

Research Article**AGROFORESTRY SYSTEMS: BIODIVERSITY, CARBON STOCKS AND CONTRIBUTION TO RURAL LIVELIHOOD****P. Ghimire* and S. Bolakhe**

Agriculture and Forestry University, Faculty of Forestry, Hetauda

*Corresponding author: pghimire@afu.edu.np

ABSTRACT

Agroforestry is an integrated land use system that can directly enhance agro-biodiversity and contribute to the conservation of landscape biodiversity, and also to the rural livelihoods. Considering this fact, a study was done in Bhimphedi Rural Municipality of Makawanpur district to assess farm tree diversity, carbon stock, and their contribution to the rural livelihood. The inventory for estimating above and below ground biomass of the farm trees was done using stratified random sampling. Forest biomass was analyzed by using standard allometric models to estimate the carbon content. Shannon Wiener Diversity Index was used to assess the farm tree diversity. A total of 66 households were randomly selected for socio-economic survey. Direct field observation, key informant interview, structured questionnaire survey, and group discussions were performed to assess the contribution of farm trees on rural livelihoods. The findings revealed three major agroforestry systems viz: silvi-pasture, home garden, and agri-silviculture systems were under practice in the study area. Silvi-pasture system was found as a good agroforestry system in terms of having higher species richness, tree diversity, and relatively higher amount of carbon stock per unit area (16.66 t/ha), followed by home garden (10.32 t/ha). The findings also revealed that agroforestry systems contributed 24.06% (NRs. 7580 per household/year), and 20.25% (NRs. 5365 per household/year) to the income from agriculture and livestock, respectively. Hence, it has been evident that agroforestry systems can be a potential strategy to conserve biodiversity and to improve the livelihoods of local people with the greater contribution of silvi-pasture system in an integrated tree-livestock dominating farming system of the rural areas in Nepal.

Key words: Biomass, conservation, diversity, livelihood**INTRODUCTION**

Agroforestry is one of the viable alternatives for social, economic and ecological sustainability. It is increasingly being recognized as an efficient ecological basis for increasing crop productivity, more dependable economic returns, and greater diversity (Amatya et al., 2018). It is a land use system characterized by the combination of forestry and agriculture, is an alternative to foster the much needed balance between food production and biodiversity conservation (Salinas, 2016). Agroforestry plays a better role in increasing agricultural productivity by nutrient recycling, reducing soil erosion, and improving soil fertility and enhancing farm income compared with conventional crop production (Kang & Akinnifesi, 2000). Furthermore, agroforestry offers a range of ecological, economic, social and religious functions (Idol et al., 2011).

Trees in agroforestry systems are an important resource providing products and services to the society. The existence of tree in farmland is a part of traditional as well as contemporary farming systems in rural areas of both developed and developing countries (Baral et al., 2013). It plays an important role to sustain and restore the physical environment, particularly through enrich soil fertility, reduce erosion, improve air and water quality, enhances biodiversity and sequesters carbon (Idol et al., 2011; Paudel et al., 2019). The application of agroforestry as an integrated approach to biodiversity conservation on farms in support of nature reserves has received some attention (Sanchez, 1995; Dobson et al., 1997). In the realm of agroforestry, underpinning the need for diversification is the desire to enhance the stability and productivity of agro-ecosystems (Atta-Krah et al., 2004). It is recommended that agroforestry can be seen as a tool in conjunction with appropriate conservation areas to buffer biodiversity loss, because agroforestry in some sites has 50 to 80% of the diversity of comparable natural forests and can help restrict the conversion of forests to grassland or other monospecific crops (Nobel & Dirzo, 1997). The services provided by agroforestry practices to rural livelihoods and conservation of biodiversity have attracted wide attention among agroforestry and conservation scientists (Mcneely & Schroth, 2006).

As integrated land use system agroforestry systems have unique role in stabilizing the atmospheric carbon dioxide (CO₂) concentration and reducing the carbon emissions or on increasing the carbon sink (Murthy et al., 2013). Agroforestry systems have indirect effects on carbon sequestration because they reduce harvesting pressure on natural forests as because trees are the largest source of sinks for terrestrial carbon. Nowadays, there is a growing attention in the role of different types of land C sequestration in the long term storage of carbon in forests, oceans, soils, and carbon storage in different agroforestry system (Nair et al., 2009). Emission of Carbon (C) is much higher from deforestation and forest degradation which can be managed through the sustainable management of land and

forests, and enhancement of forest C stocks through agroforestry can be considered as one of the main options for reducing greenhouse gases in atmosphere (Nair et. al., 2010; Plieninger, 2011). Agroforestry have the potential to provide options for rural livelihoods and biodiversity conservation (Kidd & Pimentel, 1992; Regmi, 2003). The main objective of this study was to investigate impact of different agroforestry systems on farm tree diversity, carbon stock storage, and their contribution on rural livelihood improvement.

MATERIAL AND METHODS

Study Area

This study was done in ward no. 5 & 6 of Bhimphedi Ruaral Municipality (RM) of Makwanpur district of Nepal in 2017. Topographically, this district entails 27°10' to 27°40' latitude and 84° 41' to 85°31' longitudes and is 34 km south of Kathmandu (DDC, 2018).

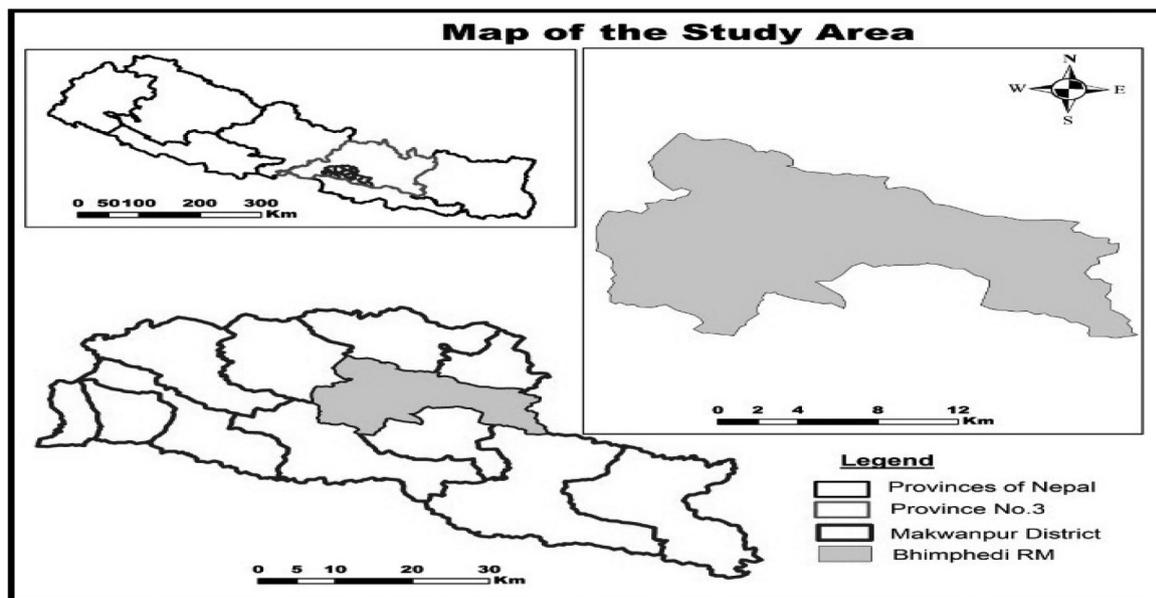


Figure 1. Map showing the study area

The district's terrain varies from valley plain to Mahabharat range. Makawanpur district has the subtropical to temperate climate. The maximum temperature rises up to 34 degree Celsius and falls down as low as minus 1.6 degree Celsius. The average annual rainfall, generally, varies from 1971 mm to 2331.3 mm. Bhimphedi RM characterized by upper tropical to temperate climate (DDC, 2018).

Sampling Design

Stratified random sampling was applied to layout the plots for surveys of vegetation for different agroforestry systems. The strata were laid out in accordance to the agroforestry practices in the study area. 21 circular plots of size 1,000 m² having radius of 17.84 m were laid out randomly to collect vegetation data.

Biophysical Measurements

Trees and poles are the major data for carbon stock analysis. Diameter at breast height (dbh) of each tree and pole was measured within 21 plots using diameter tape and height of each tree and pole was estimated using Range Finder.

Social Survey

Semi-structured questionnaire survey, key informant and focus group discussion were used to collect the socio-economic contribution of the agroforestry practices on rural livelihoods. The secondary data required were extracted from the District Profile of Makawanpur district (DDC, 2018).

Data Analysis

Tree diversity

The tree diversity was calculated by using Shannon-Weiner index (SWI). Shannon's index accounts for both abundance and evenness of the species present. The proportion of species *i* relative to the total number of

species (p_i) is calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product is summed across species, and multiplied by -1 .

$$H = -\sum p_i * \ln p_i \text{ (For species diversity)}$$

$$E = H/H_{max} = H/\ln S \text{ (For species evenness)}$$

Where, H = Shannon-Wiener index, p_i = proportion of the i^{th} species in a community, E = evenness and S = total number of species in the community (richness).

Biomass estimation

The biomass of tree includes two layers as above ground biomass and below ground biomass. Biomass was estimated by using the following equation:

Aboveground biomass

Above ground biomass include above ground tree/pole parts such as stem, branches, and leaves. The logarithmic transformation of the allometric formula was used to estimate above ground biomass with the help of DBH and height. The allometric formula suggested by Chave et al., (2005) was used to estimate the aboveground tree and pole biomass.

$$AGTB = 0.0509 * P D^2 H$$

Where,

AGTB = above ground tree, pole biomass (kg)

P = Wood Specific Gravity (g/cm^3)

D = tree diameter at breast height (cm)

H = tree height (m)

The value of P for all the species were used as suggested by Sharma and Pukkala (1990) and Jackson (1994).

Belowground biomass

Below ground biomass includes the roots of trees/poles below the ground. Below ground (root) biomass was estimated using root-shoot ratio value of 1:5; (i.e. 20% of above ground biomass), as suggested by MacDicken (1997).

Estimation of Total Carbon Stock

The biomass carbon was calculated using stock method. The carbon content is assumed to be 47% of dry biomass (IPCC, 2006). This value is a typical value of C content in the forest species investigated. The following formula was used for computing total above and below ground biomass carbon:

Total above ground biomass carbon = (Total above ground biomass of tree/poles) \times 47% and, Total belowground biomass carbon = (Total below ground biomass of trees/poles) \times 47%

RESULTS AND DISCUSSION

Abundance and species diversity under different Agroforestry systems

A total of 63 species were reported in the study area. *Bauhinia spp.*, *Leucaena leucocephala*, *Melia azedarach*, and *Litsea monopetalawere* most abundant species on the farm land. *Ficus lacor*, *Artocarpus lakoocha*, *Alnus nepalensis*, *Schima wallichii*, *Pinus roxburghii*, *Morus alba*, *Pyrus pyrifolia* etc. are other common species planted by local people (Figure 2).

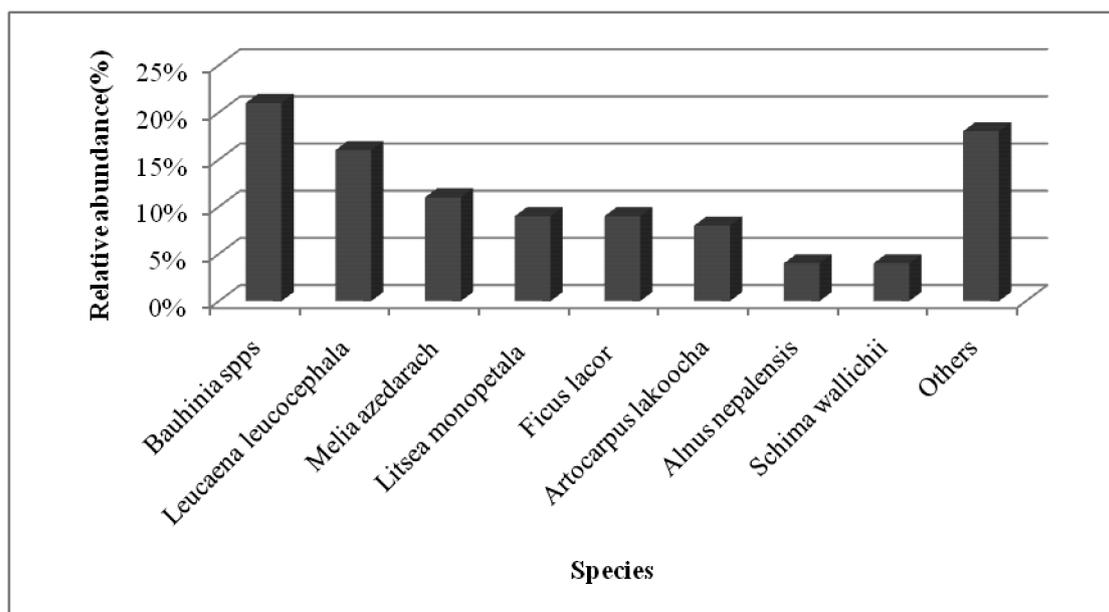


Figure 2: Relative abundance of farm trees species in the study area

Three major types of agroforestry systems were under practice in the study area viz: home garden, agri silviculture, and silvo pastoral. Species richness and tree diversity index were assessed among the different agroforestry systems. Silvi-pasture system had the highest species richness and Shannon Weiner Index for tree diversity followed by home garden and agri-silviculture respectively (Table 1). Khanal (2011) found higher species richness and tree diversity index in silvo-medicinal system in Kaski district, Nepal. Baral et Al., (2013) reported higher species richness and farm tree diversity index in home garden followed by road side plantation and agri-silviculture in Kanchanpur district, Nepal. The difference in the result may be attributed to the change in the physiographic zones, and within a given physiographic zone, it varies with location. The distribution of higher number of individual tree species was the prime reason for higher species richness and tree diversity index for silvo-pastoral system. But in overall condition the wide individual distribution of the few tree species was the main reason for lower overall tree diversity index which is similar to Kharal and Oli (2008). However, the contribution of such agroforestry systems to conservation of biodiversity and landscape restoration cannot be neglected.

Table 1. Species richness and tree diversity under different agroforestry systems

Agroforestry systems	Species richness	Shannon Weiner Index
Silvi-pasture	31	0.52
Home garden	22	0.29
Agri-silvi	13	0.15

Biomass and carbon stocks under different Agroforestry systems

The biomass and carbon stock per unit area were assessed among three different agroforestry systems. The study found average above and below ground biomass of different agroforestry system was 19.82t/ha and 3.96 t//ha, respectively, (Table 2). Accordingly, average above and below ground carbon stock for different agroforestry systems was 9.32 t/ha and 1.87 t//ha respectively, which is similar to the finding of a study in Kanchanpur district, Nepal (Baral et al., 2013). The total carbon stocks accumulated by agroforestry systems in the study area was 33.58 t/ha. In Nepal, the mid-hills agroforestry system is estimated to store about 48.60 t C per hectare (Paudel et al., 2017). Singh & Panday (2011) cited in Paudel et al., (2017) also reported that home garden in India can store 16-36 t/ha/yr carbon stock. Similarly, Nair et al., (2009) reported that mixed species system can accumulate 15.29 t/ha/yr carbon stocks in Puerto Rico. Hence, enhancement of forest C stocks through sustainable management agroforestry system can be considered as one of the main options for reducing greenhouse gases in the atmosphere and subsequently minimizing the problem of climate change.

Table 2. Biomass and carbon stocks under different agroforestry systems

Agroforestry systems	Biomass(t/ha)		P value (ANOVA) for total Biomass	Carbon stock(t/ha)		No. of Plots	P value (ANOVA) for total Carbon
	Above ground	Below ground		Above ground	Below ground		
Silvipasture	29.50	5.90	0.010*	13.86	2.80	7	0.040*
Home garden	18.30	3.66	0.010*	8.60	1.72	7	0.040*
Agri-silvi	11.68	2.34	0.010*	5.50	1.10	7	0.040*
Average	19.82	3.96	0.010*	9.32	1.87		0.040*

Note: * $p < 0.05$

There is a significant difference in the accumulation capacity of different agroforestry system in the study area. The total amount of carbon stocks (t/ha) is significantly different for all three agro-forestry systems ($p < 0.05$).

Socio-economic characteristics of respondents

Sixty six households (HHs) were randomly selected for socio-economic survey to get the information about contribution of agroforestry practices on rural livelihoods. Of the 66 respondents surveyed during the study, 34 were male and 32 were female. To avoid gender bias, the survey was based on the availability of the household members during the field study. However, the proportion of male to female respondents represented was still male-biased (51.5% males, 48.5% females). To generate reliable information, the questionnaire survey interview was performed with respondents between 20 to 60 years of age. This was done to reflect the respondent's insight on the subject matter (Table 3).

Table 3. Socioeconomic characteristics of the respondents

Category	Indicator	Number (n)	Percentage (%)
Gender	Male	34	51.5
	Female	32	48.5
Age group	20-30 years	17	25.75
	30-45 years	23	34.85
	45-60 years	26	39.40
Education	Illiterate	10	15.15
	Primary	13	19.70
	Secondary	29	43.95
	University	14	21.20
Occupation	Agriculture	48	72.70
	Government Services	11	16.70
	Private Services	7	10.60
Annual income /year, (NPR)	<100,000	28	42.40
	100,000-200,000	24	36.40
	>200,000	14	21.20

Similarly, about 85% of the respondents were literate and the remaining 15% were illiterate (Table 3). In this study about 73 % of the HHs was dependent on agriculture related occupation, while 27 % HHs were involved in non-agricultural occupation (Table 3). Likewise, the study shows that livestock distribution was dominated by goats (42%) and was followed by cow (34%) and buffalo (24%). This shows agriculture and livestock farming was one of the important income sources for the people.

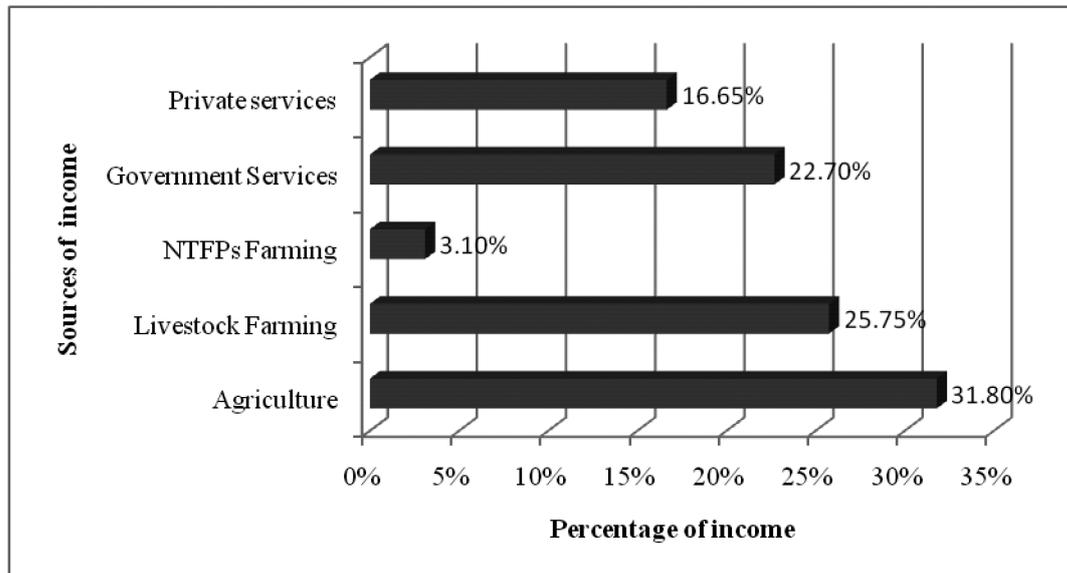
Table 4. The annual income of HHs based on land ownership

HHs annual income	Land holding of HHs		
	<0.5 ha N (%)	> 0.5 ha N (%)	Total N (%)
<100,000	18 (48.65%)	10(34.50%)	28(42.40)
100,000-200,000	13 (35.13%)	11(37.90%)	24(36.40)
> 200,000	6 (16.22%)	8 (27.60%)	14(21.20%)
Total	37 (100%)	29 (100%)	66(100%)

The average size of land holding was 0.5 ha. In the study area, 56 % of the respondents owned less than 0.5 ha of land, while 44 % owned more than 0.5 ha of land. The annual income of respondents in relation to their land holding size is shown in Table 4. There is significant differences in the HHs annual income with different land holding size ($\chi^2 = 7.83$, $df = 2$ ($p < 0.005$)). The results showed that the majority of the respondents who owned <0.5 ha land had an annual income below Nepalese Rupee (NRs.) 100,000 while the respondents who owned > 0.5 ha had an annual income between NRs. 100,000 – 200,000 or above NRs. 200,000 (Table 4).

Different sources of income

Respondents were asked about their different sources of income and how these income sources share to the total. The result shows that there were five types of major income sources. Out of five, income from agriculture (i.e. crop and vegetable farming), income from livestock farming and income from government services played key role, which makes more than three fourth of the total income (Figure 3). This shows the dependence of local people in agriculture and livestock farming for their subsistence livelihood. Baral et al., (2013) also found the similar type of result in Kanchanpur district Nepal. Agroforestry has been regarded as one of the important systems for supporting the livelihoods of a large number of rural farmers in the Nepalese hills (Pandit et al., 2014).

**Figure 3. Types of income sources and their share in total income of respondents**

Contribution of farm tree on agriculture and livestock income

Agriculture is the main source of livelihood for the majority of the people in Nepal and still 66 percent people directly engaged in farming (FAO, 2018). The average Per Capita Income (PCI) of Nepali was NRs. 106,333 (USD 1,004) annually (CBS, 2018). From the study, it was found that the agriculture income and livestock income shared 29.62% and 24.92% respectively of the total household income of the study area. Accordingly, trees on farmland contribute 24.06% (NRs. 7,580 per household/year) and 20.25% (NRs. 5,365 per household/year) on agriculture income and livestock income respectively (Figure 4). Agroforestry system has contributed significant amount to the improvement of rural livelihood in Dhading district of Nepal (Regmi, 2003). Baral et Al., (2013) also reported farm trees contribute 16.4% and 17.1% (per household/year) on farmland income and livestock

income respectively in Kanchanpur district Nepal. Hence, apart from supporting local livelihoods, these types of agroforestry systems have also contributed to diversifying livelihoods and increasing socio-ecological resilience.

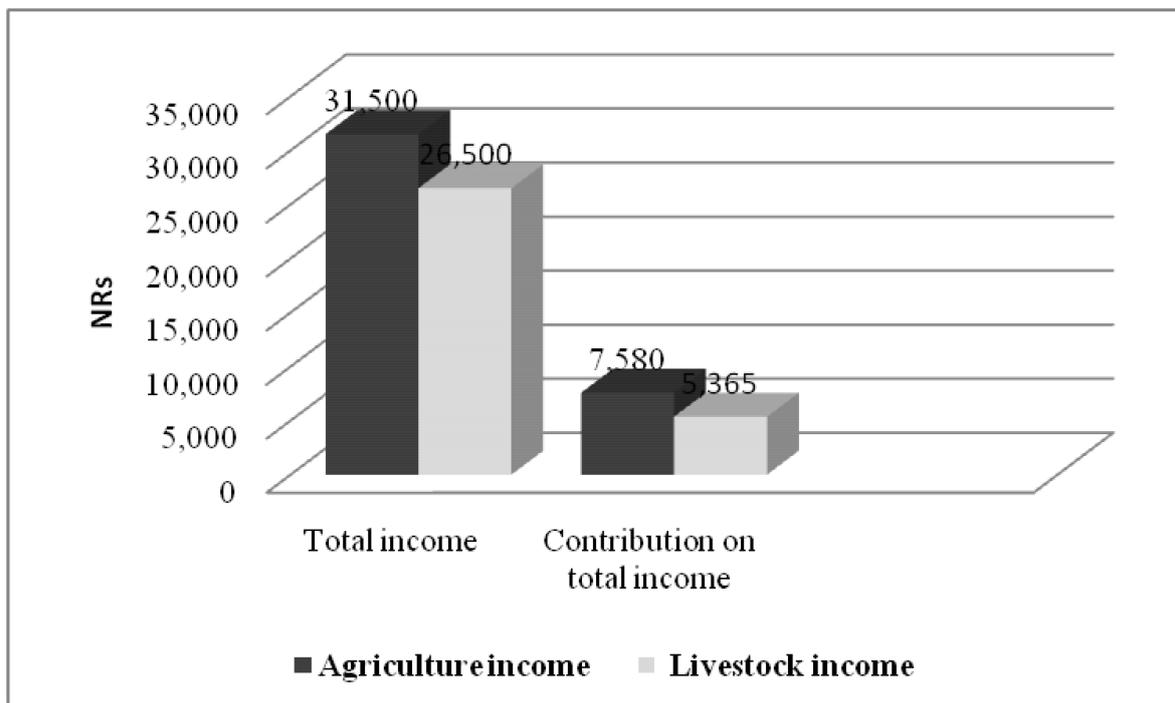


Figure 4. Contribution of farm trees on agriculture and livestock income

CONCLUSION

Species richness and tree diversity is moderate in the study area. Presence of wide diversity of tree species shows that agroforestry systems are good repository of high floral diversity, particularly, in the silvi-pasture system. This shows that improved agroforestry systems has the potential to contribute to the maintenance of biodiversity in natural farming systems, mainly due to the reduction in over reliance of rural communities on natural forest resources. The trees on agroforestry systems contributed considerable amount of carbon storage. This indicates that agroforestry systems can be one of the main options for reducing greenhouse gases in the atmosphere, and subsequently to minimize the problems associated to the climate change. Agroforestry could be a feasible alternative to less biologically diverse agriculture in balancing biodiversity conservation and production. Hence, further study aiming at analyzing the potentiality of agroforestry systems on biodiversity conservation and C sequestration are important to consider.

ACKNOWLEDGEMENTS

The authors are grateful to the local people of Bhimphedi Rural Municipality for providing information during questionnaire survey. The authors would also like to express their deepest acknowledgement and heartfelt gratitude for all the concern people and institutions for their significant contribution and support for the successful completion of this research work.

REFERENCES

- Amatya, S.M., Cedamon, E., & Nuberg, I. (2018). *Agroforestry systems and practices in Nepal- Revised Eds.* Agriculture and Forestry University, Rampur, Nepal, 108pp + xviii.
- Atta-Krah, K., Kindt, R., Skilton, J.N., & Amaral, W. (2004). *Managing Biological and Genetic Diversity in Tropical Agroforestry. Agroforestry Systems, 61*, 183-194.
- Baral, S. K., Malla, R., Khanal, S., & Shakya, R. (2013). *Trees on farms: Diversity, carbon pool and contribution to rural livelihoods in Kanchanpur District, Nepal. Banko Janakari, 23 (1)*, 3–11.
- CBS (2018). *Central Bureau of Statistics (CBS). National Planning Commission, Kathmandu, Nepal.*

- Chave, J., Andalo, C., Brown, S., Cairns, M. A., Chambers, J. Q., & Eamus, D. (2005). Tree allometry and improved estimation of carbon stocks. *Oecologia*, *145* (1), 87–99.
- DDC. (2018). District Development Committee (DDC), Hetauda, Makawanpur. Retrieved from the District Development Committee Makawanpur website: <http://ddcmakawanpur.gov.np/en/>
- Dobson, A.P., Bradshaw, A.D., & Baker, A.J.M. (1997). Hopes for the Future: Restoration Ecology and Conservation Biology. *Science*, *277*, 15–522.
- FAO (2018). Nepal at a Glance. Food and Agriculture Organization (FAO) of the United Nations. Rome, Italy. Retrieved from website: <http://www.fao.org/nepal/fao-in-nepal/nepal-at-a-glance/en/>
- Idol, T., Hagger, J., & Cox, L. (2011). Ecosystem services from smallholder forestry and agroforestry in the tropics. In W. B. Campbell & S. L. Oritz (Eds.), *Integrating agriculture, conservation and ecotourism: example from the field* (pp. 209–270). Dordrecht: Springer.
- IPCC (2006). Intergovernmental Panel on climate change (IPCC), Guidelines for National Greenhouse Gas Inventories, Volume 4. Agriculture Forestry and other land use, In Eggleston, S., Buendia, L., Miwa, K., Nagara, T., Tanabe, K. (Eds.) Hayanma, Japan; Institute of for Global Environmental Strategies (IGES).
- Jackson, J. K. (1994). *Manual of Afforestation in Nepal* (Vol. 2). Forest Research and Survey Centre, Ministry of Forest and Soil Conservation, Kathmandu Nepal. Pp 335-741.
- Kang, B.T., & Akinnifesi, F.K. (2000). Agroforestry as Alternative Land-Use Production System for the Tropics. *Natural Resources Forum*, *24*, 37–151.
- Khanal, S. (2011). Contribution of agroforestry in biodiversity conservation and rural needs fulfillment in Kaski district, Nepal. Unpublished Master thesis, Tribhuvan University, IoF, Pokhara, Nepal.
- Kharal, D. K., & Oli, B. N. (2008). An estimation of tree species diversity in rural farmland of Nepal. *Banko Janakari*, *18* (1), 3–10.
- Kidd, C. V., & Pimentel, D. (1992). *Integrated resource management: Agroforestry for Development*. C. V. Kidd and D. Pimentel (eds.). Academic Press Inc.
- MacDicken, K.G. (1997). A Guide to Monitoring Carbon Storage in Forestry and Agro-forestry Projects. In: Forest Carbon Monitoring Program. Winrock International Institute for Agricultural Development, Arlington, Virginia.
- Mcneely, J. A., & Schroth, G. (2006). Traditional Practices, Present Dynamics, and Lessons for the Future, Biodiversity and Conservation. *Agroforestry and Biodiversity Conservation*, *15*, 549–554.
- Murthy I.K., Gupta M., Tomar S., Munsri M., Tiwari R., Hegde G.T., & Rabindranath, N.H. (2013). Carbon Sequestration Potential of Agroforestry Systems in India. *J Earth Sci Climate Change*, *4*(1), 1-7.
- Nair, P. K. R., Kumar, B. M., & Nair, V. D. (2009). Agroforestry as a Strategy for Carbon Sequestration. *Journal of Plant Nutrition and Soil Science*, *172*(1), 10-23.
- Nair, P.K.R., Nair, V.D., Kumar, B.M., & Showalter, J. M. (2010). Carbon Sequestration in Agroforestry Systems. *Adv. Agron*, *108*, 237–307.
- Nobel, I.R., & Dirzo, R. (1997). Forests as Human-dominated Ecosystems. *Science* *277*, 522–525.
- Pandit, B.H., Shrestha, K.K., & Bhattarai, S.S. (2014). Sustainable Local Livelihoods through Enhancing Agroforestry Systems in Nepal. *Journal of Forest and Livelihood*, *12*(1), October, 2014.
- Paudel, D., Tiwari, K.R., Bajracharya, R. M., Raut, N., & Sitaula, B. K. (2017). Agroforestry system: An opportunity for carbon sequestration and climate change adaptation in the mid-hills of Nepal. *Oct. Jour: Env. Res*, *5*(1), 22-031.
- Paudel, P., Rimal, S., Ghimire, P., & Parajuli, K. (2019). Agro-forestry for Enhancing Adaptation of Local Community against Drought in Hilly Region of Nepal. *International Journal of Agriculture Innovations and Research*, *7* (4), 440-445.

- Plieninger, T. (2011). Capitalizing on the Carbon Sequestration Potential of Agroforestry in Germany's Agricultural Landscapes: Realigning the Climate Change Mitigation and Landscape Conservation Agendas. *Landscape Research*, 36, 435-454.
- Regmi, B. N. (2003). Contribution of Agroforestry for Rural Livelihoods: A Case of Dhading District, Nepal. Paper presented at the International conference on rural livelihoods, forests and biodiversity, 19-23 May 2003, Bonn, Germany.
- Salinas, A.M. (2016). The role of agroforestry in biodiversity conservation and ecosystem service provisioning. *Agriculture for Development*, 28,
- Sanchez, P.A. (1995). Science in agroforestry. *Agroforestry Systems*, 30, 5-55.
- Sharma, E.R., & Pukkala, J. (1990). Volume tables for forest trees of Nepal, 48. Ministry of Forest and Soil Conservation, Forest Survey and Statistics Division, Kathmandu, Nepal, 84p.

