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Agroforestry Practices for Climate Change Adaptation and its Contribution to Farmers' Income

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Abstract

Agroforestry practices offer a unique opportunity to address climate change impacts while securing the livelihoods of the rural communities. This study was carried out in Tillotama municipality of Rupandehi district, Nepal. Agroforestry system practices at the study site were identified through reconnaissance survey and discussions with ward officials. With 10% sampling intensity, purposive sampling was adopted for the study using the structured questionnaire, key informant interview, and field observation. For mean comparison, one-way ANOVA and Least Significant Difference (LSD) as post-hoc tests were carried out. Local communities were adopting eight different types of agroforestry practices under four agroforestry systems, namely agri-silvicultural, silvo-pastoral, agro-silvopastoral and silvi-fishery. The agroforestry system shared up to 50.54% of total households' income, in which income from agriculture was the highest. Agroforestry income was dependent on the economic status of the households. Change in cropping calendar was found as a major adaptation strategy. Scaling up of agroforestry system and commercialization of agroforestry products were recommended.

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Introduction

Agroforestry is a climate-smart production system and is considered more resilient than mono-cropping (Charles *et al*., 2014; Haile *et al*., 2019). It is one of the most experimented land-use systems across landscapes and agro-ecological zones in Nepal (Nair, 2007; McCord *et al*., 2015). With food shortages and increased threats of climate change, interest in agroforestry is gathering for its potential to address various on-farm adaptation needs, and fulfill many roles in AFOLU (agriculture, forestry, and other land-use) related mitigation pathways (Mbow *et al*., 2014). It can play a crucial role in improving resilience to uncertain climates through micro-climate buffering and regulation of water flow (Stigter, 2015). When it provides assets and income from carbon, wood energy, improved soil fertility, and enhancement of local climate conditions, it provides ecosystem services and reduces human impacts on natural forests (Moreno *et al*., 2018). Most of these are direct benefits for local adaptation while contributing to global efforts to control atmospheric greenhouse gas concentrations (Rosenzweig and Tubiello, 2007). Furthermore, agroforestry provides a particular example of a set of innovative practices that are designed to enhance productivity in a way that often contributes to climate change mitigation through enhanced carbon sequestration, and that can also strengthen the system's ability to adapt to adverse impacts of changing climatic conditions (Verchot *et al*., 2007; Mbow *et al*., 2014).

Climate change is projected to affect agricultural and natural ecosystems around the world, and there is no reason to expect that agroforestry systems will be spared (Luedeling *et al*., 2014). As the impacts of climate change have become apparent around the world, adaptation has attracted increasing attention (Mimura *et al*., 2015). With the world's population increase, the need for more productive and sustainable use of the land becomes more urgent. To meet the demand for food by 2050, world food production will have to increase by over 60% (Mckenzie and Williams, 2015). But the shortfall in domestic cereals production in the developing world was expected to widen from around 100 million tons in 1997 to around 190 million tons in the year 2020 (Rosegrant *et al*., 2001; Verchot *et al*., 2007). In many regions of the world, there will be limited ability for new varieties and increased fertilizer use to further increase the yields (Huang, Pray and Rozelle, 2002; Balemi and Negisho, 2012).

Agroforestry systems include both traditional and modern land-use system dynamics, and ecologically based natural resource management systems that diversify and sustain production in order to increase social, economic, and environmental benefits for land users at all scales (Pandey, 2007). Agroforestry as a tree-based system combines trees and/or shrubs, animals, and agronomic crops. It provides a particular example of a set of innovations designed to enhance REDD+ through carbon substitution, carbon conservation, and carbon sequestration in the agricultural landscape (Charles, Nzunda and Munishi, 2014). The rapid increase in Earth's surface temperature and changing precipitation pattern has resulted in direct implications to multiple sectors and livelihood of communities (Rao and Leal Filho, 2015). The poorest and vulnerable people are being affected the most (Mustafa, 2011). The data trend from 1975 to 2005 shows that the mean annual temperature has increased by 0.06°C, while the mean rainfall has decreased by 3.7 mm (-3.2%) per month per decade (MoE, 2012). Similarly, mean annual temperature is predicted to be increased between 1.3°C to 3.8°C by the 2060s and 1.8°C to 5.8°C by the 2090s while annual precipitation could reduce by the range of 10 to 20 percent across the country Nepal (Joshi and Singh, 2020; MoE, 2010). Studies also indicate that the observed warming trend is not uniform across the country. Agroforestry land-use management is necessary for increasing soil carbon stocks and socio-economic development of farmers; and the research on the carbon sequestration rate of agroforestry is necessary for making future policies and strategies on the issue of climate change. However, there were limited research (Neupane and Thapa, 2001; Regmi, 2003) carried out in the field of agroforestry, mostly focusing on soil fertility and local livelihood.

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Methodology

Study Area

The study was carried out in Gangolia village of Tilottama municipality in Rupandehi district, which lies in the Southern part of Lumbini Province of Nepal with the coordinates of 27°37′48″ N latitude and 83°27′36″ E longitude. The district Rupandehi lies in the southern and western parts of Nepal. On the East, it shares a border with Nawalparasi district, on the West with Kapilvastu district, on the North with Palpa district, and on South with India. The elevation of the district lies between 100 m to 1229 m from sea level. The total area of the district is 1,360 km^2 with 16.1% in Churia Range and the rest in the Terai[1] region. Recently, the Government of Nepal is planning to extend the agroforestry system in the Rupandehi district by considering an agroforestry pocket area. Only a few farmers have been practicing different types of agroforestry systems for few decades, although such type of study is lacking in this area.
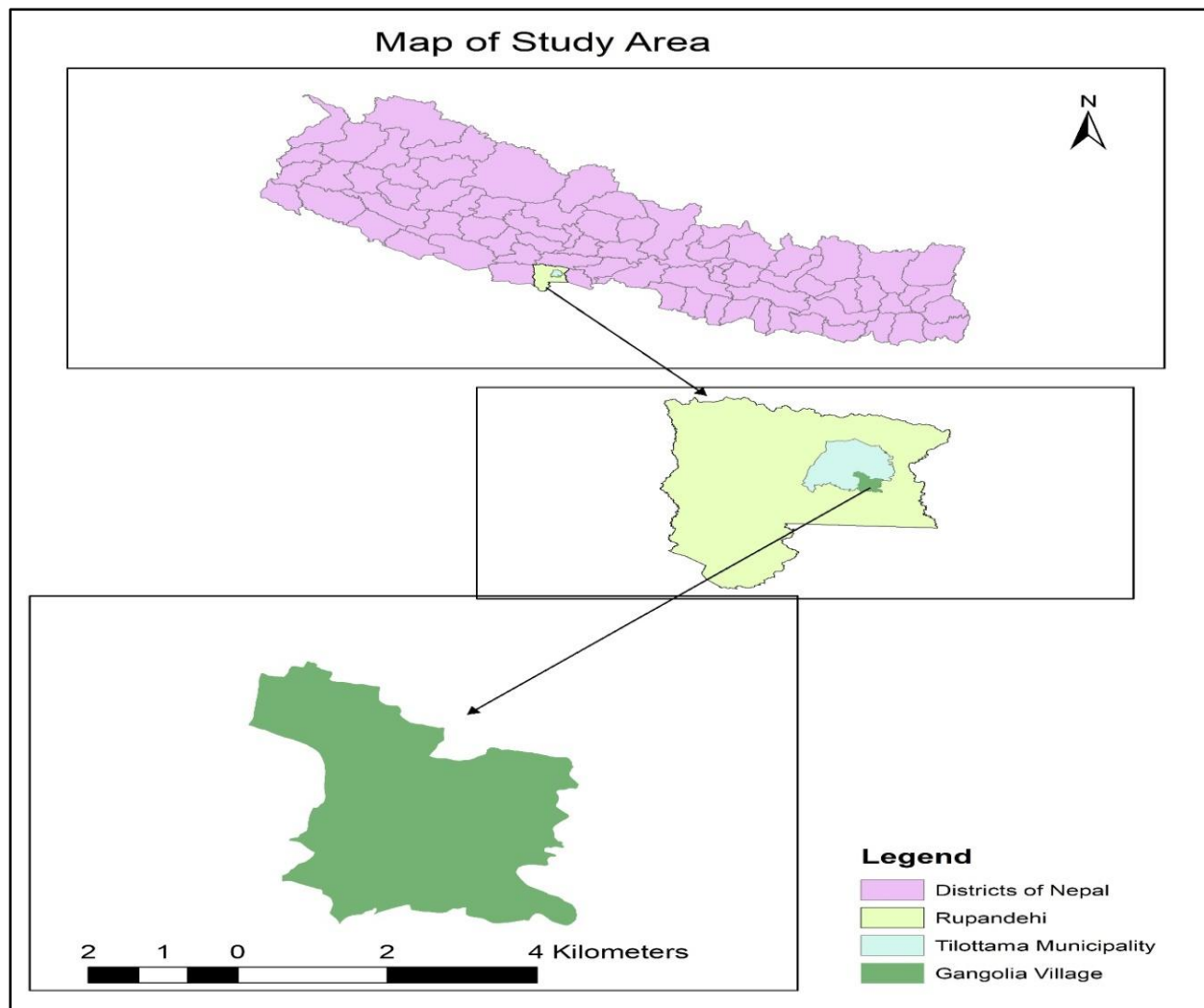

Figure 1: Map of the study area

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[1] Terai is a lowland belt of southern Nepal, mainly characterized by tall grasslands, scrub savannah, Sal forests and clay rich swamps (Dahal *et al.*, 2021).

Data Collection

The primary data were collected from the study site by employing a combination of social survey methods involving participatory techniques such as on-site field observation, household survey questionnaire, and key informant interview. The sampling used for this study was purposive sampling with a sampling intensity of 10% (Kombo and Tromp, 2006). Out of the total 304 households in Gangolia village of Rupandehi district, 33 households (10% sampling intensity) were sampled.

The various relevant and related secondary data were derived from published research papers, articles, newspapers, brochures, leaflets, annual reports, progress report and other publications of various related authorities. Secondary databases of precipitation and temperature were collected from the Department of Hydrology and Meteorology.

Data Processing and Analysis

Quantitative data were analyzed using descriptive and inferential statistics such as percentage, mean, frequency distribution, and use of graphics and parametric test i.e., F-test (ANOVA). F-test was used to compare the income of farmers from the agroforestry system with its determining factors like caste, well-being ranking, education level, and family size. Similarly, rainfall and temperature data of 30 years (1989-2018) were analyzed using the Least square curve fitting technique i.e., $Y=a+bt$ where, y=temperature or rainfall, t=time (year), a and b are constant estimated.

Results and Discussion

Socio-Demographic Status of Respondents

The age group of the respondents mostly lies between 35 to 60 years. The major castes/ethnic groups in the study area were Brahmin/Chhetri, Janjati, Dalit, and others represented by 30%, 50%, 10%, and 10%, respectively, among the sampled households. Literacy level among the sample respondents was primary level (33.3%), secondary level (30%), and higher secondary and above (36.7%). Most of the households (HHs) had 4 to 12 members. Among the sampled households, about 3.3% HHs were having less than 6 family members, 40% having 6 to 7, 40% sampled households 7 to 9 family members and 16.6% HHs more than 10 family members.

Annual Income of Farmer

The majority of the household income was from agroforestry (50.19%) followed by remittances/pensions (21.01%), services, business, and wages to be 15.79%, 9.27%, and 3.73%, respectively. An increase in size of these parameters brought about an increase in the household's annual income and, thus, contributing to poverty alleviation. Contribution of agroforestry components on total farm income of the farmers showed that mean annual income from agriculture was found to be 42%, followed by livestock, fisheries, poultry, tree and fuelwood with 27%, 16%, 11%, 3%, and 1%, respectively (Figure 2).

Mean Test of Agroforestry Income of the Farmer with respect to different Socio-economic Variables

Distribution of the socio-economic factors influencing agroforestry income showed overall significance to only wellbeing status (rich/medium/poor) of the household. In regard to caste, Brahmin/Chhetri with Janjati was significant; but Brahmin/Chhetri with Dalit and Other are insignificant at a 5% level of significance. Similarly, education level and family size are also insignificant to the total annual income of agroforestry income. So, we can conclude that level of education and family size did not affect the income from agroforestry.
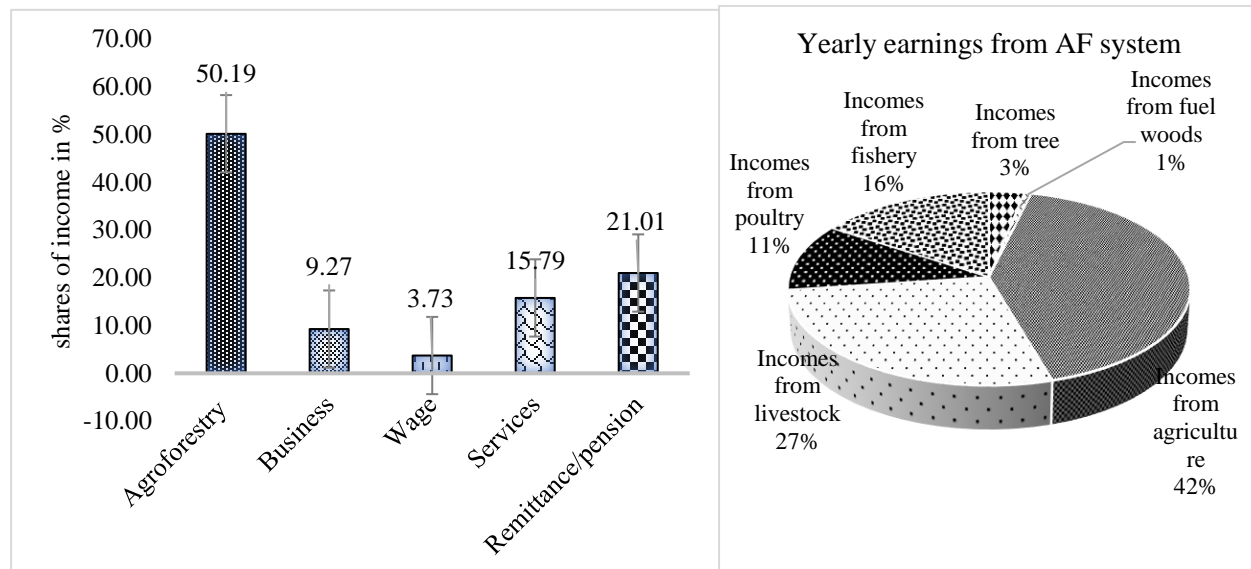
Figure 2: Gross Annual income of Farmer with Yearly Earnings from AF System

Table 1: Mean Test of Agroforestry Income of the Farmer with respect to different Socio-economic Variables

Caste					
Variables	*Co-variates*	*Sig.*	*Overall df*	*Overall F*	*Overall Sig.*
Brahimin/Chhetri	Janajati	0.890	(3, 26)	2.70	0.65
	Dalit	0.027*			
	Other	0.042*			
Wellbeing					
Rich	Middle class	0.0005	(2, 27)	9.43	0.01
	Poor	0.001			
Education level					
Primary level	Secondary level	0.852	(2, 27)	0.17	0.87
	Higher secondary & above	0.609			
Family size					
Family size	-	-	29	3.13	0.29

*The mean difference is significance at the 0.05 level.

Climate Change Adaptation Strategies through Agroforestry System Practices

Almost 30 years' climatic data from 1989 to 2018 of Bhairahawa meteorological station showed that the average annual rainfall was in increasing trend with 0.034 cm per year which is shown in figure 3. The trend of the maximum temperature was also in increasing order of 0.026°C per year as shown in figure 4.
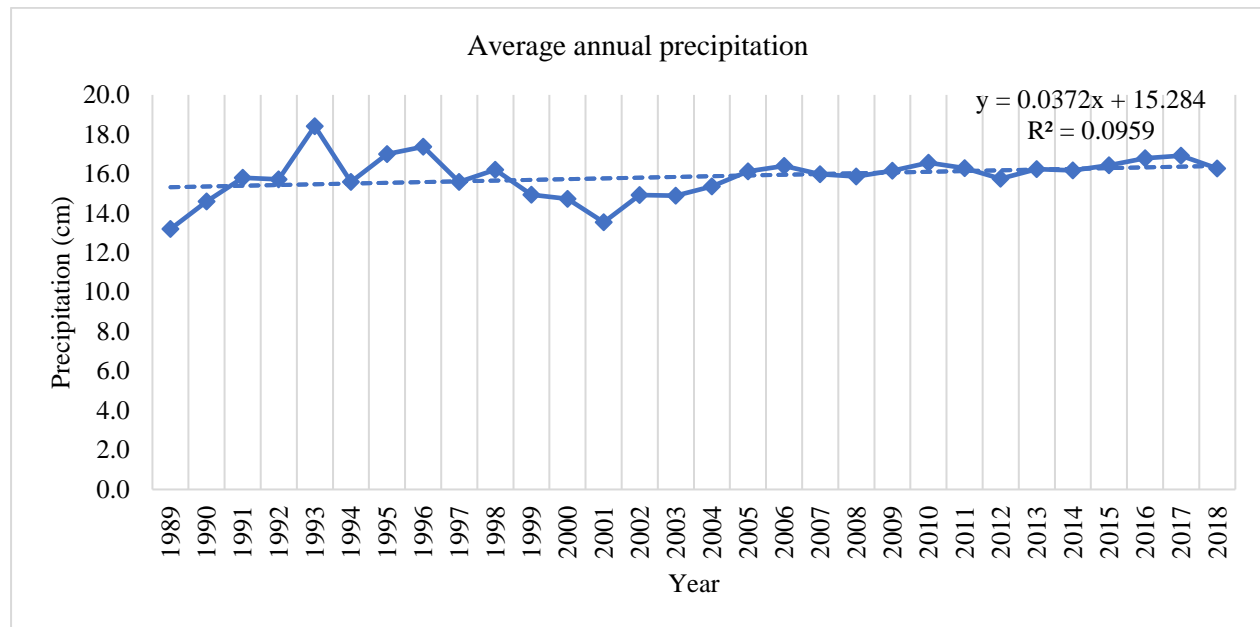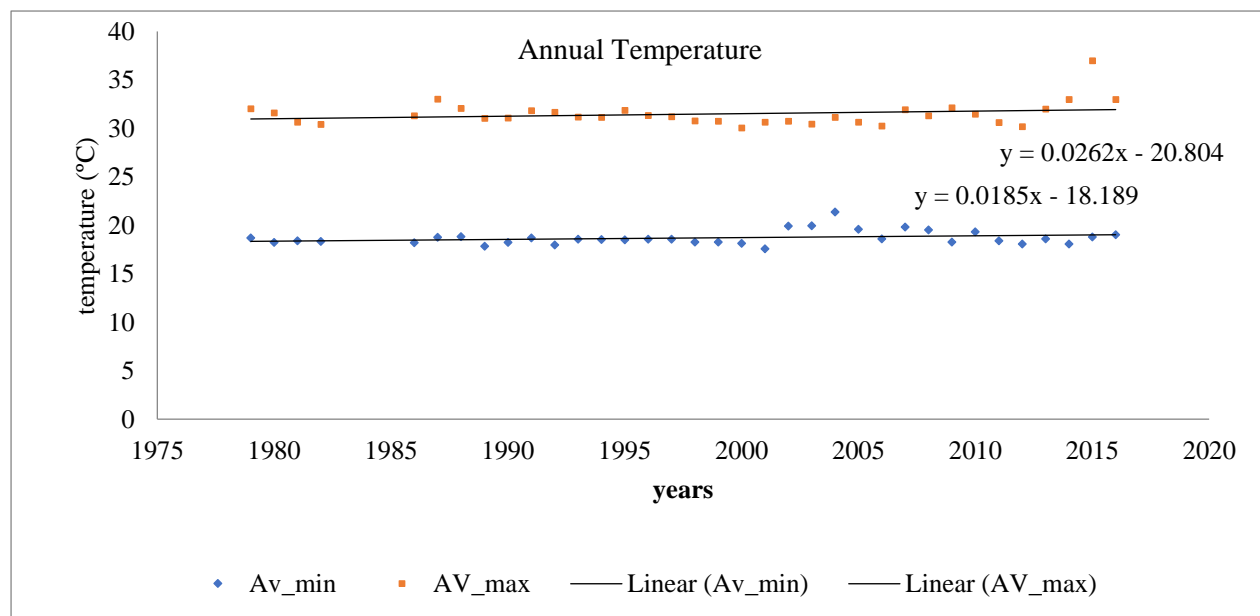
Figure 3: Average annual precipitation

Figure 4: Average annual temperature

Specific Adaptation Strategies' Adopted at Households level

The strategies adopted by the farmers against climate change were found mainly in the form of using chemical fertilizers and pesticides (25%), diversification of income-generating activities (27%), agroforestry (18%), and changing the crop calendar (30%). Similar findings like crop-livestock diversification and multiple cropping strategies were reported by several scholars (Assoumana *et al*., 2016; Gebreeyesus, 2017; Mekuria and Mekonnen, 2018).

The respondents who practiced agroforestry experienced various benefits such as improved soil fertility rate (32%), improved micro-climate (24%), increased catchment for pump set and boring (29%), and increased wood products (15%), although these methods are not sufficient to control climate change effects.
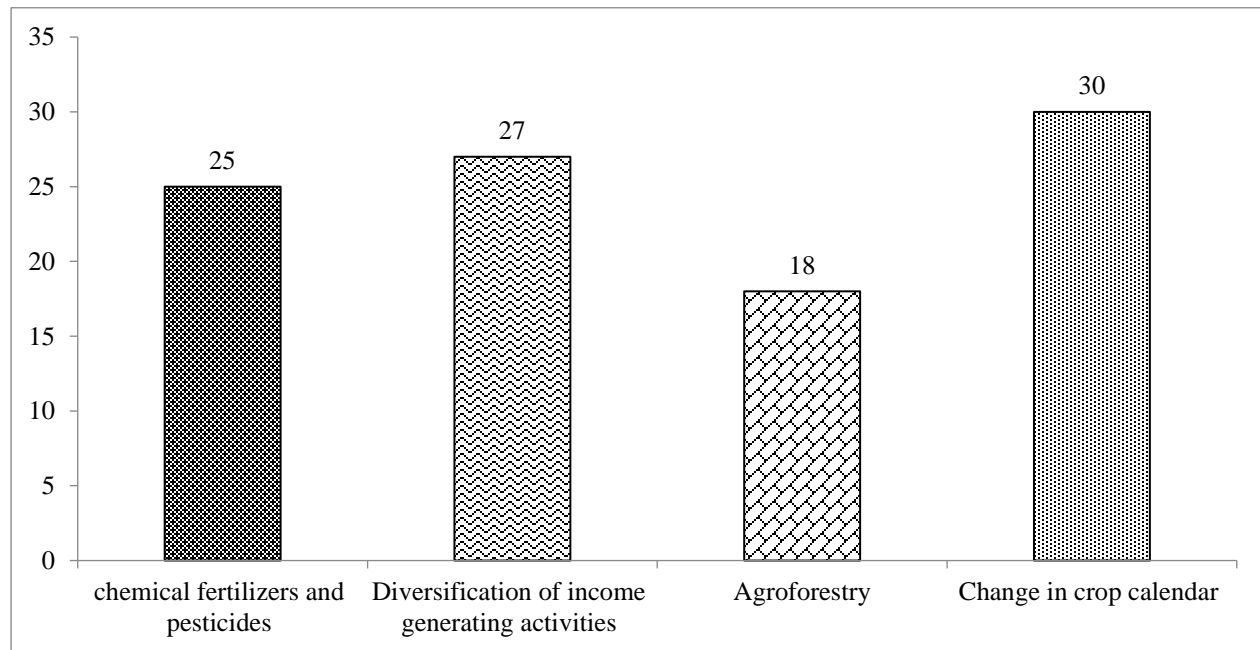

Figure 5: Specific adaptation strategies adopted at household level

Conclusion and Recommendation

Agroforestry has a significant impact on the livelihood of people engaged in agriculture primarily and on those who have low adaptive capacity. In the study area, trees on farmland were found as part of traditional practices. Agroforestry shares about 50% of total HH's income, in which the income from agriculture was highest. Income from the agroforestry system was found highly dependent on the socio-economic status of the households. The temperature has been increased by 0.026°C per year and rainfall by 0.04 cm per year. Change in the cropping calendar was found as a major climate change adaptation strategy by the farmers.

Agroforestry is one of the best options to make the community more resilient from adverse impacts of climate change through increased income and environmental services. Thus, the promotion of agroforestry practices in private land should be emphasized by the government. The practice of agroforestry should be done on a large scale to mitigate the adverse effects of climate change. Commercialization of agroforestry products should be done to enhance the farmer's income. To encourage the farmers to practice agroforestry practices, they should be provided with capacity building, training, and information to make them aware of the benefits of agroforestry.

Acknowledgement

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Authors' Declarations and Essential Ethical Compliances

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

Contribution	Author 1	Author 2	Author 3
Conceived and designed the research or analysis	Yes	Yes	Yes
Collected the data	Yes	No	No
Contributed to data analysis & interpretation	Yes	No	Yes
Wrote the article/paper	Yes	Yes	Yes
Critical revision of the article/paper	No	Yes	No
Editing of the article/paper	Yes	Yes	Yes
Supervision	No	Yes	No
Project Administration	Yes	Yes	Yes
Funding Acquisition	Yes	Yes	Yes
Overall Contribution Proportion (%)	40	30	30

Research involving human bodies (Helsinki Declaration)
Has this research used human subjects for experimentation?   No

Research involving animals (ARRIVE Checklist)
Has this research involved animal subjects for experimentation?   No

Research involving Plants
During the research, the authors followed the principles of the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora.   Yes

Research on Indigenous Peoples and/or Traditional Knowledge
Has this research involved Indigenous Peoples as participants or respondents?   No

(Optional) PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)
Have authors complied with PRISMA standards?   No

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Authors have no competing financial, professional, or personal interests from other parties or in publishing this manuscript.

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