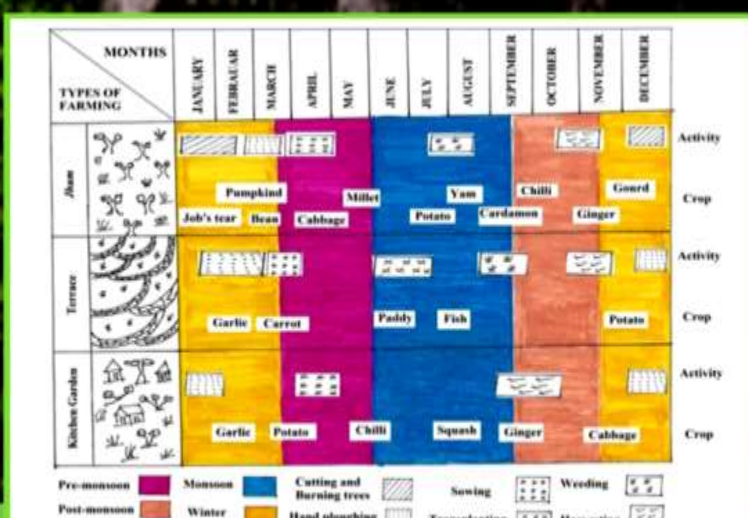
GRASSROOTS JOURNALS

Frequency : 2 times a year (half-yearly)
Language : English
DOI : 10.33002/aa
VOLUME : 03 (2023)
ISSUE : 02 (December 2023)

AGROBIODIVERSITY & AGROECOLOGY

www.grassrootsjournals.org/aa



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AGROBIODIVERSITY & AGROECOLOGY
ISSN 2564-4653 | 03(02) ● December 2023
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The Grassroots Institute
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Montreal, Quebec
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AGROBIODIVERSITY & AGROECOLOGY
ISSN 2564-4653 | 03(02) ● December 2023
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GRASSROOTS JOURNALS
ISSN 2564-4653 | 03(02) Dec 2023

AGROBIODIVERSITY & AGROECOLOGY | 03(02) DECEMBER 2023

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M – 00370 | Research Article

Changing Cropping Patterns in the Central Himalaya: Causes and Implications

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How to cite this paper: Sati, V.P. (2023). Changing Cropping Patterns in the Central Himalaya: Causes and Implications. *Agrobiodiversity & Agroecology*, 03(02): 1-18. Doi: https://doi.org/10.33002/aa030201

Received: 14 September 2023
Reviewed: 18 January 2024
Accepted: 21 January 2024
Published: 10 March 2024

Abstract
The Himalaya is experiencing significant changes in land use and cropping patterns. This paper examines the major causes and consequences of these changes in the Central Himalaya, focusing on two districts: Dehradun (Garhwal region) and Nainital (Kumaon region). Data on land use and cropping patterns for both districts were collected from the district statistical diaries and, subsequently, were analyzed. The analysis reveals that cropping patterns are undergoing substantial changes in both districts, although the change is not uniform across the regions. Various factors contribute to the shifting cropping patterns. In the recent past, there has been a notable increase in climate variability and change, with a persistent warming observed in the river valleys and mid-altitudes. Other significant factors influencing the changing cropping patterns include decline in the area and production of crops, alterations in food habits, population growth, and out-migration in the Central Himalaya.

Keywords
Cropping patterns; Land use; Climate change; Food habits; Central Himalaya

1. Introduction

The crop races/cultivars in the Himalayan region are cultivated based on agroecological conditions (Singh, 2019), and traditional agricultural practices are followed (Singh and Rana, 2019). These practices encompass subsistence cereal farming, fruit and vegetable cultivation, as well as livestock farming (Goswami, 2013; Negi *et al*., 2013; Sati, 2012). A distinctive crop rotation system known as the *Sar/Sari* system is employed, where agriculture is conducted in two *Sars* at different intervals (Kumari, Tewari and Singh, 2009). In the *Sar* system, one *Sar* is cultivated with a specific crop while, simultaneously, another *Sar* is used for growing a different crop. After six months, the roles are reversed, and one *Sar* is left fallow, with this cycle continuing (Pande *et al*., 2016; Ravera *et al*., 2019; Sati, 2005, 2009; Sen, 2015). These farming systems are tailored to the environmental conditions of the specific locality (Martin and Sauerborn, 2013; Thrall, Bever and Burdon, 2010). Over the past decades, there has been a noticeable decrease in the cultivated area (Joshi and Palni, 2005). Fallow land has increased, attributed to out-migration, and the number of people engaged in farming has decreased by 2.6% (Pathak, Pant and Maharjan, 2017).

The agriculture in the Central Himalaya has experienced significant changes in terms of cropping patterns, cultivation practices, crop production, and productivity. This region is characterized by rich agrobiodiversity, diverse bio-physical resources, and varying weathers, offering opportunities for cultivating a wide range of crops. In the past, cropping patterns were primarily determined by agronomic considerations and the consumption needs of farmers. However, recent trends suggest a shift towards more market-oriented practices. Additionally, changing cropping patterns may be influenced by shifts in food consumption habits. Despite agriculture being the main occupation and a major source of income in rural areas, its contribution to the State Domestic Product (SDP) is relatively low (approximately 6%).

The cropping pattern in the Central Himalaya underwent a significant transformation in the 1970s when a substantial amount of arable land was converted into fruit belts, primarily for the cultivation of temperate fruits. The state government took initiatives to establish several fruit belts along the temperate climatic zones. Initially, the output from fruit plants, especially apples, was considerable, and farmers were able to export apples to regional and national markets. However, in the 1980s, the fruit plants were affected by a flyspeck and Sooty Blotch disease, leading to a decline in production. Another challenge was the marketing of apples. Due to the perishable nature of apples and the absence of cold storage facilities in apple-growing areas, farmers did not reap the benefits of apple cultivation, even though the income generated was less than the cost incurred. Consequently, the cultivation of apples witnessed a substantial decline. The production of other fruits, such as citrus[1], also decreased; and in many areas, the cultivation of fruits has completely vanished.

Subsequently, the arable land in the Central Himalaya shifted towards cash crops, predominantly in the river valleys and middle altitudes. However, over time, the cultivation of cash crops also experienced a significant decline. Following this trend, there was an attempt to introduce medicinal plants, but this initiative did not prove successful. Eventually, farmers reverted to traditional agricultural practices, recognizing its importance in providing livelihoods for rural communities. At present, the primary agricultural activities in the region revolve around the cultivation of paddy and wheat, signifying a return to more conventional farming methods. This shift in focus back to traditional agriculture reflects the resilience and importance of practices that sustain the livelihoods of the rural poor in the Central Himalaya.

The Central Himalaya, primarily consisting of the state of Uttarakhand, became a separate state of the Republic of India in 2000. In the past, millets, pulses, and oilseeds served as the main crops and staple foods. However, the present scenario sees a shift towards wheat and paddy as staple foods. The region has experienced climate change marked by high variability in temperature and rainfall, leading to noticeable alterations in cropping patterns. Temperature trends are increasing, while rainfall is observed to decrease in highland areas. Changing food habits over time, coupled with the challenges of an increasing population and low production and productivity of millets, have further contributed to shifts in cropping patterns in the Central Himalaya. The hilly and

[1] Category of fruits, such as oranges and lemons

mostly infertile soil, prone to erosion from heavy monsoon rainfall due to the steep slopes and undulating terrain, adds to the agricultural challenges. Most crops are rainfed, except in plain areas and river valleys, resulting into nominal production and productivity levels.

This article investigates the changing cropping patterns in the Central Himalaya, focusing on two districts – Dehradun and Nainital, by analysing two years of data (2011-12 and 2021-22) encompassing the area, production, and productivity of crops. It aims to discern changes in these parameters over the specified period and elucidate the major causes and implications of altering cropping patterns. The central hypothesis posits that climate change and evolving food habits have played a significant role in driving the changes observed in cropping patterns in the Central Himalaya. To address these issues, the study considered two main research questions: firstly, what are the primary causes and consequences of the observed changes in cropping patterns? And, secondly, how can the production and productivity of crops be enhanced to ensure sustainable livelihoods in the region? Through a comprehensive analysis of the gathered data and exploration of these research questions, the study aims to contribute valuable insights into the dynamics of agricultural practices in the Central Himalaya.

2. Study Area

The Central Himalaya, an integral part of the larger Himalayan region, shares borders with Nepal to the east, Tibet (China) to the north, Himachal Pradesh to the west, and Uttar Pradesh to the south. Characterized by its mountainous terrain, the region exhibits varied altitudes ranging from 200 m to over 7,000 m (Figure 1). About 93% of the area is mountainous mainland, with approximately 16% covered by snow-capped peaks. The Central Himalaya features three-dimensional landscapes: the river valleys, the Middle Himalaya, and the High Himalaya. In this study, two districts of the Central Himalaya – Dehradun and Nainital - were selected. Both districts exhibit a mix of plain and mountainous terrain, with the Doon Valley, a part of the Dehradun district, being notably fertile. Historically, the Doon Valley was renowned for cultivating Basmati rice; however, contemporary trends show a transformation of agricultural fields into densely population settlements. The Tarai (wet) region in the Nainital district boasts extensive fertile tracts where paddy and wheat are cultivated. The river valleys are narrow, offering limited arable land, yet crops are irrigated in these areas. The Middle Himalaya boasts extensive arable land and a high population concentration, with cropland relying on rain-fed agriculture. The highlands comprise lower highlands, alpine pasturelands, and the perpetual snow-clad Himalaya. Human settlements practicing agriculture are limited to the lower highlands, where crops are grown only during the summer season. Alpine grasslands in the highlands also support the growth of medicinal plants during the summer. Overall, the arable land constitutes only 18%, while 64% of the region is covered by forests showcasing diverse ecosystems, from monsoon deciduous forests to pine forests, mixed oak forests, coniferous forests, and alpine meadows. The Ganga River, along with its numerous sub-tributaries, originates and flow through the Central Himalaya, providing abundant water resources. However, despite the ample water supply, irrigation facilities are insufficient. The agro-climatic conditions are favourable, contributing to rich crop diversity. Nevertheless, marginal farmers predominantly engage in subsistence agriculture with low output. In recent times, there has been a decrease in both the area and production of crops, accompanied by changes in land use patterns in the Central Himalaya.

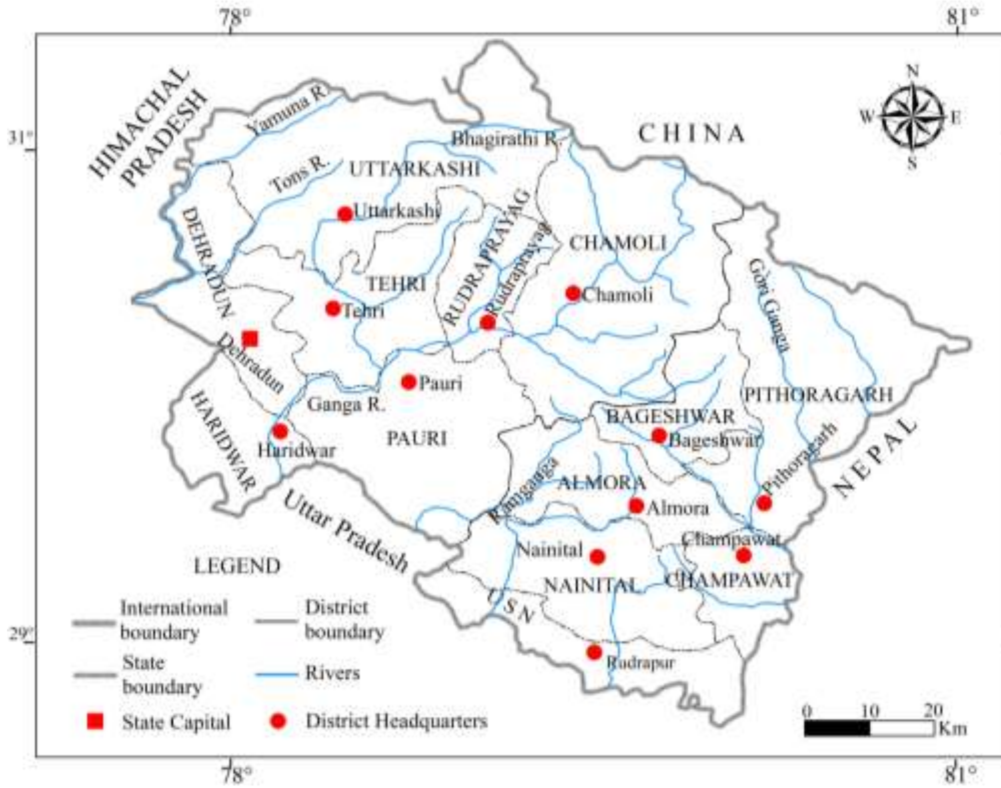

Figure 1: Location map of the Central Himalaya

3. Methodology

This study relies on data compiled from secondary sources, specifically the Statistical Diaries of Dehradun and Nainital districts. Initial data compilation involved obtaining land use data for the years 2011-12 and 2021-22 for both the districts. Subsequently, data on the area and production of key crops, including food grains, pulses, oilseeds, sugarcane, and potatoes were gathered for the same years. Additionally, information on the area and production of fruits and vegetables was gathered for the years 2011-12 and 2021-22. The compiled/acquired data underwent thorough analysis, revealing changes in land use and land cover between 2011-12 and 2021-22. The study also examined alterations in the area and production of various crops, calculating crop productivity. The findings were visually represented through bar graphs to illustrate changes in the area, production, and productivity over the specified time frame. This analytical approach aimed to provide a comprehensive understanding of the evolving agricultural landscape in the study area.

In this study, climate data were analyzed using information gathered from the Meteorological Department based in Dehradun for the two meteorological centres – Dehradun (600 m) and Mukteshwar (2,700 m). These two centres represent the plain regions and the highland areas of the Central Himalaya, respectively. Specifically, average annual temperature and rainfall data from 2012 to 2022 were examined. The analysis utilized linear regression models to illustrate the variability and changes in temperature and rainfall over the specified period. The findings of the climate data analysis contribute to understanding the evolving climate patterns in the region. Additionally, the study explores the impact of climate change on cropping patterns, shedding light on how shifts in temperature and rainfall may be influencing agricultural practices in the Central Himalaya.

4. Results

4.1 Land Use Patterns and Changes

In the Dehradun district, the forest covered 55.3% of the total area in 2021-22. The land use distribution included 14.9% for cultivable wasteland, 1.9% for current fallow, and 4% for other fallow land. The net area sown accounted for 9.4%, while the area sown more than once and the gross sown area were 4.8% and 14.2%, respectively. Regarding irrigated areas, the net irrigated area constituted 4.7%, and the gross irrigated area was 7.4%. Over the period from 2011-12 to 2021-22, significant changes were observed in land cover. There was a decrease of -0.24% in forest area, -19.3% in net area sown, -18.3% in gross area sown, and -16.5% in gross irrigated area. In contrast, there was an increase in cultivable wasteland by 17.41%, current fallow land by 106%, orchards, trees, and bushes by 13.4%, and net irrigated area by 22.3%. These changes indicate shifts in land use patterns and agricultural practices in the Dehradun district during the specified period.

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Over the decade from 2011-12 to 2021-22 in Nainital district, several changes in land cover were observed. Barren land decreased significantly by 53.4%, and a small portion of forest cover also diminished. Agricultural areas were affected, with a 10.5% reduction in net area sown and a 7.4% decrease in gross area sown. Irrigated land saw declines as well, with a decrease of 11.6% in net irrigated area and 10.1% in gross irrigated area. On the other hand, cultivable wasteland increased by 14.8%, and current fallow land experienced a substantial growth of 67.1%. Pasture land expanded by 102%, while land used for purposes other than agriculture decreased by 11.8%. These changes in land

[2] The land, which was arable but now abandoned and categorized as cultivable wasteland.

cover reflect shifts in land use patterns, likely influenced by various factors impacting the Nainital district's landscape.

4.2 Diversity in Major Crops

The Central Himalaya boasts a rich diversity of crops. Major crop varieties include food grains, pulses, oilseeds, fruits, vegetables, and spices, each comprising several crop races or cultivars as detailed in table 1. The distribution and types of these crops exhibit variations across different climate zones within the region. Altitude and climate influence significantly the area under cultivation and the production of these crops, contributing to the unique agricultural landscape of the Central Himalaya.

Table 1: Major crops and their diversity

Variables	*Major crops*
Food grains	Paddy, wheat, barley, maize, Manduwa (Ragi/finger millet)
Pulses	Urd (black gram), Masur (red lentil), Gram (chick pea), Peas, Tour (pigeon pea, Moth (mat bean)
Oilseeds	Mustard, Til (sesame seed), groundnut, sun flower, soybeans
Sugarcane	Single crop
Potato	Single crop
Fruits	Mango, guava, papaya, litchi (*Litchi chinensi*), lemon, blood orange (malta), orange, Galgal (Hill lemon), elephant citrus, apple, pear, peach, plum, apricot, walnut, almond
Wild fruits	Kafal (box berry), Kilmori (*Berberis asiatica*), Timli (*Roxburgh fig*), Amla (Indian gooseberry)
Vegetables	Capsicum, spinach, pumpkin, cucumber, brinjal, bottle guard, bitter guard, snake guard, beans, Arbi (taro root), potato, onion
Spices	Chili, turmeric, garlic, ginger

4.3 Cropping Patterns – Changing Arable Land

4.3.1 Dehradun District

The Dehradun district exhibits a rich agricultural diversity, as outlined in table 2. A variety of food grains, pulses, and oilseeds are cultivated across the entire district. In the 2021-22 period, the highest area was under food grain (40% of the total crop area), followed by fruits, vegetables, sugarcane, and pulses. Potato and spices had nominal area. In terms of changes in cropping patterns, a notable decrease was observed across all crops under food grains, with a significant overall decrease of 28.5%. Area under oilseeds has decreased by 45%, followed by pulses (42.8%), potato (24%), and sugarcane (16.3%). There was an increase in the area of spices, vegetables, and fruits. Overall, 15.6% decrease was noticed in area from 2011-12 to 2021-22.

4.3.2 Nainital District

Similar to the Dehradun district, in the Nainital district, the highest area is under food grains (55.5%), followed by fruits (15.3%). The area under other crop was less than 10% (Table 3). Sugarcane and potatoes are also grown in the Nainital district. Comparing changes in cropping patterns, like Dehradun, the Nainital district witnessed a decrease in the area under food grains (15%).

However, the area under pulses increased (22.8%). The area of potatoes has increased by 36.9%, while the area under oilseeds decreased (20.8%). The fruit area has decreased by 57.4%, vegetables by 32.2%, and sugarcane by 31%. Overall, the total crop area in Nainital has decreased by 13.3%. These changes underscore the dynamic nature of agricultural practices in the Nainital district.

Table 2: Cropping patterns, changing arable land 2011-12 to 2021-22 (ha) in Dehradun district

Variables	*2011-12*	*%*	*2021-2022*	*%*	*Change (%)*
Food grain (n=6)	42,362	47.6	30,304	40.4	-28.5
Pulses (n=6)	4,146	4.7	2,371	3.2	-42.8
Oilseeds (n=5)	1,537	1.7	842	1.1	-45.2
Sugarcane	4,624	5.2	3,868	5.2	-16.3
Potato	664	0.7	504	0.7	-24.1
Fruits	25,609	28.8	26,408	35.2	3.1
Vegetables	9,104	10.2	9,669	12.9	6.2
Spices	885	1	1,083	1.4	22.4
Total	8,8931	100	75,049	100	-15.6

Note: n=crop cultivars/races

Table 3: Cropping patterns, changing arable land 2011-12 to 2021-22 (ha) in Nainital district

Variables	*2011-12*	*%*	*2021-2022*	*%*	*Change (%)*
Food grain	46,310	48.5	39,343	55.5	-15
Pulses	2,106	2.2	2,586	3.6	22.8
Oilseeds	6,056	6.3	4,794	6.8	-20.8
Sugarcane	3,952	4.1	2,727	3.8	-31
Potatoes	2,398	2.5	3,282	4.6	36.9
Fruits	25,454	26.7	10,834	15.3	-57.4
Vegetables	8,683	9.1	5,876	8.3	-32.3
Spices	481	0.5	1,425	2	196
Total	95,440	100	70,867	100	-25.7

*Turmeric, potato, ginger, and garlic were reported in 2019-2020.
**Among pulses, black soybean (*Glycine max* (L.) Merrill), kidney bean (*Phaseolus vulgaris* L.) and horse gram (*Macrotyloma uniflorum*), were reported in 2019-2020

4.3.3 Comparison of Changing Cropping Patterns in Dehradun and Nainital Districts

In figure 2, the changes in the area under cultivation in the Dehradun and Nainital districts between 2011-12 and 2021-22 are depicted. Notably, there is a significant decrease in the area dedicated to crops such as food grains, oilseeds, and sugarcane. Potato cultivation witnessed a decline in Dehradun, while it increased in the Nainital district. Meanwhile, there was a substantial increase in the area under pulses in both districts. The trend is evident, highlighting a significant overall decrease in the area under cultivation for all principal crops in both Dehradun and Nainital districts.

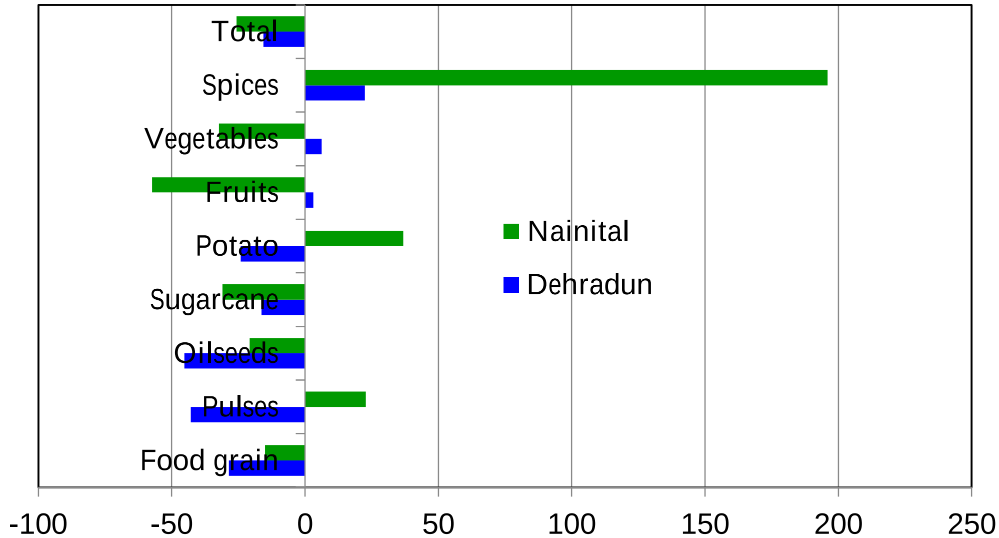

Figure 2: Change in the area (%) 2011-12 and 2021-22

4.4 Changing Production Patterns

4.4.1 Dehradun District

In the Dehradun district, the highest production was observed in sugarcane (58.3%), followed by food grains (16.1%) and vegetables (14%). The production of other crops was less than 10%. The overall decrease in food grain production was 8.4%. However, there was a remarkable increase in pulse production by 74.7%, and a 29.4% increase in oilseed production. Sugarcane production increased by 10.2%, whereas potato production decreased by 55%. Despite the varied changes, an overall 3.4% increase in the production of all crops was observed (Table 4).

Table 4: Production (metric tonnes) of principal crops and change (%) from 2011-12 to 2021-2022 in Dehradun district

Variables	*2011-12*	*%*	*2021-2022*	*%*	*Change (%)*
Food grain	88,492	16	81,056	16.1	-8.4
Pulses	1,199	0.2	2,095	0.4	74.7
Oilseeds	493	0.1	638	0.1	29.4
Sugarcane	266,850	48.3	293,968	58.3	10.2
Potatoes	14,721	2.7	6,628	1.3	-54.9
Fruits	66,566	12	40,059	7.9	-39.8
Vegetables	107,093	19.4	70,755	14	-33.9
Spices	7,551	1.4	9,002	1.8	19.2
Total	552,965	100	504,201	100	-8.8

4.4.2 Nainital District

Sugarcane contributed the highest production among crops (36.5% in 2021-22), followed by food grains (23.2%), fruits (19.4%), vegetables (10.6%), potatoes (7.4%) (Table 5). In terms of change in the production of crops, there was the highest increase in spices (98.6%), followed by pulses (67.9%), and potatoes (57.4%). On the other hand, the production of some crops decreased with 56.4% of oilseeds, 27% vegetables, and 15.7% sugarcane. Despite these variations, the overall production of all crops has decreased by 4.5%.

Table 5: Production (metric tonnes) of principal crops and change (%) from 2011-12 to 2021-2022 in Nainital district

Variables	*2011-12*	*%*	*2021-2022*	*%*	*Change (%)*
Food grain	117,802	19.9	131,350	23.2	11.5
Pulses	1,698	0.3	2,851	0.5	67.9
Oilseeds	1,1293	1.9	4,925	0.9	-56.4
Sugarcane	245,024	41.4	206,434	36.5	-15.7
Potatoes	26,599	4.5	41,875	7.4	57.4
Fruits	102,214	17.2	109,389	19.4	7
Vegetables	82,711	14	59,700	10.6	-27.8
Spices	4,415	0.7	8,769	1.6	98.6
Total	591,756	100	565,293	100	-4.5

4.4.3 Comparison of Changes in Production in Dehradun and Nainital districts

In terms of production changes, both districts witnessed an increase in pulses production (Figure 3). Notably, the production of potatoes, sugarcane, oilseeds, and food grains increased in the Nainital district, while experiencing a decrease in the Dehradun district. The Nainital district, characterized by a large rural population, demonstrated nominal changes in both the area and production of crops. Conversely, the Dehradun district, with a predominantly urban population and significant in-migration, underwent the conversion of arable land into dense settlements, resulting in a decrease in both area and production. These contrasting dynamics highlight the distinct agricultural landscapes and demographic influences in the two districts.

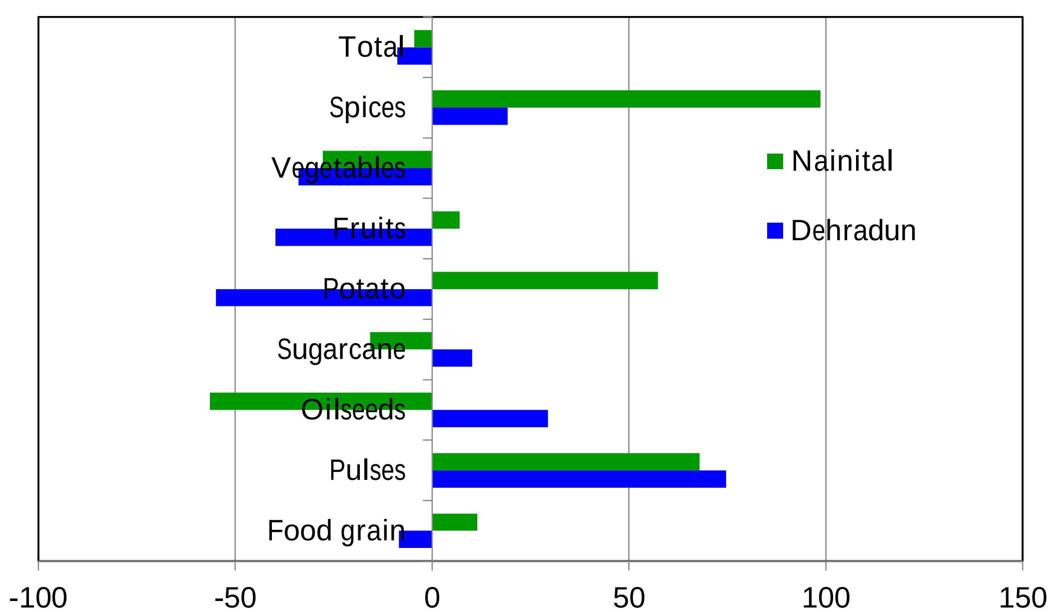

Figure 3: Change (%) in production, 2011-12 and 2021-22

4.4.4 Productivity of Crops and Changes

The change in crop productivity between 2011-2012 and 2021-2022 was observed in both the Dehradun and Nainital districts (Table 6). Notably, crop productivity exhibited both increasing and decreasing trends, and variations were observed between the two districts. There was a noticeable increase in the productivity of paddy and wheat crops in both districts. Moreover, productivity increased for total food grains, total pulses, and total oilseeds. Overall, there was an increase in overall productivity. These trends highlight the complex dynamics influencing crop productivity, which can vary across different crops and districts.

Table 6: Productivity in (metric tonnes/ha)

Crops	*Dehradun*			*Nainital*		
	2011-12	*2021-2022*	*Change (%)*	*2011-12*	*2021-2022*	*Change (%)*
Food grain	2.1	2.7	28.6	2.5	3.3	32
Pulses	0.3	0.9	200	0.8	1.1	37.5
Oilseeds	0.3	0.8	167	1.9	1	-47.4
Sugarcane	57.7	76	31.7	62	75.7	22.1
Potato	22.2	13.2	-40.5	11.1	12.8	15.3
Fruits	2.6	1.5	-42.3	4	10.1	152.5
Vegetables	11.8	7.3	-38.1	9.5	10.2	7.4
Spices	8.5	8.3	-2.4	9.2	6.2	-32.6
Total	6.2	6.7	8.1	6.2	8	29

4.4.5 Comparison in the Productivity in Dehradun and Nainital districts

As depicted in figure 4, the productivity of crops increased in both districts, except for potatoes in the Dehradun district. Remarkably, despite a significant decrease in arable land, productivity experienced a notable increase, primarily attributed to the adoption of intensive agriculture practices. Farmers engaged in agriculture continue to practice intensive farming methods, contributing to enhanced productivity despite challenges such as reduced land availability. This trend underscores the resilience and adaptability of agricultural practices in the face of changing landscapes and land use patterns.

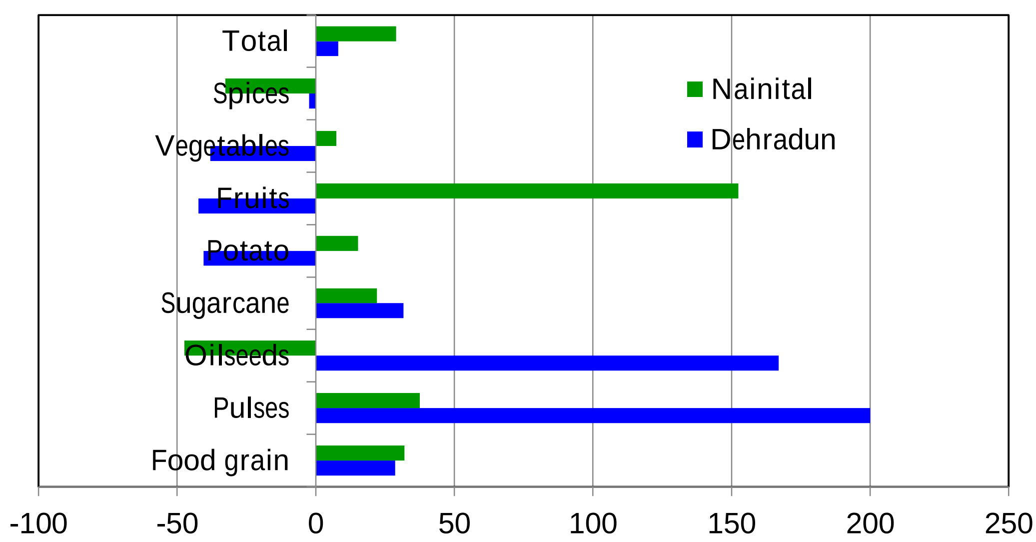

Figure 4: Change (%) in productivity, 2011-12 and 2021-22

5. Factors Affecting Changes in Land Use and Cropping Patterns

The changing cropping patterns in the Central Himalaya are influenced by various factors, among them are the climate change, increasing population, shifting food habits, and land abandonment due to out-migration. These factors are separately described below.

5.1 Climate Change

Climate change, recognized as a global phenomenon, has widespread effects on the Earth system, impacting rainfall and temperature patterns, water resources, glaciers, and biodiversity. The Himalayan region is particularly vulnerable to these changes, with significant consequences for both natural and cultural aspects.

5.1.1 Average Annual Temperature (°C) in Dehradun and Mukteshwar

Figure 5 illustrates the variability and change in average annual temperature from 2012 to 2022 in both Dehradun city and Mukteshwar service centre. Notably, Dehradun city consistently experiences higher temperatures than Mukteshwar, primarily due to differences in altitude. Dehradun city, situated at an average altitude of 600 meters, contrasts with Mukteshwar village, which has an average altitude of 2,500 meters. The temperature in Dehradun exhibits variation, ranging from a lowest recorded temperature of 23°C in 2015 to the highest 28°C in 2022. Despite fluctuations, there is an observable increasing trend with high variability, as indicated by an R^2 value of 0.118. The increasing temperature trend is more pronounced, with an R^2 value of 0.249. In Mukteshwar, where temperature variability is also high, the lowest average temperature was recorded as less than 15°C in 2015, while the highest temperature reached 19°C in 2022. These temperature trends and variations underscore the dynamic nature of climate conditions in both locations, with potential implications for agriculture and cropping patterns.

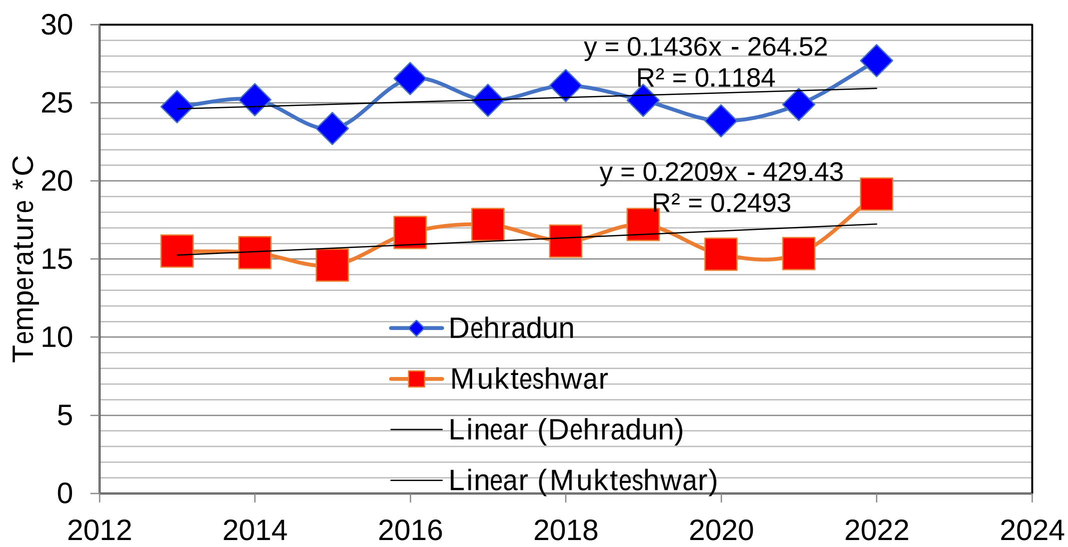

Figure 5: Average annual temperature (°C) in Dehradun and Mukteshwar

5.1.2 Average Annual Rainfall (mm) in Dehradun and Mukteshwar

Figure 6 illustrates the high variability and change in average annual rainfall from 2012 to 2022. The observed trend is not uniform, displaying contrasting patterns between Mukteshwar and Dehradun. While Mukteshwar experienced a decreasing trend in rainfall, Dehradun, conversely, witnessed an increasing trend. In Mukteshwar, the lowest recorded rainfall was less than 10 mm in 2022, and the highest rainfall occurred in 2015, exceeding 115 mm. Dehradun, on the other hand, recorded its lowest rainfall of less than 10 mm in 2013 and 2022, while the highest rainfall was registered at above 80 mm in 2020. These divergent trends in rainfall patterns between the two locations highlight the localized nature of climate variations in the Central Himalaya, emphasizing the need for region-specific analyses when studying the impacts on cropping patterns.

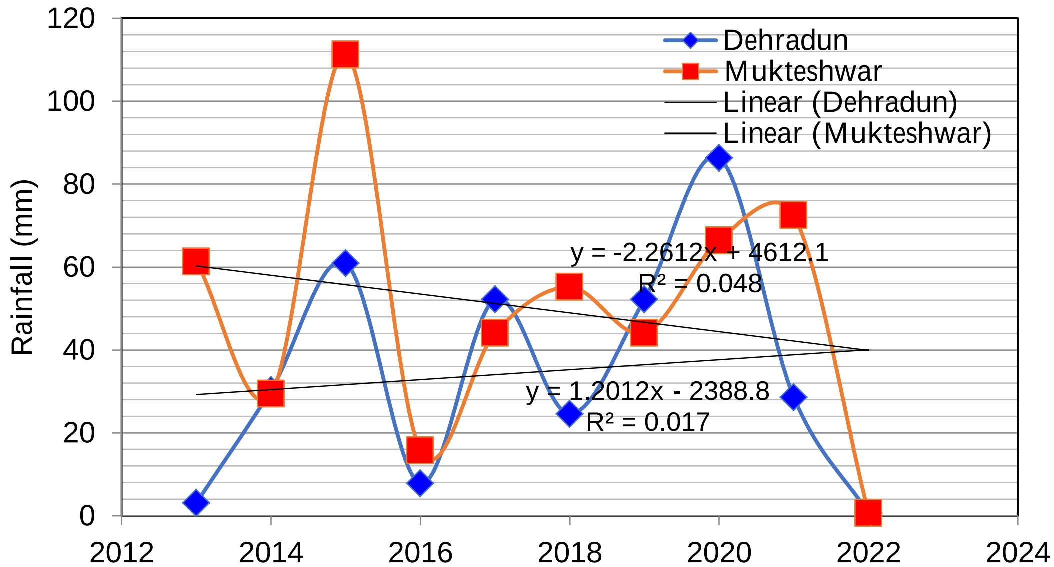

Figure 6: Average annual rainfall (mm) in Dehradun and Mukteshwar

The pronounced variability and changes in temperature and rainfall, as observed in the study of the two districts in the Central Himalaya, have had a significant impact on cropping patterns. The noticeable decreases in the area, production, and productivity of crops, particularly those grown in the highlands, can be attributed to the observed trends of decreasing rainfall and increasing temperatures (DoM, 2023). These climatic shifts are likely influencing agricultural conditions, posing challenges to traditional cropping practices and necessitating adaptations in response to the evolving climate in the Central Himalayan region.

5.2 Increasing Population

The increasing population is a key factor driving changes in land use and cropping patterns in the Central Himalaya. During the given period, population increased by more than 20% (SHB, 2023). However, the increase in population was uneven. The author observed that the limited availability of land for settlements and agriculture has prompted the use of arable land for construction, leading to the conversion of forest lands into cultivable areas.

5.3 Shift in Food Habits

Traditional food habits in the region revolved around millets, which were staple crops grown in the middle altitudes and highlands, contributing to the region's rich agrobiodiversity. These crops, along with a variety of fruits and vegetables, were cultivated predominantly during the rainy season, relying on rain-fed agriculture.

Owing to modernization and cultural changes, there has been a significant shift in the food habits of the local population. The increased production of wheat and paddy in the river valleys and plains has played a role in altering dietary preferences. This shift has resulted in a substantial decrease in the cultivation of millets, along with a reduction in the cultivation of fruits and vegetables. Many areas have witnessed the abandonment of land previously dedicated to these crops.

5.4 Migration

In-migration and out-migration are crucial drivers of changing cropping patterns, impacting both the areas of origin and destination. Rural areas experience land abandonment due to out-migration, while urban areas receiving migrants witness the conversion of arable land into settlements. Consequently, both sending and receiving areas are undergoing significant changes in land use and cropping patterns due to migration dynamics.

6. Discussion

The study examined the changing land use and cropping patterns in two districts, Dehradun and Nainital, from 2011-12 to 2021-22, with a specific focus on analysing the evolving climate in these regions. Significant changes were observed in land use patterns in both districts during the specified period. There was a notable decrease in forestland, net area sown, gross area sown, and irrigated land in both Dehradun and Nainital districts. Conversely, there was an increase in cultivable wasteland, fallow land, and pastureland. The Dehradun district experienced a decrease in arable land, primarily due to widespread in-migration from rural areas, leading to the construction of settlements instead of agricultural land. A similar trend was observed in the Nainital district, contributing to an increase in barren land and pastureland in both districts. Despite the decrease in forest area in both districts, the extent of reduction was relatively lower, attributed to the presence of two national parks — Rajaji National Park in the Dehradun district and Corbett National Park in the Nainital district. These protected areas have contributed to maintaining the forested areas within the districts.

In the traditional society, dietary habits were predominantly influenced by the production of food grains and millets, leading to a significant allocation of land for food grain cultivation. The rich agrobiodiversity of the region resulted in a substantial area dedicated to fruits and vegetables. The climate and irrigation facilities also favoured the cultivation of sugarcane, primarily in the plain areas, contributing to a considerable area under this crop. However, over time, there has been a substantial decrease in the area under food grains, pulses, oilseeds, sugarcane, and potatoes. In contrast, the area under fruits, vegetables, and spices has witnessed a nominal increase. The Dehradun district, known for its fertility, is grappling with the issue of shrinking arable land, impacting the overall agricultural landscape. The Nainital district, facing a different scenario, experienced a significant decrease not only in the area of food grains but also in fruits and vegetables. The overall decrease in agricultural areas was more pronounced in the Nainital district compared to the Dehradun district. These shifts underscore the changing dynamics in land use and cropping patterns, influenced by evolving dietary preferences and challenges specific to each region.

Regional changes were evident in the Nainital district, characterized by a decrease in production, particularly for oilseeds, sugarcane, and vegetables. When comparing the production of crops between the two districts, it was observed that the Dehradun district experienced a higher decrease compared to the Nainital district. The productivity trends also displayed variations between the two districts. In the Dehradun district, there was a significant decrease in the productivity of potatoes, fruits, and vegetables. On the other hand, the Nainital district saw a decline in the productivity of oilseeds and spices. Despite these variations, the overall productivity showed an increase. It is noteworthy that the Nainital district exhibited higher productivity levels than the Dehradun district, even though the latter had a larger agricultural area. These findings suggest distinct patterns in production and productivity dynamics, influenced by local factors and agricultural practices in each district.

7. Conclusions

The Central Himalaya has a rich tradition of practicing traditional farming systems, with diverse crop races/cultivars and cropping patterns varying across the river valleys, middle altitudes, and highlands. In the past, the prominent practice of Barahnaja[3] involved cultivating twelve or more traditional cereals and millets on a single cropland. However, over time, and influenced by factors such as climate change, increasing population, changing food habits, and out-migration, there has been a significant shift in cropping patterns. Currently, the staple crops in the region are paddy and wheat, with crop-growing areas gradually moving to higher altitudes due to the warming of river valleys and middle altitudes. The study suggests the necessity of conducting a comprehensive base-level survey to assess the current situation regarding changing cropping patterns and the shifting of crop races to higher altitudes. This assessment could inform the re-delineation of agro-ecological zones, facilitating the selection of suitable crop races for cultivation in different agro-climatic zones. Such an approach could contribute to sustainable agricultural practices in response to the evolving environmental and demographic conditions in the Central Himalaya.

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Author' Declarations and Essential Ethical Compliances

Author' Contributions (in accordance with ICMJE criteria for authorship)
This article is 100% contributed by the sole author. S/he conceived and designed the research or analysis, collected the data, contributed to data analysis & interpretation, wrote the article, performed critical revision of the article/paper, edited the article, and supervised and administered the field work.

Funding
No funding was available for the research conducted for and writing of this paper. Therefore, acknowledging any support agency is not applicable in case of this research or the written work. However, informal support of institutional supervisors, colleagues and respondents is duly acknowledged.

Research involving human bodies or organs or tissues (Helsinki Declaration)
The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

Research involving animals (ARRIVE Checklist)
The author(s) solemnly declare(s) that this research has not involved any animal subject (body or organs) for experimentation. The research was not based on laboratory experiment involving any kind animal. The contexts of animals were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of ARRIVE does not apply in cases of this study or written work.

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The author(s) solemnly declare(s) that this research has not involved the plants for experiment or field studies. Some contexts of plants are also indirectly covered through literature review. Thus, during this research the author(s) obeyed the principles of the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora.

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GRASSROOTS JOURNALS
ISSN 2564-4653 | 03(02) Dec 2023

AGROBIODIVERSITY & AGROECOLOGY | 03(02) DECEMBER 2023

Published by The Grassroots Institute (Canada) in partnership with University "Lucian Blaga" from Sibiu (Romania) and Fondacija Alica Banja Luka (Bosnia i Herzegovina). Website: https://grassrootsjournals.org/aa

M – 00371 | Research Article

Agroforestry: Enhancing Farm Tree Diversity and its Role in Rural Livelihoods

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How to cite this paper:
Lamichhane, U. and Ghimire, P. (2023). Agroforestry: Enhancing Farm Tree Diversity and its Role in Rural Livelihoods. *Agrobiodiversity & Agroecology*, 03(02): 19-33. Doi: https://doi.org/10.33002/aa030202

Received: 21 November 2023
Reviewed: 02 February 2024
Accepted: 20 February 2024
Published: 15 March 2024

Abstract

Agroforestry represents a land use strategy grounded in ecological principles, offering benefits such as increased crop yields, consistent financial returns, and broader agricultural diversification. This study was conducted in Makawanpurgadhi rural municipality, from Makawanpur district, Nepal, which aimed to evaluate various agroforestry systems, the diversity of farm trees, and their impact on rural income. Field observation, interviews with key informants, and questionnaire survey were employed to augment socio-economic information, with a randomly selected sample of 106 households (i.e. Landowners). Farm tree diversity was assessed using the Shannon Wiener Diversity Index. The study identified five important agroforestry systems: homegarden, silvi-pasture, agrisilviculture, silvofisheries, and agrisilvihorticulture. The Silvi-pasture system reported as a promising agroforestry approach demonstrating greater species richness and diversity of farm tree compared to homegarden and agrisilvihorticulture. Moreover, agroforestry systems contributed significantly to household income, with 36.92% (NRs. 25,700 or USD 193 per household per year) attributed to agriculture and 28.88% (NRs. 16,900 or USD 127 per household per year) to livestock raring. It is recommended that agroforestry systems have a great deal of potential to conserve biodiversity and enhance rural livelihoods.

Keywords

Agriculture; Farm land; Farm trees; Income; Agroforestry

1. Introduction

Reducing pressure on forests and expanding the environment beyond forest areas are primary objectives of recent government policies and initiatives. Agroforestry (AF) systems are considered a viable solution to address land management and ecological concerns while also meeting the demands of a growing population and crop diversity (FAO 2003; Salinas, 2016; Schnell *et al.*, 2015). It integrates forestry, agriculture, and other land uses into the same unit of land to safeguard the production of diverse ranges of products and services while promoting enhanced environmental sustainability (Paudel *et al.*, 2019; Reed *et al.,* 2017; Shin *et al.,* 2020). In Nepal, AF plays a critical role in producing food, fuel, timber, and other minor forest products, thereby generating income for underprivileged communities and contributing to environmental conservation (Amatya, Cedamon and Nuberg, 2018; Paudel *et al.,* 2019).

AF is an approach to land management that offers eco-agricultural solutions by integrating goals for improved food security with benefits in biodiversity conservation, particularly through promoting the use of native tree species (Acharya, 2006; Atta-Krah *et al.,* 2004; Reed *et al.,* 2017). Trees in and around agricultural lands provide valuable goods and services to communities. Agroforestry systems are critical for preserving and restoring the physical environment. They play an important role in reducing erosion, enriching soil fertility, reducing pollution, and promoting biodiversity conservation (Acharya, 2006; Atta-Krah *et al*., 2004; Ojha *et al.,* 2022). Soil fertility degradation, increased soil erosion, and decreased agricultural output have all been linked to declines in forest cover. Agroforestry shows promise as a solution to address these issues (Amatya, Cedamon and Nuberg, 2018; Carter and Gilmour, 1989; Paudel *et al.,* 2019). Studies worldwide indicate advancements in tree growth on private farmlands to counter the loss of forest trees (Baral *et al*., 2013; Ghimire and Bolakhe, 2020; Kang and Akinnifesi, 2000; Thapa *et al.*, 1994).

Agriculture has historically served as the primary source of income across the Nepalese hills, with subsistence agriculture forming the backbone of economic activity in this region, closely intertwined with forest resources. These small-scale farming systems have traditionally relied on forest products, which provide a diverse array of goods and services crucial for both biodiversity conservation and subsistence (Acharya, 2006; Neupane *et al*., 2002; Ojha *et al.,* 2022). Agroforestry is a multidimensional approach to sustainable land management that offers numerous advantages for both rural communities and biodiversity conservation. Because of this, it has garnered considerable attention from conservation scientists seeking innovative solutions to environmental challenges (Acharya and Kafle, 2009; McNeely and Schroth, 2006; Ojha *et al.,* 2022). Despite this potential, Nepal's agricultural and forestry development plans have historically placed little emphasis on promoting agroforestry (Amatya, Cedamon and Nuberg, 2018). However, recent years have seen increased recognition of agroforestry's crucial role in sustaining rural agriculture, leading to initiatives aimed at promoting agroforestry at the farm level. While the focus has traditionally centered on trees within forests, those outside forested areas or on farms in Nepal represent vital resources for enhancing sustainable development and livelihoods. Furthermore, despite their significant contributions to human well-being and environmental preservation, trees on farmland and in various land use types around human settlements have not been systematically integrated into the national forest inventory (DFRS, 2015; Ghimire *et al.,* 2021). In this backdrop, this study primarily aims to evaluate farm tree diversity and its impact on rural livelihood enhancement.

2. Materials and Methods

2.1 Study Area

This research was conducted in ward number 6 of Makawanpurgadhi rural municipality, located in Makawanpur district, Nepal (Figure 1). This municipality shares borders with Bakaiya rural municipality to the east, Bhimphedi rural municipality to the west and north, and Hetauda Sub-metropolitan City to the south. Topographically, the district spans from 27°10' to 27°40' latitude and 84° 41' to 85°31' longitudes, with Makawanpurgadhi rural municipality situated 34 km south of Kathmandu and 17 kilometers north of Hetauda city. The area experiences a tropical to subtropical climate, characterized by an average annual temperature of 28 degrees Celsius and approximately 240 mm of rainfall. Geologically, the region represents the upper Chure range and lower Mahabharat Hill's alternate strata, consisting of shale, schist, quartzite, and phyllite, alongside limestone beds, and various granite and gneiss (Bajracharya *et al.,* 2007; MRM, 2023). Agriculture and livestock farming are the primary occupations in this area.

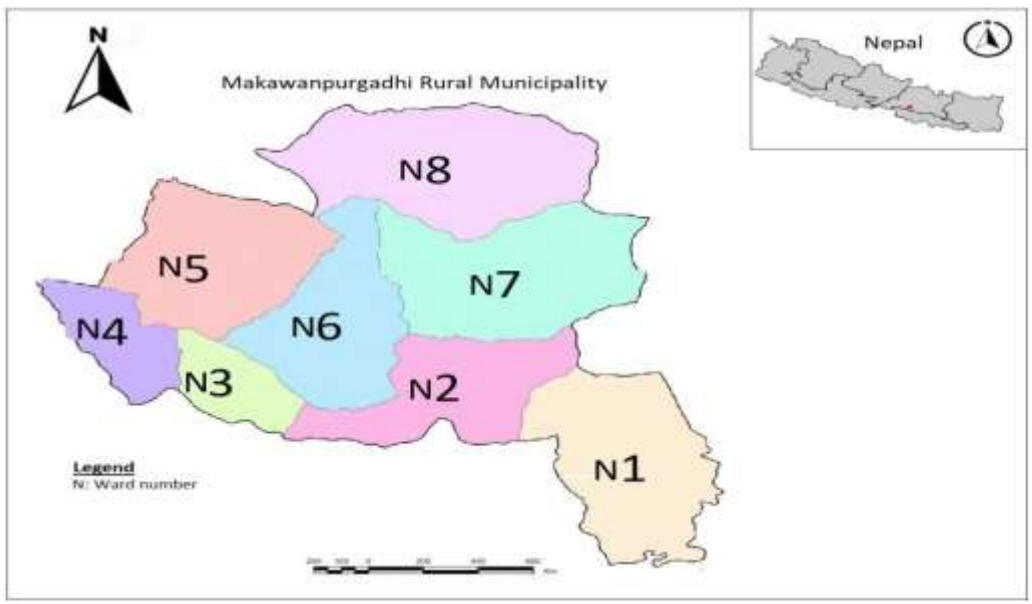

Figure 1: Map illustrating the study area

2.2 Sampling Method and Data Analysis

The research employed both qualitative and quantitative approaches to investigate the existing agroforestry system, tree diversity, and its contribution to local livelihood improvement. For the vegetation survey, circular plots (n=43) of size 1,000 m² with a radius of 17.84m were purposively laid out according to the prevalent agroforestry systems. During the vegetation survey of the household farm sample, all tree species and the number of individuals within each plot were counted. Subsequently, farm tree diversity was determined applying the Shannon-Weiner index, which considers both the evenness and abundance of the species present (Maturin, 1988). Shannon-Weiner index is represented by *H*, which is determined as:

$H = -\sum P_i * ln\, P_i$

Where, H =Shannon-Wiener index,

Similarly, the term evenness is represented by E, which is calculated as:

E = H/ lnS

Where, E= evenness,

H= The Shannon Diversity Index,

S= Total number of species with in the community

For socio-economic data analysis, a questionnaire survey was conducted on 106 farm households (including those from sample plot located households and adjoining households) to augment necessary information. Additionally, to validate and cross-check the data from the household survey, 3 focus groups and 23 key informant interviews were conducted. The collected data were analyzed using SPSS and presented through tables, graphs, figures, and charts to facilitate logical interpretation.

3. Results

3.1 Agroforestry Systems Adopted

In a given ecosystem, tree diversity plays a critical role in maintaining natural environmental equilibrium. This becomes particularly crucial in areas where natural forest encroachment and land degradation are diminishing biodiversity, potentially resulting in the loss of the natural ecosystem. This study reported five major agroforestry systems: homegarden, silvipasture, agrisilviculture, silvofisheries, and agrisilvihorticulture (Table 1). A survey of 106 household farms revealed that the majority of households adopted homegardens (58%), followed by silvipasture (41%), agrisilviculture (16%), silvofisheries (9%), and agrisilvihorticulture (4%). Homegardens are primarily adopted by households to fulfill their nutritional needs, ensure food security, preserve agrobiodiversity, and promote environmental sustainability.

Table 1: Agroforestry systems and species combinations

S.N.	*Types of Agroforestry System*	*Description*	*Major Species Combination*	*Percentage of HHs used*
1.	Homegarden	Growing cereals, vegetable spices with firewood, and fodder species.	*Mangifera indica, Atrocarpus heterophulus, Persea americana,* along with banana, pineapples, chili, turmeric, and vegetable species.	47%
2.	Silvipasture	Raising forest trees with livestock in the same land.	*Litsea monopetala*, *Ficus* sp., *Bauhinia* sp., grasses and livestok in rain faded land or fallow land.	24%
3.	Agrisilviculture	Cultivating seasonal agricultural crops along with mixed tree species.	*Tectona grandis, Dalbergia sissoo, Eucalyptus camaldulensis, Albizia lebbek* along with agricultural crops (such as Turmeric and ginger).	16%
4.	Silvofishery	Fish farming in conjunction with forest tree species.	*Mangifera indica, Dalbergia Sissoo, Eucalyptus camaldulensis*, *Bauhinia variegata,*	9%

S.N.	*Types of Agroforestry System*	*Description*	*Major Species Combination*	*Percentage of HHs used*
			Litsea monopetala on the riser of the fish ponds.	
5.	Agrisilvihorticulture	Growing agricultural crops alongside horticulture plants and forest trees.	Fruit–trees (such as banana, mango), along with agricultural crops alongside *Eucalyptus camaldulensis, Dalbergia Sissoo.*	4%

3.2 Diversity and Abundance of Species across various Agroforestry Systems

A total of 71 tree species were documented in the study site. Among these, *Mangifera indica*, *Atrocarpus heterophulus*, *Litsea monopetala*, *Artocarpus lakoocha,* and *Shorea robusta* emerged as the major tree species found on farmland (Figure 2). The two most abundant tree species planted on farmland were *Mangifera indica* and *Artocarpus heterophyllus*. Additionally, the tree diversity index and species richness were also estimated for every agroforestry system under the study, as detailed in table 2. The silvipasture system demonstrated the higher diversity index and species richness as compared to homegardens and agrisilvihorticulture, respectively. The silvipasture system emerged as the most diverse agroforestry system adopted, highlighting its preference and variability within the Makawanpurgadhi rural municipality.

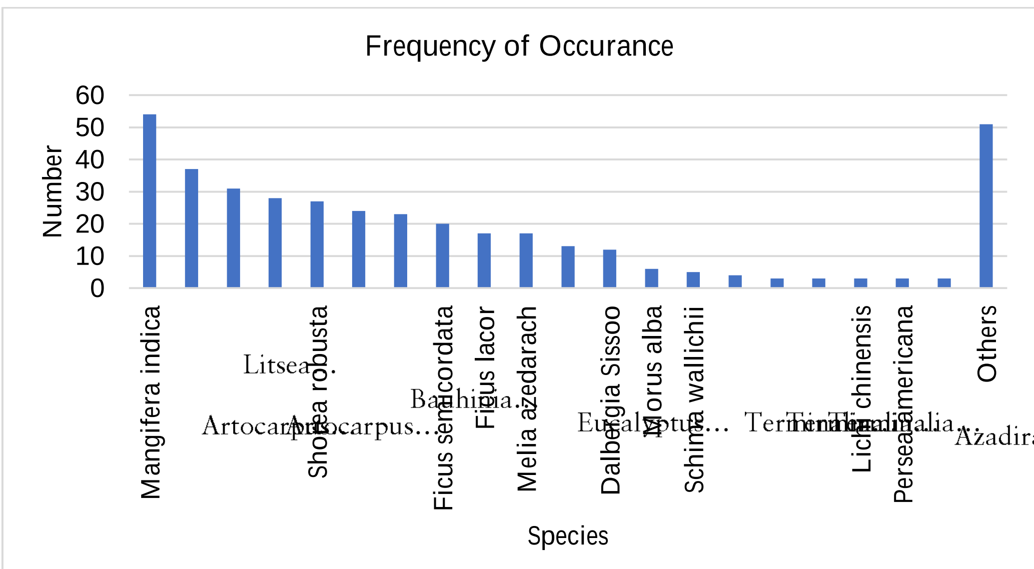

Figure 2: Frequency of farm tree species occurrence

3.3. Different Sources of Income of Studied Households

The socioeconomic data of 106 farm households was analyzed through a questionnaire survey to determine how much agroforestry systems contribute to rural livelihoods. Among the 106 farm households surveyed, 69 were male respondents and 37 were female respondents (Table 3). Additionally, 61.32% of the households were engaged in agriculture-related occupations, while 38.68% relied on non-agricultural occupations, including government and private services (Table 3). Furthermore, the average annual income of the households was determined to be NRs. 170,990 (equivalent to USD 1,286), with the majority of households (43) falling into the category with an annual income of less than NRs. 150,000 (equivalent to USD 1,128) (Table 3).

Table 2: Species richness and farm tree diversity across various agroforestry systems

S.N.	*Agroforestry Systems*	*Species richness*	*Shannon Weiner Index*
1.	Homegarden	26	0.37
2.	Silvipasture	38	0.62
3.	Agrisilviculture	15	0.24
4.	Silvofishery	7	0.10
5.	Agrisilvihorticulture	21	0.30

Table 3: Socio-economic attributes of studied households

Class	*Attributes*	*Number*	*Percentage (%)*
Gender	Male	69	65.10
	Female	37	34.90
Occupation	Agriculture	65	61.32
	Government services	22	20.76
	Private services	19	17.92
Annual income (NRs.)	<150,000 (<USD 1,128)	43	40.57
	150,000-200,000 (USD 1,128-1,504)	37	34.90
	>200,000 (>USD 1,504)	26	24.53

3.4 Farm Trees' Contribution to the Agricultural and Livestock Income

Agroforestry is a land management strategy in which parts of forestry and agriculture are combined to provide a variety of benefits, including fuelwood, timber, food, fodder, and other agricultural and forestry-related goods and services within a given area and time frame. Respondents were queried regarding their overall income as well as the relative contributions of different income sources. According to the study findings, out of the average net annual household income, income from agriculture and livestock constituted 40.70% and 34.21%, respectively. Furthermore, the adopted agroforestry systems in the study area contributed 36.92% (NRs. 25,700, equivalent to USD 193, per household per year) and 28.88% (NRs. 16,900, equivalent to USD 127, per household per year) to the agricultural income and income from livestock farming, respectively (Figure 3).

4. Discussion

Agroforestry is not a novel practice; rather, it is emerging as a science. The objective of agroforestry development in Nepal is to mitigate environmental degradation while also fulfilling the demand for fodder, non-wood forest products, fuelwood, and small timber, including aromatic and medicinal plants, both now and in the future (Amatya, Cedamon and Nuberg, 2018). Although, agroforestry practice has long been a longstanding part of traditional farming techniques in Nepal, they have also been shown to harbor higher biodiversity than Nepalese forests and provide farmers with additional market alternatives (Acharya, 2006). This study identified five major agroforestry systems, with the majority of households preferring homegardens due to their immediate access to fresh produce (Table 1). In terms of tree diversity, silvipasture systems demonstrated the higher species richness and diversity index, with home gardens and agrisilvihorticulture coming in second and third, respectively (Table 2). Nepal's agroforestry system has become increasingly diverse due to the country's growing commercialization and abandonment of agricultural land (Ulak *et al.,* 2021). The farmer-led approach is undeniably one of the most significant strategies for increasing tree cover in rural agriculture. This finding is in line with Ghimire and Bolakhe (2020) and Khanal (2011) who reported greater tree diversity and species richness in silvipasture systems in Makawanpur and Kaski districts, respectively. However, Baral *et al.* (2013) found that homegarden in the Kanchanpur district of Nepal exhibited higher tree diversity and species richness compared to agrisilviculture. The differences in results can be accounted to variations in geographic regions, which differ depending on the location within a specific zone. Nonetheless, it is evident how agroforestry techniques enhance farm tree diversity and contribute to environmental restoration.

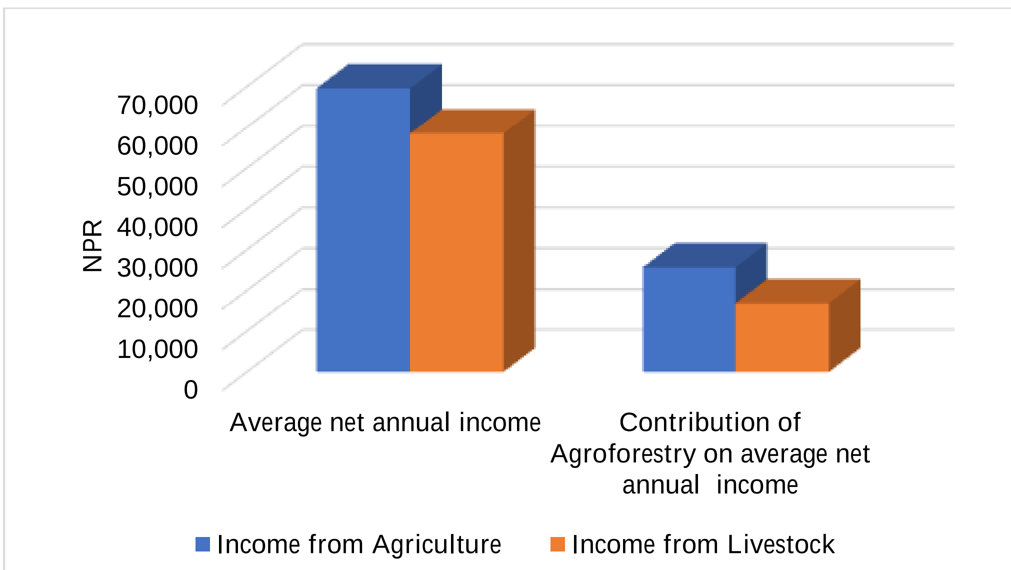

Figure 3: Contribution of agroforestry systems on agriculture and livestock income

Agroforestry strategy play a critical role in addressing hunger, improving local livelihoods, conserving biodiversity, and bolstering institutional and societal adaptability to climate change (Mbow *et al.,* 2014). In Nepal, agriculture remains the primary means of income for the majority of the population, with approximately 70% still engaged in agricultural activities (FAO, 2023; GC and Hall, 2022). Rural farmers rely on farmland to meet their daily needs, with the average per capita income (PCI) in Nepal standing at NRs.

186,067 annually (equivalent to USD 1,399) (CEIC Data, 2023). A significant portion of households (61.32%) in the study area were engaged in agricultural activities (Table 3). The average annual income of households was determined to be NRs. 170,990 (equivalent to USD 1,286). Of the total average net annual household income, income from agriculture and livestock constituted 40.70% and 34.21%, respectively. Notably, agroforestry systems contributed 36.92% and 28.88% to agriculture income and livestock income, respectively. According to the Agroforestry Network (2018), nine of the seventeen Sustainable Development Goals (SDGs) can be addressed through agroforestry. Of these, nine have the potential to be addressed through agroforestry, with a particular emphasis on goals including No poverty; Zero hunger; Climate action; and Life on land. This indicates the significance of agroforestry systems for improving local livelihoods in Nepalese context. These findings are consistent with those of Ghimire and Bolakhe (2020), who documented that in the Makawanpur district, agroforestry systems contributed 24.06% and 20.25%, respectively, to agricultural income and income form livestock rearing. In Kanchanpur district, similar results were also observed by Baral et al. (2013) where farm trees contributed 16.4% and 17.1% to agricultural income and income from livestock rearing, respectively. Therefore, agroforestry holds immense potential to uplift rural livelihoods by reducing local communities' dependence on forest resources.

5. Conclusions

A total of 71 farm tree species were documented across the five different agroforestry systems studied. Greater diversity index and species richness for farm tree were observed in Silvipasture, compared to homegarden and agrisilvihorticulture, respectively. Agroforestry in the study site contributed 36.92% and 28.88% to agriculture income and livestock income per household per year, respectively. These findings show the importance of suitable trees planted outside of forests can support rural communities' livelihoods and biodiversity. Future local and national forest sector strategies must take these resources into consideration, because trees outside of forests are essential for the upliftment of livelihoods of the local people.

6. Acknowledgements

The authors extend their sincerest gratitude to the local households of Makawanpurgadhi rural municipality for generously sharing their information during the questionnaire survey and field observations. Their cooperation and willingness to contribute to this study were invaluable and greatly appreciated.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	Author 1	Author 2
Conceived and designed the research or analysis	Yes	Yes
Collected the data	Yes	No
Contributed to data analysis and interpretation	Yes	Yes
Wrote the article/paper	Yes	No
Critical revision of the article/paper	Yes	Yes
Editing of the article/paper	Yes	Yes
Supervision	Yes	Yes
Project Administration	Yes	No
Funding Acquisition	No	No
Overall Contribution Proportion (%)	70	30

Funding

No funding was available for the research conducted for and writing of this paper. Therefore, acknowledging any support agency is not applicable in case of this research or the written work. However, informal support of institutional supervisors, colleagues and respondents is duly acknowledged.

Research involving human bodies or organs or tissues (Helsinki Declaration)

The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

Research involving animals (ARRIVE Checklist)

The author(s) solemnly declare(s) that this research has not involved any animal subject (body or organs) for experimentation. The research was not based on laboratory experiment involving any kind animal. The contexts of animals were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of ARRIVE does not apply in cases of this study or written work.

Research on Indigenous Peoples and/or Traditional Knowledge

The author(s) solemnly declare(s) that this research has not involved any Indigenous Peoples as participants or respondents. The contexts of Indigenous Peoples or Indigenous Knowledge were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) and Self-Declaration in this regard are appended.

Research involving Plants

The author(s) solemnly declare(s) that this research has involved the plants for experiment or field studies. Some contexts of plants are also indirectly covered through literature review. Thus, during this research the author(s) obeyed the principles of the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora.

Research Involving Local Community Participants (Non-Indigenous) or Children
The author(s) solemnly declare(s) that this research has directly involved local community participants or respondents belonging to non-Indigenous peoples. But, this study did not involve any child in any form directly. The contexts of different humans, people, populations, men/women/children and ethnic people are only indirectly covered through literature review. A sample copy of the Consent Form implying prior informed consent (PIC) of the respondents is appended.

(Optional) PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)
The author(s) has/have NOT complied with PRISMA standards. It is not relevant in case of this study or written work.

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INFORMATION AND CONSENT FORM FROM RESPONDENTS
(Non-Indigenous or Indigenous Respondents)

This form was translated into local language for the respondents

Title of the Research: Agroforestry: Enhancing Farm Tree Diversity and its Role in Rural Livelihoods

Principal Researcher: Uchita Lamichhane
Faculty of Forestry, Agriculture and Forestry University, Hetauda-10, Makawanpur district, Bagmati Province, Nepal

Research Supervisor: Pramod Ghimire
Faculty of Forestry, Agriculture and Forestry University, Hetauda-10, Makawanpur district, Bagmati Province, Nepal

A) INFORMATION TO PARTICIPANTS

1. Objectives of the research

The objectives of this study were to evaluate various agroforestry systems, farm tree diversity, and their contribution on rural income.

2. Participation in research

The researcher will ask you several pertinent questions. This interview will be recorded in written form and should last about 50-60 minutes. The location and timing of the interview will be determined by you, depending on your availability and convenience.

3. Risks and disadvantages

There is no particular risk involved in this project. You may, however, refuse to answer any question at any time or even terminate the interview.

4. Advantanges and benefits

You will receive intangible benefits even if you refuse to answer some questions or decide to terminate the interview. You will also contribute to a better understanding on how farm trees promotion can transform rural livelihoods.

5. Confidentiality

Personal information you give us will be kept confidential. No information identifying you in any way will be published. In addition, each participant in the research will be assigned a code and only the researcher will know your identity.

6. Right of withdrawal

Your participation in this project is entirely voluntary and you can at any time withdraw from the research on simple verbal notice and without having to justify your decision, without consequence to you. If you decide to opt out of the research, please contact the researcher at the telephone number or email listed below. At your request, all information concerning you can also be destroyed. However, after the outbreak of the publishing process, it is impossible to destroy the analyses and results on the data collected.

B) CONSENT

Declaration of the participant

- ⇨ I understand that I can take some time to think before agreeing or not to participate in the research.
- ⇨ I can ask the research team questions and ask for satisfactory answers.
- ⇨ I understand that by participating in this research project, I do not relinquish any of my rights, including my right to terminate the interview at any time.
- ⇨ I have read this information and consent form and agree to participate in the research project.
- ⇨ I agree that the interviews be recorded in written form by the researcher: Yes ( ) No ( )

Signature of the participant : ____________________ Date : _____________________

Surname : _________________________________ First name : _________________________________

Researcher engagement

I explained to the participant the conditions for participation in the research project. I answered to the best of my knowledge the questions asked and I made sure of the participant's understanding. I, along with the research team, agree to abide by what was agreed to in this information and consent form.

Signature of the researcher : uchita Date : 13-06-2023

Surname: Lamichhane First name: Uchita

- ⇨ Should you have any questions regarding this study, or to withdraw from the research, please contact Ms. Uchita Lamichhane by e-mail uchitalamichhane@afu.edu.np

- ⇨ If you have any concerns about your rights or about the responsibilities of researchers concerning your participation in this project, you can contact the Pramod Ghimire, Faculty of Forestry, Agriculture and Forestry University, Hetauda-10, Makawanpur district, Bagmati Province, Nepal by e-mail pghimire@afu.edu.np

GRASSROOTS JOURNALS

ISSN 2564-4653 | 03(02) Dec 2023

AGROBIODIVERSITY & AGROECOLOGY | 03(02) DECEMBER 2023

Published by The Grassroots Institute (Canada) in partnership with University "Lucian Blaga" from Sibiu (Romania) and Fondacija Alica Banja Luka (Bosnia i Herzegovina). Website: https://grassrootsjournals.org/aa

M – 00372 | Research Article

Traditional Ecological Farming Practices in the Eastern Himalayan Mountain Environment: Case of a Naga Village, Nagaland (India)

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How to cite this paper: Saha, S., Hussain, S., Deka, N., Mahanta, R. and Bhagabati, A.K. (2023). Traditional Ecological Farming Practices in the Eastern Himalayan Mountain Environment: Case of a Naga Village, Nagaland (India). *Agrobiodiversity & Agroecology*, 03(02): 34-58. Doi: https://doi.org/10.33002/aa030203

Received: 14 December 2023
Reviewed: 11 February 2024
Accepted: 27 February 2024
Published: 15 March 2024

Abstract

The farming systems practised by the tribal communities in the mountain environment of the North-Eastern region of India are eco-friendly and local climate responsive. These play a significant role in ensuring food security and conserving the local agro-ecological diversity. These farming practices are rooted in the local ecological set up, and they reflect the Indigenous people's response to the environment of the area. The inhabitants of the Khonoma village of Kohima district, Nagaland, the study village, have been traditionally practising unique *Alder* tree-based *jhum* (shifting) cultivation, terrace-based *panikheti* (wet cultivation) and kitchen gardening based on their Indigenous knowledge and skills. They have been practising mixed farming by integrating crops, fish and livestock. The local communities have also evolved some methods for managing the natural settings to sustain their agriculture and livelihoods. This study is an attempt to investigate the methods of traditional farming system of Khonoma, a mountain village in the Eastern Himalayas. This study is based on primary data/ information collected through household survey using semi-structured household survey schedule, participatory rural appraisal (PRA), focus group discussion (FGD), and interviews with key informants and personal field visit in early 2021. The terrace-based *panikheti*, adopted by the people of Khonoma village, has been proved a location specific eco-friendly method for soil and water conservation. The *Alder* tree-based *jhum* practice, as opined by the villagers, is a sustainable livelihood option in the context of the mountain ecological setting and unique cultural values of the people.

Keywords

Ecological farming, Agrobiodiversity; Ethnic community; Mountain environment; Eastern Himalaya

1. Introduction

The ecological farming practices have been gaining popularity as an alternative to the conventional modern farming system due to its minimum environmental impact, ecological adaptability and affinity to cultural values (Deka, 2012; Schoonhoven and Runhaar, 2018). Extensive use of agrochemicals, HYV seeds and irrigation in modern agriculture temporarily triggers the productivity of certain crops, but their impact on the ecosystem and peasant society is far reaching (Altieri and Koohafkan, 2008; Conway, 1987). Modern agricultural practices have now proved to be responsible for the degradation of the associated ecology, declining natural fertility of soil, depletion of ground water (Shetty, Ayyappan and Swaminathan, 2013), loss of local crop diversity, and disappearance of agriculture related cultural attributes (Deka and Bhagabati, 2010; Gliessman, 2007). In comparison to diversified cropping and integrated farming, monocropping is given more importance in the modern farming systems. Farmer's choice on agricultural inputs and implements has also been taken over by external agencies and, thus, agriculture has become increasingly capital intensive (Dorin, 2022). Thus the modern agricultural methods, where substantial amount of money is needed for procuring agricultural inputs and implements, have posed a challenge to the farmers, particularly the small and marginal farmers, in the developing countries. These challenges have become more and more acute under the influence of climatic change and other associated phenomena. These are now facing frequent crop loss due to some climate related phenomena like drought, floods and other extreme weather events and certain newly appeared diseases, pests and insects.

Traditional agro-ecosystem in the marginal environment provides various ecosystem goods and services such as regulation of soil and water quality, biological pest control, pollination, support to biodiversity, etc. for sustaining the life and livelihoods of the local communities (Power, 2010; Gauchan *et al.,* 2020; Sharma and Rai, 2012). The diverse agriculture and the associated Indigenous knowledge and skills practised by the Indigenous communities across the world have been reckoned essential climate resilient agriculture (Bisht, 2021; Erisman *et al*., 2016; Mekbib *et al*., 2017). Diversification of agriculture by integrating crops, livestock and fishes is considered as an important strategy to adapt to the climate change risk (Aiman Raza, 2007; Altieri and Koohafkan, 2008; Karki, Burton, and Mackey, 2020). It has been observed that many traditional crop varieties under traditional farming methods have higher productivity, nutritive value and give stable production (Bisht, 2021; DeLonge, Miles and Carlisle, 2016; Maikhuri, Rao and Saxena, 1996.; Khumairoh *et al*., 2021) and resistance to pests and diseases (Mulumba *et al.,* 2012). Moreover, the ecological farming practices are very rich in agrobiodiversity, which ensures stable production and food and nutritional security (Erisman *et al*., 2016; Swaminathan, 1986). Unlike modern agriculture, the traditional farming is based on organic inputs, biological pest management system, local crop varieties, self-seed conservation and locally invented soil and water management systems. Therefore, these farming practices are considered as ecologically sustainable, economically viable and culturally acceptable (Deka, 2012; Sharma and Rai, 2012). It also provides scope for development of agro- and ecotourism as an alternative opportunity for livelihood (Amloy *et al*., 2024; Ba *et al*., 2018). Several studies claimed that the rate of environmental destruction in primitive methods of subsistence farming like shifting cultivation is very limited than the monoculture of plantation farming (Henley, 2011; Morton, Borah and Edwards, 2020). In shifting cultivation, farmers maintain forest cover by a short cropping period and long fallow phase for forest regeneration (Kerkhoff and Sharma, 2006). The long fallow period has high potential for carbon sequestration and forest recovery (Thong *et al.*, 2020) and also helps in maintaining organic carbon and nitrogen stocks in soil (Terefe and Kim, 2020).

The tribal communities inhabiting the Himalayan mountain environment of North-East India have been practising some Indigenous farming systems (IFS) such as paddy-cum-fish farming of Apatani community of Arunachal Pradesh, bamboo drip irrigation-based farming in Meghalaya, wet rice cultivation in Assam, *Zabo* irrigation-based wet rice cultivation in Nagaland, and so on. Shifting cultivation, locally called *jhum*, is one of the dominant forms of agriculture practiced in the hilly areas of this region. Several studies show that the shifting cultivation practices of North-East India is rich in crop diversity (Asati and Yadav, 2014; Payum *et al.*, 2021). *Alder*-based *Jhum* cultivation, terrace-based *Panikheti* and kitchen gardening of Khonoma village in Nagaland are century-old ecological farming practices where the farmers developed unique system for soil, water and agrobiodiversity conservation based on their Indigenous knowledge and skills (KTDB 2009; Roy, Debnath and Nautiyal, 2020).

2. Objective of the Study

This study has been carried out with the following objectives:

1. To investigate nature and types of traditional farming practices and crop cycles developed by the Indigenous communities based on the local climate, ecology and indigenous knowledge system.
2. To study the traditional strategies adopted by the hill farmers for soil conservation and water management in different farming practices.

3. Geographical Background of the Village

This study has been carried out in a typical Naga village called Khonoma, located in Sechü-Zubza sub-division of Kohima district, Nagaland (Figure 1). The village is located at $25^0 39' 21.20''$ N latitude and $94^0 1' 18.27''$E longitude at a distance of 20 km from Kohima town and around 80 km from Dimapur town. It is surrounded by Jotsoma village on the north, and Mezoma village on the west. Being located at the foothill of the Barail range, the village is a part of the Eastern Himalaya and Indo-Burma Biodiversity Hotspot (Chase and Singh, 2012). The physiography of the village is hilly ranging from gentle slope to steep rugged hillsides. The village is drained by a small stream called Dzüza and its tributary Khurü forming a valley plain with moderate slope. The average elevation of the Khonoma is around 1,455 m from the mean sea level.

The area receives an annual rainfall of 2,000 to 2,500 mm and most of the rainfall occurs during May to September. The area experiences cold and winter season from October to March. Temperature varies from 15^0C to 30^0C during summer and 5^0C to 25^0C during winter. The village is inhabited by the Angami Naga tribe. It has 424 households with a total population of 1,943 as per 2011 Census. The old people reported that the village is about 700 years old. The village is divided into three clans, called *Khel*-Merhüma (M-Khel), Semoma (S-Khel) and Thevoma (T-Khel). Literacy rate is 83.41%, which is higher than state's average (2011 Census). Although the village is rich in forest resources, agriculture is the main source of livelihood of the people.

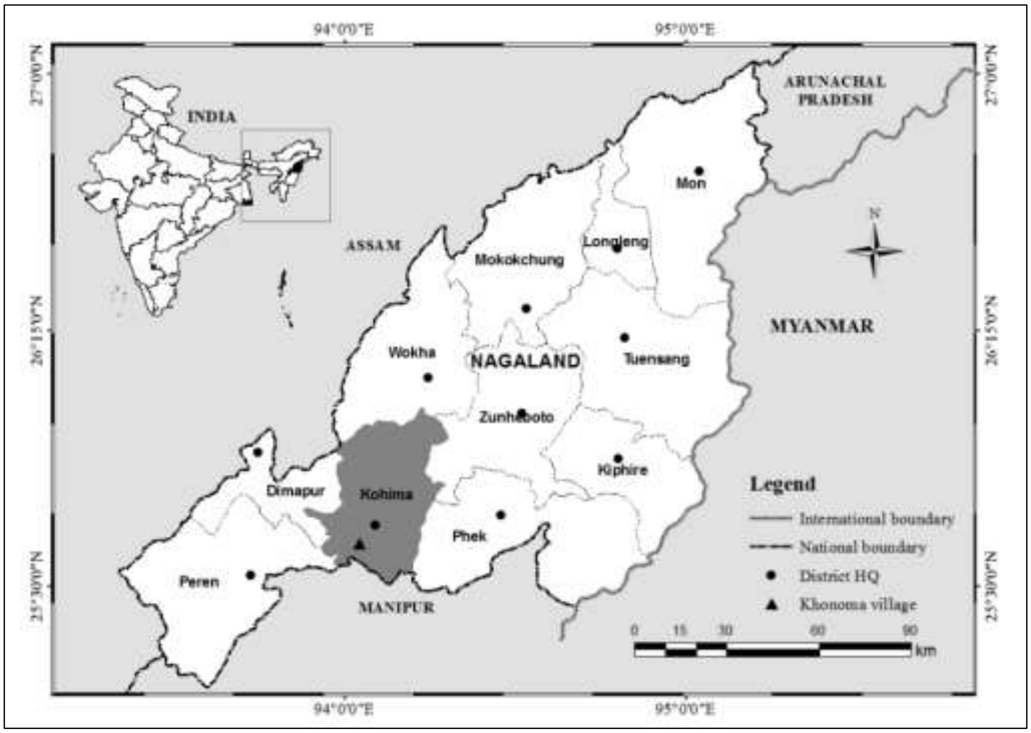

Figure 1: Location of Khonoma village in Nagaland

3. Methods

Descriptive and qualitative methods were followed in conducting this study. Data were collected through purposively designed household survey schedule, intensive field observation, interviews and focus group discussion (FGD) with the local communities following Participatory Rural Appraisal (PRA) approach (Figure 2). Household survey was conducted covering 50 selected households (12% of total households) during the month of February 2021. Simple random sampling procedure was followed for the selection of households. Out of the total respondents, 60% were males and 40% were females. In addition to household survey, several stakeholders, including Secretary of Khonoma Village Development Board (BDV), members of women self-help groups, and members of farmers' club were interviewed.

Participatory resource map of the village has been prepared to understand the agricultural land use pattern of the village and the associated problems. Local people were asked to draw their village map on the ground. They drew the map on the ground using sticks and placed different colour powder (*ranguli*) to indicate agricultural lands (both the terrace fields, *jhum* fields), irrigation canals, kitchen gardens, fish ponds, forests etc. of their village. After the completion of drawing, a stick was handover to a senior participant to explain their village map. A transact walk was performed along with the farmers in order to verify the prepared map with the existing agricultural land use pattern and the associated problems. A small group consisting of 6-7 villagers, including the village headman and women farmers, were asked to participate in the transact walk in order to investigate the Indigenous land use pattern and its relations with the existing irrigation system, soil quality, forest cover and regenerated forest growth after *jhum* (shifting cultivation) cycle completed.

A crop calendar was prepared with the help of villagers to study the seasonal cycle of crop farming and associated agriculture activities in Khonoma. A chart was drawn on the ground with the time scale (month wise) in horizontal direction and the type of agriculture, crops and farming activities on the vertical axis. The participants were asked to place some materials such as stones, stick, etc. on the ground chart as per the activities required during different season for *jhum* cultivation, terrace farming and kitchen gardening different months.

Figure 2: Focus group discussion and interview (Photo Credit: Sourav Saha)

5. Results and Discussion

5.1 Socio-economic Condition of the Village

The household level data on socio-economic background of the farmers, farming types, land size, farm income and food security of the farmers of the village provide an idea about the farming practices and its role on the livelihood sustainability of the villagers. The sample survey shows that only 4% of the total households of the village are engaged in the service sector and the rest 96% is in agriculture. Average family size of the sample households is 6 persons. Among the sample households, as many as 127 members are found to get involved continuously in agriculture where 73 (57.48%) are female farmers clearly indicating the dominant role played by the females in farming. During the off-farm season (January-February), some farmers are engaged in other activities like wage labour (14%), basketry (8%), honey collection (4%), driving (4%), masonry (6%), weaving (10%), gardening (4%) and petty vending (7%). It is also found that 66% of the surveyed households have livestock, mainly piggery and poultry. Table 1 gives a brief description of the methods of farming in Khonoma village.

Table 1: Households involved in different methods of cultivation

Method of cultivation	*No. of households*	*Percentage*
Only alder base *jhum*	2	4%
Only terrace (wet rice) cultivation	16	32%
Both *jhum* and terrace	32	64%
Kitchen garden	34	68%

It has been reported that the majority of the households (86%) of Khonoma village are self-sufficient in food production for the entire year, while 14% households need to purchase rice for some months of the year.

5.2 Agricultural System

The natural landscapes of Khonoma have been used by the villagers through generations based on their Indigenous knowledge and skills; and, as such, they have developed a sustainable land use system (Figure 3). The farming system operated by the villagers facilitated conservation as well as sustainable use of the natural resources. Three distinctive agricultural systems namely, alder based *jhum*, terrace farming and kitchen gardening are observed in the village. The cropping cycle of each of the farming systems is closely associated with the rhythm of monsoonal rain (Figure 4). *Jhum* cultivation begins in winter season (December-January) with the process of slash and burn. Sowing of seeds starts during pre-monsoon period (April-May). The Eastern Himalayan region generally receive good amount of rainfall during the pre-monsoon period, which favours the growth of *jhum* crops. Transplantation of wet rice is done during the month of June-July. Post-monsoon is the season of harvesting when the farmers remain busy in harvesting crops from both the *jhum* and terrace fields. Cropping during the winter season is very limited due to scarcity of water in the hill slopes. Vegetables are grown in the kitchen gardens and some parts of the terrace fields with the help traditional system of irrigation.

There is no use of modern agricultural inputs and implements in farming carried out in the village. Human labour provided by the family members is the most important input. The seeds come from the previous year's stock. The villagers have their own method of seed conservation. Only a small section of the farmers is found to purchase seeds of certain crops such as potato, carrot, cabbage, etc. from the market. The villagers follow a unique land tenure system. Lands used both for terrace and *jhumming* are owned individually. The farmers have no land records and they do not follow any standard land measurement. Most of the farmers have agricultural land both for *jhumming* and terracing. Every household on an average have 3.3 terraced plots and 2.4 *jhum* plots. The size of plots in terracing is very small as compared to the *jhum* fields. It is noteworthy here that the decision for selection of land for *jhum* cultivation, irrigation management, etc. is taken by the people collectively.

Figure 3: Pattern of Land use and land cover of the study village

5.3 Alder-Based jhum *Farming*

The Himalayan Alder tree (*Alnus nepalensis*) naturally grows throughout the Himalayan countries such as Afghanistan, Pakistan, Nepal, Bhutan, India, Myanmar and China (Kehie, Khamu and Kehie, 2017). Several studies have shown that the *A. nepalensis* has been widely used in traditional agroforestry system for hill slope land management and soil conservation (Huber, Matiu, and Hülsbergen, 2018; Rana *et al.*, 2018). This tree hosts nitrogen-fixing bacteria, which help in enhancing soil fertility (Kehie, Khamu and Kehie, 2017; Rana *et al.*, 2018; Rathore, Karunakaran, and Prakash, 2010; Sharma *et al.,* 2008). Alder tree-based agroforestry, mixed with various commercial crops like cardamom, oranges, tea, etc., has been found economically helpful for the farmers (Mortimer *et al*., 2015; Sharma *et al.,* 2002). The Himalayan Alder is also a native plant to Khonoma village, which grows at an elevation of above 1,000 metres. The luxuriant growth of Alder trees in the mountains provides necessary base for the development of a unique system of shifting cultivation. Unlike the traditional *jhum* cultivation of North-East India, the villagers of Khonoma practise *jhum* cultivation in a different way. They cultivate a number of crops integrating with the Alder tree (Cairns, Keitzar and Yaden, 2010).

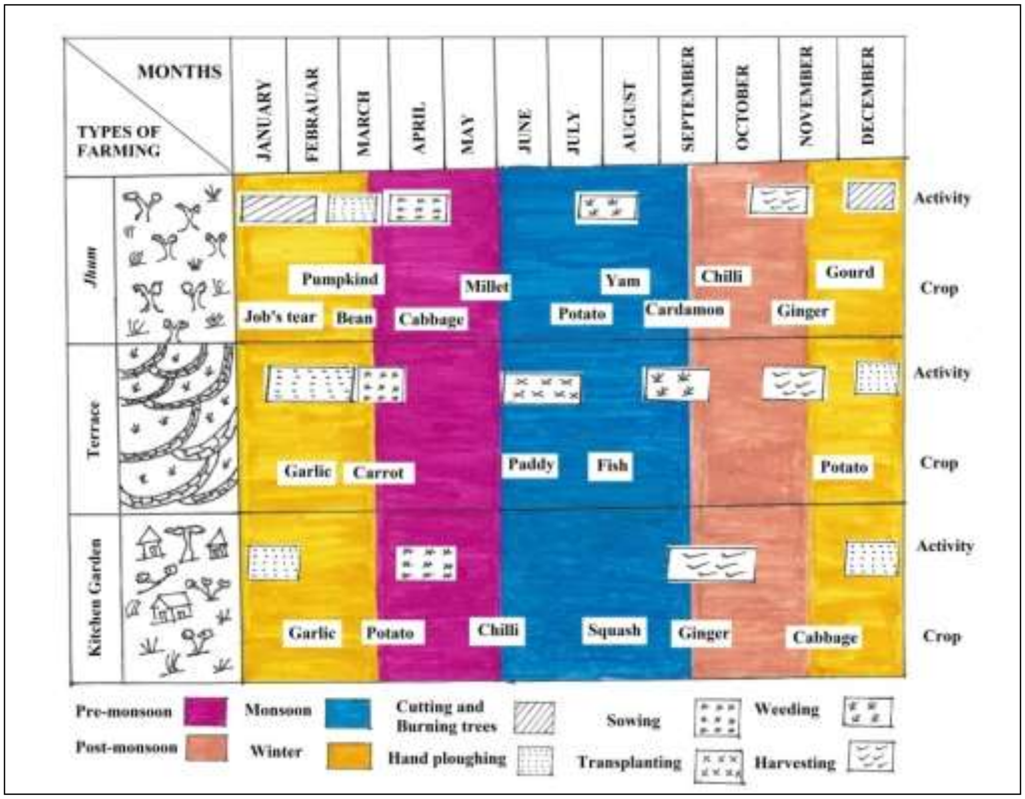

Figure 4: Farming cycle in Khonoma village

Before or after the slash and burn operation, the Alder trees are pollarded at the height of 2 meters from the ground. The vertical growth of the tree is restricted by pollarding the main trunk, leaving only few branches for apical growth. This practice not only keeps the crops underneath the trees from being shaded but also provides the benefit of fuel wood and organic manure. They use the pollarded branches as firewood and timber and the leaves and ashes of small tree branches as manure. As the growth of Alder tree is very fast, the branches become mature enough for *jhumming* within 5-6 years from the time of pollarding. Therefore, the farmers of this village can manage their *jhum* cycle within 5-6 sites of the forest patches without destroying the new forest lands. It is estimated that more than 80% of the firewood requirement of the village is met from the trees obtained from the *jhum* fields, which greatly reduces the pressure on the natural forest for firewood. Thus, the Alder-based *jhum* cultivation in Khonoma village sets a unique instance of ecological farming which, unlike the common *jhum* practice, does not cause forest loss and ecological imbalance in the mountain landscape of the Eastern Himalayas.

The villagers usually follow 5-6 years *jhum* cycle. After the pollardition and clearance of forests, they cultivate the land for two consecutive years. During this time, the growth of pollarded tree branches is restricted by cutting them carefully, and then for the next 3-4 years these are allowed to grow freely during the fallow period (Figure 5). Thus, the tree branches get enough time to grow and produce wood within the 5-6 years of *jhum* cycle. The farmers of Nagaland have also been practising various Indigenous soil conservation techniques for *jhum* land management (Singh, Devi and Singh, 2016). Usually during the rainy season, top soil of *jhum* fields, which contain enormous nutrients, gets eroded by the surface runoff (Yadav *et al*., 2006). To check such top soil erosion the villagers of Khonoma adopt the technique of contour bund using locally available natural materials such as stones, tree branches, log, bamboo, etc. The series of parallel as well as random bunds constructed by them across the hill slope minimize the speed of surface runoff and thus help in soil conservation.

The process of *jhum* cultivation begins with the clearing of forests by pollarding the Alder tree branches in the months of December and January. In January, they collect the dried branches for firewood and burn the slash (Figure 5). The activities such as digging of land for ploughing, mixing of ash and final preparation for sowing seeds are done in February and in the month of March generally seeds are sown. A number of crops such as potato, maize, bean, yam, pumpkin, cabbage, gourd, cucumber, etc. are grown together as mix-cropping. Job's tear (*Coix lacryma-jobi* L.) is sown in the month of April. Thus, the farmers apply intercropping methods in *jhumming*. July-August is the main harvesting season. In the second year, the same fields are used for cultivation of various cereal crops such as millet, sesame, etc. At present, farmers of the village have started cultivating large cardamom in some selected *jhum* fields

5.4 Terrace Farming

Like other communities of Nagaland, the Angami Naga farmers of Khnoma village have also some specific terraces for wet rice cultivation. Based on their Indigenous ecological knowledge and skills they have developed the terrace landscape in the valleys of the Dzüza and Khurü streams. These valleys are surrounded by hills and forests playing a significant role in the terrace farming. Besides these main streams, there are several small streams and springs originating from these hills, which provide necessary water to the fields. The soil characteristics and water quality of the terrace fields of the village are largely influenced by the natural forests around. Residual ash and other organic materials from *jhum* fields of the surrounding hills are drained to the valley to enhance the soil fertility. Therefore, the terrace fields adjacent to the hills have rich humus content that favours luxuriant growth of the crops. Based on the location the terrace fields of the village are divided into 14 units and each unit is identified with specific name like Ketsazhu, Keyafa Phi, Kenofú, Kelizü, Tehuphi, Chadaphi, Jüpfüzhu, Rülie liezú, Kerükhú, Nyúzekú, Púcha, Púgú, Mechakha, and Sikha liezú. Among these fields, Ketsazhu, Kerükhú, Chadaphi and Kenofú are the cold water fields, meaning the water of these fields remain cool as these are shadowed by the forests of the hills. Wet terraced paddy is the major crop of the village. The farmers cultivate various traditional rice varieties depending upon the suitability land (Table 2). In the cold-water fields, they plant the varieties suitable for cold-water environment. Similarly, the fields where the surface water becomes relatively hot due to direct sunshine insolation the villagers cultivate certain rice varieties that can tolerate warm water. Thus, the farmers of the Khonoma have been preserving several traditional rice varieties through generations. Each rice variety has unique aromatic and morphological characteristics. In Khonoma village, as many as 20 local varieties of rice have been in use. The farmers are very sincere in conserving the seeds of the local rice varieties. The farmers also collect seeds from other farmers of the village or the neighbouring villages in exchange to their seeds. They do not use any kind of chemical fertilizer and pesticides. Cow dung, pig dung, chicken privy, rice husk and ash are mainly used in the terrace fields as manure.

Figure 5: Alder based *jhum* farming practices at Khonoma village (Photo Credit: Sourav Saha)

Note: **A**-Alder tree in fallow *jhum* field; **B**- Burning after pollarding; **C**-Soil protection bund suing stone; **D**- Tree branches lying on hill slope to minimize flow speed and top soil erosion; **E**- Branches growing out after pollarding; **F**-Mixed crop in *jhum* field

The farmers begin the process of field preparation in the months of December and January by ploughing the lands, which thereafter involve different stages of cultivation (Table 3). During February and March, they level the surface of the field by breaking the large pieces of soil called *Chickro* and then keep the field fallow until the arrival of monsoon. In the meantime, during January-February, the seedlings are raised in the fields over adjacent high lands adjacent. Irrigation canals are cleared with the onset of monsoon and water is drained to the fields during April-May. The sides of the plots are plastered with soil paste to prevent water leakage except for the outlet point. The surface soil is turned and mixed so that the weeds get decomposed. Then the soil is levelled and bunds are plastered finally. During June-July, the rice seedlings are transplanted. Weeding is done after two-three weeks of transplantation. In October, again weeding is done before harvesting the crops. Some paddy fields are used for cultivation of potato, garlic and other vegetables during the *rabi* (December-March) season (Figure 6). However, large parts of the terrace fields remain fallow during this period due to scarcity of water.

Table 2: Traditional rice varieties cultivated in Khonoma village

Variety (Vernacular name)	*Morphological characteristics*	*Field condition*	*Uses*
1. Thevürü	Small, red,	Warm water	Food
2. Thevürü	Medium, round, white	Both cold and warm water	Food
3. Thevürü	Round and long, little tail, white	Both cold and warm water	Food
4. Ngoba	White	Warm and excess water	Food
5. Ngoba	Red	Warm and excess water	Suitable for eating
6. Ngodi	Red	Excess water	
7. Üisevolhunya		Cold water	Food, local beer
8. Rheninya	White	Cold water	Snakes and local beer
9. Krumiavinya	White	Cold water	Snakes and local beer
10. Dzükounya	Less production (cultivate only in one or two plots)	Cold water	Snakes and local beer
11. Kenonya		Warm water	Food
12. Shünino	Less cultivated now	Warm water	Food
13. Tsorenyü	White	Warm water	Food
14. Tekhwerü	White	Warm water	Food
15. Abor	White	Both cold and warm water	Food
16. Rosholha	White	Warm water	Food
17. Akaülha	White		Local beer
18. Mekrielha	Red, small, sticky	Both cold and warm water	Food
19. Mekrielha	White, long, less sticky	Both cold and warm water	Food
20. Mekrielha	White, long, long stem, high productive	Warm water	Food

Source: Focus group discussion with the farmers of Khonoma, 24 February 2021

Table 3: Works involved in terrace paddy field

Process	*Period*	*Work*
Tekhuhi	December-January	Digging soil/ plough the field
Niekrovü	February-March	Break the large pieces of soil into small size
Tekhunie	April	Watering the field first time through canal water and plastering the raised bund of plots
Sepuhu	May	To mix soil and to hide the grasses bellow the soil
Khopone	May	Final plastering the terrace *khupo* (bund) for water storage and flow
Tekhuse	June-July	Transplanting of paddy
Dzüva	August	Release water from the field and keep the field dry for 20 days to a month; weeding; shake the rice plant and scratch the roots so that the plant gets stronger and healthier
Khuporhe	August	Remove the grass from the border of the field and ensure the free flow of water (mainly do by women flock)
Thiphiviü	September	Remove the dry paddy leaves
Liekhro	October	Bind the paddy plants in bundles so that rice can be harvest easily
Liere	October	Harvest

Source: Focus group discussion with the farmers, February 2021

The farmers have traditionally developed a type of irrigation and water management system in their terraced wet paddy fields, which they call *Panikheti*. They channelize the hill stream water by constructing earthen canals and irrigate the terrace fields. The excess amount of water is transferred from one plot to another plot through specific outlets made in the fields' margin *khupo* (bunds). Bamboo pipes are commonly used for inter-field water supply. It is found that about 1/3rd of the terraced plots receive irrigation water throughout the year and remained wet, while other plots remained dry during the winter season. The plots, which receive water throughout the year, are more productive than the other plots. Ponds/ fisheries are most common in the terrace fields of the village. The farmers keep one or two *lha* (plot) of their wet plots as a pond for rearing fish and irrigating crops in the dry season (Figure 7). During June-July, the farmers release fish fingerlings in some paddy fields and harvest during October-November after the harvest of paddy. The farmers get extra benefits from the integration of fish farming in the paddy fields. It increases the soil fertility (adding nitrogen) and provides additional benefit to the farmers (Halwart, 1998; Saikia and Das, 2008). Some studies show that the rice yield is higher in fish-cum-paddy fields than the normal paddy fields (Lu and Li, 2006; Tsuruta *et al.*, 2011). In addition to pisciculture, the practice of apiculture (rearing of bee) is very common in the terrace fields of Khonoma. The farmers of Khonoma have skill of making beehives boxes by using tree trunks. They keep the beehive boxes on the *bunds* of terrace fields for honeybee and, thus, get honey as an additional product. Thus, the farmers have skilfully used the *bunds* of the terrace fields for productive purposes.

Figure 6: Terrace fields during *kharif* (A,B) and *rabi* (C,D) season (Photo Credit: Sourav Saha)

Figure 7: Dry and wet terrace fields (A), beehives (B) and fisheries (C & D) in the terrace fields (Photo Credit: Sourav Saha)

Figure 8: Kitchen gardens backside the residential plots (Photo Credit: Sourav Saha)

5.5 Kitchen Garden

Kitchen gardening is also very common among the people of Khonoma village. Besides *jhum* and terrace fields, the vegetable farming is done in the small kitchen gardens located close to the residential areas. Average size of the kitchen gardens varies from 0.012-0.017 acre. As the agricultural fields, both *jhum* fields and terraces are far from the residential area, the villagers cultivate various vegetables for their daily consumption (Figure 8).

The villagers cultivate different season vegetables such as cabbage, king chilli, tomato, chayote, spinach, mustard leaf, ginger, garlic, onion, eggplant, potato, yam, pumpkin, etc. in their kitchen gardens. Like *jhum* and terrace fields, the farming methods in kitchen gardens are purely organic. Fire wood ash of their kitchen, pig dung and poultry's excreta are used as manure in these gardens. Kitchen gardens are mostly rain fed and sometime they irrigated from their households. The women are mostly taking care about the kitchen gardens. As the plots are tiny and much closed to residential area, they can nurture more intensely.

6. Conclusion

From the above discussion, it can be concluded that the indigenous Angami Naga tribal community of Khonoma village of Nagaland has successfully adopted micro-level location specific strategies for farming and maintaining sustainable agriculture practices. Their farming practices are not only ecologically adaptive but also economically sustainable. Except manual labour, capital investment for other input budgets are very negligible. The villagers do not use any chemical fertilizers and pesticides in their farmland.

The Alder-based shifting cultivation of the village demonstrates the effective use and conservation of forest and soil by limiting the process of deforestation. The practice of integrated pisciculture and apiculture in the wet terrace paddy fields of the village is a sustainable and effective for land and water management in the hilly environment. All the farming practices of the village are cost effective and the farmers are self-sufficient in terms of seeds, manure, etc. Maintenance of crop diversity through their age-old farming practices not only helps in conservation of agrobiodiversity but also provide scope for adaptation and development of climate resilient agriculture.

In the present context of climate change, rapid environmental degradation and forest cover loss, the traditional farming system practiced by the ethnic communities of the ecologically sensitive mountain areas of the Eastern

Himalayas set a good example of sustainable agro-ecosystem evolved locally by the people of the area. The traditional agricultural knowledge and skills of the Indigenous communities that they developed through generations have, of late, attracted attention of the ecologists, agricultural scientists and environmentalists because of the negative effect of the modern agriculture on the environment. This Alder based *jhum* and terraced paddy cultivation if diffused to other parts of the Eastern Himalayan region, may help in mitigating the problem of environmental degradation on the one hand and ensuring the livelihood sustainability of the mountain-dwellers on the other.

7. Acknowledgement

This research was supported by the Department of Science and Technology (DST), Government of India, under Climate Change Programme - National Mission for Sustaining the Himalayan Ecosystem (Grant No. DST/CCP/MRDP/191/2019 Dated 18/03/2020). The authors are grateful to Gauhati University for providing a conducive environment for preparing the manuscript during the period of research work. Special thanks go to Mrs. Moonmon Googoi and Miss Thejanguno Peseyie for their help in field survey. The authors are also thankful to the villagers of Khonoma village, Nagaland for their generous support in collecting primary information.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	Author 1	Author 2	Author 3	Author 4	Author 5
Conceived and designed the research or analysis	Yes	Yes			
Collected the data	Yes	No			
Contributed to data analysis and interpretation	Yes	Yes			
Wrote the article/paper	Yes	No			
Critical revision of the article/paper	Yes	Yes			
Editing of the article/paper	Yes	Yes			
Supervision	Yes	Yes			
Project Administration	Yes	No			
Funding Acquisition	No	No			
Overall Contribution Proportion (%)	70	30			

Funding

This research was supported by the Department of Science and Technology (DST), Government of India, under Climate Change Programme - National Mission for Sustaining the Himalayan Ecosystem (Grant No. DST/CCP/MRDP/191/2019 Dated 18/03/2020).

Research involving human bodies or organs or tissues (Helsinki Declaration)

The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

Research involving animals (ARRIVE Checklist)

The author(s) solemnly declare(s) that this research has not involved any animal subject (body or organs) for experimentation. The research was not based on laboratory experiment involving any kind animal. The contexts of animals were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of ARRIVE does not apply in cases of this study or written work.

Research on Indigenous Peoples and/or Traditional Knowledge

The author(s) solemnly declare(s) that this research has involved Indigenous Peoples as participants or respondents. The contexts of Indigenous Peoples or Indigenous Knowledge were also indirectly covered through literature review. Therefore, copy of a Consent Form and a Self-Declaration in this regard are appended along with this article.

Research involving Plants
The author(s) solemnly declare(s) that this research has involved the plants for experiment or field studies. Some contexts of plants are also indirectly covered through literature review. Thus, during this research the author(s) obeyed the principles of the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora.

Research Involving Local Community Participants (Non-Indigenous) or Children
The author(s) solemnly declare(s) that this research has directly involved local community participants or respondents belonging to non-Indigenous peoples. However, this study did not involve any child in any form directly. The contexts of different humans, people, populations, men/women/children and ethnic people are also indirectly covered through literature review. A sample copy of the Consent Form implying prior informed consent (PIC) of the respondents is appended.

(Optional) PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)
The author(s) has/have NOT complied with PRISMA standards. It is not relevant in case of this study or written work.

Competing Interests/Conflict of Interest
Author(s) has/have no competing financial, professional, or personal interests from other parties or in publishing this manuscript. There is no conflict of interest with the publisher or the editorial team or the reviewers.

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INFORMATION AND CONSENT FORM FROM RESPONDENTS
(Non-Indigenous or Indigenous Respondents)
This form was translated into local language for the respondents

Title of the Research: Traditional Ecological Farming Practices in the Eastern Himalayan Mountain Environment: Case of a Naga Village, Nagaland (India)

Principal Researcher: Dr. Sourav Saha, Department of Geography, Mahapurusha Srimanta Sankaradeva Viswavidyalaya, Nagaon-782001, Assam (India)

Research Supervisor: Dr. Ratul Mahanta, Dr. Nityanana Deka and Dr. Abani Kumar Bhagabati
Gauhati University, Guhahati-782001

A) INFORMATION TO PARTICIPANTS

1. Objectives of the research

The objectives of this study were to investigate the nature and investigate nature and types of traditional farming practices and crop cycles developed by the indigenous communities based on the local climate, ecology and indigenous knowledge system.

2. Participation in research

The researcher will ask you several pertinent questions. This interview will be recorded in written form and should last about 50-60 minutes. The location and timing of the interview will be determined by you, depending on your availability and convenience.

3. Risks and disadvantages

There is no particular risk involved in this project. You may, however, refuse to answer any question at any time or even terminate the interview.

4. Advantanges and benefits

You will receive intangible benefits even if you refuse to answer some questions or decide to terminate the interview. You will also contribute nature and types of traditional farming practices and crop cycles developed by the indigenous communities

5. Confidentiality

Personal information you give us will be kept confidential. No information identifying you in any way will be published. In addition, each participant in the research will be assigned a code and only the researcher will know your identity.

6. Right of withdrawal

Your participation in this project is entirely voluntary and you can at any time withdraw from the research on simple verbal notice and without having to justify your decision, without consequence to you. If you decide to opt out of the research, please contact the researcher at the telephone number or email listed below. At your request, all information concerning you can also be destroyed. However, after the outbreak of the publishing process, it is impossible to destroy the analyses and results on the data collected.

B) CONSENT

Declaration of the participant

- ⇨ I understand that I can take some time to think before agreeing or not to participate in the research.
- ⇨ I can ask the research team questions and ask for satisfactory answers.
- ⇨ I understand that by participating in this research project, I do not relinquish any of my rights, including my right to terminate the interview at any time.
- ⇨ I have read this information and consent form and agree to participate in the research project.
- ⇨ I agree that the interviews be recorded in written form by the researcher: Yes ( ) No ( )

Signature of the participant : ____________________ Date : ____________21.07.2023________

Surname : ____________ ________________ First name : ______________ _____________

Researcher engagement

I explained to the participant the conditions for participation in the research project. I answered to the best of my knowledge the questions asked and I made sure of the participant's understanding. I, along with the research team, agree to abide by what was agreed to in this information and consent form.

Sourav Saha

Signature of the researcher : Date : 22-07-2023

Surname: Saha First name: Sourav

- ⇨ Should you have any questions regarding this study, or to withdraw from the research, please contact Dr. Sourav Saha by e-mail sourav.saha626@gmail.com
- ⇨ If you have any concerns about your rights or about the responsabilités of researchers concerning your participation in this project, you can contact the Dr. Ratul Mahanta, Department of Economics, Gauhati University, Guwahati-781014 Assam, by email rmeco@gauhati.ac.in

SELF-DECLARATION FORM

Research on Indigenous Peoples and/or Traditional Knowledge

1. Conditions of the Research

1.1 Was or will the research (be) conducted on (an) Indigenous land, including reserve, settlement, and land governed under a self-government rule/agreement or?

Yes

1.2 Did/does any of the criteria for participation include membership in an Indigenous community, group of communities, or organization, including urban Indigenous populations?

No

1.3 Did/does the research seek inputs from participants (members of the Indigenous community) regarding a community's cultural heritage, artifacts, traditional knowledge, biocultural or biological resources or unique characteristics/practices?

Yes

1.4 Did/will Aboriginal identity or membership in an Indigenous community used or be used as a variable for the purposes of analysis?

No

2. Community Engagement

2.1 If you answered "Yes" to questions 1.1, 1.2, 1.3 or 1.4, have you initiated or do you intend to initiate an engagement process with the Indigenous collective, community or communities for this study?

Yes

2.2 If you answered "Yes" to question 2.1, describe the process that you have followed or will follow with to community engagement. Include any documentation of consultations (*i.e., formal research agreement, letter of approval, PIC, email communications, etc*.) and the role or position of those consulted, including their names if appropriate:

First of all, the village headman of the local community was approached and consulted about the purpose of the study. Then with his help the other community members respondents were approached for a PRA meting and group discussions. They were consulted during the meeting. Verbal agreement was done for information use and analysis.

3. No Community Consultation or Engagement

If you answered "No" to question 2.1, briefly describe why community engagement will not be sought and how you can conduct a study that respects Aboriginal/ Indigenous communities and participants in the absence of community engagement.

Not Applicable

- ⇨ Name of Principal Researcher: Dr. Sourav Saha
- ⇨ Affiliation of Principal Researcher: Department of Geography, Mahapurusha Srimanta Sankaradeva Viswavidyalaya, Nagaon-782001, Assam (India)

Signature: Sourav Saha

Declaration: Submitting this note by email to any journal published by The Grassroots Institute is your confirmation that the information declared above is correct and devoid of any manipulation.