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FACULTY OF AGRICULTURE AND TECHNOLOGY

AUTOREFERÁT DISERTAČNÍ PRÁCE

DISSERTATION'S SUMMARY

Dissertation Topic

OPPORTUNITIES FOR SUSTAINABLE AGRICULTURE IN MOUNTAINOUS LANDSCAPE OF NEPAL

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Dissertation summary

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Abstrakt

Udržitelné zemědělství v horské krajině Nepálu má zásadní význam pro zlepšení potravinové bezpečnosti, zachování biologické rozmanitosti a zlepšení životních podmínek. Rukopis s názvem „Příležitosti pro udržitelné zemědělství v horské krajině Nepálu" zkoumá udržitelné zemědělské postupy v náročném nepálském terénu se zaměřením na ekologické zemědělství, odolnost vůči klimatu a rozvoj řízený komunitou. Studie se zaměřuje na revitalizaci opuštěné zemědělské půdy, zejména v okrese Dolakha, kde jsou tradiční postupy ohroženy degradací půdy, změnou klimatu a socioekonomickými tlaky, jako je vylidňování venkova.

Hlavním cílem tohoto výzkumu je posoudit stav a status udržitelného zemědělství ve středních kopcích Nepálu, pokud jde o opuštěnou nebo nedostatečně využívanou zemědělskou půdu, a identifikovat vhodné oblasti pro ekologické zemědělství s využitím multidisciplinárního přístupu. Kromě toho je cílem tohoto projektu zlepšit porozumění potenciálním dopadům klimatických změn na ekologické zemědělství v regionu a navrhnout účinné adaptační strategie. Studie zkoumá inovativní možnosti využití půdy, zejména v oblasti ekologického zemědělství, a jejím cílem je informovat o politice a zlepšit postupy, které podporují udržitelnost a odolnost místních zemědělských komunit. Mezi specifické cíle patří stanovení výchozího stavu pro hodnocení potenciálních strategií opětovného využití opuštěné nebo nedostatečně využívané zemědělské půdy, pochopení příčin opouštění půdy a identifikace socioekonomických faktorů, jako je migrace a degradace půdy, které k tomuto problému přispívají.

Značný důraz je kladen na zkoumání vhodných možností využití půdy, které upřednostňují ekologické zemědělství. Studie identifikuje odolné plodiny, které jsou schopny odolávat klimatickým výzvám a zároveň odpovídají preferencím místních zemědělců. Integrace tradičních znalostí s moderními zemědělskými technikami má za cíl zvýšit ochranu životního prostředí a produktivitu. Tento cíl zahrnuje analýzu potenciálních přínosů a problémů navrhovaných postupů využívání půdy, přičemž je zajištěna jejich dlouhodobá ekologická a ekonomická životaschopnost. Hypotéza předpokládá, že účinné opětovné využití opuštěné zemědělské půdy může přinést významné ekologické a ekonomické výhody. Tím, že se tento výzkum zabývá základními příčinami opuštění půdy a navrhuje udržitelná řešení, zdůrazňuje potenciál ekologického zemědělství pro zlepšení zdraví půdy, zvýšení biologické rozmanitosti a zlepšení sekvestrace uhlíku.

Problematika opouštění půdy je zkoumána v globálním i národním kontextu, přičemž je zohledněno, že k tomuto jevu přispívají změny na trhu práce, změna klimatu a zhoršování

životního prostředí. Faktory, jako je migrace do měst, nedostatečný přístup na trh, pokles dostupnosti pracovních sil na venkově a eroze půdy, vedly k tomu, že rozsáhlá zemědělská půda zůstává nevyužita.

Propojením udržitelných postupů podporovaných moderními technologiemi s tradičními zemědělskými postupy v Nepálu studie ukázala, jak lze udržitelná řešení přizpůsobit různorodým agroekologickým zónám země. Zjištění navíc ukazují, že ekologické zemědělství a agrolesnictví využívající původní a klimaticky odolné plodiny mohou zvýšit odolnost místních zemědělských systémů vůči změně klimatu, podpořit biologickou rozmanitost a zachovat kulturní význam v rámci místních komunit.

Tato studie s využitím geografických informačních systémů (GIS), klimatického modelování a socioekonomických průzkumů hodnotí vhodnost krajiny a zemědělství v okrese Dolakha. Tyto metodiky usnadňují mapování vhodnosti půdy, hodnocení klimatických podmínek a modelování růstu plodin v různých terénech. Díky identifikaci optimálních lokalit pro udržitelné zemědělství nabízí tento přístup poznatky založené na datech pro efektivní plánování využití půdy.

Souhrnně lze říci, že tato studie přispívá k udržitelnému využívání zemědělské půdy, které vyvažuje ochranu životního prostředí a ekonomickou životaschopnost. Díky řešení vzájemně propojených problémů, jako je opouštění půdy, ekologické zemědělství a změna klimatu, mohou výsledky této studie přispět k odolnosti a udržitelnosti zemědělských postupů ve středohorách Nepálu.

Abstract

Sustainable agriculture in the mountain landscapes of Nepal is crucial for improving food security, conserving biodiversity and improving livelihoods. The manuscript titled "Opportunities for Sustainable Agriculture in the Mountainous Landscape of Nepal" explores sustainable agricultural practices in Nepal's challenging terrain, focusing on organic agriculture, climate resilience and community-driven development. The focus of this study is on the revitalization of abandoned agricultural land, particularly in the Dolakha district, where traditional practices are threatened by land degradation, climate change and socio-economic pressures such as rural depopulation.

The main objectives of this research is to assess the condition and status of sustainable agriculture in the middle hills of Nepal, regarding abandoned or underutilized agricultural land, and to identify suitable areas for organic farming using multidisciplinary approach. In addition, this project aims to enhance understanding of the potential impacts of climate change on organic agriculture in the region and propose effective adaptation strategies.

By exploring innovative land use options, particularly in the area of organic agriculture, the study aims to inform policy and improve practices that promote sustainability and resilience of local farming communities. Specific objectives include establishing a baseline for evaluating potential reuse strategies for abandoned or underutilized agricultural land, understanding the causes of land abandonment, and identifying socio-economic factors such as migration and land degradation that contribute to the problem.

A significant emphasis is placed on exploring suitable land use options that prioritize organic agriculture. The study identifies resilient crops capable of withstanding climate challenges while aligning with local farmers' preferences. The integration of traditional knowledge with modern agricultural techniques aims to enhance environmental conservation and productivity. This objective entails analyzing the potential benefits and challenges of proposed land use practices, ensuring they provide long-term ecological and economic viability. The hypothesis posits that the effective reutilization of abandoned agricultural land can yield significant environmental and economic benefits. By addressing the root causes of abandonment and proposing sustainable solutions, this research underscores the potential of organic agriculture to enhance soil health, increase biodiversity, and improve carbon sequestration.

The issue of land abandonment is examined in both a global and national context, acknowledging that shifts in the labor market, climate change, and environmental degradation contribute to this phenomenon. Factors such as urban migration, inadequate market access, a decline in rural labor availability, and soil erosion have resulted in extensive farmlands being left unused.

By linking sustainable practices, supported with modern technologies, with traditional agricultural practices in Nepal, the study illustrated how sustainable solutions can be tailored to the country's diverse agroecological zones. In addition, the findings indicate that organic farming and agroforestry, using indigenous and climate-resilient crops, can enhance the resilience of local farming systems to climate change, fostering biodiversity, and preserving cultural relevance within local communities.

Utilizing Geographic Information Systems (GIS), climate modeling, and socioeconomic surveys, this study assesses the landscape and agricultural suitability of the Dolakha District. These methodologies facilitate the mapping of land suitability, evaluation of climatic conditions, and modeling of crop growth across diverse terrains. By identifying optimal locations for sustainable agriculture, this approach offers data-driven insights for effective land use planning.

In summary, this study contributes to sustainable agricultural land use that balances environmental conservation with economic viability. By addressing the interconnected challenges of land abandonment, organic agriculture, and climate change, the findings of this study can conribute to the resilience and sustainability of agricultural practices in Nepal's mid-hills.

Contents

1. Introduction

Nepal's mountainous landscapes present unique challenges and opportunities for agriculture. The mid-hills and high-altitude regions are characterized by diverse ecological zones, varying microclimates, and cultural practices that significantly influence agricultural productivity. Sustainable agriculture in these regions is crucial for improving food security, conserving biodiversity, and enhancing the livelihoods of rural communities. Following literature review explores the current state of research on sustainable agriculture in Nepal's mountainous regions, focusing on abandoned agricultural lands, organic farming, resilient crops, and the socioeconomic factors influencing agricultural practices.

2. Aims and hypotheses

Aims of the Study

The primary objective of this study is to assess the condition and status of sustainable agriculture in the mid-hills of Nepal's mountainous region, especially organic agriculture, with the emphazise on abandoned or underutilized agricultural land. The study seeks to explore suitable land use options for this type of landscape and evaluate their environmental and economic impacts to contribute to the development of a sustainable organic farming model for mountain farmers in Nepal.

Specific Objectives:

1. Assess the condition and status of abandoned or underutilized agricultural land in the mid-hills of Nepal's mountainous region.
2. Explore suitable land use options for abandoned or underutilized agricultural areas, focusing on organic agriculture and sustainable practices.
3. Identify and promote resilient crops that can withstand changing bio-climatic conditions while aligning with the preferences of local farmers, contributing to a sustainable organic farming model.

Hypothesis:

The hypothesis of this study is that the reutilization of abandoned agricultural land in the mid-hills of Nepal's mountainous region can lead to substantial environmental and economic benefits, particularly through the promotion of organic agriculture.

3. Literature review

Sustainable agriculture in the mountainous landscapes of Nepal offers significant opportunities for enhancing food security, conserving biodiversity, and improving livelihoods (Bhatta et al., 2020). Assessing abandoned agricultural lands is critical for identifying potential areas for revitalization and informing sustainable land use strategies (Adhikari et al., 2015). Research indicates that integrating organic farming practices can restore degraded lands, improve soil health, and reduce reliance on chemical inputs, thereby enhancing overall agricultural sustainability (Regmi & Ogle, 2018; Poudel et al., 2019). Promoting resilient crops that can withstand changing climatic conditions is essential for ensuring food security in these vulnerable regions (Khanal et al., 2019; Sitaula et al., 2020). By focusing on indigenous crop varieties that are naturally adapted to local environmental conditions, stakeholders can support local food systems while preserving cultural heritage and enhancing biodiversity (Khanal et al., 2019). Additionally, incorporating local farmers' preferences into crop selection processes fosters greater acceptance and successful adoption of new agricultural practices (Shrestha & Bhatta, 2018).

The socioeconomic context is equally vital in shaping sustainable agricultural development in Nepal (Thapa et al., 2017). Access to resources, market opportunities, and policy support significantly influence farmers' adoption of sustainable practices (Shrestha & Bhatta, 2018). Government policies, community-based initiatives, and capacity-building efforts are essential for empowering local farmers and facilitating the transition toward sustainable agriculture (Pandit & Schmidt, 2016). Despite the existing research, significant gaps remain that must be addressed to effectively guide future research and policy initiatives (Thapa et al., 2017). Comprehensive studies integrating biophysical and socioeconomic factors are crucial for assessing land use sustainability in abandoned agricultural areas (Adhikari et al., 2015). Additionally, there is a need for longitudinal studies to evaluate the long-term impacts of organic farming practices on soil health and biodiversity (Poudel et al., 2019). Exploring the role of local knowledge in promoting sustainable agriculture can enhance adaptive capacities and resilience among farming communities (Shrestha & Bhatta, 2018). Understanding cultural and social dynamics is also important for developing effective strategies that consider local livelihoods (Pandit & Schmidt, 2016).

Sustainability has emerged as a major concern across all economic and political sectors since the UN Conference on Environment and Development in Rio in 1992 (Siebrecht, 2020). While improved crop varieties, management practices, and external inputs like fertilizers have increased food production, they have also jeopardized natural resources, leading to environmental degradation, including air and water pollution, soil depletion, and diminishing biodiversity (Willer et al., 2008; Pingali, 2012;). The criticisms of the Green Revolution and conventional agriculture have prompted the exploration of more sustainable alternatives (Lampridi et al., 2019). This context has positioned organic agriculture as a viable alternative, promoting sustainability through environmentally friendly practices. According to the Food and Agriculture Organization (FAO), organic cultivation eliminates chemical inputs, thus increasing crop yields without harming ecosystems (Kazi et al., 2014).

Organic farming is emerging as an effective solution for sustainable agriculture, especially as this sector grows rapidly in many countries (Rigby & Caceres, 2001). Studies indicate that organic farming systems are generally more environmentally beneficial than conventional systems (Pacini et al., 2004). Furthermore, organic practices hold significant potential for enhancing sustainable agro-landscape management and promoting landscape diversity (van Mansvelt et al., 1998). The environmental benefits of organic farming include strengthening local food markets, enhancing biodiversity, improving soil quality, reducing contamination, and optimizing water use (Anand et al., 2019).

Nepal's mountainous landscape, characterized by diverse agroecological zones and unique geographical features, presents both challenges and opportunities for sustainable agriculture (Rasul & Sharma, 2016). The country’s topography, ranging from the Terai plains to the peaks of the Himalayas, offers distinct ecological and climatic conditions that shape agricultural practices (Tiwari et al., 2019, 2023). For centuries, Nepal’s mountain communities have relied on traditional farming systems that evolved in harmony with the environment, reflecting a deep-rooted relationship between culture and agriculture (Rasul & Sharma, 2016). However, increasing pressures from climate change, population growth, and declining soil fertility necessitate a shift toward more resilient and sustainable practices (Tiwari et al., 2019).

The mountainous regions of Nepal face significant challenges and opportunities in achieving sustainable agricultural development (Shrestha et al., 2018; Gauli et al., 2023). These areas feature diverse agroecological conditions, including nutrient-rich crops with market potential as niche products (Gauli et al., 2023). Rapid population growth, environmental degradation, and the impacts of climate change have heightened vulnerabilities, threatening food security and livelihoods (Shrestha et al., 2018). Traditional farming methods, coupled with limited market access and inadequate infrastructure, complicate the adoption of sustainable practices (Thapa et al., 2017). Additionally, issues like low soil fertility and weakened farm-forest linkages hinder sustainable land management (Gauli et al., 2023). Nevertheless, Nepal's agroecological diversity and suitable land for agroforestry present opportunities for integrating sustainable practices (Rasul & Sharma, 2016). The country also possesses traditional knowledge, skilled labor, and the potential to adapt new technologies, all essential for enhancing agricultural productivity and sustainability (Regmi & Ogle, 2018; Gauli et al., 2023;). There are untapped opportunities to promote sustainable agriculture that enhances productivity, conserves biodiversity, and improves resilience among farming communities (Pandit & Schmidt, 2016).

Identifying sustainable agricultural practices is crucial for ensuring food security in these mountainous regions, where harsh climatic conditions and limited arable land pose unique challenges (Regmi & Ogle, 2018). Furthermore, the unique ecosystems of Nepal’s mountains are highly susceptible to degradation from unsustainable practices, making it imperative to identify sustainable agricultural opportunities for environmental conservation (Gafsi et al., 2010). The increasing impacts of climate change further necessitate resilient agricultural practices that empower farmers to adapt (Sitaula et al., 2020). Integrating traditional knowledge with modern agricultural techniques is vital for crafting solutions tailored to local contexts and fostering community engagement (Adhikari et al., 2015). Understanding these opportunities is essential for informing policy frameworks that support sustainability and address barriers to practice adoption (Morris & Potter, 1995). Given the urgency of enhancing food security, conserving the environment, and improving livelihoods, this study aims to provide valuable insights into sustainable agricultural development strategies tailored to the unique challenges faced by mountain farmers in Nepal.

In this context, fostering sustainable agriculture in the mountainous regions of Nepal offers significant potential for improving food security, conserving biodiversity, and enhancing rural livelihoods (Rasul & Sharma, 2016; Regmi & Ogle, 2018). These combined factors create a fertile ground for developing sustainable agricultural systems that benefit both the environment and local communities (Thapa et al., 2017). Fostering sustainable agriculture in Nepal’s mountainous regions offers substantial potential for improving food security, conserving biodiversity, and enhancing rural livelihoods (Rasul & Sharma, 2016; Regmi & Ogle, 2018). By focusing on abandoned agricultural lands, stakeholders can tap into underutilized resources, promoting organic farming and resilient crops that are better suited to local conditions and market demands (Shrestha et al., 2018; Khanal et al., 2019). Considering the socioeconomic context is crucial for developing tailored strategies that address local needs and empower communities (Thapa et al., 2017). Addressing existing gaps in organic farming is essential for guiding future research and policy initiatives aimed at fostering sustainable agriculture in these unique environments (Morris & Potter, 1995; Wilson, 1997).

Despite the opportunities, significant challenges remain in promoting sustainable agriculture in Nepal’s mountainous regions (Gauli et al., 2023). The remoteness of many mountain communities complicates access to markets, agricultural inputs, and extension services, limiting farmers’ ability to adopt new technologies (Pandit & Schmidt, 2016; Paudel et al., 2020). Furthermore, soil degradation, exacerbated by deforestation and overgrazing, poses a serious threat to the long-term viability of mountain farming systems (Gautam et al., 2003; Sitaula et al., 2020). This degradation undermines soil fertility, diminishing agricultural productivity and food security for local communities (Adhikari et al., 2015). Addressing these challenges requires a concerted effort from government agencies, international partners, and local communities to improve infrastructure, restore degraded landscapes, and enhance access to knowledge and resources (Gafsi et al., 2010; Sharma et al., 2021). By collaborating on these initiatives, stakeholders can create a supportive environment for sustainable agricultural practices that benefit both people and the planet (Scialabba & Mueller-Lindenlauf, 2010). Therefore, it is essential to conduct this study, which aims to explore the current state of research on sustainable agriculture in Nepal's mountainous regions. This investigation will focus on how abandoned or underutilized agricultural lands can be revitalized for sustainable organic farming practices. The study will also examine the cultivation of resilient crop varieties that can withstand the challenges posed by climate change and other environmental pressures. Additionally, it will analyze the socioeconomic factors influencing agricultural practices, such as access to resources, market opportunities, and community preferences. By understanding these interconnected elements, the research seeks to identify actionable strategies that can enhance agricultural sustainability, improve local livelihoods, and promote biodiversity conservation in these vulnerable landscapes. Ultimately, this study will contribute to a comprehensive understanding of how to leverage existing agricultural resources while addressing the pressing challenges faced by farming communities in Nepal's mountainous regions.

4. Material and Methods

This methodology aims to provide a robust analysis of the opportunities for sustainable agriculture in Nepal's mountainous regions, with a focus on the Dolakha area. The study primarily employed qualitative methods with an emphasis on semi-structured interviews, literature review, supplemented by quantitative data collection and analysis and stakeholder engagement. It also integrated an interdisciplinary approach, combining insights from agricultural sciences, climate change studies, land use management, and socio-economic development.

The literature review focused on abandoned or underutilized agricultural land, the process of agricultural land abandonment and organic agriculture. The semi-structured interviews covered a range of topics such as types of agriculture, organic farming practices, impacts of climate change, sustainability of current agricultural practices, economic effectiveness, land abandonment, and alternative options for improving agriculture. Field data on questionnaire collection included information on land ownership, agricultural production, agriculture intensification, and the use of abandoned terraces. Stakeholders such as municipality representatives, cooperative members, farmers, and agricultural experts were engaged to gather diverse perspectives. The questionnaire was based on the semi-structured interview topics and were included detailed questions on increasing the efficiency of organic farming and the potential uses of abandoned plots. Through a combination of qualitative and quantitative approaches, the study addresses challenges like organic farming, climate change, and land abandonment while offering practical recommendations for improving agricultural sustainability. The combination of advanced spatial data (GIS, Remote sensing data, and EcoCrop modelling) with on-the-ground insights (household questionnaire survey, interviews, focus groups) ensured a holistic analysis of sustainable agricultural opportunities in Dolakha.

4.1 Areas of interest

Collecting comprehensive data on land ownership, production trends, land-use intensity, and organic farming potential is essential for promoting sustainable agriculture in Dolakha of Nepal.

Geographically, Dolakha is located between 27°28' and 28°0' north latitude and 85°50' and 86°32' east longitude, with an altitude ranging from 732 to 7148 meters above sea level, reflecting its diverse topography from lowland areas to high mountainous regions (Dolakha Agriculture Development Office [DADO], 2015). The total area of the district is 2142.87 km²

(DADO, 2015). In terms of land use, Dolakha has a significant portion of its territory dedicated to agriculture, forests, and grasslands.
Dolakha District encompasses a range of climatic zones, including subtropical, warm-temperate, cool-temperate (in mountainous areas), subalpine, and alpine climates. This diversity in climate is a result of the district's varied topography, which spans from lowland areas to high-altitude mountain regions. The average annual air temperature in Dolakha ranges from 3°C to 22°C, reflecting the wide variation in temperature across different elevations (VDC Profile, 2009).

The total population of Dolakha District is 186,557 people, with a gender distribution of 99,554 women and 87,003 men, resulting in a population density of 87 people per square kilometer. The district comprises 45,688 households, with an average household size of 4.08 persons (CSB, 2011). The majority of the population identifies as Hindu (71.05%), followed by Buddhists (28.59%), and a small percentage classified as "other" (0.36%). The ethnic composition of the district is diverse, with Chhetri making up 35.8%, Tamang 15.9%, and Brahmin 9.8%.

According to the Nepal Human Development Report (2014), Dolakha has a Human Development Index (HDI) score of 0.459 and a Human Poverty Index (HPI) score of 35.7, indicating significant challenges in terms of human development and poverty alleviation (UNDP, 2014).

The study encompasses 2 wards of Bhimeshwor Municipality—Boch and Lakuridanda along with all 6 wards of Shailung Rural Municipality: Dudpokhari, Bhusafeda, Maghapauwa, Katakuti, Fasku, and Sailungeswor (Figure 1).

Figure 1: Area of interest in the Dolakha district

4.2 Research Design

The socio-cultural study employed a multi-method research design that incorporated qualitative semi-structured interviews, a field questionnaire, and secondary data analysis (Figure 2). This design integrates the socio-cultural aspects of farming with environmental and economic dimensions, providing a comprehensive perspective on the opportunities for sustainable agriculture in the area. A mixed-methods approach was adopted, combining both quantitative and qualitative data collection (Table 1). The quantitative methods included a household survey with 260 respondents from eight wards (formerly Village Development Committees), along with GIS and remote sensing data analysis. Additionally, input was gathered from 25 district-level experts, including representatives from the municipality, agriculture and forestry departments, landowners, private farmers, researchers, and NGO representatives.

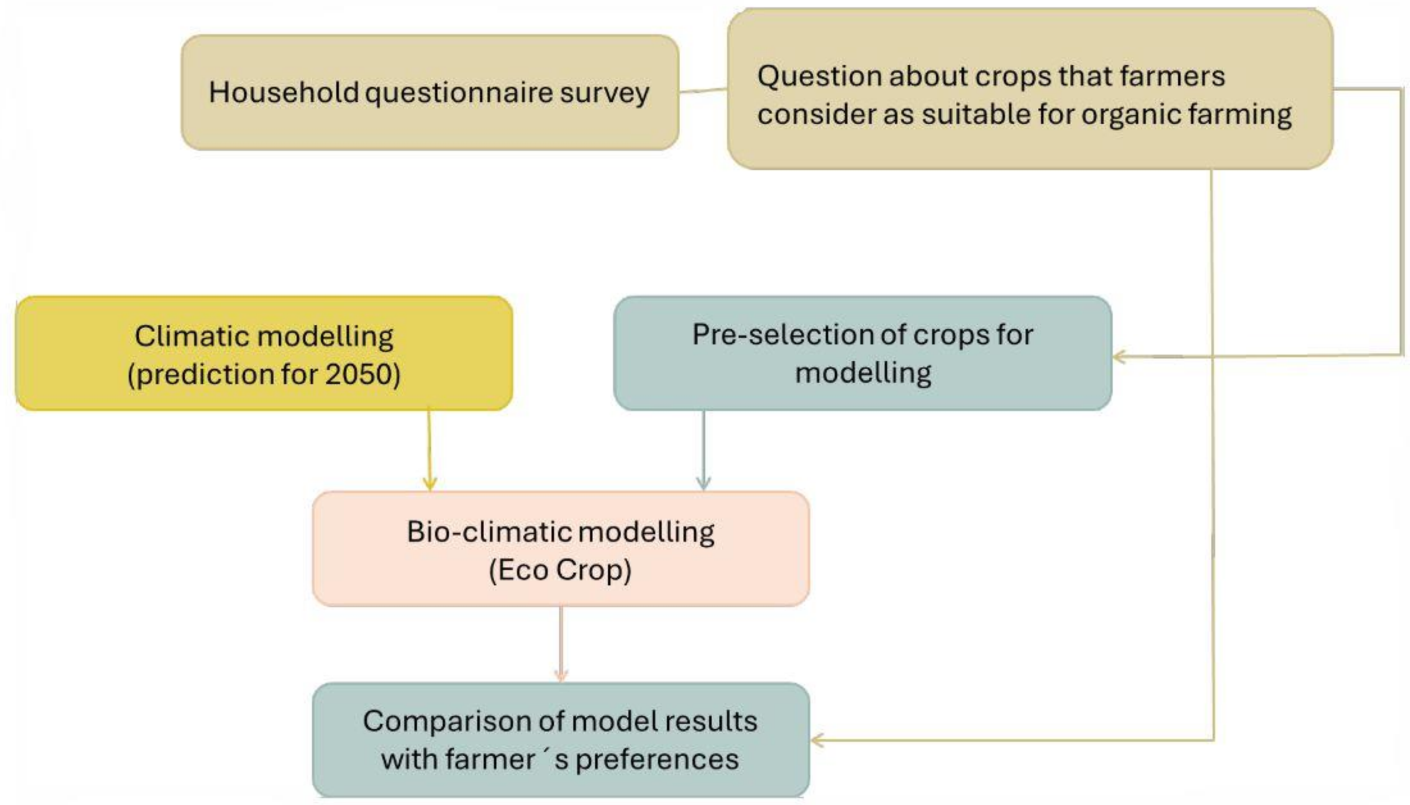

Figure 2: Scheme of the research concept

Table 1: Research questions, their topics and methods of data collection

Research questions	Question topics	Data collections
What are the types of agriculture in your locality and the major crops grown there?	Major agriculture crops, organic crops, prospective organic crop, key crops grown in the area	Focus group discussions, key informant interview, household Survey
How can organic farming be made efficient?	Ecological intensification, production diversification, economic effectiveness, examine the prevalence of organic farming and potential crops for expanding organic agriculture	Focus group discussions, key informant interview
What are the development interventions and reasons of agriculture intensification	Development interventions, role and support from government and other agencies, effects of climate change on agricultural practices, problems, driving factors and reasons of agriculture intensification, sustainability of current agricultural practices, improve economic efficiency of farming, method like ecological intensification, production diversification, and the development of non-productive farming activities	Literature review, policy documents, key informant interview
What are the effects/impacts, problems and reasons of agriculture land abandonment	Status of land abandonment, driving factors of land abandonment, eco-environmental and social consequences of farmland abandonment, solutions for reusing abandoned land such as reforestation, livelihood pasturing or organic farming restoration	Key Informant interview, household survey

5. Results and discussion

5.1. Socio-economic and Agricultural Dynamics

This study, based on a household survey involving 260 questionnaires, key informants interviews and focus group discussions, offers important insights into the socio-economic and agricultural dynamics across eight wards within Bhimeshwor Municipality and the Shailung Rural Municipality in Dolakha District, Nepal. The data were analyzed using Principal Component Analysis (PCA), which helps explain the variability in socio-economic factors across these wards.

A notable finding in the PCA analysis is the prevalence of the Brahmin caste in wards with high agricultural activity and greater adoption of agricultural technologies. Similar studies have observed that social stratification and caste hierarchies in rural communities can impact land ownership, access to credit, and participation in agricultural endeavors. The Brahmin community, which has traditionally enjoyed a higher socio-economic status, have better access to these resources, enabling them to adopt modern agricultural practices more readily compared to other caste groups (Figure 3).

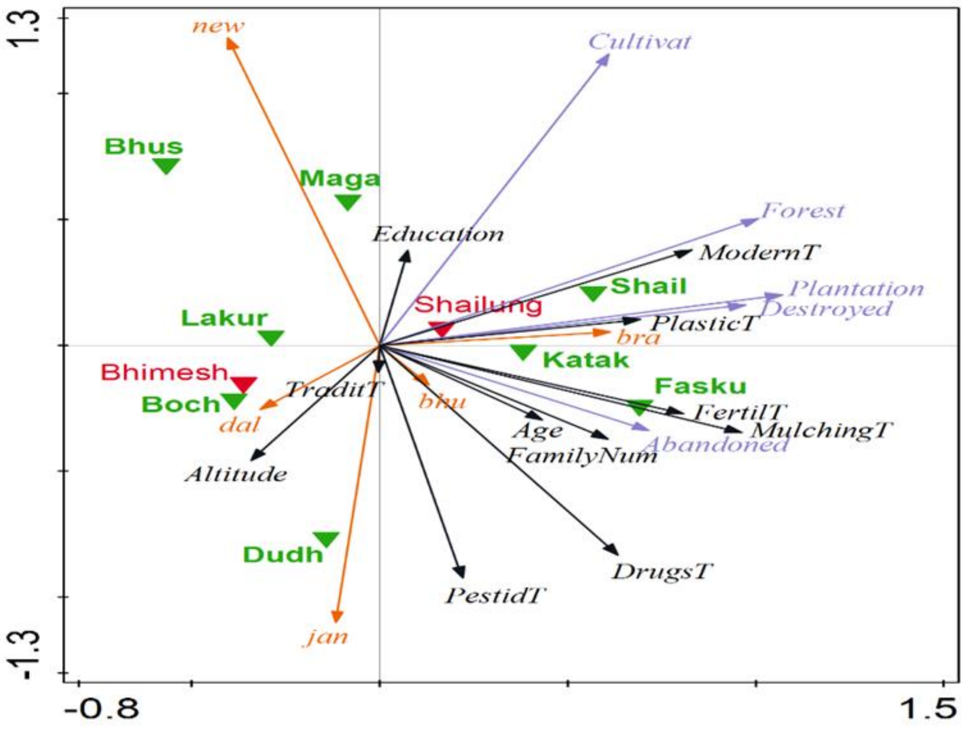

Figure 3: Principle component analysis (PCA) on Socio-economics and agriculture dynamics

Bhimeh (Bhimershwor Municipality) and Shailung (Shailung Rural Development) and Eight Wards namely: Bocha, Bhus: Bhusapheda, Dudh: Dudhpokhari, Fasku, Lakur: Lakuridanda, Maga: Maghapauwa, Shail: Shailungeswori, Katak (Katakuti)

Land types: Cultivat (Cultivated land), Plantation (Plantation/greasland), Abandoned (Abandoned land) and Destroyed (Destroyed by flood/landslide)

Caste/ethnic groups: Jan (Janajati), dal (Dalit), bra (Brahmin), bhu (Bhujel), new (Newar)

5.1.1 Involvement in Agriculture Farming by Age Groups and Wards

The analysis of agricultural involvement by age group reveals distinct patterns in economic activity. Individuals aged 10-16 and 16-40 are the most active in farming, followed closely by those in the 41-65 age group. Wards like Bhusapheda, Dhudhpokhari, Katakuti, and Shailungshwori have aging farming populations. As older farmers face physical limitations, they increasingly shift to less labor-intensive crops or leave land fallow. This underutilization of land is linked to younger generations migrating for better opportunities, a trend also seen globally in rural farming communities. Older farmers struggle with declining health, reduced access to labor, and economic pressures, limiting productivity (Figure 4).

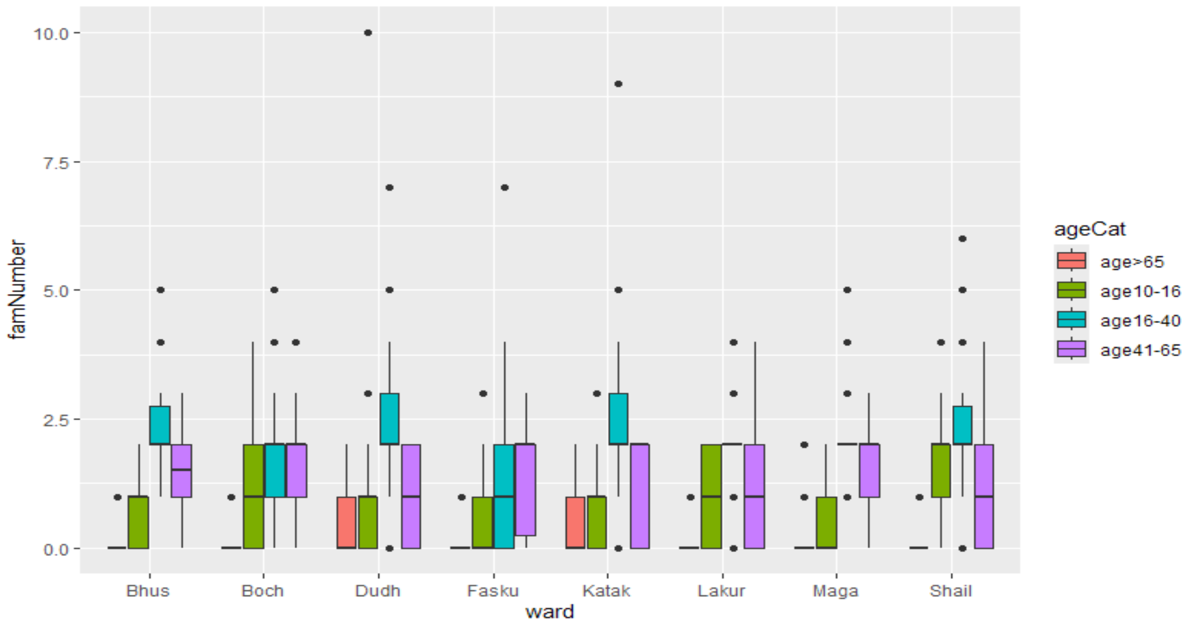

Figure 4: Involvement in agriculture farming by age groups and wards

Eight Wards namely: Bocha, Bhus: Bhusapheda, Dudh: Dudhpokhari, Fasku, Lakur: Lakuridanda, Maga: Maghapauwa, Shail: Shailungeswori, Katak (Katakuti)

5.1.2 Landholding Patterns in the Study Areas

Land types assessed include cultivated land, private forests, plantations/grasslands, abandoned land, and land destroyed by floods or landslides. Bhusapheda, Maghapauwa, and Fasku show the highest levels of cultivated land. These areas have a stronger agricultural presence, with larger portions of land actively used for farming. These wards focus on maintaining productive farming systems, supporting local economies and ensuring food security, possibly due to more favorable agricultural conditions or stronger local incentives. Katakuti, Shailungeswori, and Bocha exhibit higher levels of land abandonment, particularly non-irrigated khet land (traditionally used for paddy and other staple crops). Abandonment is primarily attributed to the distant location of khet land, making it harder to maintain, especially in remote or less favorable agricultural environments. Bocha, Fasku, and Shailungeswori have experienced increasing out-migration to Kathmandu and foreign labor markets, leading to a rise in absentee landlords (Figure 5). Migration has contributed to land abandonment over the past 30 years, as families relocate or focus on off-farm income, reducing the available labor force for farming.

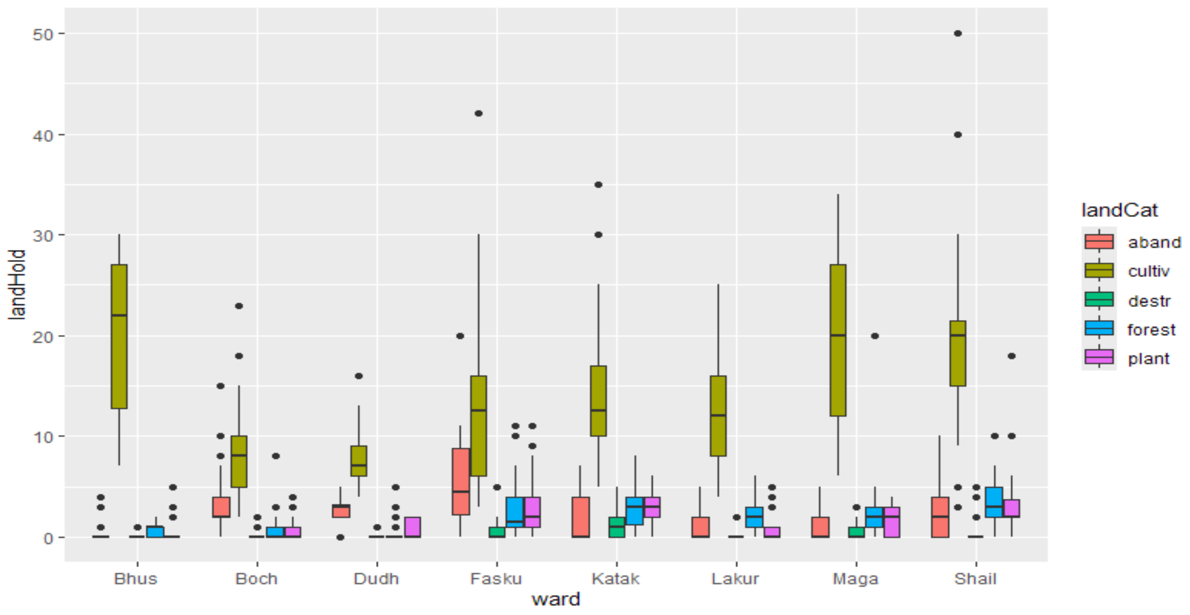

Figure 5: Land holding patterns by wards

Eight Wards namely: Bocha, Bhus: Bhusapheda, Dudh: Dudhpokhari, Fasku, Lakur: Lakuridanda, Maga: Maghapauwa, Shail: Shailungeswori, Katak (Katakuti)

5.2 Evolution of Agricultural Practices: From Traditional Methods to Intensification in the Study Areas

The Table 2 below presents the results of Canonical Correspondence Analysis (CCA). The explanatory variables were selected using the forward selection method, ensuring that only those with a statistically significant effect on the response variables were included.

Table 2: Explanatory variables using forward methods

Question	Explanatory variables	Expl. var. (%)	Pseudo-F	p
Q1	ward, municipality, agr. tools	49.4 (47.2)	22.0	0.002
Q2 total	ward, modern tools, cultivated land holding	31.0 (28.3)	11.2	0.002
Q3 total	ward, caste, position, forest holding	36.0 (32.3)	9.8	0.002
Q4	ward, caste, position, agr. tools-pestid., drugs for animals, fertilizers	37.6 (33.5)	9.1	0.002
Q5-Q9	ward, caste, agr. tools, cultivated and destroyed land holding	39.9	35.7	0.002
Q11	ward, agr. tools - fertilizers	17.3 (14.6)	6.5	0.002

Q12	ward, agr. tools – pesticides, fam. members 16-20	41.9 (39.8)	20.1	0.002
Q13	ward, N position	17.1 (14.5)	6.4	0.002
Q14	ward, N position	11.8 (9.0)	4.1	0.002
Q15	ward, caste, cultivated land holding	14.0 (9.8)	3.4	0.002
Q16_best practice	ward, agr. tools – plastic tunnels	28.7 (26.4)	12.6	0.002
Q16_problems	ward, N position, agr. tools-pestid., drugs for animals	24.0 (20.9)	7.8	0.002
Q17-Q19	ward, caste, altitude, agr. tools – modern, cultivated and destroyed land holding	26.5 (22.0)	5.9	0.002

5.2.1 Major Types of Agricultural Farming: Traditional, Intensive, and Cash Crop Practices

These clusters illustrate how farming practices are distributed based on local conditions, resource availability, and market integration, providing valuable insights into the agricultural dynamics across the wards (Figure 6).

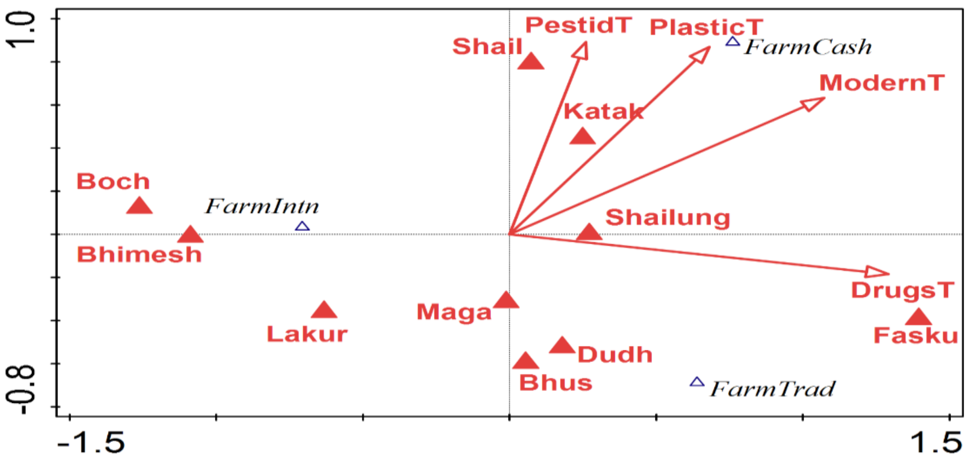

Figure 6: Major agricltureu types by wards

Eight Wards namely: Bocha, Bhus: Bhusapheda, Dudh: Dudhpokhari, Fasku, Lakur: Lakuridanda, Maga: Maghapauwa, Shail: Shailungeswori, Katak (Katakuti)

FarmTrad: Traditional farming/organic farming, FarmIntn: Agriculture intensification FarmCash: Cash crops farming

5.2.2 Major Agriculture Crops in the Study Areas

Wards like Katakuti, Fasku, and Shailungeswori, which have integrated pesticides and modern farming technologies, prefer cash crops and spices such as ginger, turmeric, and chili due to their high market value (Figure 7).

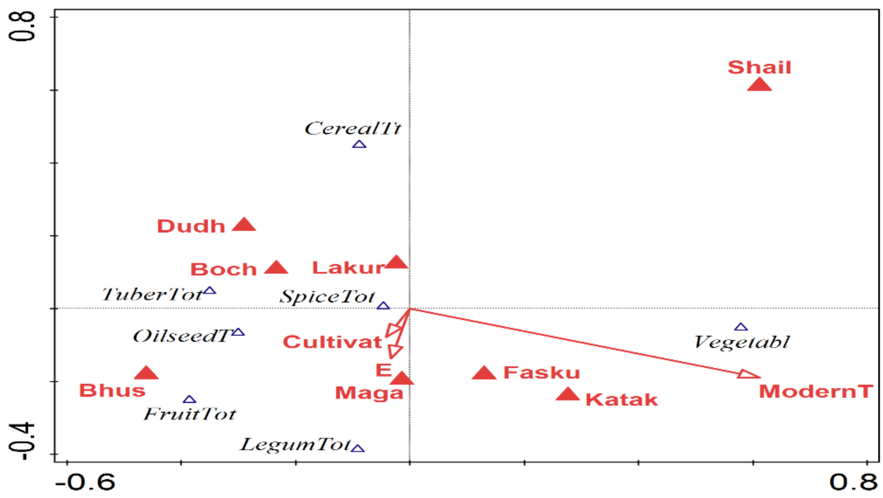

Figure 7: CCA analysis of major agriculture crops in the study areas
Eight Wards namely: Bocha, Bhus: Bhusapheda, Dudh: Dudhpokhari, Fasku, Lakur: Lakuridanda, Maga: Maghapauwa, Shail: Shailungeswori, Katak (Katakuti)

CerealTot: Cereals, TuberTot: Tubers/bulb seeds, Vegetabl: Vegetables, OilseedT: Oil seed), SpicesTot: Spices, FruitTot: Fruits, LegumTot: Leguminous grains,

5.2.3 Traditional Crops (Without Using Chemical Fertilizers or Pesticides)

Households with larger forest holdings tend to integrate agroforestry practices, growing crops traditionally alongside forest products (Figure 8).

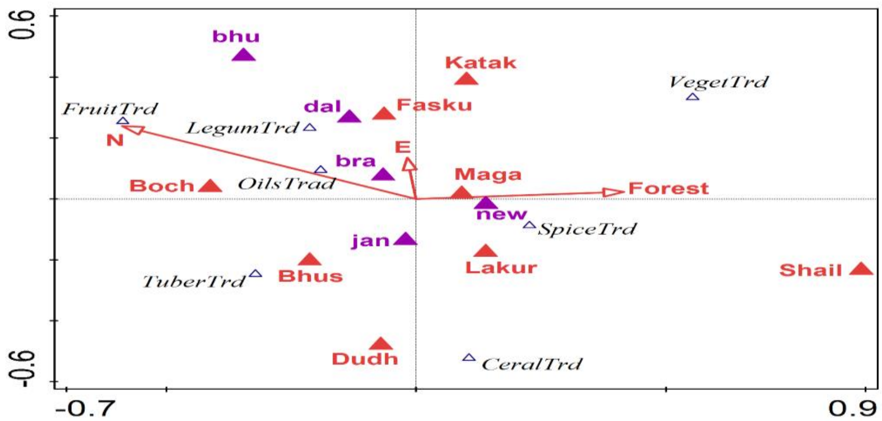

Figure 8: Traditional crops (without using chemical fertilizers or pesticides) in relation to ward, caste position and the use of traditional farming practices
Eight Wards namely: Bocha, Bhus: Bhusapheda, Dudh: Dudhpokhari, Fasku, Lakur: Lakuridanda, Maga: Maghapauwa, Shail: Shailungeswori, Katak (Katakuti)

Caste/ethnic groups: Jan (Janajati), dal (Dalit), bra (Brahmin), bhu (Bhujel), new (Newar)

CeralTrdt: Cereals, TuberTrd: Tubers/bulb seeds, VegTrd: Vegetables, OilTrd: Oil seed), SpiceTrdt: Spices, FruitTrd: Fruits, LegumTrd: Leguminous grains

5.2.4 Crop patterns of the agriculture varities

The Table 3 below outlines the major crops cultivated in each season across various categories in the study areas.

Table 3: Crop patterns in the study areas

Crops	Winter	Summer
Cereals	Wheat, Finger Millet, Barley, Buck Wheat	Rice, Maize, Finger Millet, Wheat Barley, Naked Barley
Tubers/Bulb Seeds	Potato Colocasia, Yam, Garlic, Onion, Sweet Potato	Potato, Colocasia
Vegetables	Spinach, Cabbage, Cauliflower, Tomato, Local Radish, Bean	Tomato, Eggplant, Pumpkin, Cauliflower, Radish, Tomato
Oil Seeds	Mustard, Sunflower, Soya Bean	Soya Bean, Mustard Seed, Sunflower
Spices	Turmeric, Ginger, Chilies, Garlic, Cardamom	Fresh Chilies, Coriander, Garlic, Ginger, Onion
Fruits	Orange, Lemon, Japanese Persimmon, Kiwi, Avocado	Kiwi, Pear, Japanese Persimmon, Avocado
Leguminous Grains	Chickpeas, Black Gram, Horse Gram, Cow Pea, Broad Bean	Beans, Soybeans, Cow Pea
Grass	Fodder Grass (Napier)	Fodder Grass, Summer Grazing Crops
Others	Medicinal Plants	Medicinal Plants, Cash Crops

Wards with better access to modern agricultural inputs (e.g. Bocha, Bhusapheda, Shailungeswori) are more likely to grow cash crops and high-yielding crops during both winter and summer seasons, including vegetables and fruits, which are often treated with pesticides and enhanced with fertilizers (Figure 9).

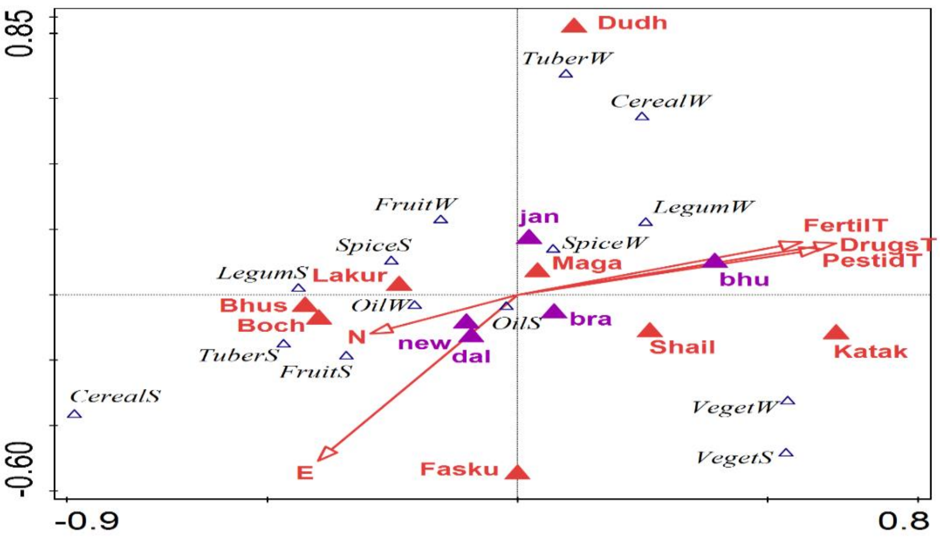

Figure 9: CCA of crop patterns in relation to ward, caste, position, and the use of agricultural tools and services

Eight Wards namely: Bocha, Bhus: Bhusapheda, Dudh: Dudhpokhari, Fasku, Lakur: Lakuridanda, Maga: Maghapauwa, Shail: Shailungeswori, Katak (Katakuti)

Caste/ethnic groups: Jan (Janajati), dal (Dalit), bra (Brahmin), bhu (Bhujel), new (Newar)

CeralS/W: Cereals Summer/Winter, TuberS/W: Tubers/bulb seeds Summer/Winter, VegetS/W: Vegetables Summer/Winter, OilS/W: Oil seed Summer/Winter), SpiceS/W: Spices Summer/Winter, FruitS/W: Fruits Summer/Winter, LegumS/W: Leguminous grains Summer/Winter

5.2.5 Use of Chemical Fertilizers, Compost, and Organic Farming Practices

In Shailungeswori and Katakuti, some farmers expressed uncertainty about the time demands of organic farming, indicating a potential knowledge gap in these areas (Figure 10).

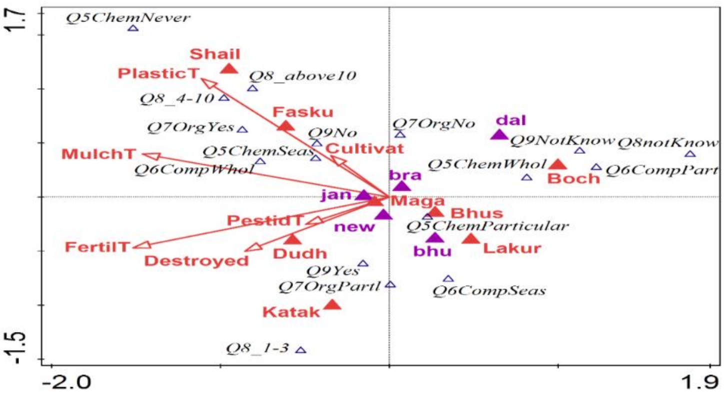

Figure 10: Use of chemical fertilizers, compost, and organic farming practices

Eight Wards namely: Bocha, Bhus: Bhusapheda, Dudh: Dudhpokhari, Fasku, Lakur: Lakuridanda, Maga: Maghapauwa, Shail: Shailungeswori, Katak (Katakuti)

Caste/ethnic groups: Jan (Janajati), dal (Dalit), bra (Brahmin), bhu (Bhujel), new (Newar)

5.2.6 Effects of Climate Change on Agriculture Farming

Farmers across various wards have observed effects related to climate change that influence their agricultural practices. These effects vary by geographical location (ward), use of agricultural tools, and application of fertilizers (Figure 11).

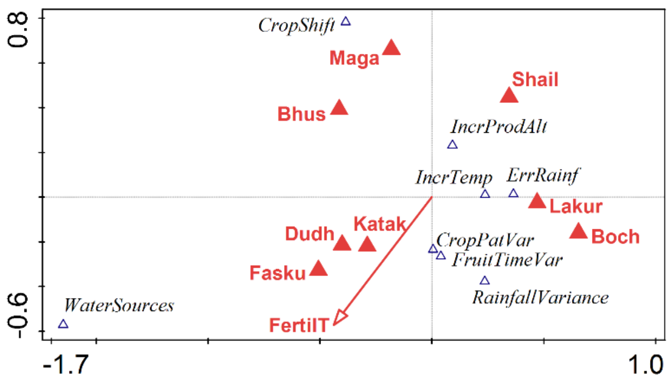

Figure 11: Effects of climate change on farming

Eight Wards namely: Bocha, Bhus: Bhusapheda, Dudh: Dudhpokhari, Fasku, Lakur: Lakuridanda, Maga: Maghapauwa, Shail: Shailungeswori, Katak (Katakuti)

InreTemp: Temperature increased, CropShift: Crop Shifting altitude, IncrProdAlt: Increasing productivity in higher altitude, ErrRainf: Erratic rainfall, RainfalVariance: Rainfall patter variance, FruitTimeVar: Fruiting/cultivation time variance, CropPatVar: Crop pattern variance and WaterSources: Volume of water/sources

5.2.7 The Sustainability of Current Agricultural Practices

Support for small-scale farmers through technology transfer, financial aid, and education is essential for enhancing their role in sustainable agriculture (Figure 12).

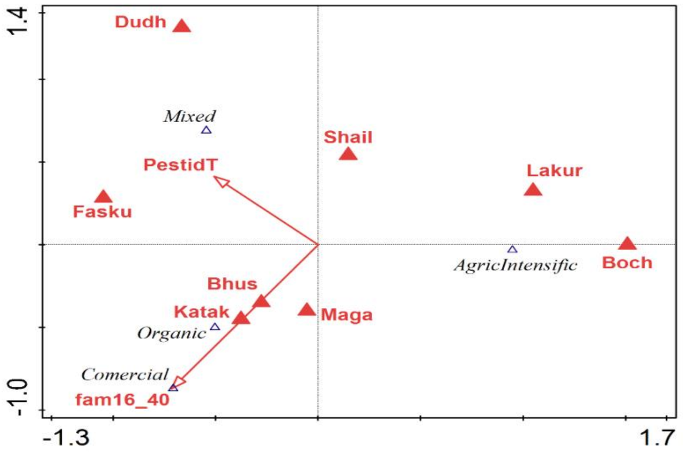

Figure 12: The sustainability of current agricultural practices by wards
Eight Wards namely: Bocha, Bhus: Bhusapheda, Dudh: Dudhpokhari, Fasku, Lakur: Lakuridanda, Maga: Maghapauwa, Shail: Shailungeswori, Katak (Katakuti)

Organic: Organic farming, AgrricIntensfic: Agriculture intensification farming, Mixed: Mixed farming both traditional and intensification and Commercial: Commercial farming

5.2.8 Improving the Economic Effectiveness of Farming

Crop rotation, strongly supported in Katakuti and Maghapauwa, enhances soil fertility and reduces input costs, while monocropping in Bocha and Lakuridanda leads to lower long-term productivity (Fig. 13).

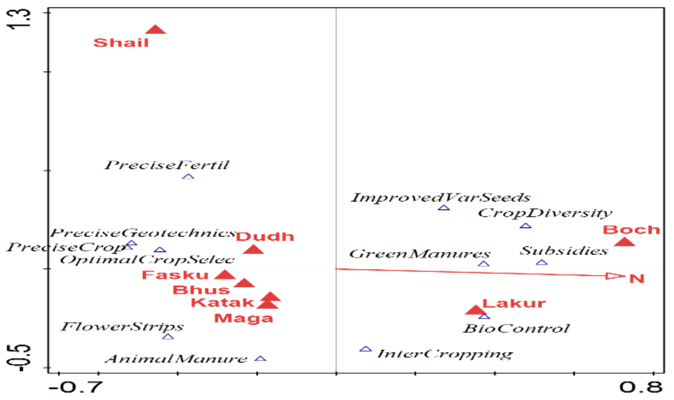

Figure 13: Improving the economic effectiveness of farming
Eight Wards namely: Bocha, Bhus: Bhusapheda, Dudh: Dudhpokhari, Fasku, Lakur: Lakuridanda, Maga: Maghapauwa, Shail: Shailungeswori, Katak (Katakuti)

Subsidies: Subsidies from government/authorities, ImprovedVarSeeds: Improved varieties seeds, OptimalCropSelec: Optimal crop selection, PreciseCrop: Precise crop rotation, PreciseFertil: Precise fertilization, PreciseGeotechnics: Precise agrotechnics, GreenManures: Use of Green manures, CropDiversity: Crop diversity, AnimalManure: Manure use or other links between crops and animals, FlowerStrips: Use of flower *strips and other semi-natural elements, BioControl: Improvement of plant protection (i.e. biocontrol) and InterCropping: Intercropping, undersowing*

5.2.9 Possibilities for Increasing Organic Farming Efficiency

Wards Lakuridanda and Bocha, characterized by a strong market orientation, are likely to demonstrate heightened support for attracting consumers to organic products. These wards may recognize that consumer demand is a critical driver of economic success in organic farming. Respondents from Bhusapheda, Dhudhpokari, and Shailungshwori, who prioritize health awareness, might exhibit stronger agreement with the notion that promoting the health benefits of organic products can enhance farming efficiency (Figure 14).

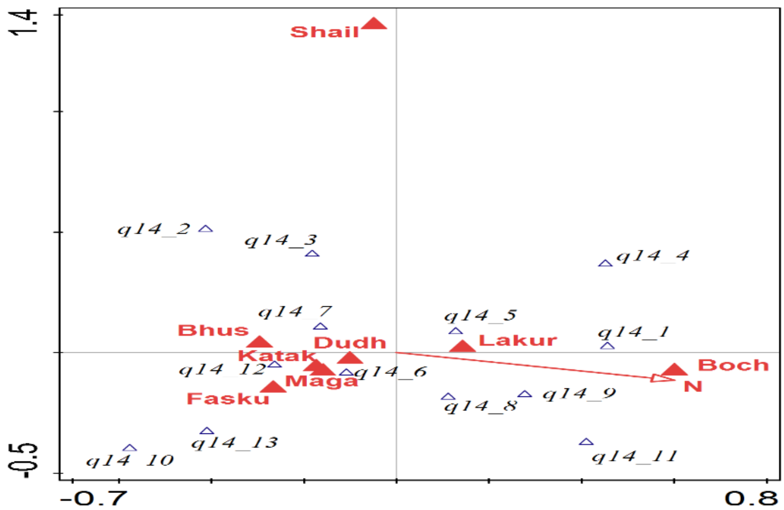

Figure 14: Possibilities for increasing organic farming efficiency
Eight Wards namely: Bocha, Bhus: Bhusapheda, Dudh: Dudhpokhari, Fasku, Lakur: Lakuridanda, Maga: Maghapauwa, Shail: Shailungeswori, Katak (Katakuti)

q14_1: Attraction of consumers towards organic products, q14_2: Health issues propagation, q14_3: Awareness regarding harms of chemical fertilizer, q14_4: Lab test provision (e.g soil. seed and other component), q14_5: Access of market and its availability, q14_6: Livestock management, q14_7: Fodder/forage development, q14_8:Compost prepare/quality/techniques, q14_9:Agriculture services, q14_10: Organic brand/certification, q14_11:Crop diversity, q14_12: Production diversification(innovative combination of cultivated crops and bred animals), q14_13: Complex approach and development of non-productive functions and pre and post farming processes.

5.3 Land Use Practices and Agriculture Abandoned land

5.3.1 Current Land-Use Practices on Agriculture land

Approximately twenty-nine percent (28.8%) of migrant households and 0.8% of non-migrant households reported that their agricultural lands had been abandoned. In contrast, 74% of migrant households and 59% of non-migrant households indicated that their lands were underutilized. Notably, only 26% of migrant households and 49% of non-migrant households have continued traditional farming practices (Figure 15).

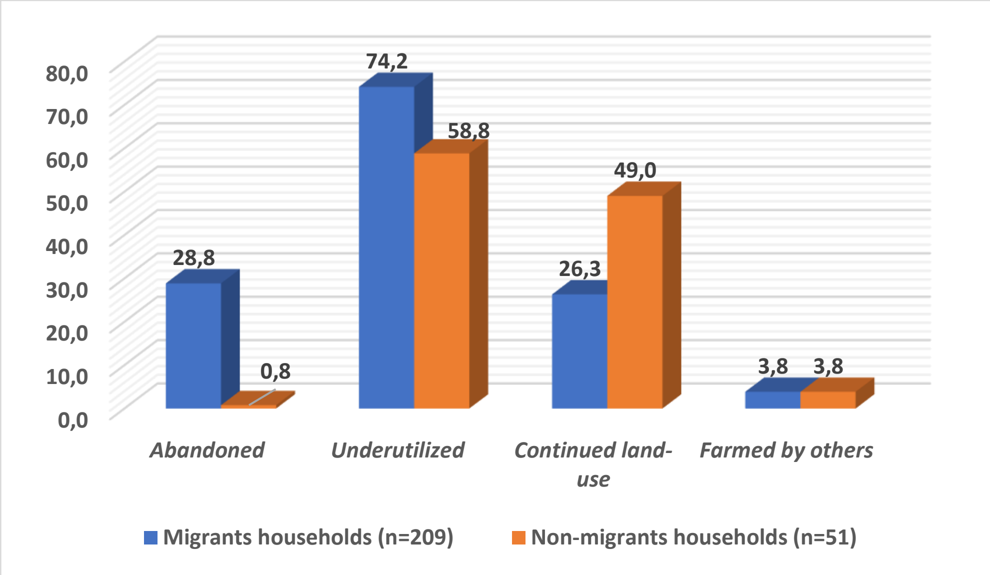

Figure 15: Current land-use practices on agriculture land

5.3.2 Driving factors of agriculture land abandonment

The Figure 16 highlights several driving factors contributing to agricultural land abandonment, with percentages reflecting the proportion of respondents who identified these factors as significant.

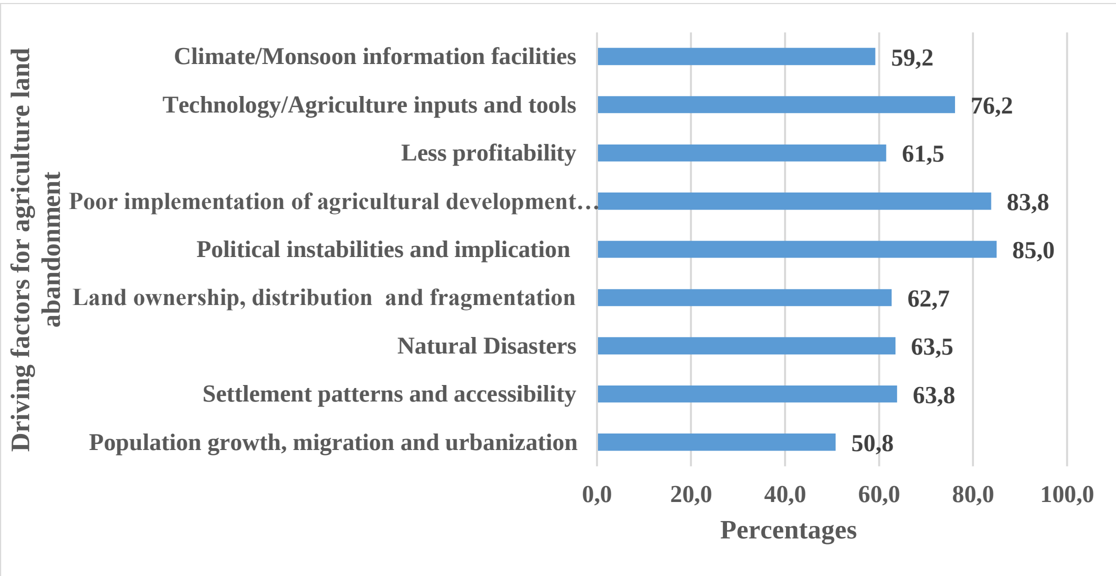

Figure 16: Driving factors contributing to agricultural land abandonment

5.3.3 Current Status of the Longevity of Abandoned Lands

The Figure 17 indicates that the highest rates of recent land abandonment are observed in Bocha (19.7%) and Lakuridanda (9.5%), where land has been left unused for less than a year.

5.8% of respondents reported that their land had been abandoned for less than a year, suggesting that recent abandonment is relatively low overall.

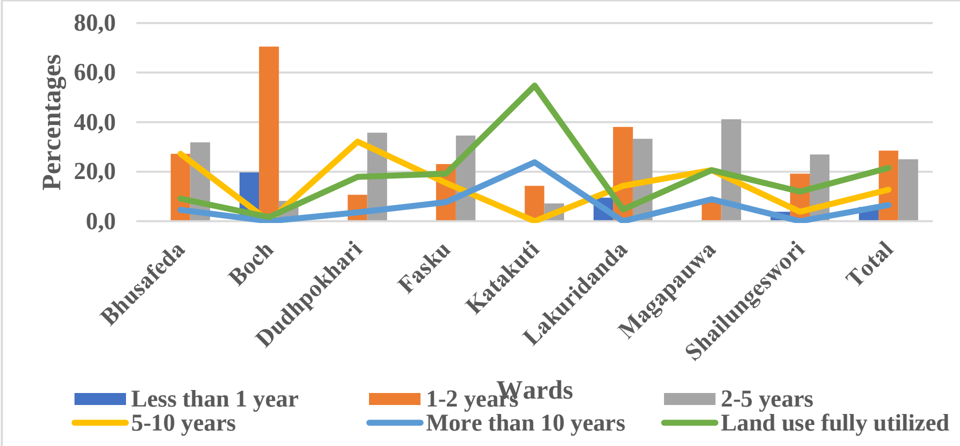

Figure 17: Current status of the longevity of abandoned lands

5.3.4 Status of Abandoned Land

Respondents were asked to share their views on the extent of agricultural land abandonment in their local areas, excluding underutilized land from their assessments. A notable portion of the land is classified as landless or actively used, suggesting efficient land utilization in these regions (Figure 18).

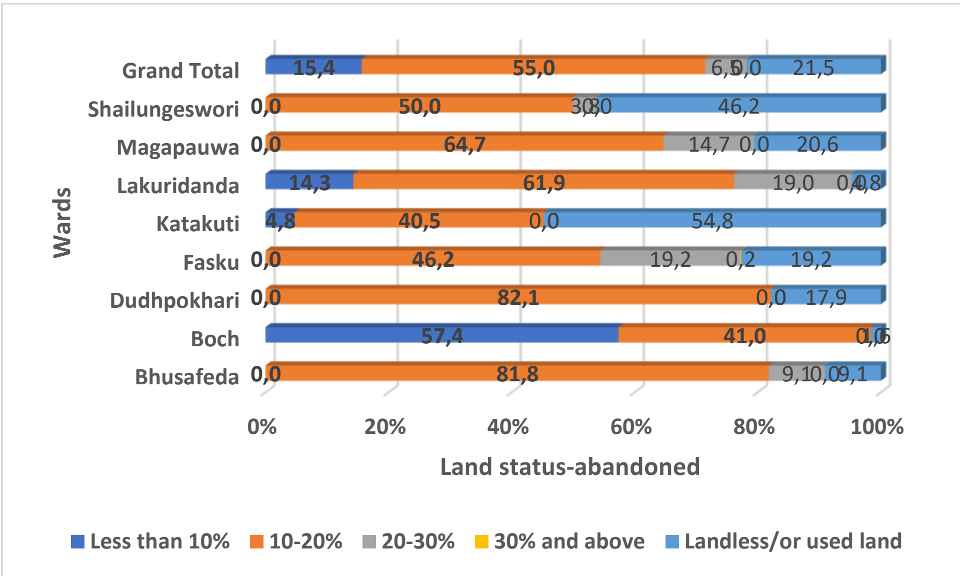

Figure 18: Status of agriculture land abandoned by wards

5.3.5 Positive Impacts of Land Abandonment

Land abandonment, where agricultural or previously utilized land is left unmanaged, can lead to various ecological, environmental, and socio-economic outcomes. The survey results capture respondents' perceptions, emphasizing the positive effects of land abandonment (see Figure 19).

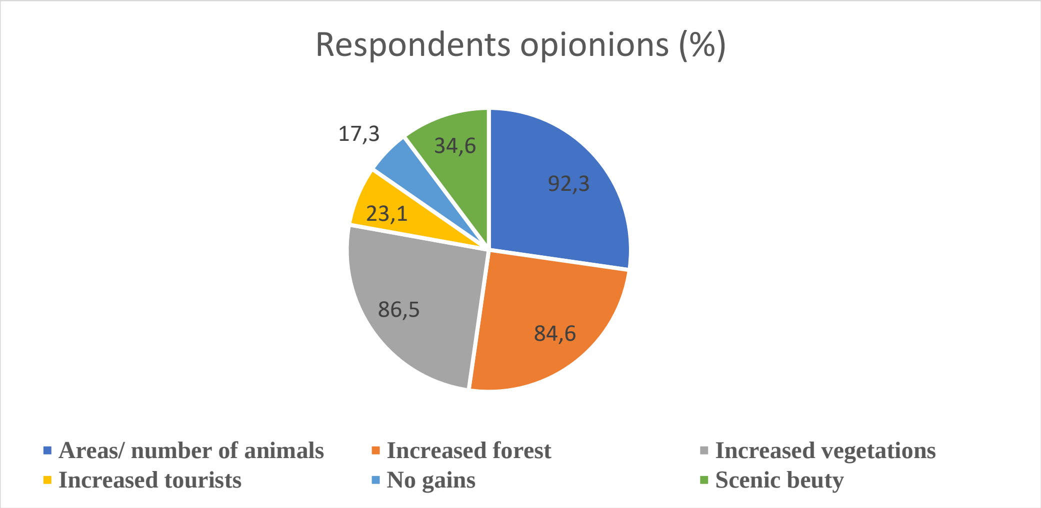

Figure 19: Positive impacts of land abandonment

5.3.6 Alternative Approaches to Managing Abandoned Land

Research has demonstrated that farmers with access to such information are better equipped to manage risks and improve yields, making it a vital component of any strategy aimed at re-engaging with abandoned lands (see table 3).

Table 3: Alternative approaches to managing abandoned land

Alternative options	Perceptions (%)
Enhancing the access to markets and government incentives	86.5
Developing risk-mitigation strategies through agro-advisory systems	84.6
Improve information technology infrastructure to make market, climate, and crop management	55.8
Ensure high quality agricultural inputs, such as certified seeds, fertilizers, and pesticides	46.2
Promoting mixed agroforestry systems	88.5
Value-added market chains	80.8
Providing financial incentives (e.g., soft loans or subsidies,	69.2
Develop and/or technical support are potential options	88.5
Commercial dairy farming, with a substantialincrease in fodder trees, fruit farming	61.2
0ff -season vegetable farming	65.4
High value cash crops cultivation (e.g. Alaichi, herbals)	50.0
Vegetation cover and promote soil protection practices such as tree cover planting and mulching	42.3

5.3.7 Management solutions/options for abandoned land

Natural afforestation is viewed favorably, particularly by experts, suggesting a preference for allowing the land to regenerate naturally, which can yield long-term ecological benefits (Figure 27).

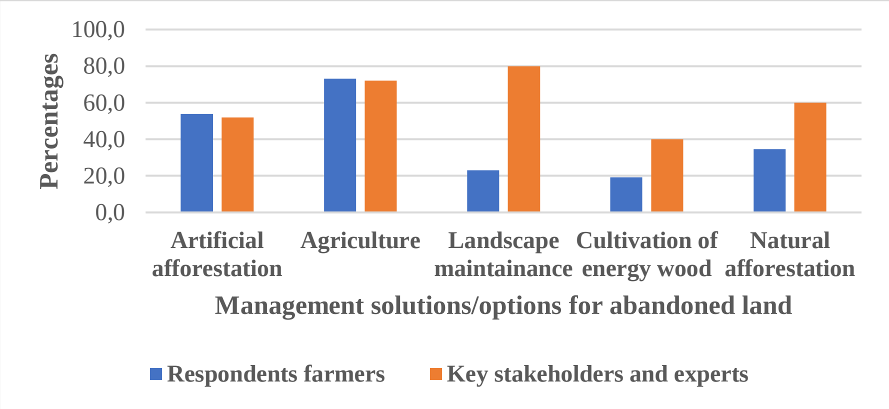

Figure 20: Management solutions/options for abandoned land

5.4 Land Suitability for organic farming and Modeling

5.4.1 Modeling of Change in Suitability of Growth Condition for the Selected Crops

The objective of this study was to develop a simple model for evaluating the suitability of numerous crops for the Dolakha district, specifically for two climatic zones (subtropical and temperate), but with applicability to other geographic regions as well. To this end, the research team collaborated with farmers, experts, and local partners to identify the most widespread types of organic agriculture and the prospects of organic agriculture for other cropping models (Table 4-6).

Table 4: Selected crops for modelling (based on the questionnaire survey), Pechanec et al. 2024

Crop type	Crop name	Scientific name used in EcoCrop
Oil seeds	Mustard	Brassica nigra
Cereals	Maize	Zea mays L. s. Mays
Cereals	Barley	*Hordeum vulgare L.*
Cereals	Millets (finger millet) (kodo)	Eleusine coracana (L)Gaertn
Cereals	Buckwheat	Fagopyrum esculentum Moench
Cereals	Wheat	Triticum aestivum
Vegetables	Cabbage	Brassica oleracea L.v capi.
Vegetables	Cauliflower	Brassica oleracea L.v botr.
Vegetables	Spinach (broadleaf)	Spinacia oleracea L
Vegetables	Onion	Allium cepa
Vegetables	Local radish (rato mula)	Raphanus sativus L. (C.R.)
Vegetables	Tree tomato	Cyphomandra betacea (Cav.)

Tubers	Potato	Solanum tuberosum
Tubers	Yam	Dioscorea bulbifera
Tubers	Colocasia	Colocasia affinis
Spices	Chilies	Capsicum frutescens
Spices	Garlic	Allium sativum
Spices	Ginger	Zingiber officinalis
Leguminous crops	Beans	Phaseolus vulgaris L.
Leguminous crops	Soyabean	Glycine max (L.) Merrill

According to the classification of Food and Agricultural Organization, FAO, land suitability for agriculture were classified according to four levels of FAO's classification (Table 5).

Table 5: Classification of Food and Agricultural Organization, FAO

Suitability Class	Class Name	Rating Range (1-100)	Class Description
S1	Highly Suitable	95-100	Land having no significant limitations or only minor limitations
S2	Moderately Suitable	85-95	Land having limitations which in aggregate are moderately severe
S3	Marginally Suitable	65-85	Land having limitations which in aggregate are severe
N1	Currently Not Suitable	40-65	Land having so severe limitations which may be surmountable in time

Table 6: The proposed Land suitability levels and their land characteristics (excerpted and modified from Pramanik, 2016)

Suitability class	Land qualities/characteristics	Remarks
Highly suitable	Gentle slopes (0^0–3^0) with gullies, high soil moisture with lower elevation, fine loamy to coarse loamy soil, good drainage capacity	Most suitable for agriculture, favorable area for intensive agriculture if irrigation facilities are available
Moderately suitable	Gentle to stiff slopes (3^0–10^0) with micro terracing, medium soil moisture with lower elevation, coarse loamy soil, moderate drainage capacity	Suitable land for farming practices with proper management, suitable for terrace cultivation
Marginally suitable	10^0–20^0 slope, less soil moisture with higher elevation, coarse loamy to gravel loamy soil, low drainage availability	Less suitable land for agriculture with careful farm management, necessary protections from drainage and intensive erosion
Currently and permanently not suitable	Precipitous slope with rocky lands, dry soil, dense forest, barren land, loamy skeletal soil, no drainage availability	The land is not suitable for agriculture, areas under dense vegetation, settlement, barren lands, open rocks

5.4.2 Climate modelling

Data downloaded from WorldClim were used to generate raster information for the necessary bioclimatic parameters for the study area in 2050, within a GIS environment. These parameters include Annual Mean Temperature, Annual Precipitation, Mean Temperature of the Warmest Quarter, and Precipitation of the Driest Month. The prediction of Annual Mean Temperature is illustrated in Figure 21. Bioclimatic parameters for current climate conditions and the predicted state in 2050 (for the area at the border of Lakuriada, Bhusapheda, and Maghapauwa) are listed in Table 7.

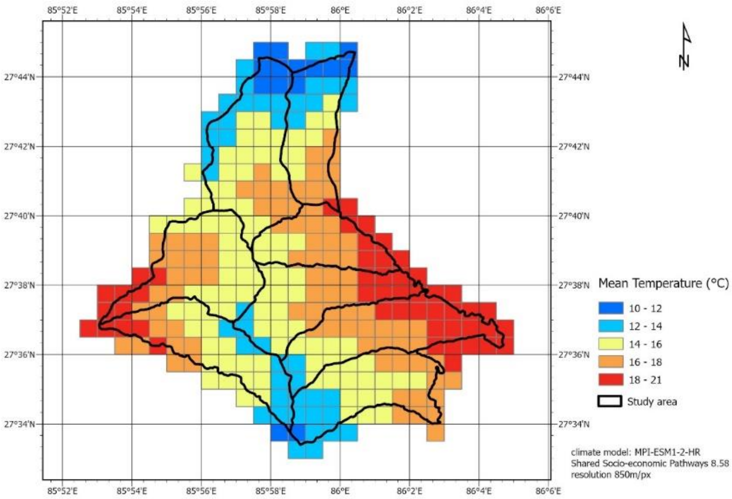

Figure 21: Projected annual temperate in 8 selected wards, Dolakha District in 2050, Pechanec et al. 2024

Table 7: Bioclimatic parameters for actual climate normal (1970-2022) and the predicted state in 2050 (for the area at the border of Lakuridada, Bhusapheda and Maghapauwa), Pechanec et al. 2024.

Prediction for 2050	Actual climate normal	Bioclimatic variables
16.6	15.7	BIO1 = Annual Mean Temperature
10.5	11	BIO2 = Mean Monthly Range
50	47.7	BIO3 = Isothermality (BIO2/BIO7) (×100)
413.9	429	BIO4 = Temperature Seasonality (standard deviation ×100)
25	24	BIO5 = Max Temperature of Warmest Month
4	2	BIO6 = Min Temperature of Coldest Month
21	22	BIO7 = Temperature Annual Range (BIO5-BIO6)
20.5	19.6	BIO8 = Mean Temperature of Wettest Quarter
11.5	10	BIO9 = Mean Temperature of Driest Quarter
20.7	19.8	BIO10 = Mean Temperature of Warmest Quarter
10.8	9.3	BIO11 = Mean Temperature of Coldest Quarter
2031	2050	BIO12 = Annual Precipitation
553	553	BIO13 = Precipitation of Wettest Month
9	10	BIO14 = Precipitation of Driest Month
114.6	115.2	BIO15 = Precipitation Seasonality (Coefficient of Variation)
1337	1380	BIO16 = Precipitation of Wettest Quarter
33	36	BIO17 = Precipitation of Driest Quarter
1329	1380	BIO18 = Precipitation of Warmest Quarter
39	43	BIO19 = Precipitation of Coldest Quarter

Bioclimatic modelling was conducted for current climate conditions and projected conditions in 2050 for each of the 20 pre-selected crops. Conditions were evaluated separately for each ward, with basic cultivars of crops considered in accordance with FAO databases and strategies. The results are presented in tables, with each table corresponding to a specific ward. These tables categorize the area of each ward into six suitability categories: not suited, very marginal, marginal, suitable, very suitable, and excellent. An example of the suitability results for Bhusafedi Ward is provided in Table 8.

Table 8: Modelling of suitability of 20 selected crops (area of the ward belonging to individual categories of land suitability) for actual climatic conditions and prediction of future climatic conditions in 2050. Ward Bhusapheda, Pechanec et al. 2024

Name	Scientific name	Area of the ward (km²) belonging into the individual category of suitability						Area of the ward (km²) belonging into the individual category of suitability					
		Actual climatic conditions						Predicted climatic conditions for 2050					
		<Not suited>	Very marginal	Marginal	Suitable	Very suitable	Excellent	<Not suited>	Very marginal	Marginal	Suitable	Very suitable	Excellent
	Oil Seeds												
Mustard	*Brassica nigra*	-	-	-	22.592	1.559	-	-	-	-	20.169	3.918	0.063
	Cereals crops												
Maize	*Zea mays subsp. Mays*	23.570	0.273	0.308	-	-	-	22.987	0.856	0.308	-	-	-
Millets (finger millet)	*Eleusine coracana*	-	-	-	-	23.843	0.308	-	-	-	-	23.570	0.580
Buckwheat	*Fagopyrum esculentum*	24.151	-	-	-	-	-	24.151	-	-	-	-	-
Wheat	*Triticum Aestivum*	24.151	-	-	-	-	-	24.151	-	-	-	-	-
Barley	*Hordeum vulgare*	12.786	10.784	0.581	-	-	-	3.169	19.818	1.164	-	-	-
	Spices												
Chilies	*Capsicum frutescens*	12.010	8.159	3.401	0.273	0.308	-	3.169	15.804	3.619	1.251	0.308	-
Garlic	*Allium Sativum*	-	-	-	3.169	20.401	0.581	-	-	-	-	21.871	2.280
Ginger	*Zingiber officinalis*	23.019975	-	-	1.131	-	-	12.52816	-	-	11.315	0.308	-
	Tubers/Blub Crops												
Colocasia	*Colocasia affinisesculenta v. Ant.*	-	-	-	0.000	13.287	10.863	-	-	-	-	1.523	22.628
Potato	*Solanum tuberosum*	13.545	10.025	0.581	-	-	-	3.169	20.401	0.581	-	-	-
Yam	*Dioscorea alata, Dioscorea bulbifera L.*	23.020	-	-	-	0.550	0.581	14.297	-	-	-	2.864	6.990
	Vegetables												
Local radish (*rato mula*)	*Raphanus sativus L.*	-	-	-	8.614	14.957	0.581	-	-	-	-	23.570	0.581
Spinach - broad leaf	*Spinacia oleracea*	23.843	0.308	-	-	-	-	23.843	0.308	-	-	-	-
Onion	*Allium cepa L. v. Cepa*	-	-	20.169	3.982	-	-	-	-	-	14.305	9.265	0.581
Cabbage	*Brassica oleracea var. Capitata*	-	-	20.169	3.982	-	-	-	-	19.964	4.187	-	-
Cauliflower	*Brassica oleracea var. Botrytis*	20.169	3.674	0.308	-	-	-	19.163	4.407	0.580	-	-	-
Tree Tomato	*Cyphomandra betacea (Cav.)*	20.892	2.679	0.581	-	-	-	4.678	8.860	7.354	2.951	0.308	-
	Leguminous crops												
Beans	*Phaseolus vulgaris*	-	-	-	-	-	24.151	-	-	-	-	-	24.151
Soyabean	*Glycine max*	23.570	0.273	-	0.308	-	-	22.592	0.979	0.272	0.245	0.063	-

The majority of soil units within the study area are classified as highly suitable or moderately suitable for the cultivation of beans, millet, mustard, and cabbage. Conversely, pumpkin and potato are classified as marginal or very marginal, while spinach is predominantly classified as unsuitable. The outcomes of the proposed bioclimatic model align with the observed conditions in the region between 1970 and 2022 and the projected scenarios between 2041 and 2060.

A further set of results comprises a map of the entire study area, which illustrates the bioclimatic modelling of land suitability for selected crops in both the current and modelled future climatic conditions. Figures 22 and 23 illustrates the aforementioned results for a single selected crop: barley and beans. The maps demonstrate that the most suitable areas for the majority of the pre-selected crops are situated in the northern and southern regions of the study.

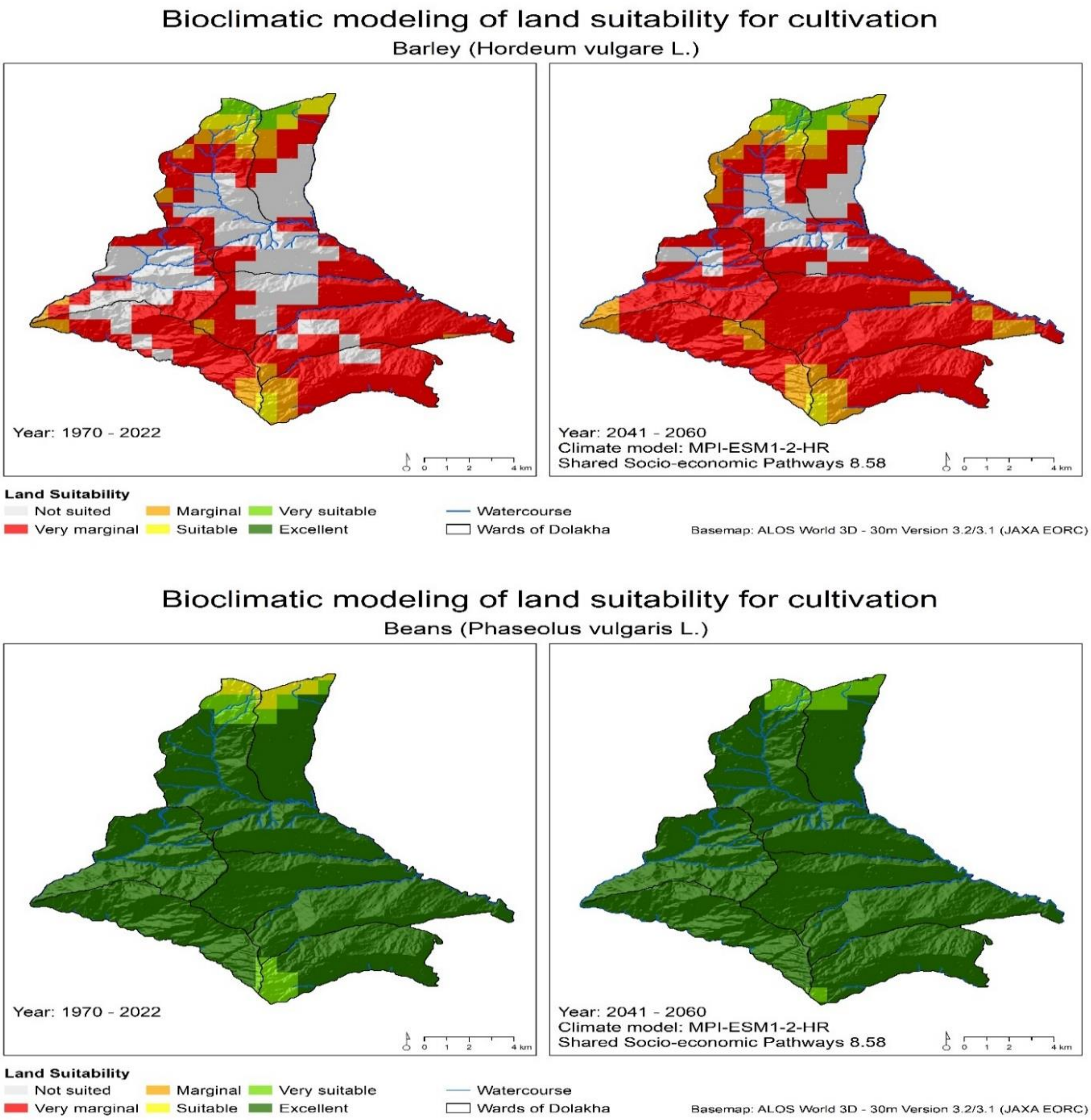

Figure (22-23): Bioclimatic modeling of land suitability for cultivation barley and bean in the study area including the 8 wards

5.4.3 Comparison of model results with survey of local people /farmers preferences

A further crucial piece of information was the perspective of farmers on the impact of climate change in their locality. The fundamental interpretation of these opinions is illustrated in Figure 24.

The model results indicated that some crops, selected by local people (respondents of the questionnaire) as suitable, were in fact categorised as "not suited" or "very marginal". This was the case for buckwheat in the majority of wards (with the exception of Lakuridada) and for Colocasia in Sailungeswor. Additionally, wheat exhibited unfavorable outcomes in the suitability model, despite being classified as "suitable" (Lakuridada) or "marginal" (Bocha) in certain wards (Table 12).

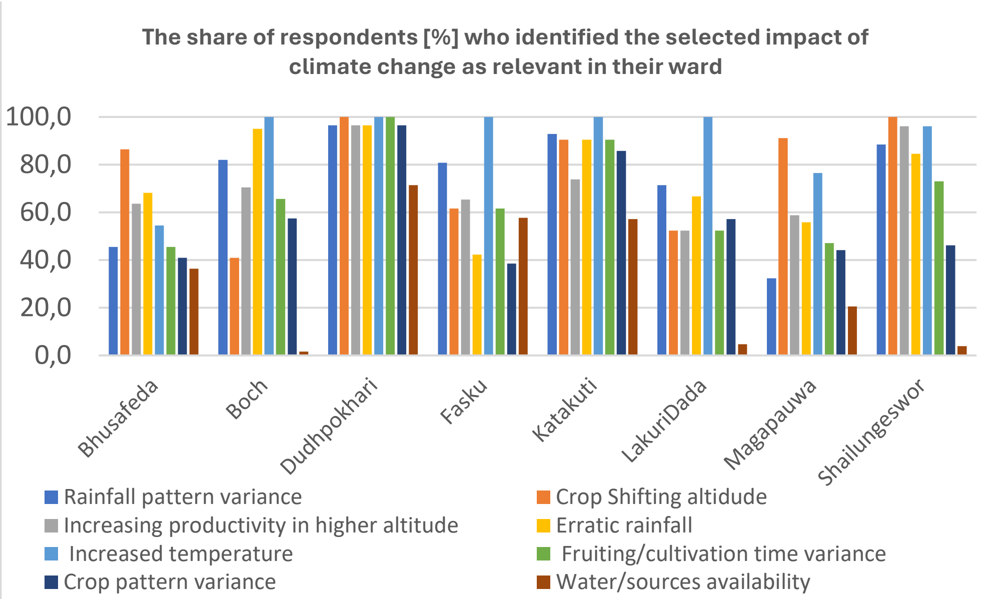

Figure 24: Impact of climate change in individual wards of Dolakha region, results of the questionnaire survey, Pehanec et al. 2024.

Table 1: Summary of the suitability modelling results according to the EcoCrop model (selection of three best suited crops for each ward in current and future climatic conditions) and the level of their suitability according to the questionnaire survey findings, Pechanec et al. 2024

Ward	Area of agricultural land (km^2)	Actual suitability					Suitability according to respondents	Prediction of future suitability					Suitability according to respondents
		Crop	Excellent		Very suitable		Share of respondents from selected ward indicating this crop as suitable for organic farming (%)	Crop	Excellent		Very suitable		Share of respondents from selected ward indicating this crop as suitable for organic farming (%)
			Area (km^2)	% from agricultural land	Area (km^2)	% from agricultural land			Area (km^2)	% from agricultural land	Area (km^2)	% from agricultural land	
Bhusaphedi	24.15	Beans	24.15	100.00	0.00	0.00	18.10	Beans	24.15	100.00	0.00	0.00	18.10
		Colocasia	10.86	44.98	13.29	55.02	68.20	Colocasia	22.63	93.69	1.52	6.31	68.20
		Finger millet	0.31	1.28	23.84	98.72	72.73	Garlic	2.28	9.44	21.87	90.56	63.40
Bocha	17.92	Beans	13.55	75.63	2.02	11.29	31.10	Beans	14.38	80.24	3.54	19.76	31.10
		Local radish	4.45	24.81	7.26	40.52	47.50	Local radish	5.21	29.05	8.00	44.63	47.50
		Colocasia	4.04	22.55	6.94	38.71	91.80	Colocasia	8.27	46.15	6.11	34.09	91.80
Dudhpokhari	21.46	Beans	21.02	97.93	0.44	2.07	7.10	Beans	21.41	99.74	0.06	0.26	7.10
		Colocasia	5.90	27.47	12.80	59.63	100.00	Colocasia	13.37	62.28	7.80	36.36	100.00
		Local radish	1.89	8.80	18.60	86.66	21.40	Garlic	5.56	25.89	15.91	74.11	96.40
Fasku	24.27	Beans	24.15	99.49	0.00	0.00	34.60	Beans	24.15	99.49	0.00	0.00	34.60
		Local radish	0.12	0.51	24.15	99.49	53.80	Garlic	5.10	21.03	19.17	78.97	80.77
		Garlic	1.87	7.70	22.40	92.30	80.77	Yam	13.72	56.51	1.70	7.01	65.38
Katakuti	21.77	Beans	21.77	100.00	0.00	0.00	97.60	Beans	21.77	100.00	0.00	0.00	97.60
		Colocasia	10.52	48.33	10.67	48.98	95.20	Colocasia	17.83	81.87	3.95	18.13	95.20
		Garlic	0.58	2.67	21.07	96.79	97.62	Garlic	3.75	17.22	18.02	82.78	97.62
LakuriDada	27.69	Beans	22.80	82.34	3.50	12.64	33.30	Beans	24.74	89.35	2.95	10.65	33.30
		Local radish	6.26	22.61	12.71	45.89	71.43	Colocasia	13.80	49.85	10.93	39.49	47.62
		Finger millet	0.00	0.00	24.01	86.71	47.60	Garlic	4.48	16.19	23.20	83.81	95.24
Magapauwa	15.66	Beans	15.66	100.00	0.00	0.00	52.90	Beans	15.66	100.00	0.00	0.00	52.90
		Colocasia	11.40	72.80	4.26	27.20	97.10	Colocasia	15.66	100.00	0.00	0.00	97.10
		Finger millet	0.00	0.00	15.66	100.00	71.40	Yam	9.51	60.69	0.00	0.01	35.29
Sailungeswor	21.24	Beans	18.14	85.40	3.10	14.60	3.80	Beans	0.57	2.70	20.67	97.30	3.80
		Local radish	3.10	14.60	18.14	85.40	65.40	Colocasia	13.14	61.85	6.92	32.60	0.00

The levels of match between modelling results and findings of questionnaire survey are differentiated by colours as follows: Green - Very high, Olive green - Rather high, Beige - Moderate, Light red - Low).

5.5 Socio-economic and Agricultural Dynamics

5.5.1 Key Socio-economic Factors Influencing Agriculture

The study identified critical variables impacting agricultural practices, including landholding size, availability of agricultural tools, altitude, education level, caste, age of respondents, and family size. These factors collectively contribute to the economic and social differentiation observed among the wards. For instance, landholding size has been consistently associated with agricultural productivity and the adoption of modern farming techniques (Seufert et al., 2012). This observation aligns with global studies indicating that larger landholdings enable farmers to invest in advanced agricultural technologies, thereby enhancing productivity (Reganold & Wachter, 2016b). Landholding size is a crucial determinant of agricultural productivity, with larger landholdings positively correlating with higher agricultural output and increased adoption of modern farming techniques, which in turn reinforces existing socio-economic inequalities (Pingali, 2012). In this analysis, wards such as Shailungshwori, Katakuti, and Fasku stand out for their larger cultivated areas, which facilitate the use of technologies like plastic tunnels, mulching, and enhanced fertilization techniques. Smallholder farmers, on the other hand, often struggle to access modern technologies due to limited financial and land resources (Feder & Umali, 1993). However, this focus on larger landholdings may overlook the potential of smallholder farming, especially when supported by targeted policies and technologies suited to their scale. Research from South Asia highlights how small farms can be highly productive when supported by appropriate innovations, such as precision farming tools and cooperative farming models (Hazell et al., 2010).

The study's findings emphasize the need for targeted agricultural policies that take into account the socio-economic dynamics at play within each ward. For instance, implementing land reform policies that facilitate land access for disadvantaged groups can help bridge the resource gap and promote sustainable agricultural practices across different wards (IFOAM, 2020). Another possibility are targeted subsidies for modern agricultural technologies aimed at marginalized caste groups to reduce financial barriers to technology adoption (Subedi, 2010) or capacity-building programs that provide education and skills training for disadvantaged communities, enabling them to adopt and utilize modern farming practices (Chhetri et al., 2012). As Banerjee and Duflo (2011) argue, addressing structural inequalities is essential for promoting sustainable and inclusive growth, particularly in rural economies where social hierarchies often dictate access to resources.

5.5.2 Major Types of Agricultural Farming: Traditional, Intensive, and Cash Crop Practices

Traditional/Organic Farming is predominantly observed in wards such as Dudhpokhari, Bhusafeda, and Fasku. In these regions, farmers utilize traditional cultivation methods that prioritize minimal use of synthetic inputs such as pesticides and chemical fertilizers.

Research suggests that this commercialization can lead to increased economic viability for farmers, but it also necessitates careful management of resources to ensure environmental sustainability (Lal, 2020). These study highlight the significant influence of geographical factors, resource availability, and market integration on the farming practices adopted in each ward. In areas where traditional farming prevails, initiatives could help farmers access organic certifications, creating better market opportunities and incentivizing sustainable practices (IFOAM, 2020). In wards where agricultural intensification is viable, it is crucial to provide farmers with access to modern tools and sustainable practices that enhance productivity without depleting natural resources (Altieri, 2018). Regions focused on cash crops could benefit from improved access to markets, agricultural technologies, and financial resources to maximize the profitability of their commercial ventures (Kremen et al., 2012).

5.6 Agricultural Practices and Opportunities for Organic Farming in the Context of Climate Change

Cereal crops, particularly rice, maize, and wheat, are the most widely cultivated across most wards, with their prevalence largely dictated by climatic suitability and irrigation availability. The integration of modern farming technologies in wards like Katakuti, Fasku, and Shailungeswori not only promotes the cultivation of cash crops and spices—such as ginger, turmeric, and chili—but also aligns with market demands for high-value produce (Kremen et al., 2012). The successful adoption of such technologies is associated with enhanced economic returns for farmers, showcasing the benefits of modern agricultural practices in improving productivity and profitability (Lal, 2020).

Farmers with larger plots tend to focus on high-yield crops that benefit from modern inputs, reflecting global trends where larger farms are often more productive due to economies of scale (Foley et al., 2011). Conversely, smaller landholdings, as observed in wards like Katakuti and Fasku, favor the intensive cultivation of vegetables and leguminous grains.

6. Conclusions

This study provides a comprehensive analysis of the agricultural dynamics in Dolakha District, Nepal, with a particular focus on key factors such as landholding size, socio-economic status, geographical conditions, resource availability, market integration, and technology adoption with regard to farming practices in each ward. The data indicates that larger landholdings in wards such as Shailungeswori, Katakuti, and Fasku demonstrate higher productivity due to better access to modern agricultural tools and practices. Conversely, marginalised groups, particularly those affected by caste-based disparities, face limited access to resources. In order to address these disparities, it is necessary to implement policies such as land redistribution and credit facilitation.

The research findings indicate a transition from traditional agricultural practices to a more diverse range of approaches, including the cultivation of cash crops and the adoption of organic farming methods. The study identifies potential avenues for sustainable agriculture in Nepal's mountainous regions, with a particular emphasis on agroecology, agroforestry, climate-smart agriculture, and sustainable livestock management.

The complexity of agricultural land abandonment was examined; factors such as labour migration, high farming costs and low profitability were identified as contributing to underutilisation. The remaining labour force, which is often composed of the elderly and women, frequently encounters difficulties in coping with outdated tools and methods, thereby exacerbating agricultural inefficiency. The results showed that Effective management strategies, such as agroforestry and mixed farming, together with precision agriculture and water-efficient systems can facilitate the balancing of ecological gains with productive land use.

The climatic modelling employed in the study identifies suitable crops for organic farming under future climate projections, thereby suggesting an increased viability of crops by 2050. The application of the EcoCrop model in the Dolakha district demonstrates its effectiveness in evaluating a diverse range of crops with limited climate data. The results of the study indicate that the model is effective in appraising a heterogeneous assortment of crops with constrained climate data. The model permits the incorporation of a range of bioclimatic variables, thereby conferring value as a tool for evaluating agricultural suitability in regions where comprehensive datasets may be lacking. The model identified the northern and southern parts of the district as the most suitable for the pre-selected crops, characterised by lower temperatures during the hottest months and higher precipitation during the driest months. The modelling results lend support to local preferences for crops such as beans, radish, garlic, colocasia and finger millet, thereby emphasising the potential for alignment between current practices and climate-smart agriculture.

The survey identified specific agricultural practices that could be employed as viable alternatives, namely off-season vegetable farming, commercial dairy farming, and the cultivation of high-value cash crops. It has been demonstrated that the cultivation of high-value crops, including spices, herbs, and medicinal plants, can yield significant revenues from modest land holdings, thereby providing a compelling motivation for the reclamation and utilisation of previously abandoned lands. The study underscores the necessity for region-specific strategies that integrate traditional knowledge with modern practices. It is imperative that communities are engaged, that policies are targeted and that infrastructure is invested in if resilience against climate change is to be enhanced and rural development promoted. In conclusion, the findings provide a strategic framework for policymakers, agricultural planners, and local communities to enhance productivity, sustainability, and ecological resilience in Dolakha District and other mountain regions in Nepal.

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iii. Community Based Bio-diversity Management project in selected areas of Eastern Hill Districts (Sankhuwasava, Terhathum and Taplejung) of Nepal.
iv. Women's Empowerment through Community Based Sustainable Livelihood Enhancement in 3 VDC of Dolakha, Nepal.
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vi. Integrated Rural Development and Nature Conservation Project in Chure, hill area of Chitwan district, Nepal.
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Publications and other experiences

- **Pechanec, V., Prokopová, M.,** Cudlín, P., Khadka, C., , **Karki, R**., & **Jakubínsk, J (2024).** Sustainable Organic Farming Crops in Nepal in Climate Change Conditions: Predictions and Preferences. Journal: Land, Volume: 13, 1610 **https://www.mdpi.com/2073-445X/13/10/1610**
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- Paper Presented on " Social Etnereprises and Rural Revitalization : Context Trends and Best Practices in Nepal" organized by Social Enterprise in Asia, PRRM and RRN , 11 January 2023.
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- Small -scale Commercial Vegetable Production to Promote Livelihood and Food Security in the Rural Hills of Nepal, derived from action research, published in August 2010 as a briefing paper of RRN No.5
- Member of research committee of Rural Reconstruction Nepal for its research activities and to support graduate students for research grants and thesis supervision coming from different universities of Nepal.
- Advisor for Master's thesis (2008) and study conducted on "Cardamom Cultivation and its Effects on Rural Livelihoods: A Case Study of Selected VDCs of Sankhuwasava District, Nepal" in collaboration between RRN and School of Environment, Management and Sustainable Development, Pokhara University, Nepal.

- Sustainable Rural Livelihood Programme: A Case of Community Development Program in Sankhuwasava District, Nepal. A study report presented at Nepal Community Development Workshop organized by International Research Foundation for Development, Minnesota USA and IFD Nepal, on 22-23 June 2007.
- Main supervisor to Master's Theses for two students of Masters Program in Rural Development at Tribhuvan University, Nepal. The theses entitled" An Assessment of Sustainable Rural Livelihood Program in Sankhuwasava" and "Impact Assessment of Rural Community Infrastructure Sustainable Development Project" in Dang district of Nepal (2004 -2005).
- 1998 June- December 2005: Team Leader for Farmer Field School/Integrated Pest Management Program at RRN.
- NGO Initiatives in the Reduction of Bonded Child Labours in Nepal, Vol.8, Issue 1, January 2004. The article published in The Reconstruction, quarterly publication of Rural Reconstruction Nepal.
- Status of food security in the hills of western Nepal: A policy review paper on government food aid program in Nepal, 2005 (unpublished)
- Country paper on Bonded Child Labour in Nepal for South Asia Regional Consultation workshop held in July 2003, Kathmandu, Nepal
- Role of Small Scale Irrigation for Household Food Security, Paper presented in "National Workshop on Food Security organised by National Alliance for Food Security (NAFOS) in Kathmandu, December 2000.

- Country paper on “Integrated Approach for Intervention Program in Elimination of Bonded Child Labourers” in South Asia Partners’ Regional Exchange Programs Addressing Bonded Child Labourer in the South Asia region organized in January 2001 in New Delhi, India.
- Managing Development through Institution Building, a paper presented in the UPLB in March, 1997
- Prospects and problems of NGOs in Rural Development of Nepal, Policy Issue paper presented in the Department of Development Management, University of Philippines at Los Banos, August, 1998
- Farmer Organisation and Institution Building for Sustainable Development, a paper presented in the University of Philippines at Los Banos (UPLB) in February, 1998
- Thesis entitled on' Management of Non Degree Training of International Rice Research Institute (IRRI), The Philippines, 1998

Major trainings and conference attended:

- 1-4 April 2024 in Phonm Penh, Cambodia: Participated in Asia Pacific Knowledge Exchange Program sustainable forestry, climate resilience, and nature-based solution and the program is organized by the Climate Investment Fund- CIF and Asian Development Bank, World Bank
- Represented Regional Board Member for Institute of Social Enterprises in Asia (ISEA), Manila Philippines (2019-2021)
- Presented Paper on “ Revitalizing Rural Communities, Youth Engagement and Social Entrepreneurship in the Context of Nepal “ at Virtual Conference of 3rd. SEAL Asia , (Social Enterprise Advocacy and Levering Asia Conference, organized by Institute of Social Enterprise in Asia, Manila Philippines , 16-17 September 2020
- Participated the Conference on Beyond Labels, Beyond Borders, International Solidarity Conference on the Rights of Climate Migrants held on 17-19 September 2019, Quezon City, Philippines
- Organized more than 20 workshops in Innsbruck, St. Polten and Graz of Austria about the Nepal’s Development Initiatives, Fund Raising Program for DKA Austria during 25 November – 13 December 2013.