Agroforestry Practices and Their Contribution to Biodiversity and Rural Livelihoods in Bundikali Rural Municipality of Nawalparasi District, Nepal

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LETTER OF RECOMMENDATION

This is to certify that the dissertation entitled "**Agroforestry Practices and Their Contribution to Biodiversity and Rural Livelihoods in Bundikali Rural Municipality of Nawalparasi District, Nepal**" submitted by Mr. Rabindra Bhattarai for the partial fulfillment of the requirements for Master of Science in **Biodiversity and Environmental Management(BEM)** From Tribhuvan University was completed under my supervision and guidance. He has worked sincerely and the entire work is primarily based on the results of her thesis work and has not been submitted for any other degree. Therefore, I recommend this dissertation for the final evaluation and acceptance.

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LETTER OF APPROVAL

This dissertation entitled "**Agroforestry Practices and Their Contribution to Biodiversity and Rural Livelihoods in Bundikali Rural Municipality of Nawalparasi District, Nepal** l" submitted at Central Department of Botany, Tribhuvan University by Mr. Rabindra Bhattarai has been accepted for the partial fulfillment of requirements for Master of Science in **Biodiversity and Environmental Management (BEM)**.

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I, Rabindra Bhattarai, hereby declared that this thesis entitled " Biodiversity in Agroforestry Ecosystem and Its Influence on Livelihood in Bundikali Rural Municipality of Nawalparasi District, Nepal" is my original work and has not been submitted, in any form, either in whole or part, for a degree at any institution. All other sources of the information used are properly acknowledged.

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ABSTRACT

Research related to the field application of agroforestry practices and socio-economic factors related to it are still scarce. In the present investigation, tree species diversity, livelihood and carbon sequestration were studied in the traditional agroforest of Budikali Rural municipality of Nawalparasi district. A quadrat size of 20× 20m (400m^2) was set up and tree inside the plot were listed. The sample HHs were 100 (8.09 %). Participatory Rural Appraisal was used to obtain data from the family farmers. The collected data were analyzed by using Statistical Package for Social Science (SPSS) and MS- Excel where frequency distributions, standard deviation were mostly used. Shannon-Winner (S-W) diversity index was used to analyze farm tree biodiversity. The major castes/ethnic groups in the study area were *Magar, Kami, Chhetri, Bhramin, Damai, Newar, Darai, Sarki,* and *Gharti*. The sample households (HHs) had a minimum of 0.101 hectares and a maximum of 5.23 hectares of land. The average land hold of households was 0.61± 0.58 hectares. Respondents, 24% of them had small size LSU, 59% medium size, 16 % large size. *Khet* land, *Bari* land, *Kharbari* land, Woodlot are four landuse type in agroecosystem. Total 74-tree species belonging to 37 families. Total 1003 tree individuals were recorded, with the density of 250.75 tree/ ha. The tree species in AF mainly used for fruits (23%), fodder and fuelwood (12.16%), fuelwood (12.16%), timber wood (12.16%). S-W index (H) **=** 3.87, Hmax = 0.9003, the result showed that species richness and evenness were very high in the study area. (= 3.67). Based on land use type there were high species richness and evenness of tree in *Khet* land (3.82) followed by *Bari* land, *Kharbari* land and woodlot respectively. There were highest number of trees 188 in DBH class 20-29 in *Bari* land. Based on land use type carbon stock was higher in woodlot (30.09±18.80 tons/ha) followed by *Kharbari* land (28.72±11.95 tons/ha), *Bari* land (28.36±14.35 tons/ha), and *Khet* land (20.47±15.51 tons/ha). The study has discovered that AF trees subsidize several products like fuelwood, fruits, medicine, fodder and biodiversity conservation. AF can play extensive role in reducing atmospheric concentration of CO_2 by storing carbon in above and belowground biomass and growing biomass for biopower and biofuels and thereby replacing fossil fuel. Hence, this study recommends a strong need to strengthen promotion of AF and promotion to policy makers.

Keywords: *Agroforestry, Livelihood, Treediversity, Carbonstock*

ABBREVIATIONS AND ACRONYMS

CCA	Canonical Correspondance Analysis
DCA	Detrended Correspondence Analysis
P	Level of Significance
R2	Coefficient of Determination
SPSS	Statistical Package for Social Science
AF	Agroforestry
CFUG	Community Forestry User Group
HH	Household
HHs	Households
GDP	Gross Domestic Product
CO_2	Carbon dioxide
GHGs	Green House gases
C	Carbon
CDM	Clean Development Mechanism
LP gas	Liquefied Petroleum Gas
DBH	Diameter Brest Height
LSU	Livestock Unit
ha	Hactre
No.	Number
SD	Standard Deviation
SWDI	Shannon-Weaver Diversity Index
NRs	Nepalese Rupees
Kg	Kilogram
ICRAF	International Center for Research in Agroforestry

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CHAPTER ONE: INTRODUCTION

1.1 Background

Agroforestry system (AF) is defined as a land use system that assimilates trees with agriculture crops and livestock simultaneously to get more economic returns and better social and ecological benefits on a sustainable yield than from monoculture on the same unit of land, particularly under conditions of low levels of technological inputs on marginal sites (Raintree, 1982). Old-style agroecosystems, which include ʺforest gardensʺ or ʺhome gardens,ʺ combine trees with an understory of annual or perennial crops and sometimes livestock. Approximately eighteen different AF practices have been recognized, although each has an unlimited number of variations (Nair, 1993). This provision of food, fiber, fodder, medicine, and building materials are obtined from most traditional AF pracice. Villagers live adjacent to their gardens and maintain them through many generations (Noble and Dirzo 1997). The whole farming system in which hill farmers are engaged can be considered as AF (Garforth *et. al*., 1999). Thus, AF is an established land-use systems and technologies where woody perennials (trees, shrubs etc.) are intentionally grown on the same land with crops and/or animals, in some form of spatial arrangement or chronological sequence. Countries having less forest cover can be benifited by the development of tree-based introcropping and leads to reduce the dependence on natural forest.Such AF system can stimulate farmers to produce wood along with annual crops (Sisi *et. al.,* 2010). These systems provide ecosystem services like nutrients recycling, regulation of microclimate and local hydrological processes, and suppression of undesirable organisms and detoxification of noxious chemicals are surplus beyond the production of food (Sileshi *et. al.,* 2007). System that assimilates trees with agriculture crops contribute to the agricultural environment by reducing wind velocity and wind erosion, controlling sheet and rill erosion, mediating solar radiation and regulating soil and air temperatures, increasing field moisture, and improving soil nutrients (Yin, 2004).. AF is increasingly being identified as an integrated land use that can directly enhance plant diversity while reducing habitat loss and fragmentation (Noble and Dirzo 1997). Traditional AF practices have contributed massively to food security and environmental protection, the need to meet the increasing needs of the population. These systems are considered as diversity enhancing land use systems especially in the context of inter-species diversity as it brings together crops, shrubs, trees and in some cases livestock on the same piece of land (Atta-Krah *et. al.,* 2004). These systems have the potential to support as high as 50-80 percent of the biodiversity of the comparable natural system (Noble and Dirzo 1997). Among the major challenges facing the world today are deforestation, land ruin, unmanageable farming practices, loss of biodiversity, increased risks of climate change and rising hunger, poverty and malnutrition. This land-use option can address many of these global challenges. The thoughtful inclusion of trees in agricultural landscapes has been a common practice among farmers for a very long time and has played important roles in conserving crop and tree diversity. In current times, scientists have become interested in the environmental services that AF practices maintaining watershed functions, retaining carbon in the plant-soil system, and by supporting the conservation of biological diversity (Schroth *et. al.,* 2013).

1.2 Rationale of the Study

Despite some impressive scientific and technological advances, AF rural development efforts were frequently unsuccessful (Nair 1996). The land is a dynamic natural resource and is the basis of our existence. Due to the emergent pressure of exponential growth in the human and livestock population, it has been wide-open to various pressure and abuse resulting in the destruction of land, harm of biodiversity and declining cultivable land. These have increased the gap between demand and supply for rural needs gratification. Today, the existing provision to agriculture and forestry are inadequate to meet the demand for food, timber, fuel, fodder, and other minor products. This is the correct time to exercise an option to convert low productive and less exploitable land into a productive goal mine by adopting AF for variation and sustainable biomass production. This research helps to assess the contribution of AF to meet the needs of rural farmers. As the AF technique encompasses a wide variety of systems and diverse array of the crop, livestock, and trees species, this research will be an attempt to find out the contribution in the conservation of precious natural resources. The integration of traditional knowledge with scientific research is required for the development of improved AF systems (Dixon *et. al.,* 2001). The selection of proper multipurpose tree species for AF by suitable management practices is a key factor for improving overall productivity per unit of land (Tiwari *et. al.,* 2017). A massive AF program along with encouraging AF should be implemented throughout the country for protecting the country from future fuelwood crises and serious ecological tragedy. It is important to study AF systems because of their ability to sequester carbon as well. This study aims at a wider understanding of how AF systems are affecting the people who participate in them and how those people perceive their socio-economic wellbeing. This study mainly explores plantations that are located in the foothills of the North facing Churya hill of Kaligandaki riverbank, and it evaluates the aboveground biomass and carbon stock storage of AF plantations with different dominant shading trees. It will also assist the various stakeholders and decision-makers in the allocation of resources for more programs in the Churya region.

1.3 Objective of the Study

The general objective of the study is to increase our understanding in the role of agroforestry in biodiversity conservation and rural livelihood.

Specific Objectives

- To analyze the contribution of AF in rural livelihood**.**
- To assess the present status of AFs tree biodiversity in the study area
- To assess the prospects of trees potential earning from selling carbon store in tree.

CHAPTER TWO: LITERATURE REVIEW

2.1 AF and biodiversity

The United Nations Convention on Biological Diversity (UNCBD) defines ′biodiversity′ as ″ the variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.″ Spatial and ecological scales are therefore fundamental concepts in biodiversity studies. AF can be classified as eco-agriculture, since the mixing of productive woody perennials in farming systems (which is the definition of AF) is one of the eco-agriculture strategies of mimicking natural habitats to conserve some wild biodiversity. (Kindt *et. al*., 2004).The pattern of distribution of various vegetation structures and the mixture with diverse tree-based farming are interesting features concerning floristic and eco-diversity at a landscape level (Backes, 2001). Thus, woody species diversity can contribute to ecosystem productivity and sustainability under conditions of heterogeneity in species traits and environmental characteristics in agricultural landscapes (Kindt *et. al*., 2004). Rural people not only depend on wild plants as sources of food, medicine, and fodder but also developed methods of resource management, which may be important for the conservation of some of the world's important species and habitats. (Fifanou *et. al*., 2011). AF, deliberate management of shade trees with crops has the potential for providing habitats outside formally protected land, connecting nature reserves and alleviating resource-use pressure on conservation areas. The role of AF systems in protection species diversity and achieve that these systems can play an important role in biodiversity conservation in human-dominated landscapes (Das *et. al*., 2005). The diversity of life in all its forms and at all levels of the organization, has come under serious threat in many places in recent times.

2.2 AF and Livelihood

Livelihood is fusion of capabilities, assets (including both material and immaterial resources) and activities for a means of living (Scoones, 1998). AF in the comprehensive sense encompasses a complete range of production systems, from forest to crop monoculture. In relationships of alignment, structure, management practices, and production functions well-marked variations exist among these systems and the diversity of life in all its forms and at all levels of organization. Within the current context, a suitable land-management system increases total production, combines crops, tree crops, forest plants and or animals simultaneously or consecutively and applies management practices harmonious with the cultural patterns of the local population (Benge *et. al.,* 1987). AF can be addressed as eco-agriculture since the incorporation of productive woody perennials in farming systems is one of the eco-agriculture strategies of imitating natural habitats to conserve some wild biodiversity (Kindt *et. al*., 2005). Trees are the single most important source of fodder for livestock, which in turn provides draught power for cultivation, food products such as milk and meat, and maintains soil productivity through compost and manure.

2.3 AF and Carbon Stocks

The global carbon cycle has acknowledged the most attention in recent years as it has become obvious that increased levels of CO_2 in the atmosphere are causing changes in our climate at a shocking and accelerating rate (IPCC, 2001). Under the Kyoto Protocol′s Article 3.3, AF was recognized as an option of mitigating GHGs. Since then, the Carbon restoration potential of AF systems has fascinated greater attention of concern authorities. It is striking because of its applicability to a large number of people and areas currently in agriculture, as well as its observed potential for sinking pressure on natural forests. In count to the difficulty caused by diverse factors such as climate, soil type, tree-planting densities, and tree management as well as specific difficulties arising from requirements for monitoring, verification, seepage assessment and the establishment of credible standards, AF estimations agitated by the problem of estimating the area under AF practices (Makundi *et. al.,* 2004). According to the IPCC (2007), AF systems offer significant chances for creating synergies between both adaptation and mitigation actions with a technical mitigation potential of carbon in terrestrial ecosystems.

Globally, C trading is rapidly expanding, and the CDM of the Kyoto Protocol offers an attractive economic opportunity for survival farmers in developing countries, the major practitioners of AF, for selling the C sequestered through AF activities to industrialized countries. It will be an environmental benefit to the global community at large as well (Nair *et. al*., 2009). IPCC (2007) also indicated in its special report that the conversion of wasteland and grassland to AF has the best prospective to soak up atmospheric carbon dioxide other than direct benefits. Since carbon dioxide is the major greenhouse gas, representing 77% of total anthropogenic GHG productions, its lessening is very indispensable from the atmosphere. Carbon sequestration is the capturing atmospheric carbon dioxide and storing for the long term through natural (soils/vegetation) and engineering techniques (Schrag 2007). The boundary planting of AF systems like Alley cropping, Shelterbelts, and windbreaks should be encouraged among farming HHs living within the forest reserves in Nigeria. This will enhance sustainable forestland use while offering low cost of carbon sequestration for combating the effect of climate change (Adetoye *et. al*., 2017). Among all the natural techniques, AF provides a win-win opportunity to achieve the objectives of carbon sequestration and climate change mitigation and adaptation. AF is often considered a cost-effective strategy for climate change mitigation. AF systems store carbon in the soils and woody biomass, and these reduce greenhouse gas emissions from soils (Prasad *et. al*., 2012). The political environment is also favorable for enhancing smallholder involvement in GHG-mitigation projects. The success in the implementation of such projects will depend on the farmers′ willingness to participate in the project (Nair *et. al*., 2009)

AF is an important strategy to sequester C from both developed and developing nations. Forest and farm-based AF both have equally important roles in reducing carbon emissions and providing food security to the people of rural areas. AF and sustainable agricultural methods help to mitigate climate change (Tiwari *et. al*., 2017).

2.4 Shannon's diversity index

Shannon diversity index (H1) is high when the relative abundance of the different species in the sample is even and decreases when few species are more abundant than the other is. It is based on the theory that when there are many species with even proportions, the uncertainty that a randomly selected individual belongs to a certain species increases and thus the diversity. It relates the proportional weight of the number of individuals per species to the total number of individuals for all species (Kent and

Coker, 1992). The Shannon-diversity index (H_1) was calculated, to analyses the diversity of tree/shrub species per farm and it was calculated as follows:

$$H1 = -\sum_{i=1}^{s} \mathrm{Pi} \ln P_i$$

Pi = the proportion of individuals or abundance of the I^{th} species expressed as the proportion of the total abundance lnPi =natural logarithm of pi S= the number of species i= 1, 2, 3...s

2.5 The Hill Farming System

AF plays a vital role in attaining sustainability in the hills farming system (Yadav, 1992). Woody perennials maintained in delineation strips across the slopes and around the fields. The contribution of these trees contribute to the production of fodder and firewood and their protective function in reducing the erosion hazards and thereby making crop production possible in those steep slopes where profitable cropping would otherwise be extremely difficult .The integrated hill farming system is representative of the low to mid-hills of Nepal. Around 40 percent of the cultivated land, 31 percent of the grazing land, and 50 percent of the forests of the country are located in the mid-hills, principally arranged in terrace farming small land holdings, sloping marginal land and rain-fed agriculture are the characteristic features of hill farming in Nepal (Paudel *et. al.,* 2011). High topography coupled with prodigious climatic disparities makes the farming system extremely diverse and labor intensive (Thapa, 2015). The peculiarity of this type of farming system is that it is mixed, diverse and subsistence orientated, since it has a close interaction between crops, animals, and forests, which makes it very similar to the highland mixed and/or rainfed mixed farming system category of the Food and Agriculture Organization of the United Nations (FAO) (Dixon *et. al*., 2001).

2.6 Types of Farm Land

2.6.1 *Bari*

Rain fed terraces located higher on the hill slopes, known as *Bari* lands, are often used for maize-based cropping systems (Poudel *et. al.,* 2011). The common cropping patterns of the integrated system in non-irrigated *Bari* lands are maize – millet/pulses (black gram/cowpea/rice bean)–fallow; maize-vegetable-fallow; maize-mustard/ buckwheat- fallow, as well as maize-fallow (Paudel *et. al*., 2011). The number of trees that farmers put on their *Bari* land vary with the altitude and the aspect of the area. The trees are generally are of fodder, fuel and timber species.

2.6.2 *Khet* land

Lower terraces on the hill known as *Khet* lands, generally have access to the irrigation that is necessary for rice-based cropping systems (Poudel *et. al*., 2011). The number of trees planted on Khet is less s compared to *Bari*. Most commonly, fuelwood and timber species replanted and if situated near the house, the timber species are also planted. In the Terai area, generally, people have been planting trees on their bunds (Shrestha, 2002)

2.6.3 *Kharbari* land:

This is a unique type of silvopastoral system practiced by ethnic groups. In this type of AF System, terraces or sloping grazing lands claimed from the contiguous forest are managed to protect and promote grass "Khar" (*Typha angustata*) as well as fodder trees such as *Ficus semicordma "Khanew", Ficus glaberimma "Pakhuri", Garruga pinnata "Dabdabe".* Livestock, such as buffalos, cows, and goats are raised for milk, meat, manure, and draught power. A considerable portion of mid-hill land is under *Kharbari* which is permanently occupied by *Khar* (*Typha angustata*) grass, other ground grass, fodder as well as timber too (Shrestha, 2002).

2.6.4 Woodlot

The area is set aside more or less entirely for trees; such an association is known as a woodlot. Vegetables or crops are often intercropped in the woodlot in the early periods of establishment, but with time wood production is the most important use. In small-scale farming areas, woodlots are often very small, 0.1 hectares or less. Large-scale farms may have woodlots of many hectares (Ndayambaje *et. al.,* 2013). The main purpose of having a woodlot is to protect agricultural fields from soil erosion, prevent water springs from drying up, prevent landslips and landslides, and maintain watercourse flows. The management of these areas bestowed with the communities in the villages (Amatya, 1999).

2.7 Agroforestry forestry systems in Nepal

The Nepalese AF systems normally comprise livestock, crops and tree crops (Garforth *et. al.,* 1999), with exclusions that include specific AF practices such as home gardens, silvopasture production and forest-based systems such as cardamom planting with alder *Alnus nepalensis* (Amatya and Newman 1993). In mid hills of Nepal, there is intermixing of the tree with agriculture land, which indicates the peripheral effects on natural forest (Uddin *et. al.,* 2015). That is why the recent assessment, done by the government of Nepal represent other woodlands as 4.38% where forest covers 40.36% and combined form 44.74% of the total area of the country. The other wooded land represents the tree on farmland and fallow land with the tree (DFRS, 2015). In the context of Nepalese hills, AF practice has a special significance, because it has been an integral part of the farming system to sustain agricultural practices, to support livestock production, and to produce forest products for HHs consumption (Amatya and Newman 1993). Its special importance in the hills is due to the heavy dependence of farming HHs on tree resources, and the need to sustain farming and to generate environmental benefits. The traditional farming system in Nepal has not been appropriate to sustain agricultural production and the present level of food requirements. AF practice in Nepal seems like recent practices followed in developed countries but they are not methodically managed. The challenge towards the traditional AF practice in mid-hills is to manage scientifically for the betterment of the livelihoods, sustainable production, and upgrading of the socio-economic state of the people (Tiwari *et. al.,* 2017).

2.8 Farm based agroforestry forestry system

The population of Nepal grown rapidly that's why more people have required increasing amounts of food and commodities from agriculture and natural resources. The land use pattern of Nepal is changing in the time being due to the climatic effect and insurgency in the country (Paudel *et. al.,* 2016). The hill farming system features a corresponding relationship among crops, trees, and livestock. The planted trees species of trees and shrubs grown on farms are an integral component of local economies (Tiwari *et. al.,* 2017). AF plays a dynamic role in accomplishing sustainability in the hills farming system (Yadav, 1992). AF is a vital part in increasing agricultural productivity since it plays a vital role nutrient recycling, reducing soil erosion, and improving soil fertility and increasing farm income compared with conventional crop production (Kang and Akinnifesi, 2000). Additionally, AF also has promising potentials for reducing deforestation while increasing food, fodder, and fuelwood production (Young, 1997).

2.8.1 Home garden (Agro hortisiviculture) systems

Gardens, usually homestead gardens, are multilayer, with a wide variety of species and dense associations with no organized planting arrangement, common throughout the Terai and the hills (Yadhav, 1992). Home gardens, found in rural or urban areas, are characterized by structural complexity and multi-functionality, which enables the delivery of different benefits to ecosystems and people. The home garden size ranges from 0.02 ha – 1.2 ha (average 0.3 ha). Home gardens are an important site for in situ conservation. Many studies have been carried out in various countries to demonstrate that high levels of inter- and intra-specific plant genetic diversity, especially in terms of traditional crop varieties and landraces, are preserved in home gardens (Galluzzi *et. al*., 2010). In Bangladesh home gardens, which are maintained by at least 20 million HHs, represent one possible strategy for biodiversity conservation. There is significant botanical richness that was exhibited in the home gardens across southwestern Bangladesh (Kabir, M. E., and Webb, E. L. 2008). Farmers have protected fodder, fuelwood and other plant species in their home gardens, such as *litsea monopetela, Artocarpus lakoocha, Bauhinia purpuria, Leucaena leucocephela* of fodder trees, *Michela champaca, schima walllichi and Dalbergia sissoo* among the fuelwood and timber species in the hills (Neupane, 1999). Many families engage in food production for subsistence or small-scale marketing and the variety of crops and wild plants provides nutritional benefits. At one go, home gardens are important social and cultural spaces where knowledge related to agricultural practices is transmitted and through which HHs may improve their income and livelihoods (Das *et. al*., 2005).

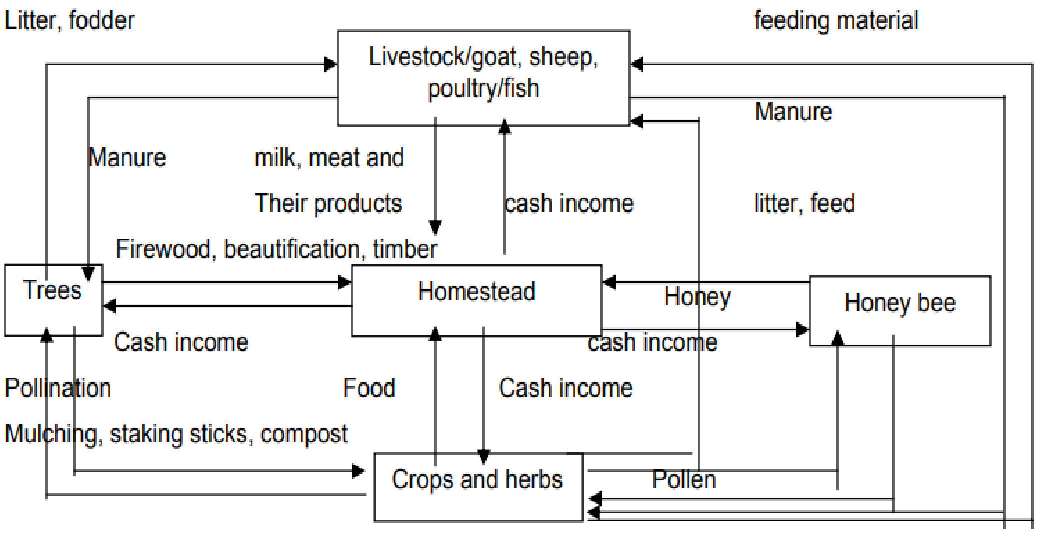


Figure1. Inter-linkage/Interrelation among various commodities in Nepalese home gardens (Gautam *et. al*., 2006)

2.8.2 System of crop cultivation inter-cropped with fruit trees (Agrohorticulture)

The agro-horticulture arrangement island managing system in which trees instantaneously managed with fruit trees and vegetable production (Yadhava, 2009). This system is a common feature as a home garden with fruit trees and wood as a windbreak. This type of AF system is the principal in the Terai regions. Horticulture crops such as mango, litchi are intercropped with agriculture crops mainly maize, wheat, vegetables and cash crops (Amatya, 1994).

2.8.5 Alley cropping (Hedgerow intercropping)

In this structure fast growing, nitrogen-fixing shrubs are planted as hedgerows, while food crops are inter-planted between these windbreaks. The system provides wood and green foliage for fodder or green manure for food crops (Galluzzi *et. al.,* 2010). Small trees or shrubs planted and trimmed frequently to prevent them from shade effect. Trees are grown in relatively dense rows (between 2 to 4 m wide, never more than 6 m apart). Crops are grown in the alleys between the tree rows. Mainly farmers in the middle and high mountain physiographic zones of Nepal have adopted this system (Amatya, 1999).

2.9 Forest-based AF systems

2.9.1 Taungya System

This system practiced only in the Terai region of Nepal. One of the main purposes of this structure is to encourage farmers to grow crops between trees. The practice has shown that the growth of trees in intercropping areas is 3-4 times better than in areas where intercropping has not been practiced (Amatya, 1999).

2.9.2 Shifting cultivation

Shifting cultivation in general is a system of farming in which fields are prepared by cutting down the natural vegetation. The shifting field agriculture is characterized by a rotation of' fields rather than of crops, with a short period of cropping alternating and long fallow period, and clearing employing slash-and-burn (Dhakal, 2000). This scheme of cultivation is practice in the middle mountain physiographic zones of Nepal, mainly in the eastern region, frequently on very steep slopes. This is an adaptive forest management practice predicated on sound scientific principles that productively hill and mountain lands, conserves the forest, soil, and water resources, and is ecologically preferable to alternative agricultural and forestry activities (Kerkhoff and Sharma, 2006). Rotation cycles have shrunk to less than five years in many places, checking oak regeneration and resulting in a replacement by bamboo and *Eupatorium*, an invasive wild plant (Tiwari *et. al.,* 2017). Shifting cultivation in Nepal, locally called as Khoriya and Bhasme, is a land use practice in which indigenous communities clear and cultivate secondary forests in plots of different sizes, leave these plots to regenerate naturally through fallows of medium to long duration (Fujisaka *et. al.,* 1996). However, the current government policies are not compassionate to shifting cultivation practices, hence fueling up the conflicts among the shifting cultivators and forest management authorities, along with land tenure issues (Kafle, 2011).

2.9.3 Livestock and Tree integration System

Livestock raising is an integral part of the HHs economy and of the farming system that supports and supplements crop production and is an additional source of HHs income. It is also an important source of nutrition, especially for the hill dwellers and is closely associated with social prestige and religion (Yadhava, 2009). Almost every farm family maintains livestock: cattle buffalo, sheep, goat, pig and poultry. However, the types of livestock raised vary in terms of the ecological belt ethnicity and the elevations in the hills. Livestock is a specialized activity of the mountains, while in the hills it is subsidiary. Nepal has one of the highest per capita livestock per HHs in the world and thus has one of the world's highest livestock population per unit of land. A very large proportion of the livestock is found in the Hills with about 60 percent of all livestock concentrated in the Middle Hills. Livestock statistics in Nepal are variable and not sufficiently accurate to judge trends in animal populations changed with any degree of accuracy (Upadhyay, 1993).

CHAPTER THREE: METHODOLOGY

3.1 Description of Study Area

3.1. Study area

This study was conducted in Baundikali Rural Muncipality, which lies in the Curya hill of Mahabharat range. It has an area of 91.9 km². According to the population census of 2011, it has 15,734 individuals. Among them 6,990 are Males and 8,744 are Females.

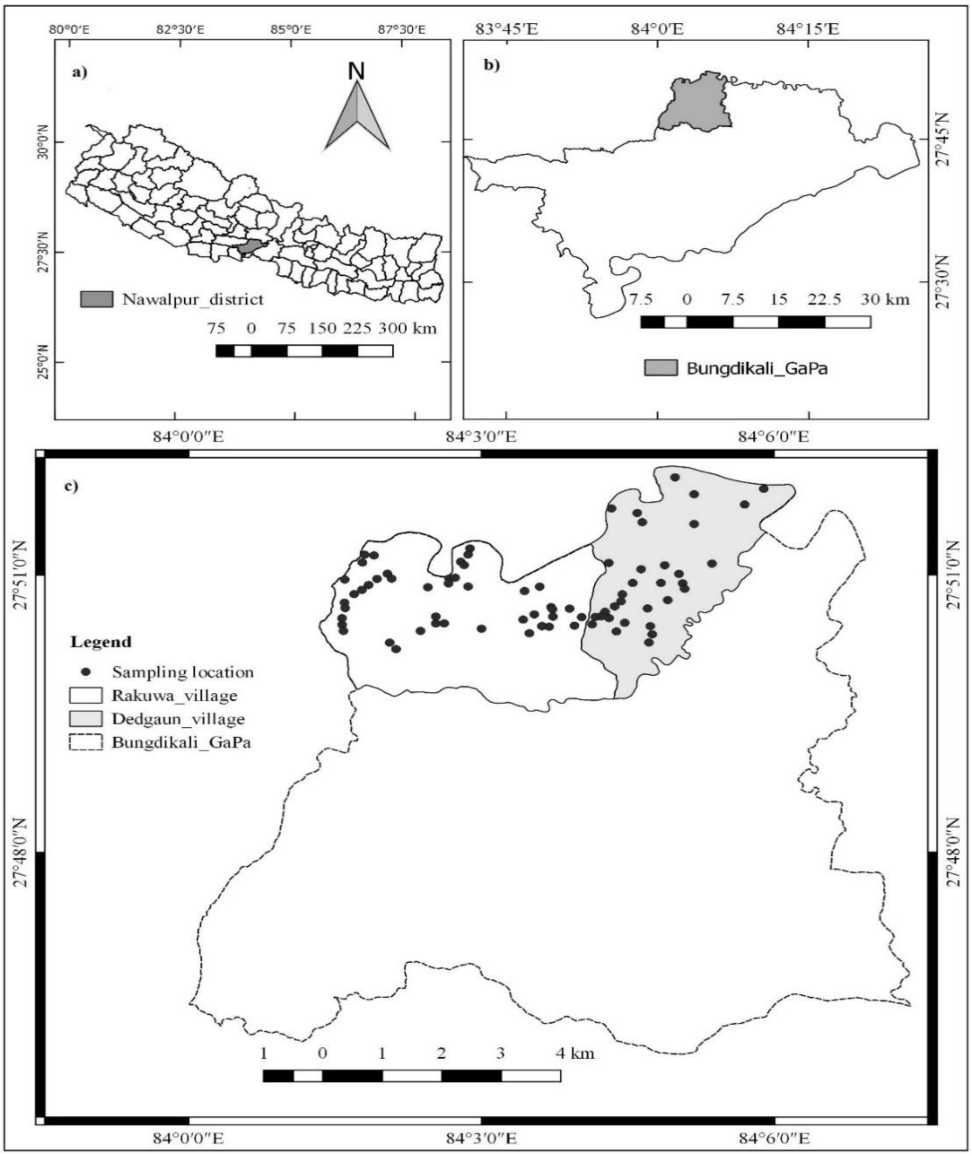


Figure 2: Map of a) Nepal showing Nawalpur district, b) Nawalpur district showing Baundikali rural-municipality, c) Baundikali rural-municipality showing Rakuwa and Dedgaun village. (Map prepared using QGIS).

The research conducted in ward number one and two Baundikali Rural Municipality (sampling plot altitude range from 310 m. to 862 m). Two village were selected for the study to encompass all ethnic group, where Major ethnic groups in these two villages are Magar, *Chhetri, Brahmin, Newar, Dalit, darai* and *Gharti*. (Deadgoun, Rakuwa) Dedgaun and Rakuwa, are located in the Hills in the north-end of Nawalparasi district. Rakuwa is a scattered community located in the Hills next to the neighboring district Palpa.The study area lies on the bank of the Holy Kali Gandaki River and is surrounded by mountains in all sides.The total number of HHs in the study (including both ward number one and two) site is 1236. Both the village lies in kaligandaki river basin, forming a small valley, which provides north-facing slope with small flat land drained by small seasonal water streams.

3.1.1 Agroforestry practice in study area

Farm based agroforestry system is in practice in this area. The hill farming system features a corresponding relationship among crops, trees, and livestock. The planted trees species of trees and shrubs grown on farms are an integral component of local economies (Tiwari *et. al.,* 2017). The agro-horticulture arrangement island managing system in which trees instantaneously managed with fruit trees and vegetable production (Yadhava, 2009). Home gardens, found in rural or urban areas, are characterized by structural complexity and multi-functionality, which enables the delivery of different benefits to ecosystems and people. The home garden size ranges from 0.02 ha – 1.2 ha (average 0.3 ha). This system is a common feature as a home garden with fruit trees and wood as a windbreak. In this structure fast growing, nitrogen-fixing shrubs are planted as hedgerows, while food crops are inter-planted between these windbreaks. The system provides wood and green foliage for fodder or green manure for food crops (Galluzzi *et. al.,* 2010). Small trees or shrubs planted and trimmed frequently to prevent them from shade effect. Trees are grown in relatively dense rows (between 2 to 4 m wide, never more than 6 m apart). Crops are grown in the alleys between the tree rows. Mainly farmers in the middle and high mountain physiographic zones of Nepal have adopted this system (Amatya, 1999).

3.1.2 Climate

Among the five main climatic types present in Nepal (Temperate, Polar, Cold, Arid and Tropical) (Karki *et. al.*, 2015), Nawalparasi districts has tropical savannah and temperate climate with dry winter and hot summer. The vegetation sampling area of the present lies in sub tropical region.

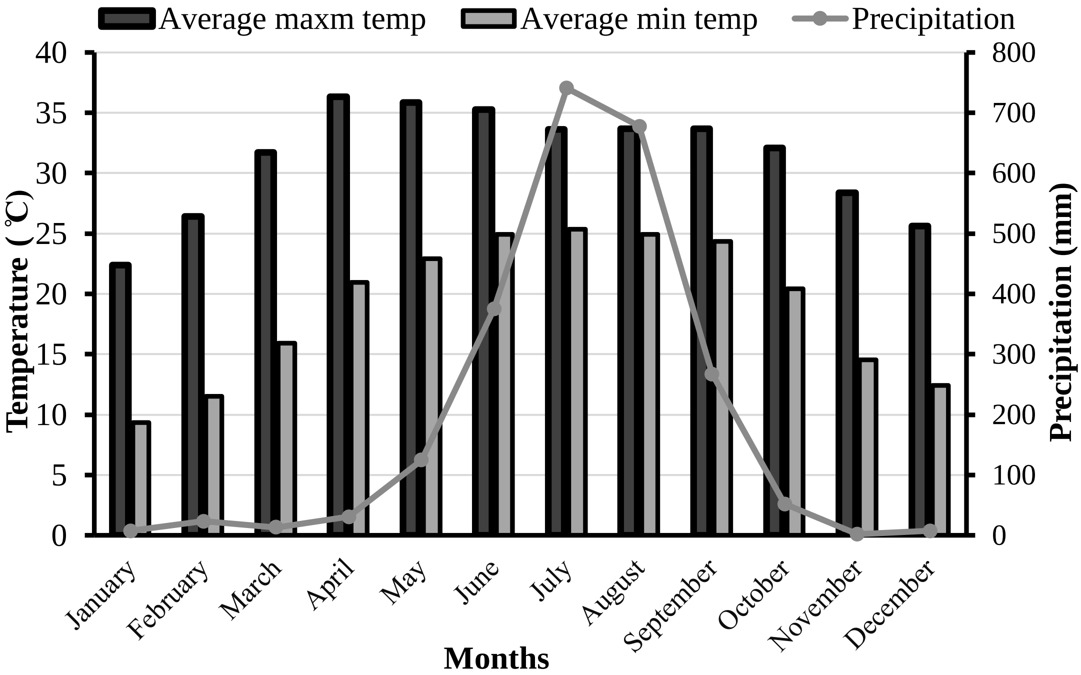


Figure 3. Ten years (2008-2017) monthly mean temperature and precipitation. Data was obtained from Department of Hydrology and Meteorology, Kathmandu on Feb 2019. Two Meteoeological Stations, Dumkibas and Bharatpur were consider for precipitation and temperature, respectively.

To characterize the climate of the study area, meteorological data for the last ten years (2008-2017) recorded at the nearest stations has been presented. Meteorological stations Dumkibas for precipitation and Bharatpur for temperature were considered. Temperature data from Dumkibas station was unavailable and Bharatpur falls under the same climatic region of study area therefore, temperature data from Bharatpur station was considered for analysis. Dumkibas showed average annual precipitation of 1933 mm. Similarly, average annual maximum temperature was 31°C and average annual minimum temperature was 19°C. The mean maximum temperature recorded was 36°C during April and mean minimum temperature recorded was 9°C during January (**Figure 3**). Furthermore, highest amount of precipitation recorded during July followed by August and June, which represents monsoon season (June-August).

3.2 Data Collection

3.2.1 Primary data collection

A. Interaction with Local Line Agencies

Separate meetings were organized with local women's community, rural municipal Office, and ward office and school for soliciting the general information about social aspects of the study area and to cross check for the validity of data of questionare survey.

B. Questionnaire Survey

The questionnaires were tested initially in some households (HHs) during the earliest survey and were finalized by uniting the feedbacks from farmers. HHs survey was also conducted to collect quantitative information on demographic characteristics and their farming activities. The questionnaire was prepared in English first and then translated into Nepali, after modifying the questionnaire, HHs survey was carried out to those HHs in which the sampling of the tree was done, means the HHs was determined by the sampling land ownership. Head of the family, elderly individuals or available household members were interviewed. Information on the total amount of firewood, fodder, and timber consumed from the AF tree species all-round the year was also noted**.**

C. Local names of plants

The informants were cheered to inspect the plant closely and were gently queried for explanations if answers appeared unpredictable. While giving several local names to one botanical species and vice versa were common phenomena: nonetheless, many errors were uncovered by giving attention to mismatches in the field. Informants were not pushed to give a name if they were uncertain.

D. Vegetation Sampling Design

Sampling was conducted in premonsosn season of 2018.The quadrat size of 20× 20m ($400m^2$) was used (Bhattarai et. al., 2018). Sample plots were randomly selected using GPS points marked on the map of the AF land. Side by side, the owner of the land was selected for the HHs survey (Baral et al., 2013). Ten transect lines were laid at a distance of 200 m from each other along Kaligandaki riverbank to south hilltop across the villages and farms. Transects were maintained along the foot trails, 100 points were selected for Deadgaun and Rakuwa villages. Sampling plots of 20m x 20m were established at each selected point for tree parameter measurements. In each sampling plot, all individual trees were counted and diameter at breast height (at 1.37 m from ground level) of all tree species (with greater than 10 cm) were measured using DBH tape. Height of each individual trees were measured using clinometer by trigonometric Methods.

$$H = \tan\theta \times b + a$$

Where,

H = total height of tree in meter

θ = angel of elevation to the top of tree from observer eyes

b = distance between the tree base and observer in meter

a = eye - height of the observer in meter

3.2.2 Secondary Data Collection

Secondary data were collected from the various sources and records like- reports published by related project, Nepal AF Foundation, District Agriculture Development Office and District Soil Conservation Office. Maps, journals, publications, reports of other line agencies, published or unpublished and relevant literature were also consulted in the library and the relevant websites to make better understanding, interpretation, and analysis of the research.

3.3 Data Analysis

Data analysis and interpretation: Data collected from the HHs survey were analyzed through Xcel and interpreted on average. All the information collected from HHs survey were put together and qualitatively analyzed to produce concrete results. Ecological data analysis was conducted to find density, frequency, relative density, relative frequency and Importance Value Index (IVI) following Zobel *et. al.*, (1987), Sharma and Chalise 2012.

A. Frequency (f_i)

Tree frequency (expressed in percentage) calculated as the number of times a tree species is present in a given number of plots (Zobel *et. al.*,, 1987). Frequency reflects the distribution of a species in a given area. If a species is distributed uniformly in an area, there is greater probability of its occurrence in all plots and it would have maximum frequency. The relative frequency was calculated as the ratio of the frequency of a given species to the total frequency of all species.

$$f_i = \frac{ni}{N} * 100$$

Where,

f_i = Frequency of species i

n_i = Number of quadrats in which species i occurred

N = Total number of quadrats studied

B. Relative frequency (Rf)

$$Rf_i = \frac{fi}{f} * 100$$

Where,

Rf_i = Relative frequency

f_i = Frequency of species i

f = Sum of frequencies for all species

C. Density (d_i)

Density is the number of individuals per unit area. Tree density, expressed as trees per hectare (ha), explains the dominance of different tree species in an area and gives an idea of how closely trees are growing. The relative density was calculated as the ratio of the density of a given species to the density of all species (i.e., total density). It is the study of numerical strength of a species in relation to total number of individuals of all species.

$di = ((n_i / (N^* A))*10000$

Where,

di = Density (ha^{-1}) of species i

n_i = Total number of individuals of species i

N = Total number of quadrats studied

A = Area of a quadrat

D. Relative density (Rd_i)

$Rd_i = (d_i / D)*100$

Where,

Rd_i = Relative density of species i

d_i = Density of species i

D = Total density of all species

E. Dominance (do_i)

Dominance is the amount of ground covered by the tree trunk. Basal area is an indicator of the size of the standing stock. It is the area of the cross-section of a stem at breast height (1.37m) and computed by employing the following formula:

Basal area (Ba_i) = $(\pi d^2) / 4$

Where, d = mean diameter in meter at the breast height of individuals of that species.

$do_i = ((Ba_i /(N^*A))^* 10000$

Where,

do_i = Dominance (ha^{-1}) of species i

Ba_i = Total basal/coverage area of species i

N = Total number of quadrats studied

A = Area of a quadrat

F. Relative dominance (Rdo_i)

$Rdo_1 = (doi / Do)*100$

Where,

Rdo_1 = Relative dominance of species i

doi = Dominance/coverage of species i

Do = Total dominance/coverage of all species

G. Importance Value Index (IVI)

Tree dominancy in the surveyed areas were determined by ordering the Importance Values of each tree species. Importance Value was obtained by summation of the relative frequency, relative density, and relative dominance.

$IVI_x = RF_x + RD_x + Rdo_x$

Where,

IVI_x = Importance Value Index of species x

RF_x = Relative Frequency of species x

RD_x = Relative Density of species x

Rdo_x = Relative Dominance of species x

H. Diversity index

Diversity index is a mathematical measure of species diversity in a given community based on the species richness (number of species present) and species abundance (number of individuals per species) (Peet, 1974). The most commonly used diversity index in ecology is Shannon–Wiener diversity, which was calculated using the following formula:

Shannon–Wiener index $\mathbf{H} = -\sum_{i=1}^{s}(pi)(\log pi)$

Where,

H = Shannon index of species diversity

Pi = Proportion of the total number of individual of species i

S = Number of species

The Shannon index assumes that individuals randomly sampled from an indefinitely large population. The index also assumes that all species are represented in the sample High value of H is representative of more diverse community. A community with only one species has H value of zero. If the species are evenly distributed then the H value would be high.

I. Above Ground Tree Biomass (AGTB)

The diameter at breast height (DBH) of 1.3 m along with the height of all trees having DBH greater than 0.1 m were measured by using a diameter-tape and clinometer, respectively, in a randomly laid-out concentric forest plots of 400 m^2 area by delineating a square plot of (20m × 20m). Geographic location (latitude, longitude, and elevation) of each plot (20m × 20m) was recorded using the Global Positioning System (GPS) from the center of the plot. The allometric equation as suggested by Chave *et. al*., (2005) was used for Above Ground Tree Biomass (AGTB. Allometric equations are established in a purely empirical way based on exact measurements from a relatively large sample of typical trees (Hairiah *et. al*., 2011). The equation is appropriate for the moist forest stand with the annual rainfall between 1500-4000 mm . This method was also recommended for the moist forest by Ministry of Forests and Soil Conservation, Government of Nepal (MOFSC, 2009).The AGTB (in ha^{-1}) was calculated using DBH (in cm), height (in m) and wood-specific gravity (in g/cm3) of the trees according to equation 1 below:

$$AGTB = 0.059 * \delta D^2 H \quad \text{.....................} \quad (1)$$

Where, δ = wood specific gravity (g cm-3)

D= tree diameter at breast height (cm)

H= height of the tree (m)

Dry wood specific gravity was extracted from (Zanne *et. al*., 2009), the unknown wood density of some tree species was taken as average 0.6 gm/cm^3 (Ganguly and Mukherjee, 2016). Belowground biomass was an approximation; the recommended root-to-shoot ratio value of 1:5 was used as recommended by MacDicken (1997). The carbon stock was calculated by summing the carbon stock of the individual carbon pools of each plot. The biomass stock densities were converted to carbon stock by using the carbon fraction of 0.47 (IPCC 2006).

J. Trees composition pattern: multivariate analysis

Ordination was carried out in this study, the ordination of samples and species is constrained by their relationships to environmental variables (Chahouki, 2013). Detrended correspondence analysis (DCA) is highly reliable and useful tool for data exploration and summary in community ecology (Shaw, 2009). It is an indirect gradient analysis which examines the environmental causes of vegetation patterns by arranging the species according to their floristic. The first DCA axis is correlated with b-diversity and gives a measure of species turnover (Hill and Gauch, 1980). From DCA ordination, the value of the DCA first axis length of gradient 2.474 and eigenvalue 0.622 were obtained which indicated nonlinear relationship among species along the main gradient. Canonical correspondence analysis (CCA) was appropriate to explain the species environment relationship.

Direct gradient analysis ordinates the data according to the independent variable and then investigates how the dependent variables correlate to the ordination scores. Canonical correspondence analysis (CCA) is a direct gradient analysis that displays the variation of vegetation in relation to the included environmental factors by using environmental data to order samples (Kent and Coker, 1992). Monte Carlo permutation test was used to determine the significance of relations between species composition and environmental variables (Ter Braak, 1987). In present study, CCA was carried out to understand the relationship between different land use type (*Khet, Bari, Kharbari*, Woodlot,) and altitude of study area. These parameter were tested for their significance in governing the species distribution pattern, using Monte Carlo permutation with 9999 permutation at significant level $p < 0.05$(**Table 20**).

K. Statistical Method

Quantitative and qualitative data of tree species were obtained from questionnaire survey and plot sampling. Quantitative data were analyzed by simple statistical method to calculate mean, percentage, standard deviation and range. Qualitative data were analyzed by ordering and ranking. The relationships between carbon stocks and other variables (species richness, species density, basal area, height and DBH) were tested using simple linear regressions and correlation. Statistical Package for the Social Sciences (SPSS) Version 23.0 was used for the statistical data analysis and multivariate analysis (ordination) was done by canocoo version 4.5.

CHAPTER FOUR: RESULTS

4.1 Socioeconomic Status of Respondents

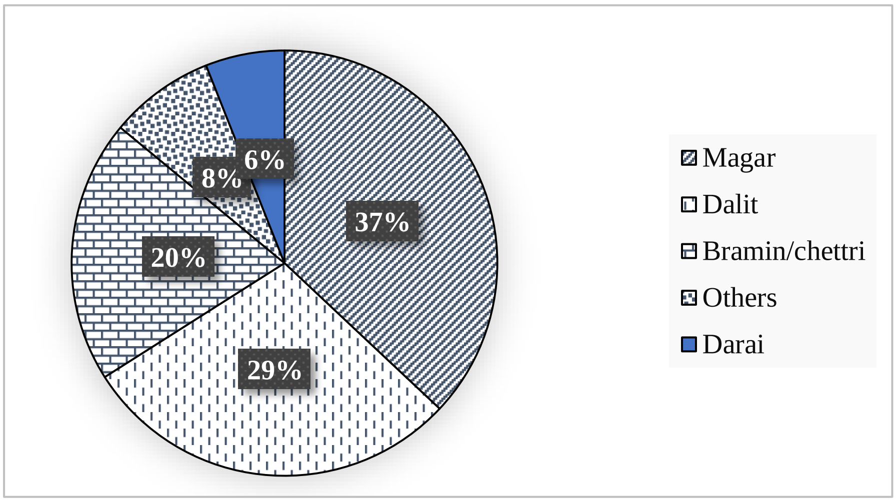


Figure 4: Ethnicity of respondents

The total number of HHs in the study (including both ward number one and two) sites was 1236. The age of the respondents varied between 17 to 90 years. Among the total respondents, 68 % were male and 32% were female. The sample HHs were 100 (8.09 %). The major castes/ethnic groups in the study area were *Magar, Kami, Chhsetri, Bhramin, Damai, Newar, Darai, Sarki,* and *Gharti* (**Figure 4**). Among them, *Magar* represented by 37 HHs, *Dalit* represented by 29 HHs, *Bhramin/Chhsetri* represented by 20 HHs, Derai represented by 6 HHs and others different caste (Newar, Gharti, etc.) represented by eight HHs. Out of total sample HHs respondent, one of them was below 20 year, 10 of them were 20 to 30 years, 22 of them were 30 to 40 years, 20 of them were 40 to 50 years, 16 of them were 50 to 60 years and 31 of them were above 60 years (**Table 1**).

Table 1: Gender and age class of respondents

	Gender		**Age class**					
	M	**F**	**<20**	**20-30**	**30-40**	**40-50**	**50-60**	**60<**
Respondent	68	32	1	10	22	20	16	31

The HHs size varied from one to 13 members. Out of all the sample HHs two of them had one to three family members, 40 had 3 to 6 family members, 49 had more than 6 to 10 family members and 9 had more than 10 family members (**Table 2**).

Table 2: Family size of respondents.

Size class	Number of individuals in a family	Respondent
Small	1-3	2
Medium	3-6	40
Large	6-10	49
extra large	10<	9

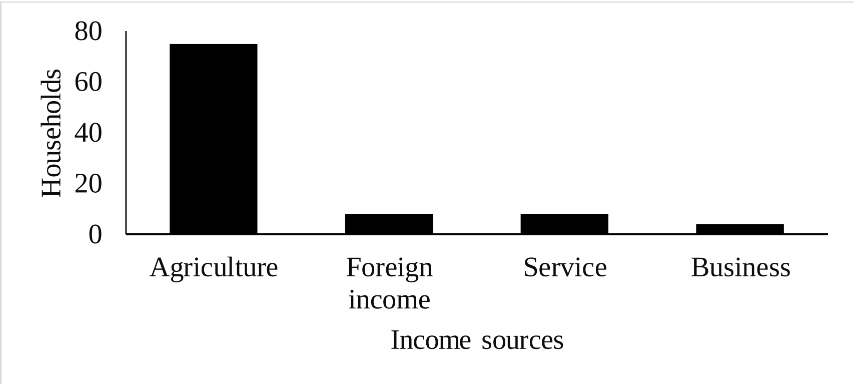


Figure 5: Income sources of households

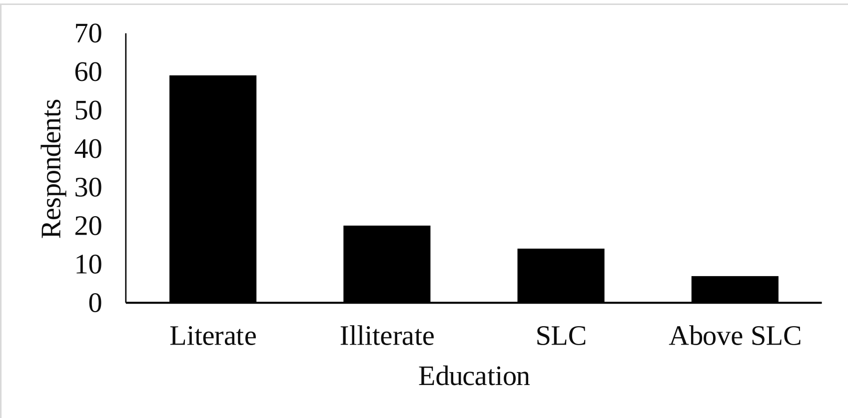


Figure 6: Education background of respondents

In terms of family income source 75% HHs depended on agriculture, 8% HHs depended on foreign income, 8% HHs depended on service, and agriculture and 4 % HHs depended on business and agriculture (**Figure 5**).

Out of total respondent, 20 % of them participated in AF training and 80 % had not been participated in any type's AF training. Out of total respondents, 59% of them were literate, 20% of them were illiterate, 14% of them were SLC and 7% of them were above SLC (**figure 6**).

4.2 The energy source of the respondents'

The main source of energy HHs of the respondent was fuelwood, 98% respondents used firewood as the main source of energy of cooking. Out of all the respondents, 36% of them used only fuelwood as an energy source. 18 % of them used LP gas and firewood while 14% of them used Kerosene and fuelwood. 12% of them used Biogas and fuelwood, 8% of HHs used LP gas, biogas, and fuelwood, and 7 % of them used Biogas, kerosene, and fuelwood. 3 % of them used LP gas, kerosene, and fuelwood and at last 2 % of them used LP gas, bio gas and kerosene as a source of energy (**Table 3**).

Table 3: Energy source of the respondents

Source of fuel	**No. of HHS**
Fuelwood	36 %
LP gas and fuelwood	18 %
Kerosene and fuelwood	14 %
Biogas and fuelwood	12 %
LP gas, bio gas, and fuelwood	8 %
Bio gas and kerosene and fuelwood	7 %
LP gas, kerosene, and fuelwood	3 %
LP gas, bio gas, and kerosene	2 %

4.3 Livestock Holding and Grazing Pattern

Respondents, 24% of them had small size LSU, 59% medium size, 16 % large size (**Table 4**). The livestock in the study site was commonly stall feed and graze. The buffaloes found to be almost stallfed and rarely grazed. The cows, oxen, and goats were grazed during the daytime and stallfeed in the morning and evening .Out of all sampled HHs 54 involved in stall-feeding and 87 of them involved in both stall -feeding and grazing (**Table 5**).

Table 4: LSU Size Classes in the study site

Size of livestock	Livestock unit	Respondents	Percentage (%)
Small	<1	24	24
Medium	1-2.5	59	59
Large	2.5<	16	16
None	0	1	1

Note: 1 buffalo/2 cow=1 LSU, 10 goats/pigs = 1 LSU, 100 chicks = 1 LSU (FAO, 2018)

Table 5: Feeding techniques adopted in the area

stall feed	stall feed/graze	None
54	87	1

4.4 Landholding, Land use, and Existing Cropping Practices

Four types of AF land were in practice in the study site. *Khet* land, *Bari* land, *Kharbari* land, and woodlot. Rice was the chief crop in the *Khet* land. Usually, in *Khet* land, the number of trees was less, since it causes shading effect for crops and it also attracts birds which may destroy the cereals. However, if the *Khet* land was in slope enough trees were planted to resist the sliding of terrace land (**Table 6**).

Table 6: Land use types of respondents**.**

Land holding status(ha)	Mean(ha)	Sd	min- max(ha)
Khet	0.15	0.25	0-1.12
Bari	0.36	0.22	0-1.78
Kharbari	0.05	0.12	0-1.02
Woodlot	0.04	0.14	0-1.32
All types of landuse	0.61	0.58	0.101-5.23

The sample HHs had a minimum of 0.101 hectares and a maximum of 5.23 hectares of land. The average land hold of HHs is 0.61± 0.58 ha. The data showed the sample HHs had the highest dependence on Bari land (mean *Bari* land is 0.36± 0.22 ha) and the least dependence on woodlot (mean woodlot is 0.04 ± 0.14 ha). (Table 6) The mean value of *Khet* land and *Kharbari* land was 0.15±0.25 hectares and 0.05±0.12 hectares respectively.

The major cropping patterns.

Khet land

Rice + Wheat + Maize

Rice +Potato + Maize

Rice +Wheat +Vegetables

Rice + Lentils + Vegetables

Rice + Vegetables + Rice

***Bari* land**

Maize + Millet+Ginger/Turmeric-Fallow

Maize+Millet+Vegetables

Maize +Legumes +Potato+ Fallow

Maize +Ghaiya +Vegetables+Fallow

4.5 Methods of Using Forest Products

Forest products used for multidimensional purposes. Poles and timber used for making furniture and agriculture equipment like spade and plough as well for constructing houses and shade for domesticated animals. Twigs mainly used for supporting climbers in the kitchen garden and vegetable field. The foliage of fodder trees and grasses used to feed animals. Irregularly shaped timber, poles, and branches of tree used as fuel. Leaf and litters used on bedding and compost manure (**Table 7**).

Table 7: Use of AF products**.**

AF products	Uses	Examples
Poles and timber	Furniture and agriculture equipment	Spade, plough, shade, chair, bed box etc
Twigs	Supporting climbers	Kitchen garden, vegetable field
Timber and Branches of tree(irregularly shaped)	Fuel	Firewood for cooking
Foliage and grasses	Fodder	Animal feed
Foliage,leaves and litters	Manure	Bedding and compost

4.6 Seasonal Availability of Fodder

In the rainy season (June- November), green grasses were available so, at this period, no other agricultural offshoots and fodder trees were provided to the livestock. The agricultural by byproducts saved for the dry season. Cows, oxen, and goats grazed in the dry season in community land, forests and agricultural fields after harvest of crops. Similarly, many types of fodder collected from forests when there had been a scarcity of fodder in private land and agricultural offshoots. Kabro (*Ficus lacor*), Kimbu (*Morus alba*), Ramsing (*Garuga pinnata*), Khania (*Ficus semicordata),* Dumri (*Ficus racemose)* and Ipil ipil *(Leucena leucocephala*) leaves are the major sources of fodder for milking buffaloes and cows during the wiry period (**Table 8**).

Table 8: Seasonal Availability of Fodder

Season	Fodder	Livestock
Rainy season	Green grass	Buffaloes, cow and goats
Dry season	Grazing / agricultural offshoots	Oxen, cow and goats
Lean period	Foliage of fodder tree	Milking buffalo and cow

4.7 Species diversity

In the study area, total 74 tree species were found. Fruit species were in highest number and fodder tree were in highest number of individuals. Fodder tree species were most dense. Live fence species were in lowest number and density (**Table 9**).

Table 9: Tree diversity in sampling sites

Types	Number of species	Total individuals	Tree/ha
Fodder tree	15	394	98.5
Fruit tree	19	161	40.25
Timber tree	18	282	70.5
Live fences	2	17	4.25
Medicine	8	49	12.25
Others (agriculture need)	12	100	25
Total	74	1003	250.75

Based on land use, the density fodder trees were highest and lowest tree density found in fence. Woodlot had highest tree density (280.36 tree/ha) (**Table 10**).

Table 10: Tree diversity in different land use types

Land use type		**Fodder**	**Fruit**	**Timber**	**fence**	**Medicine**	**Others**	**Total**
Bari	number of species	16	16	15	2	4	10	63
	Number of individuals	87	43	65	4	10	32	241
	density (tree/ha)	75	37.07	56.03	3.45	8.62	27.59	207.7
Khet	number of species	14	12	14	2	7	7	56
	the total of each species	64	24	49	2	10	12	161
	density (tree/ha)	106.6	40	81.67	3.33	16.67	20	268.3
Kharbari	number of species	14	12	14	2	7	7	56
	the total of each species	64	24	49	2	10	12	161
	density (tree/ha)	106.6	40	81.67	3.33	16.67	20	268.3
Woodlot	number of species	13	11	6	1	5	7	43
	a total of each species	76	24	32	3	10	12	157
	density (tree/ha)	135.7	42.86	57.14	5.36	17.86	21.43	280.3

4.8 Shannon index of total species of the Study site

S-W index (H**) =** 3.87, Hmax = 0.9003, the result showed that species richness and evenness were very high in the study area. (= 3.67). Based on landuse there were high species richness and evenness of tree in *Khet* land (3.82) followed by *Bari* land, *Kharbari* land and woodlot respectively (**Figure 7**). Based on ethnic groups the Magar community had highest number of tree species and Derai community had least number of tree species.

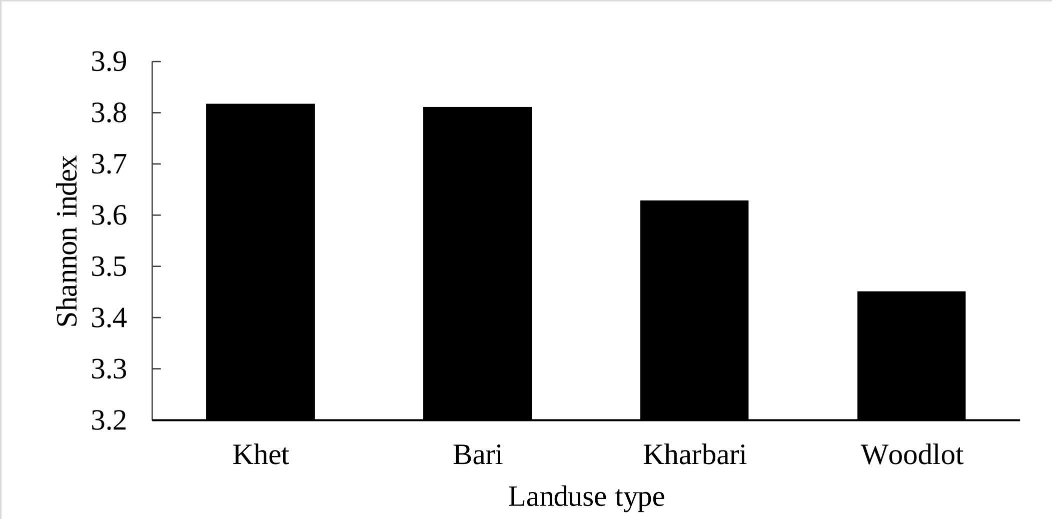


Figure 7: Shannon index based on land use type

There were highest number of trees (188) in DBH class 20-29 in *Bari* land. The trees with DBH greater than 40 were in least number in all types of AF land (**figure 8**).

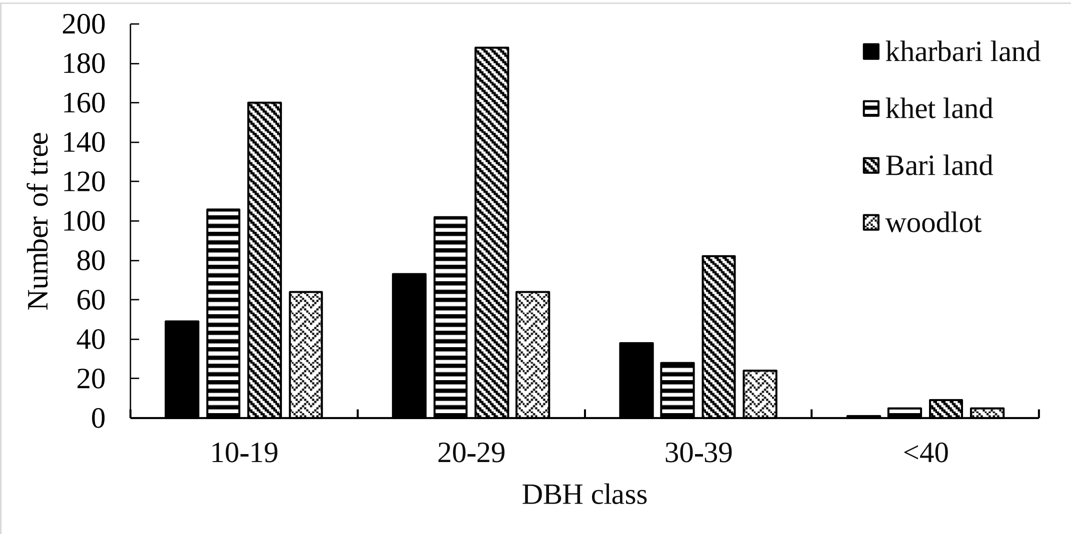


Figure 8: DBH class of tree species on each landuse type

Since p-value is more then given significance level 0.05 for this problem, There is no difference between the mean species number for at least two of the five ethnic groups.

Table 11: One Way Analysis of Variance of species number of ethnic groups

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	23.046	4	5.762	.840	.503
Within Groups	651.704	95	6.860		
Total	674.750	99			

Since p-value is less, then given significance level 0.05 for this problem.There is a difference between the mean species number for at least two of the four-landuse types

Table 12: One Way Analysis of Variance of species number of landuse.

	Sum of Squares	df	Mean Square	F	sig.
Between groups	113.003	3	37.668	6.437	0.001
Within groups	561.747	96	5.852		
Total	674.750	99			

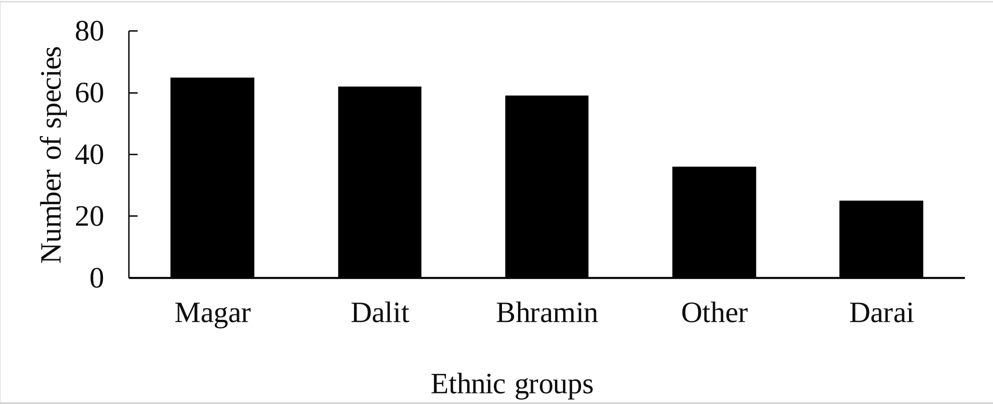


Figure 9: Species number based on ethnic groups.

Shannon index of diversity according to the species listed in the different ethnic communities was found to be high in Dalit community (3.79) followed by Bhramin, Magar, others (Newar, gharti kumal) and Darai (**Figure 10**).

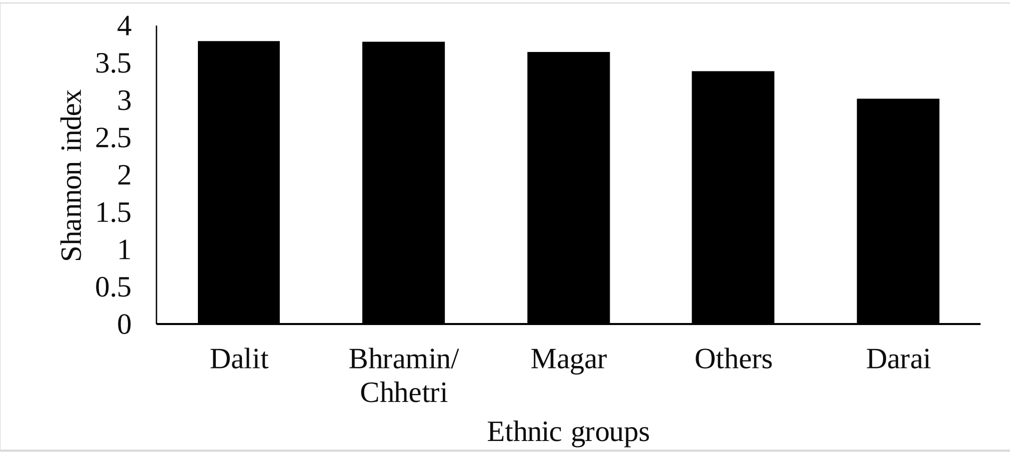


Figure 10: Shannon index of diversity based on ethnicity on the study site.

4.9 The dominance of trees species in study site

Ecological dominancy of tree species in study site are *Garuga pinnata* (IVI =14.65) followed by *Lagerstroemia parviflora, Schima wallichii, Ficus semicordata, Ficus lacor, Ficus racemose, Leucena leucocephala, Ficus hispida, Litsea polyantha,* and *Mangifera indica*. (**Table13**). Among top ten dominat species, seven of them had fodder value and one was fruit tree and remaining two were timber value (**Table 13**).

Table 13: Dominance of trees species in study site

Local name	Scientific name	Rf	Rd	Rdo	IVI
Ramsing	*Garuga pinnata*	5.75	7.48	102.97	14.65
Bot dhayero	*lagerstroemia parviflora*	5.88	6.58	110.23	13.99
Chilaune	*Schima wallichii*	4.51	5.78	115.50	11.89
Khaniya	*Ficus semicordata*	4.92	5.68	86.79	11.81
Kavro	*Ficus lacor*	3.83	4.29	208.06	10.99
Dumri	*Ficus racemose*	4.24	4.19	148.95	10.49
Ipilipil	*Leucena leucocephala*	3.15	3.19	54.47	7.09
Thotne	*Ficus hispida*	2.87	2.99	54.08	6.61
Kutmero	*Litsea polyantha*	2.46	2.39	125.12	6.58
Mango	*Mangifera indica*	2.33	2.29	132.26	6.45

Note: Rf- Relative frequency, Rd-Relative density, Rdo- Relative Dominance, IVI- Importance Value Index.

4.9.1 The dominance of trees species below 500 m altitude

The ecological dominance of tree species in the study site below 500 m altitude *is Lagerstroemia parviflora* (13.45) followed by *Garuga pinnata, Schima wallichii, Ficus lacor, Ficus semicordata, Ficus racemose, Leucena leucocephala, Mangifera indica, Ficus hispida,* and *Melia azedarach*. (**Table 14**). In lower altitude, six species had fodder value, three species had timber value and remaining one was fruit tree.

Table 14: Dominance of trees species below 500 m altitude

Local Name	Scientific name	RF	RD	Rdo	IVI
Botdhayero	*lagerstroemia parviflora*	5.35	6.43	1.67	13.45
Ramsing	*Garuga pinnata*	5.60	6.43	1.40	13.43

Chilaune	*Schima wallichii*	4.87	5.70	1.69	12.26
Kavro	*Ficus lacor*	3.65	3.86	3.63	11.14
Khaniya	*Ficus semicordata*	4.62	5.33	1.10	11.06
Dumri	*Ficus racemose*	3.65	3.68	2.00	9.32
Ipilipil	*Leucena leucocephala*	3.65	4.23	0.81	8.69
Mango	*Mangifera indica*	2.92	2.76	1.89	7.57
Thotne	*Ficus hispida*	2.92	3.13	0.79	6.83
Bakaino	*Melia azedarach*	2.43	2.94	1.35	6.73

4.9.2 Dominance of trees species above 500m altitude

Table 15: Dominance of trees species above 500m altitude

Local Name	Scientific name	RF	RD	Rdo	IVI
Ramsing	*Garuga pinnata*	5.99	8.85	1.53	16.37
Botdhayero	*Lagerstroemia parviflora*	6.31	6.86	1.49	14.66
Khaniya	*Ficus semicordata*	5.68	6.19	1.39	13.26
Dumri	*Ficus racemose*	5.05	4.87	2.24	12.15
Chilaune	*Schima wallichii*	4.10	5.97	1.62	11.70
Kavro	*Ficus lacor*	4.10	4.87	2.43	11.40
Khayar	*Acacia catechu*	3.79	3.76	1.45	9.00
Kutmero	*Litsea polyantha*	3.15	3.10	1.63	7.88
Thotne	*Ficus hispida*	2.84	2.88	0.77	6.49
Saaj	*Terminalia alata*	1.89	1.99	2.07	5.96

Ecological dominancy of tree species in study site above 500 m altitude are *Garuga pinnata (16.37) followed by Lagerstroemia parviflora, Ficus semicordata, Ficus racemose,Schima wallichii, Ficus lacor, Acacia catechu, Litsea polyantha, Ficus hispida*, and *Terminalia alata.* (**Table15**). In higher altitude, six species had fodder value and four species had timber value.

4.9.3 Dominance of trees species in Bari land

Ecological dominancy of tree species in Bari land are *Lagerstroemia parviflora (IVI =16.44) followed by Garuga pinnata, Ficus semicordata ,Schima wallichii, Ficus racemose, Ficus lacor, Ficus hispida,Litsea polyantha, Acacia catechu* , and

Ficus rumphii. (**Table 16**). In the landuse, six species were fodder tree and remaining four were timber tree.

Table 16: Dominance of trees species in *Bari* land

Local name	Scientific name	Rf	Rd	Rdo	IVI
Botdhayero	*Lagerstroemia parviflora*	6.44	8.20	1.80	16.44
Ramsing	*Garuga pinnata*	5.76	8.20	1.68	15.64
Khaniya	*Ficus semicordata*	5.08	5.92	1.43	12.44
Chilaune	*Schima wallichii*	3.73	4.78	1.72	10.23
Dumri	*Ficus racemose*	3.73	3.42	2.76	9.91
Kavro	*Ficus lacor*	3.39	3.64	2.46	9.49
Thotne	*Ficus hispida*	3.39	3.42	0.86	7.67
Kutmero	*Litsea polyantha*	3.05	2.51	2.09	7.65
Khayar	*Acacia catechu*	2.37	2.96	1.58	6.91
Swami	*Ficus rumphii*	0.34	0.23	6.03	6.60

Note: Rf- Relative frequency, Rd-Relative density, Rdo- Relative Dominance, IVI- Importance Value Index

4.9.4 Dominance of trees species in *Khet* land

Ecological dominancy of tree species Khet land are *Schima wallichii (IVI=15.08),* followed by *Garuga pinnata, lagerstroemia parviflora, Ficus lacor, Leucena leucocephala, Mangifera indica, Ficus semicordata Ficus hispida,Dalbergia sissoo,* and *Shorea robusta* (**table 17**). In this land type, five species were fodder tree, four were timber tree and remaining one was fruit tree.

Table 17: Dominance of trees species in *Khe*t land

Local name	Scientific name	Rf	Rd	Rdo	IVI
Chilaune	*Schima wallichii*	6.03	7.05	2.00	15.08
Ramsing	*Garuga pinnata*	6.53	6.64	1.11	14.29
Botdhayero	*Lagerstroemia parviflora*	5.03	5.39	1.60	12.02
Kavro	*Ficus lacor*	3.02	2.90	5.08	11.00
Ipilipil	*Leucena leucocephala*	4.52	4.98	0.85	10.36
Mango	*Mangifera indica*	3.02	3.73	1.79	8.54
Khaniya	*Ficus semicordata*	3.52	3.32	1.49	8.32
Thotne	*Ficus hispida*	3.02	3.73	0.89	7.64

Sisoo	*Dalbergia sissoo*	2.01	2.49	3.02	7.52
Sal	*Shorea robusta*	2.01	1.66	3.59	7.26

4.9.5 Dominance of trees species in woodlot

Ecological dominancy of tree species woodlot *are Ficus racemose (IVI=16.36),* followed by *Ficus semicordata, Ficus lacor, lagerstroemia parviflora, Garuga pinnata, Schima wallichii, Atrocarpus heterophyllus, Ficus religiosa, Ficus rumphii* and *Litsea polyantha*. (**Table 18**). In this land type, five species were fodder tree, four were timber tree and remaining one was fruit tree.

Table 18: Dominance of trees species in woodlot

Local name	Scientific name	Rf	Rd	Rdo	IVI
Dumri	*Ficus racemose*	7.62	2.72	2.37	16.36
Khaniya	*Ficus semicordata*	6.67	2.38	1.33	16.28
Kavro	*Ficus lacor*	4.76	1.70	5.06	16.19
Botdhayero	*Lagerstroemia parviflora*	6.67	2.38	1.70	14.74
Ramsing	*Garuga pinnata*	4.76	1.70	2.64	14.40
Chilaune	*Schima wallichii*	3.81	1.36	2.32	11.23
Katahar	*Atrocarpus heterophyllus*	3.81	1.36	3.88	10.87
Pipal	*Ficus religiosa*	0.95	0.34	8.61	10.20
Swami	*Ficus rumphii*	0.95	0.34	8.61	10.20
Kutmero	*Litsea polyantha*	3.81	1.36	2.38	10.01

Note: Rf- Relative frequency, Rd-Relative density, Rdo- Relative Dominance, IVI-Importance Value Index.

4.9.6 Dominance of trees species in *kharbari* land

Ecological dominancy of tree species in kharbari are *Ficus racemose* (IVI=18.93) followed *by Garuga pinnata, Ficus lacor, Schima wallichii, Ficus semicordata, lagerstroemia parviflora, Shorea robusta, Melia azedarach, Acacia catechu,* and *Terminalia alata* (**Table 19**). In this landuse, four species were fodder tree, and remaining six were timber tree.

Table 19: Dominance of trees species in kharbari

Local name	Scientific name	Rf	Rd	Rdo	IVI
Dumri	*Ficus racemose*	7.32	8.70	2.91	18.93
Ramsing	*Garuga pinnata*	5.69	7.45	1.74	14.88
Kavro	*Ficus lacor*	4.88	6.21	3.18	14.27
Chilaune	*Schima wallichii*	4.88	7.45	1.80	14.13
Khaniya	*Ficus semicordata*	5.69	6.21	1.55	13.45
Botdhayero	*lagerstroemia parviflora*	4.07	4.35	1.93	10.35
Sal	*Shorea robusta*	2.44	3.11	3.18	8.72
Bakaino	*Melia azedarach*	3.25	2.48	2.46	8.20
Khayar	*Acacia catechu*	2.44	3.73	1.98	8.14
Saaj	*Terminalia alata*	1.63	1.24	4.14	7.01

Note: Rf- Relative frequency, Rd-Relative density, Rdo- Relative Dominance, IVI- Importance Value Index

4.10 Multivariate analysis

Table 20: DCA summary **(**total inertia **=** 9**.**985, sum of all canonical eigenvalues **=** 1**.**64**)**

Axes		1	2	3	4	Total inertia
Eigenvalues	:	0.581	0.397	0.354	0.311	9.985
Lengths of gradient	:	5.759	6.149	4.577	4.657	
Cumulative percentage variance						
of species data	:	5.8	9.8	13.4	16.5	

Table 21: Summary of CCA **(**sum of all eigenvalue**=**9**.**985, sum of all canonical eigenvalue**=**0**.**358**)**

Axes		1	2	3	4
Eigenvalues	:	0.119	0.091	0.082	0.066
Species-environment correlations	:	0.67	0.619	0.607	0.554
Cumulative percentage variance					
of species data:		1.2	2.1	2.9	3.6
of species-environment relation:		33.2	58.7	81.4	100

Species like *Ficus hispida* (ficu_his), *zizyphus mauritiana* (Zizy_mau), *Mangifera indica* (Mang_ind), *Shorea robusta* (Shor_rob), *Ficus semicordata* (ficu_sem), *Ficus* *lacor* (Ficu_lac), *Litsea polyantha* (Lits_pol) and *Terminali belirica* (term_bel) were evenly distributed along all the gradients (Species like *Aesandra butyracea* (Aesa_but), *Trewia nudiflora* (trew_nud), and *Leucena leucocephala* (leuc_leu) tend to be in *khet* land use type, while *Gmelina arborea* (Gmel_arb), *Azadirachta indica* (Azad_ind), *Terminellia chebula* (term_che) *Premna integrifolia* (Prem_int), etc. were tended to be distributed along woodlot (**Figure 11**).

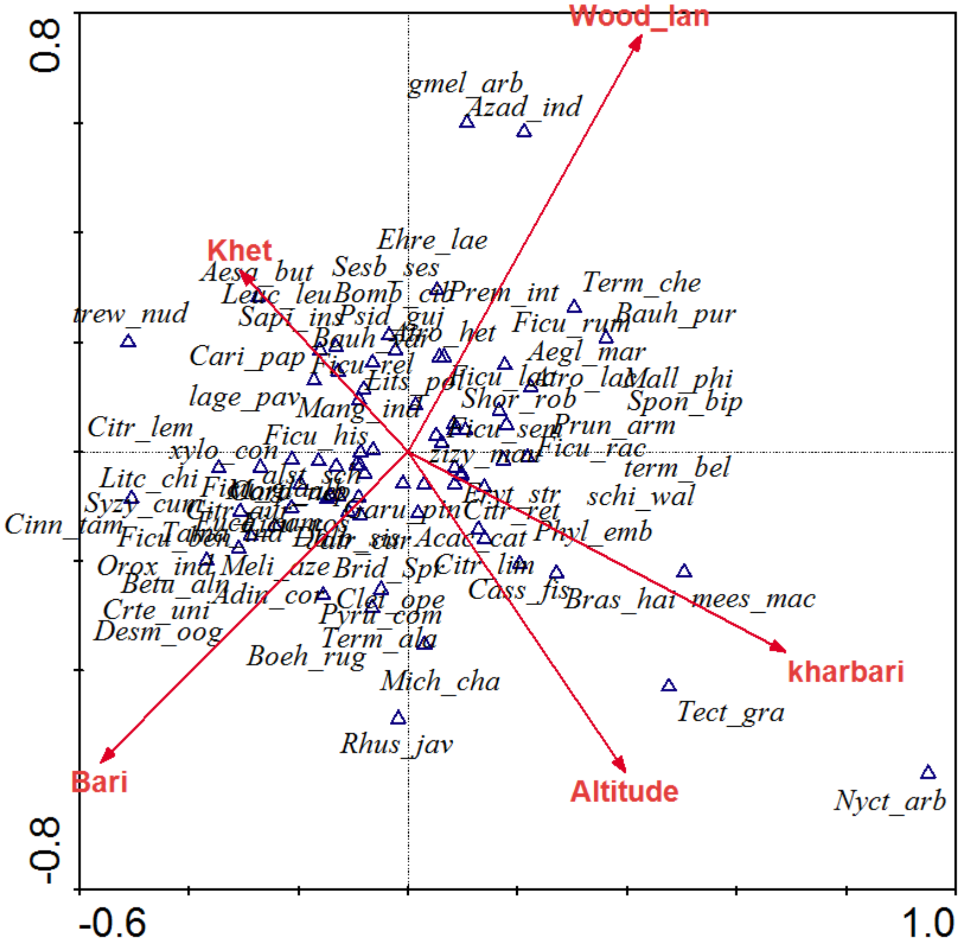


Figure 11: CCA ordination diagram showing the relationship between plant species with altitude and land use types where ∆ represents tree species and □ represents altitude and land use types.

The results shows that species like *Meesa macrophylla* (Mees_mac), *Brassiopsis hainla* (bras_hai), *Nyctanthes arbortritis* (Nyct_arb) were cultivated in *kharbari* land Few species were explain by bari land use type that was *Boehmeria rugulosa* (Boeh_rug) and *Desmodium oogenesis* (desm_oog), *Tectona grandis* (Tect_gra) and *Rhus javanica*

(Rhus_jav) shows strong relation with high elevation site while *Aesandra butyracea* (Aesa_but), *Trewia nudiflora* (Trew_nud), and *Leucena leucocephala* (Leuc_leu) showed strong relation with lower elevation site (**Figure 11**).

4.11 Numbers of Species with their respective families

In the research site 74 species of 37 families, twenty-five families had one species each; four families had two species each; two families had three species each; two families had four species each, two families have four species each; three families had five species each, and 1 family had twelve species. Moraceae family has a large number (12) of species and Euphorbiaceae, Fabaceae and Rutaceae had five number of species each. Similarly, Leguminosae and Myrtaceae had four species each (**Figure 12**).

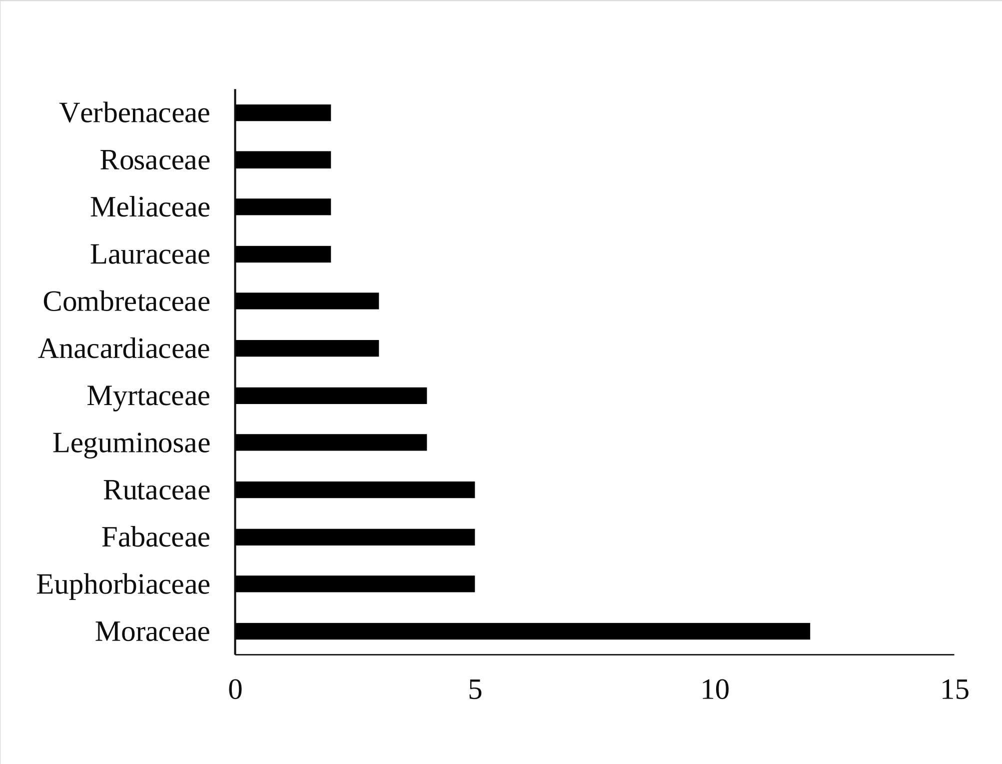


Figure 12: number of species in each families

4.12 Contribution of Agro forestry for rural needs fulfillment.

The sample HHs mainly consumed food/cash crops, firewood, fodder/grass, fruits and medicine from their AF. Some HHs did not consume AF products, so minimum consumption was null for many of the products. Mainly they utilized firewood, fodder/grass in large amount than other products (**Table 22**)

Table 22: Measure of annunal consumption of AF products (Kg) (mean ± SD)

	Kharbari(N=15)	*Khet* (N=15)	*Bari* (N=15)	Woodlot(N=15)	*Chi-Square*	*P*
Food/ Cashcrop	2066.0±1041.81	1284.14±924.37	1349.05±1471.916	2597.14±1493.223	16.71	0.001
Fruit	55.67±52.96	59.59±53.87	28.67±40.74	97.36±79.76	16.91	0.001
Firewood	2010.67±1427.02	1853.10±1020.2	2099.52±2261.48	2858.57±1860.01	5.064	0.167
Fodder	22712.00±43744.43	7885.17±5006.53	8021.43±7443.15	11252.14±5279.87	11.82	0.008
Medicine	9.27±7.71	5.90±4.79	6.38±5.18	8.14±6.07	3.07	0.38

Value based on Kruskal Wallis test having degree of freedom 3.

The sample HHs had income through AF products like food and cash crops, fruits, poles and timber, firewood and fodder. Food and cash crops, poles and timber and fruits were the main sources of income from AF products (**Table 23**).

Table 23: Measure of annual income of AF activities different AF products (mean ±SD). Annual Income (NRs.)

	Dalit	Magar	Bhrimin/Chhetri	Other	Chi-Square	P
Food/Cash Crop	9406.89±8235.02	28378.37±72483.08	28750.0±64457.14	12642.85±8445.36	9.397	0.02
Fruits	524.13±1085.17	621.621±1204.19	575.00±1138.73	700.00±1031.80	1.307	0.73
Poles/Timber	637.93±943.93	937.83±1322.31	1375.00±1074.52	971.42±988.72	6.165	0.10
Fuelwood	431.03±883.62	802.70±1921.01	450.00±985.42	142.85±534.52	2.386	0.49
Fodder	196.55±543.45	689.18±2267.98	335.00±678.44	1071.42±1979.28	1.904	0.59
Food/Cash Crop	155.17±445.28	232.43±555.30	597.50±1121.38	192.85±389.20	5.286	0.15

Value based on Kruskal Wallis test having degree of freedom 3.

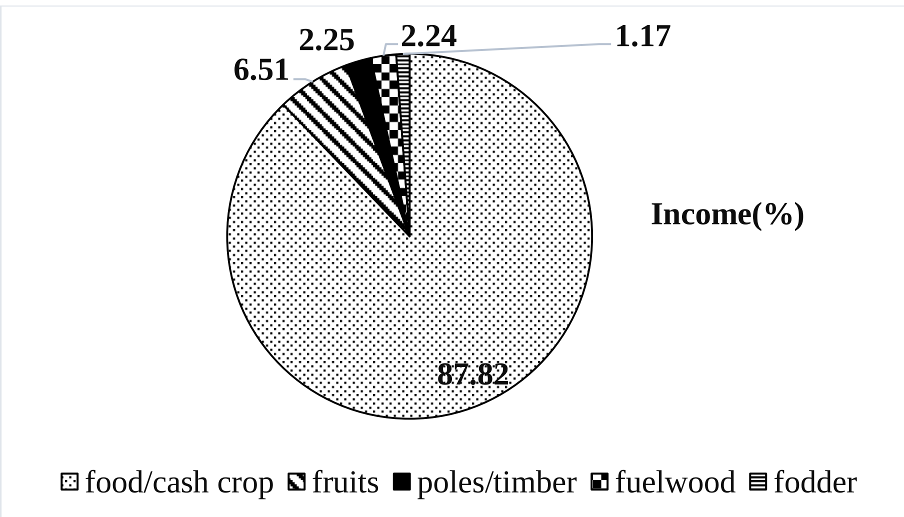


Figure 13: Income of respondent from different AF products

The cash crops products like ginger (*Zingiber officinale*), beans, *Amriso* (*Thysanolaena latifolia*), turmeric (*Curcuma longa*) yam (*Dioscorea sp.*) and colocassia fruit (*Colocasia sp.*) were sold to the local and urban market. These crops were cultivated in *Bari* land. These crops hold 87.82 percent of total income from AF (**figure 13**).

4.13 Major uses of Species

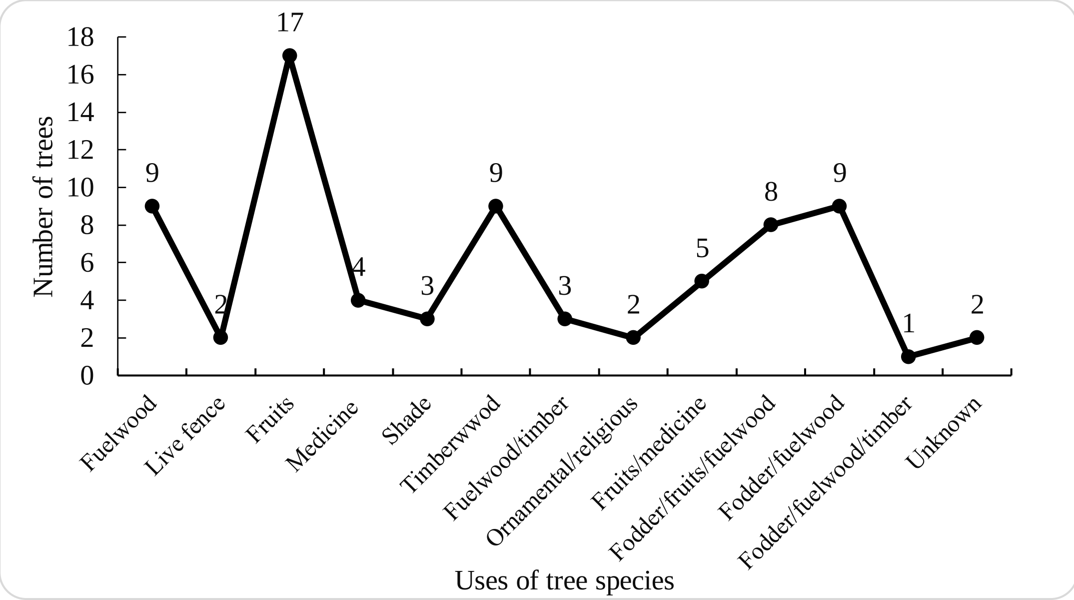


Figure 14: Major uses of species.

The tree species in AF mainly used for fruits (23%), fodder and fuelwood (12.16%), fuelwood (12.16%), timber wood (12.16%) (**Figure 14**). The tree species used as fire wood was mainly *Garuga pinnata (*14.77 %) followed by *Garuga pinnata, lagerstroemia parviflora*, *Schima wallichii*, *Ficus lacor*, *Ficus semicordata*, *Ficus racemose*, *Litsea polyantha*, and *Acacia catechu* (**Table 24**)

Table 24: Species preferred for firewood in the study site.

Local name	Scientific name	Percentage of use
Ramsing	*Garuga pinnata*	14.77
Butdhayero	*Lagerstroemia parviflora*	12.95
Chilaune	*Schima wallichii*	10.62
Kavro	*Ficus lacor*	9.84
Khaniya	*Ficus semicordata*	8.03
Dumri	*Ficus racemose*	6.22

Kutmero	*Litsea polyantha*	3.63
Khayer	*Acacia catechu*	2.85
	Others species	31.09

4. 14 Contribution of AF in carbon sequestration and potential income from carbon rent.

A. Carbon stock on altitude basis

Carbon stock was low below 500m altitude, was 23.64±15.57tons per hectare and above 500m altitude was 30.30±14.21 tons per hectare. In higher elevation, carbon sequestration was high than in lower elevation. (**Table 25**).

Table 25: Carbon stock according to altitude (mean ± SD).

Altitude	**C stock**(**tons/ha**)	**Tree biomass**(**tons/ha**)
Below 500m	23.64±15.57	50.30±33.13
Above 500m	30.30±14.21	64.46±30.25

B. Carbonstock on basis of landuse

Based on land use type carbon stock was higher in woodlot (30.09±18.80 tons/ha) followed by *Kharbari* land (28.72±11.95 tons/ha), *Bari* land (28.36±14.35 tons/ha), and *Khet* land (20.47±15.51 tons/ha). (**Table 26**)

Table 26: Carbon stock according to land use (mean ± SD)**.**

Landuse	**C stock** (**ton/ha**)	**Tree biomass**(**tons/ha**)
kharbari land (N=15)	28.72±11.95	61.10±25.43
khet land (N=29)	20.47±15.51	43.56±33.01
bari land (N=42)	28.36±14.35	60.34±30.53
Woodlot (N=14)	30.09±18.80	64.02±40.01
Total (N= 100)	26.37±15.32	56.10±32.59

Since p-value is more, then given significance level ($P > 0.05$) for this problem.There is no difference between the mean species number for at least two of the four-landuse types

Table 27: One Way Analysis of Variance of Carbon stock of landuse.

			Sum of Squares	df	Mean Square	F	Sig.
Cstock * landuse	Between Groups	(Combined)	1450.481	3	483.494	2.131	.101
	Within Groups		21776.329	96	226.837		
	Total		23226.811	99			

C. Potential income from carbon sequestration / rent

Result Base Finance initiatives consider REDD+ as an incentive and reward to strengthen emerging initiatives and actions to curb deforestation rather than a purely financial mechanism to compensate for opportunity costs. The community and collaborative forest programmes could be used, as a model to scale up finance for REDD+ the price of carbon is USD 5 per ton of carbon stock in Nepal, (Dhungana et. al., 2018). The potential income from carbon sequestration USD 131.85 per hactre in the agroforestry land of villages (**Table 28**).

Table 28: Potential income from carbon sequestration / rent

Landuse	**Mean C stock (ton/ha)**	**Price of C - rent per hactre(USD)**	**Price of C- rent per hactre (NRs.)**
kharbari land (N=15)	28.72	143.6	16729.4
khet land (N=29)	20.47	102.35	11923.8
bari land (N=42)	28.36	141.8	16519.7
Woodlot (N=14)	30.09	150.45	17527.4
All land use (N= 100)	26.37	131.85	15360.5

4.15 Relation between Different Vegetation Variables

Variable showed a statically significant correlation with each other except relation with altitude by mean DBH, number of species and mean height. All variable shows positive correlation with each other. Net carbon stock and mean height show high correlation with all variables. Mean height and species richness show positive correlation at the p= 0.05, 95% confidence level (**Table 29**).

Table 29: Correlation between different vegetation variables based on Pearson Correlations**)** analysis of plot data (n = 100). Values shown are correlation coefficients.

Pearson Correlations(n=100)					
	Altitude	**Individual**	**No._species**	**Mean_DBH**	**Mean_height**
No.of Individual	.315**				
No._species	.131	.809**			
Mean_DBH	.178	.216*	.245*		
Mean_height	.053	.354**	.287**	.386**	
Carbonstock	.236*	.638**	.577**	.742**	.608**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

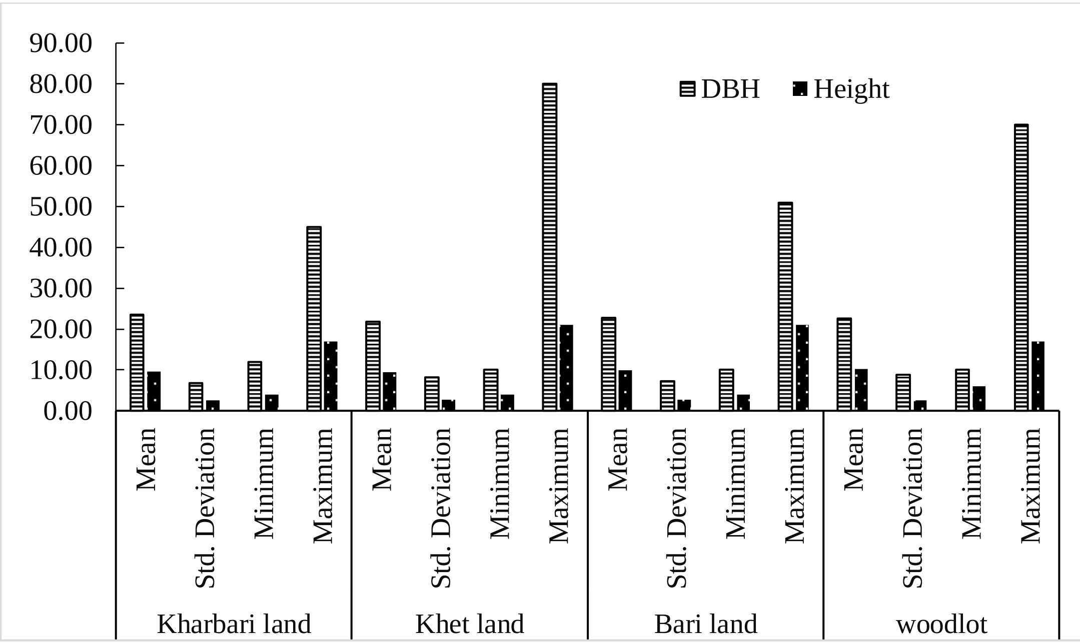


Figure 15: histogram showing DBH and height in different landuse type.

Mean height of tree in woodlot of tree was highest (10.27±2.62) m. In *Khet* land (9.48±2.70) m, *Kharbari* land (9.63±2.56) m and in *Bari* (9.90±2.78) m. Mean DBH of tree in Kharbari land was highest (23.58± 6.82) cm. and in khet land (21.76±8.11) cm, *Bari* land (22.69±7.27) cm and in woodlot (22.54±8.79) cm (**Figure 15**).

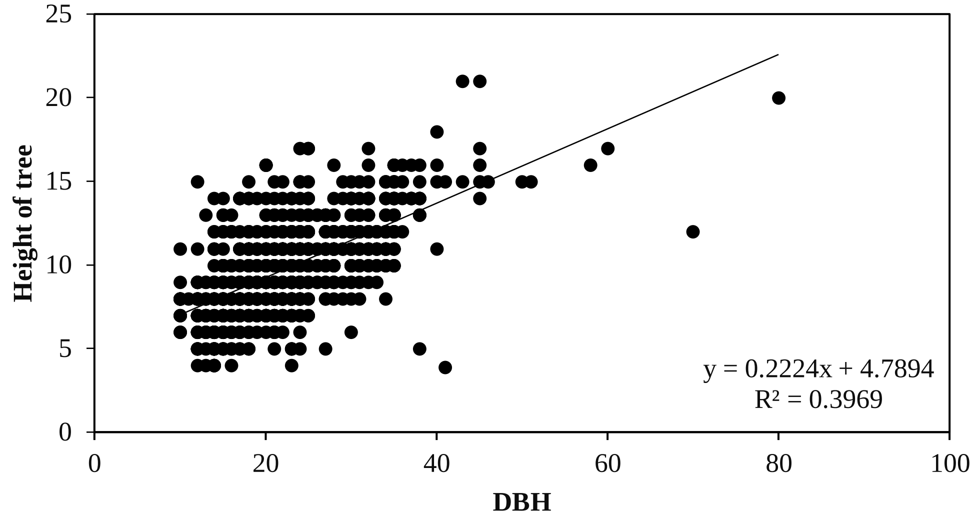
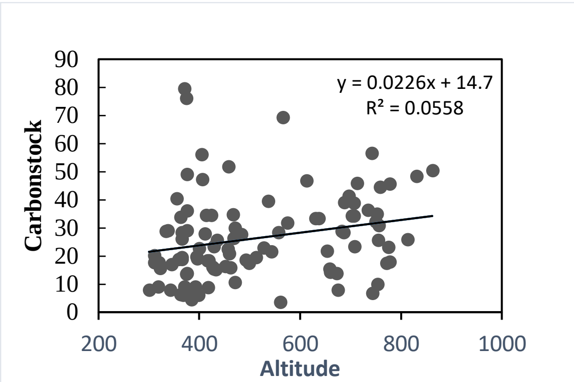
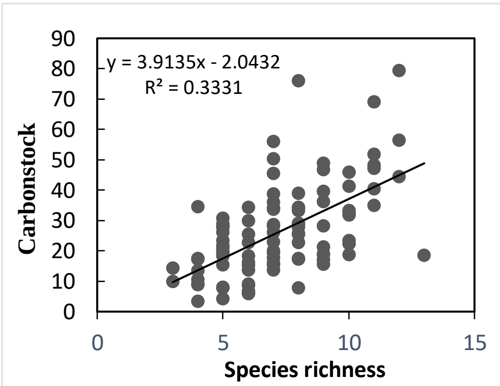


Figure 16: Fitted linear regression line between diameter at breast height (DBH) and height of tree.

The diameter at breast height (DBH) and the height of the plants showed statistically significant positive linear relationship. The number of species individuals in sampling plots and altitude of study area also had positive linear relationship (**figure 16**).





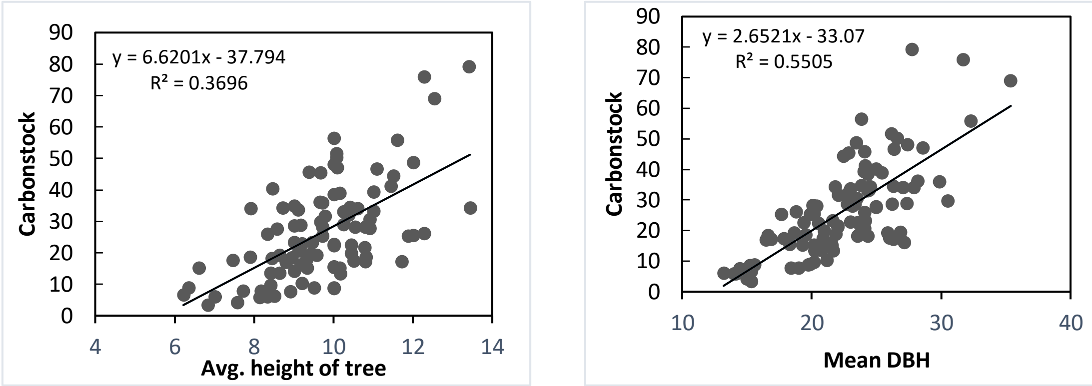


Figure 17: Fitted linear regression line between carbon stock with Altitude, Species richness, Average height of the tree, and mean DBH.

Fitted linear regression line between carbon stock with Altitude, Species richness, Average height of the tree, and mean DBH showed statistically significant positive linear relationship (**figure 17**).

CHAPTER FIVE: DISCUSSION

5.1 Tree species diversity

In this study, we found a total 74 tree species of 37 families. Overall ecological dominance Species of tree species in study site are *Garuga pinnata (*IVI =14.65) followed by *Lagerstroemia parviflora, Schima wallichii, Ficus semicordata, Ficus lacor, Ficus racemose, Leucena leucocephala, Ficus hispida, Litsea polyantha,* and *Mangifera indica.* Among the top ten dominant tree species, most of them are fodder tree and some are timber species. Whereas, other studies Rico-Gray *et. al.,* (1990) reported the predominance of food, fruit as well as medicinal plants in agroforestry ecosystem. Devi and Das (2013) had reported 71 tree species from home garden of India and 45 tree species in home garden of Indonesia (Roshetko *et. al*., 2002). Only 29 tree species in a study of farm trees in the central hills of Nepal(Carter and Gilmour 1989), but in a detailed study, recorded 101 species in the central development region in the hills which is almost similar to this research (Carter 1991). Another study reported 133 plant species during the focus group discussion in two VDCs of Parbat district in the western middle hills of Nepal (Baul *et. al.,* 2013).

This study revealed that there was higher number of species in *Bari* land, *Kharbari* land and *khet* land than woodlot respectively. In cultivated land has high tree diversity than non-cultivated land this may be due to planting of monotonous timber tree in woodlot and planting of different fodder tree, fruit and live fences in cultivable land. The forest type is mixed (both natural and plantation) in all AF land use types. The study carried out in the middle hills of Nepal showed that farmers had on average 65 trees per hectare (Oli *et. al.,* 2015). Trees on farmland contributed on average 43 % of HHs′ firewood and fodder consumption (Oli *et. al*., 2015). Sharma and Vetaas (2015) reported 183 tree species in central mid hill region of Nepal, out of which 139 in farmland and 123 in community forest shows that diversity was higher in human, manage landscape than forest. Baral *et. al.,* (2013) reported 51 species in the home garden system in Kanchanpur district far western Nepal, Khanal (2011) reported 172 farm plant species were found in the Kaski district middle hills region of Nepal, out of which majority 142 were tree species includes which includes fodder, firewood, medicine, fruits, timber and live fences. Das (1998) has found almost similar result in the farmland of eastern Nepal, has recorded more than 60 species.

5.2 Sannon diversity index of species

S-W index (H**) =** 3.87, Hmax = 0.9003**,** the result showed that species richness and evenness were very high in the study area. (= 3.67). Based on land use type there were high species richness and evenness of tree in *Khet* land (3.82) followed by *Bari* land, *Kharbari* land and woodlot respectively (**figure 7**). Another similar study in mid hill of Nepal showed 92 species, The Shannon–Wiener index was 2.46 and trees on farmland contributed on average 43 % of households′ firewood and fodder consumption (Oli *et. al*., 2015)

Shannon index of diversity in this study according to the species listed in the different ethnic communities was found to be high in *Dalit* community (3.79) followed by *Bhramin, Magar*, others (Newar*, Gharti, Kumal*) and *Darai*. The high number of trees and fodder species in *Brahmin⁄Chhetri* is high than *Janajati⁄Dalit* as the number of cattle in their HHs is also high (Pokhrel *et. al*., 2015). Here the result is against; this may be due to their involvement in other profession than agriculture in *Brahmin* and *Chhetri* community. A study showed similar result of diverity in mid hill of Nepal, the Shannon-Wiener species diversity index was 3.26 and the species evenness index 1.89. Large farms (farm area >1 ha) had the greatest tree species diversity (4.47 ± 0.52) and marginal farms the lowest (2.18 ± 0.37), indicating the positive relationship between farm size and species diversity (Baul *et. al*., 2013).

5.3 Ecological dominance of species

The ecological dominance of tree species in the study site below 500 m altitude is Lagerstroemia parviflora (13.45) followed by *Garuga pinnata*, *Schima wallichii*, *Ficus lacor, Ficus semicordata, Ficus racemose, Leucena leucocephala, Mangifera indica, Ficus hispida, and Melia azedarach*. Similarly dominancy of tree species in study site above 500 m altitude are *Garuga pinnata* (16.37) followed by *Lagerstroemia parviflora, Ficussemicordata, Ficus racemose,Schima wallichii, Ficus lacor, Acacia catechu, Litsea polyantha, Ficus hispida, and Terminalia alata.*

Among top ten dominat species, seven of them had fodder value and one was fruit tree and remaining two were timber value. In lower altitude, six species had fodder value, three species had timber value and remaining one was fruit tree. In higher altitude, six species had fodder value and four species had timber value. In *Bari,* land type 6 species were fodder tree and remaining four were timber tree. In khet land, type five species were fodder tree, four were timber tree and remaining one was fruit tree. In woodlot, five species were fodder tree, four were timber tree and remaining one was fruit tree. *Kharbari* land type 4 species were fodder tree, and remaining six were timber tree. Here in this study in each land use type, fodder trees are dominat.On the other hand, Sunwar *et. al.,* (2006) reported vegetable species as the most important component in Nepalese home gardens followed by fruit, fodder and spices. Home garden of Assam were also characterized by a high density of the fruit plants, whereas, predominance of ornamental plants was recorded in home garden of Arunachal Pradesh (Zimik *et. al.,* 2012). This may be due to the difference in the tradition, culture and food habit of the inhabiting community. In the research tree species were mainly identified, vegeatables and other herbal plants were excluded. Otherwise this study agree with sunwar *et. al.,* (2006). AF includes the attentive integration of trees with farms and landscapes and this have direct and indirect effects on farm and landscape biodiversity. There are trade-offs between the social, economic, ecological and biodiversity diversity benefits of AF associated to other land use systems AF can improve connectivity and landscape heterogeneity in multi-functional conservation landscapes. Zomer *et. al.,* (2001) found that an AF system comprising *Alnus nepalensis* and cardamom donated to the integrity of riparian strips for wildlife conservation around the Makalu Barun National Park and Conservation Area of eastern Nepal. Firstly, the quantification of trade-offs has been at the heart of the research agenda of the Alternatives to Slash and Burn (ASB) Programme harmonized by ICRAF (Tomich *et. al.,* 2001).

5.2 AF and livelihood

AF delivers all types of forest products for meeting needs of HHs. Rural farmers depend on the farm trees for fodder, timber, litter, animal bed, fruit and medicine. Regmi (2003) reported in Dhading district out of 32 species 37.5% comprised fruit, 15.5% comprised fuel and 47% comprised fodder trees. Involvement of farm trees as timber is very small as compared to nearby forest, but small pole and agricultural tools are supplied from the farm trees. The suitable climatic conditions, combined with the availability of marginal land, offer an opportunity for growing all kinds of AF species in the hills and mountains. Subsistence agriculture with a strong link to forestry is the main basis of livelihoods in Chitwan district (Acharya, 2006). This study showed that 75% of the HHs were involved in agriculture as the main source of livelihood followed by foreign employment, and local employment. Rice, corn, wheat, beans and millet are the basic crop of the village. In addition, large number of HHs depend directly on natural resources for food, fodder, fuelwood, and medicines. Baral *et. al.,* (2013) reported that farmland trees contribute 16.4% NRs. 3,689 per HHs/year in Kanchanpur district far-west terai region of Nepal. In this study, most of the farmers used firewood for cooking food and livestock concentrate feed (*kudo*) for energy. Out of all the respondents, 36% of them used only fuelwood as an energy source. 18% of them used LP gas and firewood while 14% of them used Kerosene and fuelwood. 12% of them used Biogas and fuelwood, eight of HHs used LP gas, biogas, and fuelwood, 7% of them used biogas and kerosene and fuelwood. Three of them used LP gas, kerosene, and fuelwood and at last, two of them used LP gas, biogas and kerosene as a source of energy (**Table 3**). Farm trees supplied more than half of the total annual firewood consumption; remaining firewood is collected from nearby community forests. Only collection of dry wood was allowed in the community forests. Therefore, there is no alternative to dependency on farm trees for firewood supply in the near future. *Garuga pinnata, Lagerstroemia parviflora, Schima wallichii, Ficus lacor, Ficus semicordata, Ficus racemose, and Litsea polyantha* are the major tree species prefered by respondents to use as fuelwood (**Table 24**).The entire sample HHs were dependent on agriculture for their family income. The major agriculture land types are *Khet Bari* and *Kharbari*. *Khet* land was systematically terraced in hillslope and nearby river streams where embankments are designed on the edge of each race to hold irrigated water. In *Khet* mainly rice (*Oryza sativa*), wheat (*Triticum aestivum*) and peas (*Pisum sativum*) were grown. In *khet* land irrigation facilities was setup all-round the year. *Bari* land was rain fed terraces where maize (*Zea maize*) or millet (*Elusine coracana*) are grown. In *Bari* land, many varieties of vegetables and fruits are grown for both domestic and commercial purposes. *Bari* land in the high altitude of the study area (above 500m) was utilized for commercial cultivation of mainly ginger (*Zingiber officinale*) followed by turmeric (*Curcuma longa*) yam (*Dioscorea sp*.) and colocasia fruit (*Colocasia sp*.). We witnessed that most AF species were naturally growing on the edges and farm margins along with upland crops, and on the walls of gullies and barren lands called *Kharbari* where some kinds of thatch grasses are naturally grown.

Table 22 shows that total sample HHs are consumed different forest product like firewood, fodder, fruits, grass and medicine. Maximum annual consumption of firewood sample HHs was 8600 Kg and minimum consumption was 290 kg. Maximum consumption of fodder and grass was 180000 Kg. likewise fruits 333 Kg., food and cash 8600 Kg. and medicine 27 Kg. Fodder and grass was consumed maximum no. of Kg. than other forest product because more livestock and heavy production and cultivation of exotic and native grasses have fulfilled the demand of forage of livestock. Fodder was also identified as one of the products obtained from the AF trees. Tree fodders are the major source of livestock feeds in the study area. Some of the multi-purpose tree species that provide fodder in the study area include*: Leucaena leucocephala*, *Garuga pinnata, Ficus lacor, Ficus semicordata* and *Litsea polyantha*. The trees were grown in fodder banks and these helps to provide feeds to livestock during dry season when most pastures have dried up. The quality of fodder from these trees is high (Hove *et. al*., 2003) and tree-fodder skill reduces cost of feed for livestock (Akinnifesi *et. al*., 2008). **Table 23** and **figure 13** shows that contribution of annual income from different AF activities with respect to HHs. 87.82% of income was From food and cash crop likewise 6.51% from fruits., 2.25% from poles and timber., 2.24 % from fuelwood and 1.17 % from fodder and grass. From food and cash crop maximum annual income was Rs. 4, 50,000, similarly from fruits Rs 8,000, poles and timber 10,000., fuelwood., 12,000., fodder 4800. The sale products from AF trees have a significant role in improving financial status of the HHs. This agrees to the study by Kalaba *et. al.,* 2010, who reported that income from AF products can serve a safety net for the rural HHs and can be noteworthy source of prosperity if intensively produced and achieved. The average national per capita annual income of Nepal is NRs 51,879, average per capita annual income of Nawalparasi district is 1157 $ (GON, 2011).

Livestock and livestock products have indispensable roles in generating cash, nutrition and maintaining the productivity of the farmland. The number of tress and diversity of species on farmland depends up on socio economic factors like land holding, livestock population, and land fragmentation (Acharya, 2006). Respondents in this study, 24% of them had small size LSU, 59% medium size, 16 % large size (**Table 4**). Livestock rearing is one major agricultural activity in Nepal. It donates for 11% to GDP (FAO, 2005). The major livestock of the study area were buffalo, cow, oxen and goats. Buffalo and cow were used for milk production, ox for ploughing of the land, and goat for their meat. Stall-feeding mainly contain rice straw, seasonal fodder from farmland and *kudo, dana* and other additive product from the market. The main reason for this was the lack of grazing land. The HHs having goats practiced both stall-feeding and grazing. Animals were mainly grazed on plantation sites, on riverbanks, and along roadsides. In the past, local people collected products from the natural forest areas, but after a policy change in forestry (community forest), the local people have had narrow legal access to their natural forest and hence, the numbers of trees on farmland have been increasing (Adhikari *et. al*., 2007). The cumulative demand for forage in the Mid-hill of Nepal can be addressed through the promotion of AF (Thapa *et. al*., 2000). In the Mid-hills of Nepal, livestock population has positive correlation with the number of AF species and number of trees (Acharya, 2006).The AF practice is a contributing factor for reducing impact on the natural forest and maintaining agrobiodiversity.

The result also showed that plants have food value (fruits) gained much preference. Similarly, the trees providing fodder, firewood, timber, ornamental, and boundary plants were in more number. Medicinal and traditional plants with the religious values were in study sites.

5.3 Agroforestry and Aboveground Carbon Stock

A. Diameter at breast height (DBH)

The mean DBH of the tree was higher in *Kharbari* land than in other land AF land type. The number of plants with DBH 20-29 cm was more than in Bari land. In addition, the plants with higher DBH were almost similar in all other AF landuse types. The study done in western hill region stated the DBH of trees with the mean 10.86 cm (Poudel *et. al.,* 2011) which is almost two times less than the finding from *kharbari* land of our study. In addition, another study from Dhading reported the mean DBH range from 7-10 cm (Magar, 2012).

B. Tree height

In this study, the average height of trees was found to be higher in woodlot than in other AF land types. The study conducted in Dhading reported the height of the tree to be 6.0-9.1m (Magar, 2012). In addition, another study conducted in western hill region reported the mean height of the tree to be 9.74m (Poudel *et. al.,* 2011).

C. Above ground carbon stock

The amount of carbon sequestration in a forest stand depends on its age and productivity (Alexandrov, 2007). Enhancement of forest carbon stocks through AF considered as one of the main options for reducing greenhouse gases in atmosphere (Nair *et. al.,* 2012). AF practice have indirect effects on carbon seizure because they reduce harvesting burden on natural forests as because trees are the largest source of sinks for terrestrial carbon. The above ground biomass substantially determines an ecosystem's potential for carbon storage, which plays an important role in the regulation of atmospheric CO2 and global climate change (Bunker *et. al.,* 2005).

The present study showed 23.64±15.57 tons/ha below the 500 m altitude and 30.30±14.21 tons/ha above the 500 m altitude. This difference may be due to more dense trees in high altitude. The density of house in high altitude is less and non-irrigated land like *Bari* land, *Kharbari* land and woodlot are at sloppy hills. The study conducted in Prok village of Manaslu Conservation Area stated the carbon in tree biomass as 74.6 t C/ha in northern aspect and 15.02 t C/ha in southern aspect (Sigdel, 2013). The C stock of this study less than northen aspect and almost two times greater than southern aspect.There is solid variation in the carbon sequestration potential among different plant species, regions and management. Distinctions in environmental situations can affect carbon sequestration potential even within a comparatively small geographic area. Management practices like fertilization can also easily increase carbon sequestration of species such as eucalypts (Koskela *et. al*., 2000). Based on land use type carbon stock was higher in woodlot (30.09±18.80 tons/ha) followed by Kharbari land (28.72±11.95 tons/ha), Bari land (28.36±14.35 tons/ha), and Khet land (20.47±15.51 tons/ha) (**Table 26**) In khet land there were more sparse trees to prevent paddy field from shading but in woodlot dense wood were planted and continuous loping was less. Fodder tree species of ficus small size were planted in Khet land, which have less species gravity of wood than poles and timber trees. It is estimated that a total of 48.60 ton C per hectare has been stocked in AF sites in the middle hills region (Pandit *et. al*., 2013). The amount of carbon sequestration in a forest stand depends on its age and productivity (Alexandrov, 2007).

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1. Conclusion

The study has discovered that AF trees subsidize several products like fuelwood, fruits, medicine, fodder and services such as soil upgrading and biodiversity conservation. The influence of AF acceptance on enhancement of community livelihoods were increased income by sales of the products, increased crop yield and improved health and nutrition. It can play extensive role in reducing atmospheric concentration of CO_2 by storing carbon in above and belowground biomass and growing biomass for biopower and biofuels and thereby replacing fossil fuel. Hence, this study recommends a strong need to strengthen promotion of AF and promotion to policy makers. Conserving biodiversity in approaches to organization of AF systems, along with an accurate view on natural resource management. It will provide the widest range of options for adapting to changing economic, social, and climatic conditions. The impact of agroforestry adoption on improvement of community livelihoods were increased income through sales of the products, increased crop yield and improved health and nutrition. Therefore, agroforestry is significant in improvement of rural community livelihoods. Hence, the present study recommends a strong need to intensify promotion of agroforestry and advocacy to policy makers. Lastly, we need clear government policy frameworks to support connotations among the many interest groups involved in AF research and development. AF is not a separate approach to conservation. Relatively, it needs to be seen as an element of conservation approaches, which also include policy and institutional changes, and spatial arrangements that highlight upkeep of natural habitations.

In addition, farm based AF both have alike important roles in reducing carbon releases and providing food security to the people of rural areas. AF can serve an important role in climate change mitigation, due to carbon sequestration in woody components of the systems. AF can influence farmers as they seek to adapt to climate change due to the enhancing effects of trees on local air temperatures. The efficiency of AF in biodiversity conservation depends on the strategy of the system and the nature of the biodiversity to be preserved.

6.2 Recommendation

Supplementary research, comprising suitable measurement, modelling and experimentation, is needed, contained within the following recommendations:

Conduct more research into the vital functions and roles that tree diversity plays in landscapes for conserving hidden aspects of biodiversity, providing other environmental services, and benefiting incomes.

Evaluate the landscape-level effects of new agroforestry systems, such as the enhanced fallows and rotational woodlots.

Increasing the technical assistance, rural extension, and capacitation/ training in agroforestry practices are the most important factors for increasing farmer′s willingness for agroforestry in the studied region.

The people should delivered with various types of hybrid species of food value and fodder value. Consequently, they may get fascinated towards this practice.The demands and concerns of the people regarding this practice should be well distinguished, and the concern authority should be responsible to crack it.

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ANNEX

Annex 1: Questionnaire for social data collection.

Name of the Respondent________________ Male□ Female□ Age____

Address: _______________________________HHS Size____

Income sources: a. Agriculture □ b. Business □ c. Service □ e. Labor □ f. _______

Questionnaire Survey

Secondary sources, if any? __________

HHs head Education:

Male: a. Illiterate□ b. Literate□ c. SLC□ d. Above SLC□ Female:

a. Illiterate□ b. Literate □ c. SLC □ d. Above SLC □

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1. Herd size:

Animals	Numbers	Improved variety no
Cow/Bullock		
Goat/Sheep		
Buffaloes		
yak		
Bee hive		
Others		

2. What are the feeding techniques?

Feeding Technique	
Stall feeding	
Stall feeding + Grazing	
Grazing	

3. Landholding status (in ropani)

Khet land ... Bari land...... Khar bari..... Wood lot... Total......

4. No of land fragmentation?

Khet land ... Bariland...... Kharbari..... Total......

5. Are you participating in any AF and fodder/fruit management training? If yes, what are the changes after getting training?

....

6) What would you most likely use your best land to grow?

i)Foodcrop ii)Cash crop

iii)Tree crop

iv)Others

Explain..

7) What type of crop(s) do you cultivate or what do you use the land for?

Food crop

Cash crop

Tree crop

Others (specify)

Why? ....

6. List out the tree species found in your farm land?

S.N.	Trees Name	Total Number			Trends			Where?	Major Uses
		Bari	khet	kharbari	Increasing	Decreasing	Constant		

7. What are the reasons for changing trends?

....

8. Crop Description

a) Agricultural crop on bari land

Crops				
Season				

b) What are the best-suited combination of trees and crops in bari land? And give reason for their suitability.

c) Agricultural crop on khet

Crops				
Season				

d) What are the best suited combination of trees and crops in khet land? And give reason for their suitability.

....

e) Common grass species (native and exotic)

....

e) If there is decline in yield, how are you trying to resolve the production problems?

....

9. What are cooking energy sources for home consumption?

a) Fuel wood b) Kerosene c) Bio gas d) LP gases e) Other

10) What is the source of HHs energy?

i) Own farm

ii) Forest

iii) Purchase

iv) Others (specify).

11) Name the tree species used as fuelwood

11. How much forest products are you collecting from agro forestry tree species?

Products	**Annual consumption of forest products**			
	Woodlots	**AF**	**CF/F**	**TC**
Firewood				
Fodder				
Timber				
Fruits				

medicine				

11. In which season do you provide fodder to your livestock?

Type of feed	**Season**	**Quantity/ day**	**Quantity/Year**
Green grass			
Fodder			
Straw			

12) What is the contribution of the animals in the HHs?

....

13. Have you sell any AF products in the market? If yes, specify the quantity and income?

....

a) State your average income from the sale of food/ cash crops and tree crops (AF Product)

Crop	**Income/ year**
Food / Cash crop	
Tree crop	
Fruits	
Poles/timber	
Fuelwood	
Fodder	
Total	

13. What are the Problems related AF practices?

....

14. Have medicinal plants based AF system been practiced in your private land? If yes, what are the species?

15) How do you finance your farming activities/ source of loan / credit?

i) Bank

ii) Money lenders

iii) Personal savings

iv) Family member support

v) Cooperatives

vi) Others (specify)

16) Have you been getting or already received any assistance from Government in terms of monetary support and/ or other inputs? Yes/ No If Yes what kind?

....

17) Where do you sell the Food crops and the tree crops?

Type of market	**Food crop**	**Tree crop**
Local Market		
Urban Market		
Foreign Market		
None		

18) If you are not satisfied with the marketing system, of the food crop and tree crops, what do you think can be done to improve it?

....

19) Do you receive extension support from government agencies or non-governmental organizations in using the AF technology? Yes/ No If yes, explain.

20) What is the impact of AF on the livelihood of farmers HHs as perceived by you? Explain with some evidence (if available).

....

21) What would you recommend to the government so as to enhance technology transfer and subsequent adoption in the district?

Annex 2: Field data collection sheet

Date:

Plot No: Village: Altitude ......

Slope/aspect: Ethnicity of owner:

Latitude: ..... Longitude: .... Tree canopy (%)

S.N	Name of species	DBH(cm)	Tan α	Distance(m)	Remarks
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Annex 3: Agro-forestry tree species list.

S.N.	**Plant Local name**	***Scientific name***	**Family**	**RD**	**RF**	**Rdo**	**IVI**
1	Khayar	*Senegalia catechu (*L.f.*)* P.J.H.Hurter and Mabb.	Longaniaceae	2.49	2.19	1.44	6.13
2	Karam	*Adina cordifolia (*Roxb.*)* Brandis	Rubiaceae	1.00	1.09	1.52	3.61
3	Bel	*Aegle marmelos (*L.*)* correa	Rutaceae	1.00	1.23	1.50	3.73
4	Churi	*Aesandra butyracea (Roxb.)* H.J.Lam	Sapotaceae	0.20	0.27	0.88	1.35
5	Chatiwan	*alstonia scholaris*	Apocynaceae	0.60	0.82	1.12	2.54
6	Katahar	*Artocarpus heterophyllus* Lam.	Moraceae	1.69	2.05	1.80	5.55
7	Badahar	*Artocarpus lakoocha Buch.*-Ham	Moraceae	1.50	1.50	1.79	4.79
8	Neem	*Azadirachta indica* A.Juss.	Meliaceae	0.30	0.41	1.88	2.59

S.N.	Plant Local name	*Scientific name*	Family	RD	RF	Rdo	IVI
9	Tanki	*Bauhinia purpurea* L.	Leguminosae	0.50	0.55	0.83	1.88
10	Koiralo	*Bauhinia variegate* L.	Leguminosae	1.10	1.09	0.90	3.09
11	Painyu	*Betula alnoides* Buch.-Ham. ex D.Don	Betulaceace	0.50	0.55	0.73	1.77
12	Dar	*Pouzolzia rugulosa* (Wedd.) Acharya and Kravtsova	Urticaceae	0.50	0.55	1.22	2.26
13	Simal	*Bombax ceiba* L.	Bombacaceae	1.20	1.50	2.78	5.48
14	Chuletro	*Brassiopsis hainla*	Araliaceae	1.00	0.96	0.96	2.91
15	Gaaye	*Bridelia retusa* (L.) Spreng	Phyllanthaceae	0.90	0.96	1.35	3.21
16	Mewa	*Carica papaya* L.	Caricaceae	0.90	0.82	0.45	2.17
17	Padke	*Carpenslum nepalense*	Papaveraceae	1.30	1.23	1.11	3.64
18	Rajbriksh	*Cassia fistula* L.	Leguminosae	0.30	0.27	1.01	1.59
19	Tejpat	*Cinnamomum tamala* (Buch.-Ham.) T.Nees and C.H.Eberm.	Lauraceae	0.30	0.27	0.46	1.03
20	Kagati	*Citrus aurantifolia*	Rutaceae	0.40	0.55	0.72	1.66
21	Bimiro	*Citrus medica* L.	Rutaceae	0.30	0.41	0.85	1.56
22	Nibuwa	*Citrus limon*	Rutaceae	0.90	0.82	0.96	2.67
23	Suntala	*Citrus aurantium* (L.) Osbeck	Rutaceae	0.90	0.96	0.66	2.51
24	Kyamuno	*Syzygium nervosum* A.Cunn. ex DC.	Myrtaceae	1.50	1.78	1.01	4.28
25	Sibligan	*Crateva unilocularis* Buch.-Ham.	Capparaceae	0.60	0.41	0.49	1.50
26	Sisoo	*Dalbergia sissoo* Roxb.	Fabaceae	1.79	1.64	2.02	5.46
27	Sadhan	*Desmodium oogenesis*	Leguminosae	0.80	0.68	1.25	2.73
28	Dhatrung	*Ehretia aspera* Willd.	Boraginaceae	0.60	0.68	1.43	2.72
29	Faledo	*Erythrina stricta* Roxb.	Fabaceae	0.40	0.55	0.81	1.75

30	Masala	*Eucalptptus camaldulensis* Dehnh.	Myrtaceae	0.60	0.68	0.71	1.99
31	Bar	*Ficus benghalensis* L.	Moraceae	0.40	0.41	2.16	2.97
32	Pakhari	*Ficus glaberrima*	Moraceae	1.30	1.37	1.47	4.14
33	Thotne	*Ficus hispida* L.	Moraceae	2.99	2.87	0.75	6.61
34	Kavro	*Ficus lacor* Buch.-Ham.	Moraceae	4.29	3.83	2.87	10.99
35	Dumri	*Ficus racemose* L.	Moraceae	4.19	4.24	2.06	10.49
36	Pipal	*Ficus religiosa L.*	Moraceae	0.60	0.82	3.07	4.49
37	Nimaro	*Ficus rosenbergii*	Moraceae	1.20	1.37	0.98	3.54
38	Swami	*Ficus benjamina L.*	Moraceae	0.20	0.27	5.49	5.96
39	Khaniya	*Ficus semichordata* Buch.-Ham. ex Sm.	Moraceae	5.68	4.92	1.20	11.81
40	Ramsing	*Garuga pinnata* Roxb.	Burseraceae	7.48	5.75	1.42	14.65
41	khamari	*Gmelina arborea* Roxb. ex Sm.	Lamiaceae	0.20	0.27	0.76	1.23
42	Sajiwan	*Jatropha curcas* L.	Euphorbiaceae	0.40	0.55	0.48	1.42
43	Bot dhayero	*lagerstroemia parviflora*	Lythraceae	6.58	5.88	1.52	13.99
44	Ipilipil	*Leucaena leucocephala* (Lam.) de Wit	Fabaceae	3.19	3.15	0.75	7.09
45	Litchi	*Litchi chinensis* Sonn.	Sapindaceae	0.50	0.55	1.17	2.22
46	Kutmero	*Litsea monopetala*(Roxb.) Pers.	Lauraceae	2.39	2.46	1.73	6.58
47	Royani	*Mallotus philippensis* (Lam.) Mull.Arg	Euphorbiaceae	1.50	2.05	0.88	4.43
48	Mango	*Mangifera indica* L.	Anacardiaceae	2.29	2.33	1.83	6.45
49	Bhogate	*meesa macrophylla*	Myrsinaceae	0.20	0.27	0.65	1.12
50	Bakaino	*Melia azedarach* L.	Meliaceae	2.29	2.19	1.30	5.78
51	Champ	*Magnolia champaca* (L.) Baill. ex Pierre	Magnoliaceae	0.40	0.55	2.78	3.72
52	Kimbu (Kafal)	*Morus alba* L.	Moraceae	1.50	1.64	0.77	3.90
53	Parijat	*Nyctanthes arbor-tristis* L.	Oleaceae	0.20	0.14	1.03	1.37

54	Tatelo	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	1.10	1.09	1.55	3.74
55	Amala	*Phyllanthus emblica* L.	Euphorbiaceae	1.50	0.96	0.84	3.29
56	Gidhari	*Premna integrifolia*	Verbenaceae	1.60	1.64	1.06	4.30
57	Aru	*Prunus armeniaca Lindl.*	Rosaceae	0.50	0.68	1.08	2.27
58	Belauti	*Psidium guajava* L.	Myrtaceae	1.60	1.64	0.95	4.19
59	Naspati	*Pyrus communis* L.	Rosaceae	0.60	0.82	1.01	2.43
60	Vakeamilo	*Brucea javanica* (L.) Merr.	Anacardiaceae	0.20	0.27	0.69	1.17
61	Khirro	*Falconeria insignis* Royle	Euphorbiaceae	1.30	1.37	1.04	3.70
62	Chilaune	*Schima wallichii*	theaceae	5.78	4.51	1.60	11.89
63	Sittalchini	*Moringa oleifera* Lam.	Fabaceae	0.50	0.68	1.00	2.18
64	Sal	*Shorea robusta* C.F.Gaertn.	Dipterocarpaceae	1.69	1.64	2.29	5.62
65	Amaro	*Spondias bipinnata* Airy Shaw and Forman	Anacardiaceae	0.90	1.23	1.86	3.99
66	Jamuna	*Syzygium cumini* (L.) Skeels	Myrtaceae	0.80	0.82	0.93	2.55
67	Emilie	*Tamarindus indica* L.	Fabaceae	0.40	0.68	1.67	2.75
68	Tik	*Tectona grandis* L.f.	Verbenaceae	0.30	0.41	1.16	1.87
69	Barro	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	1.00	1.23	1.06	3.29
70	Saaj	*Terminalia alata* Roth	Combretaceae	1.20	1.23	2.21	4.64
71	Harroow	*Terminellia chebula*	Combretaceae	0.60	0.82	1.31	2.73
72	Vellor	*Mallotus nudiflorus* (L.) Kulju and Welzen	Euphorbiaceae	0.20	0.27	2.61	3.08
73	Falame	*xylosma controversum*	flacourtaceae	1.30	1.37	1.31	3.98
74	rukhbayer	*Ziziphus mauritiana* Lam.	rhamnaceae	1.00	1.23	1.02	3.25

Annex 4: Name of respodents

S.N.	Name Of Respondent	M/F	Age	Add.	HHs size	Income	HHs Edu
1	Tek Raj Bhujel	M	30	Dedgaun	5	Fi	SLC
2	Talkmaya B.K	F	45	Dedgaun	9	Agri	Ill.
3	Indira Bhandari Dhakal	F	21	Dedgaun	3	Service	A. SLC
4	Chandra Kumari Pariyar	F	40	Dedgaun	5	Agri	Ill.
5	Janma Kumari Pariyar	F	27	Dedgaun	5	Agri	SLC
6	Ram Bdr. B.K	M	49	Dedgaun	5	Fi	Lil
7	Padam Bdr. B.K	M	42	Dedgaun	6	Agri	Lil
8	Motilal B.K	M	64	Dedgaun	2	Agri	Lil.
9	Santabir Thapa	M	50	Dedgaun	11	Agri	Lil
10	Motisara Saru	F	35	Dedgaun	10	Agri/FI	Lil
11	Rameshowr Bohora	M	69	Dedgaun	2	Agri	Lil
12	Chetnaran Oja	M	66	Dedgaun	8	Agri/B	Lil
13	Giriraj Bhattarai	M	58	Dedgaun	8	Agri	Lil
14	Rup Kumar B.K	M	45	Dedgaun	7	Agri	Lil
15	Hom Bdr Malla	M	72	Dedgaun	4	Agri	SLC
16	Karna Bdr Kumal	M	55	Dedgaun	6	Agri	Lil
17	Dhane Barkoti Magar	M	35	Dedgaun	5	Agri	Lil
18	Sarad Shrestha	M	40	Dedgaun	5	Agri	SLC
19	Jhyan Bdr. Sarumagar	M	58	Dedgaun	7	Agri	Lil
20	Dhan Bdr Magar	M	35	Dedgaun	6	Agri	Lil
21	Thagulal Bhattarai	M	61	Dedgaun	7	Agri/FI	Lil
22	Bhim Bdr. Sinjali	M	31	Dedgaun	6	Agri/FI	SLC
23	Man Bdr. Sinjali	M	42	Dedgaun	6	Agri	Lil
24	Mina Saru Magar	F	38	Dedgaun	5	Agri	Lil
25	Bhim Bdr. Gharti	M	70	Dedgaun	7	Agri	Ill.
26	Gita Pokhrel	M	37	Dedgaun	5	Agri	Lil
27	Kala Khamcha	F	46	Dedgaun	7	Agri	Ill.
28	Keshari Sinjali	F	36	Dedgaun	4	Agri	SLC
29	Nal. Bdr. Gaha	M	43	Dedgaun	5	Agri/B	Lil
30	Kham Bdr. Thada	M	63	Dedgaun	3	Agri	Ill.
31	Man Bdr. Thada	M	50	Dedgaun	5	Agri	Lil
32	Khim Bdr Thada	M	48	Dedgaun	5	Agri	Lil
33	Rey Bdr Gaha	M	68	Dedgaun	5	Agri	Lil

34	Shiva Bdr B. K	M	55	Dedgaun	7	Agri	Lil
35	Lal Bdr Thada	M	43	Dedgaun	7	Agri	Lil
36	Sita B.K	F	35	Dedgaun	5	Agri	Lil
37	Yam Bdr. Magar	M	65	Dedgaun	7	Agri	Ill.
38	Manndhoj Saru	M	60	Dedgaun	8	Agri	Lil
39	Purna Singh Gelan	M	50	Dedgaun	5	Agri	Lil
40	Ram Pd Shrestha	M	56	Dedgaun	5	Service	A. SLC
41	Bhuwan Sin Saru	M	35	Dedgaun	6	Agri/B	Lil
42	Mandhara Shrestha	F	68	Dedgaun	6	Agri	Ill.
43	Mishri Maya Shrestha	F	67	Dedgaun	5	Agri	Ill.
44	Netra K Shrestha	M	30	Dedgaun	10	Agri/Service	A. SLC
45	Maya Thapa Chetri	F	35	Dedgaun	5	Agri	Lil
46	Govinda Bdr. G.C	M	86	Dedgaun	6	Agri	Lil
47	Kaman Jit Darai	M	68	Dedgaun	6	Agri	Ill.
48	Eklal Darai	M	60	Dedgaun	5	Agri	Ill.
49	Indira Jit Darai	M	45	Dedgaun	10	Agri	Ill.
50	Homnath Bhattarai	M	65	Dedgaun	6	B S	A.SLC
51	Devaka Chatauji Magar	F	32	Rakuwa	4	S.Agri	SLC
52	Durga Thada Magar	M	38	Rakuwa	13	B.S	SLC
53	Tula Sinjali Magar	M	32	Rakuwa	5	Agri	Lil
54	Buddi Sagar Chhsetri	M	50	Rakuwa	5	S	A.SLC
55	Srijana Khadka	F	17	Rakuwa	6	Agr.	A.SLC
56	Laxmi Thapa Chhsetri	M	43	Rakuwa	7	Agri.	A.SLC
57	Roshan Kumar Khadka	M	20	Rakuwa	5	Agri	SLC
58	Fadindra Bdr. B.K	M	50	Rakuwa	5	Agri.	Lil
59	Imansing Marsangi	M	71	Rakuwa	3	Agri.	Ill.
60	Bhim Maya Ranamagar	F	48	Rakuwa	7	Agri	Ill.
61	Bhagawati Saru	F	38	Rakuwa	5	FI	Lil
62	Narmya Karki	F	35	Rakuwa	6	S.Agri	Lil
63	Tara Bahadur Bk	M		Dedgaun		Agri	Lil
64	Khim Bdr. Sarki	M	68	Rakuwa	8	Agri. Fi	Ill.
65	Sukmaya Gahatraj	F	60	Rakuwa	5	Agri	Ill.
66	Bhupal Gaha Magar	M	23	Rakuwa	4	Agri.	Lil
67	Basna Ale	F	23	Rakuwa	3	Agri.	SLC
68	Indra Marsangi	F	28	Rakuwa	6	Agri.	SLC
69	Sushila Ruchal	F	45	Rakuwa	6	Agri.	Lil

70	Yam Bdr. Ruchal	M	25	Rakuwa	7	Agri.	Lil
71	Bindu Marsangi Magar	M	22	Rakuwa	6	Agri.	Lil
72	Lal Bdr. Basel	M	25	Rakuwa	7	Agri. FI	SLC
73	Parbati Basel	F	70	Rakuwa	1	Agri	Ill.
74	Thaman Sing. Basel	M	45	Rakuwa	7	Agri.	Lil
75	Dilmaya Marssangi	F	50	Rakuwa	3	Agri	Lil
76	Shova Ruchal	F	21	Rakuwa	4	Agri	SLC
77	Top Bdr. Magar	M	64	Rakuwa	7	Agri	Lil
78	Panisara Adhikari	F	38	Rakuwa	4	Agri	Lil
79	Kopila B.K	F	30	Rakuwa	4	Agri.B	Lil
80	Gyanu Sunuwar	F	45	Rakuwa	5	Agri.	Lil
81	Rupa Sunar	F	30	Rakuwa	6	Agri	Lil
82	Devilal Ruchal	M	71	Rakuwa	10	Agri.S	Lil
83	Dhansari B.K	F	70	Rakuwa	6	Agri	Ill.
84	Naula Singh Sunar	M	40	Rakuwa	6	Agri.FI	Lil
85	Bhim Bdr. Sunar	M	55	Rakuwa	6	Agri.	Ill.
86	Tikaram Darai	M	62	Rakuwa	6	Agri	Lil
87	Diliram Darai	M	74	Rakuwa	8	Agri. FI	Lil
88	Tekman Darai	M	60	Rakuwa	7	Agri.FI	Lil
89	Janaki Lamsal	F	70	Rakuwa	6	Agri	Ill.
90	Hastabir Soti	M	90	Rakuwa	6	Agri	Ill.
91	Rima Basel	F	35	Rakuwa	7	Agri	Lil
92	Gobardhan Thapa Magar	M	60	Rakuwa	6	Agri	Lil
93	Chitra Maya Sotimagar	F	50	Rakuwa	9	Agri	Lil
94	Rishiram Thada	M	55	Rakuwa	4	Agri	Lil
95	Dan Bdr. Sinjali	M	40	Rakuwa	5	Agri	Lil
96	Nal Bdr. Ale Magar	M	42	Rakuwa	7	Agri	Lil
97	Dilmansing Fal Magar	M	50	Rakuwa	7	Agri	Lil
98	Khem Bdr. Marashangi	M	50	Rakuwa	5	Agri	Lil
99	Bhuwan Singh B.K	M	66	Rakuwa	2	Agri	Lil
100	Yam Kumar B.K	M	30	Rakuwa	6	Agri	SLC

Note: SLC - School Leaving Certificate, Lil - literate, Ill - Illiterate, A.SLC - Above School Leaving Certificate, Agri - Agriculture , FI - Foreign Income, S - Service, M -Male, F - Female

Annex 5: Carbn stock and biomass of each plot.

S.N.	Altitude	Ethnic groups	Landuse	Carbon stock/ha	Biomass (kg/plot)
1	345	Others	kharbari land	17.06	1452.28
2	342	Dalit	khet land	7.76	660.59
3	365	Bramin/chhsetri	bari land	28.22	2401.76
4	310	Dalit	khet land	20.09	1709.66
5	319	Dalit	bari land	17.64	1501.14
6	359	Dalit	khet land	18.77	1597.16
7	322	Dalit	khet land	15.60	1327.49
8	310	Dalit	bari land	17.58	1496.53
9	363	Magar	woodlot	6.33	538.64
10	375	Magar	khet land	48.93	4163.96
11	374	Bramin/chhsetri	woodlot	76.16	6481.78
12	370	Bramin/chhsetri	khet land	79.42	6759.25
13	424	Bramin/chhsetri	woodlot	34.46	2932.73
14	457	Dalit	kharbari land	22.48	1913.19
15	492	Bramin/chhsetri	woodlot	18.58	1581.29
16	575	Others	woodlot	31.77	2703.80
17	557	Magar	khet land	28.33	2411.34
18	566	others	bari land	69.17	5886.43
19	528	Magar	kharbari land	22.84	1943.60
20	498	Magar	bari land	17.31	1473.00
21	400	Bramin/chhsetri	woodlot	22.72	1933.61
22	536	Magar	woodlot	39.57	3367.69
23	750	Magar	kharbari land	32.19	2739.76
24	637	Magar	kharbari land	33.25	2829.72
25	471	others	khet land	10.53	895.87
26	543	Bramin/chhsetri	bari land	21.40	1821.50
27	613	Magar	bari land	46.77	3980.65
28	630	Magar	kharbari land	33.39	2841.71
29	682	Magar	bari land	28.88	2458.28
30	688	Magar	bari land	39.06	3324.66
31	696	Magar	bari land	41.29	3513.71
32	759	Magar	kharbari land	44.48	3785.43
33	735	Magar	woodlot	36.30	3089.50

34	862	Dalit	bari land	50.42	4291.37
35	831	Magar	bari land	48.28	4108.90
36	706	Dalit	bari land	38.74	3297.19
37	706	Magar	bari land	34.27	2916.20
38	708	Magar	woodlot	23.36	1988.26
39	560	Magar	bari land	3.48	296.52
40	432	others	khet land	15.23	1296.43
41	429	Magar	khet land	15.39	1310.01
42	300	others	khet land	7.90	672.51
43	426	others	bari land	16.10	1370.31
44	395	others	woodlot	19.09	1625.01
45	411	Bramin/chhsetri	bari land	27.93	2377.36
46	418	Bramin/chhsetri	khet land	18.38	1564.23
47	375	darai	khet land	13.67	1163.00
48	381	darai	khet land	6.27	533.20
49	375	darai	kharbari land	28.91	2460.66
50	392	Bramin/chhsetri	khet land	9.02	767.54
51	658	Magar	khet land	15.36	1307.10
52	756	Magar	woodlot	30.78	2619.77
53	775	Magar	bari land	23.01	1957.94
54	743	Bramin/chhsetri	bari land	6.82	580.34
55	752	Bramin/chhsetri	bari land	34.97	2976.15
56	467	Bramin/chhsetri	bari land	34.65	2948.62
57	686	Bramin/chhsetri	bari land	28.23	2402.40
58	429	Dalit	kharbari land	23.38	1989.80
59	703	Bramin/chhsetri	bari land	34.24	2913.95
60	778	Magar	bari land	45.54	3875.76
61	778	Magar	kharbari land	17.81	1515.98
62	406	Bramin/chhsetri	kharbari land	47.28	4024.08
63	458	Dalit	kharbari land	51.77	4405.85
64	404	Dalit	woodlot	56.02	4767.95
65	416	Dalit	kharbari land	18.29	1556.40
66	483	Magar	kharbari land	27.75	2362.00
67	471	Magar	khet land	29.95	2548.88
68	459	Dalit	bari land	20.89	1777.54
69	363	Dalit	khet land	33.76	2873.22

70	394	Dalit	khet land	19.69	1675.45
71	318	Magar	khet land	9.10	774.61
72	337	Dalit	khet land	29.04	2471.45
73	333	Dalit	khet land	28.75	2447.13
74	355	Dalit	khet land	40.44	3441.42
75	452	Magar	khet land	16.36	1392.33
76	365	Dalit	bari land	26.13	2223.90
77	365	Magar	bari land	19.39	1649.82
78	365	Bramin/chhsetri	khet land	18.82	1602.12
79	375	Dalit	bari land	36.07	3069.73
80	413	Dalit	bari land	34.48	2934.23
81	512	Dalit	bari land	19.45	1655.38
82	713	Dalit	bari land	45.88	3904.31
83	468	Dalit	bari land	26.23	2232.76
84	435	Dalit	bari land	25.52	2172.27
85	368	Dalit	bari land	6.10	519.45
86	417	darai	khet land	8.73	742.79
87	374	darai	khet land	13.55	1152.97
88	370	darai	khet land	8.99	765.43
89	384	Bramin/chhsetri	woodlot	4.34	368.95
90	398	Bramin/chhsetri	khet land	5.95	506.04
91	462	Bramin/chhsetri	bari land	15.74	1339.23
92	675	Magar	bari land	7.96	677.31
93	659	Magar	bari land	14.34	1220.27
94	653	Magar	woodlot	21.78	1853.37
95	672	Magar	bari land	13.71	1167.05
96	742	Magar	bari land	56.57	4814.25
97	753	Magar	kharbari land	9.89	841.51
98	755	Magar	bari land	25.55	2174.84
99	771	Dalit	bari land	17.30	1472.55
100	813	Dalit	bari land	25.74	2191.03

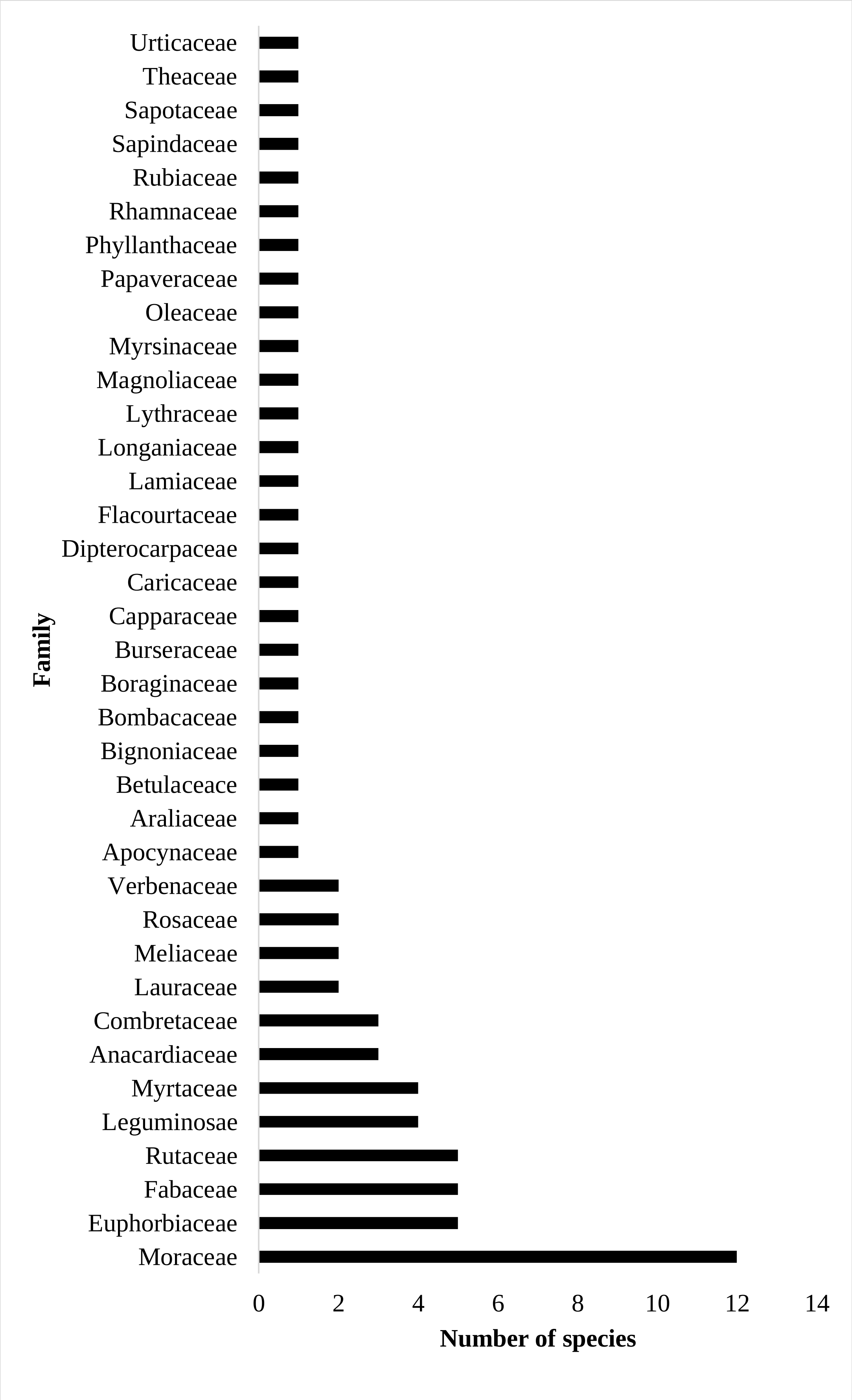
Annex 6: Uses of species

scientific name	Family	Fruits	Fuelwood	Medicine	Shade	Live Fence	Ornamental/Religious	Timber wood	Fruits/Medicine	Fodder/Fuelwood	Fodder/Fuelwood/Timber	Fuelwood/Timber	Fodder/Fruits/Fuelwood	Unknown
Phyllantus emblica	Euphorbiaceae								√					
Spondias bipinnata	Anacardiaceae								√					
Prunus armeniaca	Rosaceae	√												
Atrocarpus lacucha	Moraceae									√				
Melia azederach	Meliaceae										√			
Ficus benghalensis	Moraceae				√									
Terminali belirica	Combretaceae			√										
Aegle marmellos	Rutaceae								√					
Psidium gujava	Myrtaceae	√												
Meesa macrophylla	Myrsinaceae	√												
Lagerstroemia parviflora	Lythraceae											√		
Michelia champaca	Magnoliaceae							√						
Alstonia scholaris	Apocynaceae		√											
Schima wallichii	Theaceae											√		
Brassiopsis hainla	Araliaceae		√											
Aesandra butyracea	Sapotaceae	√												
Boehmeria rugulosa	Urticaceae							√						
Ehretia laevis	Boraginaceae		√											
Ficus racemosa	Moraceae												√	
Tamarindus indica	Fabaceae												√	
Xylosma controversum	Flacourtaceae													√
Erythrina stricta	Fabaceae													√
Bridelia retusa (L.) Spreng	Phyllanthaceae												√	
Premna integrifolia	Verbenaceae		√											
Terminellia chebula	Combretaceae			√										
Leucena leucocephala	Fabaceae									√				
Citrus lemon	Rutaceae	√												
Syzygium cumini	Myrtaceae	√												

Citrus aurantifolia	Rutaceae	√												
Adina cordifolia	Rubiaceae							√						
Atrocarpus heterophyllus	Moraceae												√	
Ficus lacor	Moraceae												√	
Gmelina arborea	Lamiaceae		√											
Ficus semicordata	Moraceae												√	
Acacia catechu	Longaniaceae											√		
Sapium insigne	Euphorbiaceae					√								
Morus alba	Moraceae												√	
Bauhinia variegata	Leguminosae									√				
Litsea polyantha	Lauraceae									√				
Cleistocalyx operculata	Myrtaceae								√					
Litchi chinensis	Sapindaceae	√												
Mangifera indica	Anacardiaceae												√	
Eucalptptus camaldunesis	Myrtaceae							√						
Carica papaya	Caricaceae	√												
Pyrus communis	Rosaceae	√												
Azadirachta indica	Meliaceae			√										
Citrus limon	Rutaceae	√												
Ficus rosenbergii	Moraceae						√							
Carpenslum nepalense	Papaveraceae		√											
Betula alnoides	Betulaceace	√												
Ficus glaberrima	Moraceae		√											
Nyctanthes arbortritis	Oleaceae						√							
Ficus religiosa	Moraceae				√									
Cassia fistula	Leguminosae			√										
Garuga pinnata	Burseraceae									√				
Mallotus philippensis	Euphorbiaceae									√				
Zizyphus mauritiana	Rhamnaceae	√												
Terminalia alata	Combretaceae							√						
Desmodium oogenesis	Leguminosae							√						
Jatropha curcas L.	Euphorbiaceae					√								
Shorea robusta	Dipterocarpaceae							√						
Crteva unilocularis	Capparaceae								√					
Bombax cibea	Bombacaceae							√						
Dalbergia sissoo	Fabaceae									√				

Sesbania sesban	Fabaceae	√												
Citrus reticulata	Rutaceae	√												
Ficus rumphii	Moraceae				√									
Bauhinia purpurea	Leguminosae									√				
Oroxylum indicum	Bignoniaceae		√											
Cinnamomum tamala	Lauraceae	√												
Ficus hispida	Moraceae									√				
Tectona grandis	Verbenaceae							√						
Rhus javanica	Anacardiaceae	√												
Trewia nudiflora	Euphorbiaceae		√											

Annex 7: family and number of species



PHOTOES

Photographs of focal group discussion

Agroforestry landscape of Rakuwa village.

Focal group discussion in Rakuwa village

DBH measurement

Focal group discussion in Deadgaun village

Measuring height and DBH of tree.

Household data collection

Household data collection

Household data collection