*
Aphid	−0.671**	−0.203	−0.564**	−0.568**	−0.286
Blister beetles	−0.395*	−0.390*	−0.444*	−0.517**	−0.119
Fall army worm	−0.173	0.079	−0.119	−0.080	0.012
In Millet					
Shoot flies	0.297	0.316	0.436*	0.491**	0.103
Stem borers	−0.161	−0.372*	−0.115	−0.218	0.020
Grass hoppers	−0.031	−0.475**	0.136	−0.024	0.431*
Aphids	−0.573**	−0.129	−0.440*	−0.438*	−0.265
Cetonid beetles	−0.700**	−0.218	−0.657**	−0.657**	−0.325
In Pulses and oilseeds					
Blister beetles	−0.369*	−0.093	−0.205	−0.209	−0.117
Red spider mites	−0.388*	−0.278	−0.363*	−0.408*	−0.131
Leaf miners	−0.305	−0.360	−0.330	−0.404*	−0.041
Thrips	−0.483**	−0.168	−0.301	−0.320	−0.099
Mustard aphids	0.512**	−0.036	0.306	0.141	0.026
Soybean leaf bug	−0.086	−0.200	−0.061	−0.120	0.297
Platypriahystrix	−0.357	−0.157	−0.250	−0.269	0.060

In Vegetables					
Greenhouse white fly	−0.209	−0.469**	−0.287	−0.402*	0.047
Tutaabsoluta	−0.164	−0.066	−0.093	−0.100	0.025
Black cut worm	0.283	0.482**	0.345	0.462*	−0.102
Mites	−0.519**	−0.173	−0.424*	−0.436*	−0.149
Acerialycopersici	−0.162	0.129	−0.089	−0.038	−0.011
Aphids	−0.439*	−0.214	−0.392*	−0.417*	−0.112
Thrips	−0.545**	−0.296	−0.495**	−0.540**	−0.174
Leaf miners	−0.296	−0.288	−0.287	−0.343	−0.194
Pieris spp.	−0.326	−0.566**	−0.391*	−0.529**	−0.070
Red pumpkin beetle	−0.374*	0.172	−0.076	−0.015	−0.121
Cucurbits Fruit fies	−0.415*	−0.263	−0.313	−0.358	−0.042
Correlation between population dynamics of white grubs of Uttarakhand state v/s climatic conditions from 2011 to 2020 (10 years)					
Xylotrupesgideon	0.439**	0.222	0.314*	0.254	0.178
Brahmina coriacea	0.418**	0.140	0.340*	0.286*	0.110
Holotrichialongipennis	0.097	0.250	0.149	0.243	−0.177
Holotrichiarosettae	0.169	0.239	0.174	0.268	−0.153
Holotrichiaseticollis	0.249	0.431**	0.123	0.310*	−0.236
Lepidiotasticticoptera	0.239	0.361*	0.090	0.247	−0.170
Lepidiota stigma	0.235	0.590**	0.308*	0.444**	−0.186
Maladerasimilana	0.216	0.272	0.275	0.370**	−0.154
Anomaladimidiata	0.418**	0.287*	0.156	0.210	0.002

Annexure 8: Details of physiographic zones and farming situations in the state

Table A8.1 Details of physiographic zones and farming situation in the state

SN	Zone	Farming situation	Soil Type	Rainfall (mm/yr)	Districts	Principal farm produces and Livestock
1	Zone A upto 1000m	Tarai irrigated	Alluvial	1400	US 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, lentil, rapeseed, mustard, potato, mango, litchi, guava, peach and plums. Livestock-buffalo and cattle
		Irrigated lower hills (600-1000m)	Alluvial sandy soil	2000-2400	Champawat, Pauri Garhwal, Dehradun, Nainital, Tehri Garhwal	Rice, wheat, onion, chilli, pea, potato, reddish, cauliflower, pulses, oil seeds, soybean, mango, guava, peach and plums. Livestock-buffalo and cattle
		Rainfed lower hills (600-1000m)	Residual sandy loam	2000-2400	Champawat, Pauri Garhwal, Dehradun, Nainital, Tehri Garhwal, Bageswar	Rice, wheat, pulses, maize, finger millet mango, guava, peach and plums. Livestock-buffalo, cattle and goat
2	Zone B (1000-1500m)	Mid hills south aspect (1000-1500m)	Sandy loam	1200-1300	Champawat, Nainital, Almora, Dehradun, Tehri Garhwal, Bageswar, Rudraprayag	Rice, wheat, pulses, finger millet, tomato, potato, cole crops, peach and plums. Livestock-cattle, sheep and goat

3	Zone C (1500-2400)	High hills (1500-2400m)	Red to dark	1200-2500	Pithoragarh, Almora, Chamoli, Bageswar, Rudraprayag	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, Rudraprayag	Amaranth, buckwheat, peas, cole crops, apple and potato Livestock- sheep and goat

Annexure 9: Bioprospecting

Table A9.1: Some important wild edibles of Garhwal Himalaya (Vegetables, Fruits, Seeds/Grains, spices and condiments, oils and beverages) having potential for bioprospecting

Botanical Name	Vernacular Name	Part used	Uses
Angelica glauca	Chora	Underground part	Edible
Asparagus filicinus	Jhinjan	Tuberous root	Edible
Cyperus rotundus	Motha	Underground part	Edible
Dioscoreabulbiflora	Genthi	Rhizome	Edible
Orchis latifolia	Hatajari	Roots	Edible
Vigna vexillata	Pholi	Underground part	Edible
Adhatodazeylanica	Basing	Young shoot/ leaves	Edible
Amoranthuscaudatus	Marchhu	Young shoot/ leaves	Edible
Bergenia ciliate	Patharchhata	Young shoot/ leaves	Edible
Oxalis corniculata	Chalmosi	Young shoot/ leaves	Edible
Rheum australe	Archa	Young shoot/ leaves	Edible
Rumex hastatus	Kilmoru	Young shoot/ leaves	Edible
Smilax glaucophylla	Kanjolya	Young shoot/ leaves	Edible
Urtica dioeco and U. parviflora	Kandali	Young shoot/ leaves	Edible
Bauhinia purpurea	Guiral	Flowers	Edible
Bombax ceiba	Semwal	Flowers	Edible
Woodfordiafruticosa	Dhaula	Flowers	Edible
Ficus auriculata	Timla	Unripe fruit	Edible
Aegle marmelos	Bel	Fruit	Edible When Ripe
Aesculus indica	Pangar	Fruit	Eaten roasted
Cornus capitata	Bhamor	Fruit	Eaten When Ripe
Elaeagnus angustifolia	Giwain	Fruit	Eaten raw/ Ripe
Fragaria vesca	Bhuinkaphal	Fruit	Eaten raw/ Ripe
Grewia optiva	Vimal	Fruit	Eaten raw/ Ripe
Myrica esculanta	Kaphal	Fruit	Eaten raw/ Ripe
Prunus sp.	Chula/payan/jamni	Fruit	Eaten raw and Ripe
Rhus parviflora	Titnulya	Fruit	Eaten raw
Cannabis sativa	Bhang	Seeds/grains	Eaten raw and roasted

Cleome viscose	Jakhya	Seeds/grains	Used as spices
Impatiens balsamina	Manjruya	Seeds/grains	Eaten raw
Juglans regia	Akhore	Fruit	Dry Fruits
Allium griffthianum	Jambo	Seeds/grains	Spice and condiments
A. humile	Laadu	Seeds/grains	Spice and condiments
Alpinia galanga	Kalji	Rhizome	Spice and condiments
Angelica glauca	Choru	Seeds/grains/roots	Spice and condiments
Mentha arvensis	Pothya	Leaves	Spice and condiments
Zanthoxylum acanthopodium	Timru	Fruits/seeds	Spice and condiments
Brasica napus	Lahiya	Seeds	Oil
B. Juncea	Rai		
Prunus armeniaca	Chula	Seeds	Oil
Buxus wallichiana	Papri	Leaves/barks	Non Alcoholic Beverage
Cassia occidentalis	Chakunda	Seeds	Non Alcoholic Beverage
Hippophaerhamnoides	Amlich	Fruits	Non Alcoholic Beverage
Punica granatum	Darim	Fruits	Non Alcoholic Beverage and Chatni
Rhododendron anthopogon	Botyachaa	Leaves	Non Alcoholic Beverage
Rhododendron arboreum	Burans	Flowers (petals)	Non Alcoholic Beverage
Taxus baccata	Thuner	Bark and leaves	Non Alcoholic Beverage
Viola sp.	Somaya	Leaves	Non Alcoholic Beverage
Andrachne cordifolia	Bhotti	-	Alcoholic Beverage
Bupleurum falcatum	Tirmiri	-	Alcoholic Beverage
Datura stramonium	Dhatura	-	Alcoholic Beverage
Hemidesmus indicus	Morchiyapar	-	Alcoholic Beverage
Rubasellipticus	Hinsar	-	Alcoholic Beverage
R. niveus	Kali hinsar	-	Alcoholic Beverage
Toraxacum officinale	Karhatu	-	Alcoholic Beverage

Table A9.2: Some important fibre-yielding plants from Garhwal Himalayas

Botanical Name	**Vernacular Name**	**Part Used**	**Uses**
Agave cantala	Cantala	Stem	Fibre for rope, basket,mat etc
Boehmeria platyphlla	-	Stem	Do
cannabis sativa	Bhangla	Stem	Do
Cissamplelos pareira	Pani bel	Stem	Do
Girardiana palmate	-	Stem	Do
Grewia optiva	Vimal	Stem	Do
Hibiscus canabinus	Bimli/ambari	Stem	Do
Urtica palviflora	Kandali	Stem	Do
Bahuniavahlii	Mallu	Bark	Do

Ichnocapus frutescence	Kalidudhi/bel kamu	Bark	Do
Marsdeniaroylei	Shengori	Stem/ bark	Fibre for fishing
cryptolepisbuchananii	Singhi/medhasinghi	Stem/ bark	Do
Paran ciliate	Safed bel	Stem/ bark	Do

Table A9.3: Plants from Garhwal Himalyas with prospects for use in handicrafts

Botanical name	Vernacular name	Part used for
Asculusindicxus	Pangar	Cooperage, toys etc.
Buxus semipervirons	Papri	Wood is used for making cricket bats, hockey sticks and other sports items
Cannabis sativa	Bhangla	Ropes and cordage
Cedrus deodara	Deodar	Boxes, bed etc.
Chimonobambusa falcate	Go-ringal	Baskets and other handcraft items
Dendrocalamusstrictus	Tham	Do
grewiaoptiva	Vimal	Ropes and cordage etc.
Ichnocarpus frutescens	Belkarm	Baskets etc.
Rhododendron arboreum	Burans	Cooperage and other domestic items
Taxus bacata	Thuner	Boxes and other domestic items
Thamnocalamusspathiflora or Arundinaria spathiflora	Deoringal	Baskets and other handicraft items

Table A9.4: Plants used as dyes,insecticides, piscicides and in the making brooms

Botanical name	Vernacular name	Part used	Uses
Berberis aristate	Kingore	Wood and roots	Dyes (yellow)
B. chitria	Chotar	Wood and roots	Dyes (yellow)
Cornus capitata	Bhamore	Stem	Red
Juglans regia	Akhore	Leaves and fruits	Yellow dye
Mallotusphillippensis	Ruina	Ripe fruits	Orange Dye
Myrica esculenta	Kaphal	Stem	Brown dye
Prinsepia utilis	Bhekhal	Fruits	Blue dye
Aresaematortuosum	Meen	Tubers	Insecticide/ pesticides
Butea fructicosa	Dhak	Seeds	Insecticide
Hedera napalensis	Laglya	Leaves	Repellents
Cedrus deodara	Deodar	Seeds	Repellents
Murayakoenigii	Gandhela	Leaves	Repellents
Zanthoxylum acanthopodium	Timru	Fruits	Insecticide/ pesticides
Diploknemabutyracea	Cheura	Seeds	Piscicides
Houtyunia cordata	Machhalia	Entire plant	Piscicides

Annexure 10: Component of PKVY

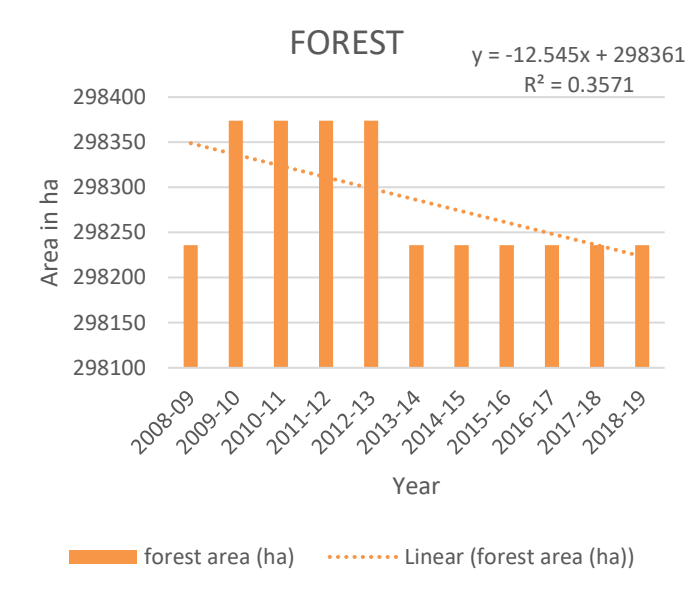
Table A10.1: Components of PKVY

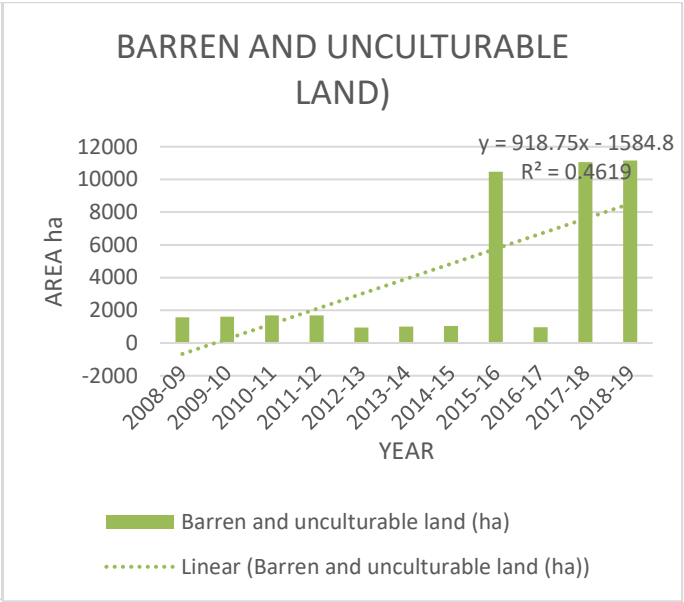
Adoption of PGS certification through cluster approach	Mobilization of farmers& local people to form a cluster in 50 acres for PGS (Participatory Guarantee System) certification Conducting of meetings and discussions of farmers in targeted areas to form an organic farming cluster Exposure visits to a member of cluster to organic farming fields Formation of the cluster, farmer pledge to PGS, and Identification of Lead Resource Person from cluster Training of cluster members on organic farming
PGS Certification and Quality control	● Training on PGS Certification ● Training of trainers (lead resource persons) ● Registration of farmers ● Soil sample collection and testing ● Process documentation of conversion into organic methods (Inputs used, cropping pattern, Organic manures and fertilizer used, etc.) for PGS certification ● Inspection of fields of cluster member ● Residue analysis of samples in NABL ● Certification Charges ● Administrative expenses for certification
Adoption of the organic village for manure management and biological nitrogen harvesting through cluster approach	● Conversion of land to organic ● Introduction of cropping system; Organic seed procurement or raising organic nursery ● Traditional organic input Production Units like Pachagavya, Beejamruth, and Jeevamruth, etc ● Biological Nitrogen Harvest Planting (Glyricidia, Sesbania, etc)

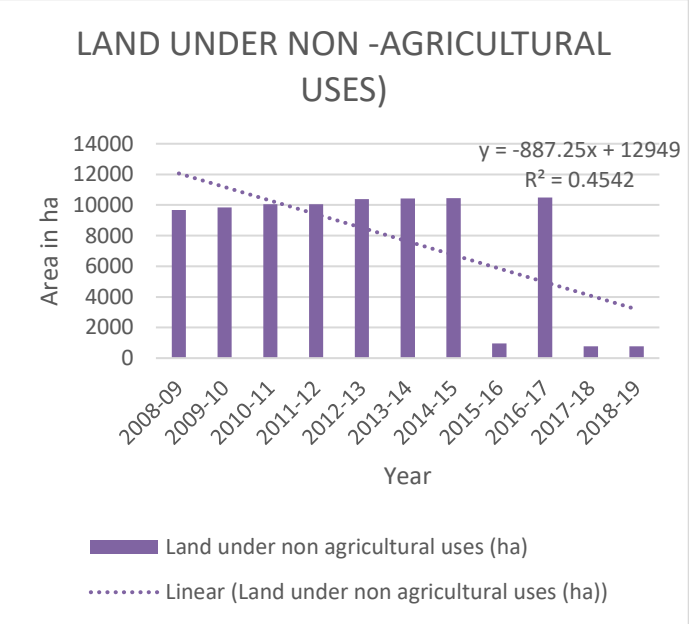
	● Botanical extracts production units (Neem cake, Neem oil)
Integrated Manure Management	● Liquid Biofertilizer consortia (Nitrogen fixing /Phosphate Solubilizing/ potassium mobilizing biofertilizer) ● Liquid Biopesticides (Trichoderma viridae, Pseudomonas fluorescens, Metarhiziumanisopliae, Beauveria bassiana, Paecilomyces verticillium) ● Neem Cake/ Neem Oil ● Phosphate Rich Organic Manure / Zyme Granules ● Vermicomposting
Custom Hiring Centres (CHC) charges	● Agricultural implements (as per SMAM (Sub-Mission on Agricultural Mechanization) guidelines) ● (Power tiller, Paddy thresher, Furrow opener, Sprayer, Rose can, Top pan balance) ● Walk-in tunnels for horticulture (as per guidelines of MIDH (Mission for Integrated Development of Horticulture**)**) ● Cattle shed / Piggery for animal compost (as per Guidelines of Gokul Scheme, Department of Animal Husbandry & Dairying)
Packing, Labelling, and branding or organic products of cluster	● Packing material with PGS logo + Hologram printing ● Transportation of organic produces ● Organic Fairs

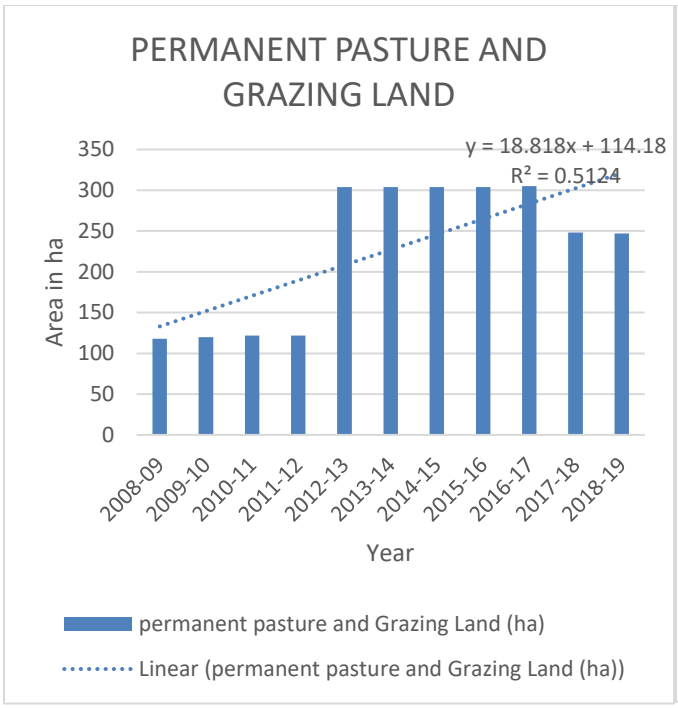
Annexure-11: LULC Trends

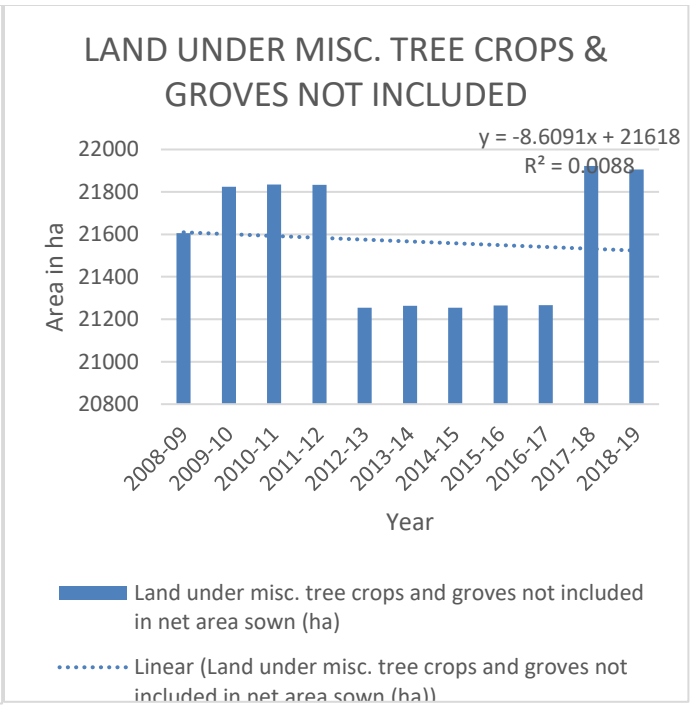
11.1 Nainital

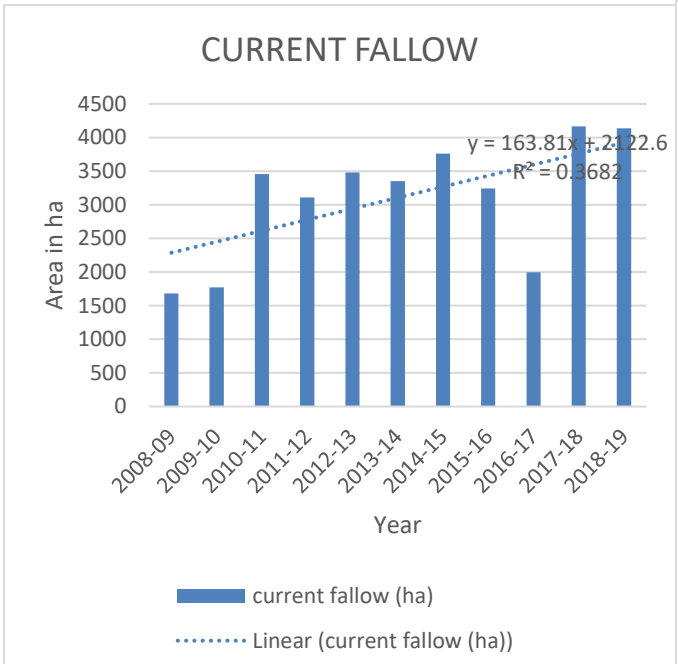


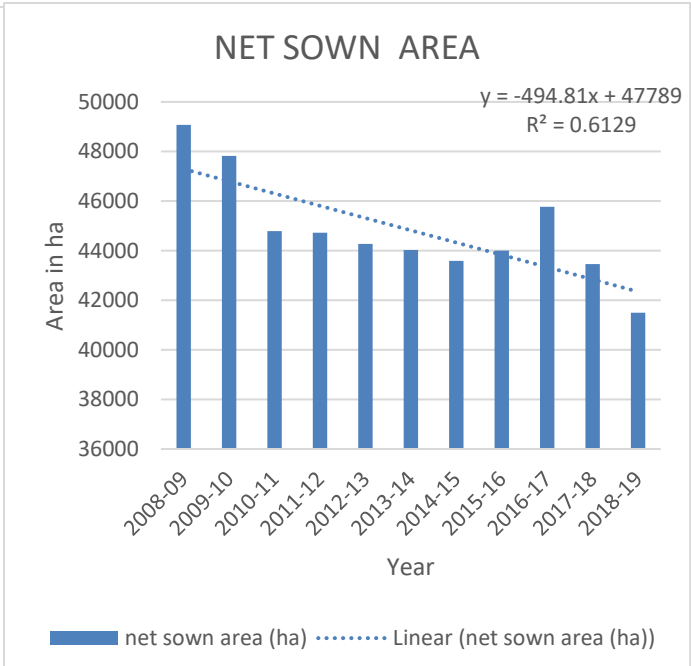




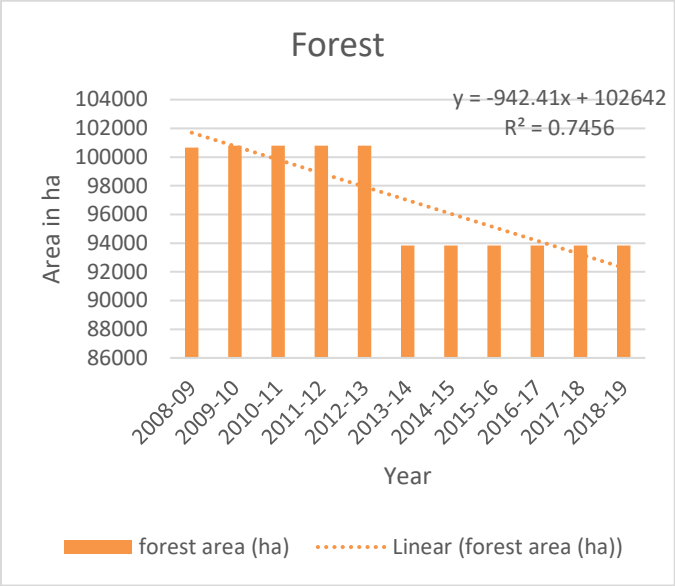

PERMANENT PASTURE AND GRAZING LAND
y = 18.818x + 114.18
R² = 0.5124
Area in ha
350
300
250
200
150
100
50
0
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
Year
permanent pasture and Grazing Land (ha)
Linear (permanent pasture and Grazing Land (ha))

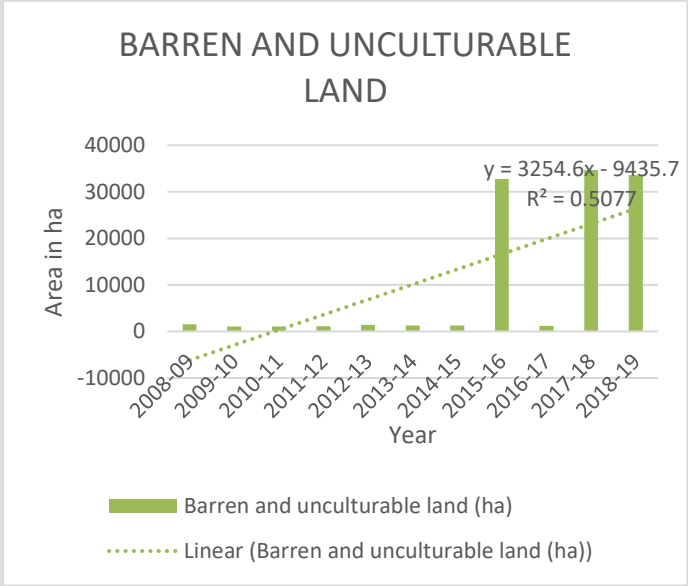

LAND UNDER MISC. TREE CROPS & GROVES NOT INCLUDED
y = -8.6091x + 21618
R² = 0.0088
Area in ha
22000
21800
21600
21400
21200
21000
20800
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
Year
Land under misc. tree crops and groves not included in net area sown (ha)
Linear (Land under misc. tree crops and groves not included in net area sown (ha))

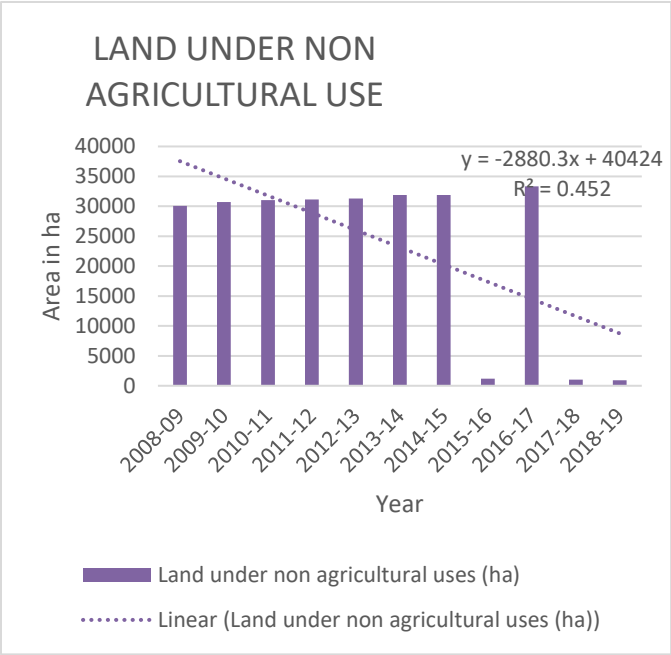

CURRENT FALLOW
y = 163.81x + 2122.6
R² = 0.3682
Area in ha
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
Year
current fallow (ha)
Linear (current fallow (ha))

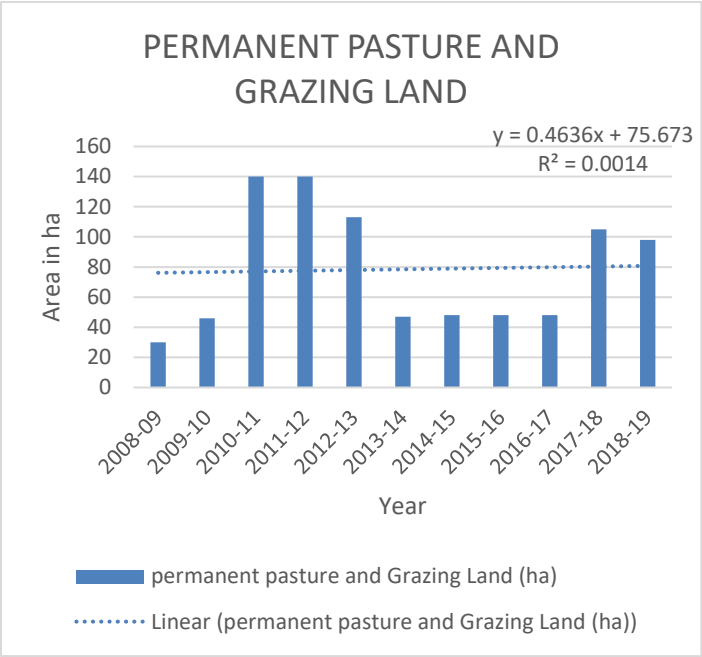

NET SOWN AREA
y = -494.81x + 47789
R² = 0.6129
Area in ha
50000
48000
46000
44000
42000
40000
38000
36000
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
Year
net sown area (ha)
Linear (net sown area (ha))

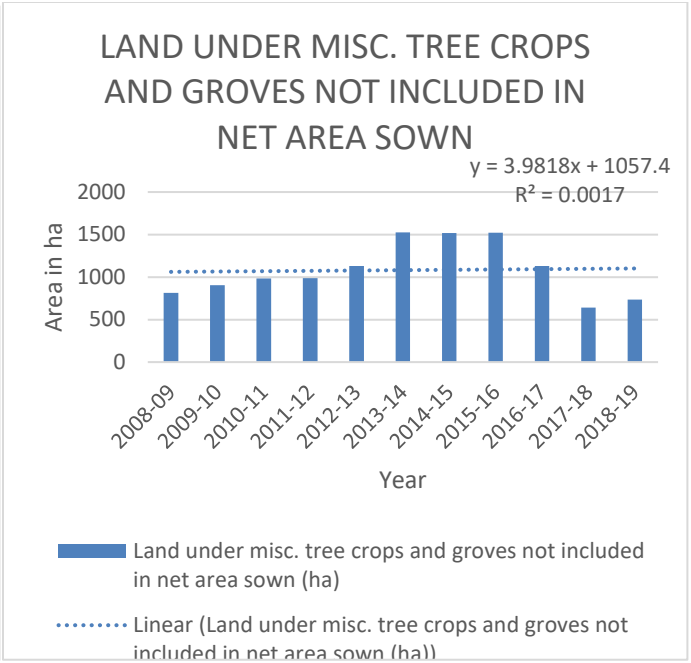
11.2 Udham Singh Nagar

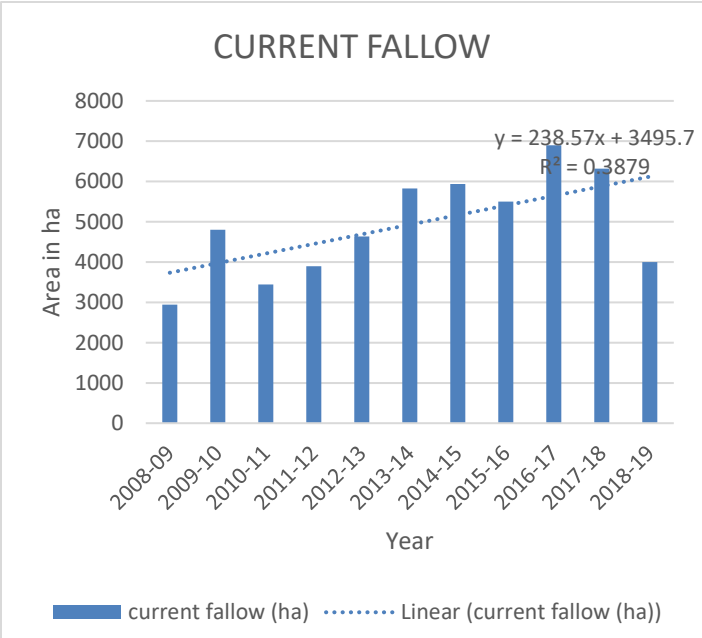


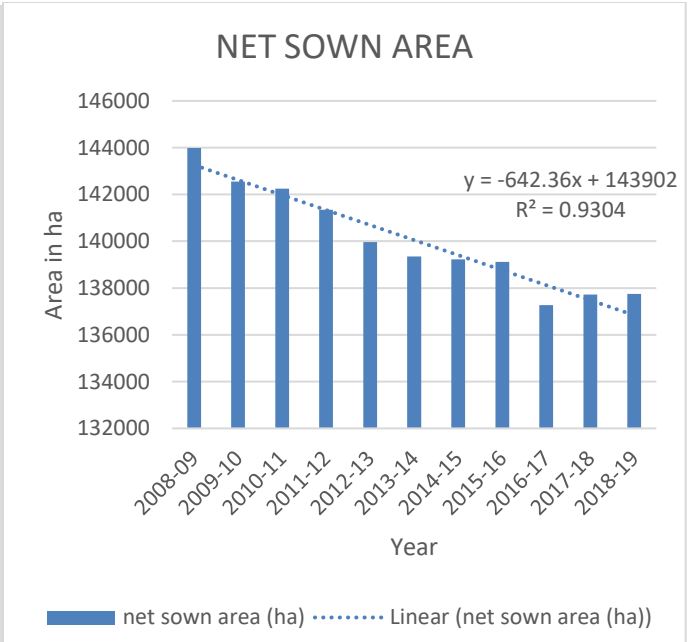





PERMANENT PASTURE AND GRAZING LAND
y = 0.4636x + 75.673
R² = 0.0014
Area in ha
160
140
120
100
80
60
40
20
0
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
Year
permanent pasture and Grazing Land (ha)
Linear (permanent pasture and Grazing Land (ha))


LAND UNDER MISC. TREE CROPS AND GROVES NOT INCLUDED IN NET AREA SOWN
y = 3.9818x + 1057.4
R² = 0.0017
Area in ha
2000
1500
1000
500
0
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
Year
Land under misc. tree crops and groves not included in net area sown (ha)
Linear (Land under misc. tree crops and groves not included in net area sown (ha))


CURRENT FALLOW
y = 238.57x + 3495.7
R² = 0.3879
Area in ha
8000
7000
6000
5000
4000
3000
2000
1000
0
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
Year
current fallow (ha)
Linear (current fallow (ha))


NET SOWN AREA
y = -642.36x + 143902
R² = 0.9304
Area in ha
146000
144000
142000
140000
138000
136000
134000
132000
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
Year
net sown area (ha)
Linear (net sown area (ha))