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Agroforestry: An Inspirational Case of Diversified Farmers Income and Climate Change Adaptation Strategy in the Mid-hills of Central Nepal

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KEYWORDS

Agroforestry
Climate Change
Adaptation strategy
Chepang community

ABSTRACT

Agroforestry (AF) plays an important role in food security, climate change mitigation and adaptation, and environmental resources preservation and restoration. This study was carried out in Raksirang rural municipality of Makwanpur district, Nepal aiming at assessing existing AF practices, their contribution to climate change adaptation, household income and livelihood improvement of the indigenous *Chepang* Community. Mixed methodological approaches including key informant interviews, group discussions, household surveys were employed for data collection. The data were analyzed by using descriptive and inferential statistics (percentage, mean, frequency distribution, graphics) and F-test. Local communities have been found practicing various AF systems including Agri-silviculture, Silvo-pasture, Horti-silviculture, Apiculture and Silvo-fishery. Adoption of AF practices contributed 72.82% of total Household's income, in which income from livestock was highest (32.88%). The strategies followed by the local communities in response to climate change included planting of trees and grasses, improved farming practices by growing commercial fruits; replacing farm activities with non-farm activities; use of farm yard manure, chemical fertilizer, pesticides and planting crop earlier than actual sowing time. Trees and grass plantation should be done periodically and promotion of Non-Timber Forest Products (NTFPs) in their AF practices should be encouraged. It will finally contribute in the improvement of local adaptation.

INTRODUCTION

Agroforestry (AF) is an environment friendly land use strategy that combines annual food crops, perennial trees and shrubs, and/or livestock on the same unit of land to maximize total productivity (Toppo et al., 2018). AF combines agricultural and forestry technologies to create a land use system that is more diverse, productive, profitable, healthy and sustainable. Approximately 70% of the Nepalese population relies on the forest, and 66% on both agricultural and forest products (ACIAR, 2014; Amatya et al., 2018). AF has potential to replace Nepal's

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input-intensive agriculture because it is an integrated and multipurpose land use (Dhakal and Rai, 2023). Input intensive agriculture is a farming method that primarily depends on outside resources, such as artificial fertilizers, pesticides, labor, energy and water, to produce large yields and rapid crop development(https://ffacoalition.org/articles/intensive-agriculture/). Some agroforestry practices, such as timber based and fishery-based, which require less labor than input-intensive agriculture, give Nepalese farmers the chance to revitalize their family economies and thereby address the problem of farmland abandonment (Dhakal and Rai, 2023). Trees or shrubs are purposely used within agricultural systems in AF systems, or non-timber forest resources are cultured in forest settings. Integrating trees into agricultural systems can be complicated and difficult to implement in many conditions, and there is no single plan that works for every region, but the benefits are substantial (Ospina, 2017). According to Paul *et al.* (2017), an increase in land-use efficiency leads to a land-use system that reconciles agricultural provisioning with a variety of ecosystem services, including climate change, improved farm revenue, carbon sequestration, etc. Setting up appropriate AF systems and supporting their long-term growth in farm-based communities have been highlighted as a feasible strategy for expanding rural livelihood opportunities while maintaining ecological balance (Aryal et al., 2019). Increased productivity, economic benefits, social wellbeing, and enhanced ecological goods and services are all advantages of AF systems for the farmers as well as for the local and national prosperity over traditional agriculture and forest production methods. According to a study conducted in Ethiopia, AF and farm diversification practices improve the sustainability of land management and maximize the economic return on investment for farm households (Kassie, 2018). AF meets present and future requirement of multiple products such as food, timber, fodder, fuel wood, leaf litter, medicine related to agriculture and forestry and also protects against environmental degradation. As a result, AF is progressively becoming a new area of study for natural scientists.

The Earth's climate is changing at a quicker rate than at any other times in recorded history, owing mostly to human activity. There is scientific consensus that unmanaged carbon emissions would result in global warming of at least several degrees Celsius by 2100, posing significant dangers to human society and natural ecosystems on a local, regional, and global scales (https://climateknowledgeportal.worldbank.org/overview). Climate change is more than an environmental concern as it has the potential to undermine the effectiveness of Nepal's development efforts. The average temperature in Nepal has risen 0.60°C in the last decade, compared to a global increase of 0.74°C over the last hundred years (http://www.globalpost.com). Recent research by the Asian Development Bank estimated that by 2050, climate change will cost Nepal around 2.2 % of its yearly GDP equivalent. The warming in Nepal is complicated because it is not uniform across the country's surface area or by altitude. According to estimates, weather-related disasters account for up to 90% of agricultural losses in Nepal, with drought alone accounting for roughly 40% and floods for another 23% of damage (Ramasamy and Regmi, 2014).

Adaptation to climate change in developing nations is critical, and it has been identified as a high or urgent priority by them (UNFCCC, 2007). Over the next decade, to combat the existential threat of climate change, USAID has developed a new climate strategy which includes preventing 6 billion metric tons of global greenhouse gas emissions, conserving 100 million hectares of critical landscapes, and improved climate resilience of 500 million people (USAID, 2022). According to World Population Review 2021, Nepal is one of the 30 poorest countries in the world, with one-third of its population living in multifaceted poverty (GON and UNDP 2020). Nepal, a Least Developed Country (LDC), is ranked 147th out of 189 nations and belongs to the medium human development group (GON and UNDP 2020). Due to poverty, insufficient resources, and greater susceptibility to natural disasters, the effects of climate change disproportionately affect vulnerable individuals and ecosystems (Mal et al., 2018). Local governments and organizations frequently fail to protect the most vulnerable people of marginalized communities and low-income nations (UNDP, 2019). Although the necessity of climate action is acknowledged worldwide, existing efforts are insufficient to resolve the problem. Nepal is trying to implement climate change adaptation measures in 750 communities and 120 village councils by 2030 A.D (GoN, 2017), which will help in achieving UN Sustainable Development Goals (SDGs) (Giri et al., 2023). It also seeks to develop climate-smart farming and villages while reducing the consumption of ozone-depleting substances and carbon dioxide emissions from various sectors (GoN, 2017). Adaptation is a worry and a necessity in underdeveloped countries since vulnerability is high and adaptability is low there. Priority areas for adaptation are particularly needed for poorer, ethnic, and resource-dependent groups, and analysis of the components of vulnerability and adaptive capacity of vulnerability contexts is more effective for building local adaptation plans (Khadka et al., 2022). Adaptation has drawn a lot of attention as the effects of climate change have become more obvious all around the world (Mimura et al., 2015). AF is frequently seen as a key climate-smart option with numerous important co-benefits and a cost-effective climate change adaption method. Despite growing interest, there is still lack of knowledge about the effectiveness, practicality, and societal repercussions of nature-based climate change solutions (Kabisch et al., 2016).

With rising food shortages and climate change risks, AF is gaining popularity for its ability to meet a variety of on-farm adaptation demands and play a variety of roles in agriculture, forestry, and other land-use (AFOLU) mitigation pathways (Mbow et al., 2014). AF systems offer a variety of environment friendly techniques that are used to combat climate change, suggest ways to create harmony between agroforestry and climate change, and maintain the ecosystem's sustainability (Jhariya et al., 2019; Sarveswaran et al., 2023). AF is a promising agro-ecological approach to climate change adaptation because many agroforestry systems offer a wide range of benefits in addition to climate change adaptation, such as synergies with climate change mitigation through carbon sequestration and diversification of household income sources through production of fruits, fodder, wood for fuel and construction, medical substances, fibers, and waxes (Meybeck et al., 2020). The study area, Raksirang, is vulnerable to changing climate as it lies in the ecologically fragile mountain foothills, known as Chure region. This region is more fragile and liable to soil and water related disasters (Gyawali and Tamrakar, 2018). According to Tiruwa et al. (2021), intense rainfall during monsoon causes significant soil loss in the Chure region. In this context, wise use of natural resources and practice of environment friendly methods such as AF are essential on such lands. In view of the above realities, this research was carried out to assess existing AF practices, their contribution to climate change adaptation, household income and livelihood improvement of local people.

MATERIALS AND METHODS

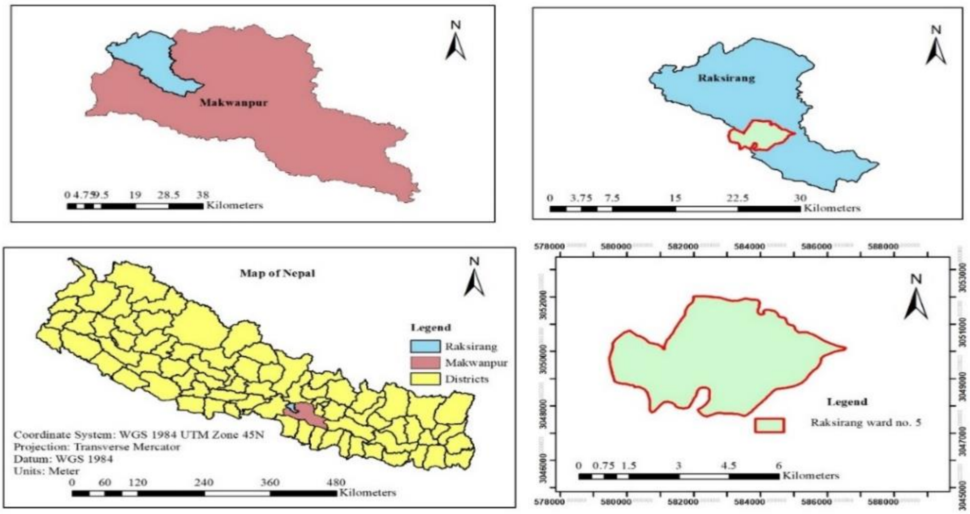

Figure 1: Map of the study area.

Study area

Rabang and Jirkhidada villages at Raksirang Rural Municipality-5 of Makwanpur district (Figure 1), lies in the Southern part of Bagmati Province of Nepal (27°32’53.19”N and 84°50’39.13”E).

Ward no. 5 covers an area of 18.14 sq.km and is inhabited by 540 households, with a total population of 3453 as stated in Raksirang Municipality’s ward profile 2075. The rural municipality features extremely diverse geography and climate with elevation ranging from 300 to 2,300m above sea level. Temperature of this municipality usually ranges from a minimum of 5° Celsius in winter to a maximum of 35° Celsius in summer with mean annual average of 18° Celsius. Agriculture is the main occupation of this municipality and most of the land is covered by hills and forests. The study area lacks easy access to market facilities. Most of the farmers grow rice paddy, wheat, millet, maize, black gram, horse gram and a variety of off-season vegetables. Major tree species found in these two villages are Chiuri (*Diploknema butyracea*), Ipil Ipil (*Leucaena leucocephala*), Tanki (*Bauhinia purpurea*), Khanyu (*Ficus semicordata*), Badahar (*Artocarpus lakoocha*), Dabdabe (*Garuga pinnata*), Kutmero (*Litsea monopetala*), Barro (*Terminalia belerica*), Bakaino (*Melia azederach*), Harro (*Terminalia chebula*), etc.

Data collection

Initially, a reconnaissance survey was carried out to be familiarized with the study area and the potential respondents. Primary data were collected using mixed methodological approach involving field observation, key informant interview, group discussion and household (HH) survey. A questionnaire survey was administered in each of the 42 HHs of the study area. The data gathered for well-being ranking pertained to livestock, agriculture, fruits, poultry, broom grass, apiculture, non timber forest produtcs (NTFPs) and fishery. The Department of Hydrology and Meteorology (DHM) provided a secondary database on temperature and precipitation. The 30 years’ climatic data from 1991 A.D. to 2021A.D. of the study areas were taken from the Meteorological Station for the analysis of climatic data, mainly temperature and rainfall (Table 1).

Table 1: Meteorological stations used in the study

Station	Name	District	Code	Latitude	Longitude	Elevation
1	Shilinge	Makwanpur	0930	27.6351	84.7415	802
2	Hetauda N.F.I.	Makwanpur	0906	27.42021	85.02521	452

Data analysis

Quantitative data were analyzed using descriptive and inferential statistics like percentages, means, and frequency distributions, and parametric tests like the F-test (ANOVA) with data analysis tools such as Microsoft Excel and SPSS. The F-test was used to compare farmers' income from the AF system with determining characteristics such as, well-being, education level and family size. Well-being ranks were identified on the basis of annual income, namely 1st rank (>45,000), 2nd rank (≤45,000 to >40,000), 3rd rank (≤40,000 to >12,000) and 4th rank(≤12,000) using simple Classification and Regression Tree (CART) approach in R-Studio. Qualitative data were analyzed using visuals, such as basic tables, charts, graphs, and other pictorial representations. Similarly, the linear regression was used to examine rainfall and temperature data, i.e., Y=a+bt where y=temperature or rainfall, t=time (year), and a and b were constant values.

RESULT AND DISCUSSION

Status of respondents

The study area comprises 42 HHS, all belonging to only one ethnic group of Chepang. The ages of the respondents varied from 25 to 80 years. Regarding their educational level, 30.95% of them were illiterate, 50.38% had primary level education and 16.67% had secondary level education. HH's size varied from 3 to 18 members. Among them 40.48% HHs had less than 6 members, 52.38% had 6 to 8 members and 7.14% had more than 8 members.

Gross annual income of farmers

AF contributed 72.82% to the HH income, followed by labor wages 13.68%, salary 7.86%, allowance3.67, others 1.45% and crafts 0.52% (*Figure 2*).

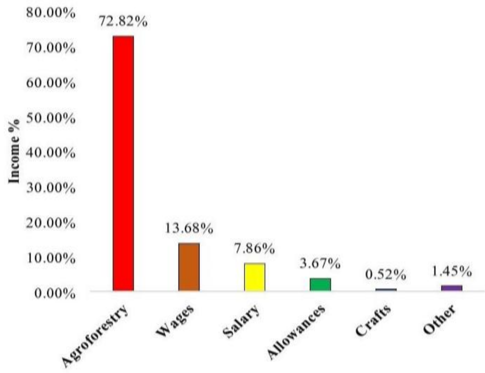

Figure 2: Gross annual income of the HH

Total annual income of farmers from AF system

AF component which contributed most, that is 32.88%, to the farmers' income was livestock, followed by agriculture 26.08%, fruits 19.5%, apiculture 6.69%, broom grass 5.71%, poultry 5.33%, medicinal plants 3.32% and fishery 0.49% (*Figure 3*).

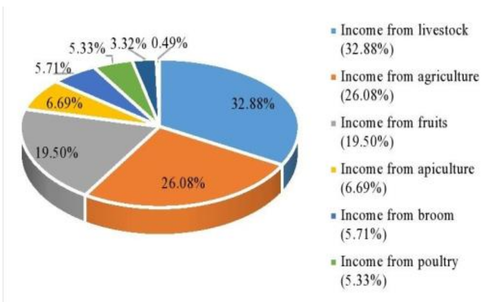

Figure 3: Yearly income from AF system

AF income of farmers with respect to different Socio- economic factors

Only HH's wellbeing level was found significant (0.00) with respect to total annual income from AF, whereas education level and family size were insignificant (0.15) and (0.59) at 5% level of significance. Thus, it can be said that AF income was unaffected by education or family size.

Livestock holding

It was found that 66.67% respondents had less than 5 Livestock Unit (LSU) (Table 2).

Similarly, 28.57% of the respondents had 5-10 LSU and 4.76% of the respondents had more than 10 LSU. Buffaloes and cows were kept mainly for milk and manure production, oxen for ploughing and manure production and goats for meat.

Table 2: Livestock holding

No. of livestock unit	Respondents
<5	28
5 -10	12
>10	2

Note: 1 LSU = 1 buffalo = 1.2 cow/ox = 4 goats (Thapa and Poudel, 2000)

Agroforestry System and Practices in Study Area

Based on the field observation, AF systems practiced in the study area were Agri-silviculture, Silvopasture, Silvofishery, Apiculture and Hortisilviculture as shown in (Table 3). Among them Silvofishery system was found only in specific HHs whereas Agri-silviculture is predominant across all sites.

Table 3: AF system practices in study area

Agroforestry system	Arrangement of components	Species
Agri-silviculture (crops and trees including shrubs)	Cereal crops and lentils are grown on terraced cultivated land under widely spaced naturally growing fodder tree species.	Cereal crops: Black gram (*Vigna mungo*), Maize (*Zea mays*) and Horse gram (*Macrotyloma uniflorum).* Trees: Tanki (*Bauhinia purpurea*), Badhar (*Artocarpus lakoocha*), Dabdabe (*Garuga pinnata*), khanyu (*Ficus semicordata*), Ipil (*Leucaena leucocephala*) etc.
Silvo-pastoral (Fodder trees: forage grasses and animals)	Forage grasses are grown on terraced Bari under fodder trees; goat, ox in cut and carry system.	Fodder species : Chiuri (*Aesandra butyracea),* Dabdabe (*Garuga pinnata*), Tanki (*Bauhinia purpurea*), Khasreto , Ipil (*Leucaena leucocephala*) Grasses: Napier (*Pennisetum purpureum),* Makaichari (*Euchaleana maxicana*), Amriso (*Thysanolaena maxima*)
Silvo-fishery	Multi species tree planting around fish ponds which would conserve soil, retain soil moisture, bond the soil and supplement to livestock.	Trees such as: Tanki (*Bauhinia purpurea*), Bakaino (*Melia azederach*), Khanyu (*Ficus semicordata)* are planted around fishery ponds that also includes Banana (*Musa paradisiaca*), Papaya (*Carica papaya),* Napier grass (*Pennisetum purpureum*) and Amriso (*Thysanolaena maxima*) around theponds.
Apiculture	Combination of trees and bees	Mostly Chiuri (*Aesandra butyracea*) are planted for bees.
Hortisilviculture	Multipurpose trees, fodder trees, fruit trees	Fruits trees: Lemon (*Citrus limon*), Banana (*Musa paradisiaca*), Pineapple (*Ananas comosus*), Papaya (*Carica papaya*), and Mango (*Mangifera indica*). Tree/Fodder species: Khanyu (*Ficus semicordata*), Bakaino (*Melia azedarach*), Tanki (*Bauhinia purpurea*), and Badhar (*Artocarpus lakoocha*), Kimbu (*Morus alba)*

Changes in Climate Parameters

Rainfall

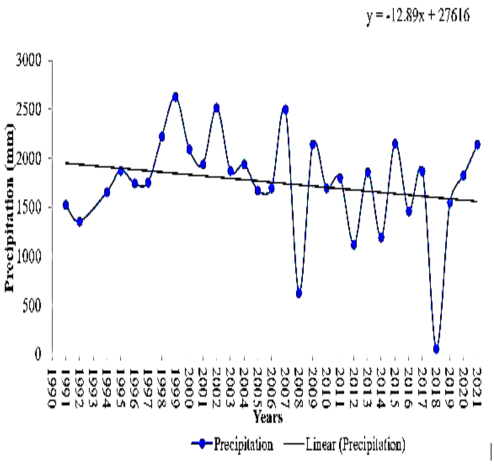

Figure 4: Average annual precipitation

The analysis of average annual precipitation (Figure 4) showed decreasing trend since linear equation showed negative relation with year. From 1991A.D. to 2021 A.D., the average precipitation over the study area elucidated that rainfall was decreasing at the rate of 12.89 mm per year with erratic rainfall pattern. Highest mean annual rainfall (2634.1mm) was recorded in 1999 and lowest mean annual rainfall (60.8mm) was recorded in the year of 2018.

Temperature

The examination of temperature demonstrated that mean maximum temperature decreased by 0.03℃, while mean minimum temperature increased by 0.04℃ in the interval of 1991A.D. to 2021 A.D. since linear equation showed a negative and positive year-to-year relationship respectively. The average temperature over the research region has shown that the greatest maximum temperature was observed in 2009 A.D. (30.84℃) while the lowest maximum temperature (29.08℃) was recorded in 2005 (Figure 5).

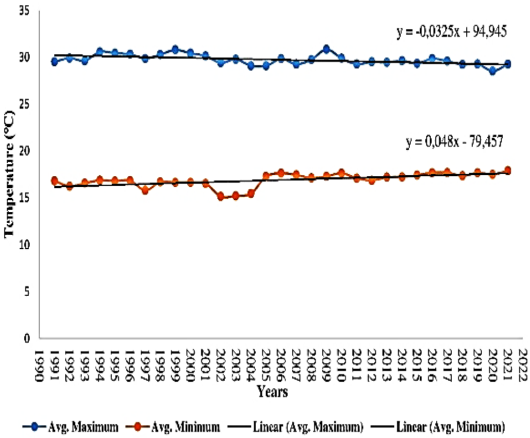

Figure 5: Average annual temperature

Major Climate-induced disasters in Study Area

As stated in Raksirang municipality's profile 2018 A.D., floods and landslides in the Jirkhi River in 2002 killed countless livestock and flooded animal sheds. Majority of the respondents (33%) claimed landslide to be the main reason followed by flood (26%) (*Figure 6*). This may not be entirely related to climate change but rather to long-term events with complicated origins as stated by Khatri et al. (2016). Landslides may have been directly sparked by road construction and digging in sloping terrain and climate change has significantly influenced the intensification of these events. Along with this drought, diseases and pest, hailstone, thunderstorm, invasive species, and frost are other consequences of climate change in the study area perceived by 17%, 8%, 4%, 4%, 6% and 2% of the respondents respectively. According to the respondents, crop yield has declined due to these impacts and farmers have been facing crop failure followed by economic loss.

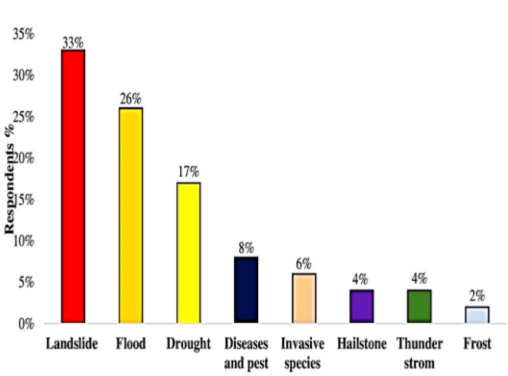

Figure 6. Climate-induced disasters in study area.

Adaptation Strategies at Households Level

Local people in the research area claimed changes in their environment; however, they were unsure if they were as results of climate change and when asked about adaptation to counteract impacts of climate change, 65% of the respondents answered that they had taken various local adaptation measures knowingly or unknowingly, exactly about climate change. Major adaptation measures in response to climate change included planting trees and grasses, improving farming system by growing commercial fruits, replacing farm activities with non-farm activities, using manure, fertilizer, pesticides and planting crop earlier than actual sowing time. Major crops in the study area were maize, millet and black gram. Previously, maize, millet and black gram used to be sown in the month of April-August, May-July and Mid-July respectively. Now in response to climate change, the sowing time has been shifted to one month earlier than actual sowing time. It is crucial to keep in mind that implementation of these adaptation measures should not be seen as a substitute for other techniques; rather, they should be seen as complementary ways to reduce adverse impacts of climate change.

Major Benefits from Agroforestry System

The implementation of AF in the research area had a significant impact on *Chepang* community. From focus group discussion and HH survey, it was found that they had experienced various benefits after AF practices such as production of multiple items to meet their needs like vegetables, fruits, fodder, forage and leaf litter for HH use and farming. AF practices have increased their income from the sales of honey, broom, and fruits. They have also improved micro-climate and farm site environment through reduction in surface runoff and soil erosion and rehabilitation of degraded land. The roots of trees strengthen the soil structure and canopy covers provide significant benefits by lowering the soil temperature for crops planted below, which possibly reduces the surface runoff and soil erosion due to heavy rainfall and help in the prevention of landslides to some extent. These measures aid some degree in coping with the effects of climate change even though they are insufficient to control them.

DISCUSSION

From the study, it is clear that various AF practices were very influential among *Chepang* people to improve their income and HH status in the changing climatic context. AF practices in the study area were initiated by Manahari Development Institute-Nepal (MDI-Nepal) after the huge flood and landslide, two decades ago, in 2002 A.D. MDI-Nepal made an effort to assist farmers in rehabilitating the degraded area by using both an appropriate form of Sloping Agricultural Land Technology (SALT) and a suitable combination of fruits and fodder species to promote environment conservation and local livelihood promotion. The project successfully introduced various AF practices which integrated horticulture, livestock and small-scale income generation schemes. Main activities included planting bananas, pineapples, lemon, mango, litchi and fodder trees, grasses and green manure crops along with providing support for farmers' livelihoods. AF systems aid farmers to adapt to the adverse effects of climate change. In terms of adaptation to climate change, the banana and pineapple varieties promoted by the project appear to be well chosen in view of already observed changing precipitation patterns, with winter rainfall becoming scarcer and periods of drought becoming longer (IGES, 2009).

Respondents, during the HH survey, reported that they have been cultivating on *Khoriya* land (slash and burn areas) for centuries but before the introduction of AF, the produce was barely sufficient to meet their HHs' requirements and there was not much diversity in terms of fruit trees and vegetables. But at present, this study found that Khoriya land has been improved with the establishment of trees and fruits. And also IGES report 2009 mentioned that soil erosion on steep slopes has been significantly reduced, preserving land productivity and reducing the contamination of aquatic habitats. The focus group discussion and key informants have revealed that AF needs to be further promoted and also people in the study area are encouraged and motivated towards AF as it provides both environmental and socio-ecological benefits. Apiculture is also promoting AF practice in study area. In past 4% of the respondents practiced apiculture after receiving training from National Government Organization (NGO) named "*Nepal Chepang Sanskritik Punarutthan Sangha*". But in last few years, apiculture practice has gradually increased among HHs as people have gained more profits. "*Nepal Chepang Sanskritik Punarutthan Sangha*" has conducted one house one bee hive program and encouraged to plant *Chiuri (Diploknema butyracea)* as *Chiuri flower* is the main source of nectar for honey bees and is the resource to uplift the lifestyle of Chepang people. Similarly, Niguretar Agricultural Cooperative Ltd, had provided training related to forest nursery, goat farming, bee farming and awareness program about the importance of broom grass and conservation of Chiuri.

On both global and regional scales, atmospheric temperature is most likely the most extensively used indicator of climate change (Jones and Briffa 1992). Precipitation is an important metric since it is linked to severe climate change impacts like droughts and floods. It is found that rain water is the main source of soil moisture in the study area, and it is obvious that they are very vulnerable to variability in rainfall pattern due to climate change. Similarly, the research conducted in Chitwan district also mentioned that 50% of Chepang HHs were solely dependent on rain fed water and were most vulnerable to climate change (Khanal et al., 2019). The majority of respondents thought that the available adaptation alternatives were inadequate to handle the danger and consequences of climate change.

CONCLUSION

Based on the findings of the study, it is concluded that AF practices significantly aid in changing the socio-economic condition of the local people. Climate change has a great impact on marginalized indigenous groups, specially Chepang, as they are poor in terms of knowledge and have low adaptive capacity. The study demonstrated that AF contributed about 72.82% of total HH's income, in which income from livestock was highest (32.88%). Agri-silviculture, Silvopasture and Hortisilviculture were highly preferred and practiced. Mean maximum temperature had decreased by 0.03°C/yr. while mean minimum temperature had increased by 0.04°C/yr. and rainfall had decreased by 12.89 mm/yr. Local people have been adapting local strategies such as adoption of various AF practices, replacing farm activities with non-farm activities, using manure, fertilizer, pesticides and planting crop earlier than actual sowing time in response to climate change.

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