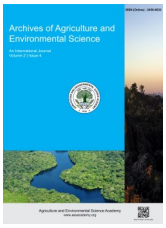
Archives of Agriculture and Environmental Science 7(3): 463-472 (2022)
https://doi.org/10.26832/24566632.2022.0703021

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



REVIEW ARTICLE

# Farming in the mountains of Nepal: crops, soil fertility, livelihoods and farm-forest linkages

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**ARTICLE HISTORY**

Received: 03 July 2022
Revised received: 18 August 2022
Accepted: 21 September 2022

**Keywords**

Agroecological practices
Farm-forest linkage
Livelihoods
Mountain farming
Niche-product development

**ABSTRACT**

In national plans, policies, and earlier development programs, livelihoods of mountain people in the Nepal Himalayas were overlooked, rendering them more susceptible to climatic risk and disaster. The management of marginal mountain agricultural land is crucial for food security, improved living conditions, and environmental protection. For enhancing livelihoods and ecological benefits, mountain agriculture is vital, however, a consolidated review on mountain farming is limited in Nepal. We used "mountain" AND "Nepal" AND "farming" OR "agriculture" in the literature's title published between 1978 and 2021 on Google Scholar and did an in-depth review of papers on the four thematic areas: mountain crops, soil fertility, livelihoods, and farm-forestry linkages. We observed a variety of nutrient-rich mountain crops with a market potential as niche products, low and deteriorating soil fertility of agricultural lands, a weakening of the farm-forest links, and an increase in the diversity of mountain livelihood choices. Small landholdings, labor outmigration mainly men, feminization of mountain farming, and food insecurity are the greatest challenges to the growth of agriculture in mountainous regions. There are, however, ample opportunities to make mountain regions green through agroforestry and community forests, to improve livelihoods by introducing niche value chains for products, to explore payment for ecosystem services through downstream-upstream linkages, and to recognize their traditional knowledge and practices through citizen science research and development.



**Citation of this article:** Gauli, P., Bhatta, S., Singh, S.K., Shrestha, K., Nidal, B., & Atreya, K. (2022). Farming in the mountains of Nepal: crops, soil fertility, livelihoods and farm-forest linkages. *Archives of Agriculture and Environmental Science*, 7(3), 463-472, https://dx.doi.org/10.26832/24566632.2022.0703021

## INTRODUCTION

Households in mountainous regions rely on agriculture for their major means of income support, food and nutrition. Besides the production of food for human use, mountain agriculture also helps to sustain the socio-ecological interactions that exist between people and the natural environment in mountains. Mountain regions have their own unique climates and ecosystems, which provide a diversity of agricultural growing seasons. This provides ample opportunity for the cultivation of a wide range of mountain crops and the development of specialized market segments. Potatoes, amaranth, beans, and buckwheat are some of the more significant traditional crops because they are not only staple foods but are green vegetables that are rich in nutrients. As a result, these crops ensure that marginalized people living in mountain areas have access to food and adequate nutrition (Palikhey *et al.*, 2016; Pudasaini *et al.*, 2016). However, mountain residents are often excluded from developmental supports, which may result in a high risk of vulnerability to shocks and pandemics, including poverty. This is the case in Nepal, although mountains are abundant in natural resources and provide essential ecological services to economies

all over the world (Pant and Rasul, 2013).The isolation, steep elevation, harsh terrain, infertile soil, and rising outmigration all contributed to a decrease in mountain food output, which impacted people's ability to provide food for themselves (Phuyal, 2013). In addition, there is limited land potential for growing production areas in mountains. This is mostly because of the lack of arable land, and a decrease in the amount of land held by each individual because of increasing population and land fragmentation. Recent road construction, technological advancements, and consequent market penetration have significantly influenced land use and land cover change. These factors have influenced the amount of forest cover, mountain crops, people's livelihoods, and ecological services (Shrestha, 2014). Nepal still has a long way to go to adopt and spread new ideas and technology, especially in farming communities in mountainous areas.

Mountain soils act as a carbon sink, which can contribute to the reduction of atmospheric $CO_2$ concentration and the attenuation of the greenhouse effect (Lützow *et al.*, 2006). Because of recent shifts in agricultural techniques and growing resource constraints, Nepal is confronting a significant challenge regarding the deterioration of the quality of its soil. Non-agricultural uses of fertile land, land fragmentation, cultivation in marginalized areas, cultivation on the slopes, overgrazing, burning of crop residues, imbalanced use of agrochemicals, and declining use of organic manure are some changes that have occurred. We have observed an increasing trend in the application of chemical fertilizers over the past couple of decades. This has resulted in detrimental effects on the environment of the soil, putting the fertility status of the land in jeopardy. The increasing cropping intensity and introduction of nutrient-demanding cash crops (such as potatoes) are two factors that have contributed to this trend. It has forced farmers to lower the size of their livestock herds to compensate for labor shortages and declining farm-forest linkages. This has harmed the availability of farmyard manure and compost in mountain agriculture (Paudel and Thapa, 2001). It is common knowledge that rural communities living in areas dominated by agriculture benefit from the presence of forests and trees on those landscapes as goods and services essential to the maintenance of their way of life (Foli *et al.*, 2014; Reed *et al.*, 2017; Sunderlin *et al.*, 2005). Integrating crop, livestock, and forestry system components minimizes the use of agrochemicals, improves farmyard manure and farm biodiversity, and reduces the need for new areas for crop or livestock production. In addition, this practice reduces the amount of land that is needed for crop or livestock production (Landers, 2007; Pacheco *et al.*, 2012). Integrating crop, animal, and forestry systems is promising to boost the efficacy and sustainability of resource utilization in farm production and land management for agricultural production (Wilkins, 2008). Many economic, ecological, and other benefits come from successfully integrating crops and cattle. These benefits include multiple micronutrients like vitamin A, vitamin $B_{12}$, and riboflavin, as well as calcium, iron, zinc, and a variety of vital fatty acids (Herrero *et al.*, 2013). Systems that are good for the environment and the climate, like integrated crop, livestock, and forestry systems, have a big part to play in increasing the amount of food and energy that can be made, even though water, land, and other inputs limit (Pacheco *et al.*, 2012).

Recently, planners and policymakers, as well as residents of mountain areas, have appreciated the influence that modernization in agriculture may have and the necessity of sustainable farming to improve the resilience of people's lives. Agroecology, which integrates the biophysical and socioeconomic aspects of farming into organized agroecosystems at different hierarchical levels, is now an absolute requirement for farming on a global scale. This is because farming with agroecological principles is the only way that can ensure agriculture's continued viability (Caporali, 2015). Agroforestry, multiple cropping, and the conservation of agrobiodiversity are a few agroecological practices that have been adapted to mountain farming in Nepal. Using more agroecological practices can facilitate the surmounting of obstacles inherent to mountain farming. The management of marginal mountain agroecosystems is becoming an increasingly critical issue for ensuring food security, improving living conditions, and protecting the environment. For mountain agriculture, the development and implementation of agroecological methods are absolutely necessary to achieve economic returns and enhance ecological services. Consolidated studies on Nepal's mountain agroecological practices are rare. In this review, we looked at scientific papers published between 1978 and 2021, to assess mountain livelihoods through mountain crops, soil fertility practices, and farm-forest linkages. Aside from this, we discussed some problems that come with farming in mountains and listed some ways to make farming in mountains more sustainable.

### Literature search and review protocol

Using the software known as Publish or Perish, a search was conducted on Google Scholar. In the publication's title, the keywords that were chosen were "mountain" AND "Nepal" AND "farming" OR "agriculture." On January 3, 2022, we searched for literature published between 1978 and 2021. There were 47 publications retrieved, and six of them were identical to one another. We could not access 18 publications. This review does not consider theses, reports, abstracts, and books. In the end, a review protocol was developed and used to conduct an in-depth analysis of 15 papers. We gathered data on the following four topical areas: mountain crops; mountain soil fertility; mountain agriculture and livelihoods; and farm-forest linkage in mountain agriculture (Figure 1).

## RESULTS AND DISCUSSION

### Mountain crops

The most popular crops are maize, wheat, potato, and finger millet. Barley and buckwheat are planted in fewer locations since they are related to the cultural features of the community (Pudasaini *et al.*, 2020). Millet, maize, and potatoes are the most significant summer crops, and they are planted on dry soil that

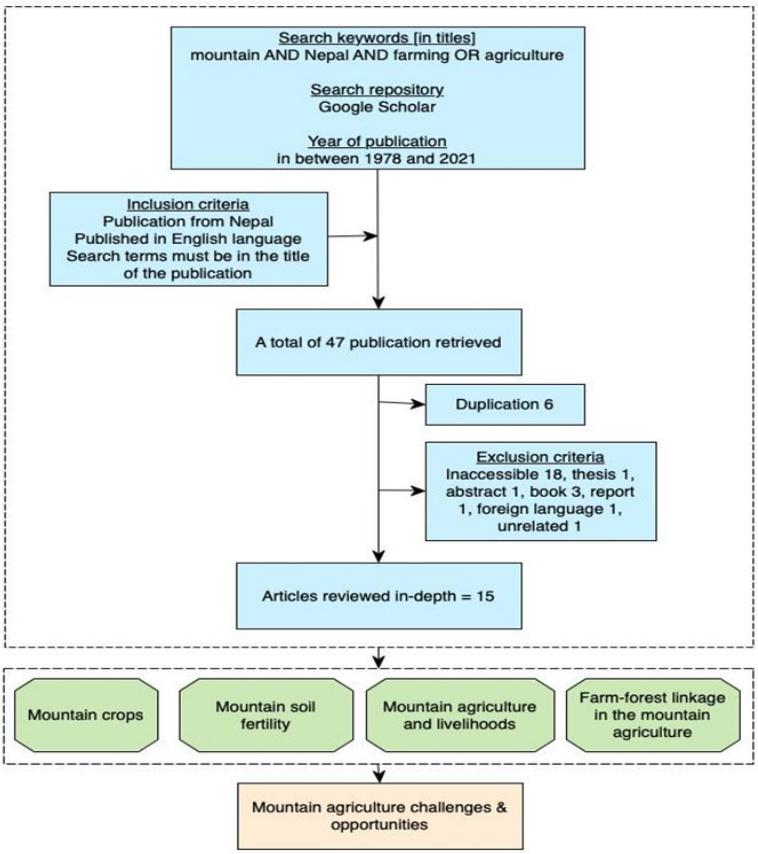


**Figure 1.** *Literature search criteria and protocol.*

slopes outward toward the edges (called Bari land) (Tulachan, 2001; Burris, 2014). The winter crops consist primarily of wheat and barley. Because of irregular climatic conditions, such as cold waves, the country's winter crops are inflicting damage (Sherchand, 1990). Rice, especially in the lower elevation, is the most valuable crop among cereals because its price is more than twice as high as the price of millet and maize (Burris, 2014). It is often grown at lower altitudes on terrain that slopes inward and has access to irrigation. At the level of the household, the agricultural priorities of the smallholders have been found to have switched away from crops grown in cold climates (such as barley and buckwheat) and toward income diversification and rice-based agricultural intensification (Shrestha, 2007). Barley was the least valuable of the cereal crops to grow. Some households handle the cultivation of soybeans and lentils. Lentils are a profitable crop. However, they cannot be grown at high altitudes and are vulnerable to being eaten by monkeys, which results in just a few people cultivating them. There were a tiny number of households engaged in the cultivation of cash crops such as ginger, cardamom, and tea. In the adjoining kitchen garden, vegetables are only grown to be consumed by the garden's owners (Burris, 2014). Compared to food grains, specialized horticultural crops, such as apples and citrus fruits, have a more favorable cost-benefit ratio, and their economic significance is growing (Tulachan, 2001). Rice-based cropping patterns are common in lower elevation areas (950-1500 meters above sea level). Maize and millet-based cropping patterns predominate in mid-altitude upland areas (1500–2000 meters above sea level). Maize/potato and livestock-based highland farming systems are found in the higher altitude areas (2000–3000 meters above sea level) (Pudasaini *et al.*, 2020). To get the most out of their limited agricultural holdings, farmers employ a wide range of cropping tactics. Some examples of these techniques include double cropping and complicated intercropping (Burris, 2014).

## Mountain soil fertility

In mountainous regions, both the fertility and productivity of the soil are on the decline (Burris, 2014). Because of an imbalanced fertilizer application, soil and nutrient depletion can be so severe that most crops cannot thrive (Sherchand, 1990). This is because soils are becoming increasingly low in micronutrients such as zinc, boron, and molybdenum, and the symptoms of this deficiency are becoming more and more apparent in sensitive crops such as fruits and vegetables (Sherchand, 1990). In a similar vein, a study that compared three distinct land uses—forested, rainfed agriculture, and irrigated agriculture—found that the soil fertility in dryland agricultural fields and forested soil is decreasing, whereas the irrigated fields receive relatively more fertilizers, water, and sediments than the rainfed agricultural fields do. There is a low to an insufficient range of soil nutrients for practically all the primary crops that are cultivated in a cycle (Shah and Schreier, 1994), and there is rising pressure to make use of the resources that are available in forest areas to satisfy the basic food needs of people (Shrestha, 2014). Because of this pressure and the excessive

use of chemical fertilizers, the soils in the mountains have been damaged, and as a result, it has been a continuing challenge to preserve soil fertility and reduce soil erosion. In a similar vein, the growing application of chemical fertilizer is interfering with the natural processes that are carried out by the microorganisms that live in the soil (Dhakal *et al.*, 2021). The fertility of the soil can be restored through indigenous practices such as the use of domestic manure and the production of native species rather than exotic species, which require a higher dose of fertilizer. This has numerous benefits, not only for the soil but also for the products that are produced from the soil (Dhakal *et al.*, 2021). There is evidence that soil that has been fertilized with domestic manure increases the population of organic microorganisms, which accelerates the process of mineralization and formation of the soil, as well as nutrient enrichment and the maintenance of soil fertility in the absence of chemical fertilizer (Dhakal *et al.*, 2021). This would lead to a reduction in the chemical hazards that are present in the soil (Dhakal *et al.*, 2021). According to the findings of one study that was carried out in the Khaling Rai community, most households, which accounted for 93 percent, used organic fertilizers, notably manure collected from animals (Burris, 2014). Mountain livestock, which includes cattle, buffalo, sheep, and goats, plays an important role in the preservation of soil fertility. This is especially true in areas of the mountains where the use of chemical fertilizers may be prevented because of a lack of availability or because of the higher cost of these products (Shrestha, 2007). As a result, the most important supply of organic fertilizers comes from large ruminants such as cattle and buffalo (Burris, 2014). According to one school of thought, the quantity of animals does not have a direct effect on the fertility of the soil; rather, what matters most is the management of the manure (Tulachan and Neupane, 1999). A traditional monocropping system was replaced with agroforestry, which resulted in significant improvements to the soil's chemical parameters, including an increase in organic matter (2.19 percent), nitrogen content (0.13 percent), effective cation exchange (3.9 cmolc/kg), and phosphorus content (73.8 mg/kg) (Schick *et al.*, 2018). Higaki *et al.* (2005) demonstrated that planting Napier (*Pennisetum purpureum*) in parts of the gully catchment that had gotten worse showed that it could improve soil fertility and repair the damage to the gully catchment.

## Mountain agriculture and livelihoods

Agriculture is the primary means of income in mountain regions (Schick *et al.*, 2018). The mountain farming system is distinguished by integrating crops, cattle, and agroforestry; this method is traditional and requires a significant amount of human work (Pudasaini *et al.*, 2020). Most mountain farmers are small landholders, and the average size of their holdings is 0.42 hectares. This presents the most significant challenge to the commercialization of mountain farming. Tulachan (2001) contends that integrated production of cattle, staple crops, fruit, and vegetables contributes to every aspect of farmers' ability to sustain in mountain environments. Farm commercialization in the mountains is comparatively less because of the prevalence of tiny landholdings. Farmers can intensify land by using fruit and vegetable crops, along with income crops and livestock, to fight off the tiny landholdings. The cultivation of fruits, vegetables, and various other horticultural crops has expanded in commercial significance among mountain farmers in recent decades, which has led to an increase in the number of employment opportunities. Off-season vegetable cultivation has become increasingly profitable in recent years. Off-season production of tomatoes or cucumbers can bring up to a US $5,000/ha net return in 120 days in certain mountain niches like Dhading, Panchkhal, Pakhribas, Lumle, and Dhanubase, which is helping mountain farmers improve their livelihood and the economy of their region through both direct and indirect effects on revenue and employment (Sah, 2002). Diversifying agricultural production in mountainous areas with scattered fields, delayed planting, and intercropping can reduce the risk of crop failure and more evenly distribute work during the growing season (Schick *et al.*, 2018). A livelihood strategy that has a substantial impact on the improvement of land management in Nepal is outmigration. People who live in mountain communities have a better chance of escaping poverty and improving their economic situation because of outmigration. Outmigration also makes sure that future generations of mountain residents will have access to food and education (Burris, 2014). However, because of outmigration and a lack of labor, cropland is no longer used and is instead turned into abandoned land; this results in a decrease in the amount of agricultural land that is available per person. Because of these labor dynamics, which are driven by outmigration, there has been a change in the local demography, which has caused an acute shortage of male labor in mountain farming.

## Farm-forest linkage in mountain agriculture

The connection between agricultural practices, animal husbandry, and forest management (Figure 2) has become increasingly tenuous (Tulachan and Neupane, 1999). This is not only due to a slow decline in access to the amount of land covered by forests, but also to a deterioration in their condition, which harms local agroecosystems and agricultural output. The relationship between farms, forests, and livestock is strong in areas that have relatively abundant forest resources, while it is weak in areas that have a scarcity of forest resources (Yadav, 1990). This is because forests supply feed and bedding materials to animals, and in exchange, forests receive excrement from livestock that graze on the land. According to studies, the relationship between farms, forests, and farm animals is strong in locations where market forces have a minimal impact on agricultural transformation, but it is weak in regions where market forces encourage agriculture commercialization (Shrestha, 2014). Because of the impact of market pressures, agriculture in the mountains is becoming increasingly dependent on technological inputs and less on the resources provided by forests. Even in modern times, agricultural methods in regions with less market intrusion are more traditional. There is less use of chemical

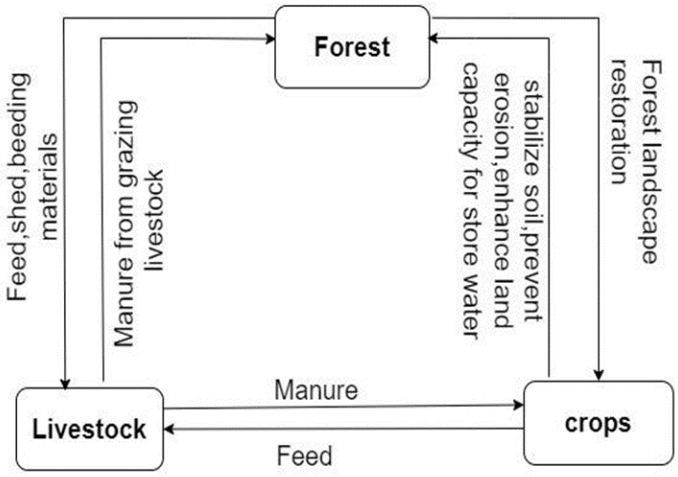


**Figure 2.** *Farm-forest linkage*

fertilizers and pesticides, and people still gather leaf litter for use as farmyard manure and compost. It has not yet been determined whether community forestry has a significant influence on the supply of fodder and leaf litter on mountain farms. According to the findings of a research, community forests have increased the supply of fodder and leaf litter for marginal fields as well as preserved the relationship between farms, forests, and livestock (Tulachan and Neupane, 1999). Other studies stated that community forests have reduced the supply of fodder and litter sources because the forest area is closed for grazing and there are strict rules and regulations in place for collecting fodder and leaf litter from the community forests. This has resulted in a weakening of traditionally sustainable farm-forestry-livestock relationships.

## Mountain agriculture challenges

Small and fragmented landholdings, outmigration, agriculture feminization and food insecurity are the major challenges in mountain agriculture. Small landholdings limit the growth and production of mountain farmers. Small landholdings have reduced forest cover by extending cultivation on steeper slopes and forested lands to meet the needs of a growing population (Burris, 2014).

Mountain villages are in danger of losing their ability to provide food for themselves because of the significant increase in the number of people moving away (Burris, 2014). According to (Pudasaini *et al.*, 2020) the outmigration of males has resulted in females taking up traditionally male roles, including those connected to traditional farming, decision-making, and other farming-related concerns. Specifically, the outmigration of males has resulted in females taking up traditionally male roles in farming. This has also led to the protection of farm agrobiodiversity in an adjacent kitchen garden and resulting in most of the land remaining uncultivated. According to Pudasaini *et al.* (2020), the engagement of female farmers is critically important to the success of traditional farming. It will be necessary for us to involve women farmers in research and development processes and to offer additional support services to motivate those women who continue farming activities while adhering to agroecological principles. This will be necessary for us to do if we opt for long-term outmigration. Outmigration led to a rise in the workload placed on the shoulders of the female members, a deterioration in women's health and concerns regarding financial stability and the availability of food in the household, and limitations placed on the research and implementation of agroecological practices. Women are not compensated for their work in agriculture or domestic labor (Dhakal *et al.*, 2021), nor are they emphasized in the development process. The adoption of heavy duty, men-oriented agricultural equipment is troublesome for mountain women because of the emotional pain that occurred in mountain women because of the absence of their spouses. The increased intensity of women's work on farms, which has also made them more vulnerable to environmental risks, has put an unfair burden on women.

Agriculture is not viable in mountain regions because of the severe locational poverty and it cannot meet the ever-increasing food demand of mountain people. Sah (2002) pointed out that there is no assurance that residents will have enough food throughout the year. They must rely on the local food market (Tatsumi, 2005). It is becoming increasingly critical to increase food security by increasing options for making a living while also protecting the mountain environment. One example of this would be better management of marginal land (Sah, 2002). With the availability of food and the need for it, ecological zones have quite distinct similarities and differences. Some of the major challenges that have been identified include the high demand for food in the mountains and the unfortunate low production within; the transition from traditional mountain-based farming to industrial farming; and limited access to new agricultural technology (Burris, 2014).

## Mountain agriculture opportunities

Despite many challenges, mountain agriculture provides ample opportunity to progress. Agroforestry is of critical importance to mountain farming and the opportunities it provides for making a living (Pudasaini *et al.*, 2020; Schick *et al.*, 2018; Sthapit *et al.*, 1998). Schick et al. (2018) examined how the introduction of

agroforestry practices in mountain locations brings about a multitude of socio-economic and ecological benefits, as well as a road for sustainable modernization and a reduction in the risk of disaster through increased financial stability. The success of these kinds of activities will help farmers in various ways, like making it easier for them to consider economic and environmental risks, giving them easier access to food, and making sure their finances are stable.

Likewise, niche value chain development in mountain areas for mountain specialty crops has been recommended. Kafle *et al.* (2018) highlighted the importance of developing specialty value chains in mountain agriculture to improve people's lives. It was expected that if mountain regions had well-developed value chains, it would be possible to cut the rate of poverty in those areas by 8%. This is because of the expansion in both household income and assets over the past few years. The rise in household income can be attributed to the higher prices received for crops and livestock. Besides this, project beneficiary farmers have improved access to markets compared to farmers who are not beneficiaries of the program. The value chain part of agriculture needs to be expanded to include everyone from the producer to the consumer. Stakeholders, credit organizations, and the government need to work together to make this happen.

Provision of payment for ecosystem services (PES) schemes for mountain people in conservation of mountain biodiversity and enhancing ecosystem services could be other possibilities in the mountain regions. Women would profit from implementing a payment system for the ecosystem benefits provided by the mountain landscape. There is only one study in our review that investigates such a method (Dhakal *et al.*, 2021). According to the findings of the study, the PES program has increased the provision of environmental services, which has a positive impact on both the well-being of humans and the environment. This strategy ensures that farm women continue to have access to acceptable working conditions, particularly those that protect their health and provide them with agricultural services. PES has increased the capabilities of women, provided property rights and social equity, and ensured the preservation of indigenous knowledge and sociocultural traditions, as well as local resources for future generations. PES programs have also been used as a sort of agricultural subsidy, which has given women the opportunity to increase both their farming activities and their profits. According to the findings of this study, PES can boost income, cash flow, and employment while also improving living conditions. In the meantime, the results help improve social protection, counteract the bad effects, and meet the basic and strategic needs of women. Finally, we see ample opportunities to work with local people in academic research in understanding local socio-ecological system. A great example of local people getting involved in scientific study is the practice of participatory plant breeding, which is used at the field level. Because of this, many farmers have developed their own unique varieties of the crop (Sthapit *et al.*, 1998). Farmers have favored the improved variety of seeds over the local type because of better productivity. The need for seeds is not met and must be supplied from outside sources. Participatory vegetable seed production is becoming more and more popular. This has helped farmers move from subsistence farming to commercial farming, which has improved their living conditions and food security (Sah, 2002).

## Moving ahead

We suggest the following measures for ensuring the long-term health of mountain farming, livelihoods, and ecosystems.

### More research is needed on mountain crop agronomy

A self-sufficient agricultural system in the Himalayan mountains formerly allowed Nepal to exist on its own. The Nepalese government has included measures to make mountain farming more resilient to climate change as part of its national strategy for adaptation and mitigation. The system is a low-input, high-nutrient, holistic farming method that respects local knowledge and culture by preserving a wide variety of edible plants. There are several challenges while trying to cultivate crops in a harsh environment with steep topography. High winds, cold, and snow are just a few of the challenges that farmers face when working in the highlands. Finding crops including varieties that can thrive in any of these environments is a top priority. Gauchan *et al.* (2020) found several crops in the mountain areas. Finger millet, cold-tolerant rice, beans, barley, foxtail millet, proso millet, buckwheat, and amaranth are a few of them. A changing climate may affect the crop rotation period (Kang *et al.*, 2009). So, future studies in mountain areas should look at how the changing climate might affect the planting dates of crops, as well as other agronomic factors like crop and variety suitability, planting density, organic manure and chemical fertilizer needs, and social acceptance.

### Focus more on improving soil fertility management practices

The soil in the mountain agroecosystem is often low in nutrients and high in acidity. In the Jhikhu Khola watershed area, the soils of major crops (wheat, maize, mustard, and rice) contained low levels of soil nutrients (Schreier *et al.*, 1994). There are numerous causes for the low soil fertility status in mountainous areas, but it is crucial to delve deeper to comprehend why formerly viable mountain agroecosystems are currently unsustainable. Prior development plans placed less emphasis on mountain soils; new high-yielding crops were introduced that caused higher use of chemical fertilizers, resulting in acidic soils; farm-forestry linkages were weakened, reducing the application of farmyard manure to the soils; and neither the public nor private sectors have prioritized in developing new specialty mountain crop varieties. Farmers may use fewer chemical fertilizers if they have a larger number of animals. This is so that the need for fertilizer can be met most effectively by the manure of cattle, buffaloes, sheep, and goats (Regmi and Zoebisch, 2004). Farmyard manure is a good source of nitrogen and other nutrients. Bari land contained more nitrogen, phosphorus, and potassium than Khet land because Bari land has a

substantial agroforestry component in the mountains, which enriches the soil with organic matter and nutrients (Regmi and Zoebisch, 2004). For instance, Neupane and Thapa (2001) demonstrated an increase in crop yield (5.7 Mg/ha per year) compared to conventional farming systems (3 Mg/ha per year) when farmers adopted agroforestry systems in Bari land because of the increased amount of farmyard manure.

In short, mountain soil is deteriorating and mountain climate is changing. Raising soil carbon levels is crucial for restoring mountain soil fertility and building climate resilience. We can accomplish this by avoiding the use of chemical fertilizers and adopting sustainable soil fertility improvement practices. Increased farmyard manure and compost production; legume intercropping; cattle urine collection and utilization; rainwater and runoff collection; and effective wastewater management are just a few sustainable soil and water management strategies that have helped improve soil fertility and crop yield (Shrestha *et al.*, 2014). The promotion of jholmal, green manuring, and mulching can decrease external inputs and increase their capacity for adaptation to create climate-resilient mountain farming (Subedi *et al.*, 2019). Governments and international bodies should conceive providing support and incentives to mountain people for adopting sustainable soil fertility and water management techniques to produce enough food and maintain healthy agroecosystems. Payment for ecosystem services could be a good scheme for rewarding mountain people.

### Strengthen farm-forest connection to increase climate resilience

Previous studies showed a weakening relationship between mountain farms and forests. However, Karki *et al.* (2018) demonstrated a good farm-forest linkage in the Kalopani community forest in the Kavrepalanchowk district. Most of the community forest user group (CFUG) in this area (268 households) make their living by raising livestock. There is a successful dairy business in the rural community. Almost every family in the village makes an extra $50 per month selling milk and dairy products, or approximately 25% of their annual income. The CFUG has installed harvest blocks in the forest area to encourage livestock, which helps to prevent the forest from being overgrazed. An average of 25 *bhari* (25 bhari (1 bhari is equivalent to 30 kg) of leaf litter is collected by an individual yearly, where it is then used as bedding material and farm manure. Every year, the members of the CFUG transfer around 30 metric tons of manure from their stable onto their farm. Agroforestry is the system of planting trees and shrubs in agricultural landscapes to improve the productivity and sustainability of agricultural production. To enhance agroforestry systems and the benefits that they provide, it is important to understand how they work together with other farm-forestry linkages. This traditional technique has strengthened farm-forestry interconnections. This approach can enhance soil quality, enhance water retention and slow down runoff, preventing soil loss and flooding in the event of intense rainfall, sequester carbon dioxide, provide habitats for wildlife and pollinators, and make landscapes more resilient to climate change.

### Focus on livelihood diversification

One of the household livelihood strategies is to diversify their sources of income (Gebru *et al.*, 2018; Pant *et al.*, 2014; Shahi *et al.*, 2022). Diversified economic activities provide long-term security and are less vulnerable (Ellis, 2000). This is so that if one source of income temporarily declines, the other source can compensate for the loss in income (Stotten, 2020). The size of the landholding determines the diversification of a household's means of subsistence because households with smaller plots of land have better options for producing both diversified food and income (Kimengsi *et al.*, 2020). In such small plots (0.5 ha), people prefer to grow traditional crops (Gauchan *et al.*, 2020). Smallholders in the mountains have diversified farms compared to large landholders. Agriculture has traditionally contributed to the food security and livelihoods of households in the mountains by providing a variety of foods and income. However, agriculture contribution to household food consumption and household income has diminished significantly over time (Hussain *et al.*, 2016). In high mountains, it is difficult to have enough food for over six months (Gauchan *et al.*, 2020). Crop area expansion can increase food production but also have negative environmental effects, so intensifying crop areas with increasing access to irrigation facilities and other inputs can increase food availability (Droogers and Aerts, 2005; Kang *et al.*, 2009). Crop diversification and land intensification can help them adapt to the effects of climate change (Alcamo *et al.*, 2007; Kang *et al.*, 2009). Water conservation, a shift in sowing time, and the introduction of new crops, such as fruits and nuts, that are more resilient to water stress and have a higher market value, are among the new farming practices adopted in the mountain region to combat climate change (Hussain *et al.*, 2016). Changes in cropping patterns and agricultural practices, the use of multipurpose plant species, livelihood diversification, and income-generating activities are essential climate change adaptation strategies (Adhikari *et al.*, 2018). Crop diversification can increase the agricultural system's resilience. Lin (2011) argues that crop diversity has a greater capacity to suppress pest outbreaks and dampen pathogen transmission, as well as protect crop production from the effects of increased climate variability and extreme events. However, if the market and structural shocks continue in the mountains, the ecosystem services will not be provided well in the future (Brunner and Regamey, 2016). The mountains' socio-ecological system is sensitive to climate change.

### Tackle mountain agriculture feminization

Another issue in mountain farming is the increasing and visible feminization of agriculture because of male labor outmigration, which also results in cropland abandonment because of labor scarcity. It comes as a surprise that most migrant households spend the smallest percentage of their remittances on agriculture (Bhandari and Reddy, 2015), and sometimes a few migrant households have no intention of engaging in traditional farming (KC and Race, 2020). As a result, the amount of work that

women do in agricultural settings has grown. Because men aren't around to do their share of the work, women fill a variety with tasks in the home and on the farm. Women entirely managed the mountain farming system, making them its most important determinants. Therefore, institutional sectors, development organizations, and policymakers that work in mountain regions need to address the feminization that outmigration and the changes that have occurred in the status of household food security have generated. Involving women's groups in the value chain has improved their ability to lead and raised household financial security (Adhikari *et al.*, 2018).

### Develop niche value chain for mountain commodity

High mountain environments' great diversity gives these regions a comparative edge in producing a range of niche products for both domestic and international consumption. Mountain specifics, including accessibility, fragility, diversity, and marginality, as well as the availability of specialized goods and services, have a big influence on value chain analysis and the choice of value chain development. We can achieve agricultural sustainability through the careful experimentation of new agricultural technologies in local niches, making them adaptable and accessible to end-users (Pant *et al.*, 2014). Developing mountain-specific products with well-established vertical and horizontal linkages could support mountain residents in coping with the effect of climate change. Allocating land for organic farming in the mountain regions could be one option. Organic farming is a way of producing food without using synthetic chemical. It uses natural methods and has been proven to be more effective than conventional farming. It has a greater positive impact on the environment and is better for the people who grow the food. It improves soil health, increases production over time, and maintains ecosystem services (Parajuli *et al.*, 2020). This helps reduce micronutrient deficiency in the mountains and provides a better life for the people. It also helps mountain people survive on the steep slopes and high altitudes of the Himalayas under intense food insecurity and climate change. However, many people in the mountains still do not know about the premium benefits of organic farming and are not aware of how to add value to the mountain farm products. Despite the numerous benefits, there are also disadvantages. The disadvantages include a lack of organic fertilizers and biopesticides, and a lack of knowledge on how to add value to organic products and limited markets in the mountainous areas. One way to promote organic farming is by selling locally grown mountain products to nearby urban markets. We can embrace organic agricultural farming through botanical pesticides, green manures, biopesticides, bio-fungicides, and kitchen and field wastes (Parajuli *et al.*, 2020). Farmers elsewhere agree that organic farming is better for the environment, promotes soil fertility, and is thought to be healthier than conventional farming (Zollet and Qu, 2018).

## Conclusion

We found a limited number of scholar articles on the mountain agriculture published in the peer-reviewed journal. Nonetheless, through an in-dept review of limited publications, we observed (i) an availability of a number of nutrient-rich mountain crops with great market potential as niche products, (ii) increasing deterioration of soil fertility on agricultural lands, (iii) a weakening of the interconnectedness between farms and forests, and (iv) a rise in the number of ways people in the mountains can make a living. The interplay between farming, forestry, and livestock is not as strong in the mountain regions that have a limited supply of forest resources, but it is robust in the mountain regions that have a reasonably abundant supply of forest resources and where there is no intrusion from market forces. Henceforth, mountain farmers can benefit from strategic and efficient utilization of forest resources. Development partners and government should realize that farming in the mountains has some limitations, for example, small farmland, male outmigration and labor shortage, women taking over mountain farming, and food insecurity. There are, however, opportunities to make mountain regions greener through developing mountain specific interventions and action plans. We recommend (i) developing suitable agroforestry systems and promoting community forests, (ii) to improve people's lives by introducing niche value chains for mountain products, (iii) to look into payment for ecosystem services schemes for downstream-upstream links, and (iv) to recognize their traditional knowledge and practices through citizen science research and development.



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