Assessment of Socio-Environmental Adaptation Strategies for Sustainable Livelihood Development in the Villages around Govind Pashu Vihar, Uttarkashi, Uttarakhand

THESIS

SUBMITTED TO THE

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For

THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY IN FORESTRY
(Forest Ecology and Environment)

By

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Under the Supervision of

Dr. V.P. Uniyal
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2021

DECLARATION

I hereby declare that the thesis **"Assessment of Socio-Environmental Adaptation Strategies for Sustainable Livelihood Development in the Villages around Govind Pashu Vihar, Uttarkashi, Uttarakhand"** submitted by me, **Ms. Rommila Chandra** (Enrolment No. **18PHD509**) to Forest Research Institute Deemed to be University, Dehradun, for the award of the degree of **Doctor of Philosophy in Forestry (Forest Ecology and Environment)**, embodies the research work carried out by myself under the supervision of Dr. V.P. Uniyal, Scientist-G, Wildlife Institute of India. The thesis has been duly checked through URKUND a plagiarism detection tool approved by F.R.I Deemed to be University and the thesis has plagiarism to the acceptable limits. No part of this thesis has been submitted for any other degree/diploma of the same Institution where the work was carried out, or to any other Institution and it fulfils the requirements of the ordinance governing award of Ph.D. Degree of F.R.I. Deemed to be University.

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This is to certify that the thesis entitled **"Assessment of Socio-Environmental Adaptation Strategies for Sustainable Livelihood Development in the Villages around Govind Pashu Vihar, Uttarkashi, Uttarakhand"** submitted by **Rommila Chandra** (Enrolment No. **18PHD509**) to Forest Research Institute Deemed to be University, Dehradun, for the award of the degree of **Doctor of Philosophy in Forestry (Forest Ecology and Environment)**, embodies research work carried out by her under my supervision. The thesis has been duly checked through URKUND a plagiarism detection tool approved by F.R.I Deemed to be University and the thesis has plagiarism to the acceptable limits. No part of this thesis has been submitted for any other degree/diploma of the same Institution where the work was carried out, or to any other Institution and it fulfils the requirements of the ordinance governing award of Ph.D. Degree of F.R.I. Deemed to be University.

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Sub: - Registration for Doctor of Philosophy Degree in Forestry.

Dear Sir/Madam,

I would like to inform you that the following decisions have been taken for your enrolment as Research Scholar for the Degree of Doctor of Philosophy in Forestry in this Institute:-

1. You have been registered for Doctor of Philosophy i.e **01.03.2019 to 31.08.2024** as PhD Research Scholar.
2. Your Enrolment number is: - **18PHD509**
   (For all further correspondence please quote your enrolment number.)
3. Name of Research Centre: - **Wildlife Institute of India, Dehradun**
4. The Topic of research approved by the FRI University: **"Assessment of socio-environmental adaptation strategies for sustainable livelihood development in the villages around Govind Pashu Vihar, Uttarkashi, Uttarakhand."**
5. Name of Discipline: - **Forest Ecology & Environment**
   (As per clause 3.3 of the Ph.D. Ordinance)
6. (i) Name of Supervisor : - **Dr. V.P. Uniyal**
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P.T.O

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Date:

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Abbreviations

AC	Adaptive Capacity
ACM	Adaptive Co-management
AES	Agroecosystem Service
CI	Cultural Importance Index
CICES	Common International Classification of Ecosystem Service
CV	Cultural Value Index
EC	Electrical Conductivity
ES	Ecosystem Service
ESA	Ecosystem Service Approach
Fic	Informant Consensus Factor
FD	Forest Department
FL	Fidelity Level
FGD	Focus Group Discussion
FRA	Forest Right Act
HHS	Household Survey
HKH	Hindu Kush Himalaya
IHR	Indian Himalayan Region
KII	Key Informant Interview
KRI	Knowledge Richness Index
LACI	Local Adaptive Capacity Index
MAP	Medicinal and Aromatic Plants
MEA	Millennium Ecosystem Assessment
PA	Protected Area
RFC	Relative Frequency Citation
RI	Relative Importance Index
SDG	Sustainable Development Goals
SES	Social-Ecological System
SLA	Sustainable Livelihood Assessment
TC	Traditional Crops
TCE	Traditional Cultural Expression

Summary

Transforming Our World: 2030 Agenda for Sustainable Development "is a plan of action for people, planet and prosperity" focusing on peace and partnership. The 17 Sustainable Development Goals (SDGs) and 169 associated targets are highly integrated and have the potential to advance to every corner of the earth. Then why mountain communities are still left behind? The FAO views mountain ecosystems as a critical component for achieving SDGs, as well as a pathway to a green economy. Mountains being the important source of ecosystem goods and services, are often the sites of poverty, hunger, malnutrition, outmigration, land abandonment and degradation. The fatal combination of remoteness, fragility and neglect has worsened the socio-economic situation of the local people.

Over the years, mountain regions have greatly suffered the loss of environmental, social and economic capital, thus endangering their survival. The disappointment amongst the mountain community is highly diverse and vary according to the geopolitical, environmental and socio-cultural conditions prevailing in a particular region. Mountain regions often share the common hardships, but their economies are shaped by various other factors. These include infrastructural development, accessibility to public services, institutions and governance, diversity and capacity of the community. The major point of negligence being peripheral location in comparison to political and economic centres, resulting in marginality. Over the years, mountain people's capacity to respond in creative ways to changing conditions often goes unnoticed.

In 1979, Prof. Theodore Schulz rightly said, "if we knew the economics of agriculture, we would know much of the economics of being poor". In order to achieve Sustainable Development Goals, no economic strategy or policy recommendation will succeed, until or unless, the rural livelihoods are recognized at par with other sectors of development. There are billions of people in a developing country like India, where smallholder farmers and landless labourer's make the majority section of poor. Being already disadvantaged for living in remote, inaccessible, fragile and harsh climatic conditions, the mountain community have a limited and seasonal scope at livelihood, mainly agricultural system and tourism. Mountains hold a vast agro-genetic diversity, offering a huge potential for food and nutrition security. But for a decade now, the traditional knowledge on local foods has been eroding, leading to a decline in agricultural diversity. The current agricultural systems have definitely succeeded in supplying

large quantities of food to global markets, but the high-external inputs and resource-intensive nature of it has aggravated the negative externalities. Despite, the significant progress post green revolution, the critical problems of poverty, hunger and inequality remains.

The study is an attempt to assess the socio-economic and ecological conditions of mountain farmers for their sustainable livelihood development, with the following three objectives;

I. Documentation of traditional knowledge and traditional cropping practices in the study area.

II. Assessment of ecosystem services in the agroecological landscape in the study area.

III. Estimating the adaptive capacity of smallholder farmers for sustainable livelihood opportunities in the study area.

The study was conducted in Govind Wildlife Sanctuary and National Park, located in Uttarkashi district of Uttarakhand (India). The entire area lies in the middle and greater Himalayas with a varying altitude of 1300m to 6323m. The terrain is almost hilly and is an important catchment for the Tons River, which is a major tributary of the Yamuna River. The protected area has a fairly dense human population with villages situated up to 2800m altitude. There are 42 villages inside and 15 villages outside the protected area. The agroecosystem in the area is complex, as it is composed of crop husbandry, livestock rearing and forests, forming an interlinked production system. In the study, village has been chosen as the smallest unit of farming system, for the reason that the study not only focuses on agro-ecological variations, but also on socio-economic differences.

The study employed a multi-stage sampling, where a combination of sampling techniques were used to select the villages as well as respondents. In the first stage, the study site was selected. It was purposely selected because of its remoteness, inaccessibility and fragility. In the second stage, all the villages in the study area were enlisted and a stratified random sampling technique was employed for the selection of villages. All villages were divided into two strata's depending upon their accessibility via motorable road. In the third stage, two villages from each stratum were randomly selected for data collection. In the final stage, a sample size was determined and households were randomly selected from each target village for data collection. The Primary data was collected through various Participatory Rural Appraisal tools, like key informant interview, focus group discussion, household survey and

field tests and observations. This allowed for an in-depth understanding of the challenges and constraints faced by the local communities for their livelihood development.

The key findings of the study were;

1. The documentation of culture, traditional agriculture and traditional knowledge clearly highlighted the uniqueness of the area for a potential socio-economic development. As per the assessment, the local people were trying to change their negative cultural image of being associated with the mythological Duryodhana. It also sheds light on the relation between medicinal plant use with the age of people, availability of medical facility and distance of households from the forest area. The knowledge richness index values call for the attention, as one could say that the younger population had knowledge about their traditional system, but it was decreasing through generations. The local farmers were trying to diversify their cropping system through cash-crop farming, which was clearly evident in the connected as well as isolated villages. The traditional crops were just being cultivated for subsistence, leading to a critical decline in the area under their cultivation. These changes indicate preference of local community for an economically productive livelihood system.

2. The economic benefits of provisioning agroecosystem services were clearly evident in the connected villages in comparison to the isolated one's because of the high apple productivity. No significant difference was observed in the soil and water conditions of connected and isolated villages, even though the former followed an indiscriminate use of fertilizers and pesticides. The study demonstrates that orchards represent a potential threat to the regional environment due to excessive use of synthetic chemicals and this could operate as an early warning system.

3. As per the local adaptive capacity index, a low adaptive capacity was recorded for the connected villages and a very low adaptive capacity for isolated villages. It was suggestive of the inherent constraints and widespread challenges being faced by the local farmers. Amongst all the determinants, the isolated villages were better off in the social as well as awareness and training aspects of livelihood development. Whereas, the connected villages were more equipped in the infrastructural setup, technological advancement and economic development. This comparison clearly highlights the differences between the conditions of mountain farmers based on the accessibility and social disparity. The adaptive capacity

recorded for the mountain villages reflects that agricultural communities in the study area are prone to be adversely impacted by external changes due to their lack of capacity and assets to cope and manage with the impacts.

Combining the perceptions of the local community with the assessment of adaptive capacity levels and agricultural policies, an imbalance of rural developmental policies catering to the mountainous region was observed. These policies lacked the potential to aid the adaptation processes as they did not involve the local needs, their traditional knowledge and understanding, and community participation. Keeping in mind the protected area status of the region, the study attempted to provide with sustainable livelihood strategies for socio-economic and cultural upliftment of the mountain community, living in the remotest regions of Indian Himalayan Region.

The thesis has been divided into six chapters. The first chapter deals with introduction and objectives of the study. The second chapter has discussed a brief resume of the earlier work carried out by various researchers in the concerned field. The third chapter describes the study area in brief. The details of the methodology and analytical techniques used to achieve study's objectives are presented in the fourth chapter. The fifth chapter is devoted to result and discussion, followed by the last chapter containing the conclusion of the study.

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Chapter 1

Introduction

"Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

-(Brundtland Report, WCED 1987)

Sustainable development, which surfaced in context with the growing concerns towards environmental exploitation, degradation and crisis, forms the driving force of the world economy in the 20th century. We often use the word without knowing its history or understanding its real meaning and the concept behind its emergence. Often the question, why is it so necessary that development be sustainable, goes unanswered. As in the 18th century, the world was preparing itself for the Industrial Revolution, the human society all around the globe was transforming itself from subsistence towards economic upliftment, linking human progress to societal growth, economic development and material advancement. Unfortunately, all the benefits of rapid economic growth and development were centered in the industrial countries, which widened the gap between the rich and the poor nations. They did not realize that this uneven distribution of benefits and wealth would become a major factor in the concept of sustainable development in the long-term. After World War II, people became aware and more conscious about the threats that rapid population growth, pollution and natural resource depletion posed to the environment, thus endangering their own survival as humans. Many scientific information regarding the environmental damage caused by human activities were published, such as, Rachel Carson's *The Silent Spring* (1962), Paul Ehrlich's *The Population Bomb* (1968), Edward Goldsmith's *A Blueprint for Survival* (1972) and Fritz Schumacher's *Small is Beautiful* (1973). And by the 1970s, people started to critically analyse and challenge the concepts of 'progress', 'growth' and 'development'.

The United Nations commissioned a group of 22 people from developed and developing countries to identify long-term environmental strategies at a global level. A report *"Our Common Future"* was released in 1987 by the United Nations' World Commission on Environment and Development (UNCED), better known as Brundtland Commission. It defined sustainable development and emphasized that "sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of

technological development; and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations" (WCED, 1987). The report not only focused on the needs of humans but was also concerned with the equitable sharing of natural resources so that global equity be achieved for future generations. It also emphasized the redistribution of these resources towards the poorer nations to encourage their economic growth and development, enabling all human beings to achieve a basic standard of living. The report stood on three fundamental pillars of social equity, economic development and environmental maintenance. Later in 2001, the United Nations Commission on Sustainable Development added one more dimension to the three-pillared structure: institutional support and balance. It ultimately highlighted the dynamic balance between – the environment, the economy and the society.

But the important challenge for sustainability was to understand, how these four dimensions interact with, and depend on each other? For example, should economic development be allowed to substitute for environmental integrity? To what extent are the under-developed and poor nations being socio-economically considered and uplifted? Less-developed countries were suspicious that sustainable development might be an ideology imposed by the wealthy industrialized countries to enforce stricter conditions and rules on aid to developing countries. There were fears that sustainable development would simply be employed to sustain the gap between developed and under-developed countries (Mitcham, 1995). The major critique was that, it did not explain the concept of economic growth and development, not adequately challenging the consumer culture across the globe. Is today's generation willing (including poor countries) to forgo consumption for good environmental quality, and leaving the resources for future? Also it is not easy to consider environmental quality as a 'product' in the market and attach a price to it (du Pisani, 2006). Are people willing to pay higher prices for the commodities and can the poor afford to? The main issue is related to the economic perspective of growth that runs on the finite resources of this planet. The goal to achieve a developed society itself has been imposed on the people all around the world. Everyone wants to come out of the status of being called an under-developed or developing or poor nation and stand tall among the developed countries. It has merely become a symbol of reputation and power. This was the case even before the publication of the Brundtland Report, but it has subsequently continued. Thus, amongst the academic circle, sustainable development is also being known as weak sustainability (Morandín et al., 2019).

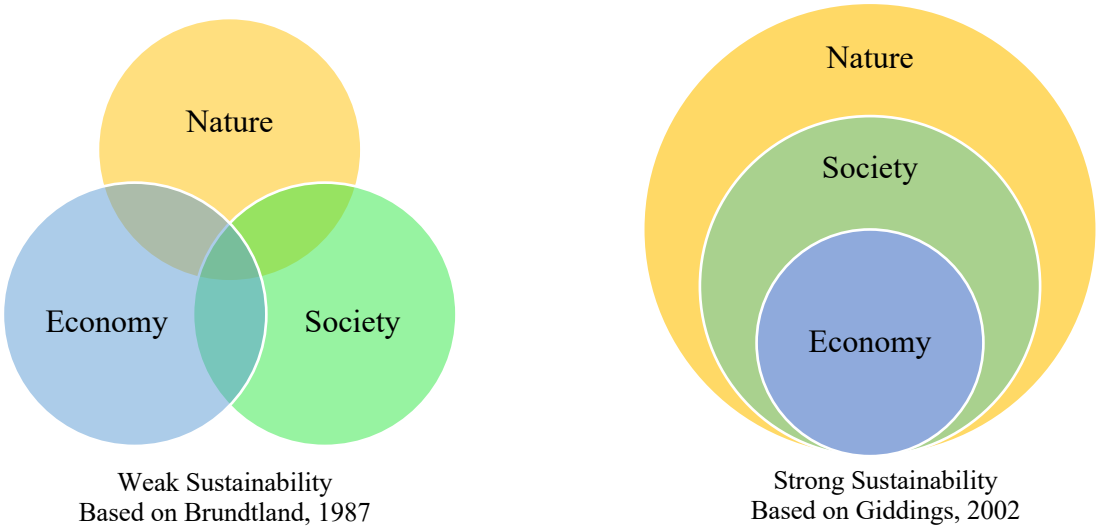


Figure 1.1 presents the comparison between weak sustainability and strong sustainability. The diagram on the left assigns the same weight to the three themes: economy, environment and society. Whereas, in the diagram on the right, the three components are nested, recognizing the importance of each (Morandín et al., 2019).

People are fighting for survival, money, security and luxury. Physical development over space to satisfy human needs has been largely responsible for the destruction of nature. As societies become more diverse, there are greater opportunities and challenges; and people migrate for a better life. There is a continuous rise in the global and local inequality. The concentration of the urban population is rising due to the outmigration of people (either from the rural areas or different countries all together) in search of a better life. Even though the living conditions in large cities are not always adequate for the disadvantaged, people in search of better opportunities continue to leave their homes and family behind. The ongoing socio-ecosystemic crisis tends to make us rethink the concept of sustainable development and the efforts undertaken to make it a reality. The current crisis of sustainability was initially generated by the focused determination to achieve economic growth and development. It was inspired by the belief that it would solve social and environmental problems. While being busy attaining economic aspirations, it doesn't come as a shock to see negligible improvement in the socio-ecosystemic problems of the world.

The missed keynote is that the impacts of natural resource utilization in the name of economic growth and development are not generated at the same scale for every human life and geographical region. In the practical sphere of globalized society, the economy has a protagonist role, focusing on the market and individual and collective decisions based only on monetary cost-benefit (Mishan and Quah, 2007; Layard and Glaister, 2012). As the monetary

profits run the world economy, it hinders analysis while dealing with people's demands and quality of life on one hand and ecosystem health on the other. Generally, human activities are strongly influenced by the comfort and luxury of consumption and not the basic needs, and over the generations, this attitude is encrusted into society. This logic is rarely questioned in the business or politics sphere; it is simply assumed, and goals are established as a function of objectives mainly related to economic growth (Morandín et al., 2018). The greatest impact on the ecosystem is the over-consumption (more than required) which is unevenly distributed amongst the nations, communities and even individuals. As the people aspire to consume in an elegant manner, the earth's limits have reached making the lives unaffordable and unsustainable. A reduction and limitation on production and consumption of products cannot be imposed on the global economy; thus the inequality in resource use needs immediate attention. Unfortunately, we live in a social structure where few people can afford it all, while the others barely manage to survive. Thus, the gap between the advantaged and disadvantaged strata of society continues to grow with time, intensifying the global social problems and conflicts. Growing concerns about poverty and unequal opportunities have allowed people to see through the real and the perceived well-being. It is not about the ideology of sustainability or sustainable development anymore, but the ethical recognition of it by interpreting the real relationship between humans and the ecosystem that sustain life on earth.

1.1 Social-Ecological Systems

In 2005, the Millennium Ecosystem Assessment (MEA) emphasized the importance of the environment in the lives of human beings in terms of ecosystem services i.e. the benefits people obtain from the ecosystem. The degradation of the ecosystem diminishes the capacity to provide services, contributes to the increased disparity between people, and is the main cause of poverty and social conflict (MEA, 2005). The requirement for a better and improved scientific basis for sustainable development than generally conceptualised is critical in today's environmentally vulnerable state. There is a need to find solutions and different options for complex sustainability problems. Social-ecological systems (SES), resilience thinking, adaptive capacity (AC) and transformability are new aspects for attaining progress, aiming to create societally oriented yet sustainable outcomes. The stability related to the interlinked dynamics of the system formed by humans and nature emerge from three complimentary attributes: resilience, adaptability and transformability. The origins of SES research include a strong focus on understanding complex system dynamics in situations of change and of

navigating uncertainties (Gunderson and Holling, 2001; Berkes et al., 2003; Folke, 2006). It aims to understand the human-environment interactions, which highly differs on a spatial and temporal basis. Ecological knowledge is an essential link between complex and dynamic ecosystems and society, giving a better understanding of adaptive management practices and institutions. This could help provide the knowledge needed to support a smooth transformation of society towards a sustainable system.

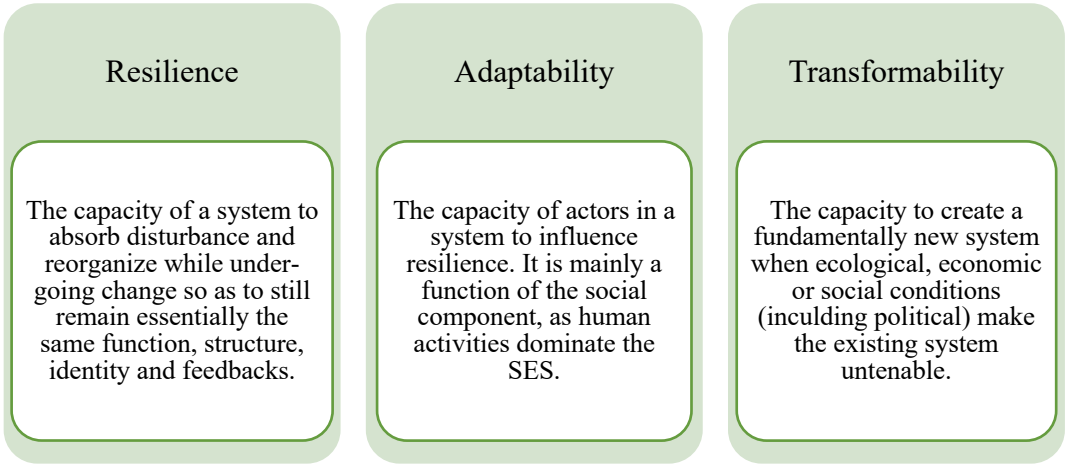


Figure 1.2 Definition of resilience, adaptability and transformability (Walker et al., 2004)

Socio-Ecosystemic Sustainability is a process that defines the relationship between cultures and the biosphere. It is an attribute of the cultural system, determined by the degree of coupling between the structure and functioning of the ecosystem with which it interacts and is a part. In this way, a specific culture can represent greater or lesser coherence with natural processes. The greater the coherence, the greater the sustainability (Morandín et al., 2019). Figure 1.3 provides an analytical framework for studying and understanding local resource management system. Where, the left side of the diagram demonstrates the natural sub-system of a given region or area; and the right side, is a set of management practices at different levels of the man-made sub-system. The major distinction for sustainable functioning of an entire system as a whole; is the ecological knowledge and understanding of the resource users' and the resource base on which they depend. Such knowledge and understanding were in turn, believed to be reflected in and built into different management practices and, in turn, framed by local institutions, primarily of the informal nature (Colding and Folke, 2001). The SES is an open system, which is majorly influenced by many externalities, such as population growth, income, technological development, market, trade, migration, political change, etc. The SES framework has also been used to understand the adaptability of SES to meet changes (natural

or anthropogenic) and challenges and transform the ecosystem dynamics towards long-term sustainability.

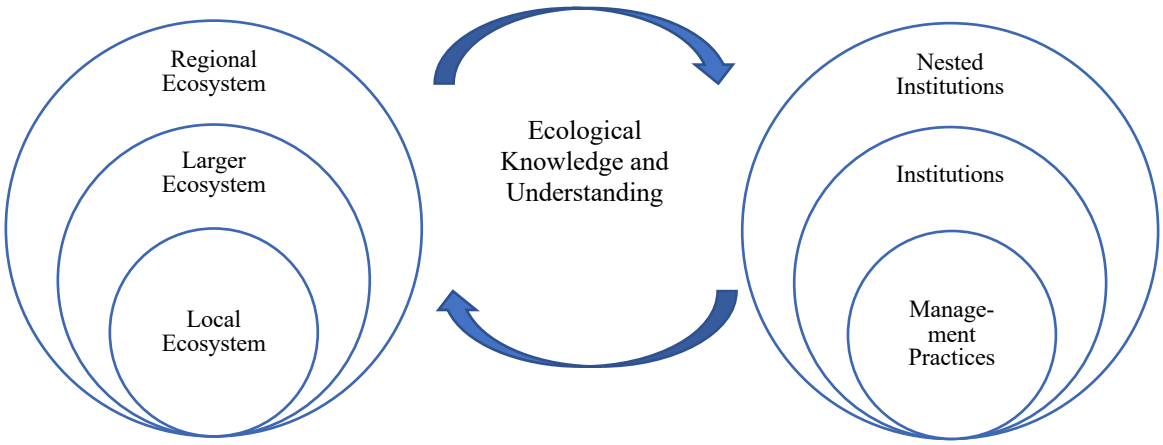


Figure 1.3 A conceptual framework of social-ecological system based on Folke and Berkes (1998)
(Source: Colding and Barthel, 2019)

1.2 Ecosystem Services

Ecosystem sustain human life by providing four types of ecosystem services: provisioning service, regulating service, supporting service and cultural service. The MEA (2005), defines ecosystem services (ES) as the benefits people obtain from the ecosystem. The Ecosystem Service Approach (ESA) is one that integrates ecological, social and economic dimensions of natural resource management (Cork et al., 2007). It was first developed by the Convention on Biological Diversity and was officially endorsed during the COP5 in 2000 in Nairobi, Kenya. Cork and colleagues (2007), hence described an ESA as the following;

i. It helps to identify and classify the benefits that people derive from ecosystems. It also includes market and non-market, use and non-use, tangible and non- tangible benefits.
ii. It also explains consumers and producers of ES for maintenance and improvement of the ecosystem for human well-being.
iii. It helps to describe and communicate benefits derived from natural and modified ecosystems to a wide range of stakeholders.

The ecosystem services can be classified as (Fig.1.4);

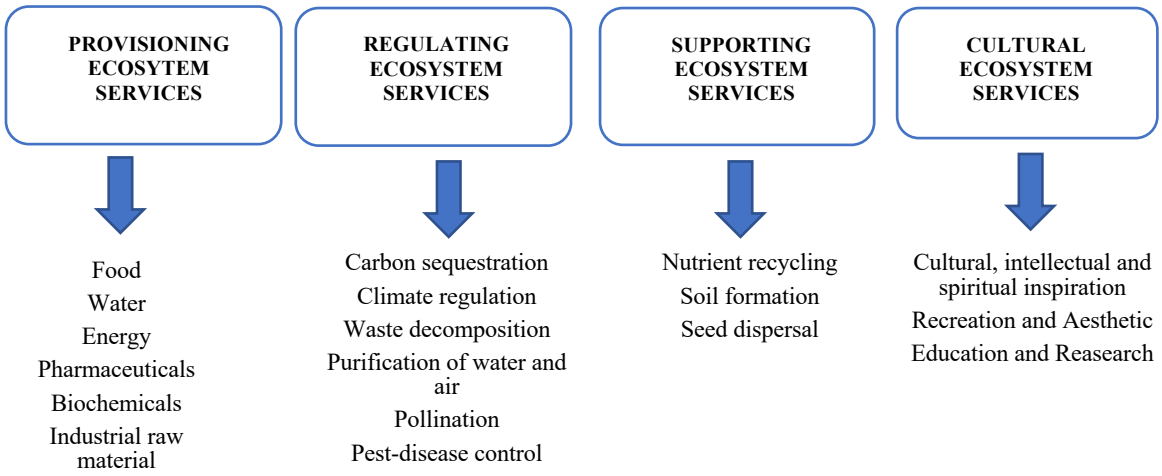


Figure 1.4 Classification of Ecosystem Services (MEA, 2005)

Globally, ecosystem values can be broadly categorized into four value systems (Körner, 2004):

- Social value: where both marketed as well as non-marketed are used for social well-being
- Cultural value: where diverse traditions and cultural landscapes forms the historical wealth of society
- Ecological value: where the species interact, associate and co-exist for the upkeep of ecological processes and functions
- Economic value: where ES produce desirable products for income generation and livelihood development, as well as protecting against crop failure.

Optimally managed engineered/modified/designed ecosystem can provide a range of important ES, for instance, more fresh water, cleaner air, greater food production, and fewer floods and pollutants (Palmer et al., 2004). In the current scenario, resilience and adaptation towards climate change is crucial, especially when many people depend on climate-sensitive sectors like agriculture, forestry and fisheries. For developing and under-developed countries, resource restrictions further burdens their ability to cope with climate-vulnerable situations, particularly in the mountain areas. Although, interest in adaptation to climate change impacts and unplanned urban development has surged in recent years, the focus has remained sectoral.

1.3 Agroecosystem

Agricultural ecosystems provide humans with food, forage, bioenergy, etc and are essential to human well-being. These systems rely on ES provided by natural ecosystems, including pollination, biological pest control, maintenance of soil structure and fertility, nutrient cycling and hydrological services. Agroecosystems also produce various ES, such as regulation of soil and water quality, carbon sequestration, support for biodiversity and cultural services. Depending on the management practices adopted by the people, agriculture can also produce numerous disservices, such as, loss of wildlife habitat, nutrient runoff, sedimentation of waterways, greenhouse gas emissions and pesticide poisoning (Zhang et al., 2007) and pollution. Thus, appropriate agricultural management practices are critical to realizing the benefits of ES and reducing the disservices from agricultural activities (Power, 2010). The conversion of undisturbed natural ecosystems to agriculture can strongly impact the system's ability to produce important ES. Still, many agricultural systems can also be an important source of services (Fig.1.5). Indeed, agricultural land use can be considered an intermediate stage in a human-impact continuum between wilderness and urban ecosystems (Swinton et al., 2007). Basic knowledge about ecosystem structure and function is increasing rapidly, but we know less about how these factors determine the provision of a complete range of ES from an individual ecosystem (NRC, 2005).

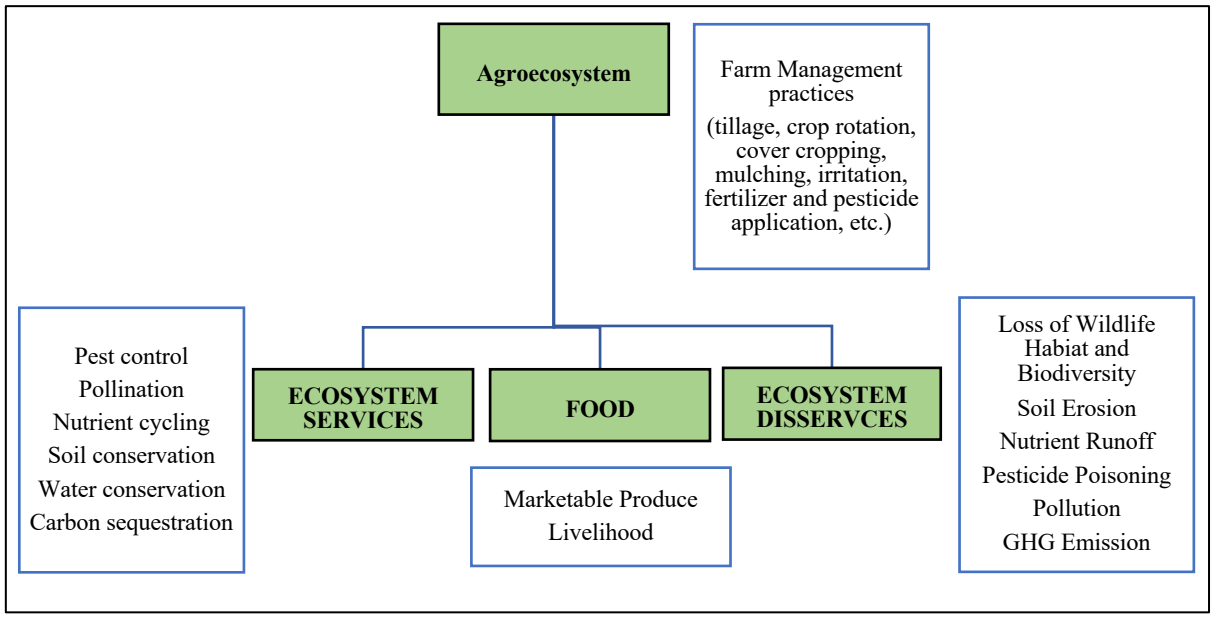


Figure 1.5 Ecosystem services and disservices from agroecosystem

1.3.1 Ecosystem Services flowing to agroecosystem

i. Biological pest control

It is an important ES that is often supported by natural ecosystems. Non-crop habitats provide the habitat and food resources required for predators, parasitoids, and insectivorous birds that act as natural enemies to agricultural pests. Thereby, reducing the need for pesticides.

ii. Pollination

It is another important ES to agroecosystem that is provided by natural habitats in the agricultural landscapes. Aizen et al. (2009), used data from the United Nations Food and Agriculture Organization (FAO) on the production of 87 globally important crops during 1961–2006 to estimate that the consequences of a complete loss of pollinators for total global agricultural production would be a reduction of 3–8%.

iii. Water quantity and quality

The provision of sufficient clean water is an essential ecological service provided to agroecosystems, and agriculture accounts for about 70 per cent of global water use (FAO, 2003). Perennial vegetation in natural ecosystems such as forests can regulate the capture, infiltration, retention, and water flow across the landscape. The plant community plays a central role in regulating water flow by retaining soil, modifying soil structure and producing litter. Deep rooting species can improve the availability of both water and nutrients to other species in the ecosystem. In addition, soil erosion rates are usually low, resulting in good water quality. Water availability in agroecosystems depends not only on infiltration and flow, but also on soil moisture retention, another type of ecosystem service. Water storage in soil is regulated by plant cover, soil organic matter, and the biotic community (bacteria, fungi, earthworms, etc.). With climate change, increased rainfall variability is predicted to lead to a greater risk of drought and flood, while higher temperatures will increase water demand (IPCC, 2007). Estimates of water availability for agriculture often neglect the contribution of green water, but predictions about water availability in 2050 depend on the inclusion of green water. Whereas more than six billion people are predicted to experience water shortages in 2050 when only blue water is taken into account, this number drops to about four billion when both blue and green water availability is taken into account (Rockstrom et al., 2009). Recently it has been suggested that farmers receive payments or ‘green water

credits' from downstream water users for good management practices that enhance green water retention and blue water conservation (ISRIC, 2007).

iv. Soil structure and fertility

Well-aerated soils with abundant organic matter are fundamental to nutrient acquisition by crops, as well as water retention. Soil pore structure, soil aggregation and decomposition of organic matter are influenced by the activities of bacteria, fungi and macro fauna, such as earthworms, termites and other invertebrates. Micro-organisms mediate nutrient availability through decomposition of detritus and plant residues and nitrogen fixation.

1.3.2 Ecosystem Disservices from Agroecosystem

Agriculture can contribute to ES, but can also be a source of disservices, such as, loss of biodiversity, agrochemical contamination and sedimentation of waterways, pesticide poisoning of non-target organisms, and emissions of greenhouse gases and pollutants (Dale and Polasky, 2007; Zhang et al., 2007). These disservices come at a high cost to humans, but there is often a mismatch between the benefits.

i. Nutrient Leaching and Pollution

The two nutrients that most limit biological production in natural and agricultural ecosystems are nitrogen and phosphorus, and they are also heavily applied in agroecosystems. Nitrogen and phosphorus fertilizers have greatly increased the amount of new nitrogen and phosphorus in the biosphere and have had complex, often harmful, effects on natural ecosystems (Vitousek et al., 1997). These anthropogenically mobilized nutrients have entered groundwater and surface waters, resulting in many negative consequences for human health and the environment. Impacts of nutrient loss from agroecosystems include ground-water pollution and increased nitrate levels in drinking water, eutrophication, increased frequency and severity of algal blooms, hypoxia and fish kills, and 'dead zones' in coastal marine ecosystems (Bouwman et al., 2009). Other ecosystem disservices from agriculture include applications of pesticides that result in loss of biodiversity and pesticide residues in surface and groundwater, which degrades the water provisioning services provided by agroecosystems.

ii. Emissions of greenhouse gases

Agricultural activities are estimated to be responsible for 12–14% of global anthropogenic emissions of greenhouse gases, not including emissions that arise from

land clearing (US-EPA, 2006; IPCC, 2007). Approximately 49% of global anthropogenic emissions of methane (CH_4) and 66% of global annual emissions of nitrous oxide (N_2O), both greenhouse gases, are attributed to agriculture (FAO, 2003). Livestock production also contributes to CH_4 and N_2O emissions (Pitesky et al., 2009), and these impacts are likely to increase through to 2050 as the demand for meat increases (FAO, 2003).

1.3.3 Ecosystem Services from Agroecosystem

On-farm management practices can significantly enhance the ES provided by agroecosystems. Agricultural practices can effectively reduce or offset agricultural greenhouse gas emissions through various processes (Drinkwater and Snapp, 2007; Lal, 2008; Smith et al., 2008). Effective manure management can significantly reduce emissions from animal waste. Replacing synthetic nitrogen fertilizers with biological nitrogen fixation by legumes can reduce CO_2 emissions from agricultural production by half (Drinkwater and Snapp, 2007). Soil carbon sequestration provides additional ES to agriculture itself, by conserving soil structure and fertility, improving soil quality, increasing the use efficiency of agronomic inputs, and improving water quality by filtration and denaturing of pollutants (Smith et al., 2008).

1.4 Mountain Ecosystem and Sustainable Livelihood

Geographic and climatic features make mountain systems extremely fragile. This condition is further exacerbated by pressure from anthropogenic and biophysical factors and, with some notable exceptions, mountain ecosystems show symptoms of deteriorating health (MEA, 2005). Mountains are a beautiful culmination of the ecosystem, the various ecosystem goods and services, which plays a significant role in economic development, ecological sustainability and human well-being. The role of mountains in global sustainable development was first recognized by the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil in 1992 through the adoption of Chapter 13 in Agenda 21. This further triggered many mountain-based initiatives across the globe, like, the declaration of 2002 as the International Year of Mountains by the United Nations General Assembly, the establishment of Mountain Forum and the Mountain Partnership, etc. Even though, after so many years of increased interest and recognition of mountain issues, the problem of poverty, vulnerability, social backwardness and economic insecurity remains the same.

According to FAO, 39% of the mountain population (both urban and rural) in developing countries were considered vulnerable to food insecurity in 2012, an increase of 30% compared to 12 years prior (FAO, 2015). The mountain system supports a ginormous human population by providing various natural goods and ES, like, food, water, medicinal plants, biodiversity, energy. Mountain systems have long been treasured and protected for its tranquillity, solitude, wilderness, and landscape beauty (Antonelli, 2015; Foggin, 2016; Price, 2015). They have aesthetic, ecological, and socio-economic importance, for the people living there, and those living far away. Mountains are among the most fragile ecosystems and are highly vulnerable to climate change. If they continue to degrade, they will fail to provide the essential services that will severely cost the local communities and the entire society living down-streams. The increase in needs, demands and living standards of people in urban areas, intensifies the pressure on natural resources, creating new stress situations.

Thus, a detailed study for the reorientation of the AC human society is necessary, utilizing the traditional knowledge and cultural values of the mountain community. The need to know the details about a region and the local community which forms the particular attributes of a mountain system is crucial for further determination of resilience of that SES and adaptability of the society towards the same. Indigenous experiences that exists around the world can in incorporated with the different economic structures. There are still cultural systems that are closely related and dependent on nature and have a treasure of ancestral knowledge passed on for generations. The economic development model based on the production and consumption cycle devalued the rural life and their culture, which generated a disturbance between the social and natural space. As the stability of a system is continuously changing and shifting, the “adaptive” part of both governance and community is required in all the phases of livelihood advancement. Thus, a different approach towards resource governance, social upliftment and livelihood well-being is required for Sustainable Livelihood Development (than currently being applied).

The Green Economy Agenda and the idea of Green Growth focus on rearticulating the concept of economic growth and development pattern which the world has been following all along. This might result in improved human well-being and social equity along with a significant decrease in environmental risks and scarcities. In an era of uneven socio-economic development, it is important to examine the role of mountains and mountain communities in the green economy. It is critical to appreciate their culture and traditional knowledge for

mitigating the emerging challenges that we face. When the mountain issues are introduced into the mainstream global discussions, only then, the local groups and communities in the mountains will have access to opportunities to promote sustainable development in the mountains.

"By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people". - Vision of the Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets 2010

1.5 Problem Statement

Livelihoods in the mountain areas are more susceptible to economic and environmental changes than the lowlands counterparts. The reason being: harsh topography, remoteness, lack of institutional, tele-communication and road development, poor infrastructure, insufficient educational and health facilities and especially, too little opportunity. The incidence of poverty makes the mountain people considerably more vulnerable to the risks and uncertainties related to global changes. The increasing pressures of climate change, globalization, urbanization, institutional evolution, create new challenges and threats for the mountain ecosystem and people. These pressures lead to impacts, like, natural disasters, outmigration, land abandonment, ecosystem degradation, food crisis, water scarcity, and they have serious implications on the people living in the downstream area. As the current global challenges have been seriously affecting the mountain regions and their inhabitants; the knowledge, experience and capacity of the local mountain communities to manage their fragile ecosystem has been significantly ignored for years, which might offer a big opportunity for addressing the increasing environmental issues.

The Indian Himalayan Region (IHR) is among the most diverse regions in the world in terms of socio-cultural and environmental set-up. It represents the significant biodiversity hotspots and provides several ecosystem services to people living within or outside the region. Unfortunately, the IHR faces enormous pressure from global and regional changes which are a combination of natural and anthropogenic factors. The rapid demographic change and economic growth in Uttarakhand has increased the demand for natural resources leading to overall exploitation, unsustainable use and ecosystem degradation. The region-specific (mostly concentrated in the plain area of the State forming the urban centres) development has

drastically changed the levels of production-consumption cycle and infrastructure investment. The potential crisis is endangering the sustainability of the mountain ecosystem and the multitude of goods and services they provide. Even though the mountain ecosystem is crucial for the human prosperity, these services haven't received adequate recognition in national economic or infrastructural planning and decision-making. The needs of mountain communities are taken for granted and their potential for a sustainable livelihood combating the environmental changes are often over-looked. This lack of appreciation has accelerated unsustainable use, exploitation and rapid degradation of the natural asset.

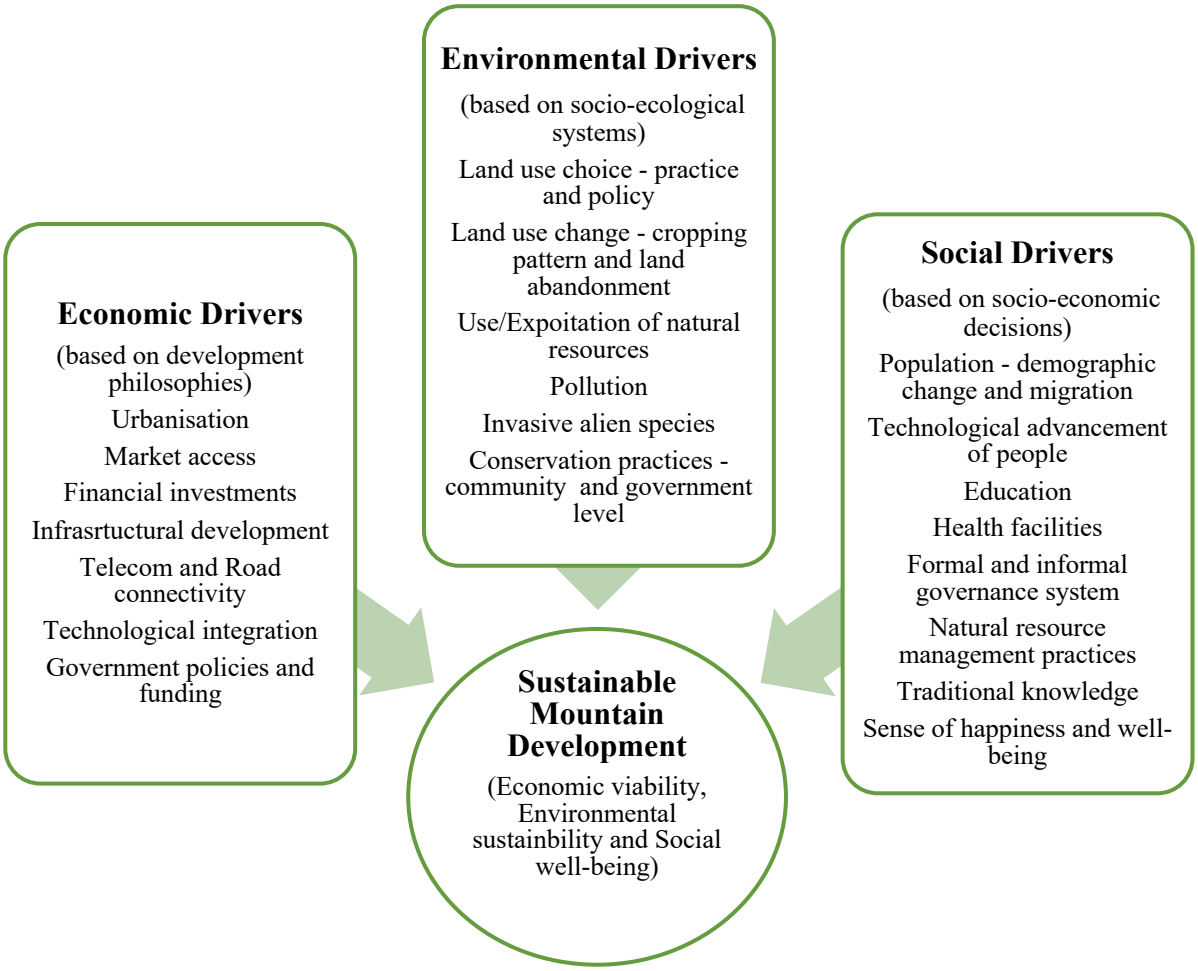


Figure 1.6 Drivers of change in the mountainous region of Uttarakhand

In Uttarakhand, the potential of traditional knowledge of mountain communities usually goes unappreciated during policy formulation and implementation. These people can generate positive externalities, which, if channelled appropriately and with adequate incentive mechanisms, can help address the global natural changes, including natural disasters and

climate change. The speed with which the world is changing economically and environmentally has hugely impacted the social fabric in the mountains. For example, male family members migrate to the cities for a better income and employment, leaving their female counterparts and old-aged family members behind which either leads to agricultural land abandonment or feminisation of mountain agriculture. The hardships in the mountains and poor living standards has driven the young generations out from their native lands. This creates immense difficulty in maintaining our traditional knowledge, culture and practices, which will long be forgotten, if the outmigration continues.

The demographic shift has increased the population naturally, with the serious problem of urban sprawl has also been heightened in Uttarakhand. Migration from rural to urban areas in Uttarakhand is a major challenge, with a comparison between 2001 and 2011 Census Data showing a slow decadal growth of population in most of the mountain districts of the State. From 2001-2011, Uttarakhand witnessed a period of high economic growth, with a moderate population growth at 1.74% per annum which is higher than the national average. However, this figure was 0.70% in the hill districts, and in the plains district, this was 2.82%. Further, the population growth rate in the rural areas of the hill districts was even lower at 0.38%, though this figure for the urban areas of the hill districts is much higher. When 13 districts population changes were analysed, Almora and Pauri districts showed an absolute population decline. Data also points towards above-average high rate of decadal increase in population in districts like Dehradun, Udham Singh Nagar and Haridwar. At present (as per the 2011 Census), about 17% population of the hill districts of Uttarakhand lives in urban areas, while in the plains district 42% of the population lives in the urban areas. This trend of outmigration impacts the people left behind and the areas, including both, from where people migrate to where they temporarily settle down.

Technological advancement has also affected the local and indigenous socio-cultural practices in Uttarakhand. With a gradual integration of the local community into the regional markets, the rural people have advanced from subsistence farming to more of market-based agricultural production. There is a huge shift from the traditional crops (TC) and cropping practices to cash crop cultivation. This leads to intense utilisation of natural resources, chemical inputs (fertilizers and pesticides), high yielding variety seeds, and rising incomes and enhanced livelihoods. The point of concern is, whether the shift in livelihood practices is sustainable, and for how long the mountain ecosystem can sustain this human pressure. There is practically a

decline in the traditional way of living in the hills and hence the culture of Uttarakhand is fading away.

1.6 Core Principles of the Study

a. Meeting the needs of poor people is fundamental – The decision about the use and management of ecosystem services should benefit the poor specifically by increasing food and livelihood security. This can be achieved through the provision of a sustainable and equitably distributed supply of provisioning ecosystem services that are of direct importance to human health and well-being (notably food, fibre, biofuel, water related services); reduced risk and severity of impacts from some system shocks on lives and livelihood; and opening up new and alternative opportunities for income generation.
b. People use and modify natural resources which provides material and immaterial benefits to their livelihoods. It might lead to ecosystem disservices, depending on the practice.
c. Cross scale interactions of ecosystem services in an agricultural landscape focus on the provision of ecosystem services along with societal values, needs, and use. Economic heterogeneity and management practices of these services across an agricultural landscape.
d. Governance mechanisms are vital tools – the provision of ecosystem services and the benefits that people derive from them are influenced by the rules, practices and institutions that govern the use and management of natural resources.
e. Building resilience is about enhancing the capacity for sustainable livelihood development.

1.7 Objectives of the Study

The economic deprivation, social backwardness and isolation from the developmental activities have contributed to the alienation of the mountain community from the urban society, which at times trigger disappointment, conflicts and non-cooperation. The mountain community which is expected to maintain, conserve and provide essential ecosystem services to the society, is not even inclusive to the national development. The conservation and development of the mountain ecosystem are not only for the local people, also for regional,

national and global communities. Modification of the developmental planning, may help achieve the livelihood
security and social equity by overcoming sectoral and regional biases. The study is an attempt to bridge the gap between the economic and socio-environmental system of the mountain community for their sustainable livelihood development; with the following three objectives:

I. Documentation of traditional knowledge and traditional cropping practices in the study area.
II. Assessment of ecosystem services in the agroecological landscape in the study area.
III. Estimating the adaptive capacity of smallholder farmers for sustainable livelihood opportunities in the study area.

1.8 Practical Utility of the Study

The various drivers of change dynamically impact the livelihoods and environmental conditions of rural people living in the mountainous areas of Uttarakhand. Healthy ecosystem and environment are necessary for the survival of not only humans but also other living organisms. In the mountain regions, linking the upstream and downstream ecosystem, society and production system is crucial for balanced decision making. Just identifying the drivers of change, the impact they cause and finding solutions, new policies and plans, will not help. It requires regional coordination and cooperation of the society and the government, strengthening across all the relevant sectors of sustainable development and livelihood opportunities. People need to change the way they see life; instead of thinking about my house and my belongings, one can change the outlook and start considering the entire ecosystem as their own home. These key issues of Uttarakhand draws regional attention, based on the conditions prevailing in a particular region at a particular time.

This study of socio-environmental assessment is logically developed, by first, experiencing the real ground situation of the rural community in Uttarakhand. Then the critical issues were identified by community interaction which led to the identification of drivers of change impacting their sustainable development. The assessment caters to the three main components of sustainable development – economy, environment and society. The global strategies adopted to attain sustainable development must evolve, reorganize and change accordingly, as there is no “one size fits all” approach to the future (Walker et al., 2004).

The governmental policies should be in context to the geographical region and community driven so that they can be modified over time to combat the inevitable changes in the mountain livelihood. This assessment will later contribute to region-based policy planning, implementation, development, conservation and decision-making. It will also highlight the importance of community participation and AC in combating any economic and environmental change. The study will also create a path for a co-managed governance system. It is important to recognize the core value of nature and the importance of equality for a balanced society. The knowledge of sustainability is not reflected and is less appreciated in the social organization in the way that other sectors like economy, communication and technology are. The study would help establish an enriching system of knowledge, by appreciating synergies among academic groups, indigenous people, local communities, and people who are responsible for public policy. In the present scenario, intellects at the global level are trying to recognize the need for a more holistic and integrated vision where every step is in harmony with nature.

1.9 Limitations of the Study

A well thought and designed research methodology may not be free from limitations, hence present methodology adopted for analysing data in the present investigation may have inherent limitations. The ecosystem is also dynamic, complex, and multifunctional, where various ES are interlinked and interdependent. Every effort was made to study and assess the socio-economic and environmental conditions prevailing in the study area. As per the resource availability and research feasibility, an in-depth study examining the complexity of the mountain ecosystem, which could be useful for developing appropriate strategies for rural development, was done. However, considering all these limitations, an earnest attempt has been made to conduct the study in a manner that will optimistically give accurate and comprehensive results for sustainable livelihood development of the mountain community.

Chapter 2

Review of Literature

A comprehensive review of literature is an integral part of any investigation. It gives an idea on the work done in the past and assists in delineation of problem area and provides the basis for interpretation and discussion of findings. Moreover, they also serve as the basis to defend findings in line with past findings. An extensive survey has been conducted to collect literature in all the aspects of the study. Literature on mountain ecosystem, vulnerability, adaptive capacity, agroecosystem and sustainable livelihood has been collected for the study's objectives.

2.1 Biodiversity, Ecosystems and Sustainable Development Goals

Living systems are dynamic and unstable, going to an unpredictable future; with increasing complexity (Prigogine and Stengers, 1997). Building the mountain ecosystem's socio-ecological resilience will be essential for achieving various Sustainable Development Goals (SDGs). SDG 15 states to preserve, revive and protect terrestrial ecosystems, for the sustainable management of forests, checking land degradation and biodiversity loss. Most specifically relevant is Target 15.4: "By 2030, ensure the conservation of mountain that are essential for sustainable development."

Mountains constitute around 24% of the world's land area, where 20% of the world's population resides. It supplies 60–80% of the world's fresh water, and is also the home to 50% of biodiversity hotspots (Rodríguez-Rodríguez et al., 2011; Maselli, 2012). For thousands of years, the natural and semi-natural landscapes of the Hindu Kush Himalayas (HKH) have been changed, impacted and metamorphosed by human history, culture, and traditional practices (Goldewijk et al., 2011; Ellis, 2015). The evolution of diverse social networks and development of trading system across the region has facilitated the exchange of cultures, knowledge, and materials (Chaudhary et al., 2015). The advancement of SES, not only played a significant part in the livelihood transformation of people living in the mountain areas; but also for those living farther, who were benefitted from the multiple ES (Blaikie and Muldavin, 2004; Nepal et al., 2014).

Figure 2.1 Sustainable Development Goals

The HKH is continuously being subjected to further change, which includes climate change (Shrestha et al., 2012) and unprecedented environmentally unfriendly development (Grumbine and Pandit, 2013; Xu and Grumbine, 2014). Elalem and Pal (2015), emphasized on the decreasing resilience of the HKH, as the rise in number and severity of natural disasters, in addition to the collapse of traditional systems of management has been evident for years. Maxwell et al. (2016), noted that the drivers of biodiversity loss, specifically land use and land cover change, over-exploitation of natural resources, habitat destruction, pollution, invasive alien species, and climate change, were becoming predominant in the HKH and were persistently expanding the domains of unsustainability (Chettri and Sharma, 2016). The diverse cultures and traditions embodied by various ethnic groups (Turin, 2005) continue to nurture the ecological system, assisting the Himalayas to deliver ES that support societies both within the region and beyond. Moreover, innovative practices have also improved the rehabilitation and conservation of ecosystems and the numerous services that they offer (Banskota et al., 2007; Sharma et al., 2007; Aase et al., 2013). This association could be strengthened through a mutual comprehension and integration of traditional customs, scientific conservation practices, regional cooperation, departmental collaboration, and investments in policy interventions.

Formerly, development and conservation had been regarded as conflicting ideas, because conservation was understood as the protection of resources, and development as the

exploitation of resources (Paxton, 1993). The main criticism of the Brundtland Report is the idea that society or economy can be understood outside the context of nature, and that in this context, a solution to socio-environmental problems can be the intensification of economic growth (Giddings et al., 2002; Robinson, 2004). Human activities have become globally inter-connected through new technology, capital markets, and governance systems, with decisions in one place influencing people elsewhere. At the same time, the capacity of the environment, from local ecosystems to the biosphere, to sustain societal development seems to have been reduced over historical time (Jackson et al., 2001; Diamond, 2005) and at an increasing pace during the past century (Folke et al., 2005). This has led to vulnerability in many places and regions with constrained options for human livelihoods and progress (Kasperson et al., 1995; Allison and Hobbs, 2004).

Sometimes change in ecosystems and society is gradual and incremental. At other times, change is abrupt, disorganizing, or turbulent (Folke et al., 2005). At the same time, the capacity of ecosystems to remain within desired states in the face of abrupt change seems to have been reduced as a consequence of human actions (Folke et al., 2004). Such alternate regimes pose new fundamental challenges to the environment and resource management (Scheffer et al., 2001). In the current scenario, ecosystem's capacity to generate natural resources and ES for human development has become vulnerable to change due to exploitative human activities, which no longer can be taken for granted. Furthermore, it is now clear that patterns of production, consumption, and well-being arise not only from economic and social relations within regions but also depend on the capacity of other regions' ecosystems to sustain them (Odum, 1989; Folke et al., 1997). Emerging theories and approaches point to the importance of assessing and actively managing resilience, adaptability and transformability of a system. The ecological basis for such an approach is developing and includes recognition of ecosystems as complex adaptive systems and the necessity to address uncertainty and surprise (Costanza et al., 1993; Levin, 1999; Carpenter and Gunderson, 2001).

2.2 Vulnerability and Adaptive Capacity

Vulnerability has its origins in natural hazards research, which favours case-study approaches focusing on household heads as rational economic decision-makers (Clay, 2017). Key aspects of vulnerability include exposure (likelihood and magnitude of climate events), sensitivity (the degree to which a population may be impacted) and AC (the ability to adjust so

as to reduce sensitivity and/or exposure) (Gallopin, 2006). The concept offers little in the way of analysing relationships between groups or the effects of development and adaptation policies on vulnerability (Hinkel, 2011). And vulnerability analyses have arguably overvalued quantifiable components seen as readily comparable across contexts, with the effect that few assessments actually conceptualize adaptation (Tschakert et al., 2013). The concepts are seen as inadequate for mainstreaming adaptation within the development (Agrawal and Lemos, 2015).

The concept of AC has gained prominence in current debates as it has been largely used in the climate change field, where it denotes 'the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities or to cope with consequences' (IPCC, 2007). The concept, however, has its roots in biology, where it was used to indicate the ability of species or organisms to become adapted to (or to be able to live and reproduce in) a certain range of environmental contingencies (Gallopin 2006).

According to Walker et al. (2002), AC is an aspect of resilience that reflects learning, flexibility to experiment and adopt novel solutions, and the development of generalized responses to broad classes of challenges.

Luers et al. (2003), defined AC as the extent to which a system can modify its circumstance to move to a less vulnerable condition.

Moser (2008), referred to it as the ability to make various deep and structural changes, to help systems better align to long-term changes in their social and environmental spheres.

Scholars have recently called for an understanding of how AC is composed of specific (climate targeted) and generic components (Eakin et al., 2014; Lemos et al., 2016). More commonly, AC can be interpretated as a static entity that households have or lack to varying degrees. In contrast, a process-oriented understanding of AC permits us to visualize how households (or other units of organization) come to differentiate in their abilities to adaptively manage uncertainty. Importantly, such an approach helps us to appreciate the roles of institutions, and development policies in enabling or constraining AC (Clay, 2017)

AC studies concentrate on adaptation processes to identify what challenges are faced by whom and why (Adger et al., 2009). It appears unevenly distributed across households, communities, regions and other analytical levels (Adger et al., 2007; Goldman and Riosmena, 2013). Paying greater attention to how local actors and institutions shape opportunities and constraints of adaptation (Agrawal, 2010; Agrawal and Lemos, 2015; Lemos et al., 2013). Eakin et al. (2014) recommend, 'rather than focusing on which specific adaptations were most effective during these periods of gradual and rapid change; it might be more useful to understand what structures, relationships, processes, and other variables allowed for (or blocked) the facilitation of such adaptations (i.e., AC)'.

According to Yaro et al. (2015), this is directly linked to the farmers' capacity to cope or adapt to climate change stresses. In relation to farmers at the local level, Asante et al. (2009) and Nakuja et al. (2012) assessed their adaptive capacities by using attributes such as knowledge, use, availability, accessibility and consultation. According to Defiesta and Rapera (2014), indicators used in recent times are largely based on the Sustainable Livelihood Framework, which comprises five assets categories - human, social, natural, physical and financial capital - from which livelihoods of people are built (Serrat, 2010).

Adhikari et al. (2018) highlights, how adaptation strategies at a household level 'were changing resource-use patterns and gradually shifting livelihoods from existing practices to newer ones more suitable for a changing environment'. Various studies have found the limited practice of adaptation options by smallholder farmers due to a limited capacity to implement them (Alam et al., 2017; Pandey et al., 2018). Some identified constraints include lack of money, access to adequate information, inadequate technical knowledge and awareness, and unclear property rights to promote household-level adaptation practices (Bastakoti et al., 2017).

Bhatta et al. (2015) studied how the remoteness of mountain communities limits their communication and transportation, resulting in marginalised, vulnerable conditions and a relatively low capacity to adapt to changes. 'Their ability to adopt these strategies is mostly based on their ability in terms of economy and external support from society and other actors.' Niraula and Pokharel (2016) state how 'AC of local community has increased due to the formation of natural capital, livelihood capital, strong grassroot institutions, and the capacity to manage and use forest landscape restoration.

Several studies have shown how people's perception on environment changes match with the conclusions derived from institutionalized scientific research (Maddison, 2006; Devkota, 2014). While, by definition, people's perception is changing per se, at the same time as it is shaped by a complex interaction of socio-economic and cultural aspects (Vedwan, 2006; Gbetibouo, 2009), it remains that perception and traditional local knowledge can fill data-less related gaps (Huntington, 2000; Joshi et al., 2019).

Piya et al. (2012), recommends that the 'analysis of AC from the perspective of asset possession demonstrates that AC is not only determined by the level of economic development, but also by the social and human factors. Mesfin et al. (2020), confirmed that 'AC is not only determined by the availability of assets, but also by the processes and functions needed to mobilize these resources.'

2.3 Social-Ecological Systems

Berkes and Folke (1998) started to use the concept of SES as an integrated approach of humans-in-nature and related the concept to resilience (Folke, 2016). This approach emphasized that people, societies, cultures and their economies are all embedded parts of the biosphere which shapes the ecosystems. At the same time people, communities, economies, societies, cultures are fundamentally dependent on the capacity of the biosphere to sustain human development (Folke et al., 2011). SES are complex adaptive systems. Complex adaptive systems possess critical thresholds, multiple drivers of change, and reciprocal feedbacks between social and ecological components (Levin et al., 2013). Many recurring environmental and natural resource challenges tend to be reinforced by the lack of recognition that ecosystems and the social systems that use and depend on them are intimately linked (Reyers et al., 2013; Biggs et al., 2015).

A core focus of sustainability science is on transitions towards sustainability, including improving society's capacity to use the earth in ways that simultaneously meet the needs of a much larger but stabilizing human population, that sustain the life support systems of the planet, and that substantially reduce hunger and poverty (Clark, 2007; Matson et al., 2016). The resilience approach to transformations is less about planning and controlling but more about preparing for opportunity or creating conditions of opportunity for navigating the transformations (Chapin et al., 2010).

There has been substantial progress in understanding the social dimension of ecosystem management, including organizational and institutional flexibility for dealing with uncertainty and change (Dietz et al., 2003; Anderies et al., 2004) and social capital (Adger, 2003; Pretty, 2003). Social sources of resilience, such as social capital (including trust and social networks) and social memory (including experience for dealing with change) (McIntosh, 2000), are essential for the capacity of SES to adapt to and shape change (Folke et al., 2003). Efforts are taking place to mobilize, make use of, and combine different knowledge systems and learning environments to enhance the capacity for dealing with complex adaptive systems and uncertainty (Ludwig et al., 2001). It comes as no surprise that knowledge of ecosystem dynamics and associated management practices exists among people of communities that, interact for their benefit and livelihood with ecosystems, on a daily basis and over long periods of time (Berkes et al., 2000; Fabricius and Koch, 2004). The way such knowledge is being organized and culturally embedded, its relationship to institutionalized, professional science, and its role in catalyzing new ways of managing environmental resources have all become important subjects (Gadgil et al., 2000; Davis and Wagner, 2003).

There is a growing literature on the potential in combining local knowledge systems with scientific knowledge to cope with change in resource and ecosystem management, including understanding climate change (Riedlinger and Berkes, 2001) and managing fisheries, biodiversity, and landscape dynamics (Gadgil et al., 2003; Moller et al., 2004). It has been argued that such self-organized local responses for active adaptation to environmental change have emerged among communities and societies that have survived over long periods of time (Gadgil et al., 1993). Unfortunately, the work-around culture concentrates once again on obtaining a monetary value and the commercialization of cultural products in global markets (UNESCO, 2009). In these terms, sustainable development represents a limited interpretation of the biosphere, socio-ecosystems, and culture (Morandín et al., 2018).

2.4 Trade-offs and Synergies in an Agroecosystem

The provision of ES depends on biophysical conditions and changes over space and time due to human-induced land cover, land use and climatic changes. Paetzold et al. (2010) note that the status of an ES is influenced not only by its provision, but also by human needs and the desired level of provision for their service by the society, which connects supply and demand of ES inseparably. A framework is followed which integrates the concept of ecological

integrity as the base for the supply of regulating, provisioning and cultural ES (Muller and Burkhard, 2007). Ecological integrity means the preservation against non-specific ecological risks that are general disturbances of the self-organizing capacity of ecological systems (Burkhard et al., 2012). This self-organizing capacity is based on structures and processes in ecosystems; and applied in several case studies (Muller, 2005; Burkhard and Muller, 2008). Land use and related land cover modifications have a strong impact on ecological integrity. Alterations of ecological integrity lead to increasing or decreasing supplies of selected or bundles of ES; on which human societies depend. The regional supply of ecosystem goods and services is directly determined by the regional ecological integrity, which is influenced by human actions and decisions such as land cover change, land use and technical progress.

The abundance, diversity and continuity of resources used by organisms depend not only on land cover, i.e., the composition and configuration of land cover types (Fahrig et al., 2011), but also on land use, i.e., agricultural, forestry and water management practices, at different levels in space (Pelosi et al., 2010; Vialatte et al., 2019). MEA (2005), clearly specified that the ES concept has been acknowledged as a way to communicate the dependence of human society on ecological life support systems. Studies that incorporate community perceptions, values, attitudes, and beliefs may generate more meaningful insights into the contribution of ES to human well-being than purely biophysical assessment (Martín-López et al., 2012). Combining local perceptions and knowledge with scientific input allows for a holistic, contextual analysis of locally relevant ES (Seppelt et al., 2011). The results of Kandel et al. (2018), indicate that 'the people of Barshong gewog (Bhutan) depend highly on freshwater, agriculture and forest ecosystems for their livelihoods and economy.'

While being highly specialized in the biomass production, the conventional agroecosystems are often accused of considerably impacting ecological structures and processes (Matson, 1997; Tilman et al., 2002; Zhang et al., 2007). This affects humans and the ecosystem itself, which is highly dependent upon a wide range of ecological processes. A transition towards alternative and supposedly more sustainable agroecosystem is hampered by a lack of knowledge on the environmental and social impacts of these innovative practices (Wezel et al., 2013). To date, science is failing to capture the complexity and multidimensionality of socio-ecological agroecosystems (Fanny et al., 2015). Integrated Ecosystem Service Assessment is an emerging method to get a holistic insight into complex SES (Gomez-Baggethun et al., 2014). Indeed, identifying and quantifying ES bundles is

essential to foresee impacts of land management on ES supply, trade-offs and synergies, and thus on ES beneficiaries (Boogaard et al., 2010).

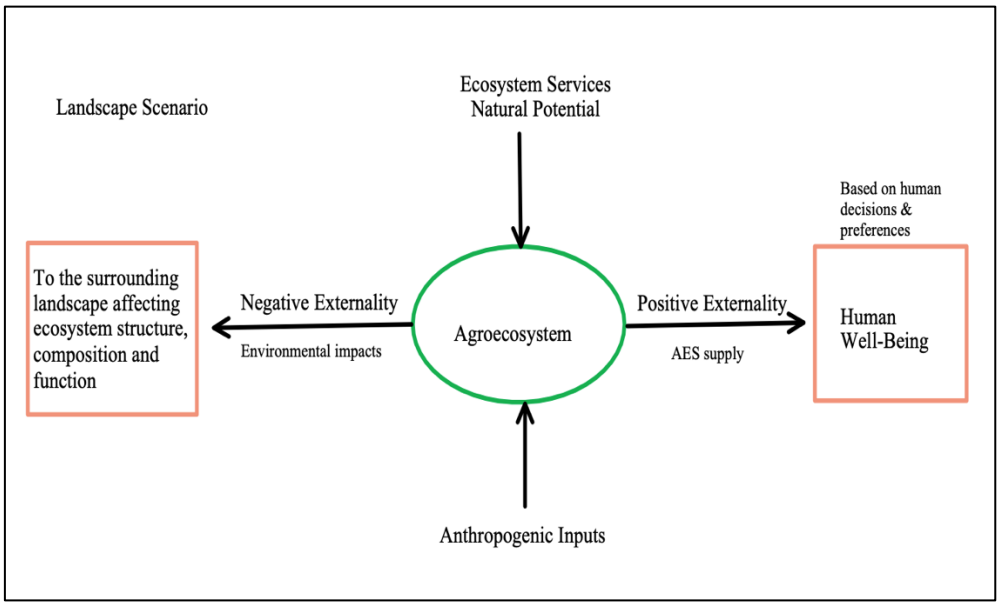


Figure 2.2 Trade-off and Synergy in an Agroecosystem

Common drivers that affect multiple ecosystem functions, processes and services, can result in trade-offs and synergies (Bennett et al., 2009) impacting the ecological landscape as a whole. When one ES increases at the cost of another (Ziv et al., 2012), it results in ecosystem trade-offs, whereas, synergies occur when both the ES increase or decrease as a team (Bennett et al., 2009; Haase et al., 2012). While integrating ES in landscape planning, management, and decision making (de Groot et al., 2010), trade-off analysis should be acutely reviewed, notably for alternative ways to sustainable land use in the future (Rounsevell et al., 2012). If any ecosystem management practice seeking to maximise the production of one or more ES fails to take trade-off evaluation into account, in that case, it can lead to substantial decline in the provision of other ES (MEA, 2005; Bennett et al., 2009).

The complexity of interdependence and interactions among ES is high in managed mountain ES (Grêt-Regamey et al., 2008), where marginally or periodically productive sites may be relatively more sensitive to climate and socio-economic shifts (Sharma et al., 2009). The heterogeneity of topography and other landscape characteristics makes spatial dynamics of mountain ecosystem more important than temporal, where climate change may influence the components of the ecosystem differently (Shrestha et al., 2012). Therefore, when managing trade-offs, the spatial distribution and dynamics of ES, and their interaction with structural

changes in agriculture and forestry must be taken into consideration while policy formulation and governance for sustainable livelihood development.

Current intensive and high-input agricultural practices affect the ability of these systems to provide some ES, which in the longer term can offset their ability to produce large amounts of food and fibre (Tilman et al., 2001). A key future challenge is to improve the understanding of biological processes and environmental consequences of agricultural intensification, so that they can be managed and enhanced to ensure sustained food production for the growing human population (Robertson and Swinton, 2005). To demonstrate the value of ES in the arable sector for the maintenance of profit and sustainable practices, field assessments have been carried out in a Danish combined food and energy system (Porter et al., 2009) and also in New Zealand arable farmlands (Sandhu et al., 2008).

A singular focus on maximizing harvestable goods carries hight costs and risks for the broader availability of ES (MEA, 2005) and the sustainability of food systems themselves (Garnett et al., 2013). There is substantial evidence that agriculture; that relies on continued chemical or synthetic inputs to sustain yield is often associated with significant degradation of water quality and quantity, increased greenhouse gas emissions, and disruptions of natural pest control, pollination, and nutrient cycling processes (Klien et al., 2007).

Soil represents a component of the natural capital containing approximately 1500Pg of organic carbon (1m depth), which exceeds the amount of carbon stored in phytomass and the atmosphere (Scharlemann et al., 2014). Soil is a potential source of a large part of ecosystem service because of the several soil-based physiochemical and biological processes resulting in several functions. These soil organic carbon related ES have an increasing societal value to the extent that monetary valuations of these services are emerging (Costanza et al., 2014; Lal, 2014a, 2014b). Based on the evidence that soil interconnects the various carbon pools (i.e. atmosphere, hydrosphere, biosphere and geosphere) and that changes in soil organic carbon may significantly impact the overall global carbon cycle (Lal, 2016), it could be inferred that reductions in soil organic carbon stocks may negatively affect certain ES, like, regulation of atmospheric carbon dioxide, supply of nutrients to plant (Montanaro et al., 2017).

Agroecosystem/agroforestry offer appreciable services of ecological balance besides improving soil quality, crop productivity, carbon sequestration capability and restoration of degraded lands (Bangroo et al., 2013). The soil organic carbon and soil total nitrogen

concentration are the immediate measures of soil quality (IPCC 2007). Soil organic carbon maintains soil quality by supplementing nutrients, improving cation exchange capacity, supporting biodiversity, and improving soil aggregation and water-holding capacity (Bationo et al., 2007). Carbon content in the soil (1m depth) is almost twice the biotic pool or atmospheric carbon (Lal, 2004; Smith, 2008). Therefore, even slight changes in the soil organic carbon pool can significantly affect the global carbon cycle, climate, and soil properties (Powlson et al., 2011). It has been reported that converting natural vegetation to arable land effects soil carbon storage and fluxes (Powers, 2004; Yimer et al., 2007; Wang et al., 2008; Demessie et al., 2013). This invariably results in losses of soil organic carbon and soil total nitrogen due to change in carbon biomass inputs, accelerated soil organic matter decomposition, and loss of particulates through mechanical clearing, water and wind (Powlson et al., 2011).

Inadequate plant-available soil moisture at the root zone can be a serious limitation to agricultural production, causing loss of yields and even crop failure. Irrigation has been introduced to avoid such risks compensating for gaps between crop requirements and soil water availability (Montanaro et al., 2017). In addition, given the increasing competition for fresh water among urban, industrial and agricultural sectors, the reduction of the consumptive water footprint in irrigated crops via increasing the ratio of green (rain-sourced) to blue (irrigation-sourced) component of water footprint is highly desirable to minimize that competition and/or increase the surface of irrigated land. Recently, the positive impact of improved irrigation methods management on water footprint (Chukalla et al., 2015) has been demonstrated. However, improving soil aggregation and pore distribution through increased soil organic carbon stocks might improve water infiltration and in turn, the soil water storage capacity (Franzluebbers, 2002; Saxton and Rawls, 2006), increasing the green component of water footprint.

The diverse ecosystems of the HKH forms the essential natural capital and play a critical role in protecting the life-support systems in the mountains and beyond (Maharana et al., 2000; Kubiszewski et al., 2013; Sharma et al., 2015). A large proportion of the rural population in the HKH region still lives in poverty (Gerlitz et al., 2015). Their daily requirements and conditional existence is highly dependent on ES (Paudyal et al., 2015; Sharma et al., 2015; Chaudhary et al., 2016). The conventional conservation approaches have become a subject of concern, and the concept of ES has risen to prominence (Singh, 2002;

Naidoo et al., 2008), meantime the relevance of mountain ecosystem has also been widely accepted across global platforms (UN 1992). The main pressures on the mountains results from changes in land-use practices, infrastructure development, unsustainable tourism, fragmentation of habitats, and climate change. (EEA, 2002). These changes have depleted forests and broader biological diversity and disrupted the hydrological regimes of Himalayan watersheds reducing recharge of springs and availability of water for drinking, sanitation and crop production, threatening food and livelihood security (Chapagain et al., 2016; Scott et al., 2018). One of the challenges that policy-makers and administrators face while addressing the threats to the ecological integrity of the Himalayas; is the fact that there is still lack of information available about ecological standing and anthropogenic impacts in the region, hindering the prediction of the losses that will occur as a result of external disturbance (Chettri et al., 2010).

A non-monetary evaluation scheme based on indicators categorized and mapped in relation to relative supply/demand scales. The derivation of suitable indicators for the assessment of ecosystem functions and their capacities to supply services is an important step in order to know what will be evaluated. Appropriate ES indicators need to be quantifiable, sensitive to changes in land cover, temporarily and spatially explicit and scalable (van Oudenhoven et al., 2012). Different ecosystems have different functions based on their structures and processes (i.e. their integrity). Consequently, their capacities to supply particular ES which are used by humans can vary strongly (Bastian et al., 2012). The individual ecosystem capacities to supply services are strongly linked to (a) natural conditions; e.g. natural land cover (vegetation foremost), hydrology, soil conditions, fauna, elevation, slope and climate as well as (b) human impacts; mainly land use but also emissions, pollution, etc.

Montanaro et al. (2017) observed that the services provided by an ecosystem exist only because people (human capital) exist as beneficiaries of those services. However, a gap existed in the scientific literature, as demonstrated by the relatively low number of studies that consider the socio-cultural context, including stakeholder participation, and indicates the need for a more integrated ESA to support decision-making. Integrated approaches need to consider the different values associated with agroecosystems, which extend beyond productivist approaches normally assigned to cropping, livestock and agroforestry systems, to ensure that ecosystem service flows are sustainable and ES synergies promoted through sustainable intensification

processes that favour food provisioning services but also contribute to other environmental, socio-cultural and economic benefits (Balzan et al., 2020).

2.5 Sustainable Livelihood

Scoones' (2009) conviction that a 'central future challenge must be integrating livelihoods thinking and understandings of local contexts and responses with concerns for global environmental change'.

Livelihood's perspectives start with how different people in different places live. Scoones (1998) mentioned that 'livelihood is about assets (material and social resources), and activities for a means of living'. A livelihood can be considered sustainable when it can cope with and recover from stresses and shocks, maintain and further enhance its capabilities and assets. Sustainability debates became part-and-parcel of market-oriented solutions and top-down, instrumental global environmental governance (Berkhout et al. 2003). The wider concerns about complex livelihoods, environmental dynamics and poverty-focused development, however, remained on the side-lines (Scoones, 2009).

The sustainable livelihood approaches (SLA) recognize the diversity of the farm household livelihoods. The various activities and functions of the household member's, using diverse assets lead to multiple priorities and strategies and, therefore produce numerous outcomes. There is an interconnection between the utilization of resources and in meeting the livelihoods requirements. The individuals need to make use of opportunities in an appropriate manner and not get involved in any activities or tasks that cause wastage of resources.

A SLA thus encompasses analysis of the context in which people live (i.e. their socio-economic, technological, demographic, agroecological and political context); their access to natural, human, social, physical and financial assets (and their ability to put these to productive use); the institutions, policies and organisations that determine people's access to these assets and the returns they can achieve; the priorities that people identify in confronting the problems they face as well as the different strategies they adopt in the pursuit of these priorities (Ashley and Carney 1999).

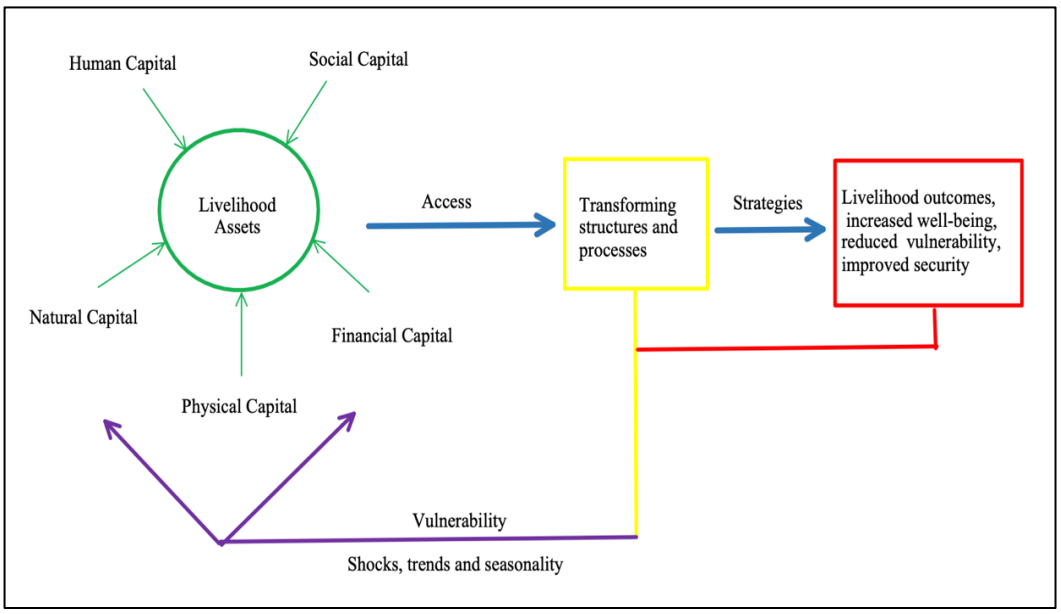


Figure 2.3 Sustainable Livelihood Framework (based on DFID, 2000)

SLA offers a place-based perspective that concentrates upon the activities that people engage to make a living and the material and social assets that facilitate those activities (Chambers, 1983). SLA illustrated development as differential challenges and opportunities arising largely due to variations in capitals and capabilities among households and social groups (Bebbington, 1999). Livelihoods frameworks centre on the human agency (Clay, 2017). They are premised on the idea that rural producers develop livelihood strategies from various combinations of assets (or capitals, including natural, social, cultural, human and economic) and entitlements (the ability to make use of assets), which are delimited through formal and informal resource-regulation institutions (Bebbington, 1999; Leach et al., 1999; Scoones, 1998). Accordingly, assets are seen to vary across space and over time (both between and within households), and as relational in the sense that the livelihood decisions of some actors may create fluctuations in the assets and entitlements of others (Ellis, 2000).

The SLA helps in understanding vulnerability, as livelihood assets and capabilities, which are key determinants of a community's capacity to adapt to climate and socio-economic change. By understanding communities' natural livelihood assets and capacities, it is possible to develop livelihood policies, strategies, and institutions to improve community resilience while fostering livelihood diversification, increased well-being, reduced vulnerability, improved food security, and more sustainable use of the natural resource base (Macchi, 2011).

Environment-development scholars have recognized linkages between adaptation and political economies of natural resource access and use, drawing attention to the state-society negotiations about sharing risks and benefits (Adger et al., 2003). As such, adaptation research can benefit from a more practical, empirical and participatory approach to understanding local experiences with changing climatic conditions (Smit and Wandel, 2006). A primary impediment to integrating SLA and adaptation lies in the under-conceptualization of livelihoods with regard to dynamic spatio-temporal processes (Clay, 2017).

Regional and national strategies have had different impacts on mountain poverty and may even increase the vulnerability of mountain livelihoods. Development in mountain areas is uniquely conditioned, as their socio-ecological system has distinct characteristics, usually termed as “mountain specificities”. The positive specificities like, biological diversity, adaptation mechanism, climate, and culture offers development opportunities for mountain people, but at the same time, negative specificities, such as, inaccessibility, fragility, and marginality constraint the regional development.

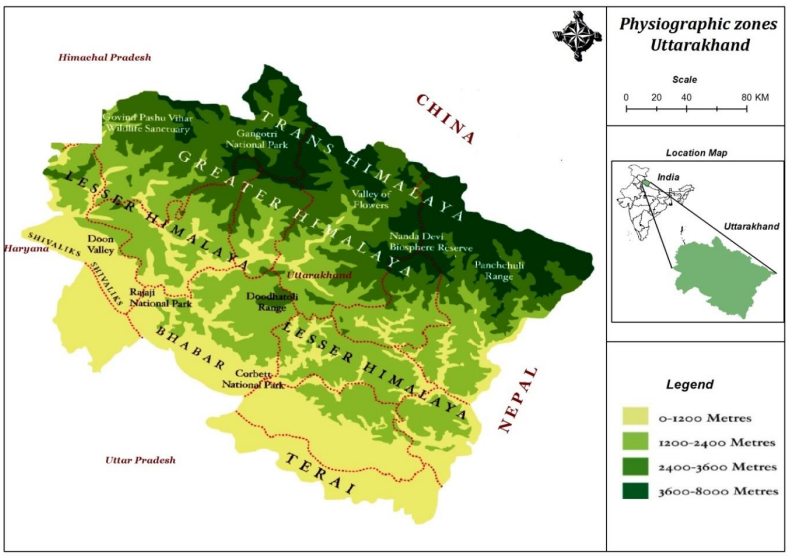
Chapter 3

Description of the Study Area

This chapter presents the agroecological background of the study area along with its general profile. This chapter is divided into two sections. The first section deals with a brief profile of Uttarakhand State. The second section deals with a brief description of general, geographical, climatic, and agroecological features of the selected study area.

3.1 Brief Profile of Uttarakhand State

Uttarakhand, the 27th State of the Republic of India, was initially carved out of Uttar Pradesh on 9th November, 2000. It lies between 28º 43′ – 31º 27′ N latitude and 77º 34′ - 81º 02′ E longitude. Uttarakhand finds its mention in the ancient Hindu scriptures, by the name of Kedarkhand, Manaskhand and Himavant. For the various holy places and shrines, it is also called the Land of the Gods – Dev Bhoomi. The geographical area of the State is 53483 sq. km, which is divided into two regions, namely Garhwal region and Kumaon region, which together comprises of 13 districts. It is located in the foothills of the Himalayas, sharing the borders with China (Tibet) in the north, Nepal in the east and inter-state boundaries with Himachal Pradesh in the west and Uttar Pradesh in the south. Physio-graphically, Uttarakhand represents a unique cross-section of the Himalayas and the vast Gangetic Plains, with forests and rich biodiversity being the wealth of the State.



Map 3.1 Physiographic divisions of Uttarakhand

Table 3.1 Statistics of Uttarakhand, 2019-20 (Directorate of Economics and Statistics, Govt. of Uttarakhand and as per Census, 2011)

Area	**:**	53483 sq. km
(a) Hill area	**:**	46035 sq. km
(b) Plain area	**:**	7448 sq. km
Population (As per census 2011 Provisional data)	**:**	10,086,292
Decennial Growth rate (2001-2011)	**:**	18.81 per cent
Density of Population	**:**	189 per sq. km
Sex Ratio	**:**	963 per thousand
Child sex ratio (0-6 years age group)	**:**	890 per thousand
Total Literacy rate	**:**	78.80 per cent

3.1.1 Land Use Pattern of Uttarakhand

Out of the total geographical area, 86% is the hilly area, and 14% is the State's plains. Only about 14% of the total area is cultivable and approximately 5% is the culturable wasteland in Uttarakhand. Due to its location, diverse climatic conditions, and biodiversity; sectors like organic farming, off-season vegetable cultivation, and cultivation of medicinal and aromatic plants can be promoted.

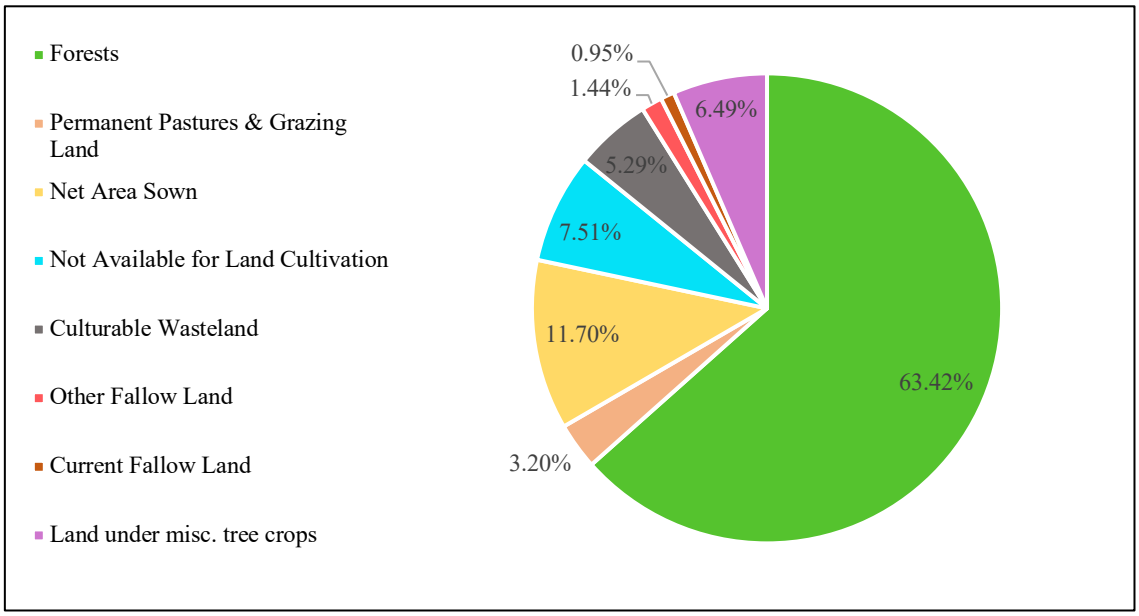


Figure 3.1 Land Use Pattern of Uttarakhand – 2019 (Forest Survey of India)

3.1.2 Agriculture and Agro-climatic zones

Agriculture is a predominant sector in the State's economy, which contributes around 23% in State's GDP. The average size of land-holding is 0.95 ha. The operational land holdings in Uttarakhand are mostly marginal or small in nature. The sector continues to remain dependent on rainfall, and the net irrigated area in the State is 3.23 lakh ha.

Table 3.2 Altitudinal zones of Uttarakhand and their farming details

Zone	Farming Situation	Soil	Rainfall (mm/year)	Principle crops and livestock
Zone A up to 1000 m	Tarai irrigated	Alluvial	1400	Rice, wheat, sugarcane, lentil, chickpea, rapeseed, mustard, mango, litchi, guava, peach, plums. Livestock: Buffalo and cattle
	Bhabhar irrigated	Alluvial mixed with boulders and shingles	1400	Rice, wheat, sugarcane, rapeseed, mustard, potato, lentil, mango, litchi, guava. Livestock: Buffalo and cattle
	Irrigated lower hills (600–1000 m)	Alluvial sandy	2000-2400	Rice, wheat, onion, chilly, peas, potato, radish, cauliflower, pulses, oilseeds, soybean, mango, guava, plums, peaches. Livestock: Buffalo and cattle
	Rainfed lower hills (600–1000 m)	Residual sandy loam	2000-2400	Finger millet, maize, rice, wheat, pulses, mango, guava, plums, peaches. Livestock: Buffalo, cattle and goat
Zone B 1000 – 1500 m	Mid hills, south aspect	Sandy loam	1200-1300	Rice, finger millet, wheat, potato, tomato, peas, cole crops, pulses, peach, plums. Livestock: Cattle, sheep and goat
Zone C 1500 – 2400 m	High hills	Red to dark	1200-2500	Amaranth, finger millet, French-beans, cole crops, potato, peas, peaches, plums, pear, apple, stone fruits. Livestock: Cattle, sheep and goat
Zone D 2400 m	Very high hills	Red to dark black clay	1300	Amaranth, buckwheat, peas, cole crops, apple, potato. Livestock: sheep and goat

The major cereal crops of Uttarakhand includes, rice, wheat, barley, maize, finger millet, and others. The various pulses grown in the State are; urad, masoor, peas, gahat, rajma, gram, soyabean, etc. The major oilseeds sown are rapeseed, mustard, sesamum and groundnut. The area and agricultural productivity under principal crops are as follows (Directorate of Economics and Statistics, Government of Uttarakhand, 2021).

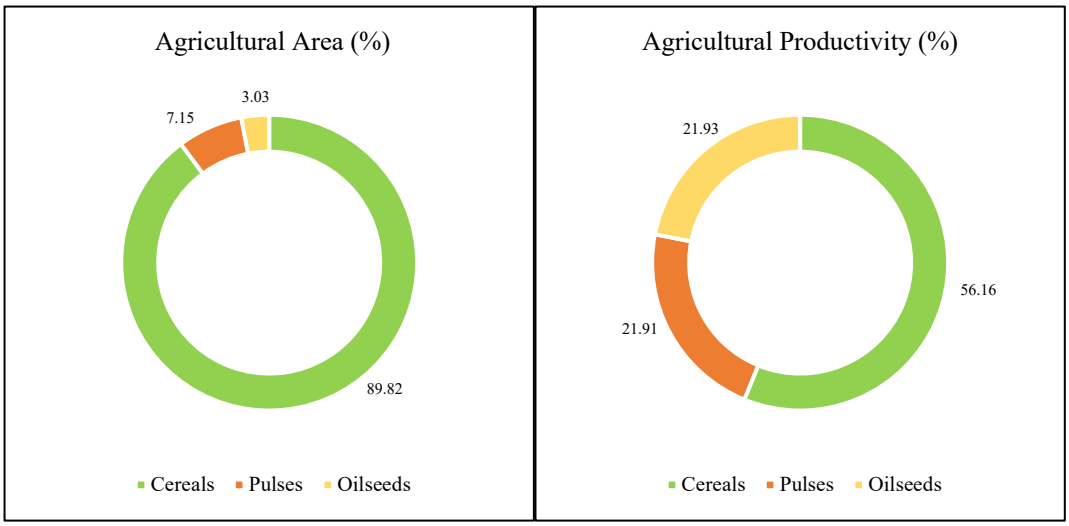


Figure 3.2 Agricultural area and productivity under principal crops in Uttarakhand

3.1.3 Horticulture

The geographical attributes and climatic conditions of the State are ideal for the production of temperate and sub-tropical fruit crops. Fruits like; apple, pear, peach, plum, apricot, walnut are produced in the hilly area, while mango, litchi, mandarin, orange, lemon, Indian gooseberry, guava and pomegranate are mostly grown in Tarai and valley area. Major vegetables produced are potato, cauliflower, tomato, onion, brinjal, pea, cabbage and okra. The State has a unique advantage of organic farming and off-season vegetable production, which can be further explored profitably. Major spices are ginger, garlic, turmeric and chilly.

Table 3.3 Area and production statistics of horticultural crops in Uttarakhand, 2019-20 (Department of Horticulture and Food Processing, Uttarakhand)

Crops	**Area (ha)**	**Production (MT)**
Fruits	181485.55	677369.75
Vegetables	72071.35	645637.99
Potatoes	26769.38	368641.46
Spices	14536.07	96282.04
Flowers	1635.05	1914.13

3.1.4 Forest and Wildlife

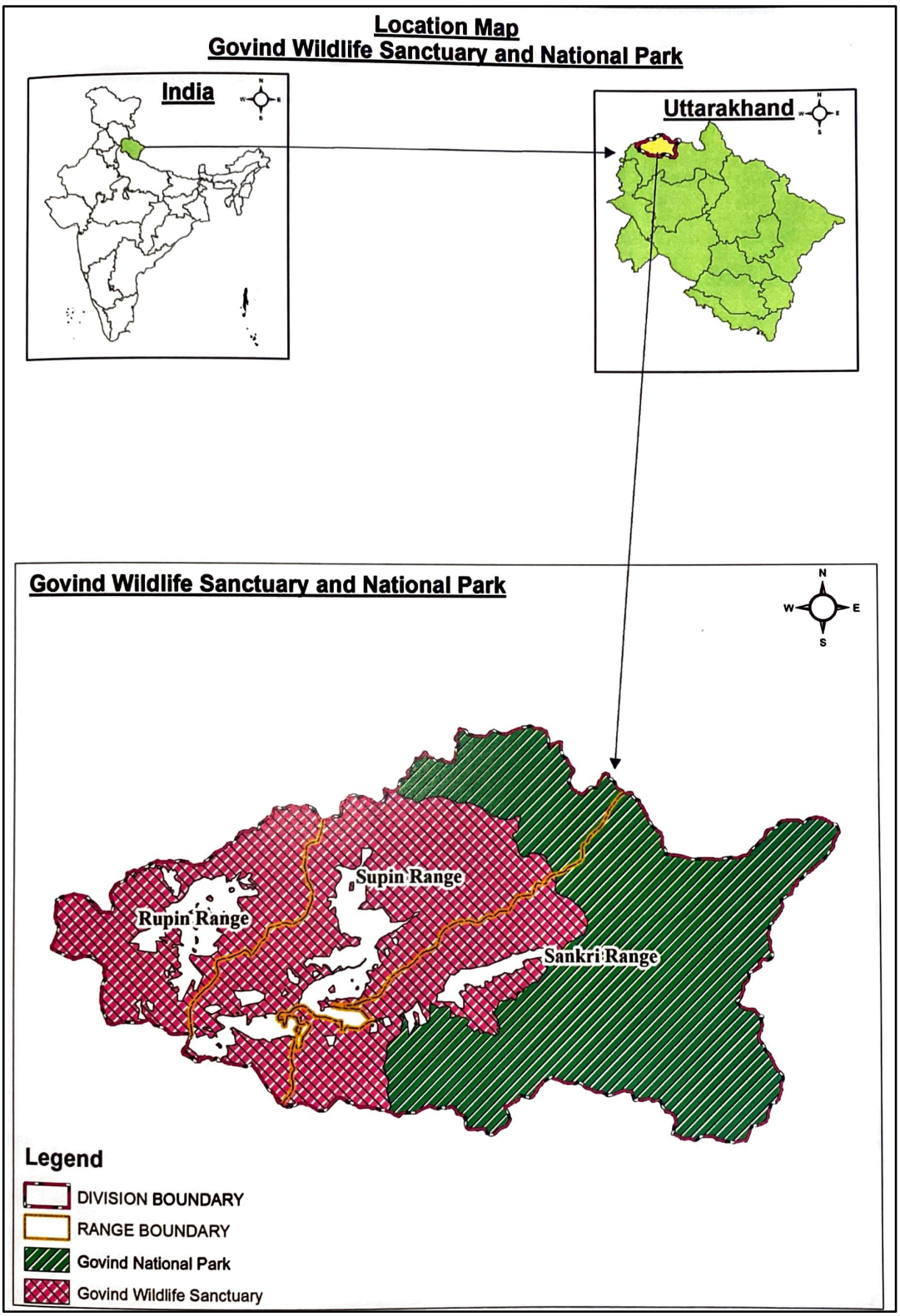
Uttarakhand is rich in forest and wildlife resources. Six National Parks, seven Wildlife Sanctuaries and four Community Reserves constitute the Protected Area Network of the State, covering 3.24% of its geographical area. The Forest Cover in the State is 24,303.04 sq. km which is 45.44% of the State's geographical area. Forest Cover in the State has increased by 8.04 sq. km compared to the previous assessment reported in 2017 (FSI, 2019).

3.2 Brief Profile of the Study Area

The research area selected for the proposed study was the Govind Wildlife Sanctuary and National Park, which forms a part of the high Western Himalayas. It was established on 1st March, 1955. It spreads over an area of 957.969 sq. km with a varying altitude of 1300m to 6323m. It is located between 35º 55′ N - 31º 17′ N latitude and 77º 47′ E - 78º 37′ E longitude in the revenue district of Uttarkashi (Block – Mori) in the State of Uttarakhand. The protected area (PA) is adjoining with the forest division of Uttarkashi to the east, Upper Yamuna to the south, the Tons to the west, all within Uttarakhand, except the northern limits, which is contiguous with the forests of Himachal Pradesh. A part of the Upper Tons Valley was notified as a Sanctuary in 1955 (485.88 sq. km), while it was notified as a National Park in 1991 (472.08 sq. km).

The average rainfall in the area is 1500mm, generally in the months of July-August. The landscape experiences extreme cold weather with at least three to four months of snowfall in winters and a permanent snowline in the higher reaches. The landscape is an extremely important catchment for the Tons River, which is a major tributary of the Yamuna River. The two major rivers, Rupin and Supin, flows through the Sanctuary, joining at Naitwar, and forms the River Tons, which later joins Yamuna at Kalsi.

The sanctuary is hugely fragmented by 42 villages located in three valleys along the Supin, Tons and Rupin rivers. Of the three, the Supin valley that runs south-east has just four villages. The remaining 38 villages are located along the Tons and Rupin river valleys within the limits of the Sanctuary and the National Park. A large number of sheep, goat, cattle, mules and horses, belonging to the local inhabitants as well as migratory pastoral communities graze during summer season within the limits of these protected areas.



Map 3.2 Location Map of the Study Area

Plate No.1 Regional landscape of the study area

Map 3.3 Map of the Study Area

3.2.1 Climate

The climate of the PA is generally temperate with well-marked seasonal variations. Owing to a large variation in altitude, the lower valleys of the Rupin-Supin rivers have a sub-tropical climate while the highest parts remain perpetually under snow. The spring season (mid-March to mid-June) is characterized by occasional showers of rain sometimes accompanied with thunderstorms and hail. The lower valleys are uncomfortably hot during June before the rain occurs. The average rainfall in the area is 1500mm, which mostly occurs in the monsoon season, generally beginning by the middle of June and till the second week of September. The autumn (mid-September to mid-December) is pleasant with a clear weather. The landscape experiences extreme cold weather during the winter season (mid-December to mid-March), with heavy snowfall and a permanent snowline in the higher reaches.

3.2.2 Vegetation and Wildlife

The area harbours a rich array of habitats, unique vegetation types and floral diversity, which varies according to altitude and climatic conditions in the area. Depending upon the terrain, altitude and aspect, a number of vegetation types can be recognized in the area. The vegetation varies from tropical deciduous forest, to temperate forest at mid altitudes, coniferous, sub-alpine and alpine forest in the higher reaches of the region. In the temperate belt, the forest is mostly dominated by, maples (*Acer spp*.), hazel nut (*Corylus jacquemontii*), horse chestnut (*Aesculus indica*), hornbeam (*Carpinus viminea*), Himalyan mulberry (*Morus laevigata*), elm (*Ulmus wallichiana*), among others. The riverine area between Taluka and Osla supports patches of mixed conifer forests, moist deodar (*Cedrus deodara*) forests, oak (*Quercus leucotrichophora* and *Q. dilatata*) and burans (*Rhododendron arboreum*). The stream banks have riverine forests characterized by alder (*Alnus nepalensis*), low altitude birch (*Betula alnoides*) and others. The natural treeline in the area lies around 3500+200m above mean sea level. The treeline vegetation is represented by burans (*Rhododendron campanulatum*), high altitude fir (*Abies spectabilis*) and brown oak (*Quercus semecarpifolia*). The alpine meadows, locally termed as Bugyals are rich in herbs such as species of *Ranunculus, Anemone, Corydalis, Cardamine, Arenaria, Potentilla, Geranium, Senecio, Silene, Primula, Gentiana, Pedicularis* and *Impatiens*, etc. In addition, the alpine zone is extremely rich in high-value medicinal plants, like, gandrayan (*Angelica glauca*), salam panja (*Dactylorhiza hatagirea*), kutki (*Picrorhiza kurrooa*), dhoop (*Jurinea macrocephala*) and atis (*Aconitum heterophyllum*).

The mammalian fauna in the area includes; snow leopard (*Uncia uncia*), mountain weasel (*Mustela altaica*), brown bear (*Usrus arctos*), asiatic black bear (*Selenarctos thibetanus*), wild pig (*Sus scrofa*), Himalayan musk deer (*Moschus chrysogaster*), sambar (*Cervus unicolor*), barking deer (*Muntiacus muntjak*), Himalayan tahr (*Hemitragus jemlahicus*), bharal or blue sheep (*Pseudois nayaur*), etc. Among avi-fauna, Himalayan monal (*Lophophorus impejanus*), koklass pheasant (*Pucrasia macrolopha*), kalij pheasant (*Lophura leucomelanos*) and cheer pheasant (*Catreus wallichii*) are prominent.

3.2.3 Agriculture

The agroecosystem in the area is complex, as it is composed of crop husbandry, livestock rearing and forests, forming an interlinked production system. Terraced slopes, constituting the entire agricultural land, are generally rainfed along with few sources of small natural streams (locally known as nala) in some of the fields. The cropping pattern is divided into two growing seasons: Kharif (April-October) and Rabi (October-April). The TC cultivated in the area are; kuttu/buckwhet (*Fagopyrum esculentum* and *Fagopyrum tataricum*, jau/barley (*Hordeum himalayense*), ragi/fingermillet (*Elusine coracana*), bhangjeera (*Perilla frutescens*), kulthi/horsegram (*Macrotyloma uniflorum*), chaulai (*Amaranthus spp*.), and local varieties of rice (*Oryza sativa*) locally famous as red rice and wheat (*Triticum Aestivum*), but unfortunately the area under these crops have declined over the years.

Cash crops are generating significantly higher employment and helping in diversifying farm incomes. The particular suitability of hills for horticulture have resulted in shifting of cropping patterns from agriculture to fruit crops. The change from traditional subsistence agriculture to cash crop-based farming such as potato and kidney beans is rising in the area. The terraced farms have been largely converted into apple orchards in the last seven years. The mountain farmers have managed to harness the local niches, provided by the agro-climatic conditions of the region. The ongoing transformation has yet not eliminated the traditional crops from the present cropping pattern, as these crops are still used for household consumption.

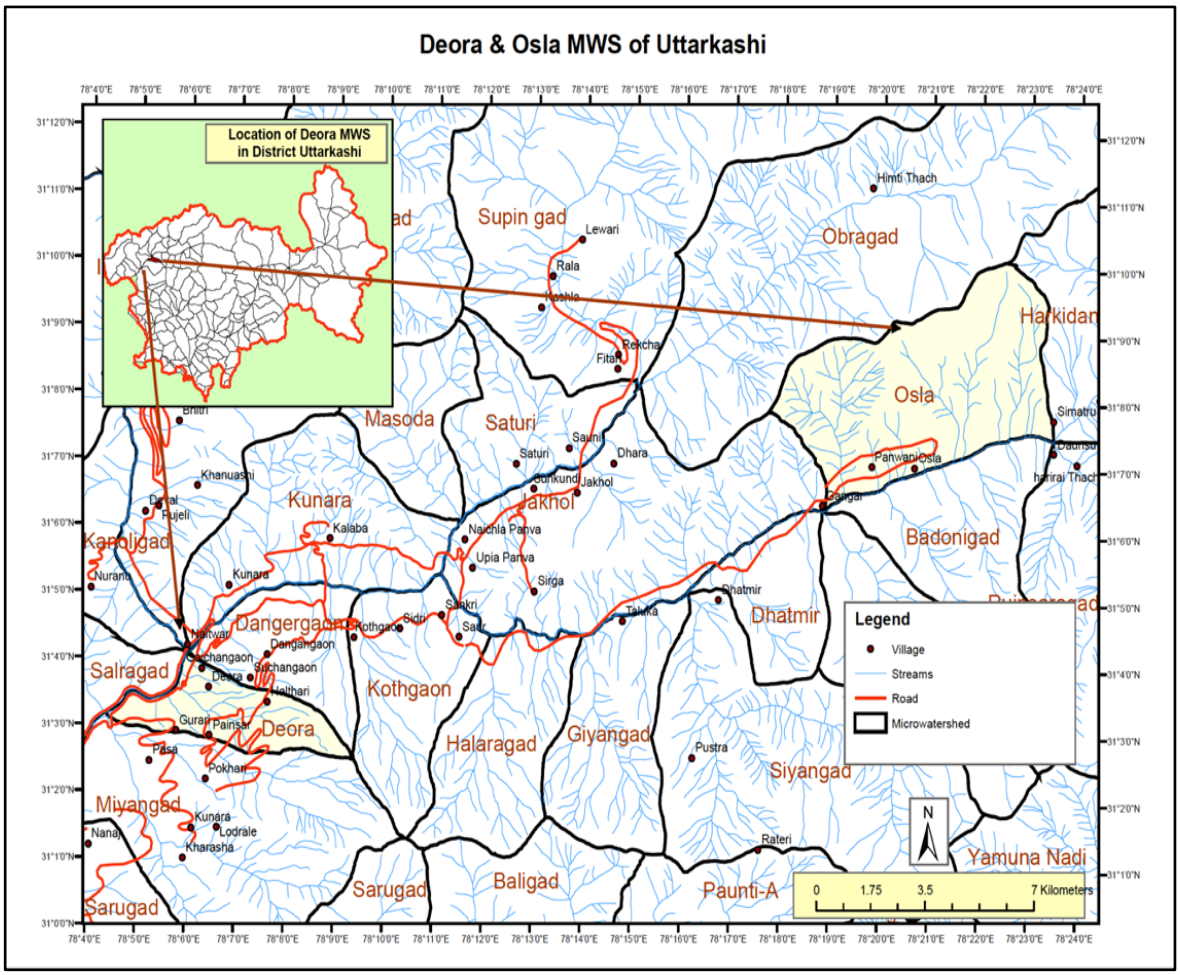
Plate No.2 Agricultural landscape in the study area

5.7.1 Baseline data of the selected villages in the Study Area

From a total of 42 villages in the Sanctuary, four villages were selected through stratified random sampling, giving connected (Gainchwan Gaon and Deora) and isolated (Dhatmeer and Osla) villages.

Table.3.4 Baseline data for the selected four villages (Census Data, 2011)

S.No.	Name of the Village	Name of the Micro-Watershed	Area of the village (ha)	Total no. of household	Total Population
1.	Gainchwan Gaon	Dangergaon	137.76	192	783
2.	Deora	Dangergaon	44.18	99	443
3.	Dhatmeer	Dhatmeer	269.16	192	809
4.	Osla	Osla	378.56	151	725



Map 3.4 Map of the selected villages

Plate No.3 Household condition in the connected villages

Plate No.4 Household condition in the isolated villages

Chapter 4

Research Methodology

Every research follows a systematic procedure to conduct a study in the light of the predetermined objectives. Research methodology is an integral part of any scientific investigation. It deals with the framework within which the study has been conducted. A sound methodology is the pre-requisite for accurate results from any research investigation. Research methodology not only talks about the research method, but also the logic behind the methods in the context of the research study and explain why we are using a particular method or technique and why we are not using others, so that research results are capable of being evaluated either by researcher himself or by others. This chapter deals with the description of the research process involving research procedures and techniques and operationalization of different concepts used to fulfil the objectives of the study. Further keeping eye upon this, a scientific and systematic procedure was developed and adopted for conducting the investigation.

4.1 Conceptual Framework

Himalayan agroecosystems are very diverse and rich due to a wide range of varied geographical features, socio-economic conditions, and cultural factors. Inaccessibility, fragility and marginality define characteristics of mountain regions, which make agriculture inherently vulnerable in the Himalayas (Gerlitz et al., 2015). The relationship between the ecosystem and the socio-economic benefits derived by the local communities is explained in the given figure (Fig.4.1).

The SLA recognizes the diversity of the farm-based livelihoods. The various activities and functions of the members of the households, using assets, lead to multiple priorities and strategies and, therefore, produce numerous outcomes. There is an interconnection between the utilization of resources and in meeting the livelihoods requirements. The individuals need to use opportunities in an appropriate manner and not get involved in any activities or tasks that cause wastage of resources.

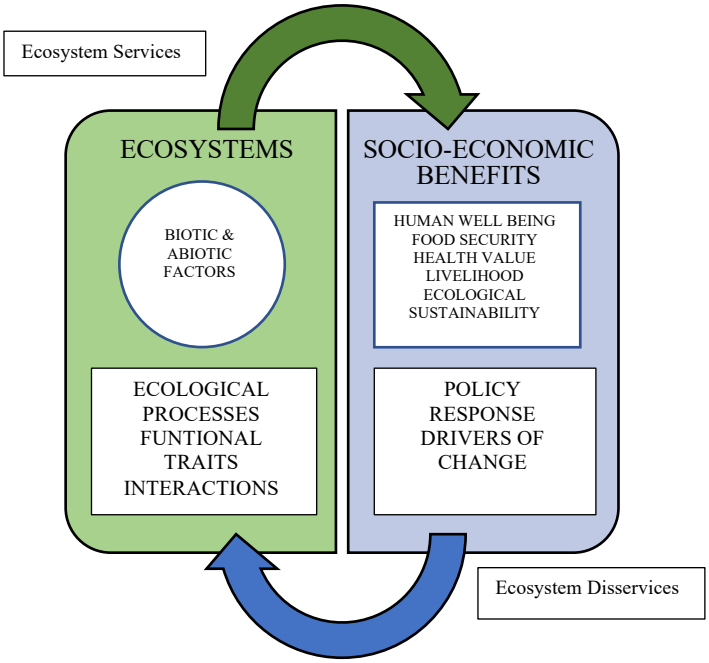


Figure 4.1 Link between Ecosystem and Society

Agricultural practices are the mainstay of the people of Uttarakhand, and a large section of the Himalayan population depends on agriculture-based activities for their livelihood. Agriculture in the Himalayan region is closely interlinked with traditional crop cultivation, animal husbandry and forest-related enterprises, and all activities to form an integrated production system for sustainable livelihoods. Local communities also possess a great deal of ethnobotanical knowledge and rich cultural heritage. The provision of ES depends on biophysical conditions and changes over space and time due to human- induced land cover, land use and climatic changes, which influences human well-being. A suitable set of indicators were derived for the assessment of ES in an agroecological landscape, in order to quantify and evaluate them.

The local people are rational decision-makers, considering both; the availability of various capitals and the vulnerability they face. Any modification in their existing livelihood pattern is either a result of their changed interest or the availability of natural resources and capital. Under the prevailing hardships and complexities of the mountainous households, if the people face external stress (like climate uncertainty), they attempt to counter the impact by modifying and adjusting their living mechanism, depending on their AC for the same.

4.2 Research Design

The research work was started with bridging the thoughts regarding the problem areas, related literature review, and basic research gaps, which helped in preparing a scientific research proposal based on the concepts developed. During the research process, the series of discussions and brain storming with the supervisor encouraged critical thinking, which gave a clearer picture of the concepts used in this research. Finalization of the theoretical, conceptual and practical framework helped develop the field-work plan for generating the information. This research was based on both; the exploratory and descriptive methods, which formed the blueprint for the collection of data, measurement and analysis. The study focuses on understanding the past, current and future challenges and opportunities that could shape the traditional knowledge and skills, resilience, subsistence, natural resource utilisation and AC of the local communities. Finally, conclusions were drawn for policy recommendations necessary at various levels to support the livelihood of the mountainous community.

Based on the conceptual framework, the research design was prepared following three principles:

- The methods selected for data collection were both qualitative and quantitative in nature
- Emphasis on participatory tools
- Multi-method approach, ensuring data triangulation

4.3 Data Sources and Data Collection Methods

4.3.1 Primary Data

The primary data is the first-hand information generated directly from the respondent's household by the researcher. The nature of the study essentially required face-to-face interaction, hands on facts and figures, ideas and real-life experiences, to perform the situation analysis. The Primary data was collected through various Participatory Rural Appraisal tools, as they offer a quick and affordable method for gaining insightful and accurate data (Younus, 2014; Paudyal et al., 2015). The qualitative and quantitative data at the community level were collected through Key Informant Interview, Oral and Life History Interview, Household

Survey (HHS) and Focus Group Discussions (FGDs), personal observation, transect walks and field tests (Fig.4.2).

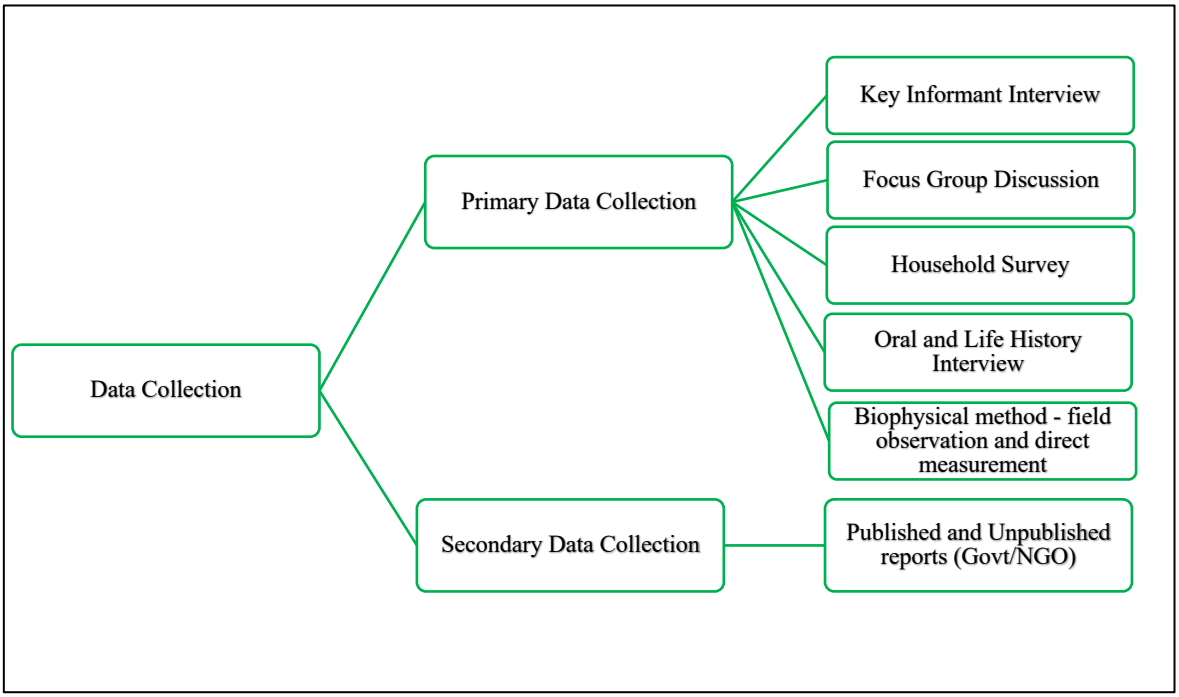


Figure 4.2 Methodological framework for data collection

a) Key Informant Interview

They were held with knowledgeable people from the local community of the selected villages, district administrative and agricultural department staff and government officers. The interviewees were selected through snowball sampling and purposeful sampling method, based on their knowledge and relevance with the research questions. This approach ensured the greatest possible amount of information about the actual condition of the landscape. The initial interview was that of the *Pradhan*, who is an elected head of village Gram Sabha (i.e. purposeful sampling). The selection of subsequent interviewees were achieved with the guidance of the previous research participant (i.e. snowball sampling). Each interview was structured in nature. During the selection of participants, it was ensured that a wide range of views and experiences were included, representing a diverse income group and livelihood type. A general baseline data about the village and its livelihood was collected, like the major cropping pattern, source of water, socio-economic condition of the area, political system, government aid and help, education status, health facility, etc. A major part based on their perception towards current economic status and development, their strengths, drawbacks and suggestions were also discussed.

b) Oral and Life History Interview

Oral history interview (recall events from past and reflect on them) and life history interview (information on entire biography of respondent) were conducted using unstructured questionnaire. The population of the selected village were sampled according to stratified random sampling, where the population was stratified according to the age, thus giving a range of traditional data from the old and elderly; as well as the current mindset scenario of the younger generation living in the study area. The old and elderly were questioned about the socio-economic and environmental changes in the area and the perceived impacts on the livelihood, traditional knowledge and culture. It helped in documenting the changing mindset of people towards traditional farming practices and cropping patterns. The village's younger generation was also interviewed on questions, like their education status and job aspirations, migration, agroecosystem based economy, ideas related to agriculture/horticulture, and the various societal problems they face. The most important aspect that was discussed with the younger people was their cultural understanding and traditional knowledge about local variety of crops, wild fruits and vegetables, and medicinal plants. This helped in taping the extent of traditional knowledge in the area and whether it was extending over generations or diminishing with time.

c) Household Survey

An important set of data at the household level was collected through HSS, which were conducted in the form of a semi-structured interview. The questionnaire contained both open as well as closed ended questions. The questionnaires were initially pretested to check the efficacy and suitability of the questions. For pretesting, ten households from a non-selected village were interviewed prior to the actual HHS of the targeted sample households. This allowed the reorganization and modification of the questions before the actual data collection. The households for the interview were randomly selected based on the sample size. The questions were specific in nature, like, number of household members, education status of the family, income status, source of water, area under cultivation, cropping pattern, farm yield, etc. While designing the questions, certain key points were kept in mind, like research questions, what we want to know, how would we answer, avoidance of ambiguous terms, long questions, technical terms, and negative questions.

Plate No.5 Primary data collection – Interviews

d) Focus Group Discussions

After a series of individual and household interviews, separate FGDs among the villagers were organized in the form of unstructured interview. As the main purpose of the study is to document the major adaptation practices for sustainable livelihood and assessment of ES in the study area, participants were chosen (purposeful sampling) based on who could contribute more in the discussion and help generate data. The questions were based on the problems they face regarding livelihood generation, the constraints in relation to accessibility, government aid, climatic fluctuations, and institutional development. Their local adaptation strategies and ideas for a stable economic community were also discussed; so that they felt as a part of this research, development and adaptation process. Half of the participants were women for gender inclusiveness. Separate group discussions for male and female participants were not organized, as the study aims primarily to identify adaptation measures at different levels rather than the documentation of gender-based disaggregated adaptation practices. To ensure effective engagement of participants in the discussion (quality) rather than to involve as many participants as possible (quantity) within each group, the role of the facilitator was played; so that a moderated discussion among participants could be accomplished, instead of asking questions repeatedly. This technique allowed the development of an understanding about why people feel the way they do. The participants argued and challenged each other's view, thus it helped in getting more realistic answers.

e) Biophysical method – field observation and direct measurement

A transect walk across the study area was also conducted to verify information collected through the interviews and FGDs. This method was useful for both in-depth information collection and triangulation of information. Important observed information was noted and photographs of the area were also taken to illustrate the research work. For the direct measurement of various parameters, soil and water sampling was done using appropriate methodologies.

Obtained information from the primary source of data was assumed to be accurate, as participant observation method was implemented during questionnaire filling and interviews during the field survey, given that no biasness was done in the selection of the participant as well as data collection. During the entire process, cross questioning was done to verify the data obtained. Interviews, discussions and field observations supported in the cross-checking of the data obtained during the questionnaire survey, thus marking the reliability of the information.

Plate No.6 Primary data collection – Focus Group Discussions

4.3.2 Secondary Data

An extensive review of related books, journals, articles, research paper, reports, thesis, websites and research centres, was used to obtain the secondary data. The data related to climate was obtained from the meteorological department of Uttarakhand. Published and unpublished reports of relevant government entities and non-governmental organizations (NGOs) will be reviewed as secondary sources. These included operational plans of community forests, Van Panchayats and the Forest and Agriculture department.

4.4 Questionnaire Designing

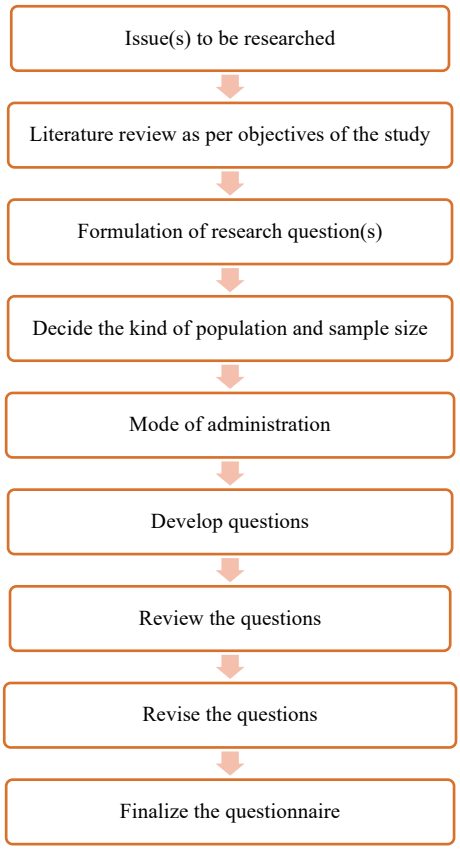


Figure 4.3 Steps in designing the questionnaire

A well-designed questionnaire is essential for a successful research survey. Thus, for the preparation of the questionnaire, a thorough literature review was done, and certain general rules were kept in mind;

- The questions were designed to directly answer the research questions.
- Decide beforehand what exactly the researcher wants to know.
- Put yourself in the position of the respondent.

- Avoid ambiguous terms in the questions.
- Keep the questions short and easy.

A pilot study was conducted before administering the actual survey, and it helped ensure that the survey questions operate well. The details of the survey questionnaire are given in Appendix-A.

4.5 Sampling Design

The study employed a multi-stage sampling technique, where a combination of sampling techniques was used to select the villages in the study area. In the first stage, all the villages in the study area were enlisted. A stratified random sampling technique was employed for the selection of villages. All villages were divided into two strata's depending upon their accessibility via motorable road. Thus, two groups were formed, where one comprised of villages that were easily accessible by roads and were mostly on the road head. The other group was formed by the villages which were inaccessible and the only way to reach them was by hiking, trekking or porter/mule/horse rides. In the second stage, two villages from each strata were randomly selected for data collection. During the random selection of villages from the two strata, an assumption was made that the local communities may have differences in their traditional knowledge and skills, natural resource utilisation, and AC for socio-economic development. In the third stage, sample size was determined, and households were randomly selected from each target village for data collection.

4.5.1 Sample Size

The calculation aims is to determine an adequate, reliable and representative sample size, which can estimate results for the whole population with a good precision. For the research study, Cochran's formula for proportions was used.

Cochran's formula for calculating sample size when the population is infinite:

$$n_0 = \frac{Z^2 * p * (1 - p)}{e^2}$$

Where, n_o is the sample size, z is the selected critical value of desired confidence level, p is the estimated proportion of an attribute that is present in the population and e is the desired level of precision.

Cochran's formula for calculating sample size when the population is finite:

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}}$$

Where, N is the population size.

4.6 Analytical Framework and Analytical Tools

Analytical framework helps a researcher to approach a problem with logic and in a systematic manner.

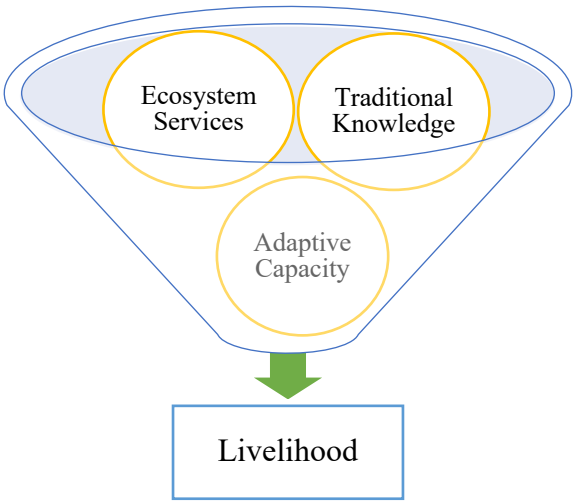


Figure 4.4 Analytical framework

The Fig.4.4 presents the analytical framework for the analysis of sustainable livelihood development in the mountainous region. This framework focuses on the decisions of a community, the values they assign to different environmental factors, and how these choices for livelihood generation affects the landscape as a whole. It is based on the assumption that the choices one makes are highly influenced by the socio-economic constraints, cultural values and personal history and experience of an individual. The framework also assumes that the biophysical characteristics and environmental conditions of the study area influences

livelihood and decision making, as they provide limitations and opportunities for agricultural production. The framework assumes that the present actions might affect the environmental conditions, which might later affect future system dynamics for sustainable livelihood generation.

The following analytical framework was used for empirical analysis to achieve the study's different objectives. The data collected were subjected to analysis and interpretation, under the following broader categories:

4.6.1 Traditional knowledge and local's perception

a) Simple descriptive methods
b) Quantitative Indices
    - Relative Frequency Citation (RFC)
    - Relative Importance Index (RI)
    - Cultural Importance Index (CI)
    - Cultural Value Index (CV)
    - Informant's Consensus Factor (Fic)
    - Fidelity Level (FL)
    - Knowledge Richness Index (KRI)

4.6.2 Agroecosystem services

a) Simple descriptive method
b) Preference Assessment (Socio-cultural method)
c) Indicator-based Assessment (Biophysical method)

4.6.3 Adaptive Capacity

a) Indicator-based Assessment
    - Relative scoring and ranking (Expert-based method)
    - Weighted Average Index (WAI) and ranking
    - Local Adaptive Capacity Index (LACI)

4.6.1 Traditional knowledge and local's perception

To examine the traditional knowledge and local's perception about livelihood, simple descriptive methods using PRA tools was done. The respondents were selected randomly from the pre-determined age-group categories, i.e., below 25 years (young generation), 25-50 years (adult generation) and above 50 years (old generation). A gender-wise demarcation was also kept in mind while collecting the information. Participatory resource surveys with the local people's help were also organized to establish a trust connection with the local community. A set of primary information was collected under the three sub-themes;

a) Traditional cultural expression (TCE)
b) Traditional crops (TC)
c) Ethno-botanical knowledge on medicinal and aromatic plants (MAP)

All the ethnobotanical indices are founded on the basic structure of the ethnobotanical information: "informant *I* mentions the use of the species *s* in the use-category *u.*" (Tardío and Pardo-de-Santayana, 2008). Thus, the survey yields *NS* number of species, with *NC* number of use-categories and *N* number of informants. For studying the cultural importance of the cited medicinal plants, the use-reports (UR) for each species were calculated based on the differentiated health ailment categories. UR is expressed as (Tardío and Pardo-de-Santayana, 2008);

$$UR_s = \sum_{u=u_1}^{u_{NC}} \sum_{i=i_1}^{i_N} UR_{ui}$$

First, the UR of all the informants (i_1 to i_N) within each ailment category for that particular species was summed, followed by all the UR for each ailment category (u_1 to u_{NC}).

The comparison of importance of each cited species was attempted, using the following indices;

i. Relative Frequency Citation (RFC) – This index was obtained by dividing the number of respondents who mention the use of the species i.e., frequency citation (FC_s), by the total number of respondents participating in the survey (N). The value of RFC varies from 0 (when nobody refers to a plant as a useful one), to 1 (when all the respondents mentioning it as useful) (Tardío and Pardo-de Santayana, 2008).

It doesn't require the use-category and was calculated as:

$$RFC = FC_s / N$$

ii. Relative Importance Index (RI) – It was calculated for all the cited species using the formula given by Pardo-de-Santayana (2003). The RI index varies from 0 (when nobody mentions it) to 1 (frequently mentioned as useful).

$$RI_s = \frac{RFC_{(max)} + RNU_{(max)}}{2}$$

Where, $RFC_{(max)}$ is the FC_s for a species over the maximum value of FC in all the species of the survey, given by:

$$RFC_{(\max)} = FC_s / FC_{(\max)}$$

Where, $RNU_{(\max)}$ is the relative number of use reports for different ailment categories for the same species over the maximum value of usereports amongst all the species in all the categories, given by:

$$RNU_{(\max)} = NU_s / NU_{(\max)}$$

iii. Cultural Importance Index (CI) – It is calculated by the summation of UR in every ailment category mentioned for a species divided by the total number of respondents (N). This index elaborates upon the extent of the use for a species and diversity of its use. A greater value of CI for a species signifies that the particular species is widely used for that health problem. It also measures the relative importance of each plant use (Tardio and Pardo-de Santayana, 2008). The UR is the total number of respondents who mention a use for a species in the different ailment categories.

$$CI_s = \sum_{u=u_1}^{u_{NC}} \sum_{i=i_1}^{i_N} UR_{ui} / N$$

iv. Cultural Value Index (CV) – It was given by Reyes-García et al. (2006) and is calculated using the flowing formula;

$$CV_s = RNU_s \times RFC_s \times CI_s$$

Theoretically, the maximum CV value will be reached when all the contributing factors reach their maximum values (which is unlikely that all the respondents mention the use of all the species). The value of the index varies from 0 to the total number of use-category (in this case ailment categories) in the study.

v. Informant's Consensus Factor (Fic) – In order to check the homogeneity in the use of medicinal plants (as mentioned by the respondents) in the different ailment categories informant's consensus factor was calculated using the following formula (based on Heinrich et al., 1998).

$$Fic = \frac{N_{ur} - N_t}{N_{ur} - 1}$$

Where, N_{ur} is the number of use reports for a particular ailment category and N_t is the number of species used for a particular health ailment by all the respondents. ICF ranges from 0 to 1, where a high value of ICF means high rate of consensus amongst the respondents.

vi. Fidelity Level (FL) – It helped in determining the most preferred species used in the treatment of a particular ailment. Following formula based on Friedman et al. (1986) was used to calculate the FL;

$$FL\ (\%) = {}^{N_p}/_{N} \times 100$$

Where, N_p is the number of use-reports for a given species for a particular ailment and N is the total number of uses reported for species for any major ailment.

vii. Knowledge Richness Index (KRI) – It was calculated separately for the pre-determined age group classes. Following formula was used (based on Araujo et al., 2012 and Alencar et al., 2014);

$$KRI = 1/\sum Ji^2$$

$$J_i = R_i/R_{ui}$$

Where, R_i is the number of plant species mentioned by the respondent, R_{ui} is the total number of species mentioned by the unit (N=1000). The value of KRI ranges from 0 to infinity, where the lower value of KRI indicates a higher knowledge of medicinal plants by the respondents and vice versa.

4.6.2 Agroecosystem services

Agroecosystem services (AES) assessment was done at farm scale, and a landscape was chosen which was inhabited by the indigenous and local communities, as they have a long-term relationship with their ecosystem. The research was conducted in the mountain agroecosystem, where contrasting farming systems were assessed to explore the AES. To deepen and structure our understanding of sustainable agricultural landscape, the farming systems were further compared with uncultivated fields. Various methods (including both qualitative and quantitative) were used to assess the AES in the study area, along with farmer's perception of their dependency on these services. Two main approaches were adopted;

- Social AES valuation, representing the extent to which they value the associated agroecosystem
- Biophysical quantification of AES indicators.

During the FGDs, all participated in an active process of co-creating knowledge about their local farming system; based on farmers perceptions. Leaving aside the monetary valuation of ES, socio-cultural methods were used with the aim to assess the human preferences for ES. Preference assessment was done using ranking and free listing exercises.

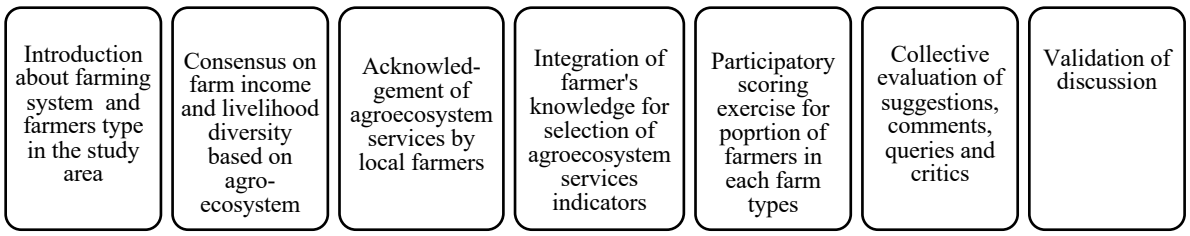


Figure 4.5 Steps involved in social agroecosystem services valuation (based on Teixeira et al., 2018)

Based on the group discussion's, two important quantitative variables were selected to study the diversity of farming systems in two different kinds of sampled village settlements (connected and isolated). The first variable was 'number of crops produced on the farm', and the other was 'number of agricultural policies in which the household participated'. The data collected through HHS were tested to explain the variation (if any) among the variables and the farm types.

After a thorough review of the Millennium Ecosystem Assessment (MEA) and Common International Classification of Ecosystem Services (CICES), those ES were selected which were relevant to an agroecosystem. To quantify the different aspects of AES in the study

area, a set of ecological indicators were determined based on the discussion with the experts and the local farmers and stakeholders (Table 4.1). The selection of the indicators was based on precision, time and resource feasibility. The actual AES was indicated by crop yield for regional relevant production system and decision making. Further, the associated environmental externalities were indicated by soil and water conditions. Thus, an emphasis was laid on the chemical inputs and its impact on the soil and water conditions of the region.

Table 4.1 List of AES indicators selected for biophysical assessment

CICES Section	**CICES Division**	**AES Indicator**	**Method Description**	**Reference**	**SDG Target**
Provisioning	Nutrition	Yield	Weight of crops per unit area (kg/ha)	Dale and Polasky (2007); Kragt and Robertson (2014)	2.3 Double agricultural productivity and incomes 2.4 Sustainable Agriculture
	Water	Water quantity	Surface water utilisation for farming purpose (l/s)	de Groot et al. (2010)	
	Material	Raw material	Weight of plant per unit area (kg/household//ha)	Daily et al., 1997	
Regulating and Maintenance	Bio-physical environment	Carbon sequestration	A measurable component of soil organic carbon content (%)	Soil Quality (2017), Verhulst et al. (2010), Palm et al. (2014)	2.4 Sustainable agriculture 13.2 Integrate climate measures into national policy 15.3 Reverse land degradation
		Soil Fertility	A measurable component of available nitrogen (%), phosphorus (ppm) and potassium (ppm) in soil		
		Soil and water Quality	Chemical/pesticidal concentration in soil and water – estimated by pH and EC	Loewy et al. (2003), Mottes et al. (2014)	
		Diversity of pollinators	Diversity of pollinators - spotting different species	Nicholls and Altieri (2013)	2.4 Sustainable Agriculture

i. Yield of the crops were determined using the information given by farmers during HHS, where one had to believe the respondent. An average crop productivity (in kg/ha) was calculated for connected and isolated villages, so as to compare the farming system and variety of crops produced across the landscape.

ii. Raw material obtained from the farm fields was determined by questionnaire method and cross-checked by weight survey method (Martin, 1995). The amount supplied for different households were quantified to give an average quantity collected by a household per year (kg/household/year).

iii. The water supplied for the agricultural purpose was calculated using a bucket method based on flow of water (l/sec) in the field.

iv. For the assessment of the biophysical environment, soil testing and analysis were done. 180 soil samples were collected from the study area. The sampling sites were randomly selected from each system for the collection of soil samples from two different depths of 0-15cm and 15-30 cm. Soil samples from different depths were weighed, labelled and stored in separate collection bags at the site of sampling. For the analysis, quartering technique was used for the preparation final soil sample, which were air dried and weighed again; crushed, and passed through a 2mm sieve.

The following parameters of soil were analysed using different methodologies and their interpretation was based on Muhr et al., 1965 (Table 2).

a) pH – determined in a soil-water suspension using digital pH meter
b) Organic carbon (OC) – determined by Walkley and Black (1934) method
c) Total nitrogen (N) – estimated using micro Kjeldahl digestion and distillation method (Jackson, 1967)
d) Available phosphorus (P) – estimated using photoelectric colorimeter (Allen, 1989)
e) Available potassium (K) – estimated using flame photometer (Jackson, 1967)

Table 4.2 Interpretation of soil rating

Rating	**OC (%)**	**N (kg/ha)**	**P (kg/ha)**	**K (kg/ha)**
Low	<0.40	<272	<12.40	<113
Medium	0.40-0.75	272-554	12.40-22.40	113-280
High	>0.75	>554	>22.40	>280

Plate No.7 Soil sampling

v. For the determination of soil and water quality in the study area, electrical conductivity (EC) of soil and water samples was measured by digital conductivity meter. The water samples were collected and properly labelled from different sources, namely, field drainage water, river water, tap water, and spring water. Information on synthetic fertilizers and pesticides were collected from the farmers; regarding their identity and application rate.

vi. Pollinator observations in different management systems were observed during bloom period of different crops; thus, majority of the fields were visited all-round the year. To standardize the observations, the visits were made between 07:00 and 12:00 hour, under favourable climatic conditions. During each farm visit, two sites were randomly selected to assess the farm level pollinator abundance (based on Nicholson et al., 2017), and one hour observation was made in each selected site per visit per farm. Only those pollinators were recorded, which landed on the flower, making it a legitimate visit for resource collection. The individuals/pollinators were primarily identified with the help of farmers, which were later referred to experts and compared with the published material.

4.6.3 Adaptive Capacity

In this study, AC was employed to mean smallholder farmers' accessibility and usage of resources to enhance their ability to cope with the changed standards of living and adapt towards a more sustainable livelihood. The indicators used for the study were mostly based on the Sustainable Livelihood Framework, comprising of five assets categories – human, social, natural, physical and financial. The study tried to design a sector- (agriculture/horticulture) and region- (mountainous area) specific assessment using indicators, keeping in mind the regional, socio-economic and cultural background. Thus, a local adaptive capacity index (LACI) approach was used to calculate the AC. This approach provides specific geographic AC of farmers for informed policy directives (Alhassan et al., 2018).

After a thorough study of the literature, the determinants of farmers' AC were first categorised into economic, social, technology, infrastructure, institution, awareness and training. After being reviewed and discussed with the supervisor and other experts, a final set of indicators were finalised for the main determinants. Both the determinant and indicators were weighted by assigning relative scores, based on the community's perception. Two assumptions were taken into consideration: (i) the AC perception might vary among the individuals/community and experts, and (ii) accessibility of the village (location) will impact

the agricultural-based livelihood constraints as well as the local AC for socio-economic development.

Table 4.3 Determinants, their specific indicators and the related assumptions (Based on: Abdul-Razak and Kruse, 2017 and Alhassan et al., 2018)

Determinant	Indicator	Indicator Assumption
Economic Resources	Diversity of source of income	A farmer with more diverse sources of income, availability of remittances and access to credit are more economically able to adapt to socio-economic stress than the one's without them.
	Remittance	
	Access to credit	
Social Capital	Access to family/household labour	More access to family/household labour enhances the social capital of the farmers. Participation in farmer-based organisations or others enhances the social networking.
	Participation in farmer-based organisations	
	Participation in other organisations	
Awareness and Training	Knowledge and acceptance of climate change	Knowledge and acceptance of climate change is an important step that enhances AC. Farmers with higher levels of education and greater access to climate information have increased potential to accept and adapt to stressors and are often more prepared. The number of years of experience in farming is highly correlated with the level of knowledge and skill related to adapting to any change and variability using technology which can be further enhanced with access to agricultural extension services.
	Level of literacy	
	Access to climate, agriculture, livestock and other livelihood related information,	
	Farming experience	
	Formal and informal training	
	Access to extension service	
Technology	Knowledge of seed varieties	Farmers with more knowledge on seed varieties, soil moisture retention, soil fertility are more capable of adapting to adverse impacts of change.
	Knowledge of soil moisture retention technique	
	Knowledge of soil fertility and management	
	Knowledge of farm mechanization	
	Rain water harvesting	
	Adaptation of eco-friendly farming practices	
Infrastructure	Land holding size	Farmers with large land holdings and ownership, stand a better chance of diversifying their farming practice. Farmers with access to irrigation infrastructure have greater capacity to adapt to drought. Access to good road network and market enhances farmers' access to input and output sources.
	Land holding ownership	
	Irrigation infrastructure	
	Access to road	
	Access to market	
	Processing and storage unit	
Institutions	Government subsidy	Farmers with access to government subsidies, disaster relief assistance and/or NGO support enhances AC in times of climate shocks and disturbances.
	Disaster relief assistance	
	Governance system	

In the first phase of analysis, the finalised six determinants of AC and their respective indicators were presented, discussed and ranked by the experts. The ranking technique of Fabbris (2013) was applied while conducting the interviews. Then the ranking scores were relatively proportioned to an assumed maximum (total) AC score of 100. The Ranking I score for each determinant is the average of all the ranking scores assigned to it by all the experts.

In the second phase, a weighted average index (WAI) analysis was applied to assess the satisfaction level of the local community in correspondence to the determinants of AC. This helped validate the developed framework for assessing the local AC, as the determinants and indicators were broadly characterized, supported and calculated on the basis of expert's knowledge, experience and ranking scores. For WAI, the individual respondent was asked to score the determinant for their satisfaction level based on a 0-2 Likert Scale (0 – low, 1 – moderate and 2 – high).

WAI was estimated using the following formula;

$$\text{WAI} = \frac{F2W2+F1W1+F0W0}{F2+F1+F0} = \frac{\sum FiWi}{\sum Fi}$$

Where, F = frequency; W = weight of each scale; I = weight (2 = high satisfaction, 1 = moderate satisfaction and 0 = low satisfaction)

In the third phase, surveyed questionnaires were assessed and a composite index approach was used to identify the LACI score for each respondent (based on Abdul-Razak and Kruse, 2017). The interviewees assessed the indicators using a Likert scale of 0 to 5 (0 being the minimum and 5 being the maximum on the scale of satisfaction) based on the farmers' perception regarding its utility in mountain farming and livelihood. The LCAI score was calculated in the following three stages;

a) Calculation of the score for each indicator – the indicator score for each indicator was separately determined by aggregating the respondent scores relative to a Likert scale of 0 to 5.

   Equation 1:

   I = (Cumulative response score/Maximum response score)x5

b) Calculation of the capacity score for each determinant – it involved the summation of the indicator scores (in the previous step) for each determinant relative to their respective ranking score.

Equation 2:

Capacity Score D_x= (ΣI(D_x)/the maximum ΣI(D_x)) x Ranking score for D_x

Where, ΣI(D_x) = the cumulative I scores for D_x

c) Calculation of the LACI – it involved the summation of capacity scores of all the determinants and converting it to an AC index between 0 and 5.

Equation 3:

ACI= (ΣD/100)x5

Where, ΣD=the summation of the capacity scores of all the determinants

The levels of AC were categorized as follows **(**based on Egyir et al., 2015);

Table 4.4 Categorization of Adaptive Capacity

Level of Adaptive Capacity (AC)	**ACI score range**
Very high AC	4.01-5.00
High AC	3.01-4.00
Moderate AC	2.50-3.00
Low AC	1.51-2.49
Very low AC	0.00-1.50

Chapter 5

Result and Discussion

This chapter deals with the results of empirical analysis pertaining to different objectives of the study, under different sections. The chapter is divided into four sections. The first section 5.1 is related to the documentation of traditional knowledge and traditional agriculture in the study area. The second section 5.2 deals with the assessment of agroecosystem services in the study area. The third section 5.3 covers the results regarding the the farmers' local adaptive capacity. Finally, in section 5.4 sustainable livelihood development strategies for the region have been suggested.

5.1 Traditional Knowledge and Traditional Agriculture

5.1.1 Traditional Cultural Expression

A country has its roots embedded in its rich cultural heritage, building the cultural identity of its citizens. The Tons River valley is a land of legends and is considered to be the birthplace of Sanskrit epic Mahabharata. According to the local mythology, the Pandava attempted their descend to heaven (*Swarg*) via the Swargarohini peak but only Yudhishter (the eldest Pandava) could make it. The local community of this region claim to trace their lineage to Kaurava clan and regard themselves as the descendants of Duryodhana (the eldest Kaurava). It is believed that the local people mourned and wept so much on the death of Duryodhana in the battle of Kurukshetra that their tears became the river named 'Tamas' (meaning sorrow). The same river is now known as Tons and its water is still not used by the older generation for drinking purpose, as the local belief goes that the tears still continues to flow. The old people of the valley believe that their ancestors did not worship Duryodhana for his evilness but because he was powerful. They also believe that Duryodhana did not actually die in Mahabharata war but actually fled to the Tons valley. Some of the elders also claim that the people of the valley fought on the side of Kaurava. According to the local inhabitants, neither any king of Garhwal nor any British were ever able to claim authority over the valley. The elder generation is completely dedicated and loyal to their lineage and deity. There is a beautiful temple in the village of Jakhol which is dedicated to Duryodhana.

Plate No.8 Temples in the selected villages

Karan Temple at Deora village

Someshwar Maharaj Temple at Dhatmeer village

Someshwar Maharaj Temple at Osla village

Earlier the local people use to worship Duryodhana as their deity, but now many people reject any association with the Kaurava and claims Lord Shiva as their deity. The villagers have distanced themselves from the mythological belief, as it was giving their region and people a bad image. The temples in the village of Osla and Dhatmeer are now dedicated to Someshwara Maharaj (a manifestation of Lord Shiva) which were once the temples of Duryodhana. The residents of Naitwar, Gainchwan Gaon and Deora village associate their lineage to '*Daan Veer Karan*' and pray for prosperity at the Karan temple in Deora. The villages under the realm of Duryodhana practiced animal sacrifice and took intoxicants, opposite to those following Karan. Soon, the educated men of the valley claimed their deity to be Someshwara Maharaj and outlawed the traditional practices. Traditionally during festivals, the Duryodhana was carried outside on a palanquin made of freshly cut pine saplings. Whereas, Karan was placed on a tiger skin (a symbol of royalty) instead of a wooden palanquin.

Several local festivals are celebrated in this region. Every year in January (Pos Mah), *'Pos ka Tyohar'* is celebrated, in which different food items are prepared every day, like, *'churoli'* (chappati stuffed with poppy seeds, urad pulse or coconut), *'khiseer'* (urad *khichdi*), *'adka'* (goat and sheep intestines filled with rice, phaphar and salt). On the day of Makar Sankranti, a fair is organized at Deora. The villages of *'Singtur Patti'* (ridge/landscape/region) are divided into two teams – *'Pansai'* and *'Sathi'*. According to the local tradition, whenever a cow dies in the Deora village, its skin is used to make a ball (shape of football). The priests at the Karan temple offers prayers to facilitate the process of sanctity. To make the ball strong and durable, it is coated with a red paste made of natural ingredients. Every household of *Singtur Patti* contributes some amount of rice which along with the ball is kept in Karan temple. On the day of Makar Sankranti, the people of *Pansai* and *Sathi* dresses up and gather on the ground located between the two villages – Gainchwan Gaon and Deora, and cheer their respective teams. The event gets started with a series of drum beats and local songs. Both the teams gather on either side of the ground and the coordinator throws the ball in the center of the ground. The chief *purohit* (priest) blows the conch shell, ladies shower flowers and the game begin. The two teams are supposed to get the ball on their assigned side of the ground. This is known as '*Gaind* (ball) *ka mela*' or 'Gendua Fair'.

Plate No.9 Traditional cultural expression

Traditional dress and ornaments of the Tons valley

Traditional musical instruments – Dhol and Damaon

During the sowing of kharif crops*, 'Karan Maharaj ka Mela*' for good crop and prosperity, is organized at Deora temple. All the people of *Singtur Patti*, who follow Karan as their deity, gathers in the celebrations with *'dhol, damaon,* and *rangsingho'*, wearing their traditional dresses and ornaments. They perform traditional songs and dance like, *'tandi* and *ranson'*. It is believed that the god blesses one of the locals by communicating through the human body which is known as the *'mali'*, who walks and dances on sharp *'dangre/fharsa'* and puts it in the mouth as well. A *'Someshwara Maharaja ka Mela'* is also organized in Dhatmeer, which is generally attended by all those locals who follow Someshwara. The idol of Someshwara is placed with sanctity at one place, where the attendee's worship the deity by singing songs and dancing. There is a different side to Diwali festival as well. When the entire nation is busy celebrating Diwali, the people of Tons valley ensure a good kharif yield of rice, chaulai and mandua. After the harvest, almost a week-long Diwali festivity in the region begins, known as *'Budhhi Diwali'*.

5.1.2 Traditional Crops

In the selected valley, the pre-dominant land use is rainfed agriculture, where all the households are involved in farming. The cropping system is divided into two seasons, i.e. kharif (April-October) and rabi (October-April). The local people generally rely on agriculture produce to meet their daily food requirement, therefore, 100% households are subsistence in nature. Out of the various predominant food crops, 29 crop species (cereals, millets, pulses) are grown in the traditional agroecosystem of the study area (Table 5.1).

Table 5.1 List of traditional crop species cultivated in the study area

Crop Species	Common Name	Local Name	Use
Allium cepa	Onion	Pyaz	Vegetable
Allium humile	Chives	Faran	Condiment
Amaranthus frumentaceus	Amaranth	Ramdana	Grain
Amaranthus oleracea	Amaranth	Chaulai	Vegetable
Brassica compestris	Mustard	Sarson	Vegetable and Cooking oil
Canabis sativa	Hemp	Bhaang	Condiment and Vegetable

Chenopodium album	Wild Spinach	Bathuwa	Vegetable
Cleome viscosa	-	Jakhiya	Condiment
Echinochloa frumentacea	Barnyard Millet	Jhangora	Grain flour
Eleusine coracana	Finger Millet	Mandua	Grain flour
Fagopyrum esculentum	Buckwheat	Oggal	Grain flour
Fagopyrum tataricum	Buckwheat	Phaphar	Grain flour
Glycine spp.	Soyabean	Kala Bhatt	Pulse
Glycine soja	Soyabean	Bhatt	Pulse
Glycine max	Soyabean	Soyabean	Pulse
Hordeum himalayens	Naked Barley	Owa-jau	Grain flour
Hordeum vulgare	Barley	Jau	Grain flour
Macrotyloma uniflorum	Horse Gram	Gahat	Pulse
Oryza sativa	Paddy	Red Rice	Grain
Perilla frutescens	Perilla	Bhangjeera	Condiment and Cooking oil
Phaseolus vulgaris	Kidney Bean	Rajma	Pulse
Setaria italica	Foxtail Millet	Kauni	Grain
Solanum tuberosum	Potato	Aalo	Vegetable
Triticum aestivum	Wheat	Gehun	Grain flour
Vigna angularis	Adjuki Bean	Rains	Pulse
Vigna mungo	Black Gram	Urad	Pulse
Vigna radiata	Green Gram	Mung	Pulse
Vigna umbellata	Rice Bean	Bhotiya	Pulse
Zea mays	Maize	Mungri	Food

Plate No.10 Agricultural landscape of traditional crops

Agricultural field of Amaranth (*Amaranthus frumentaceus)*

Agricultural field of finger millet (*Eleusine coracana*)

Traditionally, the local people use to follow barter system of exchange; cereals, millets and pulses from the Tons valley in exchange for vegetables from the low lying nearby areas. They utilise family labour and follow agricultural practices, like, ploughing of fields, manual weeding, application of organic manure (compost, cow dung) and using the seeds of previous season crop. In order to maintain the soil fertility of their fields, the people keep one half of their land fallow during the winter season alternately for a time period of two years. Due to the commercialization of agriculture sector, the farming system in the mountains have drastically shifted towards cash crops.

The current study of the selected villages indicates that there has been a drastic decline in the area under traditional crop varieties like *Oryza sativa*, *Triticum aestivum*, *Eleusine coracana* and *Amaranthus spp*. And effectively replaced by cash crops like *Phaseolus vulgaris, Solanum tuberosum* and horticultural crops such as apple. The local people still continue to grow crops like rice, wheat, maize, ragi, other pulses as a staple for the household needs, still many of the households tends to purchase the food products like cereals, pulses, flour from the local market.

The mountain ecosystem is losing its natural resource due to a variety of factors related to economy, societal development, policy, institutional arrangement and governance. It is difficult to estimate how much of the traditional crop resource and associated knowledge has already been lost in the past decades. Thus, conservation efforts are needed to protect the surviving TC, which are not only important for the local communities but are necessary to combat the global issue of hunger and malnutrition. In an attempt to understand the complex relationship between human perspective and the factors responsible for the shift in the cropping pattern are presented in the following tables.

Table 5.2 Socio-Economic factors responsible for the loss of traditional crop diversity

1.	Economic situation	Due to the lack of economic opportunities, farmers of the valley have integrated livelihood system involving crop cultivation, livestock, forestry-based enterprise, etc. Originally, the TC were grown under marginal conditions with negligible inputs, providing low yield and low income. Thus, the local farmers shifted to other activities. For example, replacement of mixed cropping system to monocropping pattern and

		apple farming. Over the time, the area under traditional agroecosystem reduced.
2.	Population growth	As the human population increased overtime, so did their families and households. This led to the division of land amongst the family members, leading to fragmented lands and uneconomic crop yield, compelling the farmers to take up other livelihood options.
3.	Out-migration	The mountain community (specifically youth) is migrating to the plain areas for education and jobs. There is a reduced interest in traditional knowledge, culture and way of living leading to land abandonment and degradation.
4.	Labour shortage	The people are involved in multiple activities for income generation, like, labour work on dam construction site, porter, tourist guide, livestock, etc. This creates a shortage of labour for farming activities.
5.	Lack of institutional support	There poor roads, tele-connectivity, isolation and hard life has led to lopsided developmental activities. The mountain already lack infrastructural support for development, hence they giving up on traditional farming and opting for cash crops that gives them immediate returns.
6.	Change in food preferences	For many decades, people preferred finger millet flour over wheat flour or foxtail millet over rice, but now shift in the food choices is being observed. The younger generation is more inclined towards rice and wheat as staples.
7.	Social-cultural values	Due to the lack of systematic documentation of TC, MAPs, the younger generation is unaware of the importance of the rich agrobiodiversity. As the outmigration is increasing, so is the discontinuation of the cultivation of local varieties.

Table 5.3 Ecological factors responsible for the loss of traditional crop diversity

1.	Land abandonment	This has led to weed infestation and severe soil erosion, affecting the overall productivity of the land.
2.	Climatic uncertainty	Dry spells, cloudbursts, landslides, heavy hailstorm, temperature and monsoon shifts has made the farmers vulnerable towards investing their hard work, time and money into TC from which they fetch low returns.

3.	Hydrological imbalances	Drying of small streams and natural springs along with lacking irrigational facilities has made agriculture less desirable among the locals.
4.	Human-wildlife conflicts	As the villages are located along the forest fringe, the fields are often destroyed by the wild animals, creating a monetary loss for the farmers.

Table 5.4 Policy and governance system responsible for the loss of traditional crop diversity

1.	Public Distribution System	Easy availability of rice and wheat through PDS has enhanced the purchasing power of mountain community, negatively impacting the cultivation and consumption of diversified TC.
2.	Subsidies on agricultural inputs	The cost of inputs like chemical fertilizers, pesticides, agricultural equipment's has promoted a shift towards modern agriculture involving high yielding varieties or cash crops.
3.	Agricultural policies	The policies being implemented are not region specific, hence it lacks to understand the needs of mountain farmers and/or mountain agroecosystem. 'One policy for all' rule is being followed which doesn't give any fruitful returns.
4.	Government support	There is a lack of agricultural extension, training and awareness service in the mountain villages. A government based mechanism for the production of TC is unavailable. The market link is also inefficient, where the farmers have to suffer because of the middlemen.
5.	Research bias	A very little emphasis has been given to the importance of mountain-based TC and food recipes, which even have medicinal and health importance. Agricultural research is mostly concentrated in the plain fertile areas and major crops like rice, wheat and maize.

Plate No.11 Traditional practices in agriculture

5.2.3 Ethnobotanical knowledge on medicinal and aromatic plants

Despite the development of modern healthcare services, rural communities, particularly in remote mountain regions of IHR, still use a large number of medicinal plants for the treatment of various ailments (Malik et al., 2015). The results revealed that, plant-based traditional knowledge system formed the primary basis of healthcare in the study area. The geographic isolation of communities in the Tons Valley of Govind Wildlife Sanctuary and National Park, has strengthened the traditional knowledge base of medicinal plants. Local people show preferences for the use of traditional herbal remedies due to their belief in the effectiveness of folklore herbal remedies (Malik et al., 2015). In this study, local people residing in the remote and inaccessible high-altitude areas Dhatmeer and Osla largely depended upon the traditional remedies for general health issues, like, cough, cold and fever.

Table 5.5 General health infrastructure available in the study area

Name of the Village	Availability of motorable road	Walking Distance to reach the village	Distance from the market	Availability of chemist shop in the market	Primary Health Centre/ Government Hospital	Ease in availability of transport
Gainchwan Gaon	Yes	0	5-6 km	Yes	17-18 km	Yes
Deora	Yes	0	8-9 km	Yes	20-21km	Yes
Dhatmeer	No	6-7 km	6-7 km	No	43-44 km	No
Osla	No	17 km	17 km	No	54-55 km	No

The reason being lack of alternative options, inaccessibility to a medical facility and inconvenience of transport. Another reason was the proximity of the village settlements to the sub-alpine and alpine meadows (bugyals) which are the reservoirs of medicinal plants. In the study area, these ‘bugyals’ are frequently being visited by the pastoralists for livestock grazing and by tourists for trekking and camping. Even for the villages located on a roadhead or near a market (Gainchwan Gaon and Deora), the community gave preference to traditional medicine. Even though there was a primary health centre at the village Gainchwan Gaon, there was no availability of doctor or basic medical facility. Amidst, the lack of proper medical guidance, the local community was skeptical to trust the nearby chemist shops and thus continued with their traditional remedies. In case, of medical emergencies, many people have suffered due to

their physical isolation and lack of tele-connectivity in the area. It was also evident, that since the inhabitants of remote villages appreciated the use of medicinal plants, they were apparently much more aware and alert to conserve these species by sustainably utilizing them in their daily lives.

A total of 55 MAPS were recorded in the study area, which were grouped into 15 different health ailment categories (recorded in Appendix-B). The complete detail of different MAPs and their traditional uses are as given in Table 5.6.

Table 5.6 Ethnobotanical knowledge of the wild plant species used in the traditional health care system

Scientific Name	Family	Vernacular Name	Part Used	No. of diseases treated	Folk Medicinal Use	Aromatic & Condiment
Aconitum balfourii (Bruhl) Muk.	Ranunculaceae	Meetha	Tuber	1	Snakebite	
Aconitum heterophyllum Wall. Ex Royle	Ranunculaceae	Atis	Root	3	Headache, fever and stomach ache	
Aesculus indica Colebr.	Hippocastanaceae	Pangar	Fruit	3	Sore throat and rheumatic pain	
Allium stracheyi Baker	Alliceae	Faran/Jambo	Whole	4	Cough, cold, nasal and lung infection	Condiment
Angelica glauca Edgew.	Apiaceae	Choru/Gandhra-yan	Root	5	Headache, fever, skin rashes, wounds, toothache	Condiment
Arnebia benthamii	Boraginaceae	Balchari/ Laljari	Root	1	Hair growth and hair fall	
Artemisia maritima	Asteraceae	Purchu	Root	2	Stomach disorder and epilepsy	
Artemisia nilagirica (Clarke) Pamp.	Asteraceae	Kunj/Panti	Leaf	6	Boils, cuts, wounds, intestinal worms, skin infection, asthma	
Asparagus racemosus L.	Liliaceae	Satavari	Root	1	Epilepsy	
Berberis aristate DC.	Berberidaceae	Kingore/ Kilmora	Bark, Root	3	Stomach ache, eye problems, fever	
Betula utilis D. Don	Betulaceae	Bhojpatra	Bark	6	Cough, cold, cuts, wounds, jaundice, and psychological problems	
Cannabis sativa L.	Cannabaceae	Bhaang	Leaf	5	Piles, cuts, skin ulcers, burns, muscular pain	Condiment
Carum carvi	Umbelliferae	Kala jeera	Seed	1	Dyspepsia	Condiment

Cedrus deodara Loud.	Pinaceae	Devdar	Bark	4	Rheumatism, back pain, wounds and cuts	
Centella asiatica	Apiaceae	Bramhi	Whole	1	Brain functioning and power	
Chenopodium album	Chenopodiaceae	Bathuwa	Leaf	1	Constipation	Wild Vegetable
Cinnamomum tamala Nees	Lauraceae	Dalchini/ Tejpaat	Bark, Leaf	3	Throat pain, headache, diabetes	Aromatic and Condiment
Cynodon dactylon L.	Poaceae	Doob	Whole	2	Dysentery and vomiting	
Dactylorrhiza hatagirea (D. Don) Soo	Orchidaceae	Hatazari	Tuber	5	Wounds, cuts, fever, dysentery, hair growth	
Datura stramonium	Solanaceae	Dhatura	Whole	2	Skin disease and joint pain	
Dioscorea deltoidei	Dioscoreacea	Genthi	Tuber	1	Wounds	
Diplazium esculentum Sw.	Polypodiceae	Lingra	Whole	3	Anti-malarial, jaundice and constipation	Wild Vegetable
Galium aparine L.	Rubiaceae	Kuri	Leaf	1	Cooling agent	
Geranium wallichianum D. Don ex Sweet	Geraniaceae	Ratijari	Root	2	Headache and rheumatic pain	
Grewia oppositifolia Drummond ex Burret	Tiliaceae	Bhimal	Bark	1	Pregnant women for smooth delivery	
Hippophae salicifolia	Elaeagnaceae	Amees	Fruit	6	Cold, cough and gastric issues	
Hypericum elodeoides Choisy	Hypericaceae	Vasanti	Leaf, root	1	Controls vomiting	
Juglans regia L.	Juglandaceae	JangliAkhrot	Fruit	2	Treatment for ringworm, oil used for massaging the legs of pregnant women	
Lyonia ovalifolia (Wall.) Drud.	Ericaceae	Anyaar	Leaf	2	Itching and allergy, fungal infection	
Mentha longifolia (L.) Hudson	Lamiaceae	Pudina	Leaf, Flower	1	Indigestion	Aromatic
Morchella esculenta L. Peres	Helvellaceae	Guchhi	Whole	2	Cough and cold	Wild edible
Nardostachys grandiflora DC.	Valerianaceae	Jatamasi	Rhizome	5	Blood pressure, jaundice, leprosy, heart disease	

Origanum vulgare L.	Lamiaceae	Ban Tulsi	Whole	4	Fever, cough, bronchitis and epilepsy	
Paeonia emodi Wall ex Royle	Paeoniaceae	Chandra	Whole	5	Whooping cough, diarrhea, intestinal spasm, cuts	
Perilla frutescens (L.) Britton	Lamiaceae	Bhang jeera	Seed, leaf	3	Cold, abdominal pain and massaging infants	
Picrorhiza kurrooa Royle ex Benth	Scrophulaceae	Kutki	Root	3	Stomach ache, typhoid and jaundice	
Pinus roxburghii Sarg.	Pinaceae	Chir	Resin	2	Cut and wounds	Aromatic
Pinus wallichiana Jacks.	Pinaceae	Kail	Resin	1	Arthritis	
Pleurospermum angelicoides	Apiaceae	Chippi	Whole	3	Dysentery, stomach problems and typhoid fever	
Podophyllum hexandrum Royle	Podophyllaceae	Bankakri	Fruit, root	2	Cuts and wounds	
Prinsepia utilis Royle	Rosaceae	Bhaikal	Seed	2	Muscular pain and wounds	
Reinwardita indica Dumortier	Linaceae	Pauyoli	Flower	1	Mouth wash	
Rheum emodi (D. Don)	Polygonaceae	Dolu	Root	3	Boils, wounds and cuts	
Rhododendron arboretum Smith	Ericaceae	Burans	Flower	7	Bleeding nose, arthritis, boils, wounds, jaundice, blood pressure and heart tonic	Wild Edible
Rubus ellipticus Smith	Rosaceae	Hinsalu	Fruit	2	Stomach pain and dysentery	Wild Edible
Rumex hastatus (D. Don)	Polygonaceae	Janglipalak	Leaf	3	Wounds, bleeding and generation of internal heat	
Saussurea costus (Falc) Lipsch.	Asteraceae	Kut	Root	4	Toothache, jaundice, snakebite and skin problems	
Saussurea obvallata	Asteraceae	Bharamkamal	Whole	2	Cuts and wounds	
Skimmia anquetilia Taylore & Airy Shaw	Rutaceae	Kedarpatti	Leaf	3	Rheumatism, swelling and wounds	
Skimmia laureola (DC.) Zucc.	Rutaceae	Kasturapatti/ Neerpatti	Leaf	1	Scabies	Aromatic– Incense sticks
Swertia chirayita Roxb. Ex Flem	Gnetianaceae	Chirayata	Whole	2	Fever and diabetes	

Taxus baccata L.	Taxaceae	Thuner	Bark	3	Cancer, bone fracture and keeping body warm	
Thymus linearis Benth.	Lamiaceae	Van Ajwain	Whole	2	Tooth ache and stomach ache	Aromatic
Utrica dioica L.	Urticaceae	Kandali	Leaf	4	Stomach disorders, menstruation, arthritis and boils	Wild Vegetable
Zanthoxylum armatum DC.	Rutaceae	Timru	Bark, fruit	1	Toothache	

According to the recorded data, the maximum number of plant species (Fig.5.1) were used for gastro-intestinal and dermatological ailments (21 each), followed by general health problems (17), skeleton and muscle issues (16), hepatic disorder (6), dental and gynecological issues (5 each), respiratory, circulatory and body heat problems (4 each), antidote, nervous system and hair (2 each) and optical and genetic problems (1 each).

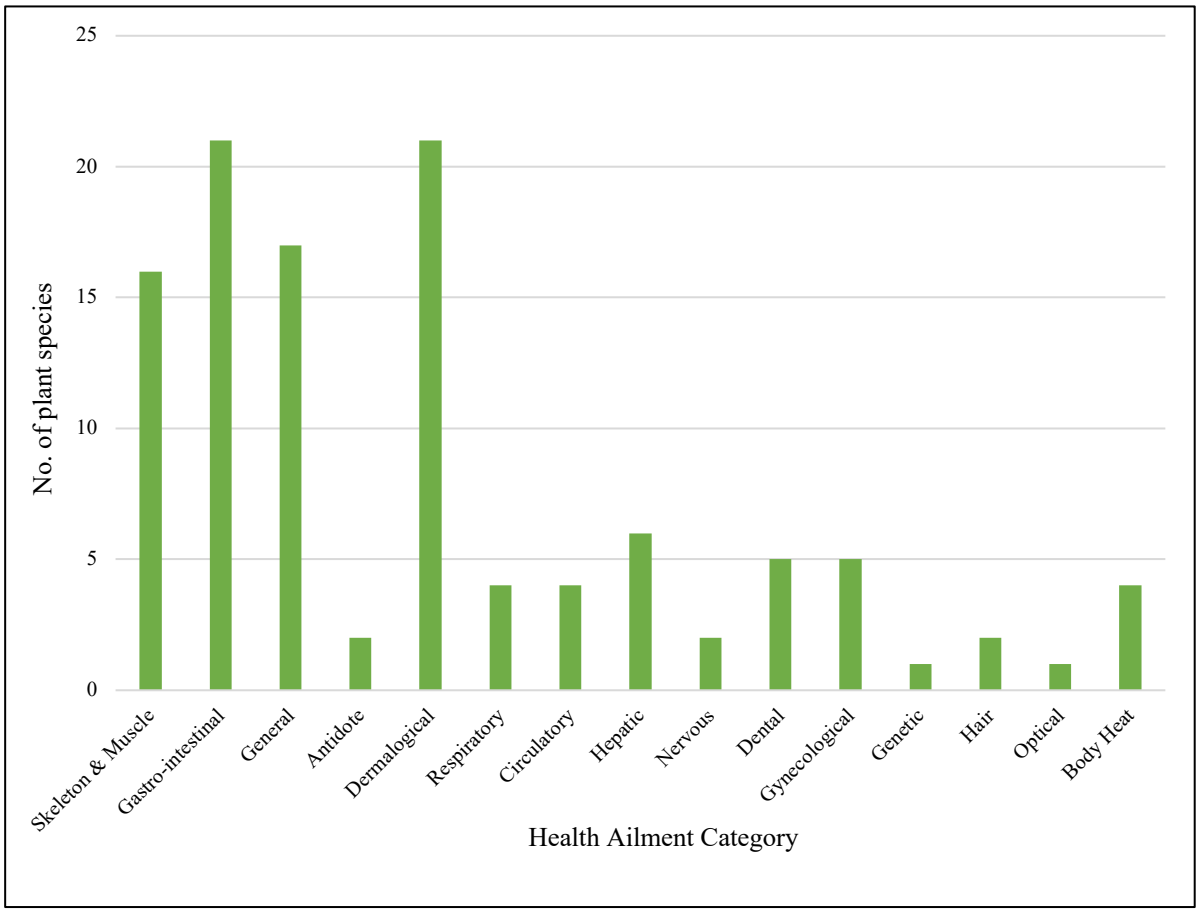


Figure 5.1 Number of plant species used to treat different health ailment categories

Different plant parts were used across the community (Fig.5.2) for traditionally curing different diseases, like, leaves contributed the most (23.64%), followed by roots and whole plant (21.82% each), bark (12.73%), fruits (9.09%), tuber, seeds and flower (5.45% each), resin (3.64%) and rhizome (1.82%). During the survey, it was evident that almost all the people interviewed were aware of few of the most common plant species, which were specially being utilized in their daily eating habits.

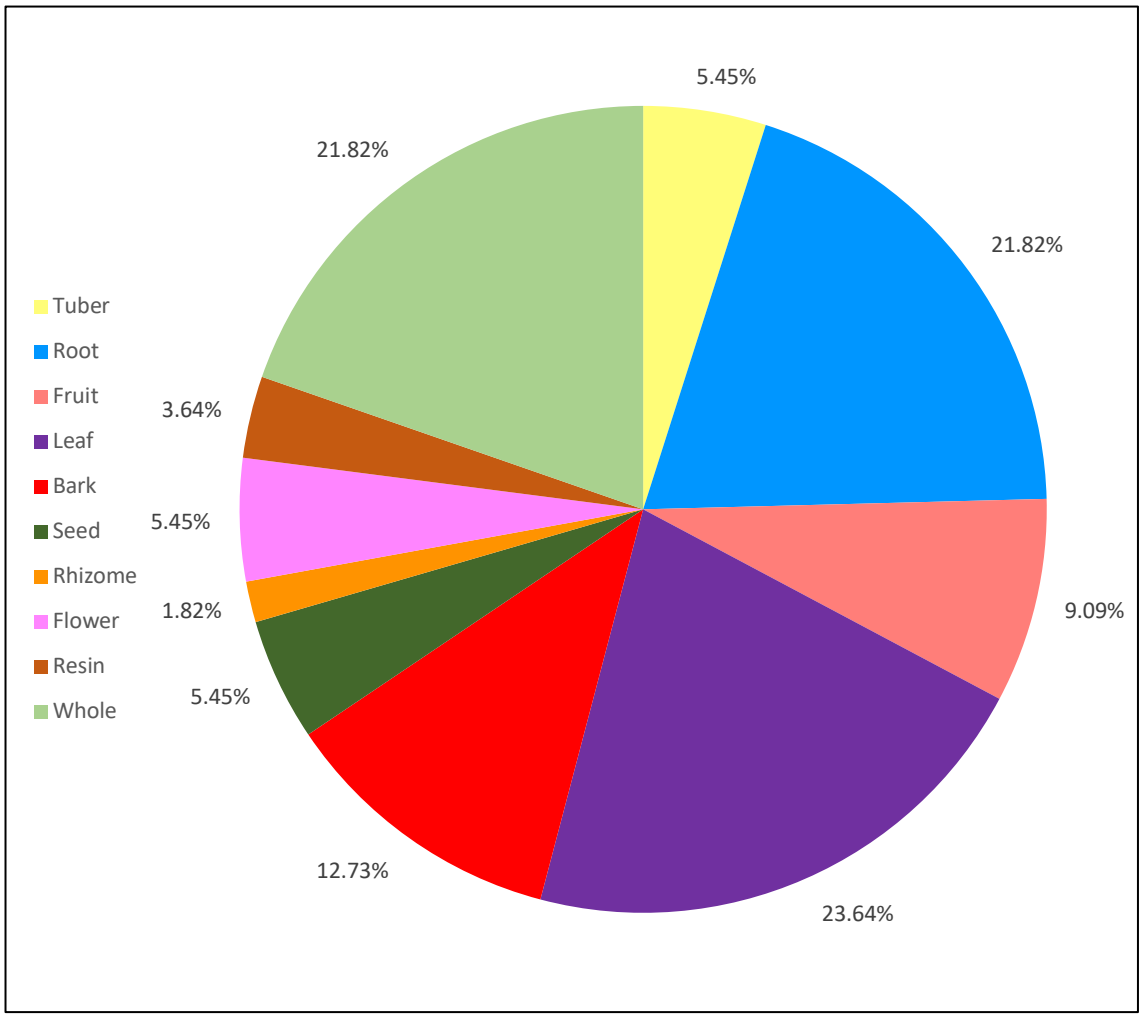


Figure 5.2 Proportion of plants parts used for curing health ailments

Plate No.12 Medicinal plants

Angelica glauca Edgew.
(Choru/Gandhrayan)

Arnebia benthamii
(Balchari/Laljari)

Picrorhiza kurrooa Royle ex Benth
(Kutki)

The Relative Frequency Citation (RFC) shows that *Allium stracheyi* Baker (faran), *Cannabis sativa* L. (bhaang), *Chenopodium album* (bathuwa), *Cinnamomum tamala* Nees (dalchini), *Diplazium esculentum* Sw. (lingra), *Mentha longifolia* (L.) Hudson (pudina), *Rhododendron arboretum* Smith (burans), *Rubus ellipticus* Smith (hinsalu) and *Utrica dioica* L. (kandali) are the most cited and widely known plant species across the three age groups, with the RFC index score of 1. These species were well recognized by the younger generation as they are used in daily household cooking in the form of vegetable, condiment/spice and wild edibles. The other highly cited species across all the age groups were, *Arnebia benthamii* (balchari), *Grewia oppositifolia* Drummond ex Burret (bhimal) and *Cedrus deodara* Loud. (deodar) with RFC index score of nearly 0.96, 0.95 and 0.94 respectively. Some of the least cited species were, *Swertia chirayita* Roxb. Ex Flem (chiryata), *Paeonia emodi* Wall ex Royle (19handra) and *Geranium wallichianum* D. Don ex Sweet (ratajari) all having the RFC index score of nearly 0.22.

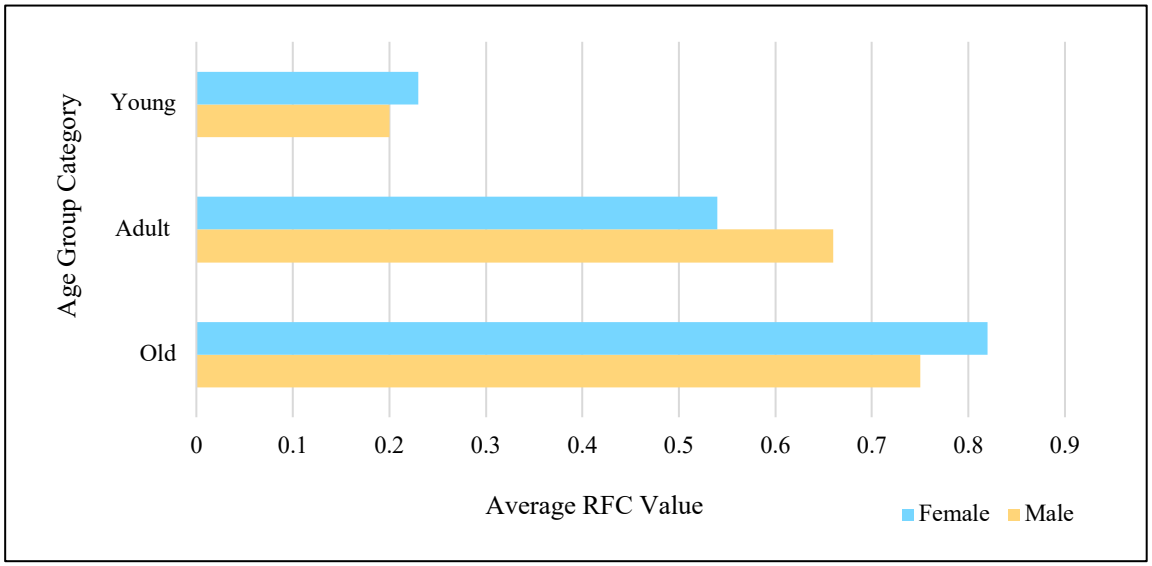


Figure 5.3 Average Relative Frequency Citation of MAP species across different age groups and gender

On comparing the species ranking based on each of the indices, namely, Relative Importance Index (RI), Cultural Importance Index (CI) and Cultural Value Index (CV), not much difference was seen. Culturally, the most important species are, *Utrica dioica* L. (kandali), *Rhododendron arboretum* Smith (burans) and *Allium stracheyi* Baker (faran) with a CI index of 1.766, 1.527 and 1.488 respectively. These species are used in the daily lives of the local community, for example, kandali is cooked in the form of vegetable as it provides warmth to the body specially during cold season, faran is used as a condiment in the daily cooking of pulses and burans flowers are used to make squash and juice keeping the body cool

and energized during the summer heat. *Asparagus racemosus* L. (satavari), *Rheum emodi* (D. Don) (dolu) and *Swertia chirayita* Roxb. Ex Flem (chiryata) are amongst the least culturally important species with a CI index of 0.204, 0.235 and 0.244 respectively, and were amongst the least cited medicinal plants as well.

Similarly, the RI and CV indices also placed *Rhododendron arboretum* Smith (burans) in the top position, because of the multiplicity in the plant use, having the highest number of use reports (NU) of 7, and was cited by all the respondents during the survey. The least important species is *Asparagus racemosus* L. (satavari) and it was cited by only 20% respondents, out of which 57% were old, 36% adult and 7% young. The species which were cited by all the respondents, still differ in their cultural value and importance based on the multiplicity of use. For example, *Cannabis sativa* L. (bhaang) has NU of 3 and *Chenopodium album* (bathuwa) has NU of 1, have CV of 0.262 and 0.067 respectively across the community, even though they were cited by all the respondents.

The result of Informants Consensus Factor (Fic) shows that the genetic and ophthalmic category had the greatest agreement with a Fic value of 1.00, the reason being that a single species was used to treat the associated health problem. For example, for genetic ailment there was only one species *Taxus baccata* L. (thuner) that was used and similarly for ophthalmic related issues, just *Berberis aristate* DC. (kingora) was used. The other categories had nearly the same Fic of 0.09. Gastro-intestinal and dermatological problems were being treated with the highest number of species (21 species each), followed by the category of general health (17 species) and skeleton and muscle (16 species).

Based on Fidelity Level (FL), the most preferred plant species for the medical treatment in the different ailment categories were, for skeleton and muscle related issues *Cedrus deodara* Loud. (deodar), for gastro-intestinal problems *Chenopodium album* (bathuwa), *Mentha longifolia* (L.) Hudson (pudina) and *Rubus ellipticus* Smith (hinsalu), for general health care *Morchella esculenta* L. Peres (guchhi), for antidote *Aconitum balfourii* (Bruhl) Muk. (meetha), for dermatological conditions *Pinus roxburghii* Sarg. (chir), for respiratory issues *Allium stracheyi* Baker (faran), for circulatory issues *Cinnamomum tamala Nees* (dalchini), for hepatic concerns *Picrorhiza kurrooa* Royle ex Benth (kutki), for nervous system related problems *Centella asiatica* (brahmi), for dental concerns *Zanthoxylum armatum* DC. (timru), for gynecological needs *Grewia oppositifolia* Drummond ex Burret (bhimal), for genetic issues *Taxus baccata* L. (thuner), for hair concerns *Arnebia benthamii* (balchari), for ophthalmic

issues *Berberis aristate* DC. (kingora) and for body heat problem *Rhododendron arboretum* Smith (burans).

Amongst the diversity of traditional practices, the weakening of traditional ethnobotanical knowledge was alarming in the study area. The Knowledge Richness Index (KRI) value was highest for the young generation (0.04), implying that they have the least knowledge about the uses of medicinal plants. The KRI value was recorded low for both adult (0.005) and old (0.004) generation group which means that they had a vast knowledge of the traditional medicinal practices. Out of the total 1000 respondents, 37 (6 adult males, 13 old males and 18 old females) of them were able to report all the 55 medicinal plants in the study area. Youngsters and students who were interviewed, knew the plant species but they possessed least knowledge about its medicinal use. It was obvious that due to education and exposure, they preferred the modern medicine over the old traditional practices.

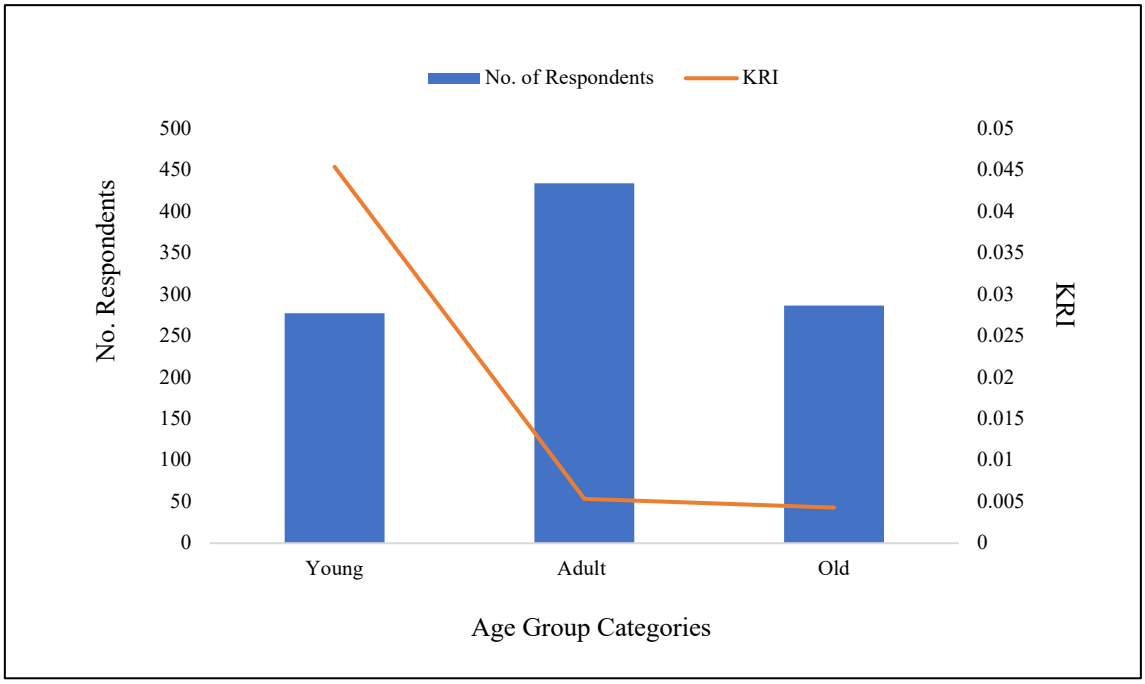


Figure 5.4 Knowledge Richness Index of Respondents

The knowledge of least cited medicinal plants remained confined with the old people, who knew the time of collection, plant parts to be used and method of medicinal preparation. Accumulation of traditional knowledge with the older generation is also a matter of concern, as the losing interests of younger generation had hindered the transfer of this knowledge. Since, the local people showed high agreement on the usage of different medicinal plants (as the informant's consensus factor was high), indicating that the knowledge system is still strong.

5.2 Assessment of Agroecosystem Services

The farming system in the mountains includes crop land, livestock and household units which altogether are linked with the surrounding forest biodiversity, forming a productive system. The locally adapted traditional crop varieties have for long protected the mountain people from absolute crop failure. The study area is still in the phase of change, as every household have some land kept aside for the TC as well. Generally, the mountains are famous for organic farming but the transition in farming practices and continuous use of synthetic chemicals poses a potential threat to the sustainability of agroecosystem.

5.2.1 Characterization of Farms

Two types of farming systems were identified during the FGDs, namely, subsistence farm and conventional farm. Based on the participatory scoring exercise, 100% households are practicing subsistence farming due to their socio-economic and geographical constraints. They utilise family labour to grow the TC of the mountain ecosystem, thus maintaining the agrobiodiversity in the region. There was no recorded use of external chemical inputs in subsistence farming, and are depended on organic manure and biological control of pests and diseases. The conventional farmers, switched from traditional crop varieties and have effectively replaced them by cash crops like kidney bean, potato and horticultural crops such as apple, pear and walnut. They continue to grow crops like rice, wheat, maize, ragi, other pulses as a staple for the household needs, but the area under them has substantially decreased in these households. There is a perceived threat of agrobiodiversity degradation in the region, as the local community prefers cash crops over the TC, for the higher market demand and monetary benefits. On one hand, area under TC has declined, but on the other, area under apple orchards and cash crops like potato and kidney bean has increased in the last eight years. The introduction of apple farming in the Tons valley has raised concerns regarding the sustainability of the agroecosystem as it requires intensive amounts of chemical inputs. The different features were categorized based on the different farm types (Table 5.7) for a qualitative characterization of the agroecosystem in the study area. Relative strength for each criterion (as per the farm type) was rated by the FGD participants as: S (small), M (medium), L (large) and NR (not relevant).

Table 5.7 Qualitative overview of the farm type (* for connected villages and ** for isolated villages)

Criterion	Farm Type	
	Subsistence	**Conventional**
Size of the farm	S	L
External inputs	NR	L*/NR**
Organic inputs	L	S*/L**
Equipment and machinery	S	S
Market-oriented	NR	L
Off-farm income	M	S*/M**
Adoption of agroecological farming practices	L	S*/L**
Agricultural diversity	M	S
Agricultural policies and projects	NR	S

The subsistence farms as well as the conventional farms in connected villages grew a larger number of crops (ANOVA, $p < 0.0001$) in comparison to the isolated villages, implementing a greater agricultural biodiversity. The major reasons given by the farmers were, geo-climatic conditions, water unavailability, labour-force, fragmented land holding and soil conditions. Due to the easy availability of farm inputs, market access and participation in agricultural policies and programs, farmers in the connected villages maintained their agrobiodiversity for income generation. The proportion of farmer households that are beneficiaries to agricultural policies and programs was significantly different in the village settlements (Pearson's Chi-squared test, $p < 0.01$). This may be due to the easy accessibility and connectivity of farmers as well as the policy- and field-workers for the implementation of the same. Approximately, 43% of households in connected villages were beneficiaries to at least one policy, where it was just 20% in isolated villages.

Plate No.13 Types of farm-land

Subsistence Farm

Conventional Farm

According to the local farmers, government national programs like PDS (Public Distribution System) and MGNREGA (Mahatma Gandhi Employment Guarantee Act) have both positive and negative impacts on the local mindset. On one hand, they helped ensure food and economic security, but on the other, people have started abandoning traditional crop farming. According to general perception, it has encouraged the local people to become dependent on purchased food. The availability of staple food grains at a price lower than the cost of production which they might incur on their own lands, along with an increase in outmigration has led to traditional crop abandonment. Many of the educated youth of the region casually rely on the money under MGNREGA, which is being transferred to their bank accounts. The survey revealed that some farmers considered these two national progarmmes as great opportunity to shift to cash cropping, as their families were food secure. There are many agricultural policy measures, such as, National Mission for Sustainable Development, National Food Security Mission, Rashtriya Krishi Vikas Yojana, Paramparagat Krishi Vikas Yojana, Pradhan Mantri Krishi Sinchai Yojana, along with continuous initiatives for subsidies, grants, land development, technological integration, industrial investment, etc. Unfortunately, nobody knows up to what extent are these being administered, implemented, monitored and evaluated?

Even though the farmers in the Tons Valley were aware about the subsidy being granted in the agricultural sector, but a few had the knowledge about the in-depth application process. They condemned the long procedural documentation system, as it required continuous visits to the block and district offices of the State agricultural department. A farmer (Narendra) in the village Gainchwan Gaon, had applied for the procurement of grading and sorting machines on subsidy (for the betterment of the entire region), but it has been pending ever since. The agricultural officers and field workers claim about frequent visits to the villages, organizing training and extension activities, but the villagers have a different story to tell. According to the farmers, the lack of post-harvest processing and management facilities with poor road connectivity makes their apple farming inferior to their neighbors.

5.2.2 Biophysical Assessment (details given in Appendix-C)

a) Yield

The local community rely on the agricultural produce to meet their household needs. The farming system in the region forms a nexus of forest, crops and livestock. The per capita agricultural land availability is highest in Osla (0.13%), followed by Gainchwan Gaon (0.11%),

Dhatmeer (0.07%) and Deora (0.06%). The farming of crops for subsistence generally follow traditional practices, like, manuring, hand weeding, manual ploughing, among others. Amaranth, finger millet, buck wheat, paddy, wheat, foxtail millet, potato and beans forms the household essentials. Cash crops like apple, kidney bean and potato have taken reigns of conventional farming with intensive use of external farm inputs. The farmers are willingly diversifying their farming system through the inclusion of other plants like pear, walnut, kiwi and MAPs. As a result of shift in farming system, there has been a reduction in the area under TC, and a substantial increase of synthetic chemicals which may lead to environmental degradation in the future.

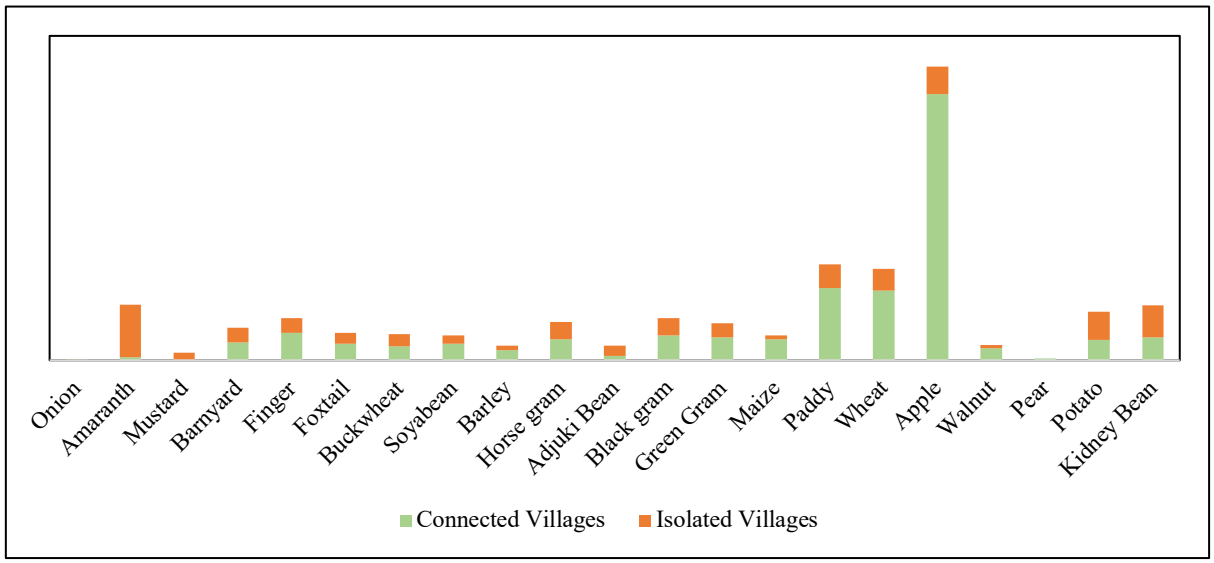


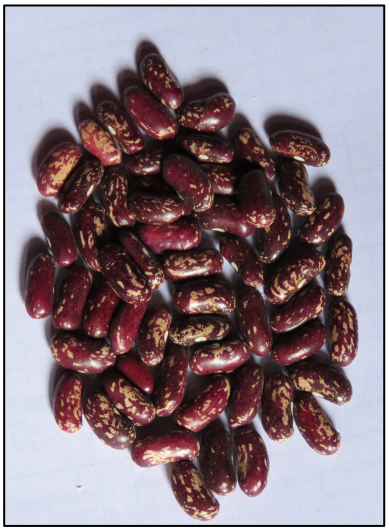
Figure 5.5 Comparison of crop productivity (kg/ha) in connected and isolated villages

The staple crops are similar across the landscape, but the dependency of isolated villages is high on amaranthus, for its easy adaptability, low water requirement, and high productivity (food and fodder). The apple orchards are flourishing in the connected villages (Gainchwan Gaon = 5674.95 kg/ha and Deora = 5811.97 kg/ha), due to climatic conditions, easy availability of inputs, connectivity and market assess. The apple orchards in isolated villages are young, hence the yield is comparatively low at 1175 kg/ha in Dhatmeer and only 13.71 kg/ha in Osla. Even though the farmers used the same varieties, the isolated villages recorded low production due to the sub-alpine climatic conditions and negligible use of synthetic inputs. The isolated villages are currently earning through superior quality production of potato and kidney bean. Of late their focus of isolated villages has shifted towards walnut production (Dhatmeer = 100.05 kg/ha and Osla = 33.23 kg/ha), for its high medicinal-use demand and value.

Plate No.14 Crops cultivated in the study area

Wheat (*Triticum aestivum*)

Buckwheat (*Fagopyrum tataricum*)



Kidney Bean (*Phaseolus vulgaris*)

Apple (*Malus domestica*)

Plate No.15 Apple nursery

b) Raw Material

Few wild seasonal condiments and vegetables are available from the agricultural fields for the household consumption. The local people used them as per the quantity produced, which varied depending on the climatic conditions. Thus, quantification of such small amount was not feasible. An average usage amount of 1-2kg/household was recorded as per the availability during HHS. These wild plants included, *faran* (Chives), *chaulai* (Amaranth), *bhaang* (Hemp), *bathuwa* (Wild spinach), *jakhiya* and *bhangjeer* (Perilla). Crop residue of amaranthus, millets, wheat and paddy is used as fodder biomass. The crop by-product consumption is greater in connected villages (2184.19 ± 56.06 kg/household/year) than isolated villages (1154.68 ± 27.89 kg/household/year), due to poor fodder value of crops grown at high altitude regions, like, potato and kidney beans.

The agriculture in the region is not shrinking in terms of total cropland area, but the transition is definitely impacting the fodder availability to individual farming families. Seasonal variation in fodder consumption is also noticed as during summer season grazing in alpine meadows, forest area and collection of tree leaf fodder is preferred. Whereas, during the winter season, as the region is snow-covered, the livestock are generally stall-fed with crop by-products. Fodder scarcity, in terms of quantity and quality, has increased the livestock dependency on grazing and lopping. It has even become problematic for women who now have to travel long distances into the forests for fodder collection. The continuous dependence of mountain community on forest ecosystem, puts the natural resources under unprecedented pressure. The diversification of agricultural system from TC to cash crops, the by-products of which do not have the desirable fodder value, further increases this pressure. According to the Forest Department, there is an increased problem of abandoned cattle on roadsides and inside the protected area, which is a direct outcome of fodder shortage.

There is a scope for strategies development, for striking a balance in demand and supply of fodder needs of the mountain farmers. Innovative thinking is necessary to envision how barren and uncultivated lands be converted into fodder lands.

Plate No.16 Collection of raw material from agricultural fields

Young cattle are stall-fed

Collection of fodder from agricultural fields

c) Water Quantity

There is a proper availability of drinking water across the villages with a systematic pipeline and tap system, and natural springs. The agricultural land can be divided into irrigated and unirrigated fields. An irrigation system was lacking in the study area, thus the farm fields were dependent on the natural sources of water, mainly rainfall and small streams (locally known as *nala*) flowing along the slope, originating from natural springs (locally known as *shrodh*). The entire agricultural system in the isolated villages is unirrigated and completely dependent on rainfall. As per Agriculture Department (Government of Uttarakhand) 40.80 ha and 12.76 ha is irrigated land in Gainchwan Gaon and Deora, respectively.

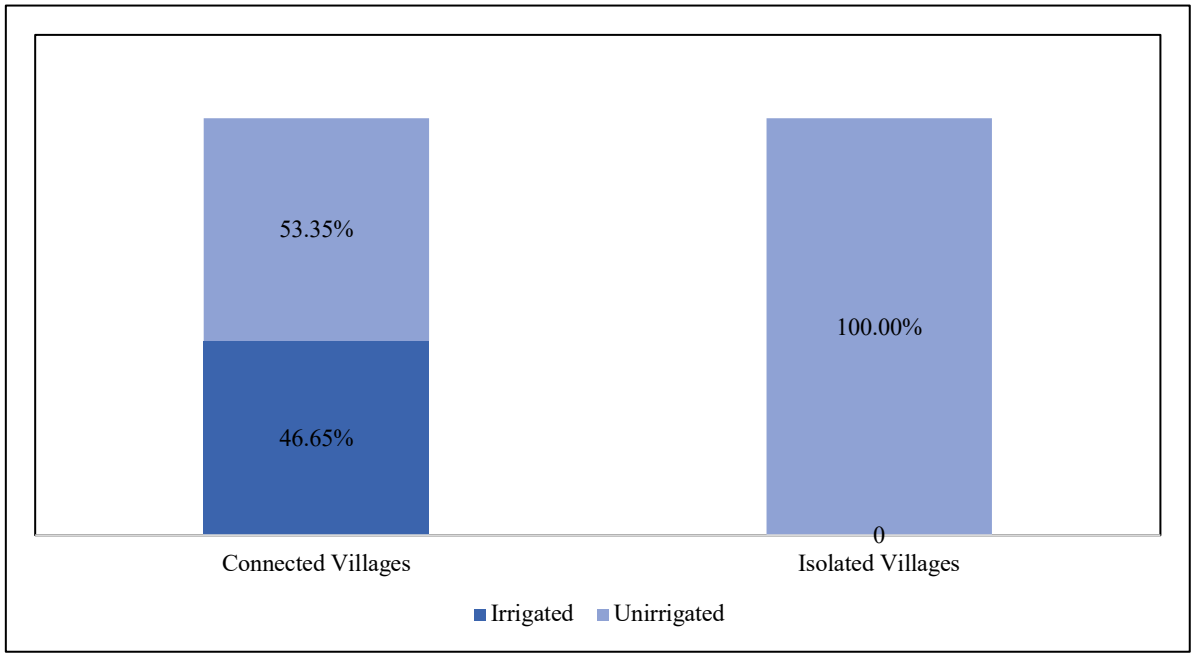


Figure 5.6 Percentage area of irrigated and unirrigated agricultural lands

The irrigation of fields is completely dependent on the natural system and slope of the land. The fields of only those farmers are irrigated which lie on the natural path of stream flow. Many a times, it became a point of conflict as sharing and diverting of water flow requires cooperation among farmers. As per the bucket method, the flow of water was recorded at 0.06 ± 0.04 litre/sec, which is not sufficient enough to irrigate the entire agricultural landscape.

Plate No.17 Natural source of water

Shrodh

Confluence of River Supin and River Rupin at Naitwar

d) Soil and Water Analysis

Table 5.8 Results of soil sample analysis (C = connected villages and I = isolated villages)

Soil Characteristics	Land Management System					
	Agriculture		Orchard		Uncultivated	
	C	I	C	I	C	I
pH	6.50 ± 0.06	6.46 ± 0.04	6.5 ± 0.06	6.46 ± 0.04	6.5 ± 0.06	6.46 ± 0.04
EC (dS/m)	1.18 ± 0.22	1.22 ± 0.07	2.63 ± 0.14	1.37 ± 0.04	1.05 ± 0.08	1.06 ± 0.08
OC (%)	0.52 ± 0.01	0.55 ± 0.001	0.65 ± 0.01	0.59 ± 0.01	0.71 ± 0.004	0.67 ± 0.01
N (kg/ha)	124.02 ± 2.96	106.60 ± 3.43	159.51 ± 3.12	137.80 ± 2.92	216.84 ± 1.91	208.65 ± 1.95
P (kg/ha)	129.84 ± 0.33	133.12 ± 0.04	158.52 ± 0.32	139.30 ± 0.25	148.45 ± 0.35	143.48 ± 0.29
K (kg/ha)	584.22 ± 2.59	631.08 ± 1.52	158.52 ± 0.51	344.77 ± 0.97	319.44 ± 0.34	501.02 ± 0.95

The intensive agricultural practices have contributed in the deterioration of soil health in various ways. A study in China reported severe soil acidification due to excessive and continued input of heavy synthetic nitrogen fertilizer and thereby suppressed crop production in a large area (Guo et al., 2010). Agricultural practices such as the excess use of inorganic fertilizer, use of pesticides, and power tillage, can negatively affect the living community in the soil by damaging their habitats and disrupting their functions (Kibblewhite et al., 2008). Edward (1975) suggested that pesticides tend to persist longer in static soil systems as compared to that in plants and animals. The effect of synthetic chemical inputs on the soil and its associated ES are corelated with their impact on primary productivity of the land. Soil pH is a factor that influences the transformation and a availability of micronutrients to plants (Shivanna and Nagendrappa, 2014). It is a predictor of various chemical activities and thus useful in making management decisions. The soil is neutral in nature, within a pH range of 6.4 to 6.6. It is considered a good range for most of the field crops as well as apple production.

EC is another important indicator of soil and water health, as it measures the amount of salts (including fertilizer salts) in the sample. Excess salt may hinder plant growth and development by affecting soil-water balance. The mean EC for cultivated lands as well as uncultivated lands, is nearly the same in connected and isolated villages. But the EC level in

orchards of connected villages is comparatively high (2.63 ± 0.14 dS/m) than those in the isolated villages (1.37 ± 0.04 dS/m). Though the EC values of all the soil samples are within the normal nature of the soil (of <4 dS/m) and belong to a low salinity class, the continuous indiscriminate use of synthetic fertilizers in the connected villages may lead to soil heath deterioration in the near future.

The mean pH of water samples is 6.5 and the mean EC value of connected villages is 0.21 dS/m and that of isolated villages is 0.18 dS/m, and these waters pose negligible salinity effect upon use, as their EC values were <0.70 dS/m and TDS values were <450 mg/L (based on Ayers and Westcot, 1985).

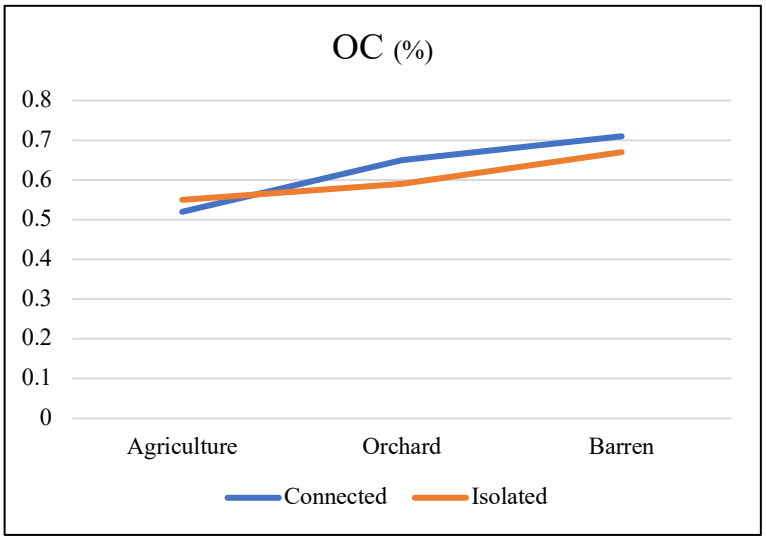


Figure 5.7 Comparison of Soil Organic Carbon in connected and isolated villages

The organic carbon (OC) is highest in uncultivated fields, followed by orchards and then crop-fields. OC recognizes the fertility status of the soil, increases the nutrient status, improves soil structure, moisture content and controls erosion and runoff. The percentage of OC ranged from 0.51% to 0.72% in the study area, indicating less variation across different management systems. Depending upon the OC content, the quality of soil may be graded as medium across the different fields.

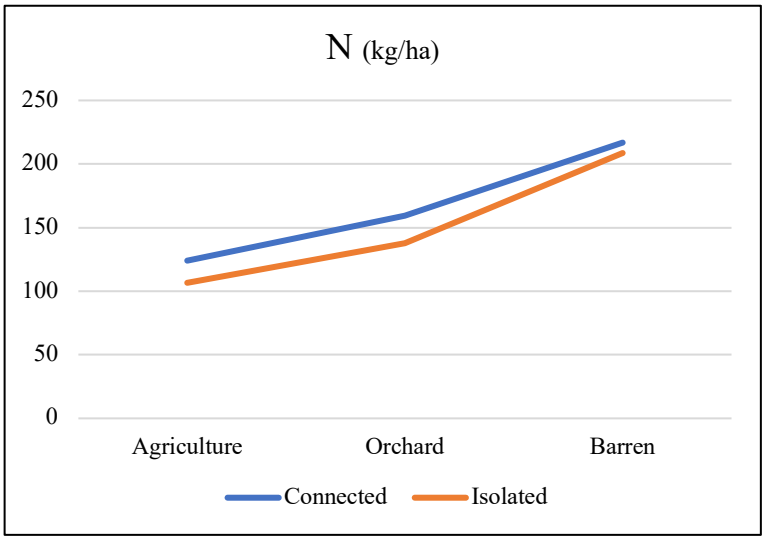


Figure 5.8 Comparison of Soil Available Nitrogen in connected and isolated villages

Nitrogen (N) is the most common limiting factor in plant growth and development. Its deficiency results in stunted growth, shedding of leaves and fruits, whereas excess of it may result in delayed maturity and insects and disease susceptibility. Available N is lowest in the crop fields of isolated villages (106.60 ± 3.43kg/ha) and highest in uncultivated fields (216.84 ± 1.91kg/ha). The overall N varied between 106.60 ± 3.43kg/ha to 216.84 ± 1.91kg/ha across the fields, indicating that the soil is poor in N and is of low rating soil. A low nitrogen content recorded in the crop-fields, may be due to crop removal, insufficient rain and negligible use of synthetic fertilizers.

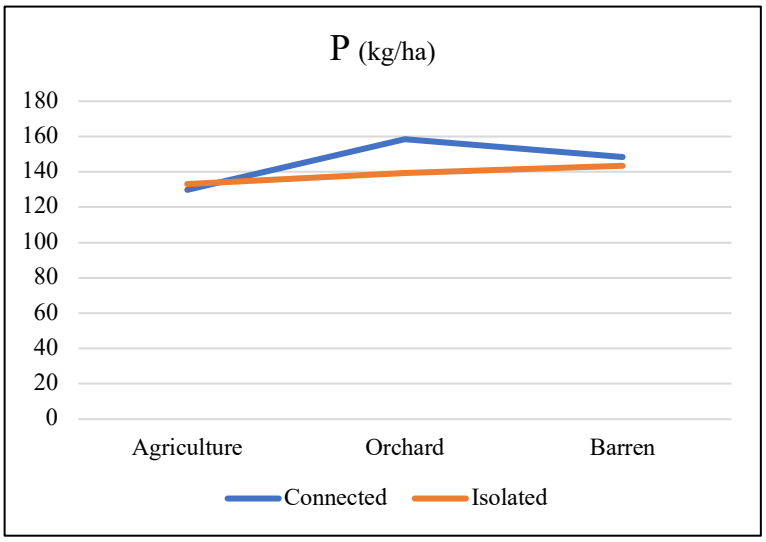


Figure 5.9 Comparison of Soil Available Phosphorus in connected and isolated villages

Phosphorus (P) is the second most important macro-nutrient, in the study area it ranged from 129.84 ± 0.33kg/ha to 158.52 ± 0.32kg/ha, signifying a high quality soil. The available P

depends on pH and EC, where a neutral pH has a significant role in enhancing P availability (Shivanna and Nagendrappa, 2014).

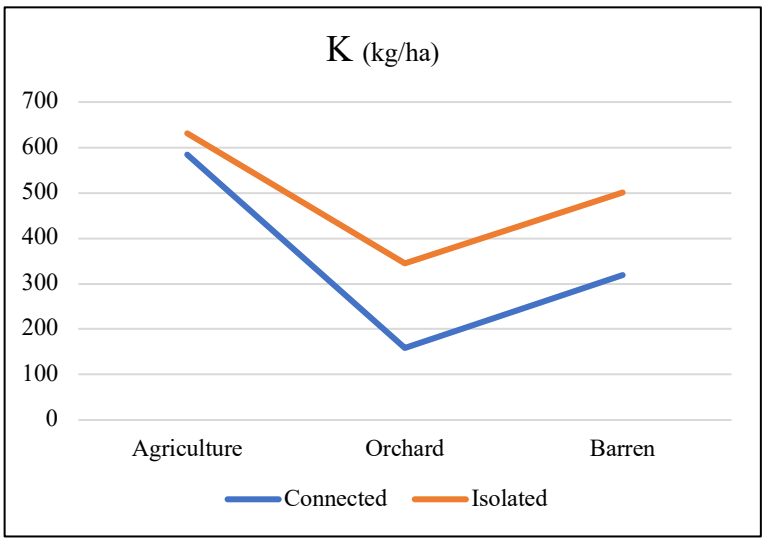


Figure 5.10 Comparison of Soil Available Potassium in connected and isolated villages

The available potassium (K) value varied between 158.52 ± 0.51kg/ha to 631.08 ± 1.52kg/ha. A medium soil rating is observed in orchard fields of connected villages, whereas rest of the management systems have high K soil rating.

Nitrogen, phosphorus and potassium are essential nutrients for the production system in both natural and agricultural systems, and thus are applied by farmers in huge amounts. Since green revolution, external chemical inputs have replaced or reduced many ES (Therond et al., 2017). In the study, the maintenance and regulatory ES are quantified on the scale of individual fields, including an evaluation of the effects of different agricultural inputs. One key assumption is that outputs from agroecosystem are not 'pure' ES per se. Instead, they are highly influenced by anthropogenic system inputs, and are bound to demands and preferences of markets and society (Bethwell et al., 2021).

e) Pollinator Diversity

A total number of 11 insect pollinators belonging to four orders and six families were identified in the study area (Table 5.9), the maximum number of which were reported from the orchards. However, threats to pollinators and the services they provide are perceived to be increasing. Issues like habitat fragmentation, use of agrochemicals, forest fires, overgrazing, climate change and non-native species, are some of the concerns affecting pollinator population.

Table 5.9 List of insect pollinators identified in the study area

Scientific Name	Common Name	Order	Family
Apis cerana	Asian honey bee	Hymenoptera	Apidae
Apis dorsata	Giant honey bee		
Apis florea	Dwarf honey bee		
Apis mellifera	European honey bee		
Bombus sp.	Bumble bee		Bombidae
Polistes sp.	Wasp		Vespidae
Pieris brassicae	Cabbage butterfly	Lepidoptera	Pieridae
Pieris candida	Indian cabbage white		
Vanessa cardui	Colourful butterfly/painted lady		
Eristalis sp.	Hoverfly	Diptera	Syrphidae
Coccinella septempunctata	Seven-spot ladybird	Coleoptera	Coccinellidae

Agricultural chemicals, such as fertilizers and pesticides have become a significant part of cash crop production in the hilly areas. One of the biggest challenge for sustainable development is to accurately assess the levels of ES in time and space to optimize the amount of additional external inputs required to reach the desired level of production (Therond et al., 2017). Many natural ES such as pollination, biological pest control, soil and water provision and quality are negatively impacted by the external chemical inputs. In cases of use, the most important aspect of these chemicals is to follow the label recommendation for the proper quantity to be applied in the fields. It is important to follow a proper timing as well as method of application, to maximize the efficiency of use only on the target groups, keeping in mind the guidelines.

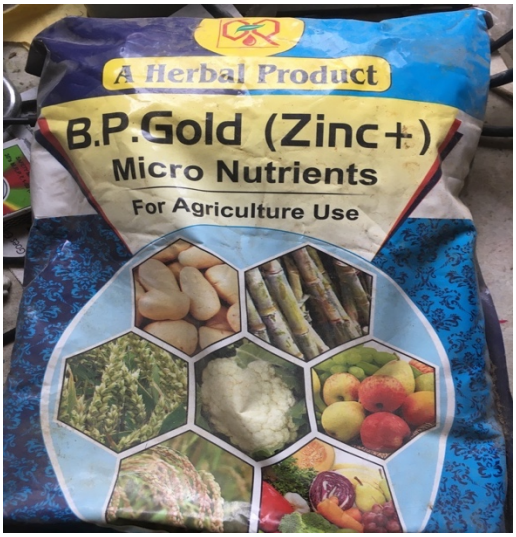
Soil is a non-renewable resource, and its preservation is essential for food and nutritional security. The basic concept of ES is to safeguard natural capital while maintaining sustainable flows of ES from nature to society (Burkhard et al., 2012a). Unfortunately, farmers in the study area, follow a pre-set notion of pesticide application like a schedule, which has led to an increase in the frequency of unnecessary spraying of chemicals. Instead of focusing on the presence or level of pest/disease infestation, it is an obligation which has become necessary to increase their production. Intensive use of pesticide also increasingly raises problems of pest resistance, which has become more difficult to control (Powles and Yu, 2010).

Plate No.18 Pest infestation in apple orchard

Stem Borer

Application of pesticide

Plate No.19 Use of chemical inputs in conventional farms



Few of the farmers complained about the ineffectiveness of pesticides used during pest-attack, thus attributing to a higher expenditure and labour cost for procurement of pesticide from private sellers of Himachal Pradesh. The competition to produce more, makes them use any chemical input available in the market, without proper knowledge, recommendation or need.

Similar, was the case with fertilizer application, the farmers had least idea about the quantity they were applying in their fields round the year. Though the chemical application of pesticides and fertilizers was limited to the apple orchards of connected villages, but in years to come its impact might be felt in the nearby fields as well. The farmers of isolated villages were not using any form of chemical inputs because of their socio-economic and physical isolation, unfavourable climatic conditions, limited agrobiodiversity, distance from market/amenities, which would have unnecessarily added to the cost of production.

5.3 Assessment of Local Adaptive Capacity

For the calculation of the LCAI, the expert's weightage scoring (out of 100) and ranking of the six determinants was the decisive factor. The results from the experts' interview and ranking score (Table 5.10) shows that, infrastructure, technology and institution were the most relevant factors determining the adaptive capacity of mountain farmers based on the local conditions of the study area. According to the experts, awareness and training was moderately important as it could help the farmers to increase their production and diversify their livelihood opportunities. The least important of all were economic resources and social capital.

Table 5.10 Ranking scores of the determinants on the basis of experts' judgement

Determinant	**Ranking Score**
Economic Resources	15
Social Capital	8
Awareness and Training	12
Technology	22
Infrastructure	25
Institution	18
(Total)	100

As the area records negligible outmigration, households had ample availability of family labor. The area also records a diversity of income sources, which not only includes agriculture, horticulture or livestock but there is a huge revenue generation from the construction labor work and tourism activities like trekking, hiking, camping and tour guide.

The result of WAI (Table 5.11) further validates the assessment framework used for calculating the adaptive capacity. As per the local community, they were highly dissatisfied with the infrastructural development and technological advancement in the area, as it affects their daily lives. The people were well aware of their social capital and income potential but demanded institutional support and guidance.

Table 5.11 Determinant Ranking based on the satisfaction level of local community

Determinant	**WAI**	**Rank (from least satisfied)**
Economic Resources	0.72	V
Social Capital	0.80	VI
Awareness and Training	0.50	IV
Technology	0.30	II
Infrastructure	0.20	I
Institution	0.40	III

Based on the level of adaptive capacity (Egyir et al., 2015), a low adaptive capacity of 1.75 was recorded for connected and a very low adaptive capacity of 1.15 was observed in isolated villages, respectively (Table 5.12). It is suggestive of the inherent constraints and widespread challenges that are being faced by the farmers within the mountain communities.

Table 5.12 Capacity Score (CS) of Determinants and Local Adaptive Capacity Index (LACI)

Determinant	**Connected Villages**	**Isolated Villages**
Economic Resources	5.02	2.62
Social Capital	2.24	3.60
Awareness and Training	3.68	3.78
Technology	10.36	6.43
Infrastructure	12.17	6.04
Institution	1.62	0.57
Aggregate CS	35.09	25.05
LACI	1.75	1.15

Based on the determinant's capacity score, there were some recorded location and accessibility related differences in AC levels of the determinants between the connected and isolated villages. Figure 5.11 demonstrates that the differences in the perception of the mountain community, actually defines the local adaptive capacity related to the different spheres of sustainability which impacts the livelihood development and diversification. The individual respondents are extremely dissatisfied with the institutional support and governance set-up in the area. Amongst the overall poor AC of the region, the isolated villages are better off in the social as well as awareness and training aspects of livelihood development, in comparison to their counterparts. Whereas, the connected villages are more equipped in the infrastructural setup, technological advancement and economic development then the isolated villages.

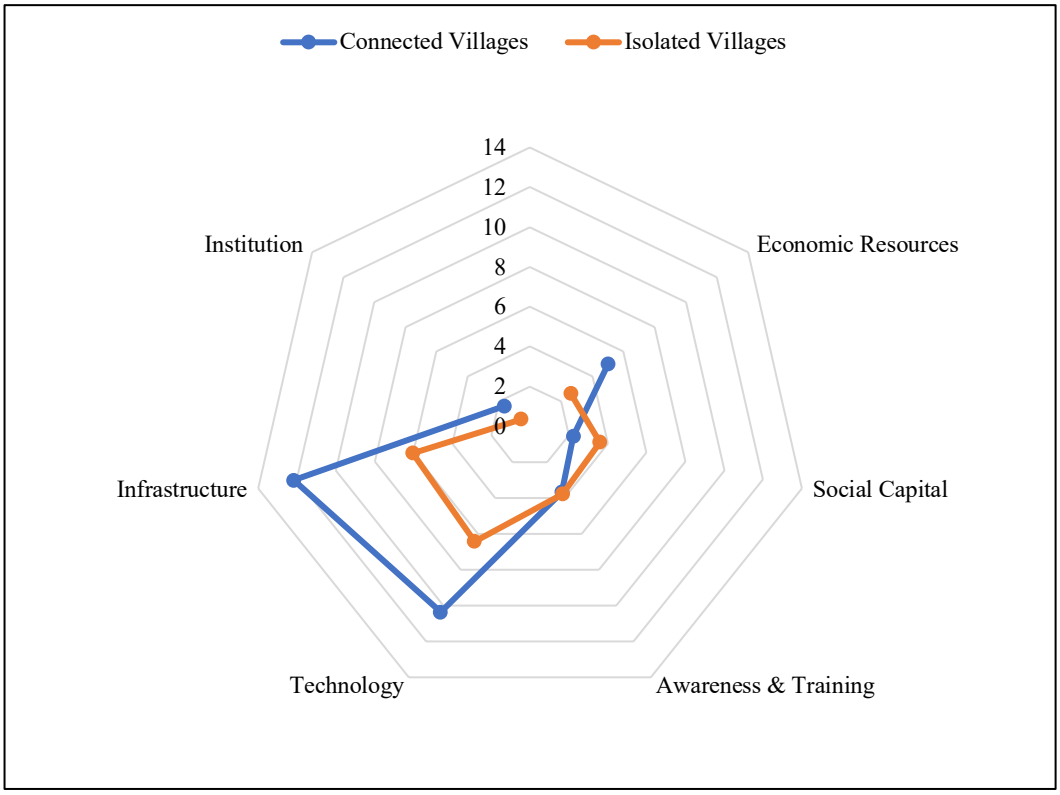


Figure 5.11 Comparison of Determinants Capacity Score based on individual respondents' perception

The comparison between the LACI of connected and isolated villages, clearly highlights the differences between the conditions of mountain farmers based on the accessibility and social disparity. The low AC is attributed to the fragile ecological conditions in the mountains coupled with the social marginality. The sustainable development of mountain farmers is driven by factors like inadequate awareness and vocational training, lack of infrastructural facilities, unavailability of financial support and credit, absence of local

institutional governance and network, among others. Though the LACI for connected and isolated villages was low and very low respectively, assets availability and local challenges clearly vary among them.

A bottom-up approach is best suited to identify local needs and assist local actions to build adaptive capacity for a sustainable livelihood. It is of utmost importance to understand and utilize the local experience and perception for a long-term sustainable transformation. At times, the locally derived measures can be accounted as faulty, as it may be difficult to replicate it in some other community and region. But to apply one solution to all is not feasible, as the constraints and challenges may vary. The adaptation option and pathway tend to be shaped by the community's participation to combat the uncertainty. The adaptation and development planning process should make efforts to account for these differences by addressing the specific dimensions. For the generation of equitable benefits in the mountain areas it is necessary to involve the local stakeholders who are able to effectively represent the voice of rural community, thus making the entire process a bit more participative in nature. It is important that the local community as well as the local government is capable to anticipate and respond to different economic and environmental changes the society might face. The incorporation of proactive decision making and governance system can improve the adaptive capacity for sustainable development. Decentralizing policy formulation and implementation process with a focus on community level adaptation program can increase the efficacy of developmental policies in assisting sustainable livelihood opportunities, without further widening the socio-economic gap.

Table 5.13 Measure of village-level parameters for sustainable development [satisfied/yes (a), neutral/don't know (b) and dissatisfied/no (c)]

Parameter	**Categorical Measure**	
	Connected	**Isolated**
Access to water	a	c
Access to electricity	b	c
Road connectivity	a	c
Telecom connectivity	c	c
Access to market	a	c
Access to health facilities	b	c
Access to new and improved farming technologies	c	c
Access to information and knowledge on climate change	c	c

Access to disaster/natural hazard relief	c	c
Support system within the community	b	a
Cooperation in farming activities	b	a
Knowledge about ecosystem system services	b	c
Community efforts to protect natural resources	c	c
Restraining local rules and norms	c	c
Equitable access to the support provided by local institution	c	c
Participation in agricultural/developmental policies and programs	b	c
Trust in local government	c	c
Trust in forest department	a	a
Satisfaction with local governance	c	c
Community participation in decision making	c	c

a) Livelihood Resources and Diversification

The capacity of households to cope with and respond to changes in climate depends heavily on access to, and control over, key assets (Daze et al., 2009). Assets include both tangible capitals (natural, physical and financial) as well as intangible ones (human and social) (Prowse and Scott, 2008). It is one of the crucial factors which enables the local community to respond during an external stress in a SES as it helps to maintain the regional economic stability. The main sources of income generation in the study area are rain-fed farming of apples, potato, kidney beans and animal husbandry. The qualitative data obtained during FGDs and field observations revealed the potential areas in other on-farm and off-farm activities like medicinal plants farming, construction labor work, wool production, and tourism in the prospect of recreation, trekking and camping. As the area has recorded very low outmigration, the income through remittances was limited to only 6% of households. The national agricultural policies and programs were not effectively transferred into an action mode strategy for rural mountain communities. According to HHS and FGD, 36% of the households were acquainted with the agricultural credit facilities. But merely, 3% of educated farmers with large land holdings and flourishing apple orchards, had access to micro-finance facilities and were based in connected villages on the roadhead and near to the market center. The diversified nature of livelihood is attributed to the availability of natural resources in a mountain ecosystem, but are often unsustainably utilized due to high illiteracy, limited awareness and absence of agricultural extension work.

b) Infrastructural Set-back

Land is one of the most important assets and a source of livelihood in the rural area, but its fragmentation and sloped landscape often makes it difficult to cultivate. In the study area, the mean land holding size is 0.4 hectare. The major problem faced by the farmers is that of connectivity. Even though connected villages (Gainchwan Gaon and Deora) are on the road-head still they face commute irregularity during monsoon and winters. Accessibility becomes an issue specially for isolated villages, as Dhatmeer and Osla are at a trekking distance of 8 km and 25 km respectively from Taluka, which is the last village a vehicle can reach. According to the farmers, they have a huge agricultural production potential but the lack of post-harvest processing, storage and transportation facilities hinders their progress. This also leads to an increase in production cost which the marginal mountain farmers are unable to face. Even though the apple quality and quantity are massive in the regional belt, they are not considered a competition in the national market for apples as their neighboring state Himachal Pradesh. The local market is not enough for the selling the produce whereas the isolated villages still practice barter system of exchange on a daily basis.

c) Innovation and Technology

A key characteristic of adaptive capacity relates to the system's ability to foster innovation and support new practices (Smith et al., 2003). It enables the rural communities to improve their livelihood, natural resource utilization habits, and existing adaptive behavior and practices. About 98% of households in both, connected and isolated villages were using improved and high yielding variety of seeds, seedlings and cuttings for the apple orchards. About 92% of households in the connected villages were using inorganic fertilizers and pesticidal chemicals in apple orchards, as their access to farm inputs is easier. This percentage use decreased to zero in Dhatmeer and Osla, because of their personal affordability, accessibility to market on a regular basis and the age of apple orchards (still being very new and young). Thus, the isolated villages generally followed organic farming. The study area lacks irrigation facilities, and the farmers depend upon rainfall or natural *nala's* (small stream or spring) opening in their fields. Soil and water conservation practices are weak and exploitative in the connected areas, as their main focus is on buying quality farm inputs. As far as the isolated villages are concerned, they mostly followed organic farming, water harvesting and soil conservation methods.

Plate No.20 Road condition in the study area

Road Condition in Connected Villages

Route Condition in Isolated Villages

d) Knowledge and Information

The ability of local community to assess, generate, receive, utilize and disseminate knowledge and information across their region, directly enhances the adaptive capacity of the socio-ecological system they live in. Literacy plays a key role in the understanding and usage of the relevant information needed for sustainable livelihood development. Most of the farmers have studied up to primary school level and had a good knowledge about their farming system. 18% of the young generation were graduates and were mostly in local jobs like construction, transport and tourism. The farmers had an understanding about climate change but only the educated youth were aware of its circumstantial consequences and corrective measures. Their only experience with a climatic extreme was that of a disastrous hailstorm which had destroyed their apple orchards five years ago. According to the local community, they had experienced temperature fluctuations, like summers becoming hotter than usual from the past two years. The main challenge was access to latest information regarding weather forecast, market or new technologies in agriculture, as the study area had a poor telecom connectivity. In the age of 5G communication, the telecom signals in the villages fluctuated every day and at times disappeared for weeks. Social networks among the villagers and local market gatherings were the only ways for information dissemination. Thus, the limited access to the outside world, isolated the entire region by slowing down the growth of agri-business for the mountain farmers.

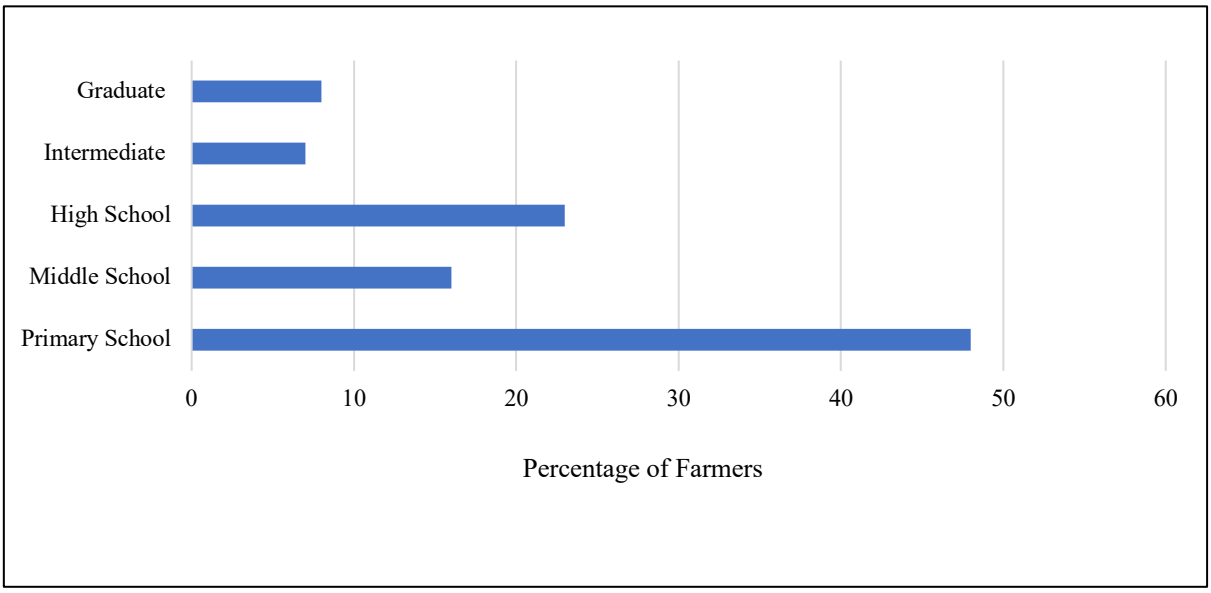


Figure 5.12 Level of Education

Plate No.21 Infrastructure condition in the study area

Primary School at Gainchwan Gaon

Primary Health Centre at Gainchwan Gaon

e) Forward-looking Governance System

The study area lacks the participatory consideration of the traditional knowledge and experience of the mountain farmers within the institutional setup of the region. Immediate reactive responses are generally short-term coping strategies which further degrades the asset base of the farmers without actually giving a sustainable solution. Taking a longer-term approach withing governance and decision-making is crucial in order to prevent maladaptive interventions (Ayers and Huq, 2009). The implementation of agriculturally based programs was more in few selected villages, one of which was Osla. Though the connected villages had an advantage of being near the block office giving them a better access to government aid, yet the agricultural extension work and training was minimum in these villages. Osla had the maximum adaptive capacity in institutional system as various research work and extension demonstrations are being implemented in the area, with tremendous support in organic farming. The selective bias treatment of local farmers by the government administrative system at the village level is the serious matter of concern. The agricultural subsidy aid was not being accessed by all, even though the farmers have the knowledge about it but the lack of guidance in order to approach it was considered the biggest hindrance. Few of the farmers enjoyed the personal preference which disturbed the equal allocation of governmental benefits.

Traditional Himalayan agricultural systems were and are still rich in agricultural biodiversity. The agroecosystems, represented by different villages in the study area, were in a dynamic transition phase of functioning. The good or bad outcomes of these farming system-based livelihoods, is clearly reflected in the target villages. The wholescale abandonment of traditional crops from farming and food habits, is causing loss of local crop genetic resources. These changes indicate preference of farmers for economically productive but biologically less diverse agroecosystems. There is an emerging situation; where the diversity of crops and animals that forms part of the Himalayan agroecosystems, supplying all kinds of nutritional needs to the local community is now declining. Clearly, the subsistence farming systems are failing to support livelihoods, and under such circumstances, the traditional multi-crop cultivation is being abandoned in favour of other off-farm options. Thus, there is a challenge to think about strategies, for putting in place mechanisms, that serve ecologically and economically sustainable livelihoods.

Plate No.22 Living condition of the local community

5.4 Sustainable Livelihood Development Strategies

Mountains are often regarded for its spectacular natural beauty, but what goes unnoticed are the livelihood struggles faced by the local mountain community. They require a livelihood structure that not only involves economic prosperity but also environmental health, cultural identity, policy and governance support. Most mountain regions share a long history of physical and political isolation. Mountain people have little contribution in decision making process that affects their socio-economic stability. Generally, mountain people lack political voice, and with limited access to transportation and communication facilities, constrain their participation in any developmental activity. Mountain issues are not addressed through sectoral legislation related to agriculture, forestry, land or water. Such region-specific governance is often negotiated with a lopsided focus and inadequate attention to the needs of local people. One thing in common with the local farmers of connected and isolated villages was, their knowledge and innovation-based approach to farming. They did not consider agriculture as means for survival alone. Their aim was to make it a profitable and economically-viable agri-business.

5.4.1 Impact of COVID-19

Due to the ignorance and unpreparedness, the global pandemic COVID-19 has severely impacted the world economy for two consecutive years. The strict travel restrictions, limited domestic and international flights with a series of lockdown, has made tourism one of the worst hit sectors of Indian economy. For the first time, mountain communities were benefitted for their remoteness and isolation, as no COVID-19 cases were reported in the study area (till 2020). But the local people felt threatened due to the unavailability of doctor or medicine. The social stress was high among the younger generation as their education was impacted due to the lockdown. The students enrolled in schools/colleges in nearby towns and cities returned back and were not able to carry on with the online classes due to the poor tele-connectivity and networks. This also affected the information dissemination among the locals regarding the latest updates on cases and government relief. The impact of COVID-19 on the socio-economic attributes of livelihood in the study area were rated on the Likert Scale of 1-5 (where, 1 = strongly disapprove, 2 = disapprove, 3 = neutral, 4 = approve, 5 = strongly approve)

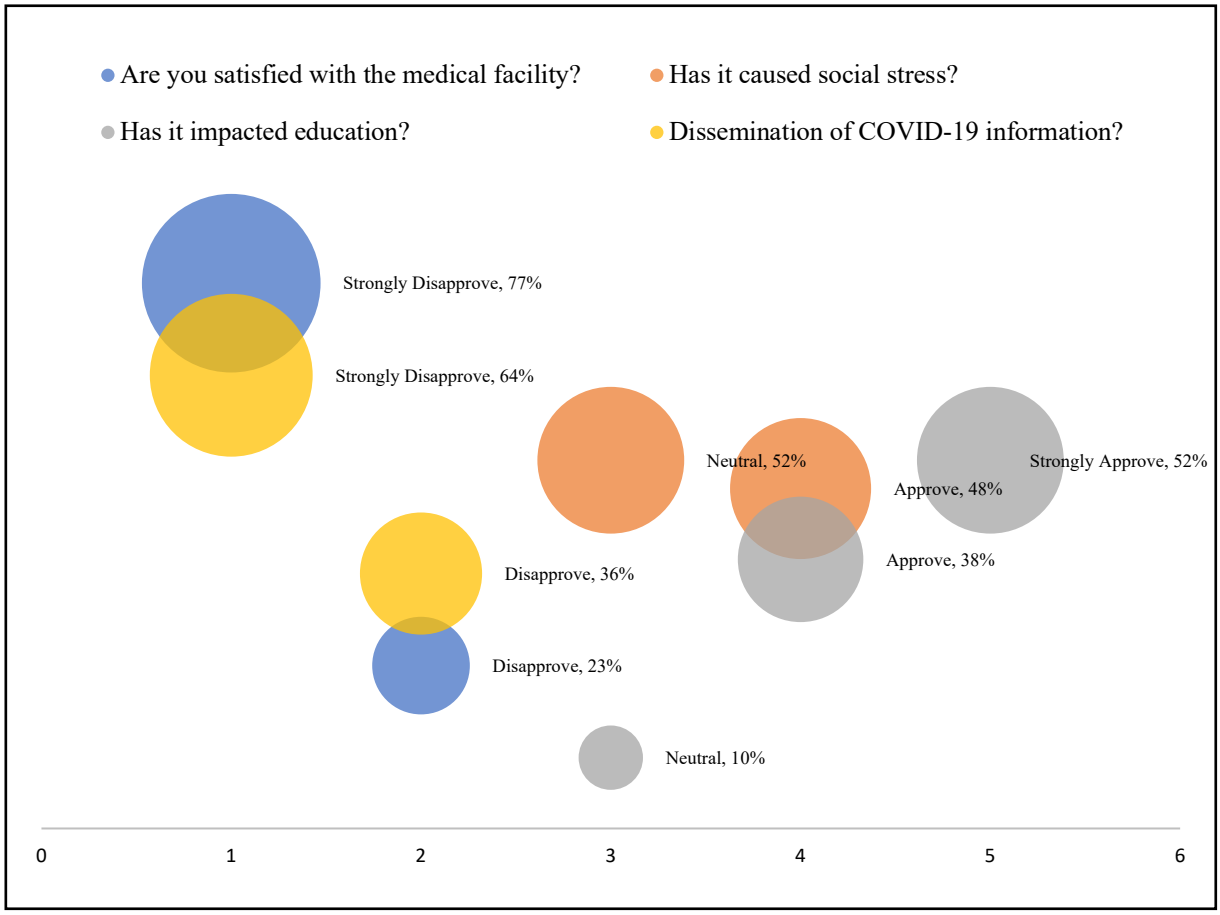


Figure 5.13 Social attributes of livelihood during COVID-19

As far as the economic attributes are concerned (Fig.5.13), the impact of COVID-19 was low. The major source of income i.e., apple farming and livestock were not much impacted, instead the local community received a higher return for apple production as the inter-state competition was minimized during the lockdown. The tourist inflow was highly impacted due to the restricted travelling and safety norms, but as per the local tour operators, the tourism sector has picked up pace post-October (2020). Though the local communities are scared of the tourists visiting the area, but they are well aware of social distancing and hygiene (mask and sanitizer). The dissatisfaction level of the people was quite high when asked about government aid and support during the difficult times of health emergency. The living situations were the same pre-pandemic as well as during the pandemic, with negligible effect on the daily lives of the people.

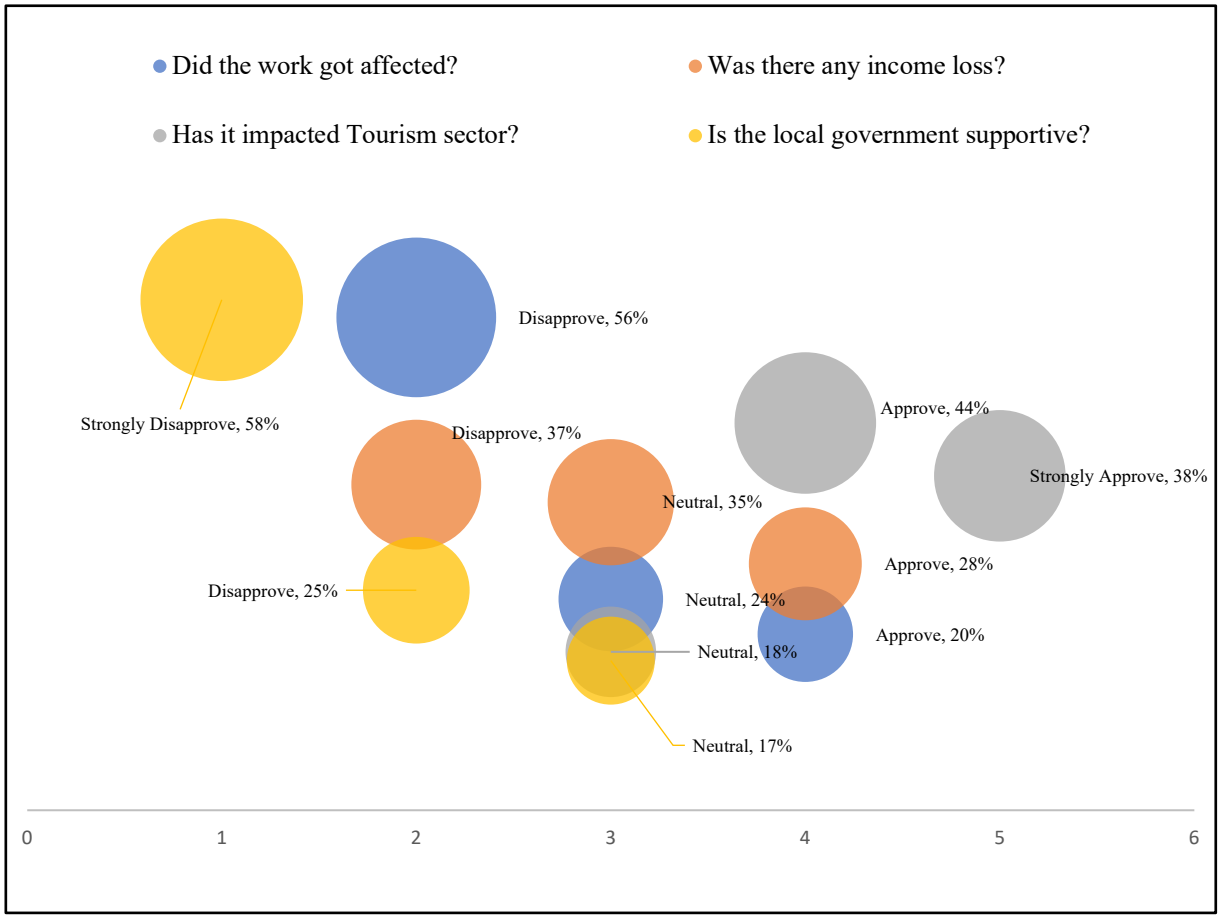


Figure 5.14 Economic Attributes of Livelihood during COVID-19

5.4.2 Agricultural Policies

The States have constitutional responsibility in the research and development of agriculture, but the central government plays an important role as they develop the national agricultural policies and initiatives and provides the necessary funds, incentives and grants for the implementation of the same at a state level. The extent of implementation of these policies depends upon the state government. There are five major sectors on which the government lays emphasis while designing the set of policies and programs relating to agriculture and food in India (Fig.5.14). Lately, environmental measures concerning farming like climate smart agriculture, sustainable agriculture and food security under climate change, have also gained prominence. Uttarakhand is continuously losing the precious agrobiodiversity and associated traditional knowledge due to various factors related to socio-economic changes, policy formulation and implementation, institutional arrangements and high rate of out-migration. The decision of mountain farmers is highly influenced by the limited economic opportunities, restricted infrastructural development and climatic conditions.

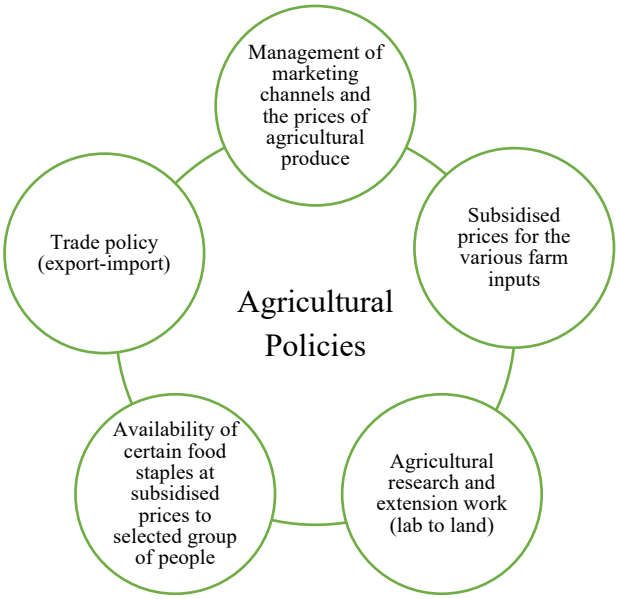


Figure 5.15 Focus of current agricultural policies

Though the shift towards cash crop farming has economically benefitted the farmers but their vulnerability towards climatic and market uncertainty has also increased. The local community only rely on 2-3 crops a year for any kind of income generation, and they might face severe loss specially in the times of natural disasters. Further, the middlemen are benefitted more than the local community, as they lack the economic means for safe transportation of their produce. Narrowing down the agricultural potential, has resulted in the abandonment of highly nutritious crops which have a huge potential in the global market. The disappearing knowledge and use of traditional crop varieties not only leads to genetic pool erosion but is also an important contributing factor in cultural erosion.

To achieve sustainable mountain development, it is essential that all the concerned stakeholders of the mountain-based livelihood activities are involved and that awareness is raised about the mountain ecosystem and the prevalent challenges faced by the local communities. It is also important to take into account the knowledge and experiences of indigenous mountain communities as well as the traditional farming practices and land-use systems. The new technologies and approaches need to complement and be integrated into local practices, for the prosperous life of isolated mountain community by attaining economic security (SDG-1 – No poverty), food security (SDG-2 – Zero hunger) and ecological security (SDG-15 – Life on land).

Table 5.14 Strength-Weakness Matrix of the provisions under different agricultural policies being implemented in the study area (as per the FGDs conducted)

Strength Matrix		**Weakness Matrix**	
Factors	**Rank**	**Factors**	**Rank**
Availability of seeds	IV	Inaccessibility	IV
Availability of pesticides	VII	Weak communication network	I
Availability of fertilizers	I	Frequency of field visits	III
Availability of farm machinery	III	Lack of field staff	VI
Availability of subsidies	II	Market for agricultural produce	I
Special attention towards SC/ST/BPL families	V	Unequal distribution of benefits	II
Field demonstrations and farmers training	VI	Illiteracy and Unawareness	V

5.4.3 Future Smart Food

Future Smart Food, generally the Neglected and Underutilized Species are nutrient-dense, climate resilient, economically viable and locally available and/or adaptable (Siddique and Xuan Li, 2019). Compared with staple food crops, future smart crops require low inputs for high outputs (macronutrients and micronutrients), are highly nutritious, and well-adapted to the marginal and extreme climate conditions with little external input (FAO: FSF, 2018). Three main crops, namely rice, maize and wheat, provide 60 percent of the world's food energy intake (FAO, 1995), which has led to two critical setbacks, namely production gap and nutrition gap. This means that tens of thousands of edible plant species remain relatively 'underutilized', with respect to their ability to contribute to the world's increasing food requirements (Chivenge et al., 2015; FAO, 2018). Future Smart Foods, by definition, also include wild food species, indigenous leafy vegetables, and wild plants and animal species which are nutritious (BI, 2017).

The paradox of sustainability is that the answer for present and future survival lies in our traditional past. Up until now, traditional mountain farmers have domesticated and conserved thousands of traditional crop species and varieties, through frequent interactions with local environment to fulfil the need of subsistence and income. Scientific studies on TC

reveal that many of these are rich source of fibre and minerals, vitamins and antioxidants and have medicinal value (Table 5.15), which are beneficial for human health.

Table 5.15 Traditional crops and their medicinal qualities (as per the FGDs)

Scientific Name	Local Name	Traditional Medicinal Uses
Amaranthus oleracea	Chaulai	Husk of grain is used for skin diseases
Echinochloa frumentacea	Jhangora	Roasted grain is given to patients suffering from low blood pressure, jaundice and diabetes
Eleusine coracana	Mandua	It averts cold and improves digestion
Fagopyrum esculentum	Oggal	Grains are used to cure fever, diarrhea and abdominal ailments
Fagopyrum tataricum	Phaphar	Used during hypertension
Macrotyloma uniflorum	Gahat	Grain soup is used as a cure for kidney stones
Perilla frutescens	Perilla	Leaves are used during cold, vomiting and abdominal pain
Setaria italica	Kauni	It provides relief during typhoid and pneumonia
Vigna mungo	Urad	Used as a plaster for fractured body parts

Uttarakhand is famous for millets (like, finger millet, foxtail millet, little millet, kodo millet, barnyard millet, proso millet) and pulses (like, soyabean, horse gram, kidney bean, adjuki bean, rice bean). Millets are the oldest foods known to mankind but their importance and cultivation has reduced after the green revolution which focused on rice and wheat. Millets have many nutritional and health promoting qualities in comparison to other staple crops and are thus referred to as a "high-energy" cereal. Pulses contain about twice the amount of protein found in whole grain cereals like wheat. In many cultures, it is also considered as a 'protein for the poor'. Pulses have a low glycemic index, low fat, high fibre, and a good source of vitamins and minerals, making them an important portion of a healthy human diet. In today's society as the people are becoming more health conscious, a nutrition transition is clearly evident. There has been an increasing interest in the TC and food culture, in an ongoing effort to diversify the diet. In the global scenario of malnutrition and over-nutrition (obesity issues), the traditional food habits are now influencing the contemporary food habits. It is important to evaluate how

education, awareness and scientific research can increase the popularity of TC in the global market, which are already dominated by a number of niche crops and pulses.

5.4.4 Medicinal and Aromatic Plants

With the escalating demand for herbal supplements, medications and cosmetics in global and international markets, cultivation of MAPs is a remunerative option in ecological and economic terms for the mountain farmers. MAP-based industries would not only expand job opportunities but the value-added processing of MAPs would increase incomes of local community. The mountain community are very well aware of the genetic diversity they possess, but requires guidance to harness its potential through cultivation. Development of a comprehensive scientific database on MAPs farming requirements, agronomic practices, their post-harvest management under different biophysical conditions can be helpful for agricultural diversification and income generation.

The following steps can be considered for the conservation of the rich biodiversity of the region and its further valuation;

a) Development of a detailed data regarding the TC, mountain (*pahadi*) cuisine, local food recipes and specialties of the region. It can be popularized in the form of published manuals, online cooking programmes and even taught in schools (Home Science course) and colleges (Hotel Management course).
b) Documentation of a scientific data regarding the MAPs at different ecological and altitudinal zones across Uttarakhand. A one-source, detailed, open-access information can be maintained regarding the medicinal and/or cosmetic use, herbal practices, preparation of herbal remedies.
c) Development of a comprehensive scientific database of TC and MAPs on farming requirements (climate, soil, manuring, irrigation, etc.), agronomic practices, their post-harvest management, nutritional and medicinal qualities under different social, regional and biophysical characteristics.
d) Establishment of resource centers in the remote rural areas of the mountains for farming-based and technological guidance. These centers can help in development of region-specific technological interventions for bridging the gap between scientific development and poor local resource users (lab to land).

e) Creation of farmers' cooperatives for mutual help and resource availability. The government can entrust these cooperatives with machines like grading and sorting machine or post-harvest processing equipment's for the member villages. These machines which are costly and hard to afford by a single farmer, can be made available on a rent basis to the villagers for equitable sharing. The rent paid can be utilized for servicing and maintenance of the machines.
f) A detailed study of demand-supply and market chain on TCs and MAPs should be conducted for a better linking of rural areas to the urban centers.
g) A collection center (for the produce) can be established in blocks for easy transport and reduced production cost for the farmers.
h) At a state level, government can provide minimum support price (MSP) for the procurement of TC and MAPs from the rural areas of Uttarakhand. It would help in building the capacity of local farmers along with minimization of exploitation at the hands of middlemen.
i) Development of integrated institutional mechanism, policy formulation, participatory decision making and adaptive governance for the interlinked production system (agriculture-forest-livestock) of Uttarakhand.
j) Policy decision can be made to promote the preparation and consumption of TC in the mid-day meals scheme, government organized events, workshops and programmes.
k) A public-private partnership mode can be developed, where the State government can coordinate with the manufacturing companies related to healthy and herbal products and set-up a contract farming production system of TCs and MAPs with the mountain farmers of Uttarakhand.
l) The agriculture department can ensure more extension services towards the remote villages for demonstration and training on organic farming and cultivation of TCs and MAPs. They can also recruit the local youth for the extension work, thus providing them an opportunity for employment and giving them a sense of belonging. The farmers adopting to these practices can be given ecological incentives for further motivation.

Plate No.23 Agriculture-based income potential

Kidney Bean (*Phaseolus vulgaris*)

Potato (*Solanum tuberosum*)

Sea Buckthorn (*Hippophae salicifolia*)

Walnut (*Juglans regia*)

5.4.5 Animal Husbandry

Livestock and farming system forms the vital source of income generation for the rural people living in the mountainous region. The Indian Himalayas support about 50 million domestic animals (1.6 animal/ha), which include cattle (47.5%), goats (15.8%), buffaloes (12.3%) and sheep (10.4%) (Bakshi and Kumar, 2019). The details of cattle population in the study area are;

Table 5.16. Cattle population in the study area

S.No.	Name of the Village	Cattle Population
1.	Gainchwan Gaon	1067
2.	Deora	1038
3.	Dhatmeer	6096
4.	Osla	2572

While diversifying beyond TC to horticulture, livestock rearing can play an important role in income generation. Introduction and production of superior quality cattle, sheep and goats with the assistance of Department of Animal Husbandry, Government of Uttarakhand, can boost the livestock sector in the study area. There is a need to formulate location-specific strategy development by considering the biophysical, climatic and socio-economic conditions. Special emphasis should be put on entrepreneurship development schemes in the State, for the skill development and training of mountain farmers. Training farmers in modern technology and equipment to commercialize livestock business can foster the needed push. The trained farmer can be further provided with institutional, infrastructural and marketing support for quality production of animal products. There is a need for a well-defined plan for provision of agricultural extension services, such as facilities for collection, grading, storage, transportation, handling, and management of produce. Production and collection centres can be established on the basis of regional availability, linking farmers directly to the marketing channel.

Plate No.24 Scope of animal husbandry

Traditional Weaving Machine (Wooden)

5.4.6 Apple Economy

At present, the apple economy in the Himalayan region can be divided into: North west and North east region. Unfortunately, in the North West Himalayan states, Kashmir and Himachal Pradesh leads the way in apple farming and domination of national market. The weak research and development institutional capacity of Uttarakhand needs an upgradation, as the apple farming in the State has yet not modernized to realize its full potential. For the survival of apple agri-business in remote mountain villages, strategies must be developed to cut down the cost of cultivation down the supply chain.

Presently, the post-harvest infrastructure facilities like, pre-cooling, storage, collection, grading/sorting, washing/cleaning and pack houses, etc., are not present. These facilities are necessary to prevent quality loss due to temperature variation, moisture loss, transportation handling damages, etc. Farm level interventions in the identified clusters of the State, may boost the production quality and quantity, by reducing damages and wastage. Therefore, there is an opportunity to establish proper storage facilities near to the study area. Government facilitation is required to ensure price stabilization, so as to avoid the interference and exploitation of middlemen. The summary of feasible interventions is given in the following table;

Table No.5.17 The rationale proposed for apple cultivation

Component	Required Intervention
Production-related	• Supply of elite planting material to the local farmers • Transfer of knowledge on best farming practices for apple cultivation and management through demonstration and training • Development of community water harvesting and storage structures near to the farmlands • Improving access to technology and farm inputs • Arrangement of agricultural extension agents for information dissemination, monitoring and evaluation
Post-harvest management and value addition	• Development of post-harvest infrastructure • Formation of farmer groups for aggregation of produce for bulk capacity • Encouraging private sector investment and agri-business development

5.4.7 Rural tourism

For centuries, the IHR has been a preferred destination for religious, spiritual, and recreational activities for both domestic and foreign visitors (Gupta et al., 2018; Sharma et al., 2016). Tourism in the IHR has become one of the fastest growing sectors in terms of economic activity and industry transects. According to the World Travel and Tourism Council (WTTC) in 2016, this sector in India contributed 9.6% of GDP creating 40.343 million jobs and 9.3% of total employment (NITI Aayog, 2018). Moreover, the IHR's tourism sector is also an important source of revenue for the State governments.

The most significant strengths of the study area are diverse geo-climatic landscapes, natural beauty, unique culture, multiple tourism attractions and the humble hospitality of the local community, offering a perfect unification of recreation and peace. The following figures (Fig.5.15) shows the inflow of tourists in the study area, highlighting that the contribution of Indian tourists is greater than international tourists (based on the secondary data of Govind Wildlife Sanctuary and National Park).

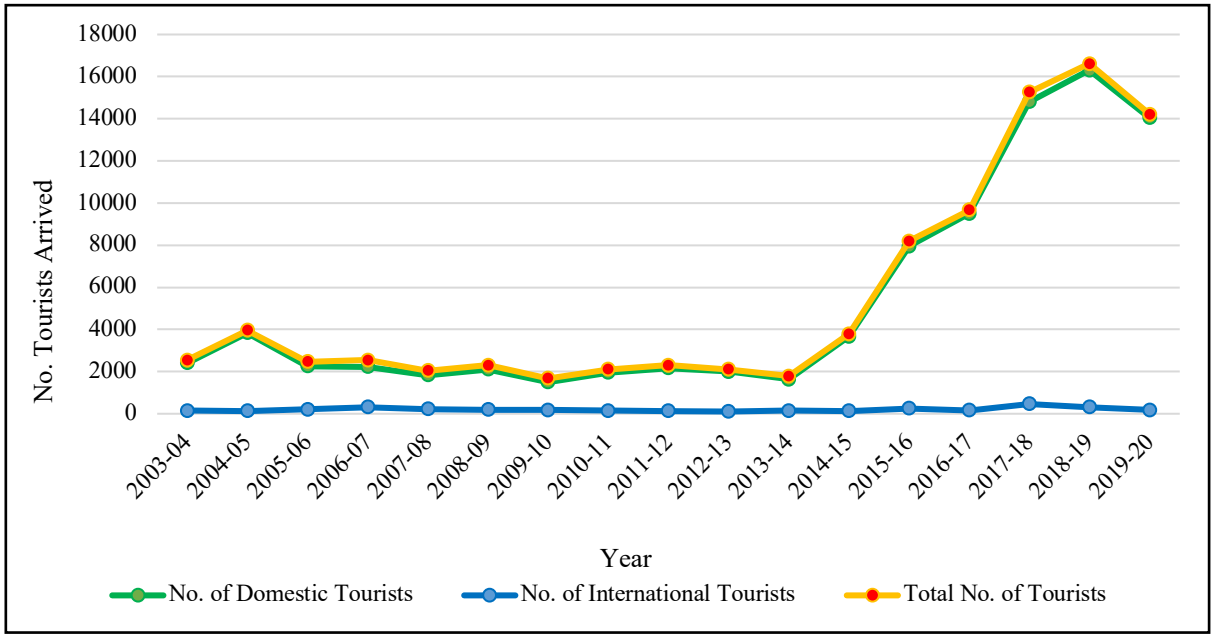


Figure 5.16 Comparison of tourist inflow over the years

The aesthetic natural beauty of Tons valley makes a perfect location for rural tourism. The region has seven trekking routes from average-intermediate to hard treks, giving an opportunity from beginners as well as expert trekkers to explore the beauty of the valley. The

routes are, Kedarkantha, Har ki Dun, Bali Pass, Borasu Pass, Dhumdhar-Kandi Pass, Ruinsara Tal and Phustara via Phulana ridge.

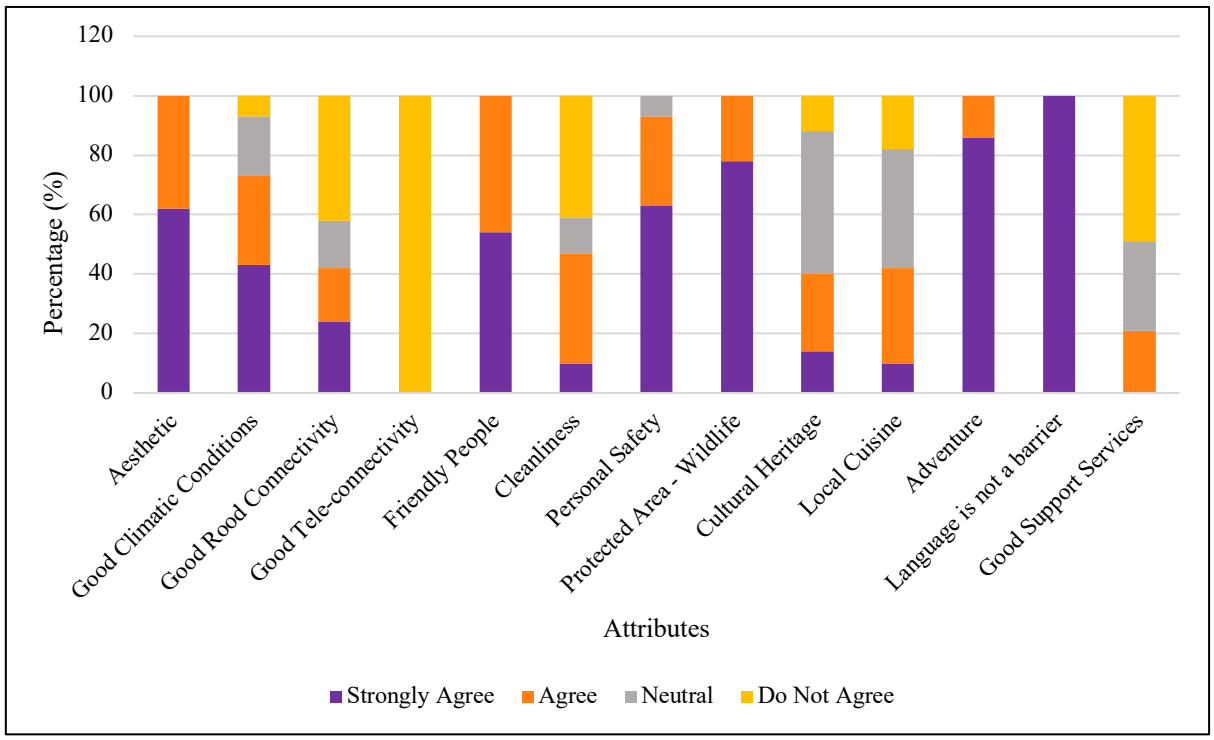


Figure 5.17 The Destination Attributes – Outlook of the Tourists (based on tourist interviews)

Tourist satisfaction with rural tourism can be defined as their evaluation of the difference between the expectations they had before visiting and the experiences they had while visiting (Truong and Foster, 2006). Satisfaction after experiencing rural tourism is an important factor in making rural tourism sustainable because it increases customer loyalty to the destination (Ryglová et al., 2018). Apart from the most common positive attributes of any hilly area like, natural and scenic beauty, climate, adventure, wildlife; the visitors were highly satisfied with the friendly nature of the local people as well as the personal safety they felt this far away from the urban civilization. The accommodation facilities were considered satisfactory by most the respondents, but their main concern was regarding the tele-connectivity. They were fearful towards any health emergency, as the area lacked appropriate health facilities as well as proper commute. The visitors suggested the development of health centers not only for the tourists but for the local people as well. They highlighted the cultural heritage and local cuisine of the Parvati Valley should be equally promoted as a part of eco-tourism. Most of them appreciated the local cuisine, food habits, regional dresses and ornaments, which fruitfully added to their experience.

Plate No.25 Scope of rural tourism

There is a scope for river rafting and river-side camping at Mori, which is already being explored. Amongst the high mountain peaks, lush red-green apple orchards and fresh air, the area can be considered for agritourism, homestay, healthy food and yoga. Agri-tourism is a concept of farm recreation referring to activities conducted on private agricultural lands, which might include overnight stays, educational and research activities, food and festivals, guided tours, etc. Thus, Agri-tourism can be defined as a commercial enterprise at a working farm conducted for the enjoyment of visitors that generates supplemental income for the owners. Agri-tourism is becoming an increasingly popular industry globally. Over the years, the concept of tourism has changed and evolved. Travel has become much more than just ticking through the mandatory list of hill stations, beaches, museums and temples. Nowadays, travelers want to slow down, discover new destinations, meet local people, learn about their culture and food and become more involved with the land they visit by actively participating in the activities that the rural people undergo in their daily chores of life.

Chapter 6

Conclusion

India is one of the world's megadiverse countries, representing a wide spectrum of geographical, biological and cultural diversity, and being extremely diverse in its genes, species and ecosystem. Livelihood security of particularly remote Himalayan community is critically linked to ecological security and access and control over their regional natural resources. The rural mountain people, generally live in a landscape which is a mix of farmland, forest and grassland. The relationship between humans and forests is subject to complex and dynamic forces, thus identifying the pathway between social and economic variables and environmental outcomes is a formidable challenge. Indigenous communities often have a deep cultural and spiritual relationship with their ancestral forest lands and age-old knowledge about biodiversity, much of which is at risk of being lost. For those concerned with policy planning, governance and management, the nexus of environment and local people have become difficult to handle. The contribution of forests and biodiversity to people's way of living, settlement, traditional knowledge and well-being is undervalued in many socio-economic assessments.

For years, collective action has been employed to use and conserve the environment, and natural resources, addressing the economic situation for growth and development. The creation of PAs has historically been the forest governance instrument most often adopted to pursue biodiversity objectives. The PA approach has achieved positive results in environmental protection and conservation, but their extent of reconciliation with the local community is not much evident. Unfortunately, the ecological sustainability and economic security of the mountain ecosystem are in jeopardy. To what extent have the national laws and policies targeted the specific situation of mountain regions? For an overall mountain development, it is important to reduce the context- and region-specific socio-economic and cultural disparities; for strengthening resilience and enhancing well-being. The specific objectives of sustainable development need to be based on people's aspirations and needs, making the developmental strategies inclusive, people-centred and regional-based. There is a need for regular reforms in traditional institutions, governance system, policies and rules, to link knowledge with action, in order to sustainably benefit the local community in their own niche. The local's perspective should become a key element of research, planning, decision-making and governance. The

mountain community have so far managed their livelihood with little assistance, even during conditions of environmental uncertainty and socio-economic variability. Therefore, the local community should complement and honourably be made a part of our formal knowledge and scientific system, by treating them equally.

6.1 Democratization of Conservation

The 42nd Amendment to the Indian Constitution, enacted in 1976, was a significant step towards biodiversity conservation. It made protection and improvement of the environment, and safeguarding forests and wildlife through incorporation in Part IV of the Constitution - Directive Principles of State Policy. It transferred the subject of wildlife and forest protection and conservation to the Concurrent List, enabling both central and state governments to make laws on such matters. Part IV-A of the Constitution - Fundamental Duties (Article 51-A) – highlighted the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wildlife, and to have compassion for living creatures. In the late 1980s, the grassroot struggle of the local community, the rise of non-governmental organizations seeking sustainable conservation and international pressure through environmental treaties, made the decision-makers rethink the concept of protection and conservation. The Forest Policy of 1988 stated the domestic requirements of forest dwellers for fuelwood, fodder, minor forest produce and construction timber as well. The Policy associated the forest management practices with the tribal people and provided the basis for Joint Forest Management programme, launched in 1990. Further, the Panchayat (Extension to Scheduled Areas) Act of 1996; required the states to make laws in harmony with the customary law, social and religious practices of the locals, and traditional management practices of community resources. Substantial changes in the conservation strategy were brought by National Wildlife Action Plan (2002), the draft National Biodiversity Strategy and Action Plan (2004) and the National Environment Policy (2006). The Biological Diversity Act of 2002 allowed regulated access to biological diversity for commercial use and other specified purposes, along with the protection of intellectual property rights, sharing the benefits arising from the biological resources and their associated knowledge. Unfortunately, the focus of the Act was limited to the documentation of local traditional knowledge than actually empowering the local community who were the actual knowledge holders.

The more significant legislative change was administered through the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act of 2006 (FRA). Under Section 3 of the Act, a wide range of rights to access and occupy forests and use forest resources were specified. Section 5 of the Act further strengthened the community's rights, as it defined the provisions related to the powers of forest rights holders. The decision to initiate the grant of forest rights was with the Gram Sabha, where Section 6 of the Act outlined the entire process for it. The Act stated that the forest rights holders cannot be resettled nor can their rights be affected, unless satisfied under Section 4(2). In case of resettlement, an 'alternative package' was to be prepared, providing a secure livelihood for the affected individuals and/or communities (Section 4(2)(d)). On an international platform, the democratization of conservation laws was discussed through two major events, Union for Conservation of Nature's World Parks Congress at Durban (2003) and the COP-7 of the Convention on Biological Diversity at Kuala Lampur (2004). But the creation of PAs has always been a debatable issue, given the traditional approach of management which excludes the involvement of local communities.

Based on the responses received on the benefits derived and problems faced by the respondents due to the PA on the well-being, few of the local people supported the importance and establishment of the PA. From the responses, 35 percent of the community, belonging to an age category of 20-30 years, claimed that the forest and wildlife conservation policies are an important concept. They respected the restrictions imposed on them. 45 percent of the community, majorly in the age group of 40-50 years of age, supported the management of PA but were not supportive of the interference posed by legislation on their traditional rights. According to them, ecological integrity was given much more importance than the lives and livelihood of the common people, which they aggressively disapproved. They demanded infrastructural advancement of their villages which was not legally possible as they formed a part of PA. The remaining 20 percent of the respondents did not appreciate the establishment of PA and were against all the rules and regulations imposed by the Forest Department (FD). Overall, the respondents were not much receptive towards the efforts of FD as their demands contravenes the law.

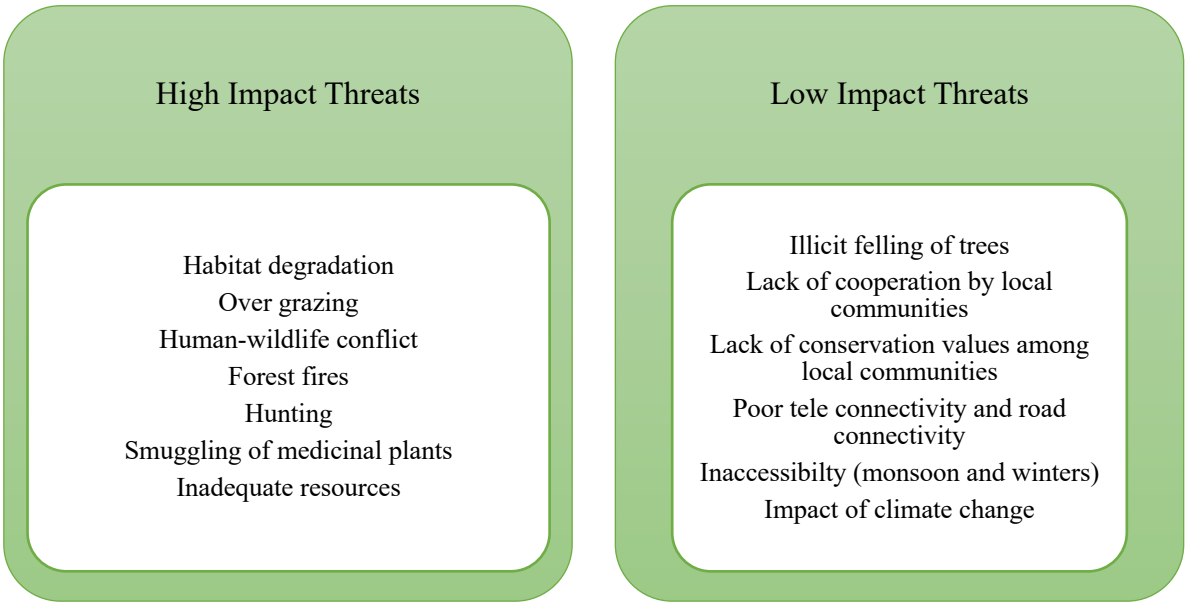


Figure 6.1 Recognized Threats to the Protected Area

6.2 Threats to Protected Area

a) Habitat Degradation – There are 42 revenue villages situated inside PA with about 25,000 human population and about 15 villages are situated outside PA with about 8000 human population within 5 km radius of PA. A lot of biotic pressure is being imposed on PA by local communities, tourists and local orchards owners. Excessive grazing, collection of fuel, fodder, small timber and medicinal plants, and indiscriminate lopping by locals and pastoralists for their livestock has led to habitat degradation and frequent erosion and landslides in the area. There are a number of villages located up to 2800 m altitude (temperate zone), thus, the dependency of the villagers on the forests is obvious. They depend solely on the forest for fodder, fuel, timber and non-timber forest produce. During the winters, when the meadows and the park area become snow covered and lower altitude grasses become unpalatable or dry up, the villager's resort to lopping of trees and collection of grasses and stack it up during the post-autumn season. Certain species like banj, moru, kharsu, panger, anga, etc., are lopped and rendered leafless. These activities coupled with agricultural practices on high slopes causes the degradation of forest cover, more so in the vicinity of villages.

Plate No.26 Habitat destruction

Plate No.27 Threat to Protected Area

b) Over Grazing – High alpine meadows in the PA constitute about 48 percent of the core zone of Govind National Park. These meadows are ideal habitats for prey species of snow leopard, e.g., bharal, Himalayan tahr, musk deer, serow, etc. These meadows, locally known as *Bugyals* have been traditional grazing grounds for local pastoral community. Though grazing is not permitted in national parks, it is estimated by the officials that more than 1,50,000 heads of sheep, cows, goats and horses graze in this area every year despite the department's best efforts to stop grazing. Due to over-grazing, there has been a decrease in the number of wild herbivores, potentially impacting the prey base of snow leopard, the apex predator in the alpine region. The continuous visitation by pastoralists and tourist to the meadows has also created a problem of weed invasion, creating a competition of native species for survival.

c) Forest Fires – It is very common in the forests and grasslands of both temperate and tropical zones during the dry seasons. The most common reason for fire outbreak is people's carelessness while burning *bidi* or cigarette on the forest grounds. Another tendency is that the inhabitants living in and around the PA deliberately set fire to promote the growth of new grasses for their livestock grazing.

d) Hunting – Although the hunting of wild animals is prohibited as per Wildlife (Protection) Act of 1972, as per the officials, the cases of hunting in remote areas of the park cannot be denied. The Director Magistrate issues no new license for arms to the people living within the 5 km radius of the PA without submitting a no-objection certificate issued by the Deputy Director of the Park. Any fire-arms issued must be registered, record maintained and monitored by the Wildlife Warden. The department has identified many locals with licensed fire-arms, and some of them possess illegal weapons too. Since, most wild animals descend the slope for food during the winters, they become vulnerable to hunting for those villagers who are also stuck up high in the snow.

e) Smuggling of medicinal plants – The forest officials have identified many villagers and outsiders who illegally collect medicinal plants from the forests and meadows for commercial sales in the plain areas. It is a major cause of concern as it leads to biodiversity loss. Many cases have been reported for the illegal usage and smuggling of Cannabis and Opium in the region, as well.

f) Wildlife health and conflicts – Although no health monitoring system exist in the PA for wildlife health, but during cases it is dealt with experts from Wildlife Institute of India. Diseases carrying domestic cattle, while grazing have been known to infect wild animals. The human-wildlife conflict is not a big issue in this PA, still cases have been recorded

where wild animals have crossed boundaries searching food and water and entered the neighbouring villages and agricultural fields. This problem has created an unfriendly public attitude towards the management system. Cases related to cattle lifting and/or killing by leopards are also reported, and in between 2012 to 2017, there have been 3 human deaths, 27 human injuries and 30 cattle lifting. In this scenario, there is payment of cash compensation as ex-gratia payment to the affected villagers. The Government of Uttarakhand has issued a circular regarding interim relief for damage by wild animals vide G.O. No. 2228/X-2-2012-19(37)/2003 dated 10.12.2012. Many times, cases of fake deaths of cattle are also reported by the villagers in the hope of compensation. Thus, a rigorous investigation and animal postmortem are carried out by the officials.

6.3 Administrative Problems as encountered by the Forest Department

a) There is inadequate staff in terms of numerical strength and technical capability. Accessibility, mobility and communication is also inadequate due to tough terrain. There is overall a lack of training, incentives and amenities to the staff.
b) There is a lack of research policy and infrastructural facilities for research purposes are almost nil.
c) The is absence of tourism policy and objectives for tourism development and management is not clear, with negligible importance being given to conservation education and nature interpretation.
d) There is a severe limitation of knowledge regarding range of biodiversity, endangered, rare and threatened species, key sensitive sites, impact on resources and even the regeneration status of various species is not clearly known.
e) There is a lack of data on the dependency of local communities on forest-based resources. Local initiative for developing and protecting common property resources is not seen much.
f) The various developmental agencies of different government departments operating for the protection and conservation of PA as well as local people are not very well coordinated.
g) The economic opportunities for the local people are not properly identified. Thus, the socio-economic well-being of locals is undermined with ecological integrity of the area.
h) There is a lack of trust and understanding between PA management staff and local stakeholders.

6.4 The Difference of Opinion

Since, the socio-economic conditions were the major concern for the local community inside the PA, the only probable solution was the resettlement of the four villages. To settle the rights of the local communities and reduce biotic pressure on the core area of the national park, the Government of India, Ministry of Environment and Forest (now MoEFCC) by F.No, 6-43/2007 Wl-I (pt-ix) Dated 20.04.2010 decided to resettle the four villages (Dhatmeer, Gangar, Pawani and Osla) outside the PA by providing a suitable compensation package including land, housing and other facilities as early as possible in a time-bound manner. This led to a divide in opinion and controversy among the local community itself. The respondents up to the age of 35 years wanted to settle in the rehabilitated area, provided the compensation given was apt. The respondents with young children wished for a better life for their family in terms of basic amenities, education and health facilities and thus agreed on leaving their homes and settling on new land. The only thing holding them back was the surety of employment once they are rehabilitated. Their concern and opinion were opposite to respondents who were old. According to them, the PA was their birthland, and their rights over it cannot be denied under any legal circumstances. They stood against the idea of rehabilitation as they wanted to die on the same land where they were born. Since, there was a divide among the people themselves, the order for resettlement could not be delivered and the four villages remained as they were.

6.5 Multifunctional Future – Integrating the culture and livelihood needs

It is increasingly acknowledged that the needs, knowledge and values of local communities associated with biodiversity conservation sites contribute to biodiversity maintenance. The importance of incorporating a more participatory approach into PA decision-making processes to foster the implementation of conservation strategies has been widely recognized in the literature. Whether human-ecosystem interaction within a PA is sustainable and whether the levels of protection are adequate are key questions, as it is often difficult to monitor the effectiveness of protection. However, an increasing amount of research show evidences that forests managed by indigenous peoples and local communities are at least as effective at maintaining forest cover as those under stricter protection regimes.

Plate No.28 The need for multifunctional future

In order to balance the protection and conservation efforts with the productive function of the agroecosystem, the cultural aspect has to be considered to develop a multifunctional, sustainable PA management plan. Local communities are more likely to comply and commit themselves to long-term conservation strategies when their knowledge and opinions are incorporated into PA decision-making processes. An appropriate governance mechanism calls for a region-specific, conflict mitigation strategy for an integrated approach, where the local community's socio-economic needs are given equal importance, as to conservation. This implies a need for improved research capacity – in the form of scientists, subject experts and local representatives, thus, making it a participatory and a bottom-up process.

Unfortunately, the co-existence of mankind and wildlife is yet not accepted, leading to ambiguities and conflicts between different rules and regulations, which needs to be eliminated through legal revisions, guidelines, monitoring, and evaluation. The decision-making power of conservation governance is all over the place, from Centre to State or even community, with differing levels of participation and power. The policy and legal frameworks are often designed in the country context; thus, regional frameworks with a consultative, coordinated and more democratic form of governance can scale-up the conservation efforts. The approach to conservation and management should go beyond State boundaries and focus on the natural landscape as a whole, looking at the cumulative strengths and vulnerabilities of the area as well as the local community.

Defined broadly from local's perspective, mountain livelihood includes several land-based activities depending upon the local environment. The scale of dependence and economic returns from these activities is further determined by the impact of mountain specificities. Thus, remote mountain villages qualify for mixed farming practices, livestock rearing and pastoral activities. Mountain niches are hidden sources of valuable bio-resources, for potential farming opportunities and agri-business development. High levels of poverty in the remote mountain villages of developing countries are not a hidden aspect. The missing dimension of farm research and development catering to the needs of mountain agriculture, leads to the under-development of mountain livelihood. The local people must be given a fair chance at socio-economic upliftment, where they don't have to leave their lands if they don't want to.

In a diverse country like India, it may never be practical to frame a single law that provides adequate legal protection to the environment, and at the same time satisfy every aspect of society. The dependency of local community on the natural resources for meeting their daily

necessities of life can be clearly noticed. The sense of belonging towards their region and forest ownership is strong but they do understand the importance of conservation. In the name of traditional rights or community rights, a legal backing for the custodianship of natural resources, can be misleading and further complicating for the conservation efforts. But for the management practices to be successful, particularly in the presence of threats and challenges, the community rights should be appreciated at a regional level, depending upon the prevailing socio-economic conditions. Thus, the governing principles of a PA needs to be flexible to encompass the wide variety of physiographical, social, economic and cultural aspect of humankind. A broader framework enabling conservation and ensuring social justice is important. For years they have been treated as two separate activities, without realizing their co-dependence, which influences the lives and livelihood of many.

6.6 Adaptive Co-management Governance System

A well balanced and simultaneously evolving governance system holds the key to the future sustainable development of the mountains. The governance system in the mountains is poorly represented across the different inter-linked institutional levels, with a limited structure and functioning. Mostly the planning, decision-making and implementing powers rest with the higher state and/or national level authorities, with negligible contribution of the local administration. This disparity in the vertical set-up of governance leads to an imbalance in dissemination of power. It creates a ridge in the governing system which is often incompatible with the agenda of sustainable development.

Managing the sustainability in a mountain ecosystem requires the balancing of ecological complexity along with socio-economic responsibilities. Many indigenous and traditional mountain dwellers have mastered this challenging balance, as they remain isolated from the external pressures. As the demand for a localized and decentralized governance system is rising across the mountainous region, it still remains unheard. The biggest drawback of a mountain governance system is the lack of appropriate and specific institutional set-up to link the upstream and downstream societies. The current governance system only addresses the social dimension without comprehending the regional component of various ecosystem processes and dynamics. In a long-run, it is not sufficient to guide a society towards sustainability. Similarly, focusing only on the environmental aspect while decision making and policy formulation for sustainability may result into limited outcomes.

Drawbacks of Mountain Governance System:

a) Poorly conceived policy framework where the representation and initiative of local community is limited when brought to scale.
b) Inadequate attention is paid to the unequal distribution of power and responsibility amongst different levels of governing system.
c) Deficit of accountability, i.e., the responsible exercise of power by an individual and/or organization in a transparent manner and also accepting the consequences of the actions taken.
d) Lack of social equity and representation, i.e., the participation and involvement of individuals (social actors/stakeholders) in decision making is certainly missing at a local level.
e) Disregard towards the rich and abundant local knowledge, as it remains underutilized and unappreciated in the policy making process.
f) Unclear lines of authority and power within a socially constructed system.
g) Cooperation in mountain governance system is hampered by the weak cross-scale political connection and representation. There is limited cross-border knowledge sharing with high stakes of regionalism, not considering themselves as one whole mountain community.

Adaptive Co-Management (ACM) as a process has its foundations in the convergence of two independently evolved concepts, adaptive management and co-management. ACM links scientists with local people and stakeholders, resource users and government officials for a collaborative resolution of problems. The ability of ACM to link the adaptive and collaborative mechanisms offers the potential to encourage observation, participation and opportunities for the local community.

The neglect of culture and traditional knowledge is long done and a reinvention of governance system is underway. The focus should be on local management and governance of a mountainous landscape, addressing the social responsiveness and fundamental duty of every individual towards the socio-ecological system, that they are a part of. The evolving knowledge of ecosystem dynamics and sustainable management already exists among the local people, as they on a daily basis have interacted with the ecosystem for their needs, benefits and livelihood. Over the years, this knowledge has been organized, culturally embedded and passed on to

generations. It has a potential to be institutionalized in new ways for an effective mountain governance.

ACM involves the decentralization of operational power and management rights, thus promoting local participation. It allows various stakeholders to share the roles and responsibilities within a defined system, where they can explore a common goal, learn, adapt and modify subsequently. Attributes that promote good governance include participation, representation, deliberation, accountability, empowerment, social justice, and organizational features such as being multilayered and polycentric.

For operationalizing ACM, the emphasis on social capital, i.e., local network, leadership and trust, is crucial. In ACM, diverse social actors are brought together under a single self-organized governance network, with a focus on common problems. The vertical linkages between the actors are vital for the flow of information and knowledge. But this multilevel institutional framework can stimulate collaboration only when there is trust among the various stakeholders that provide information, encouraging a common perspective on local policy issues.

The association between formal and informal social networks can strengthen the flexibility of the system and provide a scope for innovation in mountain governance. However, it does not replace the credibility of formal bureaucracies but instead function within its jurisdiction and guidance. Such interlinked partnership networks require a powerful leadership as well. A good leader can build a stable ACM governance system by establishing trust within communities, managing their conflicts, compiling relevant local information and mobilizing the local support for a strong governance system of which the people finally feel a part of. For an effective horizontal and vertical institutional collaboration, it is crucial to build a social capital by investing in social relationships with the local community. The various local actors and stakeholders play an important role in mobilizing the local network to cooperate with the formal governance system.

Collaborative, cooperative and participatory approaches have become increasingly significant in governmental policy formulation and implementation. ACM governance system focuses on learning and involving the local community, their social relations and social networks. For a successful institutional approach, the mountain governance system has to evolve, ensure participation and support traditional values, knowledge and culture. The key

element for a blooming partnership is to protect the community's interest from external stress and encroachments, thus encouraging them to act collectively rather than independently for a common goal, i.e., sustainable development of the mountains.

ACM isn't fully understood and faces a number of challenges, like, dealing with power disparity and inequity among the stakeholders, facilitating the vertical and horizontal institutional linking and communication, among others. Decentralization being an important component of ACM can infringe the participation, where the stronger stakeholders can control and exploit the weaker stakeholders endangering the entire concept of cooperation and collaboration. Transparency in the activities of the government officials, non-governmental organizations as well as the participating local community is very crucial for longevity of the system. If not so, doubts, conflicts and divisions may arise among the participants, thus complicating the entire process of trust building.

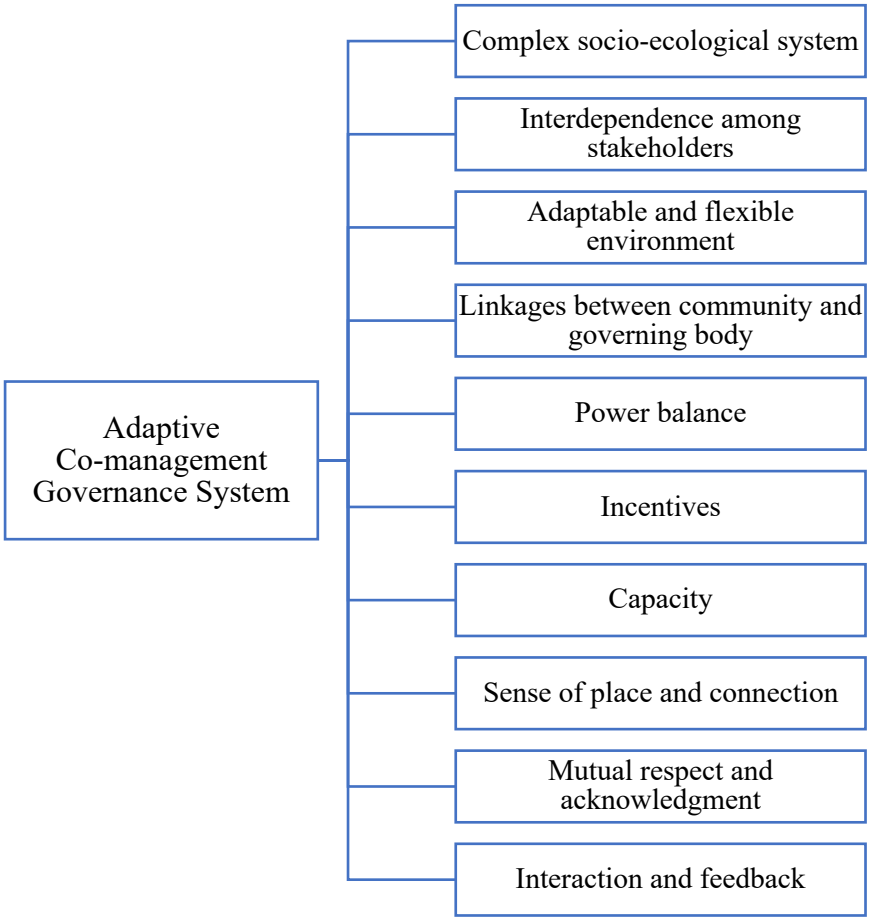


Figure 6.2 Essential Elements for Adaptive Co-management Governance System

Key elements of ACM governance system:

a) Expanding the importance of ES by recognizing its utility and value for the well-being of mountain community.
b) Involving local people in natural resource management and paying them incentives for their services. It will harness the interest of various local actors and/or stakeholders.
c) Strengthening the institutional governance system with active involvement of local people in decision-making, so that they feel a part of the system.
d) Raise awareness about the environmental changes, its consequences and management.
e) Support regional and cross-border research initiative covering the diverse element of mountain ecosystem.
f) Document the available indigenous and traditional knowledge so that it can be incorporated in the management of mountain ecosystem, which have been flourishing up until now because of ancestral skills and learning.
g) Ensuring a balanced capacity building of the governance system as well as the local community by including their voice, interests and constraints.
h) Build partnerships – linking the regional (mountain) capacity via national policies and international agreements.
i) Development of a systematic and continuous monitoring and evaluation of the mountain ecosystem.

Understanding the complexity and dynamism of mountain ecosystem with the adaptability and capacity of mountain community provides insight into the hidden opportunities for sustainable mountain development. Traditional mountain cultures have intensively managed natural resources, practiced local sustainability and demonstrated self-sufficiency. The mountain communities have little alternative to their dependence on natural resources. The inherent incentives form the basis of their local sustainability, which can be rationalized through institutional approaches, like, provision of local control over natural resource use and allocation under the guidance of administrative authorities. The participation of local stakeholders in decision making ensures the equitable use and sharing of benefits among the local people. Through the involvement and active participation of local community, finally their feeling of belongingness is aptly represented.

Mountain regions are home to culturally rich communities, and over generations their traditional and local knowledge has evolved, to adapt to the dynamic societal changes and environmental challenges. Their adaptation strategies find expression in agricultural interventions, socio-economic arrangements, and local institutional set-up. Sustainable and inclusive economies and supportive policies are crucial for enabling mountain people to escape the multidimensional poverty. The overall goal of regional mountain development should target societal disparity, while strengthening their resilience and capacity. The specific objective of sustainable livelihood development should be rooted in local, socio-cultural dynamism, focusing on the "vision for the mountain region". To achieve this vision, the guiding principles for livelihood development should be designed as: inclusive, people-centred, region-based and environmental-friendly.

Bibliography

Aase, T.H., Chapagain, P.S. and Tiwari, P.C. 2013. Innovation as an expression of adaptive capacity to change in Himalayan farming. Mountain Research and Development, 33(1), 4–10.

Abdul-Razak, M. and Kruse, S. 2017. The adaptive capacity of smallholder farmers to climate change in the northern region of Ghana. Climate Risk Management, 17, 104-122.

Adger, W.N. 2003. Social capital, collective action and adaptation to climate change. Econ. Geogr., 79:387–404.

Adger, W.N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D.R., Otto Naess, L., Wolf, J. and Wreford, A. 2009. Are there social limits to adaptation to climate change? Climatic Change, 93, 335–54.

Adger, W.N., Agrawala, S., Mirza, M.M.Q., Conde, C., O'Brien, K.L., Pulhin, J., Pulwarty, R., Smit, B. and Takahashi, K. 2007. Assessment of adaptation practices, options, constraints and capacity. In Parry, M.L., Canziani, O.F., Palutikof, J.P., Hanson, C.E. and van der Linden, P.J. Editors, Climate change. 2007. Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, 719–43.

Adger, W.N., Huq, S., Brown, K., Conway, D. and Hulme, M. 2003. Adaptation to climate change in the developing world. Progress in Development Studies, 3, 179–95.

Adhikari, S., Baral, H. and Nitschke, C. 2018. Adaptation to climate change in Panchase mountain ecological regions of Nepal. Environments, 5, 42.

Agrawal, A. 2010. Local institutions and adaptation to climate change. In Mearns, R. and Norton, A. Editors. Social dimensions of climate change: Equity and vulnerability in a warming world. The World Bank, 173–98.

Agrawal, A. and Lemos, M.C. 2015: adaptive development. Nature Climate Change 5, 185–87.

Aizen, M.A., Garibaldi, L.A., Cunningham, S.A. and Klein, A.M. 2009. How much does agriculture depend on pollinators? Lessons from long-term trends in crop production. Ann. Bot., 103, 1579–1588.

Alam, G.M., Alam, K. and Mushtaq, S. 2017. Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh. Clim. Risk Manag., 17, 52–63.

Alencar, N.L., Junior, W.S.F. and Albuquerque, U.P. 2014. Medicinal plant knowledge richness and sharing in north-eastern Brazil. Econ. Bot., 68: 371–382.

Alhassan, I.S., Shaibu, M.T., Kuwornu, K.M.J. and Osman, T.D. 2018. Measuring smallholder women farmers' adaptive capacity to climate change and variability in northern region, Ghana: a composite index approach. CCCSDA 2017 Special Issue: Environment, Technology and Sustainable Development, Vol 1, 1-9.

Allen, S.A. 1989. Chemical analysis of ecological materials. Blackwell, London.

Allison, H.E. and Hobbs, R.J. 2004. Resilience, adaptive capacity, and the "lock-in trap" of the western Australian agricultural region. Ecol. Soc., 9(1):3.

Anderies, J.M., Janssen, M.A. and Ostrom, E. 2004. A framework to analyse the robustness of social-ecological systems from an institutional perspective. Ecol. Soc., 9(1):18.

Antonelli, A. 2015. Biodiversity: Multiple origins of mountain life. Nature, 524(7565), 300–301.

Araujo, T.A.S., Almeida, A.L.S., Melo, J.G., Medeiros, M.F.T. and Ramos, M.A. 2012. A new technique for testing distribution of knowledge and to estimate sampling sufficiency in ethnobiology studies. J. Ethnobiol. Ethnomed., 8(1): 11.

Asante, F.A. and Amuakwa-Mensah, F. 2009. Climate change and variability in Ghana: Stocktaking. Climate, 3(1), 78-99.

Ashley, C. and Carney, D. 1999. Sustainable livelihoods: lessons from early experience. London: DFID.

Ayers, J.M. and Huq, S. 2009. Supporting Adaptation to Climate Change: What Role for Official Development Assistance? Development Policy Review, 27 (6): 675-692.

Ayer, R.S. and Westcot, D.W. 1985. Water quality for agriculture. FAO irrigation and drainage paper.

Bakshi, P. and Kumar, D. 2019. Mountain agriculture: Opportunities for harnessing Zero Hunger in Asia, FAO, Bangkok.

Balzan, M.V., Sadula, R. and Scalvenzi, L. 2020. Assessing ecosystem services supplied by agroecosystems in Mediterranean Europe: a literature review. Land, 9, 245.

Bangroo. S.A., Tahir, A., Mahdi, S.S., Najar, G.R. and Sofi, J.A. 2013. Carbon and greenhouse gas mitigation through soil carbon sequestration potential of adaptive agriculture and agroforestry systems. Range Management & Agroforestry, 34 (1):1-11.

Banskota, K., Karky, B. and Skutsch, M. 2007. Reducing carbon emissions through community-managed forests in the Himalaya. International Centre for Integrated Mountain Development (ICIMOD).

Bastakoti, R.C., Bharati, L., Bhattarai, U. and Wahid, S.M. 2017. Agriculture under changing climate conditions and adaptation options in the Koshi Basin. Clim. Dev., 9, 634–648.

Bastian, O., Haase, D. and Grunewald, K., 2012. Ecosystem properties, potentials and services – The EPPS conceptual framework and an urban application example. Ecological Indicators, 21, 7–16.

Bationo, A., Kihara, J., Vanlauwe, B., Waswa, B. and Kimetu, J. 2007. Soil organic carbon dynamics, functions and management in West African agroecosystems. Agricultural Systems, 94: 13-25.

Bebbington, A. 1999. Capitals and capabilities: a frame- work for analysing peasant viability, rural livelihoods and poverty. World Development, 27, 2012–44.

Bennett, E.M., Peterson, G.D. and Gordon, L.J. 2009. Understanding relationships among multiple ecosystem services. Ecology Letters, 12(12), 1394–1404.

Berkes, F., Colding, J. and Folke, C. 2003. Navigating social–ecological systems: building resilience for complexity and change. Cambridge University Press, Cambridge, UK.

Berkes, F., Colding, J. and Folke, C. 2000. Re- discovery of traditional ecological knowledge as adaptive management. Ecol. Appl., 10:1251–62.

Berkes, F. and Folke, C. 1998. Linking social and ecological systems: management practices and social mechanisms for building resilience. Cambridge University Press, Cambridge, UK.

Berkhout, F., Leach, M. and Scoones, I. eds. 2003. Negotiating environmental change: new perspectives from social science. Cheltenham: Edward Elgar.

Bethwell, C., Burkhard, B., Daedlow, K., Sattler, C., Reckling, M. and Zander, P. 2021. Towards an enhanced indication of provisioning ecosystem services in agro-ecosystems. Environ. Monit. Assess., 193:269.

Bhatt, L.D., van Oort, B.E.H, Stork, N.E. and Baral, H. 2015. Ecosystem services and livelihoods in a changing climate: understanding local adaptations in the Upper Kosi, Nepal, International Journal of Biodiversity Science, Ecosystem Services & Management, Vol. 11, No. 2, 145-155.

Biggs, R., Schlüter, M. and Schoon, M.L. Editors. 2015. Principles for building resilience: sustaining ecosystem services in social- ecological systems. Cambridge University Press, Cambridge, UK.

Biodiversity International. 2017. Mainstreaming Agrobiodiversity in Sustainable Food Systems: Scientific Foundations for an Agrobiodiversity Index. BI, Rome.

Blaikie, P.M. and Muldavin, J.S. 2004. Upstream, downstream, China, India: the politics of environment in the Himalayan region. Annals of the Association of American Geographers, 94(3), 520– 548.

Boogaard, B.K., Bock, B.B., Oosting, S.J., Wiskerke, J.S.C. and Zijpp, A.J. 2010. Social Acceptance of Dairy Farming: The Ambivalence Between the Two Faces of Modernity. Journal of Agricultural and Environmental Ethics 24, 259–282.

Bouwman, A.F., Beusen, A. H. W. and Billen, G. 2009. Human alteration of the global nitrogen and phosphorus soil balances for the period 1970 – 2050. Global Biogeochem. Cycles, 23, GB0A04.

Burkhard, B., Kroll, F., Nedkov, S. and Müller, F. 2012. Mapping ecosystem service supply, demand and budgets. Ecol. Indic, 21, 17–29.

Burkhard, B., de Groot, R., Costanza, R., Seppelt, R., Jørgensen, S.E. and Potschin, M. 2012a. Solutions for sustaining natural capital and ecosystem services. Ecological Indicators, 21, 1–6.

Burkhard, B. and Müller, F., 2008. Indicating human–environmental system properties: case study northern Fenno-Scandinavian Reindeer Herding. Ecological Indica- tors 8, 828–840.

Carpenter, S.R. and Gunderson, L.H. 2001. Coping with collapse: ecological and social dynamics in ecosystem management. Bio-Science, 6:451–57.

Chambers, R. 1983. Rural development: Putting the last first. Longman.

Chapagain, P.S., Ghimire, M.L. and Shrestha, S. 2016. Situation of springs, groundwater spring potentiality and gender roles in water management: a study of Melamchiarea, Sindhupalchok, Nepal. In: Bhuju, D.R., McLaughlin, K., Sijapati, J., Devkota, B.D., Shrestha, N., Ghimire, G.P., Neupane, P.K. (eds). Building knowledge for climate resilience in Nepal: research briefs. Nepal Academy of Science and Technology, Lalitpur, pp 87–92.

Chapin III, F.S., Carpenter, S.R., Kofinas, G.P., Folke, C., Abel, N., Clark, W.C., Olsson, P., Stafford Smith, D.M., Walker, B.H., Young, O.R., Berkes, F., Biggs, R., Grove, J.M., Naylor, R.L., Pinkerton, E., Steffen, W. and Swanson, F.J. 2010. Ecosystem stewardship: sustainability strategies for a rapidly changing planet. Trends in Ecology and Evolution, 25:241-249.

Chaudhary, S., Chettri, N., Uddin, K., Khatri, T.B., Dhakal, M., Bajracharya, B., et al. 2016. Implications of land cover change on ecosystem services and people's dependency. A case study from the Koshi Tappu Wildlife Reserve, Nepal. Ecological Complexity.

Chaudhary, S., McGregor, A., Houston, D. and Chettri, N. 2015. The evolution of ecosystem services: A time series and discourse-centred analysis. Environmental Science & Policy, 54, 25–34.

Chettri, N. and Sharma, E. 2016. Reconciling the mountain biodiversity conservation and human wellbeing: Drivers of biodiversity loss and new approaches in the Hindu-Kush Himalayas. Proceedings of the Indian National Science Academy, 82, 53–73.

Chettri, N., Sharma, E., Shakya, B., Thapa, R., Bajracharya, B., Uddin, K., et al. 2010. Biodiversity in the Eastern Himalayas: Status, trends and vulnerability to climate change. Climate change impact and vulnerability in the Eastern Himalayas—Technical report 2 (p. 23). Kathmandu: ICIMOD.

Chivenge, P., Mabhaudhi, T., Modi, A.T. and Mafongoya, P. 2015. The Potential Role of Neglected and Underutilised Crop Species as Future Crops under Water Scarce Conditions in Sub-Saharan Africa. International Journal of Environmental Research and Public Health, 12 (6): 5685–5711.

Chukalla, A.D., Krol, M.S. and Hoekstra, A.Y. 2015. Green and blue water footprint reduction in irrigated agriculture: effect of irrigation techniques, irrigation strategies and mulching. Hydrol. Earth Syst. Sci. Discuss., 12, 6945–6979.

Clark, W.C. 2007. Sustainability science: a room of its own. Proceedings of the National Academy of Sciences of the USA, 104:1737-1738.

Clay, N. 2017. Integrating livelihoods approaches with research on development and climate change adaptation. Progress in Development Studies, 18, pp. 1–17.

Colding, J. and Barthel, S. 2019. Exploring the social-ecological systems discourse 20 years later. Ecology and Society, 24(1):2.

Colding, J. and Folke, C. 2001. Social taboos: "invisible" systems of local resource management and biodiversity conservation. Ecological Applications, 11:584-600.

Cork, S., Stoncham, G. and Lowe, K. 2007. Ecosystem Service and Australian Natural Resource Management Future. Technical Report, the Ecosystem Services Working Group of the Natural Resource Policies and Programs Committee.

Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S. and Turner, R.K., 2014. Changes in the global value of ecosystem services. Glob. Environ. Change, 26,152-158.

Costanza, R., Waigner, L., Folke, C. and Mäler, K-G. 1993. Modelling complex ecological economic systems: towards an evolutionary dynamic understanding of people and nature. BioScience, 43:545–55.

Daily, G.C., Alexander, S., Ehrlich, P.R., Goulder, L., Lubchenco, J., Matson, P.A., Mooney, H.A., Postel, S., Schneider, S.H., Tilman, D. and Woodwell, G.M. 1997. Ecosystem services: benefits supplied to human societies by natural ecosystems. Issues in Ecology, 2, 18.

Dale, V.H. and Polasky, S. 2007. Measures of the effects of agricultural practices on ecosystem services. Ecol. Econ., 64:286–296.

Davis, A. and Wagner, J.R. 2003. Who knows? On the importance of identifying experts when researching local ecological knowledge. Hum. Ecol., 31:463–89.

Daze, A., Ambrose, K. and Erhart, C. 2009. Climate Vulnerability and Capacity Analysis Handbook; CARE International: Geneva, Switzerland.

de Groot, R.S., Alkemade, R., Braat, L., Hein, L. and Willemen, L. 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity, 7(3), 260–272.

Defiesta, G.D. and Rapera, C.L. 2014. Measuring Adaptive Capacity of Farmers to Climate Change and Variability: Application of a Composite Index to an Agricultural Community in the Philippines. Journal of Environmental Science and Management, 17(2).

Demessie, A. Singh, B.R. and Lal, R. 2013. Soil carbon and nitrogen stocks under chrono sequence of farm and traditional agro- forestry uses in Gambo district, southern Ethiopia. Nutrient Cycling in Agroecosystems, 95: 365–375.

Department of Economics and Statistics. 2021. Uttarakhand at a Glance (2019-20). Department of Planning, Government of Uttarakhand.

Department for International Development (DFID). 2000. Sustainable Livelihoods Guidance Sheets. Department for International Development. London.

Devkota, R.P. 2014. Climate change: trends and people's perception in Nepal J. Environ. Prot., 5, 255–65.

Diamond, J. 2005. Collapse: How Societies Choose to Fail or Survive. New York: Penguin Books.

Dietz, T., Ostrom, E. Stern, P.C. 2003. The struggle to govern the commons. Science, 302:1902–12.

Drinkwater, L.E. and Snapp, S.S. 2007. Nutrients in agroecosystems: re-thinking the management paradigm. Adv. Agron., 92, 163 – 186.

du Pisani, J.A. 2006. Sustainable development – historical roots of the concept. Environmental Sciences, 3:2, 83-96.

Eakin, H.C., Lemos, M.C. and Nelson, D.R. 2014. Differentiating capacities as a means to sustainable climate change adaptation. Global Environmental Change, 27, 1–8.

Edwards, C.A. 1975. Factors that affect the persistence of pesticides in plants and soils. Pure Appl. Chem., 42, 39-56.

Egyir, I.S., Ofori, K., Antwi, G. and Ntiamoa-Baidu, Y. 2015. Adaptive Capacity and Coping Strategies in the Face of Climate Change: A Comparative Study of Communities around Two Protected Areas in the Coastal Savanna and Transitional Zones of Ghana. Journal of Sustainable Development, 8(1), p1-15.

Elalem, S. and Pal, I. 2015. Mapping the vulnerability hotspots over Hindu-Kush Himalaya region to flooding disasters. Weather and Climate Extremes, 8, 46–58.

Ellis, E.C. 2015. Ecology in an anthropogenic biosphere. Ecological Monographs, 85(3), 287–331.

Ellis, F. 2000. Rural livelihoods and diversity in developing countries. Oxford: Oxford University Press.

European Environment Agency (EEA). 2010. Ecosystem accounting and the cost of biodiversity losses. The case of coastal Mediterranean wetlands. EEA Technical report No 3/2010, Copenhagen. 91pp.

Fabbris, L. 2013. Measurement scales for scoring or ranking sets of interrelated items. Survey Data Collection and Integration. Springer Berlin Heidelberg.

Fabricius, C. and Koch, E. eds. 2004. Rights, Resources and Rural Development: Community-Based Natural Resource Management in Southern Africa. London: Earth-scan.

Fahrig, L., Baudry, J., Brotons, L., Burel, F.G., Crist, T.O., Fuller, R.J., Sirami, C., Siriwardena, G.M. and Martin, J.L. 2011. Functional landscape heterogeneity and animal biodiversity in agricultural landscapes. Ecol. Lett., 14:101–112.

Fanny, B., Nicolas, D. and Marc, D. 2015. Contribution of diversified farming systems to the delivery of ecosystem services.

Food and Agriculture Organization (FAO). 2018. Future Smart Food: rediscovering hidden treasures of neglected and underutilized species for Zero Hunger in Asia. Bangkok.

Food and Agriculture Organization (FAO). 2015. Mapping the vulnerability of mountain peoples to food insecurity. Rome, Italy: Food and Agriculture Organization of the United Nations.

Food and Agriculture Organization (FAO). 2003. World agriculture: towards 2015/2030. Interim Report. Rome, Italy: FAO.

Food and Agriculture Organization (FAO). 1995. Dimensions of need: An atlas of food and agriculture, Italy.

Foggin, J.M. 2016. Conservation issues: Mountain ecosystems. Earth Systems & Environmental Sciences (Reference Module online). Science Direct, Elsevier Publishing Company.

Folke, C. 2016. Resilience (Republished). Ecology and Society, 21(4):44.

Folke, C., Jansson, Å., Rockström, J., Olsson, P., Carpenter, S.R., Chapin III, F.S., Crépin, A.-S., Daily, G., Danell, K., Ebbesson, J., Elmqvist, T., Galaz, V., Moberg, F., Nilsson, M., Österblom, H., Ostrom, E., Persson, Å., Peterson, G., Polasky, S., Steffen, W., Walker, B. and Westley, F. 2011. Reconnecting to the biosphere. Ambio., 40:719-738.

Folke, C. 2006. Resilience: the emergence of a perspective for social-ecological systems analyses. Global Environmental Change, 16:253–267.

Folke, C., Hahn, T., Olsson, P. and Norberg, J. 2005. Adaptive governance of social–ecological systems. Annual Review of Environment and Resources, 30:441-473.

Folke, C., Carpenter, S.R., Walker, B.H., Scheffer, M., Elmqvist, T., Gunderson, L. and Holling, C.S. 2004. Regime shifts, resilience and biodiversity in ecosystem management. Annual Review of Ecology, Evolution and Systematics, 35:557-581.

Folke, C., Colding, J. and Berkes, F. 2003. Synthesis: building resilience and adaptive capacity in social-ecological systems. Navigating social-ecological systems: building resilience for complexity and change, Cambridge University Press.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., et al. 2001. Resilience and sustainable development: building adaptive capacity in a world of transformations. Rep. Swed. Environ. Advisory Council. Ministry of Environment, Stockholm, Sweden.

Folke, C. and Berkes, F. 1998. Understanding dynamics of ecosystem-institution linkages for building resilience. Discussion Paper No. 112. The Beijer Institute of Ecological Economics, Royal Academy of Sciences, Stockholm, Sweden.

Folke, C., Jansson, A., Larsson, J. and Costanza, R. 1997. Ecosystem appropriation by cities. Ambio., 26:167–72.

Franzluebbers, A.J. 2002. Water infiltration and soil structure related to organic matter and its stratification with depth. Soil Till. Res., 66, 197–205.

Friedman, J., Yaniv, Z., Dafni, A. and Palewitch, D. 1986. A preliminary classification of the healing potential of medicinal plants, based on a rational analysis of an ethnopharmacological field survey among bedouins in the Negev desert, Israel. J. Ethnopharmacol., 16: 275–287.

Gadgil, M., Olsson, P., Berkes, F. and Folke, C. 2003. Exploring the role of local ecological knowledge for ecosystem management: three case studies. Navigating social-ecological systems: building resilience for complexity and change, Cambridge University Press. 42, pp. 189–209.

Gadgil, M., Seshagiri Rao, P.R., Utkarsh, G., Pramod, P. and Chatre, A. 2000. New meanings for old knowledge: the people's bio- diversity registers programme. Ecol. Appl., 10:1307–17.

Gadgil, M., Berkes, F. and Folke, C. 1993. Indigenous knowledge for biodiversity conservation. Ambio., 22:151-156.

Goldman, M.J. and Riosmena, F. 2013: adaptive capacity in Tanzanian Maasailand: Changing strategies to cope with drought in fragmented landscapes. Global Environmental Change, 23, 588–97.

Gallopin, G.C. 2006. Linkages between vulnerability, resilience, and adaptive capacity. Global Environmental Change, 16, 293–303.

Garnett, T., Appleby, M., Balmford, A., Bateman, I., Benton, T., Bloomer, P. and Fraser, D. 2013. Sustainable intensification in agriculture: Premises and policies. Science, 341(6141), 33–34.

Gbetibouo, G.A. 2009. Understanding farmer's perception and adaptations to climate change and variability. the case of the Limpopo Basin, South Africa IFI Discussion Paper 00849 (Pretoria: International Policy Research Institute).

Geertz, C. 1973. The interpretation of cultures: selected essays. Basic Books, New York, New York, USA.

Gerlitz, J.Y., Banerjee, S., Brooks, N., Hunzai and K., Macchi, M. 2015. An approach to measure vulnerability and adaptation to climate change in the Hindu Kush Himalayas. In: Handbook of Climate Change Adaptation, pp. 151–176.

Giddings, B., Hopwood, B. and Brien, G.O. 2002. Environment, economy and society: Fitting them together into sustainable development. Sustain. Dev., 196, 187–196.

Goldewijk, K.K., Beusen, A., Van Drecht, G. and De Vos, M. 2011. The HYDE 3.1 spatially explicit database of human-induced global land-use change over the past 12,000 years. Global Ecology and Biogeography, 20(1), 73–86.

Gomez-Baggethun, E. et al. 2014. State-of-the-art report on integrated valuation of ecosystem services. 33 European Commission.

Grêt-Regamey, A., Walz, A. and Bebi, P. 2008. Valuing ecosystem services for sustainable landscape planning in Alpine regions. Mountain Research and Development, 28(2), 156–165.

Grumbine, R.E. and Pandit, M.K. 2013. Threats from India's Himalaya dams. Science, 339(6115), 36–37.

Gunderson, L.H. and Holling, C.S. 2002. Panarchy: understanding transformations in human and natural systems. Island Press, Washington, D.C., USA.

Guo, J.H., Liu, X.J., Zhang, Y., Shen, J.L., Han, W.X. and Zhang. 2010. Significant acidification in major Chinese croplands. Science, 327 (5968), 1008-1010.

Gupta, S., Anand, S. and Gwal, S. 2018. Inbound tourism in Uttarakhand, India, before and after the 2013 Kedarnath disaster–evidence derived from social networking sites using GIS. Current Science, 114(8), Article 00113891.

Haase, D., Schwarz, N., Strohbach, M., Kroll, F. and Seppelt, R. 2012. Synergies, trade-offs, and losses of ecosystem services in urban regions: an integrated multiscale framework applied to the Leipzig-Halle Region. Germany. Ecology and Society, 17(3), 22.

Heinrich, M., Ankli, A., Frei, B., Weimann, C. and Sticher. 1998. Medicinal plants in Mexico: Healers' consensus and cultural importance. Soc. Sci. Med., 47: 1863–1875.

Hinkel, J. 2011. Indicators of vulnerability and adaptive capacity: Towards clarification of the science-policy interface. Global Environmental Change, 21, 198–208.

Huntington, H.P. 2000. Using traditional ecological knowledge in science: methods and applications. Ecol. Appl., 10, 1270–4.

Intergovernmental Panel on Climate Change (IPCC). 2007. Contribution of working group III to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

International Soil Reference and Information Centre (ISRIC). 2007. Green water credits. Wageningen, The Netherlands: ISRIC—World Soil Information.

Jackson, M.L. 1967. Soil chemical analysis. Prentice Hall, New Delhi

Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., et al. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science, 293: 629–37.

Joshi, A., Farquhar, S., Assareh, N., Dahlet, L. and Landahl, E. 2019. Climate change in Lamjung district, Nepal: meteorological evidence, community perceptions, and responses. Environ. Res. Commun., 1.

Kandel, P., Tshering, D., Uddin, K., Lhamtshol, T., Aryal, K., Karki, S., Sharma, B. and Chettri, N. 2018. Understanding social-ecological interdependence using ecosystem services perspective in Bhutan, Eastern Himalayas, Ecosphere, 9 (2):e02121.

Kasperson, J.X, Kasperson, R.E., Turner, B.L., eds. 1995. Regions at Risk: Comparisons of Threatened Environments. Tokyo: United Nations Univ. Press.

Kibblewhite, M.G., Ritz, K. and Swift, M.J. 2008. Soil health in agricultural systems. Philos. Trans. R. Soc. Lomd. B., 363-685-701.

Klein, A.M., Vaissiere, B., Cane, J., Steffan-Dewenter, I., Cunningham, S., Kremen, C. and Tscharntke, T. 2007. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B: Biological Sciences, 274 (1608), 303–313.

Körner, C. 2004. Mountain biodiversity, its causes and function. Ambio, 11–17.

Kragt, M.E. and Robertson, M.J. 2014. Quantifying ecosystem services trade-offs from agricultural practices. Ecol. Econ., 102:147–157.

Kubiszewski, I., Costanza, R., Dorji, L., Thoennes, P. and Tshering, K. 2013. An initial estimate of the value of ecosystem services in Bhutan. Ecosystem Services, 3, e11–e21.

Lal, R., 2016. Beyond COP21: potential and challenges of the 4 per Thousand initiative. J. Soil Water Conserv., 71, 20-25.

Lal, R., 2014a. Societal value of soil carbon. J. Soil Water Conserv., 69 (6), 186–192.

Lal, R., 2014b. Societal value of soil carbon. J. Soil Water Conserv., 69, 186–192.

Lal, R. 2008. Sequestration of atmospheric CO2 in global carbon pools. Energy Environ. Sci., 1, 86 – 100.

Lal, R. 2004. Soil carbon sequestration to mitigate climate change. Geoderma., 123: 1–22.

Layard, R. and Glaister, S. 2012. Cost-Benefit Analysis. Cambridge University Press: New York, USA.

Leach, M., Mearns, R. and Scoones, I. 1999. environmental entitlements: Dynamics and institutions in community-based natural resource management. World Development 27, 225–47.

Lemos, M.C., Lo, Y.J., Nelson, D.R., Eakin, H. and Bedran-Martins, A.M. 2016. Linking development to climate adaptation: Leveraging generic and specific capacities to reduce vulnerability to drought in Ne Brazil. Global Environmental Change, 36, 170–79.

Lemos, M.C., Agrawal, H., Nelson, D.R., Engle, N.L. and Johns, O. 2015: Building adaptive capacity to climate change in less developed countries. In Climate Science for Serving Society; Springer: Dordrecht, The Netherlands, 2013; pp. 437–457. ISBN 978-94-007-6692-1.

Lemos, M., Agrawal, A., Eakin, H., Nelson, D., Engle, N. and Johns, O. 2013.Building adaptive capacity to climate change in less developed countries. In G. R. Asrar & J. W. Hurrell (Eds.), Climate science for serving society, pp. 437–457, Netherlands: Springer.

Levin, S. 1999. Fragile Dominion: Complexity and the Commons. Reading, MA: Perseus.

Levin, S., Xepapadeas, T., Crépin, A.S., Norberg, J., de Zeeuw, A., Folke, C., Hughes, T.P., Arrow, K., Barrett, S., Daily, G., Ehrlich, P., Kautsky, N., Mäler, K.G., Polasky, S., Troell, M., Vincent, J. and Walker, B.H. 2013. Social-ecological systems as complex adaptive systems: modelling and policy implications? Environment and Development Economics, 18:111-132.

Loewy, R.M., Carvajal, L.G., Novelli, M. and de D'Angelo, A.M.P. 2003. Effect of pesticide use in fruit production orchards on shallow ground water. Journal of Environmental Science and Health, Part B, Vol. 38, 317-325.

Ludwig, D., Mangel, M. and Haddad, B. 2001. Ecology, conservation, and public policy. Annu. Rev. Ecol. Syst., 32:481–517.

Luers, A.L., Lobell, D.B., Sklar, L.S., Addams, C.L. and Matson, P.A. 2003. A method for quantifying vulnerability applied to the agricultural system of the Yaqui Valley, Mexico. Global Environmental Change, 13, 255−267.

Macchi, M. 2011. Framework for community-based climate vulnerability and capacity assessment in mountain areas. Kathmandu, Nepal: International Centre for Integrated Mountain Development.

Maddison, D. 2006. The Perception of and adaptation to climate change in Africa CEEPA. Discussion Paper No. 10. Centre for Environmental Economics and Policy in Africa (Pretoria: University of Pretoria).

Maharana, I., Rai, S.C. and Sharma, E. 2000. Environmental economics of the Khangchendzonga National Park in the Sikkim Himalaya, India. Geo Journal, 50(4), 329–337.

Malik, Z.A., Bhat, J.A., Ballabha, R., Bussmann, R.W. and Bhatt, A.B. 2015. Ethnomedicinal plants traditionally used in health care practices by inhabitants of western Himalaya. J. Ethnopharmacol., 172: 133–144.

Martin, G.J. 1995. Ethnobotany: a methods manual. London (UK): Earthscan Publishers Ltd.

Martín-López, B., et al. 2012. Uncovering ecosystem service bundles through social preferences. PLoS ONE, 7: e38970.

Maselli, D. 2012. Promoting sustainable mountain development at the global level: The Swiss development cooperation's involvement. Mountain Research and Development, 32(S1), S64–S70.

Matson, P.A. 1997. Agricultural Intensification and Ecosystem Properties. Science, 277, 504–509.

Matson, P., Clark, W.C. and Andersson, K. 2016. Pursuing sustainability: a guide to the science and practice. Princeton University Press, Princeton, New Jersey, USA.

Maxwell, S.L., Fuller, R.A., Brooks, T.M. and Watson, J.E. 2016. Biodiversity: The ravages of guns, nets and bulldozers. Nature, 536, 143–145.

McIntosh, R.J. 2000. Social memory in Mande. The way the wind blows: climate, history and human action, Columbia University Press, New York, 197, pp. 141–80.

Mesfin. D., Simane, B., Belay, A., Recha, J.W. and Schmiedel, U. 2020. Assessing the adaptive capacity of households to climate change in the Central Rift Valley of Ethopia. Climate, 8, 106.

Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-Being. Island Press: Washington, DC, USA, 2005; ISBN 1-59726-040-1.

Mishan, E. J. and Quah, E. 2007. Cost-Benefit Analysis. Routledge, Taylor & Francis Group - New York, USA. ISBN 9780-203-69567-8.

Mitcham, C. 1995. The concept of sustainable development: its origins and ambivalence. Technol. Soc., 17:311– 326.

Moller, H., Berkes, F., Lyver, P.O. and Kislalioglu, M. 2004. Combining science and t raditional ecological knowledge: mon- itoring populations for co-management. Ecol. Soc., 9(3):2.

Montanaro, G., Xiloyannis, C., Nuzzo, V. and Dichio, B. 2017. Orchard management, soil organic carbon and ecosystem services in Mediterranean fruit tree crops. Scientia Horticulturae, 217, 92-101.

Morandín-Ahuerma. I., Contreras-Hernández, A., Ayala-Ortiz, D. A. and Pérez-Maqueo, O. 2019. Socio–Ecosystemic Sustainability. MDPI. Sustainability, 11, 3354.

Morandín-Ahuerma, I., Contreras-Hernández, A., Ayala-Ortíz, D. A. and Pérez-Maqueo, O. 2018. Complexity and Trans-discipline: Epistemologies for sustainability. Madera Bosques, 24, e2431673.

Moser, S.C. 2008. Resilience in the face of global environmental change. Research Report 2, CARRI, Oak Ridge.

Mottes, C., Lesueur-Jannoyer, M., Le Bail, M. and Malézieux, E. 2014. Pesticide transfer models in crop and watershed systems: a review. Agron. Sustain. Dev., 34:229–250.

Muhr, G.R., Dutta, N.P. and Subramanoey, S. 1965. Soil Testing in India. USAID, New Delhi, India.

Müller, F. 2005. Indicating ecosystem and landscape organisation. Ecological Indicators, 5 (4), 280–294.

Müller, F. and Burkhard, B. 2007. An ecosystem based framework to link landscape structures, functions and services. In: Mander, Ü., Wiggering, H., Helming, K. (Eds.), Multifunctional Land Use – Meeting Future Demands for Landscape Goods and Services. Springer, pp. 37–64.

Naidoo, R., Balmford, A., Costanza, R., Fisher, B., Green, R.E., Lehner, B., et al. 2008. Global mapping of ecosystem services and conservation priorities. Proceedings of the National Academy of Sciences, 105(28), 9495–9500.

Nakuja, T., Sarpong, D.B., Kuwornu, J.K.M. and Ashante F.A. 2012. Water storage for dry season vegetable farming as an adaptation to climate change in the upper east region of Ghana. African Journal of Agricultural Research, Vol. 7(2), 298-306.

National Research Council (NRC). 2005. Valuing ecosystem services: towards better environmental decision making. Washington, DC.

Nepal, S., Krause, P., Flügel, W.A., Fink, M. and Fischer, C. 2014. Understanding the hydrological system dynamics of a glaciated alpine catchment in the Himalayan region using the J2000 hydrological model. Hydrological Processes, 28(3), 1329–1344.

Nicholls, C. and Altieri, M. 2013. Plant biodiversity enhances bees and other insect pollinators in agroecosystems: A review. Agron. Sustain. Dev., 33:257–274.

Nicholson, C.C., Koh, I., Richardson, L.L., Beauchemin, A. and Ricketts, T.H. 2017. Farm and landscape factors interact to affect the supply of pollination services. Agriculture, Ecosystems and Environment, 250: 113-122.

Niraula, R.R. and Pokharel, B.K. 2016. Community forest management as climate change adaptation measure in Nepal's Himalaya. In Climate Change Adaptation Strategies–An Upstream-Downstream Perspective; Springer International Publishing: New York, NY, USA, pp. 101–120.

NITI Aayog, India. 2018. Report of Working Group II: Sustainable Tourism in the Indian Himalayan Region.

Odum, E.P. 1989. Ecology and Our Endangered Life-Support System. Sunderland, MA: Sinauer.

Paetzold, A., Warren, P.H. and Maltby, L.L. 2010. A framework for assessing eco- logical quality based on ecosystem services. Ecological Complexity, 7, 273– 281.

Palm, Cheryl, Blanco-Canqui, H., De Clerck, F., Gatere, L and Grace, P. 2014. Conservation agriculture and ecosystem services: An overview. Agriculture, Ecosystems and Environment, 187:87–105.

Palmer, M., Bernhardt, E., Chornesky, E., Collins, S., Dobson, A., Duke, C., Gold, B., Jacobson, B., Kingsland, S., Kranz, R., Mappin, M., Martinez, M., Micheli, F., Morse, I., Pace, M., Pascual, M., Palumbi, S., Reichman, O., Simons, A., Townsend, A. and Turner, A. 2004. Ecology for a crowded planet. Science, 304, 1251-1252.

Pandey, R., Kumar, P., Archie, K.M., Gupta, A.K., Joshi, P.K., Valente, D. and Petrosillo, I. 2018. Climate change adaptation in the western-Himalayas: Household level perspectives on impacts and barriers. Ecol. Indic., 84, 27–37.

Pardo-de-Santayana, M. 2003. Las plantasen la culturatradicional de la Antigua Merindad de Campoo. Ph.D. dissertation, Departamento de Biología, Facultad de Ciencias, Universidad Autónoma de Madrid, Spain.

Paudyal, K., Baral, H., Burkhard, B., Bhandari, S.P., Keenan, R.J. 2015. Participatory assessment and mapping of ecosystem services in a data-poor region: Case study of community-managed forests in central Nepal. Ecosyst. Serv., 13, 81–92.

Paxton, L. 1993. Enviro Facts 3: Sustainable development. Howick, South Africa: Environmental Education Association of Southern Africa.

Pelosi, C., Goulard, M. and Balent, G. 2010. The spatial scale mismatch between ecological processes and agricultural management: do difficulties come from underlying theoretical frameworks? Agric. Ecosyst. Environ., 139:455–462.

Pitesky, M.E., Stackhouse, K.R. and Mitloehner, F.M. 2009. Clearing the air: livestock's contribution to climate change. Advances in agronomy, vol. 103, pp. 1–40.

Piya, L., Maharjan, K.L. and Joshi, N.P. 2012. Comparison of adaptive capacity and adaptation practices in response to climate change and extreme among the Chepang households in rural mid-hills of Nepal. Journal of International Development and Cooperation, Vol. 18, No. 4, 55-75.

Porter, J., Costanza, R., Sigsgaard, L., Sandhu, H. and Wratten, S. 2009. The value of producing food, energy and ecosystem services within an agro-ecosystem. Ambio, 38, 186–193.

Power, A.G. 2010. Ecosystem services and agriculture: trade-offs and synergies. Department of Ecology & Evolutionary Biology, Cornell University, USA. Philos. Trans. R. Soc. B Biol. Sci., 365:2959–2971.

Powers, J.S. 2004. Changes in soil carbon and nitrogen after contrasting land-use transitions in north-eastern Costa Rica. Ecosystems, 7: 134–146.

Powles, S.B. and Yu, Q. 2010. Evolution in action: plants resistant to herbicides. Annu. Rev. Plant. Biol., 61:317–347.

Powlson, D.S., Gregory, P.J., Whalley, W.R., Quinton, J.N., Hopkins, D.W., Whitmore, A.P., Hirsch, P.R. and Goulding, K.W.T. 2011. Soil management in relation to sustainable agriculture and ecosystem services. Food Policy, 36: S72–S87.

Pretty, J. 2003. Social capital and the collective management of resources. Science, 302:1912–14.

Price, M. F. 2015. Mountains: A very short introduction. Oxford, UK: Oxford University Press.

Prigogine, I. and Stengers, I. 1997. The End of Certainty; Time, Chaos and the New Laws of Nature, 1st ed.; Free Press: New York, NY, USA; ISBN 0-684-83705-6.

Prowse, M. and Scott, L. 2008. Assets and Adaptation: An Emerging Debate, IDS Bulletin (4): 42-52.

Reyers, B., Biggs, R., Cumming, G.S., Elmqvist, T., Hejnowicz, A.P. and Polasky, S. 2013. Getting the measure of ecosystem services: a social-ecological approach. Frontiers in Ecology and the Environment, 11:268-273.

Reyes-García, V., Huanca, T., Vadez, V., Leonard, W. and Wilkie, D. 2006. Cultural, practical, and economic value of wild plants: A quantitative study in the Bolivian Amazon. Econ. Bot., 60(1): 62–74.

Riedlinger, D. and Berkes, F. 2001. Contributions of traditional knowledge to understanding climate change in the Canadian Artic. Polar Rec., 37:315–28.

Robertson, G.P. and Swinton, S.M. 2005. Reconciling agricultural productivity and environmental integrity: a grand challenge for agriculture. Frontiers in Ecology and the Environment, 3, 38–46.

Robinson, J. 2004. Squaring the circle? Some thoughts on the idea of sustainable development. Ecological Economics, 48(4), 369–384.

Rockstrom, J., Falkenmark, M., Karlberg, L., Hoff, H., Rost, S. and Gerten, D. 2009. Future water availability for global food production: the potential of green water for increasing resilience to global change. Water Resour. Res., 45, pp. 16.

Rodríguez-Rodríguez, D., Bomhard, B., Butchart, S.H. and Foster, M.N. 2011. Progress towards international targets for protected area coverage in mountains: A multi-scale assessment. Biological Conservation, 144(12), 2978–2983.

Rounsevell, M.D., Pedroli, B., Erb, K.H., Gramberger, M., Busck, A.G., Haberl, H., et al. 2012. Challenges for land system science. Land Use Policy, 29(4), 899–910.

Ryglová, K.; Rašovská, I.; Šácha, J. and Maráková, V. 2018. Building Customer Loyalty in Rural Destinations as a Pre-Condition of Sustainable Competitiveness. Sustainability, 10, 957.

Sandhu, H.S., Wratten, S.D., Cullen, R. and Case, B. 2008. The future of farming: the value of ecosystem services in conventional and organic arable land. An experimental approach. Ecological Economics, 64, 835–848.

Saxton, K.E. and Rawls, W.J. 2006. Soil water characteristic estimates by texture and organic matter for hydrologic solutions. Soil Sci. Soc.. Am. J., 70, 1569–1578.

Scharlemann, J.P.W., Tanner, E.V.J., Hiederer, R. and Kapos, V. 2014. Global soil carbon: understanding and managing the largest terrestrial carbon pool. Carbon Manage., 5 (1), 81–91.

Scheffer, M., Carpenter, S.R., Foley, J.A., Folke, C. and Walker, B.H. 2001. Catastrophic shifts in ecosystems. Nature, 413:591-596.

Scoones, I. 2009. Livelihoods perspectives and rural development. The Journal of Peasant Studies, 36, 171–96.

Scoones, I. 1998. Sustainable rural livelihoods: A framework for analysis (IDS Working Paper, 72). Brighton: Institute of Development Studies.

Scott, C.A., Zhang, F., Mukherji, A., Immerzeel, W., Bharati, L., Mustafa, D., Lutz, A., Zhang, H., Nepal, S., Albrecht, T., Siddiqi, A., Qadir, M., Kuemmerle, H., Prakash, A. and Bhuchar, S. 2018. Water security: resource availability, use and governance in the Hindu Kush– Himalaya region. Chapter 8, Hindu Kush–Himalaya monitoring and assessment. Cambridge University Press.

Seppelt, R., Dormann, C.F., Eppink, F.V., Lautenbach, S. and Schmidt, S. 2011. A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead. Journal of Applied Ecology, Vol. 48, 630-636.

Serrat, O. 2010. The sustainable livelihoods approach. Washington, DC: Asian Development Bank.

Sharma, V., Agrawal, R. and Chandra, P. 2016. Religious to spiritual tourism transformation journey of Uttarakhand-A hill state in India. In Proceedings of the International conference on tourism, hospitality and marketing.

Sharma, B., Rasul, G. and Chettri, N. 2015. The economic value of wetland ecosystem services: Evidence from Koshi Tappu wildlife reserve. Nepal. Ecosystem Services., 12, 84–93.

Sharma E., Chettri N., Tsering K., Shrestha A.B., Jing F., Mool P., et al. 2009. Climate change impacts and vulnerability in the Eastern Himalayas (p. 27). Kathmandu, Nepal: ICIMOD.

Sharma, E., Bhuchar, S., Xing, M. and Kothyari, B.P. 2007. Land use change and its impact on hydro ecological linkages in Himalayan watersheds. Tropical Ecology, 48(2), 151–161.

Shivanna, A.M. and Nagendrappa, G. 2014. Chemical analysis of soil samples to evaluate the soil fertility status of selected command areas of three tanks in Tiptur Taluk of Karnataka, India. IOSR Journal of Applied Chemistry, Volume 7, Issue 11 Ver. I., 01-05.

Shrestha, U.B., Gautam, S. and Bawa, K.S. 2012. Widespread climate change in the Himalayas and associated changes in local ecosystems. PLoS ONE, 7(5), e36741.

Siddique, K.H.M. and Li, X. 2019. The potentials of future smart food for mountain agriculture achieving zero hunger: nutrient, climate-resilient, economic and social benefits. FAO - Mountain agriculture: Opportunities for harnessing Zero Hunger in Asia. Bangkok.

Singh, S.P. 2002. Balancing the approaches of environmental conservation by considering ecosystem services as well as biodiversity. Current Science, 82(11), 1331–1335.

Smit, B. and Wandel, J. 2006. adaptation adaptive capacity and vulnerability. Global Environmental Change, 16, 282–92.

Smith, P. et.al. 2008 Greenhouse gas mitigation in agriculture. Philosophical Transactions of the Royal Society B, 363, 789–813.

Smith, J.B., Klein, R.J.T. and Huq, S. 2003. Climate change, adaptive capacity and development. London: Imperial College Press.

Soil Quality. 2017. http://soilquality.org.au/factsheets, 2017. Accessed in Aug 2017.

Swinton, S.M., Lupi, F., Robertson, G.P. and Hamilton, S.K. 2007. Ecosystem services and agriculture: cultivating agricultural ecosystems for diverse benefits. Ecological Economics, 64(4): 245-252.

Tardío, J. and Pardo-de Santayana, M. 2008. Cultural importance indices: A comparative analysis based on the useful wild plants of Southern Cantabria (Northern Spain). Econ. Bot., 62(1): 24–39.

Teixeira, H.M., van den Berg, L., Cardoso, I.M., Vermue, A.J., Bianchi, F.J.J.A., Peña-Claros, M. and Tittonell, P. 2018. Understanding farm diversity to promote agroecological transitions. Sustainability, 10, 4337.

Therond, O., Duru, M., Roger-Estrade, J. and Richard, G. 2017. A new analytical framework of farming system and agriculture model diversities. A review. Agronomy for Sustainable Development, 37(3), 1-24.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R. and Polasky, S. 2002. Agricultural sustainability and intensive production practices. Nature, 418, 671–677.

Tilman, D., Fargione, J., Wolff, B., D'Antonio, C., Dobson, A., Howarth, R., Schindler, D., Schlesinger, W.H., Simberloff, D. and Swackhamer, D. 2001. Forecasting agriculturally driven global environmental change. Science, 292, 281–284.

Truong, T.H. and Foster, D. 2006. Using HOLSAT to Evaluate Tourist Satisfaction at Destinations: The Case of Australian Holidaymakers in Vietnam. Tour. Manag., 27, 842–855.

Tschakert, P., van Oort, B., St Clair, A.L. and La Madrid, A. 2013. Inequality and transformation analyses: a complementary lens for addressing vulnerability to climate change. Climate and Development, 5, 340–50.

Turin, M. 2005. Language endangerment and linguistic rights in the Himalayas: A case study from Nepal. Mountain Research and Development, 25(1), 4–9.

United Nations (UN). 1992. Report of the United Nations Conference on Environment and Development. Rio de Janeiro 3–14 June 1992. A/CONF.151/26 (Vol. 1).

United Nations Educational, Scientific and Cultural Organization (UNESCO). 2009. The 2009 UNESCO Framework for Cultural Stadistics (FCS). Montreal, Canada, 2009; ISBN 978-92-9189-083-5.

United States Environmental Protection Agency (US-EPA). 2006. Global Anthropogenic non-CO_2 greenhouse gas emissions: 1990 – 2020.

van Oudenhoven, A.P.E., Petz, K., Alkemade, R., de Groot, R.S. and Hein, L. 2012. Indicators for assessing effects of management on ecosystem services. Ecological Indicators, 21, 110–122.

Vedwan, N. 2006. Culture, climate and the environment: local knowledge and perception of climate change among apple growers in north-western India J. Ecol. Anthropol., 10, 4–18.

Verhulst, N., Govaerts, B., Verachtert, E., Castellanos-Navarrete, A., Mezzalama, M., Wall, P., Deckers, J. and Sayre, K.D. 2010. Conservation Agriculture, Improving Soil Quality for Sustainable Production Systems? In: Lal, R. and Stewart, B. A. (Eds.), Advances in Soil Science: Food Security and Soil Quality, 137–208. CRC Press, Boca Raton, FL, USA.

Vialatte, A., Barnaud, C., Blanco, B., Ouin, A., Choisis, J.P., Andrieu, E., Sheeren, D., Ladet, S., Deconchat, M., Clement, F., Esquerre, D. and Sirami, C. 2019. A conceptual framework for the governance of multiple ecosystem services in agricultural landscape. Landscape Ecol.

Vitousek, P.M., Aber, J.D., Howarth, R.W., Likens, G.E., Matson, P.A., Schindler, D.W., Schlesinger, W.H. and Tilman, G.D. 1997. Human alteration of the global nitrogen cycle: sources and consequences. Ecol. Appl., 7, 737 – 750.

Walker, B., Holling, C.S., Carpenter, S.R. and Kinzig, A. 2004. Resilience, Adaptability and Transformability in Social-ecological Systems. Ecology and Society, 9(2): 5.

Walker, B., Carpenter, S.R., Anderies, J., Cumming, G.S., Janssen, M., Lebel, L., Norberg, J., Peterson, G.D. and Pritchard, R. 2002. Resilience management in socio-ecological

systems: A working hypothesis for a participatory approach. Conservation Ecology, 6(1).

Walkley, A. and Black, I.A. 1934. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sciences, 37: 29-37.

Wang, Z., Han, X. and Li, L. 2008. Effects of grassland conversion to croplands on soil organic carbon in the temperate Inner Mongolia. Journal of Environmental Management, 86: 529–534.

Wezel, A. et al. 2013. Agroecological practices for sustainable agriculture. A review. Agronomy for Sustainable Development. Agronomy for Sustainable Development, 34(1):1-20.

World Commission on Environment and Development (WCED). 1987. Our Common Future. Oxford University Press, New York.

World Travel and Tourism Council (WTTC). 2018. Travel and Tourism Economic Impact 2018: India. Report prepared by the authority on World Travel and Tourism, London, UK.

Xu, J. and Grumbine, R.E. 2014. Building ecosystem resilience for climate change adaptation in the Asian highlands. Wiley Interdisciplinary Reviews: Climate Change, 5(6), 709–718.

Yaro, J. A., Teye, J., and Bawakyillenuo, S. 2015. Local institutions and adaptive capacity to climate change/variability in the northern savannah of Ghana. Climate and Development, 7(3), 235-245.

Yimer, F., Ledin, S. and Abdelkadir, A. 2007. Changes in soil organic carbon and total nitrogen contents in three adjacent land use types in the Bale Mountains, south-eastern highlands of Ethiopia. Forest Ecology and Management, 242: 337–342.

Younus, M.A.F. 2014. Vulnerability and Adaptation to Climate Change in Bangladesh: Processes, Assessment and Effects; Springer: New York, NY, USA.

Zhang, W., Ricketts, T.H., Kremen, C., Carney, K. and Swinton, S.M. 2007. Ecosystem services and dis-services to agriculture. Ecological Economics, 64: 253–260.

Ziv, G., Baran, E., Nam, S., Rodríguez-Iturbe, I. and Levin, S.A. 2012. Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin. Proceedings of the National Academy of Sciences, 109(15), 5609–5614.

ANNEXURE A

1. Checklist for medicinal plants and their uses

Medicinal Plant	Uses
Aconitum balfourii (Bruhl) Muk.	
Aconitum heterophyllum Wall. Ex Royle	
Aesulus indica Colebr.	
Allium stracheyi Baker	
Angelica glauca Edgew.	
Arnebia benthamii	
Artemisia maritima	
Artemisia nilagirica (Clarke) Pamp.	
Asparagus racemosus L.	
Berberis aristate DC.	
Betula utilis D. Don	
Cannabis sativa L.	
Carum carvi	
Cedrus deodara Loud.	
Centella asiatica	
Chenopodium album	
Cinnamomum tamala Nees	
Cynodon dactylon L.	
Dactylorrhiza hatagirea (D. Don) Soo	
Datura stramonium	
Dioscorea deltoidei	
Diplazium esculentum Sw.	
Galium aparine L.	
Geranium wallichianum D. Don ex Sweet	
Grewia oppositifolia Drummond ex Burret	
Hippophae salicifolia	
Hypericum elodeoides Choisy	
Juglans regia L.	
Lyonia ovalifolia (Wall.) Drud.	
Mentha longifolia (L.) Hudson	
Morchella esculenta L. Peres	
Nardostachys grandiflora DC.	
Origanum vulgare L.	
Paeonia emodi Wall ex Royle	
Perilla frutescens (L.)Britton	
Picrorhiza kurrooa Royle ex Benth	
Pinus roxburghii Sarg.	
Pinus wallichiana Jacks.	
Pleurospermum angelicoides	
Podophyllum hexandrum Royle	
Prinsepia utilis Royle	
Reinwardita indica Dumortier	
Rheum emodi (D. Don)	
Rhododendron arboretum Smith	
Rubus ellipticus Smith	

Rumex hastatus (D. Don)	
Saussurea costus (Falc) Lipsch.	
Saussurea obvallata	
Skimmia anquetilia Taylore & Airy Shaw	
Skimmia laureola (DC.) Zucc.	
Swertia chirayita Roxb. Ex Flem	
Taxus baccata L.	
Thymus linearis Benth.	
Utrica dioica L.	
Zanthoxylum armatum DC.	

2. Details about health ailment category and use reports

Health Ailment Category	No. of Species	Specific Health Issues	No. of Use-Reports	Percentage (%)
Skeleton & Muscle	16	Rheumatic pain, muscular pain, back pain, throat pain, joint pain, swelling, bone fracture, leprosy, epilepsy, arthritis	4690	11.42
Gastro-intestinal	21	Stomach ache, dysentery, vomiting, diarrhea, intestinal spasm, stomach disorder, intestinal worms, ringworm, constipation, gastric issue, indigestion, dyspepsia, piles	8590	20.91
General	17	Head ache, cough, cold, fever, sore throat, antimalarial, typhoid fever	5843	14.22
Antidote	2	Snakebite	678	1.65
Dermatological	21	Skin rash, wounds, boils, cuts, itching, allergy, skin ulcer, burns, skin infection, scabies, fungal infection	8602	20.94
Respiratory	4	Nasal infection, asthma, lung infection, bronchitis, whooping cough	880	2.14
Circulatory	4	Diabetes, blood pressure, heart disease, heart tonic	1054	2.57
Hepatic	6	Jaundice	1666	4.06
Nervous	2	Brain functioning and power, psychological problems	704	1.71
Dental	5	Tooth ache, mouth wash	2059	5.01
Gynecological	5	Menstruation, smooth delivery, massaging oil for pregnant women and infants, post-natal care	2470	6.01
Genetic	1	Cancer	516	1.26
Hair	2	Hair growth, hair fall	1240	3.02
Ophthalmic	1	Eye infection	233	0.57
Body Heat	4	Keeping body warm, internal heat, cooling agent, bleeding nose	1849	4.50

3. Details about Quantitative Indices

Species	Basic Values			Indices Values			
	FC	UR	NU	RFC	RI	CI	CV
Aconitum balfourii (Bruhl) Muk.	356	356	1	0.356	0.211	0.356	0.008
Aconitum heterophyllum Wall. Ex Royle	413	641	2	0.413	0.273	0.641	0.035
Aesulus indica Colebr.	305	412	2	0.305	0.219	0.412	0.002
Allium stracheyi Baker	1000	1488	3	1	0.600	1.488	0.298
Angelica glauca Edgew.	797	1088	3	0.797	0.498	1.088	0.173
Arnebia benthamii	960	960	1	0.960	0.513	0.96	0.061
Artemisia maritima	316	347	2	0.316	0.225	0.347	0.015
Artemisia nilagirica (Clarke) Pamp.	474	633	3	0.474	0.337	0.633	0.060
Asparagus racemosus L.	204	204	1	0.204	0.135	0.204	0.003
Berberis aristate DC.	526	751	3	0.526	0.363	0.751	0.079
Betula utilis D. Don	790	1389	4	0.790	0.528	1.389	0.293
Cannabis sativa L.	1000	1309	3	1	0.600	1.309	0.262
Carum carvi	611	611	1	0.611	0.338	0.611	0.025
Cedrus deodara Loud.	948	1185	2	0.948	0.541	1.185	0.150
Centella asiatica	620	620	1	0.620	0.343	0.620	0.026
Chenopodium album	1000	1000	1	1	0.533	1	0.067
Cinnamomum tamala Nees	1000	1126	2	1	0.566	1.126	0.150
Cynodon dactylon L.	286	286	1	0.286	0.176	0.286	0.005
Dactylorrhiza hatagirea (D. Don) Soo	606	815	4	0.606	0.436	0.815	0.132
Datura stramonium	675	888	2	0.675	0.404	0.888	0.079
Dioscorea deltoidei	664	664	1	0.664	0.365	0.664	0.029
Diplazium esculentum Sw.	1000	1329	3	1	0.600	1.329	0.266
Galium aparine L.	422	422	1	0.422	0.244	0.422	0.012
Geranium wallichianum D. Don ex Sweet	224	246	2	0.224	0.179	0.246	0.007
Grewia oppositifolia Drummond ex Burret	948	948	1	0.948	0.507	0.948	0.059
Hippophae salicifolia	505	655	2	0.505	0.319	0.655	0.044
Hypericum elodeoides Choisy	332	332	1	0.332	0.199	0.332	0.007
Juglans regia L.	637	807	2	0.637	0.385	0.807	0.068
Lyonia ovalifolia (Wall.) Drud.	344	344	1	0.344	0.205	0.344	0.007
Mentha longifolia (L.) Hudson	1000	1000	1	1	0.533	1	0.067
Morchella esculenta L. Peres	789	789	1	0.789	0.428	0.789	0.0415
Nardostachys grandiflora DC.	525	889	3	0.525	0.362	0.889	0.093
Origanum vulgare L.	488	621	3	0.488	0.344	0.621	0.061
Paeonia emodi Wall ex Royle	220	361	4	0.220	0.243	0.361	0.021
Perilla frutescens (L.)Britton	352	438	3	0.352	0.276	0.438	0.031
Picrorhiza kurrooa Royle ex Benth	612	837	3	0.612	0.406	0.837	0.102
Pinus roxburghii Sarg.	782	782	1	0.782	0.424	0.782	0.041
Pinus wallichiana Jacks.	537	537	1	0.537	0.302	0.537	0.019
Pleurospermum angelicoides	498	612	2	0.498	0.316	0.612	0.041
Podophyllum hexandrum Royle	411	411	1	0.411	0.239	0.411	0.011
Prinsepia utilis Royle	298	418	2	0.298	0.216	0.418	0.017
Reinwardita indica Dumortier	263	263	1	0.263	0.165	0.263	0.005
Rheum emodi (D. Don)	235	235	1	0.235	0.151	0.235	0.004
Rhododendron arboretum Smith	1000	1527	5	1	0.667	1.527	0.509
Rubus ellipticus Smith	1000	1000	1	1	0.533	1	0.067
Rumex hastatus (D. Don)	768	1104	2	0.768	0.451	1.104	0.113
Saussurea costus (Falc) Lipsch.	683	1050	4	0.683	0.475	1.050	0.191
Saussurea obvallata	627	627	1	0.627	0.347	0.627	0.026
Skimmia anquetilia Taylore & Airy Shaw	583	703	2	0.583	0.358	0.703	0.055
Skimmia laureola (DC.) Zucc.	383	383	1	0.383	0.225	0.383	0.009
Swertia chirayita Roxb. Ex Flem	216	244	2	0.216	0.175	0.244	0.007
Taxus baccata L.	699	991	3	0.699	0.449	0.991	0.138
Thymus linearis Benth.	566	834	2	0.566	0.349	0.834	0.006
Utrica dioica L.	1000	1766	4	1	0.633	1.766	0.471
Zanthoxylum armatum DC.	796	796	1	0.796	0.431	0.796	0.042

4. Details about Informant Consensus and Fidelity Level

Health Ailment Category	Informant Consensus Factor (Fic)	Name of the species used	Species Fidelity Value (FL%)
Skeleton & Muscle	0.997	*Aesulus indica* Colebr.	19.70
		Allium stracheyi Baker	49.20
		Artemisia maritima	12.30
		Asparagus racemosus L.	20.40
		Cannabis sativa L.	35.90
		Cedrus deodara Loud.	64.30
		Datura stramonium	42.50
		Geranium wallichianum D. Don ex Sweet	10.10
		Nardostachys grandiflora DC.	39.00
		Origanum vulgare L.	23.80
		Pinus wallichiana Jacks.	53.70
		Prinsepia utilis Royle	20.20
		Rhododendron arboretum Smith	16.60
		Skimmia laureola (DC.) Zucc.	28.20
		Taxus baccata L.	16.50
		Utrica dioica L.	16.60
Gastro-intestinal	0.998	*Aconitum heterophyllum* Wall. Ex Royle	30.40
		Artemisia maritima	22.40
		Artemisia nilagirica (Clarke) Pamp.	24.60
		Berberis aristate DC.	22.60
		Cannabis sativa L.	31.60
		Carum carvi	61.10
		Chenopodium album	100
		Cynodon dactylon L.	28.60
		Dactylorrhiza hatagirea (D. Don) Soo	15.30
		Diplazium esculentum Sw.	62.60
		Hippophae salicifolia	36.50
		Hypericum elodeoides Choisy	33.20
		Juglans regia L.	33.90
		Mentha longifolia (L.) Hudson	100
		Paeonia emodi Wall ex Royle	7.20
		Perilla frutescens (L.) Britton	8.40
		Picrorhiza kurrooa Royle ex Benth	22.50
		Pleurospermum angelicoides	31.20
		Rubus ellipticus Smith	100
		Thymus linearis Benth.	45.50
		Utrica dioica L.	41.40
General	0.996	*Aconitum heterophyllum* Wall. Ex Royle	33.70
		Aesulus indica Colebr.	21.50
		Allium stracheyi Baker	56.80
		Angelica glauca Edgew.	39.80
		Berberis aristate DC.	29.20
		Betula utilis D. Don	47.30
		Cinnamomum tamala Nees	67.40
		Dactylorrhiza hatagirea (D. Don) Soo	21.70
		Diplazium esculentum Sw.	47.50
		Geranium wallichianum D. Don ex Sweet	14.50
		Hippophae salicifolia	29.00
		Morchella esculenta L. Peres	78.90
		Origanum vulgare L.	21.30
		Perilla frutescens (L.) Britton	9.20
		Picrorhiza kurrooa Royle ex Benth	21.80
		Pleurospermum angelicoides	30.00
		Swertia chirayita Roxb. Ex Flem	14.70
Antidote	0.998	*Aconitum balfourii* (Bruhl) Muk.	35.60
		Rumex hastatus (D. Don)	32.20
Dermatological	0.998	*Angelica glauca* Edgew.	34.20
		Artemisia nilagirica (Clarke) Pamp.	19.30
		Betula utilis D. Don	50.50
		Cannabis sativa L.	63.40
		Cedrus deodara Loud.	54.20
		Dactylorrhiza hatagirea (D. Don) Soo	16.50
		Datura stramonium	46.30

		Dioscorea deltoidea	66.40
		Lyonia ovalifolia (Wall.) Drud.	34.40
		Paeonia emodi Wall ex Royle	7.50
		Pinus roxburghii Sarg.	78.20
		Podophyllum hexandrum Royle	41.10
		Prinsepia utilis Royle	21.60
		Rheum emodi (D. Don)	23.50
		Rhododendron arboretum Smith	25.70
		Rumex hastatus (D. Don)	62.30
		Saussurea costus (Falc) Lipsch.	20.00
		Saussurea obvallata	62.70
		Skimmia anquetilia Taylore & Airy Shaw	42.10
		Skimmia laureola (DC.) Zucc.	38.30
		Utrica dioica L.	52.00
Respiratory	0.996	*Allium stracheyi* Baker	42.80
		Artemisia nilagirica (Clarke) Pamp.	19.40
		Origanum vulgare L.	17.00
		Paeonia emodi Wall ex Royle	8.80
Circulatory	0.997	*Cinnamomum tamala* Nees	45.20
		Nardostachys grandiflora DC.	26.60
		Rhododendron arboretum Smith	23.90
		Swertia chirayita Roxb. Ex Flem	9.70
Hepatic	0.997	*Betula utilis* D. Don	32.70
		Diplazium esculentum Sw.	22.80
		Nardostachys grandiflora DC.	23.30
		Picrorhiza kurrooa Royle ex Benth	39.40
		Rhododendron arboretum Smith	22.90
		Saussurea costus (Falc) Lipsch.	25.50
Nervous	0.998	*Betula utilis* D. Don	8.40
		Centella asiatica	62.00
Dental	0.998	*Angelica glauca* Edgew.	34.80
		Reinwardita indica Dumortier	26.30
		Saussurea costus (Falc) Lipsch.	27.30
		Thymus linearis Benth.	37.90
		Zanthoxylum armatum DC.	79.60
Gynecological	0.998	*Grewia oppositifolia* Drummond ex Burret	94.80
		Juglans regia L.	46.80
		Paeonia emodi Wall ex Royle	12.60
		Perilla frutescens (L.) Britton	26.20
		Utrica dioica L.	66.60
Genetic	1.00	*Taxus baccata*L.	51.60
Hair	0.999	*Arnebia benthamii*	96.00
		Dactylorrhiza hatagirea (D. Don) Soo	28.00
Ophthalmic	1.00	*Berberis aristate* DC.	23.30
Body Heat	0.998	*Galium aparine* L.	42.20
		Rhododendron arboretum Smith	63.60
		Rumex hastatus (D. Don)	48.10
		*Taxus baccata*L.	31.00

ANNEXURE B

1. Details about crop productivity

Name of the Crop	Productivity (kg/ha)			
	Gainchwan Gaon	**Deora**	**Dhatmeer**	**Osla**
Adjuki Bean	104.35	88.34	219.72	224.89
Amaranth	78.92	46.57	1029.73	1252.25
Apple	5674.95	5811.97	1175	13.71
Barley	225.12	200.81	76.90	138.03
Barnyard Millet	450.24	326.07	407.83	222.60
Black Gram	570.66	499.71	393.44	341.46
Buckwheat	313.99	302.33	389.83	129.10
Finger Millet	675.36	520.43	440.80	194.84
Foxtail Millet	351.75	348.49	333.52	162.23
Green Gram	523.60	464.99	314.04	299.02
Horse Gram	495.97	410.46	334.07	402.57
Kidney Bean	514.61	473.33	844.43	544.43
Maize	548.06	369.85	120.15	47.05
Mustard	2.20	1.20	178.74	133.94
Onion	4.50	1.05	1.03	0.13
Paddy	1575.85	1533.87	630.58	402.58
Pear	46.90	28.83	0	0
Potato	306.02	581.19	709.80	508.10
Soyabean	456.92	248.82	100.46	268.38
Walnut	141.87	384.94	100.05	33.23
Wheat	1506.67	1504.47	509.96	418.19

2. Details about chemical properties of soil
(C: connected villages and I: isolated villages)

Soil Characteristics	Land Management System					
	Agriculture		Orchard		Uncultivated	
	C	I	C	I	C	I
pH	6.5	6.5	6.5	6.5	6.5	6.5
	6.4	6.4	6.4	6.4	6.5	6.5
	6.5	6.5	6.5	6.5	6.5	6.5
	6.5	6.5	6.5	6.5	6.5	6.5
	6.5	6.5	6.5	6.5	6.5	6.5
	6.4	6.4	6.4	6.4	6.5	6.5
	6.4	6.4	6.4	6.4	6.5	6.5
	6.5	6.5	6.5	6.5	6.5	6.5
	6.4	6.4	6.4	6.4	6.5	6.5
	6.5	6.5	6.5	6.5	6.5	6.5
	6.5	6.5	6.5	6.5	6.5	6.5
	6.5	6.5	6.5	6.5	6.5	6.5
	6.4	6.4	6.4	6.4	6.5	6.5
	6.4	6.4	6.4	6.4	6.5	6.5
	6.5	6.5	6.5	6.5	6.5	6.5
	6.6	6.4	6.6	6.4	6.5	6.5
	6.5	6.5	6.5	6.5	6.5	6.5
	6.5	6.5	6.5	6.5	6.5	6.5
	6.6	6.5	6.6	6.5	6.5	6.5
	6.6	6.4	6.6	6.4	6.5	6.5
	6.5	6.4	6.5	6.4	6.5	6.5
	6.5	6.5	6.5	6.5	6.5	6.5
	6.6	6.4	6.6	6.4	6.5	6.5
	6.6	6.5	6.6	6.5	6.5	6.5
	6.5	6.5	6.5	6.5	6.5	6.5
	6.5	6.5	6.5	6.5	6.5	6.5
	6.5	6.4	6.5	6.4	6.5	6.5
	6.6	6.4	6.6	6.4	6.5	6.5
	6.6	6.5	6.6	6.5	6.5	6.5
	6.5	6.5	6.5	6.5	6.5	6.5
EC (dS/m)	0.4	1.1	2.4	1.32	0.98	0.98
	0.4	1.1	2.4	1.32	0.98	0.98
	1.1	1.1	2.4	1.34	0.98	0.98
	1.1	1.1	2.4	1.34	0.98	0.98
	1.2	1.1	2.4	1.34	0.98	0.98
	1.2	1.1	2.4	1.34	0.98	0.98
	1.2	1.2	2.5	1.34	0.99	0.98
	1.2	1.2	2.5	1.34	0.99	0.99

	1.2	1.2	2.5	1.34	0.99	0.99
	1.2	1.2	2.6	1.34	0.99	0.99
	1.2	1.2	2.6	1.34	1.0	0.99
	1.2	1.2	2.6	1.34	1.0	0.99
	1.2	1.2	2.7	1.34	1.0	1.0
	1.2	1.2	2.7	1.35	1.0	1.0
	1.2	1.23	2.7	1.35	1.0	1.0
	1.2	1.23	2.7	1.35	1.0	1.1
	1.21	1.23	2.7	1.4	1.1	1.1
	1.21	1.23	2.7	1.4	1.1	1.1
	1.24	1.28	2.7	1.4	1.1	1.1
	1.24	1.28	2.7	1.4	1.1	1.1
	1.24	1.28	2.7	1.4	1.1	1.1
	1.3	1.28	2.7	1.4	1.1	1.1
	1.3	1.31	2.7	1.4	1.1	1.1
	1.3	1.31	2.7	1.42	1.1	1.2
	1.3	1.31	2.8	1.43	1.1	1.2
	1.3	1.31	2.8	1.43	1.2	1.2
	1.34	1.32	2.8	1.43	1.2	1.2
	1.34	1.32	2.8	1.45	1.2	1.2
	1.4	1.32	2.8	1.45	1.2	1.2
	1.4	1.32	2.8	1.45	1.2	1.2
C (%)	0.53	0.55	0.66	0.59	0.71	0.67
	0.52	0.55	0.65	0.59	0.72	0.66
	0.51	0.55	0.65	0.6	0.71	0.68
	0.53	0.55	0.66	0.61	0.72	0.67
	0.53	0.55	0.64	0.61	0.71	0.68
	0.53	0.55	0.65	0.6	0.71	0.68
	0.53	0.55	0.64	0.59	0.72	0.67
	0.52	0.55	0.65	0.59	0.71	0.66
	0.51	0.55	0.65	0.59	0.71	0.68
	0.53	0.55	0.66	0.6	0.72	0.67
	0.53	0.55	0.66	0.61	0.71	0.68
	0.53	0.55	0.66	0.61	0.72	0.68
	0.52	0.55	0.65	0.6	0.71	0.67
	0.52	0.55	0.65	0.59	0.71	0.66
	0.53	0.55	0.66	0.59	0.72	0.68
	0.53	0.55	0.64	0.59	0.71	0.67
	0.53	0.55	0.65	0.6	0.71	0.68
	0.52	0.55	0.64	0.61	0.72	0.68
	0.52	0.55	0.65	0.61	0.71	0.66
	0.53	0.55	0.65	0.6	0.72	0.67
	0.53	0.55	0.66	0.59	0.71	0.66

	0.53	0.55	0.66	0.59	0.71	0.68
	0.52	0.55	0.66	0.59	0.72	0.67
	0.52	0.55	0.65	0.6	0.71	0.68
	0.53	0.55	0.65	0.61	0.71	0.68
	0.53	0.55	0.66	0.61	0.72	0.67
	0.53	0.55	0.64	0.6	0.71	0.66
	0.52	0.55	0.65	0.59	0.72	0.68
	0.52	0.55	0.66	0.6	0.71	0.67
	0.53	0.56	0.66	0.6	0.71	0.68
N (ppm)	0.0032	0.0028	0.004	0.0035	0.0056	0.0053
	0.0031	0.0027	0.0041	0.0036	0.0055	0.0054
	0.0031	0.0028	0.0041	0.0036	0.0056	0.0053
	0.0032	0.0028	0.004	0.0034	0.0056	0.0054
	0.0032	0.0026	0.0042	0.0035	0.0055	0.0053
	0.0032	0.0026	0.0042	0.0036	0.0056	0.0054
	0.0033	0.0028	0.0041	0.0035	0.0055	0.0053
	0.0033	0.0027	0.004	0.0036	0.0056	0.0054
	0.0031	0.0028	0.004	0.0036	0.0056	0.0053
	0.0031	0.0028	0.0041	0.0034	0.0055	0.0054
	0.0032	0.0026	0.0041	0.0035	0.0056	0.0053
	0.0031	0.0026	0.004	0.0036	0.0055	0.0054
	0.0031	0.0028	0.0042	0.0035	0.0056	0.0053
	0.0032	0.0027	0.0042	0.0036	0.0056	0.0054
	0.0032	0.0028	0.0041	0.0036	0.0055	0.0053
	0.0032	0.0028	0.004	0.0034	0.0056	0.0054
	0.0033	0.0026	0.004	0.0035	0.0055	0.0053
	0.0033	0.0026	0.0041	0.0036	0.0056	0.0054
	0.0031	0.0028	0.0041	0.0035	0.0056	0.0053
	0.0031	0.0028	0.004	0.0036	0.0055	0.0054
	0.0032	0.0028	0.0042	0.0036	0.0056	0.0053
	0.0031	0.0028	0.0042	0.0034	0.0055	0.0054
	0.0031	0.0028	0.0041	0.0035	0.0056	0.0053
	0.0032	0.0028	0.004	0.0036	0.0056	0.0054
	0.0032	0.0027	0.004	0.0035	0.0055	0.0053
	0.0032	0.0028	0.0041	0.0036	0.0056	0.0054
	0.0033	0.0028	0.0041	0.0036	0.0055	0.0053
	0.0033	0.0026	0.004	0.0034	0.0056	0.0054
	0.0031	0.0026	0.0042	0.0035	0.0056	0.0053
	0.0031	0.0028	0.0042	0.0036	0.0055	0.0054
P (ppm)	33.3	34.12	37.8	35.7	38.12	36.8
	33.4	34.15	37.7	35.8	38.11	36.7
	33.3	34.13	37.6	35.6	38.13	36.9
	33.1	34.12	37.6	35.7	37.98	36.8

	33.2	34.15	37.7	35.7	37.88	36.8
	33.2	34.14	37.8	35.7	38.12	36.7
	33.4	34.12	37.7	35.8	38.13	36.8
	33.3	34.15	37.8	35.6	37.99	36.7
	33.3	34.13	37.6	35.7	38.12	36.9
	33.3	34.12	37.8	35.7	38.11	36.8
	33.4	34.15	37.7	35.8	38.13	36.8
	33.3	34.14	37.6	35.8	37.98	36.7
	33.3	34.12	37.6	35.7	37.88	36.9
	33.2	34.15	37.7	35.7	38.12	36.9
	33.2	34.13	37.8	35.8	38.13	36.8
	33.4	34.12	37.7	35.6	38.12	36.7
	33.3	34.15	37.8	35.7	38.11	36.9
	33.3	34.14	37.6	35.7	38.13	36.8
	33.3	34.12	37.8	35.8	37.98	36.8
	33.4	34.15	37.7	35.8	37.88	36.7
	33.3	34.13	37.6	35.7	38.12	36.8
	33.1	34.12	37.6	35.7	38.13	36.8
	33.2	34.15	37.7	35.8	38.12	36.7
	33.2	34.14	37.8	35.6	38.11	36.9
	33.4	34.12	37.7	35.7	38.13	36.9
	33.3	34.15	37.8	35.7	37.98	36.8
	33.3	34.13	37.6	35.8	37.88	36.7
	33.3	34.12	37.8	35.8	38.12	36.8
	33.4	34.15	37.8	35.7	38.13	36.7
	33.4	34.14	37.8	35.7	38.12	36.7
K (ppm)	149.0	162.0	40.5	88.7	82.0	128.5
	150.0	161.0	40.6	88.6	81.8	128.6
	149.0	162.2	40.8	87.9	81.9	128.7
	149.0	161.9	40.8	88.2	82.0	127.9
	150.0	162.0	40.8	88.4	82.0	128.8
	151.0	161.8	40.6	88.7	82.0	128.4
	150.0	161.8	40.5	88.5	81.8	128.3
	149.0	162.1	40.5	88.4	81.9	128.4
	150.0	162.0	40.5	88.6	81.8	128.5
	149.0	161.0	40.6	88.6	82.0	128.5
	149.0	162.2	40.8	87.9	81.8	128.6
	150.0	161.9	40.8	88.2	81.9	128.7
	151.0	162.0	40.8	88.4	82.0	127.9
	150.0	161.8	40.6	88.7	82.0	128.8
	150.0	161.8	40.5	88.5	82.0	128.4
	150.0	162.1	40.5	88.4	81.8	128.3
	149.0	162.0	40.5	88.6	81.9	128.4

	150.0	161.0	40.6	87.9	81.8	128.5
	150.0	162.2	40.8	88.2	82.0	128.5
	150.0	161.9	40.8	88.4	81.8	128.6
	150.0	162.0	40.8	88.7	81.9	128.7
	151.0	161.8	40.6	88.5	82.0	127.9
	150.0	161.8	40.5	88.4	82.0	128.8
	149.0	162.1	40.5	88.6	82.0	128.4
	150.0	161.0	40.5	88.6	81.8	128.3
	149.0	162.0	40.6	87.9	81.9	128.4
	149.0	162.0	40.8	88.2	81.8	128.5
	150.0	161.0	40.8	88.5	82.0	128.4
	151.0	162.2	40.8	88.4	81.8	128.8
	150.0	161.9	40.6	88.5	81.9	128.5

ANNEXURE C

1. Details of cumulative response score for the adaptive capacity indicators

Indicator	Cumulative Response Score	
	Connected Villages	Isolated Villages
Diversity of source of income	840	475
Remittance	120	20
Access to credit	45	30
Access to family labour	640	850
Participation farmer-based organizations	165	415
Participation in other organizations	35	85
Knowledge and acceptance of climate change	655	465
Level of literacy	625	275
Access to climate, agriculture, livestock and other livelihood related information	100	285
Farming experience	330	80
Formal and informal training	60	140
Access to extension work	70	645
Knowledge of seed varieties	665	310
Knowledge of soil moisture retention technique	635	350
Knowledge of soil fertility and management	410	345
Knowledge of farm mechanization	225	15
Rainwater harvesting	655	560
Adaptation of eco-friendling farming practices	235	175
Land holding size	670	480
Land holding ownership	820	970
Irrigation infrastructure	0	0
Access to roads	730	0
Access to markets	700	0
Processing and storage unit	0	0
Government subsidy	20	15
Disaster relief assistance	30	10
Governance system	220	70

2. Details of cumulative determinant score for the adaptive capacity index

Determinant	Cumulative Score	
	Connected Villages	Isolated Villages
Economic Resources	5.025	2.625
Social Capital	4.20	6.75
Awareness and Training	9.20	9.45
Technology	14.125	8.775
Infrastructure	14.60	7.25
Institutions	1.35	0.475

ANNEXURE D

Details on Focus Group Discussion

Topic	Objective of the topic	Process
Cultural mapping	Discovering the history, culture and traditions of the region	Participants were asked about their traditions related to food, festival, clothes, ornaments, and culture.
Livelihood resource mapping	Identify the resources that are most important to the livelihoods of the focus communities.	Participants were asked to draft a map of their community showing its boundaries, key facilities, and resources (including crops, livestock, houses, schools, temples, health post [local health facility], roads, forested areas, and water bodies). Next, the most important livelihood resources were divided into 6 categories: natural, physical/ infrastructure, financial, human, social, and political. The participants then prioritized the most important resources (ideally at least 2 from each category) and discussed the benefits.
Cultivation calendar	Identify the cropping pattern of the region	Participants identified their most important crops and then discussed its economic value. The participants were also asked to note any changes in cropping patterns over the past years and any other important crop-related activity.
Hazard mapping	Identify and describe the major hazards and their damage potential	Initially a general discussion was done to make sure that all participants understood the term "hazard." A list of hazards, including social and non-climate-related risks (such as diseases and political problems) were created. Participants then ranked all identified hazards according to their importance and selected the 3–5 most important hazards. Finally, the damage potential of serious hazards on livelihood was discussed.
Dependency on natural resources	Identify the natural resources on which the local people were dependent for their daily needs as well as income generation	Initially, the natural resource base was enlisted, and then each resource was discussed in detail. Information regarding its quantity, frequency and economic value were elaborated upon.
Agricultural policies	Enlisting the agricultural policies being implemented in the region	Details about the agricultural policies were discussed, keeping in mind the satisfaction level of the local farmers. Pro's and con's related to policy formulation and demands of farmers were also debated upon. Ranking of the provisions under different policies was done to formulate a strength-weakness matrix
Climate change analysis	Understand the knowledge of farmers on climate change and its impact on livelihood	Through guided discussions, participants knowledge on climate change was reviewed. The impact (if any) on the previously listed natural resources were further discussed.
Response	Identify current problems, coping strategies, evaluate their capacity, and identify possible alternative strategies.	Participants brainstormed a list of prevailing livelihood problems, possible alternative strategies based on available resources and capacity. Further, the potential of alternative development strategies were discussed based on the current scenario.

Hazard Mapping Matrix

Resources	**Hazards**								
	Drought	Landslide	Erratic rainfall	Hailstorm	Flood	Soil Erosion	Crop Pest & Diseases	Total Score	Rank
Agriculture									
Horticulture									
Forests & biodiversity									
Health									
Livestock									
Water									
Houses									
Roads									
Irrigation channels									
Wage labour									
Daily life									
Total Score									
Rank									

Comments:

ANNEXURE E

Household Survey

Questionnaire No.: Date:

Geographical Information of the Village

Q1. Name of the Village_____

Q2. GPS Location: Latitude_____ Longitude_____

Q3. Altitude_____(amsl)

Socio-Demographic Profile of Household

Q4. Name of Respondent: _____

Q5. Age: _____ Q6. Sex: M/F

Q7. Education: Illiterate/Primary/High School/Intermediate/College & above

Q8. Religion: _____ Q9. Caste: G/OBS/SC/ST

Q10. What type of house do you have?

(a) Kachha House (b) Semi-pakka House (c) Pakka House

Q11. Total no. of household members: _____

Q12. Age wise distribution of household members:

Gender	Below 8 years	Between 8 to 18 years	Above 18 years
Male			
Female			

Q13. Family education status:

Gender	Illiterate	Primary	High School	Intermediate	Bachelor	Above Bachelor
Male						
Female						

Q14. Profession:

- Primary Profession: Agriculture/Service/Self-Employed/Labour/Any Other
- Secondary Profession: Agriculture/Service/Self-Employed/Labour/Any Other
- Approximate Annual Income: _____

Q15. Land Asset:

Cultivated Land (Unit): (i) Irrigated: (ii) Unirrigated:

Uncultivated Land (Unit):

Q16. Major Sources of Energy Used:

Purpose	Kerosene	Fuelwood	Dung cakes	LPG	Biogas	Electricity	Crop Residues
Cooking							
Heating							

Q17. Preferred source of energy for cooking:

Q18. Major Sources of Water & Quantity Used:

Source	Tap	Stream	Pond	Other
Quantity				

Q19. Road Accessibility: Yes/No

If no, distance to the nearest motorable road_____

Q20. Market Accessibility Yes/No

If no, distance to the nearest market_____

Q21. Accessibility to the Basic Amenities:

Amenity	Primary School	Secondary School	College	Hospital/Health Centre	Others
Distance					

Dependence on Forest Resources:

Q22. Distance of forest from the village: _____

Q23. Fuelwood Collection:

Quantity of Collection (qty/day or week)	Own field	Forest	Community Forest	Any Other
Major fuelwood species				
Distance travelled				
Collector of fuelwood				

Q24. Fodder Collection:

Quantity of Collection (qty/day or week)	Own field	Forest	Community forest	Any Other
Major fodder species				
Distance travelled				
Collector of fodder				

Q25. Grazing

- Livestock feeding practiced: Stall fed: Yes/No Grazing: Yes/No
- Time of grazing (hours/day):
- Place of grazing: Own field/Forest/Community Forest/Bugyals

Q26. Timber logging:

- Source of timber: Own field/Forest/Community Forest/Bugyals
- Amount of timer logged annually: _____
- Use of timber extracted, if any _____

Q27. Do you have any knowledge about Van Panchayat/village forest rights/hak?
(Details)

Q28. NTFPs:

NTFP	Name	Quantity	Use
Wild fruits			
Wild vegetables			
Aromatic plants			
Medicinal plants			

Q29. Agronomic Yield:

Sector	Crops	Area under the crop	Annual Production	Selling Price	Total Income
Agriculture					
Horticulture					

Q30. Water (if natural):

Purpose	Source	Quantity used per day	Rate	Total Price
Household				
Agriculture				
Horticulture				
Livestock				
Others				

Q31. Fertilizers:

The source of purchase: _____

Sector	Name of fertilizer	Rate of application	Total quantity used (p.a.)	Cost Price (per unit)	Total expenditure
Agriculture					
Horticulture					

Q32. Pesticides:

The source of purchase: _____

Sector	Name of pesticide	Rate of application	Total quantity used (p.a.)	Cost Price (per unit)	Total expenditure
Agriculture					
Horticulture					

Q33. Is wildlife spotted around the village? Yes/No/Don’t know

Q34. If yes, is there any human-wildlife conflict in the village? Yes/No/Don’t know

Q35. If yes, what kind of harm is done? Crop loss/livestock loss/human injury/other/none

Q36. Estimated monetary amount of loss (if any):

Q37. Is there any government compensation for the loss? Yes/No/Don't know

Q38. Have you noticed an increase/decrease in conflict over the last few years?
Yes/No/Don't know (if yes, why do you think it is so?)

Q39. Suggestions for reducing the human wildlife conflict.

Q40. Do you have knowledge about climate change? Yes/No/Don't know
If yes,

Q41. Do you perceive any change in the temperature of the area? Yes/No/Don't know
If yes, increased temp./decreased temp./altered temp. range

Q42. Do you perceive any change in the rainfall pattern of the area? Yes/No/Don't know
If yes, increased rainfall/decreased rainfall/altered rainfall range

Q43. Any extreme weather event in the past? Yes/No/Don't know

Q44. Impact of climate change on livelihood:

Sector	Yes	No	Don't know
Agriculture			
Horticulture			
Forest/biodiversity resources			
Tourism			
Labour			
Others			

Q45. Climate change related problems faced:

Q46. Adaptation Measures for climate change:

Adaptation Measures	Yes	No
Crop diversification		
Different crop varieties		
New planting dates		
Shortening the length of growing period		
Mixing farming and non-farming activities		
Use of irrigation		
Changes in irrigation schedule		
Use of chemicals, fertilizers, pesticides		
Use of organic manures and bio-pesticides		
Increase water conservation on farm		
Increase soil conservation on farm		
Mixing crop production and livestock		

Livestock diversification		
Adjusting livestock management practices		
Insurance/govt. aid during crop failure		
Use of prayers and socio-cultural practices		
Others		

Q47. Do you have any knowledge about the government schemes being implemented in the area? Yes/No/Don't know

Details about the scheme:

Q48. Details about the tourism sector. (if it is a source of income for the family).

Comments:

Adaptive Capacity Survey

Indicator	Question	Points					
		0	1	2	3	4	5
Diversity of source income	Is crop farming your only source of income? Yes = 0 If No, number of economic activities do you engage in?						
Remittances received	Do you receive money from family who world outside this community? No = 0 If Yes, rarely = 1, yearly = 2, half-yearly = 3, quarterly = 4, monthly = 5						
Access to credit	How do you finance your farming activities? own financial resource = 0, borrowing within the community = 1, remittances = 2, loan within the community on interest rate = 3, loan from bank = 4, assistance from agricultural policies and programmes = 5						
Access to family labour	Do you receive free labour from household for farming activities? No = 1 If Yes, number of family members involved?						
Participation in farmer-based organizations	Are you a member of any farmers' group or organization? No = 0 If Yes, number of groups participated in?						
Participation in other organizations	Are you a member of any other organizations? No = 0 If Yes, number of groups participated in?						
Knowledge and acceptance of climate change	Do you have knowledge about climate change? No = 0 If Yes, number of reasons known for it (in detail).						
Level of literacy	Have you attended formal education? No = 0 If Yes, primary = 1, junior school = 2, high School = 3, intermediate = 4, college = 5						
Access to information	Do you have access to weather/agriculture related information? No = 0 If Yes, word of mouth = 1, newspaper = 2, radio/TV = 3, agricultural extension service = 4, research/programme/policy = 5						
Farming experience	How long have you been farming? If, subsistence = 0 If commercial, <2 years = 1, 2-5 years = 2, 5-8 years = 3, 8-10 years = 4, >10 years = 5						
Formal and informal training	Have you received any agricultural training? No = 0 If Yes, from fellow farmers = 1, private sector = 2, NGO = 3, research work = 4, government department = 5						
Access to extension work	Have you received any benefits from agricultural extension work? No = 0 If Yes, number of visits that has benefitted you in any way and rate the experience.						
Knowledge of seed varieties	Do you know about the different seed varieties of the crops? No = 0 If Yes, how many types of varieties are you using?						

	Like, indigenous, early/late maturing drought/flood resistant, disease/pest resistant , HYV.						
Knowledge of soil moisture retention technique	Do you have any knowledge of soil moisture retention/water conservation for agricultural purpose? No = 0 If Yes, number of techniques used? Like, mulching, cover crops, contour farming, ridge and furrow method, bunding, etc.						
Knowledge of soil fertility and management	Have you fertilized your farm for cultivation? No = 0 If Yes, chemical fertilizer = 1, organic manure = 2, fallow system = 3, bio-fertilizer = 4, mix methods = 5						
Knowledge of farm mechanization	Do you have knowledge about farm machinery used pre- and post-harvest? No = 0 If Yes, rate the types of equipment's and machinery used.						
Rainwater harvesting	Do you have provision for rainwater harvesting? No = 0 If Yes, rate based on its size, feasibility, the extent of use.						
Adaptation of eco-friendly farming techniques	Do you practice any eco-friendly farming activity? No = 1 If Yes, number of activities practices? Like, mulching, contour farming, composting, etc.						
Land holding size	What is the size of your farm land? <1 nali = 0, 1-5 nali = 1, 5-10 nali = 2, 10 – 15 nali = 3, 15-20 nali = 4, >20 nali = 5						
Land holding ownership	How did you obtain you land/farm? No land = 0, work as labour = 1, Rented/leased = 2, from Gram Sabha = 3, family = 4, purchased = 5						
Irrigation infrastructure	Do you have irrigation facilities? No = 0 If Yes, natural = 1, man–made channels = 2 to 5 based on the extent of use						
Access to road	How far is your farm/house from the nearest main road that connects to the town? <1 km = 5, 1-5 km = 4, 5-10 km = 3, >10 km = 2, walking = 0 and 1 based on type of path and distance						
Access to market	How far is your house from the nearest marker area? <1 km = 5, 1-5 km = 4, 5-10 km = 3, >10 km = 2, walking = 0 and 1 based on type of path and distance						
Processing and storage unit	Do you have the processing and storage unit? No = 0 If Yes, how far is it? 1-10 km = 1, 10-20 km = 2, 20-30 km = 3, 30-40 km = 4, >40 km = 5						
Government subsidy	Do you receive agriculture subsidies from the government? No = 0 If Yes, how many do you benefit from? (rate)						
Disaster relief assistance	Have you ever received disaster relief assistance when you were affected by a natural disaster? No = 0 If Yes, rate according to the level of satisfaction.						
Governance system	Are you satisfied with the local governance system? No = 0 If Yes, rate according to the level of satisfaction.						

Comments:

Tourism Survey

Destination Attribute	Tourist Response			
	Strongly Agree	Agree	Neutral	Do Not Agree
Scenery and natural beauty				
Good climatic conditions				
Good road connectivity				
Good telecom connectivity				
Friendly local people				
Cleanliness				
Personal safety				
Protected area – wildlife				
Cultural heritage				
Local cuisine				
Adventure				
Language is not a barrier				
Good support services				

Comments:

Impact of COVID-19

Socio-economic attributes	Response of local people				
	1	2	3	4	5
Dissemination of COVID-19 information?					
Are you satisfied with the medical facility?					
Has it impacted education?					
Has it caused social stress?					
Did the work got affected?					
Was there any income loss?					
Has it impacted tourism sector?					
Is the local government supportive?					

Comments:

Research Publication

- Rommila Chandra and V.P. Uniyal (2021). An ethnobotanical study of wild medicinal plants among the mountain community of Western Himalayas: A case study of Govind wildlife sanctuary and national park. An International Journal of Phytomedicines and Related Industries, ISSN: 0975-4261 (SCOPUS)

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Research Article

An ethnobotanical study of wild medicinal plants among the mountain community of Western Himalayas: A case study of Govind wildlife sanctuary and national park

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Received: November 20, 2020; Accepted: May 19, 2021

ABSTRACT

The biodiversity of Indian Himalayan Region has always provided the local mountain community with various goods and services, shaping their traditional food and healthcare system. For years, this forest-based resource subsistence has accumulated a great deal of traditional knowledge and practices, but is declining through younger generations. The present study aims to document the indigenous knowledge of the mountain community, regarding medicinal and aromatic plants, wild fruits and vegetables, in the villages around Govind Wildlife Sanctuary and National Park in the Western Himalayas. For the study, participatory rural appraisal tools (household survey, key informant interview, focus group discussion, field visit) were used to collect primary information from the local people. A total of 55 species were documented along with the uses for traditionally curing the diseases. The dependency of the community on medicinal plants was analyzed through Relative Frequency Citation (RFC), Relative Importance Index (RI), Cultural Importance Index (CI), Cultural Value Index (CV) and Fidelity Level (FL). The homogeneity of ethnomedicinal knowledge among the people was tested through Informant Consensus Factor (Fic). The respondents were divided into three age groups, old (> 50 years), adult (25-50 years) and young (<25 years) for the calculation of Knowledge Richness Index (KRI) across different generations. The study revealed that the traditional ethnomedicinal knowledge is declining among youth and it is important to identify, collect, organize and document it in some way, in order to maintain, use, disseminate and/or protect, so that the true holders of such knowledge can reap the future benefits of their culture. The study highlighted that the dependency of inaccessible and remote villages on traditional remedies was higher than the villages near roadhead. The study recommends agricultural diversification through medicinal and aromatic plant cultivation, to sustain the traditional healthcare system with a sustainable livelihood opportunity for the rural mountain community. The study suggests further research on biophysical and climatic conditions for medicinal plant cultivation, along with the demand-supply chain analysis of the same.

Keywords: Indian Himalayan region, medicinal plants, sustainable livelihood, traditional healthcare remedies, traditional knowledge

INTRODUCTION

Over the years, local and indigenous communities around the world have constantly struggled to maintain their livelihood, rights, culture and traditional knowledge. Yet, they have managed to survive, adapting their way through globalization and changing climatic conditions. Their diverse form of knowledge, deeply rooted in their

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- Participated and presented a paper titled "Impact of COVID-19 on livelihood security of mountain community" in the poster session of the International Web-Conference on Resource Management and Biodiversity Conservation to Achieve Sustainable Development Goals, organized by Academy of Natural Resource Conservation and Management (ANRCM), Lucknow on September 11-12th, 2020.

Academy of Natural Resource Conservation and Management (ANRCM)
Lucknow (U.P.), India
www.anrcm.org

Certificate of Participation

It is certified that

Ms. Rommila Chandra,
Wildlife Institute of India

Participated and presented paper entitled
Impact of COVID-19 on livelihood security of mountain community
in the **Poster Session** of the **International Web-Conference on Resource Management and Biodiversity Conservation to Achieve Sustainable Development Goals** organized online on September 11-12, 2020.

September 12, 2020

SANJAY SWAMI, Org. Secretary
NILAY BORAH, Org. Secretary
SANJAY ARORA, Secretary, ANRCM
ATUL K. SINGH, President, ANRCM

- Participated and presented a paper entitled "Revival of Agrobiodiversity for Sustainable Livelihood Development of Mountain Communities" in GROW Summer School 2020 – Agrobiodiversity in a changing climate from Sapienza University, Rome in assistance with Mountain Partnership, Platform fir Agrobiodiversity Research and Food & Agriculture Organization, on 25th September, 2020.

GROW SUMMER SCHOOL
AGROBIODIVERSITY IN A CHANGING CLIMATE

Certificate
OF ATTENDANCE

AWARDED TO

Rommila Chandra

For the successful completion of the GROW Summer School - Agrobiodiversity in a changing climate
15 - 25 September 2020

Prof Fabio Attorre — Sapienza Università di Roma
Dr Giorgio Grussu — Mountain Partnership
Prof Devra Javis — PAR Platform for Agrobiodiversity Research

In collaboration with: naturasì, Slow Food, IFOAM Organics International, Bioversity, CIAT

WITH THE TECHNICAL SUPPORT OF THE FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO)

- Participated and presented a paper titled “Assessment of Local Adaptive Capacity of Mountain Farmers: A Way Forward for Sustainable Livelihood Development” in the 3-day international workshop cum training on Green Growth Strategies for Climate Resilience And DRR: Policies, Pathways and Tools, organized by National Institute of Disaster Management, Ministry of Home Affairs (GOI) and Institute for Social and Economic Change, Bengaluru held from 26-28th November, 2020.

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New Delhi

CERTIFICATE OF PARTICIPATION

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Prof. S. Madheswaran, Director, ISEC
Prof. Sunil Nautiyal, Head, CEENR, ISEC
Prof. Anil K. Gupta, Head, ECDRM, NIDM
Maj.Gen. Manoj K Bindal, Executive Director, NIDM

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INTRODUCTION

Over the years, local and indigenous communities around the world have constantly struggled to maintain their livelihood, rights, culture and traditional knowledge. Yet, they have managed to survive, adapting their way through globalization and changing climatic conditions. Their diverse form of knowledge, deeply rooted in their

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relationships with the environment as well as in cultural cohesion, have allowed many of these communities to maintain a sustainable use and management of natural resources (Magni, 2016). The United Nations Development Agenda also acknowledges their importance, stating "traditional and indigenous knowledge, adaptation and coping strategies can be major assets for local response strategies" (UN, 2012). According to the World Health Organization (WHO), 65-80% of the world's population, particularly in developing countries, depend on plants for healing, and this is well accepted in traditional culture (Cunningham, 1988), often due to poverty, and lack of access to modern medicine (Awoyemi *et al.,* 2012). The transgenerational nature is the unique characteristic of traditional knowledge, which has never been preserved in a written form and rather has verbally/orally passed over generations. It is the information that local people possess, based on their experience and adaptation to a local culture, environment and living system which is developed over time. These traditional resources are an economic asset which can be innovatively used, traded or licensed for income generation and livelihood development. The current market of herbal drugs is estimated at 40 billion and is expected to increase by 16% in the next 3-4 years (Kumar *et al.,* 2021).

The premise of the research framework is that diverse mountain communities across the Himalayas have been using traditional knowledge and practices for years in order to cope with their geographic isolation and vulnerability. The importance of medicinal plants is increasingly being recognized from ecological, social and economic perspective (Arnold and Perez, 2001; Negi *et al.,* 2011). The knowledge of medicinal plants conservation and its use has developed a link between promoting environmental conservation and indigenous knowledge (Cameron, 2008). On one hand, there has been a decline in the practice of herbal medicine due to the change in people's attitude towards growing usage of allopathic medicine. And on the other, traditional uses and practices are often being exploited by the modern herbal, pharmaceutical, food and cosmetic industries. But recently, decreasing populations of medicinal plants in the wild due to illegal exploitation have led to discussions among conservationists, ecologists and scientists (Singh, 2002). Several medicinal plants have been listed as endangered, vulnerable and threatened due to over exploitation, reckless harvesting from the forest and alpine meadows (Uniyal *et al.,* 2006). The local people rarely receive a fair and equitable share of associated benefits arising from their traditional knowledge which they have kept alive through generations. Thus, traditional knowledge and practices across local and indigenous communities should be identified, collected, organized, registered and/ or recorded in some way, in order to maintain, use, disseminate and/or protect, so that the true holders of such knowledge can reap the benefits of their culture.

MATERIALS AND METHODS

Study area

The study was conducted in a remote mountainous region of Govind Wildlife Sanctuary and National Park, as it had sporadic access to basic medical facilities due to geographical isolation and poor connectivity. It is located in the Uttarkashi district of Uttarakhand, which lies in the middle and greater Himalayas of India. The area harbors a rich array of habitats, vegetation types and floral and faunal diversity. Chir, oak, deodar, spruce, silver fir, birch, alder, juniper, and rhododendron are some of the important forest trees found in the area. The alpine meadows, locally known as bugyals, are rich in herbs and medicinal plants. The prominent fauna in the tract includes, snow leopard, mountain weasel, brown bear, asiatic black bear, wild pig, musk deer, Himalayan thar, goral, bharal, among others. The landscape is an important catchment for the Tons river (a major tributary of the Yamuna river). Supin and Rupin, are the two tributaries of Tons which merges at the Naitwar village. The protected area is fragmented by 42 villages located in three valleys along the Supin, Tons and Rupin rivers.

Sampling technique

The study employed a combination of sampling techniques to select the target villages and local respondents for the collection of primary data. Through stratified random sampling four villages were selected, namely, Gainchwan Gaon, Deora, Dhatmeer and Osla. Initially, participatory resource surveys with the help of local people were organized for establishing a trust connection with the local

community. Then the snowball sampling technique was used for the selection of respondents for key informant interviews (KII), which was based on their sound knowledge of medicinal plants used in the study area. Later, intensive field visits and participatory rural appraisal tools like semi-structured questionnaire survey and focus group discussions (FGDs) were conducted to collect the primary information on medicinal plants and their traditional use. Secondary data sources based on government records and research publications were also analyzed, so as to prepare a detailed set of check-list and a suitable questionnaire. With the help of KII, a baseline information was collected on the traditional use of ethnomedicinal plants. Later, through household surveys and FGDs, consensus of information on the use of each plant and age group-based richness comparison was done. Depending upon the availability and willingness of the local community, from a total of 490 households and 1000 respondents from the selected 4 villages were interviewed.

Table 1: Demographic profile villages

Name of the village	Area of the village (ha)	Total no. of households (N)	Sample no. of households (n)
Gainchwan Gaon	137.76	192	129
Deora	44.18	99	79
Dhatmeer	269.16	192	129
Osla	378.16	151	109

Among the total respondents interviewed, 52% were female and 48% were male. The percent distribution of interviewees in young generation (< 25 years) was 27.80%, adult generation (25-50 years) 43.50% and old generation (> 50 years) 28.70%. Primarily, exploratory approach was used for the documentation of traditional medicinal practices in the study area in order to yield a more comprehensive and holistic view of traditional knowledge. It established a dynamic relationship between the respondent and the interviewer by establishing an understanding of underlying sentiments, opinions and motivation of the local people. It provided an insight about the lives, livelihood and problems of the mountain community, which further helped in developing a potential quantitative research. For a more detailed classification and analysis, the uses cited by the respondents were grouped into 15 health ailment categories (Table 2).

Data analysis

All the ethnobotanical indices are founded on the basic structure of the ethnobotanical information: "informant *i* mentions the use of the species *s* in the use-category *u*." (Tardío and Pardo-de-Santayana, 2008). Thus, the survey yields *NS* number of species, with *NC* number of use-categories and *N* number of informants. For studying the cultural importance of the cited medicinal plants, the use-reports (UR) for each species were calculated based on the 15 health ailment categories. UR is expressed as (Tardío and Pardo-de-Santayana, 2008);

$$UR_s = \sum_{u=u_1}^{u_{NC}} \sum_{i=i_1}^{i_N} UR_{ui}$$

First, the UR of all the informants (i_1 to i_N) within each ailment category for that particular species was summed, followed by all the UR for each ailment category (u_1 to u_{NC}).

The comparison of importance of each cited species was attempted, using the following indices;

i. Relative Frequency Citation (RFC): This index was obtained by dividing the number of respondents who mention the use of the species i.e., frequency citation (*FCs*), by the total number of respondents participating in the survey (*N*). The value of RFC varies from 0 (when nobody refers to a plant as a useful one), to 1 (when all the respondents mentioning it as useful) (Tardíoand Pardo-de Santayana, 2008). It doesn't require the use-category and was calculated as:

$$RFC = FC_s / N$$

ii. Relative Importance Index (RI): It was calculated for all the cited species using the formula given by Pardo-de-Santayana (2003). The RI index varies from 0 (when nobody mentions it) to 1 (frequently mentioned as useful).

$$RI_s = RFC_{(max)} + RNU_{(max)} / 2$$

Where, $RFC_{(max)}$ is the FC_s for a species over the maximum value of *FC* in all the species of the survey, given by:

$$RFC(max) = FC_s / FC_{(max)}$$

Table 2: Number of use-reports and their percentage in health ailment category

Health ailment category	No. of species	Specific health issues	No. of use-reports	Percentage
Skeleton & Muscle	16	Rheumatic pain, muscular pain, back pain, throat pain, joint pain, swelling, bone fracture, leprosy, epilepsy, arthritis	4690	11.42
Gastro-intestinal	21	Stomach ache, dysentery, vomiting, diarrhea, intestinal spasm, stomach disorder, intestinal worms, ringworm, constipation, gastric issue, indigestion, dyspepsia, piles	8590	20.91
General	17	Head ache, cough, cold, fever, sore throat, antimalarial, typhoid fever	5843	14.22
Antidote	2	Snakebite	678	1.65
Dermatological	21	Skin rash, wounds, boils, cuts, itching, allergy, skin ulcer, burns, skin infection, scabies, fungal infection	8602	20.94
Respiratory	4	Nasal infection, asthma, lung infection, bronchitis, whooping cough	880	2.14
Circulatory	4	Diabetes, blood pressure, heart disease, heart tonic	1054	2.57
Hepatic	6	Jaundice	1666	4.06
Nervous	2	Brain functioning and power, psychological problems	704	1.71
Dental	5	Tooth ache, mouth wash	2059	5.01
Gynecological	5	Menstruation, smooth delivery, massaging oil for pregnant women and infants, post-natal care	2470	6.01
Genetic	1	Cancer	516	1.26
Hair	2	Hair growth, hair fall	1240	3.02
Ophthalmic	1	Eye infection	233	0.57
Body Heat	4	Keeping body warm, internal heat, cooling agent, bleeding nose	1849	4.50

Where, $RNU_{(max)}$ is the relative number of use reports for different ailment categories for the same species over the maximum value of usereports amongst all the species in all the categories, given by:

$RNU_{(max)} = NU_s \; D \; NU_{(max)}$

iii. Cultural Importance Index (CI): It is calculated by the summation of UR in every ailment category mentioned for a species divided by the total number of respondents (*N*). This index elaborates upon the extent of the use for a species as well as diversity of its use. A greater value of CI for a species signifies that the particular species is widely used for that health problem. It also gives the measure of relative importance of each plant use (Tardioand Pardo-de Santayana, 2008). The UR is the total number of respondents who mention a use for a species in the different ailment categories.

$$CI_s = \sum_{u=u_1}^{u_{NC}} \sum_{i=i_1}^{i_N} UR_{ui} / N$$

iv. Cultural Value Index (CV): It was given by Reyes-García *et al.* (2006) and is calculated using the flowing formula;

$CV_s = RNU_s \times RFC_s \times CI_s$

Theoretically, the maximum value of CV will be reached when all the contributing factors reach their maximum values (which is unlikely that all the respondents mention the use of all the species). The value of the index varies from 0 to the total number of use-category (in this case ailment categories) in the study.

v. Informant's Consensus Factor (Fic): In order to check the homogeneity in the use of medicinal plants (as mentioned by the respondents) in the different ailment categories informant's consensus factor was calculated using the following formula (based on Heinrich *et al.,* 1998).

$ICF = N_{ur} - N_t / N_{ur} - 1$

Where, N_{ur} is the number of use reports for a particular ailment category and N_t is the number of species used for a particular health ailment by all the respondents.

ICF ranges from 0 to 1, where a high value of ICF means high rate of consensus amongst the respondents.

vi. Fidelity Level (FL): It helped in determining the most preferred species used in the treatment of a particular ailment. Following formula based on Friedman *et al.* (1986) was used to calculate the FL;

$FL\ (\%) = N_p\ D\ \ N \times 100$

Where, N_p is the number of use-reports for a given species for a particular ailment and N is the total number of uses reported for species for any major ailment.

vii. Knowledge Richness Index (KRI): It was calculated separately for the pre-determined age group classes. Following formula was used (based on Araujo *et al.,* 2012 and Alencar *et al.,* 2014);

$KRI = 1\ D\ \ \Sigma Ji^2$

$J_i = R_i / R_{ui}$

Where, *Ri* is the number of plant species mentioned by the respondent, R_{ui} is the total number of species mentioned by the unit (N=1000). The value of KRI ranges from 0 to infinity, where the lower value of KRI indicates a higher knowledge of medicinal plants by the respondents and vice versa.

RESULTS AND DISCUSSION

The complete detail of different medicinal and aromatic plants and their traditional uses in the study are recorded in Table 3. A total of 55 medicinal and aromatic plants were recorded, which were grouped into 15 different health ailment categories. According to the recorded data, the maximum number of plant species (Figure 1) were used for gastro-intestinal and dermatological ailments (21 each), followed by general health problems (17), skeleton and muscle issues (16), hepatic disorder (6), dental and gynecological issues (5 each), respiratory, circulatory and body heat problems (4 each), antidote, nervous system and hair (2 each) and optical and genetic problems (1 each).

Different plant parts were used across the community (Figure 2) for traditionally curing different diseases, like, leaves contributed the most (23.64%), followed by roots and whole plant (21.82% each), bark (12.73%), fruits (9.09%), tuber, seeds and flower (5.45% each), resin (3.64%) and rhizome (1.82%). During the survey, it was evident that almost all the people interviewed were aware of few of the

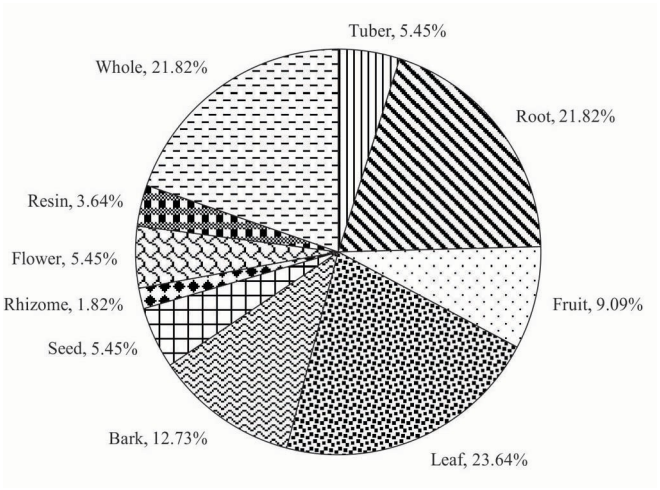

Figure 2: Proportion of plants parts used for curing health ailments

Figure 1: Number of plant species used to treat different health ailment categories

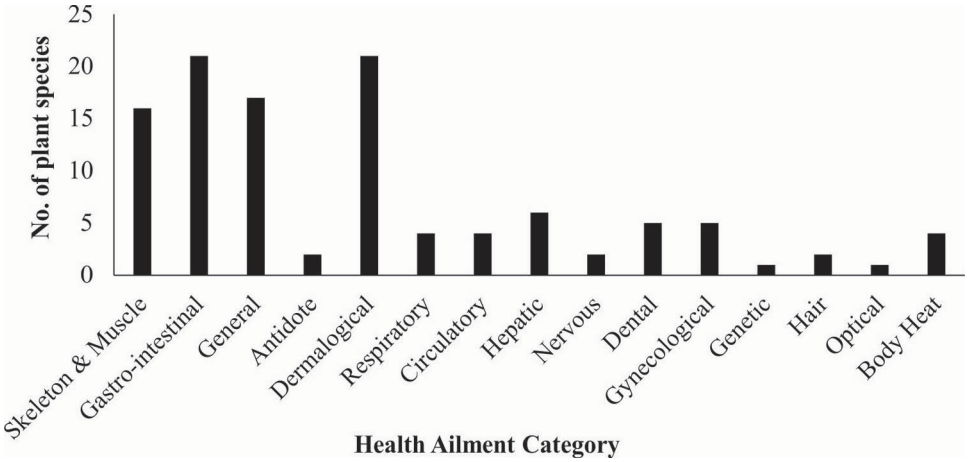

Table 3: Ethnobotanical knowledge of the wild plant species used in the traditional health care system

Scientific Name	Family	Vernacular Name	Part Used	No. of diseases treated	Folk Medicinal Use	Aromatic & Condiment
Aconitum balfourii (Bruhl) Muk.	Ranunculaceae	Meetha	Tuber	1	Snakebite	
Aconitum heterophyllum Wall. Ex Royle	Ranunculaceae	Atis	Root	3	Headache, fever and stomach ache	
Aesulus indica Colebr.	Hippocastanaceae	Pangar	Fruit	3	Sore throat and rheumatic pain	
Allium stracheyi Baker	Alliceae	Faran/Jambo	Whole	4	Cough, cold, nasal and lung infection	Condiment
Angelica glauca Edgew.	Apiaceae	Choru/Gandhra-yan	Root	5	Headache, fever, skin rashes, wounds, toothache	Condiment
Arnebia benthamii	Boraginaceae	Balchari/ Laljari	Root	1	Hair growth and hair fall	
Artemisia maritima	Asteraceae	Purchu	Root	2	Stomach disorder and epilepsy	
Artemisia nilagirica (Clarke) Pamp.	Asteraceae	Kunj/Panti	Leaf	6	Boils, cuts, wounds, intestinal worms, skin infection, asthma	
Asparagus racemosus L.	Liliaceae	Satavari	Root	1	Epilepsy	
Berberis aristate DC.	Berberidaceae	Kingore/ Kilmora	Bark, Root	3	Stomach ache, eye problems, fever	
Betula utilis D. Don	Betulaceae	Bhojpatra	Bark	6	Cough, cold, cuts, wounds, jaundice, and psychological problems	
Cannabis sativa L.	Cannabaceae	Bhaang	Leaf	5	Piles, cuts, skin ulcers, burns, muscular pain	Condiment
Carum carvi	Umbelliferae	Kala jeera	Seed	1	Dyspepsia	Condiment
Cedrus deodara Loud.	Pinaceae	Devdar	Bark	4	Rheumatism, back pain, wounds and cuts	
Centella asiatica	Apiaceae	Bramhi	Whole	1	Brain functioning and power	
Chenopodium album	Chenopodiaceae	Bathuwa	Leaf	1	Constipation	Wild Vegetable
Cinnamomum tamala Nees	Lauraceae	Dalchini/ Tejpaat	Bark, Leaf	3	Throat pain, headache, diabetes	Aromatic and Condiment
Cynodon dactylon L.	Poaceae	Doob	Whole	2	Dysentery and vomiting	
Dactylorrhiza hatagirea (D. Don) Soo	Orchidaceae	Hatazari	Tuber	5	Wounds, cuts, fever, dysentery, hair growth	
Datura stramonium	Solanaceae	Dhatura	Whole	2	Skin disease and joint pain	
Dioscorea deltoidei	Dioscoreacea	Genthi	Tuber	1	Wounds	
Diplazium esculentum Sw.	Polypodiceae	Lingra	Whole	3	Anti-malarial, jaundice and constipation	Wild Vegetable
Galium aparine L.	Rubiaceae	Kuri	Leaf	1	Cooling agent	
Geranium wallichianum D. Don ex Sweet	Geraniaceae	Ratijari	Root	2	Headache and rheumatic pain	
Grewia oppositifolia Drummond ex Burret	Tiliaceae	Bhimal	Bark	1	Pregnant women for smooth delivery	
Hippophae salicifolia	Elaeagnaceae	Amees	Fruit	6	Cold, cough and gastric issues	
Hypericum elodeoides Choisy	Hypericaceae	Vasanti	Leaf, root	1	Controls vomiting	
Juglans regia L.	Juglandaceae	Jangli Akhrot	Fruit	2	Treatment for ringworm, oil used for massaging the legs of pregnant women	
Lyonia ovalifolia (Wall.) Drud.	Ericaceae	Anyaar	Leaf	2	Itching and allergy, fungal infection	

Table 3 contd....

Scientific Name	Family	Vernacular Name	Part Used	No. of diseases treated	Folk Medicinal Use	Aromatic & Condiment
Mentha longifolia (L.) Hudson	Lamiaceae	Pudina	Leaf, flower	1	Indigestion	Aromatic
Morchella esculenta L. Peres	Helvellaceae	Guchhi	Whole	2	Cough and cold	Wild edible
Nardostachys grandiflora DC.	Valerianaceae	Jatamasi	Rhizome	5	Blood pressure, jaundice, leprosy, heart disease	
Origanum vulgare L.	Lamiaceae	Ban Tulsi	Whole	4	Fever, cough, bronchitis and epilepsy	
Paeonia emodi Wall ex Royle	Paeoniaceae	Chandra	Whole	5	Whooping cough, diarrhea, intestinal spasm, cuts	
Perilla frutescens (L.) Britton	Lamiaceae	Bhang jeera	Seed, leaf	3	Cold, abdominal pain and massaging infants	
Picrorhiza kurrooa Royle ex Benth	Scrophulaceae	Kutki	Root	3	Stomach ache, typhoid and jaundice	
Pinus roxburghii Sarg.	Pinaceae	Chir	Resin	2	Cut and wounds	Aromatic
Pinus wallichiana Jacks.	Pinaceae	Kail	Resin	1	Arthritis	
Pleurospermum angelicoides	Apiaceae	Chippi	Whole	3	Dysentery, stomach problems and typhoid fever	
Podophyllum hexandrum Royle	Podophyllaceae	Bankakri	Fruit, root	2	Cuts and wounds	
Prinsepia utilis Royle	Rosaceae	Bhaikal	Seed	2	Muscular pain and wounds	
Reinwardita indica Dumortier	Linaceae	Pauyoli	Flower	1	Mouth wash	
Rheum emodi (D. Don)	Polygonaceae	Dolu	Root	3	Boils, wounds and cuts	
Rhododendron arboretum Smith	Ericaceae	Burans	Flower	7	Bleeding nose, arthritis, boils, wounds, jaundice, blood pressure and heart tonic	Wild Edible
Rubus ellipticus Smith	Rosaceae	Hinsalu	Fruit	2	Stomach pain and dysentery	Wild Edible
Rumex hastatus (D. Don)	Polygonaceae	Janglipalak	Leaf	3	Wounds, bleeding and generation of internal heat	
Saussurea costus (Falc) Lipsch.	Asteraceae	Kut	Root	4	Toothache, jaundice, snakebite and skin problems	
Saussurea obvallata	Asteraceae	Bharamkamal	Whole	2	Cuts and wounds	
Skimmia anquetilia Taylore & Airy Shaw	Rutaceae	Kedarpatti	Leaf	3	Rheumatism, swelling and wounds	
Skimmia laureola (DC.) Zucc.	Rutaceae	Kasturapatti/ Neerpatti	Leaf	1	Scabies	Aromatic–Incense sticks
Swertia chirayita Roxb. Ex Flem	Gnetianaceae	Chirayata	Whole	2	Fever and diabetes	
Taxus baccata L.	Taxaceae	Thuner	Bark	3	Cancer, bone fracture and keeping body warm	
Thymus linearis Benth.	Lamiaceae	Van Ajwain	Whole	2	Tooth ache and stomach ache	Aromatic
Utrica dioica L.	Urticaceae	Kandali	Leaf	4	Stomach disorders, menstruation, arthritis and boils	Wild Vegetable
Zanthoxylum armatum DC.	Rutaceae	Timru	Bark, fruit	1	Toothache	

(based on Kumar and Singhal, 2019; Manikandan and Srivastava, 2015; Kala, 2015; Negi *et al.,* 2010)

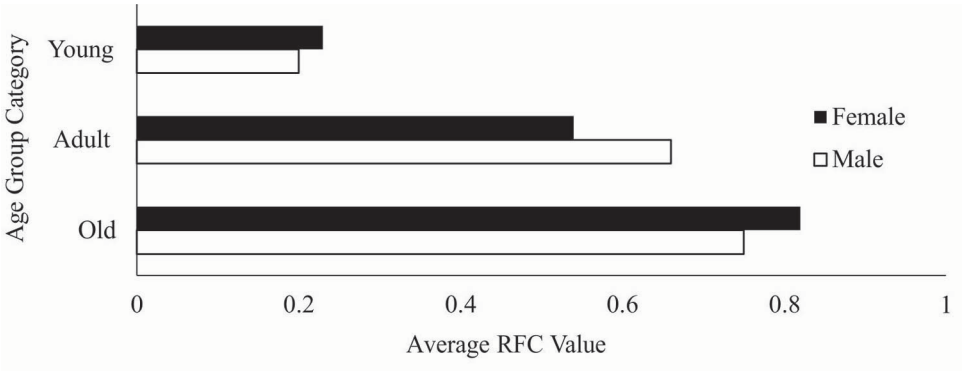

Figure 3: Average RFC of 55 species across different age groups

most common plant species, which were specially being utilized in their daily eating habits.

The RFC shows that *Allium stracheyi* Baker (Faran), *Cannabis sativa* L. (Bhaang), *Chenopodium album* (Bathuwa), *Cinnamomum tamala* Nees (Dalchini), *Diplazium esculentum* Sw. (Lingra), *Mentha longifolia* (L.) Hudson (Pudina), *Rhododendron arboretum* Smith (Burans), *Rubus ellipticus* Smith (Hinsalu) and *Utrica dioica* L. (Kandali) are the most cited and widely known plant species across the three age groups, with the RFC index score of 1. These species were well recognized by the younger generation as they are used in daily household cooking in the form of vegetable, condiment/spice and wild edibles. The other highly cited species across all the age groups were, *Arnebia benthamii* (Balchari), *Grewia oppositifolia* Drummond ex Burret (Bhimal) and *Cedrus deodara* Loud. (Devdar) with RFC index score of nearly 0.96, 0.95 and 0.94, respectively. Some of the least cited species were, *Swertia chirayita* Roxb. Ex Flem (Chiryata), *Paeonia emodi* Wall ex Royle (Chandra) and *Geranium wallichianum* D. Don ex Sweet (Ratajari) all having the RFC index score of nearly 0.22.

On comparing the species ranking based on each of the index (RI, CI and CV), not much difference was seen (Table 4). Culturally, the most important species are, *Utrica dioica* L. (Kandali), *Rhododendron arboretum* Smith (Burans) and *Allium stracheyi* Baker (Faran) with a CI index of 1.766,

Table 4: Evaluation of the Quantitative Indices (RFC, RI, CI and CV)

Species	Basic Values			Indices Values			
	FC	UR	NU	RFC	RI	CI	CV
Aconitum balfourii (Bruhl) Muk.	356	356	1	0.356	0.211	0.356	0.008
Aconitum heterophyllum Wall. Ex Royle	413	641	2	0.413	0.273	0.641	0.035
Aesulus indica Colebr.	305	412	2	0.305	0.219	0.412	0.002
Allium stracheyi Baker	1000	1488	3	1	0.600	1.488	0.298
Angelica glauca Edgew.	797	1088	3	0.797	0.498	1.088	0.173
Arnebia benthamii	960	960	1	0.960	0.513	0.96	0.061
Artemisia maritima	316	347	2	0.316	0.225	0.347	0.015
Artemisia nilagirica (Clarke) Pamp.	474	633	3	0.474	0.337	0.633	0.060
Asparagus racemosus L.	204	204	1	0.204	0.135	0.204	0.003
Berberis aristate DC.	526	751	3	0.526	0.363	0.751	0.079
Betula utilis D. Don	790	1389	4	0.790	0.528	1.389	0.293
Cannabis sativa L.	1000	1309	3	1	0.600	1.309	0.262
Carum carvi	611	611	1	0.611	0.338	0.611	0.025
Cedrus deodara Loud.	948	1185	2	0.948	0.541	1.185	0.150
Centella asiatica	620	620	1	0.620	0.343	0.620	0.026
Chenopodium album	1000	1000	1	1	0.533	1	0.067

Table 4 contd....

Species	Basic Values			Indices Values			
	FC	UR	NU	RFC	RI	CI	CV
Cinnamomum tamala Nees	1000	1126	2	1	0.566	1.126	0.150
Cynodon dactylon L.	286	286	1	0.286	0.176	0.286	0.005
Dactylorrhiza hatagirea (D. Don) Soo	606	815	4	0.606	0.436	0.815	0.132
Datura stramonium	675	888	2	0.675	0.404	0.888	0.079
Dioscorea deltoidei	664	664	1	0.664	0.365	0.664	0.029
Diplazium esculentum Sw.	1000	1329	3	1	0.600	1.329	0.266
Galium aparine L.	422	422	1	0.422	0.244	0.422	0.012
Geranium wallichianum D. Don ex Sweet	224	246	2	0.224	0.179	0.246	0.007
Grewia oppositifolia Drummond ex Burret	948	948	1	0.948	0.507	0.948	0.059
Hippophae salicifolia	505	655	2	0.505	0.319	0.655	0.044
Hypericum elodeoides Choisy	332	332	1	0.332	0.199	0.332	0.007
Juglans regia L.	637	807	2	0.637	0.385	0.807	0.068
Lyonia ovalifolia (Wall.) Drud.	344	344	1	0.344	0.205	0.344	0.007
Mentha longifolia (L.) Hudson	1000	1000	1	1	0.533	1	0.067
Morchella esculenta L. Peres	789	789	1	0.789	0.428	0.789	0.0415
Nardostachys grandiflora DC.	525	889	3	0.525	0.362	0.889	0.093
Origanum vulgare L.	488	621	3	0.488	0.344	0.621	0.061
Paeonia emodi Wall ex Royle	220	361	4	0.220	0.243	0.361	0.021
Perilla frutescens (L.)Britton	352	438	3	0.352	0.276	0.438	0.031
Picrorhiza kurrooa Royle ex Benth	612	837	3	0.612	0.406	0.837	0.102
Pinus roxburghii Sarg.	782	782	1	0.782	0.424	0.782	0.041
Pinus wallichiana Jacks.	537	537	1	0.537	0.302	0.537	0.019
Pleurospermum angelicoides	498	612	2	0.498	0.316	0.612	0.041
Podophyllum hexandrum Royle	411	411	1	0.411	0.239	0.411	0.011
Prinsepia utilis Royle	298	418	2	0.298	0.216	0.418	0.017
Reinwardita indica Dumortier	263	263	1	0.263	0.165	0.263	0.005
Rheum emodi (D. Don)	235	235	1	0.235	0.151	0.235	0.004
Rhododendron arboretum Smith	1000	1527	5	1	0.667	1.527	0.509
Rubus ellipticus Smith	1000	1000	1	1	0.533	1	0.067
Rumex hastatus (D. Don)	768	1104	2	0.768	0.451	1.104	0.113
Saussurea costus (Falc) Lipsch.	683	1050	4	0.683	0.475	1.050	0.191
Saussurea obvallata	627	627	1	0.627	0.347	0.627	0.026
Skimmia anquetilia Taylore & Airy Shaw	583	703	2	0.583	0.358	0.703	0.055
Skimmia laureola (DC.) Zucc.	383	383	1	0.383	0.225	0.383	0.009
Swertia chirayita Roxb. Ex Flem	216	244	2	0.216	0.175	0.244	0.007
Taxus baccata L.	699	991	3	0.699	0.449	0.991	0.138
Thymus linearis Benth.	566	834	2	0.566	0.349	0.834	0.006
Utrica dioica L.	1000	1766	4	1	0.633	1.766	0.471
Zanthoxylum armatum DC.	796	796	1	0.796	0.431	0.796	0.042

FC = frequency of citation, UR = number of use reports in different ailment categories, NU = Number of uses, RFC = relative frequency of citation, RI = relative importance, CI = cultural importance, CV = cultural value

1.527 and 1.488, respectively. These species are used in the daily lives of the local community, for example, Kandali is cooked in the form of vegetable as it provides warmth to the body specially during cold season, Faran is used as a condiment in the daily cooking of pulses and Burans flowers are used to make squash and juice keeping the body cool and energized during the summer heat. *Asparagus racemosus* L. (Satavari), *Rheum emodi* (D. Don) (Dolu) and *Swertia chirayita* Roxb. ex Flem (Chiryata) are amongst the least culturally important species with a CI index of 0.204, 0.235 and 0.244 respectively, and were amongst the least cited medicinal plants as well. Similarly, the RI and CV indices also placed *Rhododendron arboretum* Smith (Burans) in the top position, because of the multiplicity in the plant use, having the highest NU of 5. It was also cited by all the respondents during the survey (FC = 1000). The least important species is *Asparagus racemosus* L. (Satavari) and it was cited by only 204 respondents, out of which 57% were old, 36% adult and 7% young. The species which were cited by all the respondents (FC = 1000), still differ in their cultural value and importance based on the multiplicity of use. For example, *Cannabis sativa* L. (Bhaang) has NU of 3 and *Chenopodium album* (Bathuwa) has NU of 1 (both have FC of 1000), have CV of 0.262 and 0.067 respectively across the community.

The result of Fic (Table 5) shows that the genetic and ophthalmic category had the greatest agreement with a Fic value of 1.00, the reason being that a single species was used to treat the associated health problem. For example, for genetic ailment there was only one species *Taxus baccata* L. (Thuner) that was used and similarly for ophthalmic related issues, just *Berberis aristate* DC. (Kingora) was used. The other categories had nearly the same Fic of 0.09. Gastro-intestinal and dermatological problems were being treated with the highest number of species (21 species each), followed by the category of general health (17 species) and skeleton and muscle (16 species). Based on FL%, the most preferred plant species for the medical treatment in the different ailment categories were, for skeleton and muscle related issues *Cedrus deodara* Loud. (Deodar), for gastro-intestinal problems *Chenopodium album* (Batuwa), *Mentha longifolia* (L.) Hudson (Pudina) and *Rubus ellipticus* Smith (Hinsalu), for general health care *Morchella esculenta* L. Peres (Guchhi), for antidote *Aconitum balfourii* (Bruhl) Muk. (Meetha), for dermatological conditions *Pinus roxburghii* Sarg. (Chir), for respiratory issues *Allium stracheyi* Baker (Faran), for circulatory issues *Cinnamomum tamala Nees* (Dalchini), for hepatic concerns *Picrorhiza kurrooa* Royle ex Benth (Kutki), for nervous system related problems *Centella asiatica* (Brahmi), for dental concerns *Zanthoxylum armatum* DC. (Timru), for gynecological needs *Grewia oppositifolia* Drummond ex Burret (Bhimal), for genetic issues *Taxus baccata* L. (Thuner), for hair concerns *Arnebia benthamii* (Balchari), for ophthalmic issues *Berberis aristate* DC. (Kingora) and for body heat problem *Rhododendron arboretum* Smith (Burans).

The weakening of traditional ethnobotanical knowledge was alarming in the study area. The KRI value was highest for the young generation (0.04), implying that they have the least knowledge about the uses of medicinal plants. The KRI value was recorded low for both adult (0.005) and old (0.004) generation group which means that they had a vast knowledge of the traditional medicinal practices. Out of the total 1000 respondents, 37 (6 adult males, 13 old males and 18 old females) of them were able to report all the 55 medicinal plants in the study area. Youngsters and students who were interviewed, knew the plant species but they possessed least knowledge about its medicinal use. It was obvious that due to education and exposure, they preferred the modern medicine over the old traditional practices.

Despite the development of modern healthcare services, rural communities, particularly in remote mountain regions of Indian Himalayan Region, still use a large number of medicinal plants for the treatment of various ailments (Malik *et al.,* 2015). The results revealed that, plant-based

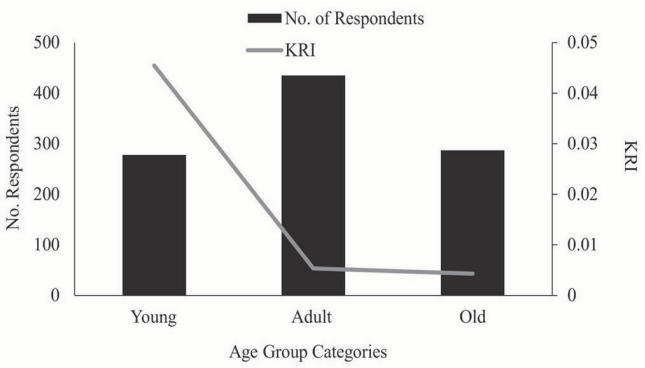

Figure 4: Knowledge richness index of respondents

Table 5: Evaluation of Informant consensus (Fic) and fidelity level (FL%)

Health Ailment Category	Informant Consensus Factor (Fic)	Name of the species used	Species Fidelity Value (FL%)
Skeleton and Muscle	0.997	*Aesulus indica* Colebr.	19.70
		Allium stracheyi Baker	49.20
		Artemisia maritima	12.30
		Asparagus racemosus L.	20.40
		Cannabis sativa L.	35.90
		Cedrus deodara Loud.	64.30
		Datura stramonium	42.50
		Geranium wallichianum D. Don ex Sweet	10.10
		Nardostachys grandiflora DC.	39.00
		Origanum vulgare L.	23.80
		Pinus wallichiana Jacks.	53.70
		Prinsepia utilis Royle	20.20
		Rhododendron arboretum Smith	16.60
		Skimmia laureola (DC.) Zucc.	28.20
		Taxus baccata L.	16.50
		Utrica dioica L.	16.60
Gastro-intestinal	0.998	*Aconitum heterophyllum* Wall. Ex Royle	30.40
		Artemisia maritima	22.40
		Artemisia nilagirica (Clarke) Pamp.	24.60
		Berberis aristate DC.	22.60
		Cannabis sativa L.	31.60
		Carum carvi	61.10
		Chenopodium album	100
		Cynodon dactylon L.	28.60
		Dactylorrhiza hatagirea (D. Don) Soo	15.30
		Diplazium esculentum Sw.	62.60
		Hippophae salicifolia	36.50
		Hypericum elodeoides Choisy	33.20
		Juglans regia L.	33.90
		Mentha longifolia (L.) Hudson	100
		Paeonia emodi Wall ex Royle	7.20
		Perilla frutescens (L.) Britton	8.40
		Picrorhiza kurrooa Royle ex Benth	22.50
		Pleurospermum angelicoides	31.20
		Rubus ellipticus Smith	100
		Thymus linearis Benth.	45.50
		Utrica dioica L.	41.40
General	0.996	*Aconitum heterophyllum* Wall. Ex Royle	33.70
		Aesulus indica Colebr.	21.50
		Allium stracheyi Baker	56.80

Table 5 contd...

Health Ailment Category	Informant Consensus Factor (Fic)	Name of the species used	Species Fidelity Value (FL%)
		Angelica glauca Edgew.	39.80
		Berberis aristate DC.	29.20
		Betula utilis D. Don	47.30
		Cinnamomum tamala Nees	67.40
		Dactylorrhiza hatagirea (D. Don) Soo	21.70
		Diplazium esculentum Sw.	47.50
		Geranium wallichianum D. Don ex Sweet	14.50
		Hippophae salicifolia	29.00
		Morchella esculenta L. Peres	78.90
		Origanum vulgare L.	21.30
		Perilla frutescens (L.) Britton	9.20
		Picrorhiza kurrooa Royle ex Benth	21.80
		Pleurospermum angelicoides	30.00
		Swertia chirayita Roxb. Ex Flem	14.70
Antidote	0.998	*Aconitum balfourii* (Bruhl) Muk.	35.60
		Rumex hastatus (D. Don)	32.20
Dermatological	0.998	*Angelica glauca* Edgew.	34.20
		Artemisia nilagirica (Clarke) Pamp.	19.30
		Betula utilis D. Don	50.50
		Cannabis sativa L.	63.40
		Cedrus deodara Loud.	54.20
		Dactylorrhiza hatagirea (D. Don) Soo	16.50
		Datura stramonium	46.30
		Dioscorea deltoidea	66.40
		Lyonia ovalifolia (Wall.) Drud.	34.40
		Paeonia emodi Wall ex Royle	7.50
		Pinus roxburghii Sarg.	78.20
		Podophyllum hexandrum Royle	41.10
		Prinsepia utilis Royle	21.60
		Rheum emodi (D. Don)	23.50
		Rhododendron arboretum Smith	25.70
		Rumex hastatus (D. Don)	62.30
		Saussurea costus (Falc) Lipsch.	20.00
		Saussurea obvallata	62.70
		Skimmia anquetilia Taylore & Airy Shaw	42.10
		Skimmia laureola (DC.) Zucc.	38.30
		Utrica dioica L.	52.00
Respiratory	0.996	*Allium stracheyi* Baker	42.80
		Artemisia nilagirica (Clarke) Pamp.	19.40
		Origanum vulgare L.	17.00
		Paeonia emodi Wall ex Royle	8.80

able 5 contd...

Health Ailment Category	Informant Consensus Factor (Fic)	Name of the species used	Species Fidelity Value (FL%)
Circulatory	0.997	*Cinnamomum tamala* Nees	45.20
		Nardostachys grandiflora DC.	26.60
		Rhododendron arboretum Smith	23.90
		Swertia chirayita Roxb. Ex Flem	9.70
Hepatic	0.997	*Betula utilis* D. Don	32.70
		Diplazium esculentum Sw.	22.80
		Nardostachys grandiflora DC.	23.30
		Picrorhiza kurrooa Royle ex Benth	39.40
		Rhododendron arboretum Smith	22.90
		Saussurea costus (Falc) Lipsch.	25.50
Nervous	0.998	*Betula utilis* D. Don	8.40
		Centella asiatica	62.00
Dental	0.998	*Angelica glauca* Edgew.	34.80
		Reinwardita indica Dumortier	26.30
		Saussurea costus (Falc) Lipsch.	27.30
		Thymus linearis Benth.	37.90
		Zanthoxylum armatum DC.	79.60
Gynecological	0.998	*Grewia oppositifolia* Drummond ex Burret	94.80
		Juglans regia L.	46.80
		Paeonia emodi Wall ex Royle	12.60
		Perilla frutescens (L.) Britton	26.20
		Utrica dioica L.	66.60
Genetic	1.00	*Taxus baccata*L.	51.60
Hair	0.999	*Arnebia benthamii*	96.00
		Dactylorrhiza hatagirea (D. Don) Soo	28.00
Ophthalmic	1.00	*Berberis aristate* DC.	23.30
Body Heat	0.998	*Galium aparine* L.	42.20
		Rhododendron arboretum Smith	63.60
		Rumex hastatus (D. Don)	48.10
		Taxus baccata L.	31.00

traditional knowledge system formed the primary basis of healthcare in the study area. The geographic isolation of communities in the Tons Valley of Govind Wildlife Sanctuary and National Park, has strengthened the traditional knowledge base of medicinal plants. Local people show preferences for the use of traditional herbal remedies due to their belief in the effectiveness of folklore herbal remedies (Malik *et al.,* 2015). In this study, local people residing in the remote and inaccessible high-altitude areas Dhatmeer and Osla largely depended upon the traditional remedies for general health issues, like, cough, cold and fever.

The reason being lack of alternative options, inaccessibility to a medical facility and inconvenience of transport. Another reason was the proximity of the village settlements to the sub-alpine and alpine meadows (bugyals) which are the reservoirs of medicinal plants. In the study area, these 'bugyals' are frequently being visited by the

Table 6: General information about the selected villages

Name of the Village	Availability of motorable road	Walking Distance to reach the village (approx.)	Distance from the market (approx.)	Availability of chemist shop in the market	Primary Health Centre/ Government Hospital (approx. distance)	Ease in availability of transport
Gainchwan Gaon	Yes	0	5-6 km	Yes	17-18 km	Yes
Deora	Yes	0	8-9 km	Yes	20-21km	Yes
Dhatmeer	No	6-7 km	6-7 km	No	43-44 km	No
Osla	No	17 km	17 km	No	54-55 km	No

pastoralists for livestock grazing and by tourists for trekking and camping. Even for the villages located on a roadhead or near a market (Gainchwan Gaon and Deora), the community gave preference to traditional medicine. Even though there was a primary health centre at the village Gainchwan Gaon, there was no availability of doctor or basic medical facility. Amidst, the lack of proper medical guidance, the local community was skeptical to trust the nearby chemist shops and thus continued with their traditional remedies. In case, of medical emergencies, many people have suffered due to their physical isolation and lack of tele-connectivity in the area. It was also evident, that since the inhabitants of remote villages appreciated the use of medicinal plants, they were apparently much more aware and alert to conserve these species by sustainably utilizing them in their daily lives. The knowledge of least cited medicinal plants remained confined with the old people, who knew the time of collection, plant parts to be used and method of medicinal preparation. Accumulation of traditional knowledge with the older generation is also a matter of concern, as the losing interests of younger generation had hindered the transfer of this knowledge. Since, the local people showed high agreement on the usage of different medicinal plants (as the informant's consensus factor was high), indicating that the knowledge system is still strong.

Uttarakhand's diverse geo-climatic conditions and rich availability of wild medicinal and aromatic plants highlights the great potential for the cultivation of the same. It can play an important role in the conservation of biodiversity as well as livelihood enhancement of the mountain people. In the study area, few of the households in the village Dhatmeer and Osla have initiated nurseries of medicinal plants. As the villagers lack scientific and technical know-how of cultivation practices involved in medicinal plants, they are still skeptical towards its successful establishment as a source of income generation. The current management practices in Uttarakhand are disorganized, as there is limited data available on the quantity and quality of medicinal and aromatic plants being supplied for trading from the region. For sustainable commercialization, it is important to map the potential cultivation areas and communities, providing local people with quality planting material, demonstration and training. Further, it requires the development of proper marketing channel, so as to synchronize the efforts of local people with the demand-supply of medicinal plants at the national level.

CONCLUSION

This study provides broad information about the traditional knowledge and practices of medicinal plants in the remote villages of Himalayas. It conceptualizes the local peoples' notions of development, for further exploring the relationship between traditional practices and sustainable use of natural resources. It clearly sheds light on the relation between medicinal plant use with the age of people, availability of medical facility and distance of households from the forest area. It provides a baseline data which can be further explored through a more scientific study of traditional medicinal formulations, which may lead to development of safe and affordable herbal medicines. This will not only make our healthcare system less dependent on the chemical drugs, but will also give an opportunity to the rural poor for growth and development. It is important to understand the regional conditions of the local mountain community, so as to assist the concerned authorities in developing policies and initiatives that could incorporate elements of traditional knowledge for income generation. With the rise in issues, like, illegal harvesting, smuggling,

climate change, bio-piracy and declining interest of younger generation, it becomes urgent to document the traditional knowledge and conserve the biodiversity. There is a need for regular reforms in traditional institutions, governance system, policies and rules, so as to link knowledge with action in order to sustainably benefit the local community in their own niche.

REFERENCES

Alencar NL, Junior WSF and Albuquerque UP (2014). Medicinal plant knowledge richness and sharing in north-eastern Brazil. *Econ. Bot.*, 68: 371–382.

Araujo TAS, Almeida ALS, Melo JG, Medeiros MFT and Ramos MA (2012). A new technique for testing distribution of knowledge and to estimate sampling sufficiency in ethnobiology studies. *J. Ethnobiol. Ethnomed.*, 8(1): 11.

Arnold JEM and Perez MR (2001). Can non-timber forest products match tropical forest conservation and development objectives. *Ecol. Econ.*, 39: 437–447.

Awoyemi OK, Ewa EE, Abdulkarim IA and Aduloju AR (2012). Ethnobotanical assessment of herbal plants in south-western Nigeria. *Acad. Res. Int.*, 2: 50–57.

Cameron MM (2008). Modern desires, knowledge control, and physician resistance: Regulating ayurvedic medicine in Nepal. *Asian Med.*, 4: 86–112.

Cunningham AB (1988). An investigation of the herbal medicine trade in Natal/Kwazulu. Investigational report number 29. Institute of Natural Resources, University of Natal, Pietermaritzburg, South Africa.

Friedman J, Yaniv Z, Dafni A and Palewitch D (1986). A preliminary classification of the healing potential of medicinal plants, based on a rational analysis of an ethnopharmacological field survey among bedouins in the Negev desert, Israel. *J. Ethnopharmacol.*, 16: 275–287.

Heinrich M, Ankli A, Frei B, Weimann C and Sticher (1998). Medicinal plants in Mexico: Healers' consensus and cultural importance. *Soc. Sci. Med.,* 47: 1863–1875.

Kala CP (2015). Medicinal and aromatic plants of Tons watershed in Uttarakhand Himalayas. *Appl. Ecol. Environ. Sci.*, Vol. 3, 1: 16-21.

Kumar M, Rawat S, Nagar B, Kumar A, Pala AN, Bhat JA, Bussmann WR, Cabral-Pinto M and Kunwar R (2021). Implementation of the use of ethnomedicinal plants for curing diseases in the Indian Himalayas and its role in sustainability of livelihoods and socioeconomic development. *Int. J. Env. Res. Pub. He.*, 18: 1509.

Kumar R and Singhal VK (2019). Traditional knowledge and conservation status of some selected medicinal herbs from Uttarkashi district in Uttarakhand, western Himalayas. *Taiwania*, 64(1): 52-64.

Magni G (2016). Indigenous knowledge and implications for the sustainable development agenda. Background paper prepared for the 2016 GEM Report – Education for people and planet: Creating sustainable futures for all, UNESCO.

Malik ZA, Bhat JA, Ballabha R, Bussmann RW and Bhatt AB (2015). Ethnomedicinal plants traditionally used in health care practices by inhabitants of western Himalaya. *J. Ethnopharmacol.*, 172: 133–144.

Manikandan R and Srivastava SK (2015). Diversity, medicinal and threatened plants in Govind pashu vihar wildlife sanctuary, western Himalayas. *Indian For.*, 141(9): 966-973.

Negi VS, Maikhuri RK, Phondani PC and Rawat LS (2010). An inventory of indigenous knowledge and cultivation practices of medicinal plants in Govind pashu vihar wildlife sanctuary, central Himalaya, India. *Int. J. Biodivers. Sci. Ecosys. Serv. Manag.*, 6(3-4): 96-105.

Negi VS, Maikhuri RK and Rawat LS (2011). Non-timber forest products (NTFPs): A viable option for biodiversity conservation and livelihood enhancement in central Himalaya. *Biodivers. Conserv.*, 20: 545–559.

Pardo-de-Santayana M (2003). Las plantasen la culturatradicional de la Antigua Merindad de Campoo. Ph.D. dissertation, Departamento de Biología, Facultad de Ciencias, *Universidad Autónoma de Madrid*, Spain.

Reyes-García V, Huanca T, Vadez V, Leonard W and Wilkie D (2006). Cultural, practical, and economic value of wild plants: A quantitative study in the Bolivian Amazon. *Econ. Bot.*, 60(1): 62–74.

Singh JS (2002). The biodiversity crisis: A multifaceted review. *Curr. Sci.*, 82: 638–647.

Tardío J and Pardo-de Santayana M (2008). Cultural importance indices: A comparative analysis based on the useful wild plants of Southern Cantabria (Northern Spain). *Econ. Bot.*, 62(1): 24–39.

UN (2012). United Nations system task team on the Post 2015 UN Development Agenda - Realizing the future we want for all. Report to the Secretary-General, New York.

Uniyal SK, Singh KN, Jamwal P and Lal B (2006). Traditional use of medicinal plants among the tribal communities of Chhota Bhangal, western Himalaya. *J. Ethnobiol. Ethnomed.*, 2: 1–14.