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# Environmental effects in the changing mountain farming system – A case study from Uttarakhand

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## Abstract

A variety of ecosystem services are impacted by the transitory shift that the mountain agricultural system is going through from traditional crop farming to a cash crop economy. The goal of the study was to comprehend how different farming methods and decision-making processes contribute to balancing the positive and negative aspects of an agroecosystem in mountainous regions. The study elaborates on the various farm types' capacity to support sustainable agroecosystems by exploring a non-monetary assessment based on biophysical indicators and farmers' perspective. Via a bottom-up methodology, an indicator-based framework was used, and primary field data collection and household surveys in two types of village settlements—connected and isolated—were used to estimate the numerical values of the selected indicators. The study's policy recommendation is that comprehensive quantitative data on agricultural landscape planning and governance would be useful in shedding light on the ways in which farming practices and agricultural policies can affect the socioeconomic and environmental consequences of agricultural policy, thereby promoting the development of sustainable livelihoods.

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A variety of ecosystem services are impacted by the transitory shift that the mountain agricultural system is going through from traditional crop farming to a cash crop economy. The goal of the study was to comprehend how different farming methods and decision-making processes contribute to balancing the positive and negative aspects of an agroecosystem in mountainous regions. The study elaborates on the various farm types' capacity to support sustainable agroecosystems by exploring a non-monetary assessment based on biophysical indicators and farmers' perspective. Via a bottom-up methodology, an indicator-based framework was used, and primary field data collection and household surveys in two types of village settlements—connected and isolated—were used to estimate the numerical values of the selected indicators. The study's policy recommendation is that comprehensive quantitative data on agricultural landscape planning and governance would be useful in shedding light on the ways in which farming practices and agricultural policies can affect the socioeconomic and environmental consequences of agricultural policy, thereby promoting the development of sustainable livelihoods.

Keywords – mountain farming, assessment, livelihood, sustainability

# 1. Introduction

Agroecosystems are managed ecosystems [1], which provide humans with food, forage, bioenergy, and are essential to human well-being. They are highly subjected to anthropogenic system inputs [2] and can affect multiple other ecosystem services [3], leading to positive and negative impacts [4] on the environment. Focusing on land use systems, we can observe that farming practices have evolved over time in response to particular historical, socio-economic, and climatic circumstances. As a result, they have shaped and altered the natural and cultural landscapes, especially in high mountain regions. It appears that several distinct traditional land use and management methods reflect this reality.

Today, climate change, biodiversity loss, and pollution threaten the well-being of about 40 per cent of the global population [5]. There are grounds for grave concern regarding the environmental problems brought on by social and economic activity. Among these social and economic activities, agriculture is one of the main factors driving global environmental change [6]. Thus, while agriculture has shaped the environment, the environment also has a significant impact on the particular types of agricultural production. The equilibrium of the mountain ecosystems is thus greatly impacted, and these ecosystems are under jeopardy from various human-imposed stressors.

Seen in terms of migration, land abandonment, ghost villages, etc., significant shifts in the land use and agricultural structure may be seen in extensive portions of the Himalayan Mountain regions. Mountain farming systems are transforming [7] with influence from constantly evolving global discourses on poverty reduction, natural resources management, biodiversity conservation, climate change, green revolution, sustainable intensification, globalization, and trade liberalization; along with a wide range of thematic disciplines concerning forest, soil, water, biodiversity, economics, and politics—all directing their functional pathway [8]. Having said that, the contemporary conversation about sustainable mountain development has increased global awareness of mountain-related issues.

The geology, climate, and soil characteristics of the mountainous terrain have long presented unique challenges for mountain agriculture, which has always had to adapt to survive. Mountain farmers frequently reside in remote lands in outlying areas and endure incredibly difficult working circumstances. Particularly when it comes to mountain farming, agriculture now serves two purposes: it provides food and income for the local people and also helps to preserve the environment. To meet the increasing food demand, farmers have improved productivity through agricultural intensification and scale management [9]. However, this has led to detrimental environmental impacts that will threaten the food security in the long run, such as greenhouse gas emissions, soil degradation, water pollution, and biodiversity loss [10]. Therefore, alleviating the conflict between agricultural production and environmental protection has become the main concern of sustainable agricultural development [11]. The challenge for environmental management is that for many poor people the desire to satisfy basic social needs often over-rides the basic environmental considerations.

The potential of landscapes to offer multiple benefits by agroecosystem to society beyond commodity production has received increasing attention in research and policy [12]. The sustainability context for agricultural systems picked up momentum as discourses on conservation, ecosystem services, food security, nutrient security, resilience, and climate adaptation pitched up in the global agenda [13]. The current scenario stresses the need to quantify the positive and negative externalities in order to assess the impacts of agricultural practices on the environment, and help shift the focus of agricultural policies towards the supply of agroecosystem goods and services. The key aspect of the study in assessing the environmental externalities is to understand the relationship between ecosystem and farming systems adopted by the farmers. The aim of the study is to elucidate the biophysical as well as social valuation of the environmental externalities associated with a mountain agroecosystem in the Indian Himalayan Region. The study explores a non-monetary assessment based on biophysical indicators and farmers' perception, to elaborate on the different farm types capacity to foster sustainable agroecosystem. Two research questions on anticipated changes in the environmental and socioeconomic conditions are addressed in this study: (i) What are the possible long-term effects of mountain agriculture on the environment? (ii) What is the impact on mountain farmers' perceptions of sustainable agricultural practices?

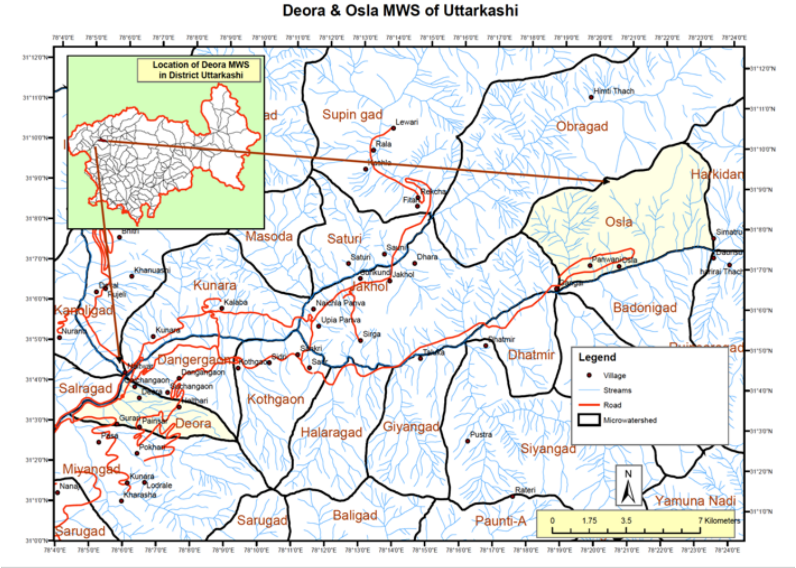
## 2. Materials and Methods

### 2.1. Study Area

The study was conducted in the villages around Govind Wildlife Sanctuary and National Park of Uttarakhand. Geo-morphically, the protected area falls exclusively within the Lesser and Great Himalayas with a varying altitude of 1300m to 6323m. The terrain is highly rugged and mountainous, widely intersected by rivers Rupin, Supin and Tons. The region has a fairly dense human population, with 42 villages inside and 15 villages outside the protected area. The agroecosystem in the area are complex, as it is composed of crop husbandry, livestock rearing and forests, forming a interlinked production system. A change from traditional subsistence agriculture to cash-crop based farming has been noticed in the area.

### 2.2. Sampling Technique

The research was carried out in the mountain agroecosystem, where contrasting farming systems were assessed to explore the environmental externalities. In order 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 environmental impact in the study area, along with farmer's perception of their dependency on the environment and natural resources for sustainable livelihood development. Two main approaches were adopted; (i) social valuation, representing the extent to which the smallholder farmers value the associated agroecosystem, and (ii) biophysical quantification of ecological indicators. Participatory rural appraisal tools like key informant interview (KII), focus group discussions (FGD) and household survey (HHS) methods were used to identify the perceptions and preferences of local farmers.



*Map.1.* Map of Study Area

Four villages were selected through stratified random sampling, namely, Gainchwan Gaon, Deora, Dhatmeer and Osla, based on their road connectivity. Thus, two kinds of village settlements were formed, viz. connected villages (Gainchwan Gaon and Deora) and isolated villages (Dhatmeer and Osla).

*Table.1*. 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 |

## 2.3. Data Collection and Analysis

### 2.3.1. Social Valuation

Two sets of open-ended questions were used in an initial survey to gather information about the following aspects that affect sustainability: (i) Which factors benefit mountain farming systems? (ii) Which factors have negative impacts on mountain farming systems? Two groups of experts were consulted: (i) smallholder farmers in the area who possessed traditional knowledge and were regarded as community experts; and (ii) scholars, researchers, scientists, government officials, and other stakeholders in the relevant field who contributed expertise based on theme of the study. This exercise was important because the inputs to the impact factors are more thorough when the stakeholders are more diverse in terms of their theme knowledge (for discipline experts) and experiences with agricultural systems (for community experts).

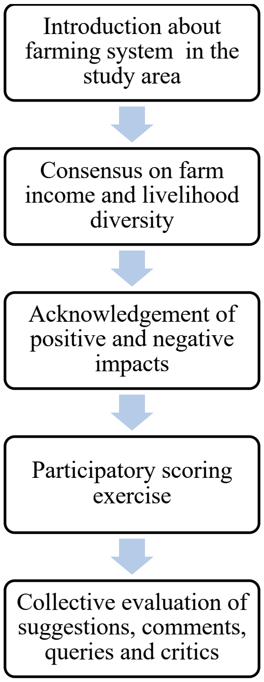


*Figure.1*. Steps involved in the participatory methodology

### 2.3.2. Biophysical Quantification

To quantify the different aspects of environmental externalities in an agroecosystem, a final set of ecological indicators were determined based on the discussion with experts and FGD with local farmers and stakeholders. The selection of the indicators was based on precision, time and resource feasibility. The numerical value of the chosen indicators were estimated via primary data collection in the field and HHS using semi-structured questionnaires.

List of ecological indicators selected for biophysical quantification is as follows:

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 [14]. 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 biophysical environment, soil testing and analysis was done. 180 soil samples (45 from each village) 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 of 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 [15].
    a) pH – determined in a soil-water suspension using digital pH meter
    b) Organic carbon (OC) – determined by Walkley and Black method [16]
    c) Total nitrogen (N) – estimated using micro Kjeldahl digestion and distillation method [17]
    d) Available phosphorus (P) – estimated using photoelectric colorimeter [18]
    e) Available potassium (K) – estimated using flame photometer [17]

*Table.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 |

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 [19], and one hour observations were 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.

## 3. Result and Discussion

### 3.1. Social Valuation

In order to conduct a social evaluation, 50 disciplinary experts and 50 community experts provided their views through KII, which were then categorised into 13 sets of positive and 15 sets of negative impacts related to the current trends of the mountain farming system in the study area (Table.3.).

*Table.3.* Impacts of Mountain Farming System on Society

| Pillar of Sustainability | Positive Impact on Society (PIS) | Negative Impact on Society (NIS) |
|---|---|---|
| **Economic** | Improvement in agribusiness and entrepreneurship development<br>Financial Stability<br>Market Infrastructure<br>Livelihood diversity<br>Management of local resources | Inadequate infrastructural support for agribusiness<br>Lacking logistics<br>Market price fluctuations<br>Post-harvest and transportation losses<br>Concentrated power dynamics |
| **Social** | Inclusive growth and rural development<br>Community interest in mountain farming<br>Engagement of traditional knowledge<br>Skill development and capacity building<br>Government support – agriculture extension services and R&D | Exploitation of low-income farmers<br>Migration<br>Off-farm livelihood opportunities<br>Lack of labour force<br>Conflicts related to outsider's investment and interference, forest and other land use facilities |
| **Environment** | Utilisation of uncultivated lands<br>Agrobiodiversity maintenance<br>Decrease in land abandonment | Loss of local cultivars and increased use of high yielding varieties and hybrids<br>Disbalance in soil and water management<br>Injudicious use of chemical fertilizer and pesticides – deterioration of soil and water quality<br>Impact on pollinators<br>Sudden losses – climate change, extreme weather events. |

The disciplinary experts and community experts were asked to rank the positive and negative effects of mountain farming on sustainable agroecosystems, on a scale of 0–2 (0 = no influence; 1 = weak influence; and 2 = strong influence). The Excel plotting of their opinion scores allowed us to ascertain the degree of activity for each impact element. Considering the cumulative scores of experts, it is quite evident that certain aspects of sustainability doesn't match the ground reality. Although mountain farming is oriented towards subsistence, it is a significant source of income for rural farming communities.

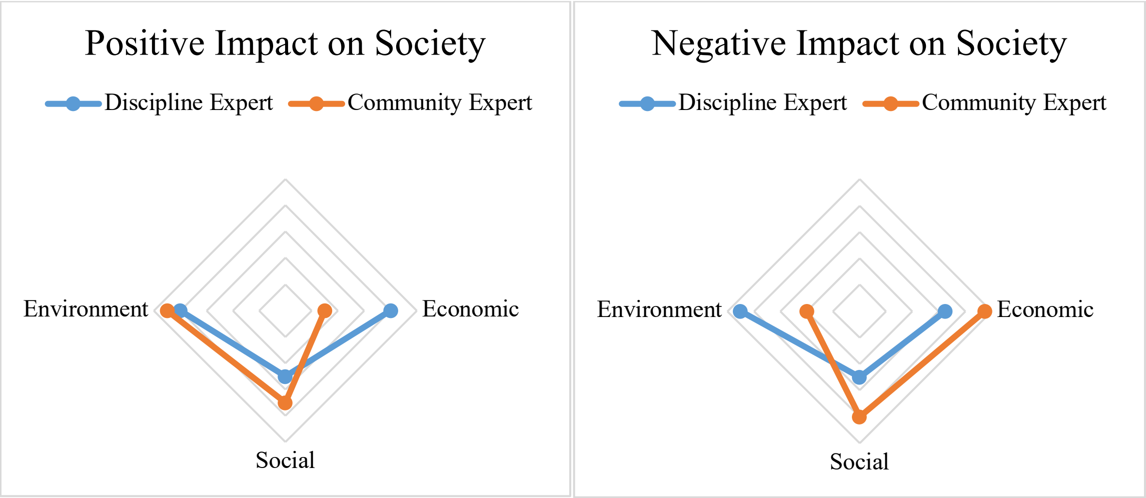


*Figure.2.* Graphical representation of positive and negative impacts of mountain farming system on the society

During the FGDs, two distinct farming systems were identified: subsistence farming and conventional farming. Originally, the villages in the study area used a barter system to exchange agricultural produce amongst the local community. Agriculture was only a means of subsistence, and there was no market selling system in place. Now in the mountains, cash crops have become the primary crop due to the commercialization of the agricultural industry. They utilise family labour to grow the traditional crops of the mountain ecosystem, thus maintaining the agrobiodiversity in the region. Subsistence farming relies on organic manure and biological control of pests and diseases; there is no documented use of external chemical inputs. Conventional farmers have effectively replaced traditional crop kinds with cash crops like kidney beans, potatoes, and horticultural crops like apple, pear, and walnut. Although they still cultivate staples for the household, such as rice, wheat, maize, ragi, and other pulses, the area under these crops has significantly shrunk in these homes. The local community favours cash crops over traditional crops due to the higher market demand and financial reward. Due to the extensive chemical inputs required, the introduction of apple growing in the Tons Valley has sparked questions about the agroecosystem's sustainability.

## 3.2. Biophysical Quantification

### i. Yield

The agricultural produce provides the domestic needs of the local people. The region's farming method creates a connection between the forest, crops, and livestock. Osla has the greatest per capita agricultural land availability (0.13%), followed by Gainchwan Gaon (0.11%), Dhatmeer (0.07%), and Deora (0.06%). Crops grown for human use are often farmed using traditional methods such as hand weeding, ploughing, and manuring, among others. The staples of the home are amaranth, finger millet, buck wheat, rice, wheat, foxtail millet, potatoes, and beans. With a heavy reliance on outside agricultural inputs, cash crops such as potatoes, apples, and kidney beans have taken over conventional farming. By including other species like pears, walnuts, kiwis, as well as aromatic and medicinal herbs, the farmers are voluntarily broadening the scope of their agricultural practices. A change in farming practices has resulted in less land being used for traditional crops and a significant rise in synthetic chemicals, which could eventually cause environmental deterioration.

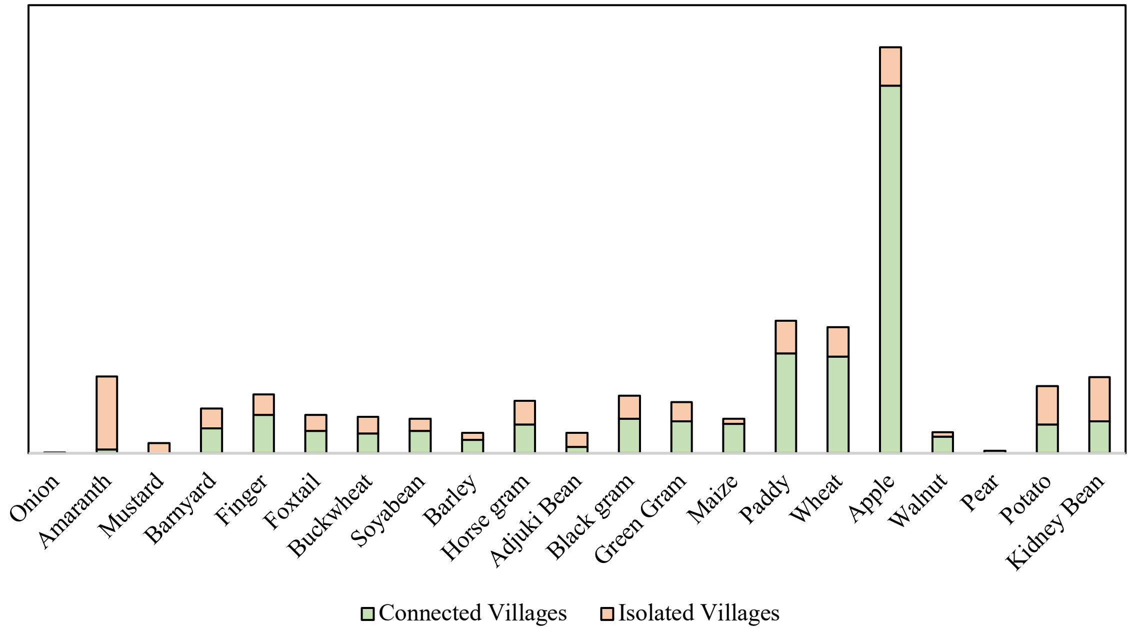


*Figure.3.* Comparison of crop productivity (kg/ha) in connected and isolated villages

While staple crops are common throughout the landscape, remote settlements rely heavily on amaranthus due to its high output (food and fodder), ease of adaptation, and low water need. In the connected villages (Gainchwan Gaon = 5674.95 kg/ha and Deora = 5811.97 kg/ha), the apple orchards are thriving because of the climate, easy access to inputs, connectivity, and market access. Due to the young age of the apple orchards in remote settlements, the yields in Dhatmeer and Osla are quite low, at 1175 kg/ha and 13.71 kg/ha, respectively. The sub-alpine climate and minimal usage of synthetic inputs contributed to the low productivity in the remote communities, despite the farmers using the same varieties. The remote settlements are currently making money from producing kidney beans and potatoes of the finest quality. Due to the high demand and value of walnuts for medicinal purposes, walnut production (Dhatmeer = 100.05 kg/ha and Osla = 33.23 kg/ha) has recently taken centre stage in the isolated villages.

### ii. Raw Material

There aren't many naturally occurring seasonal condiments and vegetables that can be obtained from farm fields for domestic use. The locals utilised them in accordance with the quantity produced, which varied based on the climate. Therefore, it was not possible to quantify such a small amount. Based on the availability during home surveys, an average consumption level of 1-2 kg/family was documented. These wild plants included Jakhiya, Bhangjeer (perilla), Bathuwa (wild spinach), Bhaang (hemp), Chaulai (amaranth), and Faran (chives). For fodder biomass, crop residue from amaranthus, millets, wheat, and rice is utilised. Due to the low fodder value of crops grown in high altitude locations, such as kidney beans and potatoes, connected villages consume more agricultural by-products (2184.19 ± 56.06 kg/household/year) than isolated villages (1154.68 ± 27.89 kg/household/year). There is a seasonal difference in the amount of fodder consumed as well; in the summer, grazing in alpine meadows and forests is preferred, as is gathering fodder made of tree leaves. On the other hand, because the area is blanketed in snow throughout the winter, livestock are typically given crop by-products through stall feeding. Livestock reliance on grazing and lopping has increased due to a lack of both quantity and quality fodder. Women who now have to walk far into forests to gather fodder are finding it particularly difficult. The mountain community's ongoing reliance on the forest ecosystem places an unprecedented strain on natural resources. This strain is further increased by the agricultural system's diversification from traditional crops to cash crops, the by-products of which do not have the desired value as fodder.

iii. Water Quantity

With the help of natural springs, tube wells, and an efficient pipeline and tap system, drinking water is readily available throughout the settlements. Since the study region lacked an irrigation system, the agricultural fields were left to rely on rainfall and little streams (known locally as *nala*) flowing along the slope, fed by natural springs (known locally as *shrodh*). In connected villages i.e. Gainchwan Gaon and Deora, there are about 40.80 ha and 12.76 ha of irrigated land, respectively

*Figure.4.* 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. It frequently turned into a source of contention because farmers must work together to share and divert water flow. Using the bucket method, the recorded water flow was 0.06 ± 0.04 litre/sec, insufficient to irrigate the whole agricultural terrain.

iv. Soil and Water Analysis

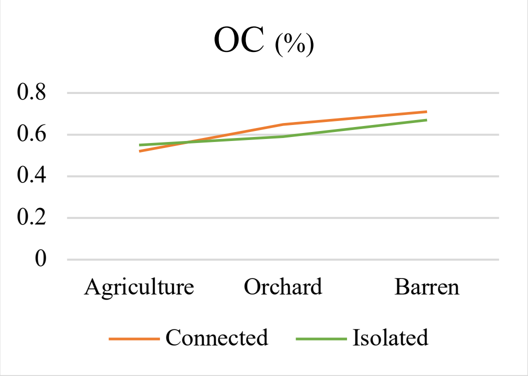
The intensive agricultural practices have contributed in the deterioration of soil health in various ways. A study in China reported severe soil acidification due to excessive and continued input of heavy synthetic nitrogen fertilizer and thereby suppressed crop production in a large area [20]. Agricultural 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 [21]. Edward in 1975 [22] 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 ecosystem services 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 [23]. It is a predictor of various chemical activities and thus useful in making management decisions.

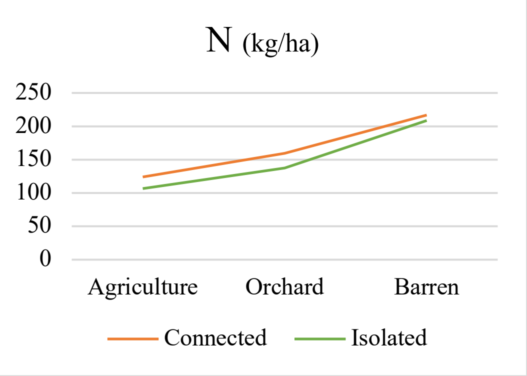
The study area's soil is neutral in nature, with a pH range of 6.4 to 6.6, according to sample analysis. It is regarded as a suitable range for producing apples and most other agricultural crops. Since EC monitors the amount of salts in the sample, including fertiliser salts, it is another crucial indicator of the health of the soil and water. By altering the soil-water balance, too much salt can impede the growth and development of plants. In both connected and isolated villages, the mean EC for both cultivated and uncultivated areas is almost the same. However, the EC level in the orchards of the connected villages is higher than that of the isolated villages (1.37 ± 0.04dS/m) at 2.63 ± 0.14dS/m. Even if the EC values of every soil sample fall into the low salinity class and are within the usual range of the soil (of < 4dS/m), the ongoing irresponsible use of synthetic fertilisers throughout the connected villages could eventually cause a decline in the health of the soil. Water samples had a mean pH of 6.5, with a mean EC value of 0.21dS/m for connected villages and 0.18dS/m for isolated villages. These waters have a negligible salinity effect when used because their TDS values are less than 450 mg/L and their EC values are less than 0.70dS/m [24].

*Table.4.* 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 |

Uncultivated fields have the greatest levels of organic carbon (OC), which is subsequently followed by orchards and crop fields. In addition to improving soil structure and moisture content, OC also raises the soil's nutritional status and regulates runoff and erosion. In the study area, the percentage of OC varied from 0.51% to 0.72%, suggesting less variation amongst various management strategies. The soil quality in each of the several fields may be rated as medium depending on the OC content. The most frequent element that restricts plant growth and development is nitrogen (N). A lack of it causes growth to be stunted and leaves and fruits to fall off, while an abundance of it can cause maturity to be delayed and increase the vulnerability of plants to insects and diseases. The amount of available nitrogen is greatest in uncultivated fields (216.84 ± 1.91 kg/ha) and lowest in agricultural fields of isolated villages (106.60 ± 3.43 kg/ha). The overall N fluctuated throughout the fields, ranging from 106.60 ± 3.43 kg/ha to 216.84 ± 1.91 kg/ha, suggesting that the soil is deficient in N and has a low rating. Low levels of nitrogen found in agriculture fields could be caused by crop removal, little precipitation, and minimal usage of synthetic fertilisers. The second most significant macronutrient is phosphorus (P), which varied from 129.84 ± 0.33 kg/ha to 158.52 ± 0.32 kg/ha throughout the study area, indicating high-quality soil. According to Shivanna and Nagendrappa (2014), the available P is dependent on pH and EC, with a neutral pH significantly increasing P availability. The available potassium (K) that was available to the farmer ranged from 158.52 ± 0.51 kg/ha to 631.08 ± 1.52 kg/ha. The orchard fields of the connected villages have a medium soil rating, while the other management systems have a high K soil rating.





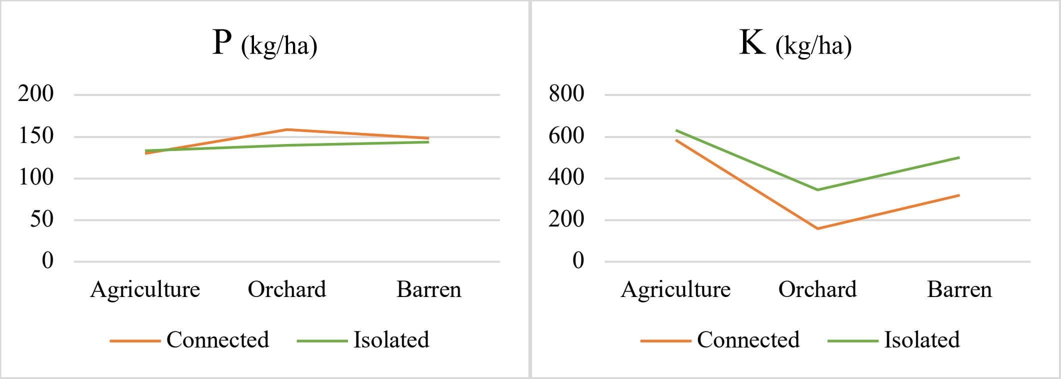


*Figure.5.* Graphical comparison of soil quality parameters in connected and isolated villages

v. Pollinator Diversity

In total, 11 insect pollinators from four orders and six families were found in the study area (Table.5.), with the orchards reporting the greatest number of these pollinators. Pollinators are thought to be under more threat than ever before, despite the benefits they bring. Concerns impacting pollinator populations include habitat fragmentation, pesticide usage, forest fires, overgrazing, climate change, and non-native species.

*Table.5.* List of insect pollinators 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 |

The ecological functions provide numerous kinds of goods and services necessary for human survival [25]. These goods and services are called ecosystem services, which are often defined as tangible or intangible benefits obtained from ecosystems by humans [26]. For agroecosystems, the ecological processes and functions are greatly influenced by human agricultural practices, thus influencing the supply of goods and services [27]. The components of agroecosystems play an important role in the maintenance of the productivity and stability of ecosystems [1]. The output of agricultural products results in the great loss of nutrients from agroecosystems, so external inputs are needed to maintain the nutrient balance of agroecosystems [28]. Therefore, farmers are the primary agents of agroecosystems as opposed to natural ecosystems.

In the study, the effects of mountain agriculture are quantified on the scale of individual fields, including an evaluation of the effects of different agricultural inputs. 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 ecosystem services [29]. One key assumption is that outputs from agroecosystem are not ‘pure’ ecosystem services per se. Instead, they are highly influenced by anthropogenic system inputs, and are bound to demands and preferences of markets and society [2]. Agricultural chemicals, such as fertilizers and pesticides have become a significant part of cash crop production in the hilly areas. Many natural ecosystem services 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 ecosystem services is to safeguard natural capital while maintaining sustainable flows of ecosystem services from nature to society [30]. 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 [31]. 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. 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.

## 4. Future of Mountain Farming

In order to understand mountain livelihood, an integrated and systematic approach to study the socio-economic conditions of local community is necessary. These very conditions create a useful distinction of mountain farming into subsistence and commercial economy. The interdependence between ecosystem services and agriculture are complex [32], where many ecosystem services provide direct production benefits to agriculture [3] and agriculture in return supplies a range of provisioning, supporting and regulating ecosystem services [33]. Thus, one can say agroecosystems are both providers and consumers of ecosystem services. The quantification and implementation of ecosystem goods and services have been among the biggest challenges of current science [34]. Paetzold *et. al.* [35] note that the status of an ecosystem services is influenced not only by its provision, but also by human needs and the desired level of provision for this service by society, which connects supply and demand of ecosystem services inseparably [36].

With further study on the relationship between ecosystem services and human well-being, the ecosystem service supply–demand relationship has attracted increasing attention in recent years [37]. The trade-offs and synergies between ecosystem services have been studied for a long time [38], especially for the trade-offs between provisioning services, regulating services, and cultural services. Research has shown that the increase of crop yield is usually at the expense of other ecosystem services [39]. Hence, further study on the trade-offs and disservices of the agroecosystem, which are dependent on the supply and demand for agricultural goods, should be prioritized for sustainable agricultural development.

Ecosystem disservices refer to the cognitive or actual negative impact on human well-being derived from ecosystem functions, processes, or attributes [40]. In some cases, the cost of ecosystem disservices exceeds the value of ecosystem services, especially for agroecosystems [41]. Most of these disservices are transformed into economic losses through quantification by economic methods such as the market value or non-market value method [42]. In recent years, a variety of alternative farming approaches to conventional intensification have been explored to optimize these trade-offs, among which organic farming, conservation agriculture, and agroforestry are the most common alternative approaches [43].

A study by Wood *et al.* [44] indicates that ecosystem services contribute to 12 SDGs and 41 sub-SDGs. Thus, we can say ecosystem services help achieve the Sustainable Development Goals (SDGs) and are a reflection of the advantages that humans receive from nature. Agroecosystems provide ecosystem services or disservices that are closely related to SDG1 (no poverty), SDG2 (zero hunger), SDG5 (gender equality), SDG6 (clean water and sanitation), SDG10 (reduced inequalities), SDG12 (responsible consumption and production), SDG13 (climate action), SDG14 (life below water), and SDG15 (life on land) [45]. Hence, agroecosystem management based on SDGs will promote the coordination between environment, society and economy in agroecosystems [46]. The synergy between ecosystem services and SDGs will be enhanced by land management options that take into account both ecology and society's feedback. Therefore, agricultural landscape design and governance will be a crucial strategy deserving of investigation in subsequent agroecosystem management in order to achieve the SDGs.

## 5. Conclusion

Agricultural research should give agroecosystem services greater attention and exploration. A planned, sustainable use of natural resources can be facilitated by knowledge of its trade-offs and synergies. The characteristics of agriculture are emphasized by the indicators chosen for the study, which also considered the opinions of community experts and discipline experts. Still, there were numerous difficulties with the study. For instance, there were no established assessment techniques and a lack of clarity regarding the meaning and implications of agroecosystem disservices. Despite the fact that the commercialization of the mountain farming system has greatly benefited farmers economically, it has also made them more susceptible to market risks, pest outbreaks, natural disasters, and changes in the climate. According to the study, commercial farming poses a risk to the local ecology because of the overuse of synthetic fertilizers and pesticides, and it may serve as an early warning system. It should be highlighted that the trade-offs between ecosystem services and agricultural landscape could worsen due to local farmers' lack of awareness. Every decision made by a farmer is influenced by a variety of factors, including social, economic, and regional constraints, which determine how farming methods will ultimately turn out. Thus, analyzing the connections between various farming techniques and ecosystem services might be helpful in developing sustainable livelihood systems.

The rich agrobiodiversity that exists in mountain agriculture has been essential in meeting the community's fundamental nutritional needs. The local community is spearheading the expansion of cash crops with the ultimate goal of generating revenue and ensuring food security for their home. While the study area was still in the early stages of transitioning from subsistence farming to a more exploitative type of commercial farming, the study was able to produce knowledge about the benefits and drawbacks of the local agroecosystem. Owing to limited resources, the study's focus was kept at the plot scale. To sustain food and livestock production, agriculture in mountain communities is intertwined with the ecosystems around it. This makes an in-depth study into the intricacy of the mountain ecology crucial, since it may help in formulating appropriate plans for rural development. Evaluating the current agricultural institutions and policies is vital in the pursuit of sustainable development, as they significantly shape rural livelihoods. Diversifying farming systems may lead to better living, but maintaining a steady supply of ecosystem goods and services requires balancing the environmental effects.

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