# Implication of Agroforestry System For Soil Carbon Sequestration And Livelihood In The Mid-hills of Nepal

yagya raj bhatt

Norwegian University of Life Sciences
Department of international environment and development studies, noragric

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# CREDIT

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Email: yagyanp@gmail.com

Noragric

Department of International Environment and Development Studies

P.O.Box 5003

N-1432 Ås

Norway

Tel.: +47 64 96 52 00

Fax: +47 64 96 52 01

Internet: http://www.umb.no/noragric

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# DECLARATION

I, Yagya Raj Bhatt, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature: _________________

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## Part 1: EXTENDED SUMMARY

# Abstract

*Agricultural practice combined with trees and livestock called "agroforestry" is one possible option for reducing emissions of green house gases in atmosphere as well as to improve livelihood of farmers. Agroforestry systems enhances organic carbon accumulation in soils by providing continuous supplies of organic matter, and increases soil microorganisms by which the nutrient cycle is preserved .Soil carbon stock under agroforestry systems were higher due to increased input of carbon through litter fall and greater root biomass. The adoption of agroforestry increases crop production, income, savings, improves food security and provides fuelwood and fodder. Tree-based agroforestry practice could have a positive effect on rural development through promotion of agricultural industries and improving local economy by increasing opportunity for employment.*

*The study was focused to illustrate the significant potential of improved agroforestry with exotic fodder species on soil carbon sequestration and livelihood of farmer in the Mid-hills of Nepal. For this study, soil samples were collected from three land use systems, Improved Agroforestry (IA), Traditional Agroforestry (TA), and Forest land in four replicas form. Soil physical and chemical properties (pH, Bulk density, SOC, Texture, NPK) were measured. Similarly, a total of 86 households (58 from project households and 28 from without project households) were interviewed to collect information on existing agroforestry practice, crop and livestock production and fodder and fuel-wood availability.*

*Improved agroforestry soil had a higher SOC than traditional agroforestry in all depths because of continuous supply of organic matter in the form of leaf litter from agroforestry. The average value of SOC was significantly higher in forest land than TA but there was no difference with IA. It reveals that improved agroforestry practice has the capacity to improve SOC more than traditional agroforestry. Improved agroforestry had more carbon stocks than traditional agroforestry because of continuous supply of organic matter from agroforestry and FYM. The households practicing improved agroforestry would receive $422.40 USD more than traditional agroforestry through carbon trading.*

*Improved agroforestry was introduced by NAF in 1999. Before then, people were practicing traditional methods. The exotic fodder species Ipil-lipil (Leucanena leucocephala), Bhatmase (Flemingia congesta), Kimbu (Morus alba), and Taki (Bauhinia purpurea) introduced by NAF*

*were frequently distributed in both NAF projects as well as without project households. The number of trees and agroforestry species were found to be different between project and without project households because of higher land holding size and efforts of NAF. It was found that the agroforestry had a pronounced effect on the fodder availability in the area. The major goal of farmers that practiced agroforestry was to increase livestock production by producing more fodder from their land. Hence, the common fodder species were frequently distributed in both project and without project areas. Therefore, the livelihood of farmers in the Mid-hills of Nepal practicing subsistence agricultural with agroforestry could be improved greatly through introducing multipurpose tree species.*

# 1. Introduction

The increasing concentration of green house gases in the atmosphere is responsible for climate change. Climate change alters the physical and biological components of the environment by which living beings are negatively impacted. An agricultural practice which combines crop, trees and livestock- called “agroforestry” (Smith *et al*., 2012), is one possible option for the reducing the emission of green house gases in atmosphere. Agroforestry plays an important role in increasing the above and below ground carbon sequestration rate and reduces emission of green house gases from agricultural sector (Branca *et al*., 2013). It also increases the resilience capacity of farmers to adopt negative impact of climate change (Verchot *et al*., 2004). Along with carbon sequestration, agroforestry has multifold environmental services like soil nutrient management, biodiversity conservation, and maintenance of air and water quality (Jose, 2009). Besides this, it is helpful in livelihood improvement of farmers through increasing food production, maintaining soil nutrients, providing fuel-wood and fodder. It can also control soil erosion and landslides in steep hills, as well as maintain soil moisture by providing organic matter through tree litter. Similarly, agroforestry can maintain nutrient cycling, increase water infiltration, and maintain soil microorganisms (Neufeldt, 2013). Trees on farm land create different environmental niches which support different types of species and increase biodiversity (Torquebiau, 2013). Hence, Agroforestry is one possible option for increasing soil carbon stocks.

### 1.1 Agroforestry and Soil Carbon Stocks

Soil carbon stocks are changed by anthropogenic activities like land-use change, deforestation through shifting carbon stocks in different components of biogeochemical cycle (IPCC, 2000). Globally, the forestry sector contributes for the 17.4% of total green houses gas emissions (IPCC, 2007). Hence, forest management is one major tool for decreasing the atmospheric $CO_2$ gas concentration through increasing the carbon sequestration rate (Lal, 2005).

Carbon sequestration rate of soil depends upon the input of dead organic matter provided by plants, soil properties such as soil structures and their aggregations, and climate (Lal, 2004). Agroforestry systems that combine trees and shrubs with crops and livestock enhances organic carbon accumulation in soils by providing continuous supply of organic matter, and it also increases soil microorganisms by which the nutrient cycle is preserved (Araujo *et al*., 2012). The practice of agroforestry supports a higher earthworm population and increases SOC than other land-use systems (Bhadauria *et al*., 2012). Soil carbon stock under agroforestry system was higher because of input of carbon through litter fall and greater root biomass (Benbi *et al*., 2012). Hence, the agroforestry may be one possible option for mitigating emission from land use changes through reducing soil degradation (Albrecht *et al*., 2003). Beside carbon sequestration, agroforestry provides food, fodder, fuel-wood, and timber which contribute to the improvement of the livelihood of farmers.

### 1.2 Agroforestry and Livelihood

Livelihood is affected by the employment, trading of material, sale of labor, home garden, food processing, livestock production, and cultivation or use of natural or common property resources (Adato *et al*., 2003). Seventy to eighty percent of rural populations of developing countries depend up on the forest resources and subsistence agricultural for their livelihood (El-Lakany, 2004). The adoption of the practice of agroforestry increases crop production, income, savings, improves food security, and provides firewood and fodder (Akinnifesi *et al*., 2008). Tree-based agroforestry practices could bring opportunities for rural development through promoting agro industries and improving local economies by reducing unemployment (Kumar *et al*., 2012). In Asia, the practice of agroforestry could be one possible option for providing food for the growing population, and reducing adverse environmental problems like land degradation and climate change (Kumar, 2006). Hence, the adoption of agroforestry could have multifold benefits that improve the quality of local livelihood. The potential of agroforestry to have a positive effect on local livelihood is influenced by different socioeconomic factors such as landholding size, livestock population, gender, and the relative importance of agriculture in household (Garforth *et al*., 1999).

Livestock rearing is one major agricultural activity in Nepal and it contributes for 11% to GDP (FAO, 2005). In the past, local people collected forest products from the natural forest, but after changes in forest regime (community forest), local people have had limited access to the natural forest. Hence, the numbers of trees on farm land have been increasing (Adhikari *et al.,* 2007, Neupane *et al*., 2001). The increasing demand for fodder in the Mid-hill region of Nepal can be addressed through the promotion of agroforestry (Thapa *et al*., 2000). The practice of agroforestry is a contributing factor in reducing human impact on the natural forest and maintaining agro-biodiversity. The number of tress and agroforestry species on farm land depends up on socio-economic factors like land holding size, livestock population, and fragmentation of properties (Acharya, 2006). Agroforestry can also be seen as a contributing factor for reducing soil erosion in upland areas, introducing more multipurpose tree species like fruit trees and medicinal plants, and can be modified to address livelihood improvement (Fonzen *et al*., 1984). Recently, some organizations -particularly Nepal Agroforestry Foundation (NAF) - are working for the promotion of the agroforestry system in the country.

### 1.3 Statement of the Problem

In Nepal, some researches were carried out in the field of forest and soil carbon sequestration like Upadhyay *et al.* (2005), Sitaula *et al.* (2004), Awasthi *et al.*, (2005), Shrestha *et al.*, (2007), Yang *et al*, (2004).These studies do not cover the potential of agroforestry for carbon sequestration. Agroforestry land-use management is necessary for increasing soil carbon stocks and socio-economic development of farmers, and the research on the carbon sequestration rate of agroforestry is necessary for making future policies and strategies on the issue of climate change. However, there were limited research (Neupane *et al.,* 2001, Neupane *et al.,* 2002 and Regmi, 2003) carried out in the field of agroforestry, mostly focusing on soil fertility and local livelihood. Hence, there is a need for research on the influence of agroforestry on carbon stocks and local livelihood.

### 1.4 Conceptual Framework

The research which highlights the potential of an agroforestry system to sequester carbon and improve livelihood will help in identifying the gap in environmental policy and its implementation. The conceptual framework of this study is presented in figure 1.

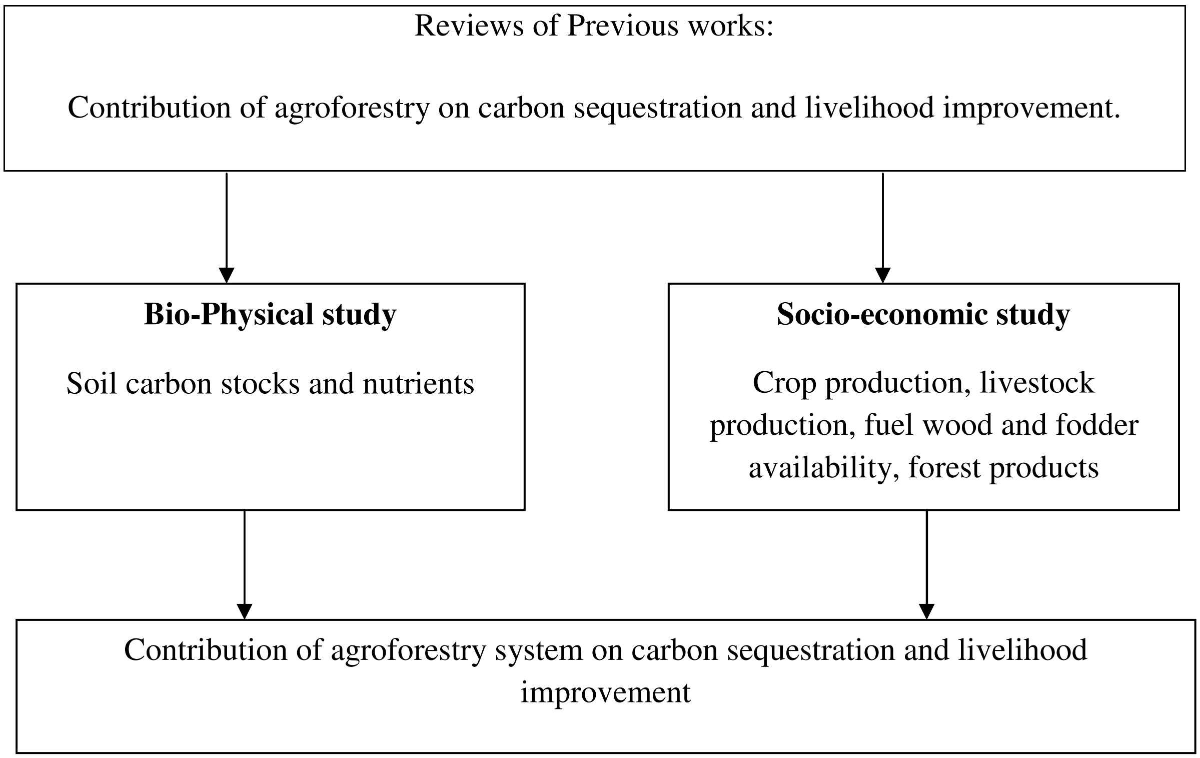


Fig 1: Conceptual framework of the study

### 1.5 Objectives of the Study

The general objective of the study was to study the contribution of agroforestry on carbon stocks and farmer's livelihoods in the Mid-hills of Nepal

The specific objectives were:

1. To assess the contribution of agroforestry on carbon stocks in the Mid-hills of Nepal.
   The sub-objectives were :

i) to quantify and compare soil physical and chemical parameters (pH, Bulk Density, SOC%, NPK and texture) under existing land-use ( Traditional Agroforestry, Improved Agroforestry and forest).

ii) to quantify and compare carbon stocks under existing landuse ( Traditional Agroforestry, Improved Agroforestry and Forest) .

iii) to estimate potential carbon benefit in economic term.

2. To illustrate the significance of agroforestry in terms of its contribution on farmers' livelihood. The sub-objectives were:

i) to study and compare existing agroforestry practices between households "with" and "without" improved agroforestry.
ii) to compare agricultural production (crop and livestock) between households "with" and "without" improved agroforestry.
iii) to compare fodder and fuel-wood availability between households "with" and "without" improved agroforestry

# 2. Materials and Methods

## 2.1 Study area

The study area is located in Dhaibung village development committee (VDC) of Rasuwa district of Central Development Region of Nepal. According to National Censes (CBS, 2001), the total population of the VDC was 4944 with population growth rate of 2.42. There are 953 households in the VDC with average household size of 5.2. In the district, 89 % of total household are dependent on agricultural activity, however, only 65% of total households have sufficient food from their farm land. The major crops of the districts are rice paddy, maize, millet, wheat, barley and buckwheat. Besides crop production, the local people are dependent on the rearing of livestock and forest- based activities. NAF (Nepal Agroforestry Foundation) has been working in the study area to promote agroforestry through different user groups since 1999. NAF has introduced exotic fodder trees Ipil ipil (*Leucaena leucocephala* and *L. diversifolia*), Calliandra (*Calliandra calothyrsus*), Bhatmase (*Flemingia congesta*), Stylo (*Stylosanthes guianensis*) during the period.

## 2.2 Research Methodology

The study contains two research papers, one in the field of biophysical studies (Paper 1) and other in the field of socioeconomic (Paper 2). The study was carried out using both qualitative and quantitative research methods.

**For biophysical study** (Paper 1), Soil samples were randomly collected from *bari* land (upland terrace) under NAF project households (Improved Agroforestry), without project households (Traditional Agroforestry), and forest land in four replications. Soil samples were collected from each 0-15, 15-30, 30-60 and 60-100 cm depths at all replicates by using a soil core.

Soil organic carbon (SOC) in the soil samples was determined by dry combustion method (Nelson *et al*., 1982). The soil pH was determined with pH meter (McLean, 1982), Total Nitrogen by Kjeldahl Method (Bremner *et al*.,1986), available Phosphorous by Olsen Method (Olsen *et al*., 1982), available Potassium by Atomic Absorption Method (Thomas 1986). Soil carbon stock was calculated by using the equation given by Pearson *et al.,* (2007). Soil data were analyzed using Microsoft Excel and Minitab. ANOVA and comparison of means were used for comparing the results of three land-use systems.

**For socioeconomic Study** (Paper 2), three wards (2, 4 and 6), the smallest administrative units that contain different villages and settlements of Dhaibung VDC were selected through purposive sampling. Thirty percent of households from both project and without project areas were selected randomly for a questionnaire survey. The recorded data were analyzed using Microsoft Excel and SPSS.

# 3. Result and Discussion

### 3.1 Paper 1:

Soil from all depths in the three land-use areas collected was slightly acidic in nature, with pH values ranging from 6.11 to 6.30. The bulk density in upper two depths (0-15 and 15-30 cm) was higher in the TA (1.44 and1.49 mg/cc), followed by IA (1.35 and 1.41 mg/cc), and forest land (1.32 and 1.47 mg/cc).There was gradual decrease in SOC with depth in all land-use areas. The average value of SOC of forest land (2.8±0.35 %) was significantly ($p<0.05$) higher than TA land (1.60± 0.22%) but there was no significant difference with IA(1.86±0.30%). SOC present at surface layer (0-15cm) of IA soil (2.49%) was higher than *bari* land (2.05 %) of Mardi watershed (Awasthi et. al., 2005). This reveals that there was more supply of organic matter from FYM (Farm Yard Manure) and leaf-litter fall in the surface layer of IA than other land-use areas. The forest soil had significantly higher ($p<0.05$) average nitrogen than IA and TA soil. The IA soil had average higher value of N and K than TA soil. This could be due to increased addition of organic matter from agroforestry which enhances soil microbial population and maintain nitrogen cycle in the soil (Araujo *et al*., 2012).

Highest value of carbon stock was recorded in forest land 36.31 kgC/m$^2$ followed by IA 24.41 kgC/m$^2$ and TA 20.89 kgC/m$^2$. Lower value of carbon stocks in agricultural land (IA and TA) than forest land could be due to high soil organic matter decomposition rate because exposure of soil and higher temperature that decreases soil organic carbon (Awasthi *et al*.,2005). Similarly, carbon stocks in surface layer (0-15cm) of IA was also higher than carbon storage in the surface layer (0-15) of the rice–wheat (30 Mg/ha) and maize–potato (20 Mg/ha) cropping systems in Mid-hill region of Nepal (Shrestha *et al*., 2006).

IA soil had 35.2 ton/ha more carbon than the TA. Benefits from the agroforestry to farmers was easy accessibility of fodder and fuel wood. There were no any other apparent monetary benefits from agroforestry to farmers. Considering the carbon rate of 12USD/ton (Pandit *et al*., 2012), famers adopting improved agroforestry would receive 422.4 USD per hector more than farmers practicing traditional agroforestry. The aboveground carbon from same area was found 78.02 ton/ha (Pandit *et al*., 2012). The total carbon stocks (aboveground and belowground) in the IA could be 332.6 ton/ha.

**3.2 Paper 2:**

It was found that all people residing in both areas (project and without project) had been practicing traditional agroforestry for the purpose of obtaining fodder and fuel-wood for a long time. Improved agroforestry with some exotic fodder trees was introduced by NAF in 1999. NAF started the work by creating different user groups and provided training to farmers on nursery management and promotion of agroforestry. The project households were actively practicing improved agroforestry for the purpose of producing more fodder. The major reason for adoption of agroforestry was to increase livestock production through producing more fodder in both households.

The number of agroforestry species and total number of plants were significantly higher ($p<0.001$) in improved agroforestry households than without project area because of higher landholding size and effort of NAF. The most common fodder species used in the Mid-hill area of Nepal, *litsea monopetala* (Kutmiro), was distributed in more than 93% households in both areas. In 1999, NAF had introduced four fodder species (*Leucanena leucocephala*, *Flemingia congesta*, *Morus alba*, and *Bauhinia purpurea*) in the project areas. These species *Leucanena leucocephala*, *Flemingia congesta*, *Morus alba*, and *Bauhinia purpurea* and *Thysanolaena maxima* were also found in 33%, 7%, 76% and 81% in without project households respectively. This showed that the adoption of improved agroforestry in the area was due to understanding its importance.

The adoption of agroforestry increased the income of local people through producing more livestock. Eighty-nine percent of project households and 68% of without project households reported an increase in agricultural income after adopting agroforestry. *Bari* land of project area was more productive than without project area due to adoption of improved agroforestry which provides green manure, supports more livestock, and maintains the nutrient cycle. The livestock unit of project households was 2.95, while that of without project households was 2.36. The higher value livestock unit in project households was because the farmers were able to produce more fodder by practicing improved agroforestry.

Mostly, people of both project and without project area collected fuel-wood and fodder from their farm land, and if this was determined to be insufficient, the lacking amount was collected from the community forest or buying from households which had surplus fodder and fuel-wood.

Improved agroforestry had made possible a greater availability in fodder and fuel wood supply. In the project area, more than 75 % of household had sufficient fodder and fuel-wood from their farmland, but in without project area only 43% of households had sufficient fodder and fuel-wood from their farm land. This proves that the practice of agroforestry had a pronounced impact on fodder availability in project areas. There were a very few 4% household that had sufficient fodder and fuel-wood for less than a 6 month period in the project areas. The annual agricultural income of the project households was significantly ($p<0.05$) greater than the without project households. The major portion of agricultural income was produced from livestock production, which was significantly ($p<0.1$) higher in the project area.

# 4. Conclusion and Recommendation

There was slightly acidic soil in all three land-use systems because of input of organic matter. Improved agroforestry soil had higher SOC than traditional agroforestry in all depths because of a continuous supply of organic matter in the form of leaf litter from agroforestry. The average value of SOC was significantly higher in forest land than TA, but there was no difference with IA. This reveals that the practice of improved agroforestry has the capacity to improve SOC more than traditional agroforestry. The soil of improved agroforestry was richer in N and K than traditional agroforestry due to maintaining nutrient cycle in soil. Improved agroforestry had more carbon stocks than traditional agroforestry because of a continuous supply of organic matter from agroforestry and FYM. The households practicing improved agroforestry would receive \$422.40 USD per hector more than traditional agroforestry through carbon trading. Similarly, NAF project households practicing improved agroforestry were also receiving other socio-economic benefits.

The number of trees and agroforestry species were found to be different between project and without project households because of higher land holding size and the efforts of NAF. It was found that agroforestry had made a pronounced effect on the fodder availability in the area. The major goal of the farmers to practice agroforestry was to increase livestock production, a major economic activity in the study area, through producing more fodder from their farm land. Thus, common fodder species were frequently distributed in both project and without project areas. The implementation of agroforestry has had a positive effect on the crop production, but the crop production only represent less than 3% of total agricultural income. The income from sale of forest product (fodder, fuel-wood, and timber) also contributes for a tiny fraction of total income. The famers were getting limited monetary benefits from agroforestry, except producing fodder for livestock. Therefore, the livelihood of farmers in the Mid-hill region of Nepal practicing subsistence agricultural with agroforestry could be improved through introducing multipurpose tree species.

The following factors should be considered for improvement of soil carbon sequestration rate and livelihood improvement through promotion of agroforestry.

- The work on soil carbon stocks measurement needs to be taken in several locations

- Periodic measurement of carbon stocks should be conducted to get the financial benefits from carbon trading,
- Both governmental and private sectors should contribute for the promotion of agroforestry through providing different types of exotic species,
- Agroforestry species having multiple benefits should be planted for livelihood improvement of the farmers.

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## Part 2: Research Papers

Paper 1: Soil Carbon Stocks as Influenced by Agroforestry System in the Mid-hills of Nepal

Paper 2: Local Livelihood As Influenced by Agroforestry System in the Mid-hills of Nepal

# Paper 1:

# Soil Carbon Stocks as Influenced by Agroforestry System in the Mid-hills of Nepal

## Abstract

*Agroforestry land management systems that integrate trees, crops and livestock have potential impact on soil carbon sequestration. The farmers of Mid-hills of Nepal have been practicing traditional agroforestry for millennia for the purpose of fodder and fuelwood production. The study was focused on the impact of agroforestry on soil carbon sequestration in an NAF project area in the Mid-hills of Nepal. For this study, soil samples were collected from three land use systems; Improved Agroforestry (IA), Traditional Agroforestry (TA), and Forest land in four replicas. Soil samples were collected from 0-15, 15-30, 30-60 and 60-100 cm depths at all replicas using a soil core. Physical and chemical soil properties (pH, Bulk density, SOC, Texture, NPK) were also measured at all depths. Soil organic carbon of improved agroforestry was not significantly different with forest land, however the SOC of traditional agroforestry was significantly ($p<0.05$) lower than forest land. Soil carbon stock in the soil profile (1 m depth) was higher in forest land followed by improved agroforestry and traditional agroforestry.*

# 1. Introduction

Soil carbon stocks are changed by anthropogenic activities like land use change, deforestation and shift in different components of the biogeochemical cycle (IPCC, 2000). There is 434 billion $m^3$ of forest area covering 30% of the total landmass of world and store 283 Gigatonnes (Gt) of carbon (FAO, 2006). Worldwide, the forestry sector contributes for the 17.4% of total green houses gas emissions (IPCC, 2007). Hence, forest management is one major tool for decreasing the atmospheric $CO_2$ gas concentration through increasing the carbon sequestration rate (Lal, 2005). Global implementation of agroforestry could remove significant amount (1.1-2.2 Pg) of carbon over the next 50 year cycle (Albrecht *et al*., 2003). The average carbon sequestration rate of the agroforestry is 0.2-3.1 t C/ha (Waston *et al*., 2000, cited in Pandey, 2002).

Carbon sequestration rate of soil depends upon the input of dead organic matter provided by plants, soil properties such as structures and their aggregations, and climate (Lal, 2004). An agroforestry system that combines trees and shrubs with crops and livestock enhances organic carbon accumulation in soils by providing continuous supply of organic matter, and increases soil microorganisms by which the nutrient cycle is preserved (Araujo *et al*., 2011). Agroforestry adoption supports more earthworm population in soil and maintain higher SOC than other land use systems (Bhadauria *et al.*,2012). Soil carbon stock under an agroforestry system is higher because of input of carbon through litter fall and greater root biomass (Benbi *et al*., 2011). Hence, the practical use of agroforestry may be one possible option for mitigating emission from land use change through reducing soil degradation (Albrecht *et al*., 2003).

In the Mid-hills of Nepal, soil erosion and fuel wood consumption are major issues for the emission of carbon (Upadhyay *et al.* 2005). Deforestation, land use changes, and forest degradation are the major factors that are decreasing the soil organic carbon of watershed of the Hindu Kush Himalayan Region. Studies revealed that there was a 29% and a 7% loss in soil organic carbon in Mardi and Fewa Watershed of Nepal respectively in the past 18 years due to the land use change (Sitaula *et al.,* 2004). It is estimated that $1.47 \times 10^6$ Mg year$^{-1}$ emission of carbon in Nepal in 1994 due to fuel wood consumption, soil erosion, and decrease in plant biomass (Upadhyay *et al.,* 2005). In the agricultural lands of Mid-hill of Nepal, soil organic carbon was low in vegetable-based cropping patterns compared to the cereal-based maize– millet system because of intensity of cultivation, tillage and application of chemical fertilizer (Tiwari *et al*., 2008). Similarly, the forest degradation and loss of crop residue are responsible for the loss of carbon in forest and agricultural land (Shrestha *et al.*, 2009).

In Nepal, farmers are highly dependent on the resources of the forest to fulfill their subsistence needs like timber, fuel wood and fodder. Nepalese people have been practicing Agroforestry for literally millennia. However, improved agroforestry with exotic species is a relatively new practice (Neupane *et al*., 2002). The community forest management system has encouraged the trend of growing trees on farm land because of limited access to the natural forest (Adhikari *et al.,* 2007). Nepal has insufficient industrial emission of green house gases, but the forest degradation and land use change are issues contributing to green house gas emission. There was limited research in the field of forest and soil carbon sequestration [Upadhyay *et al.* (2005), Sitaula *et al.* (2004), Awasthi *et al.*, (2005), Shrestha *et al.*, (2007), Yang *et al*, 2004].These studies did not address the potential of agroforestry in carbon sequestration. The induction of an agroforestry system may be one possible option to preserve forest biomes and increase carbon sequestration rate, improve livelihood of farmers by fulfilling subsistence needs, and maintain land productivity.

The general objective is to study the contribution of agroforestry on carbon stocks in the Mid-hills of Nepal. The specific objective of the research work was to

i) to quantify and compare soil physical and chemical parameter (pH, Bulk Density, SOC%, NPK and texture) under existing landuse ( Traditional Agroforestry, Improved Agroforestry and forest).

ii) to quantify and compare carbon stocks under existing landuse ( Traditional agroforestry, Improved Agroforestry and Forest).

iii) to estimate potential carbon benefit in economic term.

# 2. Methodology

## 2.1 Study area:

The study area is located in Dhaibung village development committee (VDC) of Rasuwa district of Central Development Region of Nepal. This district is rich in natural resources such as forests, rivers and a large area (1,710 $km^2$) is protected and preserved as the Langtang National Park. It is located at latitude of $28^o10'0$ N and longitude of $85^o19'60$ E. The district lies on tropical to temperate climate zone and average precipitation is 691.7 mm per annum.

There are nine administrative units, called wards, in the VDC which contain different villages and settlements. According to National Censes (CBS, 2001), total population of the VDC was 4944 with population growth rate of 2.42. There were 953 households in the VDC with an average household size of 5.2. In the district 89 % of the total households are dependent on agricultural production, however, only 65% of total households have a sufficient food supply from their farm land (BOS, 2007). The major crops of the districts are paddy (*Oryza sativa*), maize (*Zea mays*), millet (*Pennisetum glaucum*), wheat (*Triticum*), barley (*Hordeum vulgare*) and buckwheat (*Fagopyrum esculentum*). Besides crop production, the local people are dependent upon the rearing of livestock and the use of forest based resources for capital gain.

NAF (Nepal Agroforestry Foundation) has been working in the study area to promote agroforestry through different user groups since 1999. NAF has introduced exotic fodder trees namely Ipil ipil (*Leucaena leucocephala* and *L. diversifolia*), Calliandra (*Calliandra calothyrsus*), Bhatmase (*Flemingia congesta*), stylo (*Stylosanthes guianensis*) during this period.

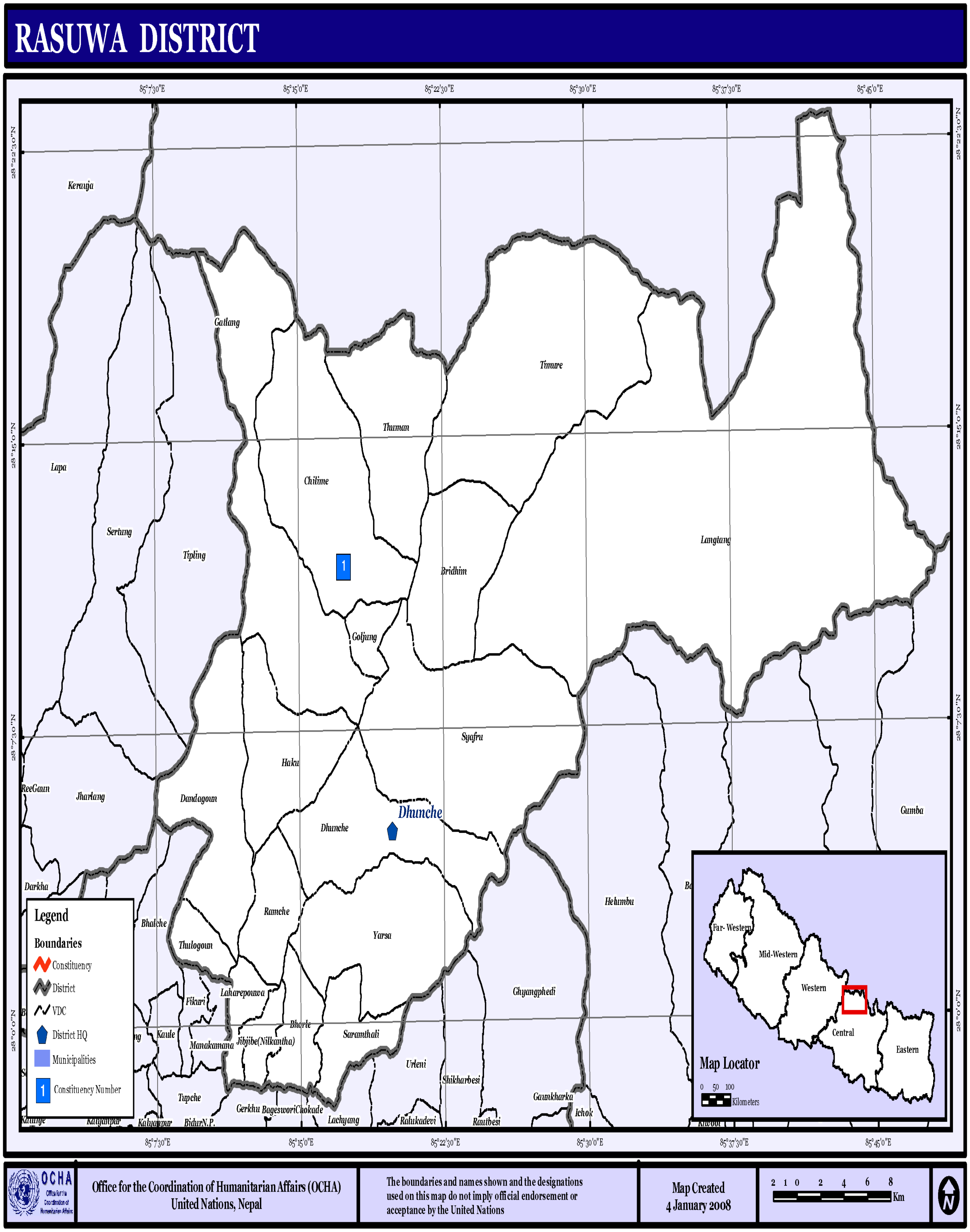



Fig 1: Map of Study Area (Source: UN, 2008)

**Traditional Agroforestry (TA)**:

The land owned by the farmers that were not member of the NAF project. However, they were practicing agroforestry by planting traditional forest trees since early human civilization for purposes of growing fodder and fuel-wood. The cropping pattern on these lands was maize-millet with tress plantation on terraces wall.

**Fig 2: Traditional Agroforestry**

**Improved Agroforestry (IA)**:

The land owned by the farmers that were members of NAF project and practicing improved agroforestry with planting exotic species like Ipil ipil (*Leucaena leucocephala* and *L. diversifolia*), Calliandra (*Calliandra calothyrsus*), Bhatmase (*Flemingia congesta*), Kimbu *(Morus alba)* and Taki (*Bauhinia purpurea*).They were getting technical training and agroforestry species from NAF. The cropping pattern of these lands was also maize-millet with tress plantation on terraces wall.

**Fig 3: Improved Agroforestry**

**Forest land**: The community forest named Niglini Pakha Community forest managed by the local people since 2005. It is situated in near the settlement. Local people usually collect fodder and fuel wood from the forest. The type of forest was Schima-Castanopsis forest with major vegetation *Castanopsis indica , Schima wallichii, Alnus nepalensis*, *Albizzia sps etc.*

**Fig 4: Forest Land**

## 2.2 Sampling

Soil samples were randomly collected from *bari* land (upland terrace) under NAF project households (Improved Agroforestry), without project households (Traditional Agroforestry) and Forest land in four replications. Soil samples were collected from each 0-15, 15-30, 30-60 and 60-100 cm depths at all replicates using soil core.

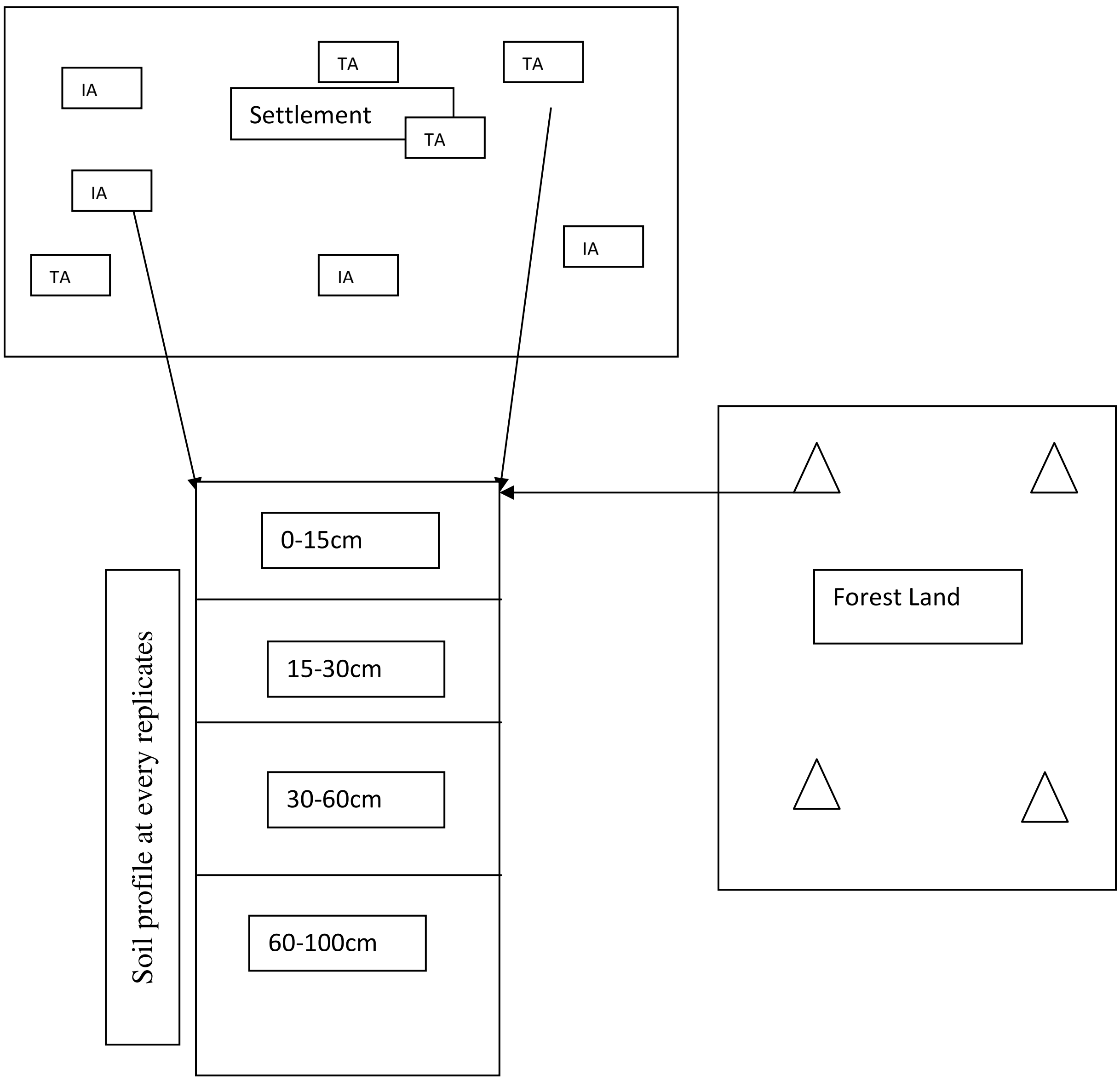



**Fig 5: Soil sampling strategy under IA, TA and Forest Land**

## 2.3 Soil Analysis

Soil Bulk Density was determined using core sampling method (Blake *et al*., 1986).The wet weight of the soil sample was obtained by using a soil core in the field. After that, soil samples were placed in pre- weighted sample bag. The soil samples were placed in the oven at 105$^{o}$C for 48 hours. The dried soil was sieved through a 2 mm sieve.

Soil organic carbon (SOC) in the soil samples was determined by dry combustion method (Nelson *et al.,*1982). The soil pH was determined with pH meter (McLean, 1982). Soil Texture was determined by Hydrometer Method. Total Nitrogen by Kjeldahl Method (Bremner *et al*.,1986), available Phosphorous by Olsen Method (Olsen *et al.,* 1982), available Potassium by Atomic Absorption Method (Thomas, 1986).

## 2.4 Soil Carbon Stocks

Soil carbon stock was calculated by using the equation given by Pearson *et al.,* (2007).

C (t / ha) = soil bulk density, (g / cm$^3$ ) × soil depth (cm) × % C

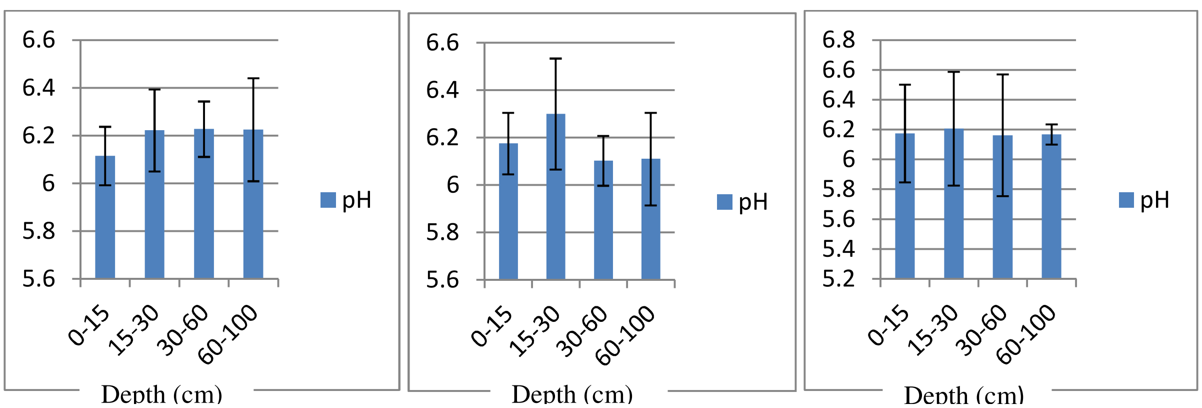
## 2.5 Statistical Analysis

Soil data were analyzed using Microsoft Excel and Minitab. ANOVA and comparison of means were used for comparing the results of three land use systems.

## 3. Result and Discussion

### 3.1. Soil Chemical and Physical Properties

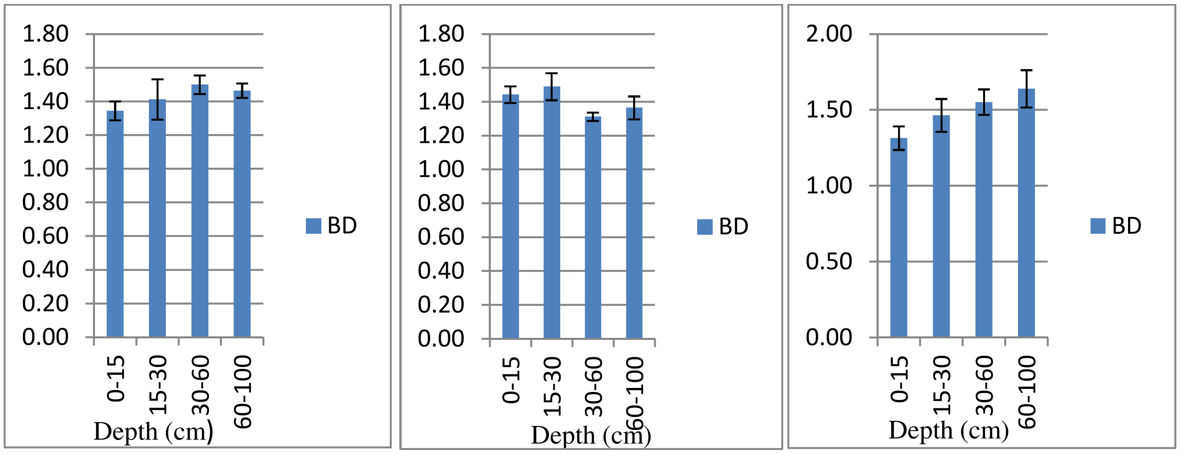
Soil in all depths in the three landuse used was slightly acidic in nature with pH value ranged from 6.11 to 6.30. The average value of soil pH of IA (6.27±0.28) was higher than forest (pH 6.19±0.29) and TA (pH 6.17±0.16). There was no significant difference in pH in different depths and land use system. Research showed that soil pH of agricultural land (Upland terraces) in the Mid-hill region of Nepal was found to be moderately to highly acidic (Desbiez *et al*., 2003, Awasthi *et al*., 2005). The less acidic soil pH might be related to greater input of organic matter in our study site. Input of organic matter on soil increases the soil pH by formation of carbon through microbial decomposition (Yan *et al*., 1996).




(IA) (TA) (Forest)

Fig 6: Variation of soil pH with depth in different land use systems

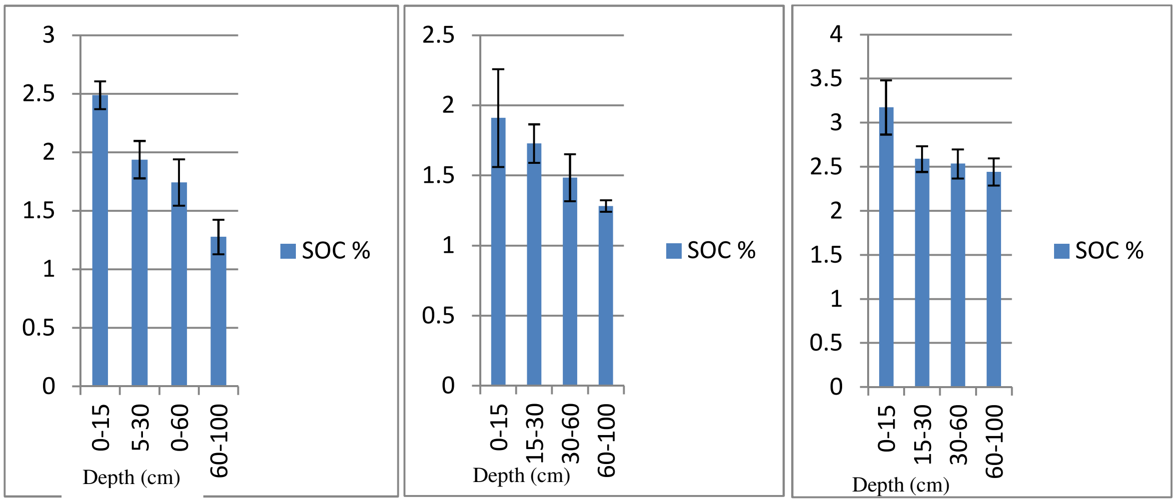
The gradual increase of bulk density with depth was found in IA and forestry land, but this trend was not observed in TA land (Fig-7). The bulk density in the upper two depths (0-15 and 15-30 cm) was higher in the TA (1.44±0.09 and1.49 ±0.16 mg/cc) followed by IA (1.35±0.11 and 1.41±0.23 mg/cc) and forest land (1.32±0.19 and 1.47±0.27 mg/cc). Less turnover of SOC in agricultural land could increase the soil bulk density in the shallow layers of soil, but there was no effect in the deeper zones (Grant *et al*., 1993). In the two lower depths of 30-60 and 60-100, bulk density was higher in forest land (1.55±0.21 and 1.64±0.30 mg/cc), followed by IA (1.50±0.11 and 1.47±0.11 mg/cc) and TA (1.31±0.06 and 1.37±0.17 mg/cc). The distribution of plant root systems in the deeper layer may have contributed to observed bulk density values under forest land. The agricultural activity increases the bulk density due to more tillage and low input of litter fall however, the bulk density in these three land use systems was not significantly different.




(IA) (TA) (Forest)

Fig 7: Variation of bulk density (mg/cc) in different land use system

There was a gradual decrease in SOC with depth in all land use patterns. The improved agroforestry had a higher value of SOC than TA in all depths. Households practicing improved agroforestry could have a higher number of trees and livestock population than traditional because there would be a higher supply of organic matter. These households were receiving training on agroforestry and nursery management as well as receiving new varieties of exotic fodder species(*Leucanena leucocephala*, *Flemingia congesta*, *Morus alba*, and *Bauhinia purpurea*, *Thysanolaena maxima and litsea monopetala)* from NAF. The SOC present in surface layer (0-15 cm) of IA soil (2.49±0.11) was higher than *bari* land (2.05 %) of Mardi watershed (Awasthi *et al*., 2005). This reveals that there was an increased supply of organic matter from FYM and leaf litter fall from agroforestry than that of other land use. The average value of SOC of forest land (2.8±0.35 %) was significantly ($p<0.05$) higher than TA land (1.60± 0.22%), but there was no significant difference with IA (1.86±0.30%). Research from the Mid-hills of Nepal proves that the forest soil had higher average SOC (3%) than *bari* land (2.5%) (Shrestha *et al*., 2004 ). Similarly, a research from the hills of India shows that the SOC of agroforestry was significantly higher than maize-wheat system followed rice-wheat system (Benbi *et al*., 2011).




(IA) (TA) (Forest)

Fig 8: Variation of mean SOC (%) with depth under different land use system

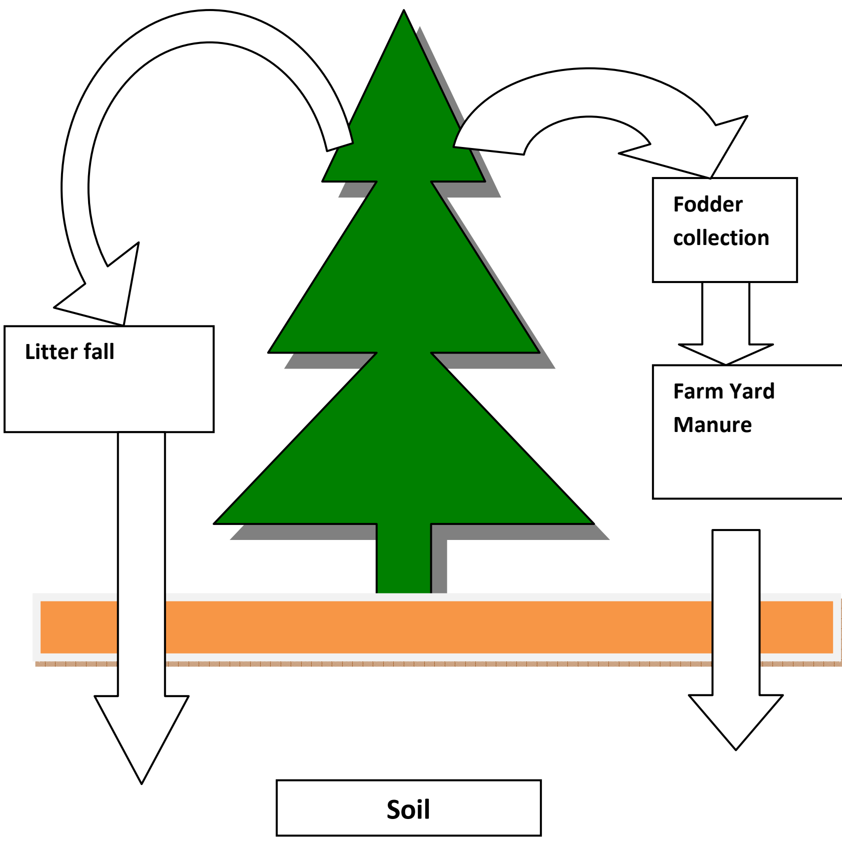



Fig 9: Process of supply of organic matter in soil from Agroforestry

There was gradual increase in clay percent with depth in IA and TA land, but in forest land there was a slight decrease in 30-60 cm and an increase in 60 to 100 cm (Fig-10). In IA, clay percent in all depths 0-15, 15-30, 30-60 and 60-100 was higher than TA followed by forest land, but the sand percent was the lowest in IA than TA followed by forest land. There was gradual decrease in the sand percent with depth in all three land use up to 30-60 cm, after that there was a slight increase. Silt percent in IA land was higher than TA land at all depths except 15-30 cm, but was lower than forest land. The sand and silt percent were higher in the forest land in all depths. In all land use systems, the highest value of silt percent was recorded in depth 30 to 60cm. The difference in sand, silt and clay in different sites is primarily due to different degrees of pedogenic processes as influenced by microclimate, vegetation, and other soil forming factors and processes.

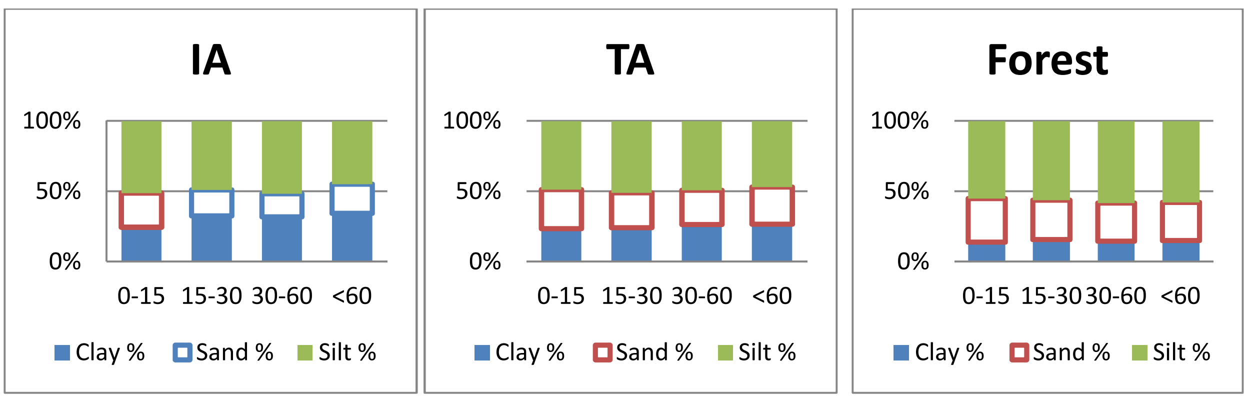



Fig 10: Texture Distribution in three land use systems

The forest soil had a significantly higher ($p<0.05$) average percentage of nitrogen than IA and TA soil (Table 1). In natural conditions, soil nitrogen is balanced by nutrient cycling thereby increasing the value of nitrogen in the forest land. The IA soil had significantly higher ($p<0.05$) average value of N and K than TA soil. This could be due to increased addition of organic matter from IA that enhances soil microbial population, which is responsible for maintaining nitrogen cycle in the soil (Araujo *et al*., 2011). Similarly, the use of FYM (Farm Yard Manure) increases the soil N (Regmi *et al*., 2002). Average value of Phosphorous is significantly higher ($p<0.05$) in TA than IA and forest soil.

Table1: Soil nutrient (N, P and K) in different land use system (mean±SD).

| Landuse | Depth | IA | TA | Forest |
|---|---|---|---|---|
| **N(%)** | 0-15 | 0.16±0.08 | 0.12±0.099 | 0.19±0.09 |
| | 15-30 | 0.09±0.05 | 0.07±0.04 | 0.17±0.11 |
| | 30-60 | 0.08±0.05 | 0.04±0.01 | 0.18±0.09 |
| | 60-100 | 0.06±0.3 | 0.04±0.02 | 0.18±0.08 |
| | | | | |
| **P(ppm)** | 0-15 | 30.90±9.73 | 36.08±5.76 | 26.95±2.45 |
| | 15-30 | 17.85±3.93 | 29.68±4.78 | 30.20±4.58 |
| | 30-60 | 15.88±4.17 | 30.18±3.15 | 27.68±5.11 |
| | 60-100 | 17.78±5.09 | 35.25±6.31 | 25.73±2.97 |
| | | | | |
| **K(%ppm)** | 0-15 | 110.91±38.19 | 82.14±18.17 | 72.26±14.75 |
| | 15-30 | 79.62±22.74 | 54.24±11.21 | 62.95±15.16 |
| | 30-60 | 89.29±33.66 | 50.03±15.93 | 56.32±6.62 |
| | 60-100 | 83.74±31.57 | 58.31±19.85 | 63.89±16.61 |

## 3.2 Comparison of soil carbon stocks under different land use systems

The highest value of carbon stock was recorded in forest land 36.31 kgC/m$^2$ followed by IA 24.41 kgC/m$^2$ and TA 20.89 kgC/m$^2$. Soil carbon stocks in the 60 cm soil profile was 27.4 MgC/ha under an Agrisilviculture system in place for five years in Chhattisgarh, Central India (Swamy *et al*., 2005,cited in Nair *et al*., 2009). Similarly, a silvopastural system in place for ten to sixteen years in Pocora, Atlantic coast, Costa Rica, soil carbon stock was 173 MgC/ha (Amezquita *et al*., 2005, cited in Nair *et al*.,2009). The soil carbon stock of the study area was found to be higher than in the other agroforestry system. This could be due to the establishment of a long term practice of an agroforestry system in the study area.

Lower value of carbon stocks in agricultural land (IA and TA) than forest land could be due to high soil organic matter decomposition rate because of exposure of soil and higher temperature that decrease soil organic carbon (Awasthi *et al*.,2005). IA soil had higher value of carbon stocks than traditional agroforestry because of supply of more FYM and litter fall from trees. The soil carbon is affected by the addition of FYM and cropping pattern (Shrestha *et al*., 2006). Similarly, carbon stocks in the surface layer (0-15cm) of IA and TA was also higher than carbon storage in surface layer (0-15) of the rice–wheat (30 Mg/ha) and maize–potato (20 Mg/ha) cropping systems in mid-hill of Nepal (Shrestha *et al*., 2006). There was a higher value of carbon stocks in the IA soil than TA soil in all depths (Table 2). IA had 3.52 kgC/m$^2$ more carbon than the TA land. This data reveals that improved agroforestry has the potential to increase carbon stocks when a well managed agroforestry system is introduced and sustained. In the depth 30-60 cm, there was 57 % more carbon in IA than TA because of the supplication of organic matter to the soil through root biomass. The literature shows that the carbon stocks under *bari* land in Mid-hill of Nepal was 16.05 kgC/m$^2$ (Shrestha *et al*., 2004). There was more carbon in the study IA area than that of the other agricultural land.

Table 2: Carbon Stocks kgC/m$^2$ in different land use system

| Depth | IA | TA | Forestry | Carbon gain (IA-TA) |
|---|---|---|---|---|
| **0-15** | 5.02±0.62 | 4.15±1.63 | 6.32±1.92 | 0.87 |
| **15-30** | 4.08±0.91 | 3.90±1.03 | 5.72±1.38 | 0.18 |
| **30-60** | 7.88±2.07 | 5.86±1.43 | 11.91±2.89 | 2.02 |
| **<60** | 7.44±1.48 | 6.99±0.81 | 13.46±1.70 | 0.45 |

## 3.3 Carbon Benefit

IA soil had 35.2 tonC/ha more carbon than the TA. Considering the carbon rate of 12USD/ton (Pandit *et al*., 2012), famers adopting improved agroforestry would receive $422.40 USD per hector more than farmers practicing traditional agroforestry. The aboveground carbon from the same area was found 78.02 ton/ha (Pandit *et al*., 2012). The total carbon stocks (aboveground and belowground) in the IA could be 332.6 ton/ha. Continuous adoption of improved agroforestry could be one possible option for reducing greenhouse gases and implementation of REDD+ (Reducing Emissions from Deforestation and Forest Degradation, the role of conservation, Sustainable Management of Forests and Enhancement of forest carbon stocks in Developing Countries). Farmers could also receive financial benefits from REED+ through carbon trading which will help with livelihood development of the area.

## 4. Limitation of Study

The study was carried out for fulfillment of a Master's Degree, however there were some limitations due to time, distance, and resource availability. First of all, the research was carried out by taking four soil samples from each land use system. These sample sizes may not represent the spatial variability. In the Mid-hills of Nepal, altitudinal variation within a village or settlement could create different environmental niches which affect the physical and biological properties of soil. However, soil samples under IA and TA were collected from same wards to minimize this source of error. Furthermore, the litter fall from one land use system could spread over another due to wind and other environmental factors. Therefore, in order to generate the result, more replicate samples should have been collected to simulate the spatial variability of SOC.

## 5. Conclusion

There was slightly acidic soil in all three land use systems because of an input of organic matter. Improved agroforestry soil had higher SOC than traditional agroforestry in all depths, presumably because of a continuous supply of organic matter in the form of leaf litter from agroforestry. The average value of SOC was significantly higher in forest land than in that of traditional agroforestry .These results reveal that an improved agroforestry practice may have the capacity to improve SOC more than traditional agroforestry. The soil in the improved agroforestry areas were richer in N and K than that of the traditional agroforestry, apparently due to maintaining the nutrient cycle in soil. Improved agroforestry soil was rich in clay and silt percent, while TA had more sand. The samples of the surface soil layer under an improved agroforestry system had more carbon stocks than that of the other agricultural land of the Mid-hills of Nepal. It was determined that the practice of improved agroforestry had the potential to sequester more carbon when compared to traditional agroforestry implementations. The households which chose to embrace the practices of improved agroforestry would experience benefits from REDD+ in monetary terms.

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# Paper 2:
# Local Livelihood As Influenced by Agroforestry System in the Mid-Hills of Nepal

## Abstract

*Agroforestry land management systems that integrate trees, crops and livestock have multiple observable benefits to livelihood. The study was intended to illustrate the significance of the value of improved agroforestry with exotic fodder species on livelihood of farmer in the Mid-hills of Nepal. A total 86 households (58 from project households and 28 from without project households) were interviewed to collect information on existing agroforestry practice, crop and livestock production, and fodder and fuel-wood availability. Improved agroforestry was introduced by NAF in 1999. Before then, people were practicing the traditional method. The exotic fodder species Ipili-lipil (Leucanena leucocephala),Bhatmase (Flemingia congesta),Kimbu (Morus alba), and Taki (Bauhinia purpurea) introduced by NAF were frequently distributed in both NAF project and without project households. The project households had significantly higher numbers of trees and species than those in without project households. Improved agroforestry had a pronounced impact on fodder availability. Hence, there were only 4% of households that had sufficient fodder and fuel-wood for less than a 6 month period of time in the project area. Household income from crop and livestock production was higher in the project area that had been practicing improved agroforestry.*

## 1.1 Introduction

The agroforestry land management system is that which integrates trees and shrubs with crops and livestock, provides fodder, fuel-wood, and food to farmers (Smith *et al*., 2012). Agroforestry can be divided into three classes on the basis of types of components constituting agroforestry viz: (1) Agrisilvicultural (includes crops and trees), (2) Silvopastoral (includes pasture/grazing areas, animals and trees) and (3) Agrosilvopastoral (includes crops, pasture/grazing areas, animals, and trees) (Nair, 1993). On the basis of socioeconomic criteria such as production, level of technology input, and management, agroforestry can be classified as commercial, intermediate, and subsistence (Lundgren 1982, cited in Nair, 1993). In commercial agroforestry, the product is garnered with the intent of sale for profit. Intermediate agroforestry are those that are in between commercial and subsistence, and mostly focused on the production of cash crops for sale and subsistence crops to meet the family's needs. In subsistence agroforestry, production of food crops and animal- product supply is primarily for the purpose of meeting the farmer's household needs (Nair, 1993).

Livelihood is affected by the availability of employment, trading of goods, cost of labor, individual food and livestock production, cultivation or utilization of natural or common property resources (Adato et. al., 2003). Seventy to eighty percent of rural populations of developing countries depend up on the forest resources and subsistence agriculture for their livelihood (El-Lakany, 2004). The adoption of agroforestry increases crop production, income, savings, improves food supply and provides firewood and fodder (Akinnifesi *et al*., 2008). Tree-based agroforestry plans offer a tangible opportunity for rural development and enrichment through promoting agro industries and improves local economies by creating means of employment previously unavailable (Kumar *et al*., 2012). In Asia, the practice of agroforestry could be one possible option for providing food for the growing population and reducing adverse environmental problems like land degradation and climate change (Kumar, 2006). Hence, the adoption of agroforestry could have multi-fold benefits that improve local quality of life. The potential of agroforestry to have a positive effect on local livelihood is influenced by different socioeconomic factors like landholding size, gender, and the relative importance and value placed on agriculture in any given household (Garforth *et al*., 1999).

### 1.2 Agroforestry in Nepal

In Nepal, the Mid-hill farmers have been practicing some form of agroforestry for an almost incalculably long time. However, improved agroforestry with the induction of exotic species is a relatively new practice (Neupane *et al*., 2001). The agroforestry systems currently in place in the Mid-hill regions of Nepal are mainly associated with crop production, livestock rearing, and tree cultivation , and are classified as agrosilvopastoral (Regmi, 2003). In traditional agroforestry practices, farmers plant trees along the terrace walls of *bari* land (upland rainfed areas) and the land is generally used for cultivation of Maize and millet (Carter *et al*.1989). The Traditional agroforestry practice of growing trees and shrubs on farm land are used as sources of fuel-wood, fertilizer, fodder, and fruits, and are shown to be helpful for purposes of socioeconomic enrichment of the people (Thapa *et al*.,2000). Agroforestry provides wide range of forest products like fodder, fuelwood, timber and services like nutrient cycle, erosion control, maintain soil microorganisms, carbon sequestration. It also significantly contributes to rural livelihood improvement through making sustainable agriculture for future generations and by increasing annual household income (Regmi *et al*, 2010).

Livestock rearing is one major agricultural activity in Nepal. It contributes for 11% to GDP (FAO, 2005). 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 limited legal access to their natural forest and hence, the numbers of trees on farm land have been increasing (Adhikari *et al.,* 2007, Neupane *et al*.,2001 ). The increasing demand for fodder in the Mid-hill of Nepal can be addressed through the promotion of agroforestry (Thapa *et al*., 2000). The agroforestry practice is a contributing factor for reducing impact on the natural forest and maintaining agro-biodiversity. The number of tress and diversity of species on farm land depends up on socio-economic factors like land holding, livestock population, and land fragmentation (Acharya, 2006). It is also a practical solution for reducing soil erosion and runoff in upland areas. Agroforestry with the introduction of more multi-purpose tree species, specifically fruit trees and medicinal plants play an important role in the issue of addressing livelihood improvement (Fonzen *et al*., 1984). Recently, organizations like Nepal Agroforestry Foundation (NAF) are working for the promotion and popularization of agroforestry systems throughout the country.

Nepal Agroforestry Foundation is a non-governmental and non-profit organization established in 1991, and has been engaged in the promotion of agroforestry through introducing exotic fodder species in Mid-hill region of Nepal. In Rasuwa, NAF has been working since 1999 by forming different farmer's user groups. The members of these user groups have been actively practicing Improved Agroforestry with the adoption of exotic species and were considered "project" households. Simultaneously, the "without project" households (non-members of NAF user groups) have been practicing Traditional Agroforestry. NAF has been working for livelihood improvement of local farmers by implementing improved agroforestry methods previously shown to be successful.

The main objective of this study was to illustrate the significance of agroforestry in terms of its contribution on local farmer's livelihood. The specific objectives were:

- to study and compare existing agroforestry practice between households "with" and "without" improved agroforestry.
- to compare agricultural production (crop and livestock) between households "with" and "without" improved agroforestry.
- to compare fodder and fuelwood availability between households "with" and "without" improved agroforestry

## 2. Methodology

### 2.1 Study Area

The study area is located in Dhaibung village development committee (VDC) of Rasuwa district of Central Development Region of Nepal. The district is rich in natural resources such as forest, river and large area (1,710 $km^2$) protected and preserved as Langtang National Park. It is located at latitude of $28^o$10'0 N and longitude of $85^o$19'60 E. The district is situated on the temperate to alpine climate zone and average precipitation is 691.7 mm per year. There are nine administrative units- called wards- in the VDC which contain different villages and settlements. According to National Censes (CBS, 2001), total population of the VDC was 4944 with population growth rate of 2.42. There were 953 household in the VDC with average household size of 5.2. In the district 89 % of total household are dependent on the agricultural activity, however, only 65% of total households have had sufficient food from their farm land (BOS, 2007). The major crops of the districts are paddy (*Oryza sativa*), maize (*Zea mays*), millet (*Pennisetum glaucum*), wheat (*Triticum*), barley (*Hordeum vulgare*) and buckwheat (*Fagopyrum esculentum*). Besides crop production, the local people have been dependent on livestock rearing and their forest based income generating activities.

NAF (Nepal Agroforestry Foundation) has been working in the study area to promote agroforestry through different user groups since 1999. NAF has introduced exotic fodder trees Ipil ipil (*Leucaena leucocephala* and *L. diversifolia*), Calliandra (*Calliandra calothyrsus*), Bhatmase (*Flemingia congesta*), Stylo (*Stylosanthes guianensis*) during the period.

Table 1: Demography of study site

| Ward No | Total Population | Male | Female | Total Household | Household Size |
|---|---|---|---|---|---|
| 2 | 532 | 268 | 264 | 106 | 5.0 |
| 6 | 442 | 214 | 228 | 84 | 5.3 |
| 4 | 414 | 202 | 212 | 72 | 5.8 |

Source: CBS, 2001.

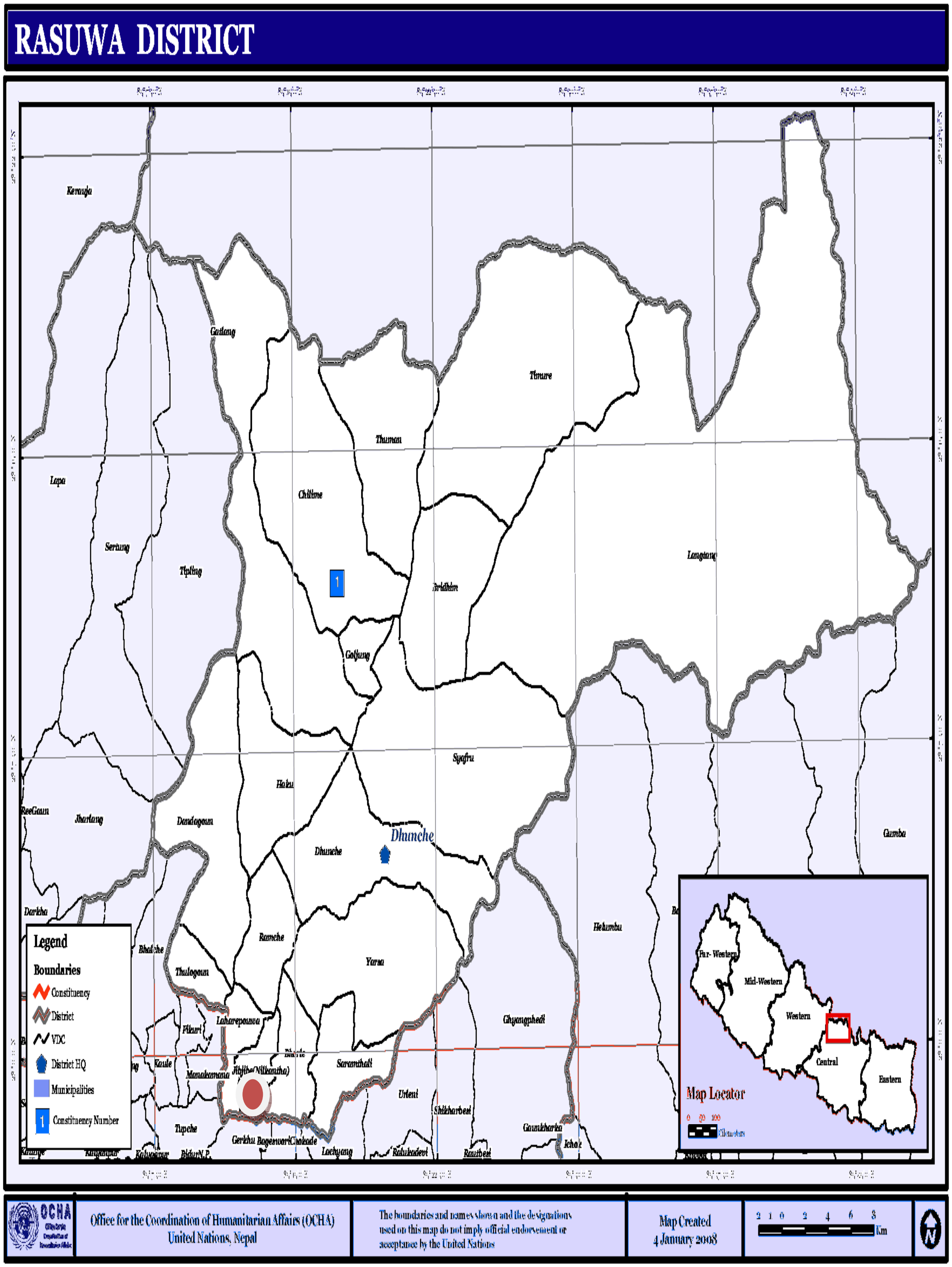


Fig 1: Map of Study Area (Source :UN, 2008)

## 2.2 Sampling and Data Collection:

Three wards; 2, 4, and 6, being the smallest administrative units that contain diverse villages and settlements, of Dhaibung VDC were selected through purposive sampling (Table 1). The selection of these three wards was based on the ability to cover both households from the NAF project area (improved agroforestry) and those from the without project area (traditional agroforestry) and to compare the results of the households with to those of the households without NAF project (Neupane *et al*., 2001). Thirty percent of households from project and without project area were selected randomly for a questionnaire survey. According to the NAF field office, there were 285 households in these three wards. Out of these there were 92 project households and 193 without project households. A total of 86 household were selected (28 from project area and 58 from without project area) for the questionnaire survey.

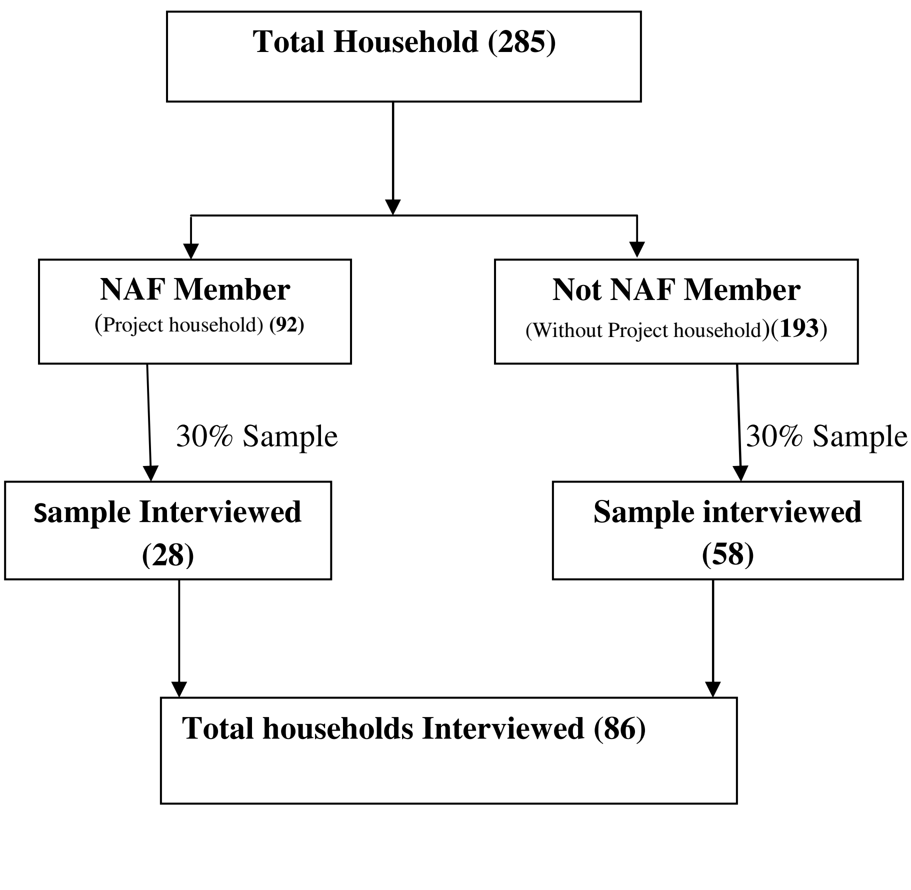


Fig 2: Sampling Procedure

## 2.3 Statistical Analysis

The data were analyzed using Microsoft Excel and SPSS . One way analysis of variance (ANOVA), mean comparison, and frequency distribution were used for comparing variables between "with project" and "without project" intervention.

## 3. Result and Discussion

### 3.1 Existing Agroforestry Practices

It was found that the majority of people residing in both areas (project and without project) had been practicing traditional agroforestry for fodder and fuel-wood to some extent. Furthermore, the adoption of agroforestry practices greatly increased after the establishment of Langtang National Park in 1973, mostly to prevent the grazing of domesticated animals in the wild uninhabited forest. It was also accelerated by changes in forest management regime (Community forest), that regulated the use of natural forest resources. On the other hand, farmers have been practicing agroforestry to fulfill their growing demand for fodder and fuel-wood in the midst of these changes. Improved agroforestry with exotic fodder trees was introduced by NAF in 1999. NAF started the work through establishing different user groups , providing training for farmers on nursery management, and initiated the promotion of agroforestry. These user groups have been actively practicing improved agroforestry by growing fodder species in terraced walls.

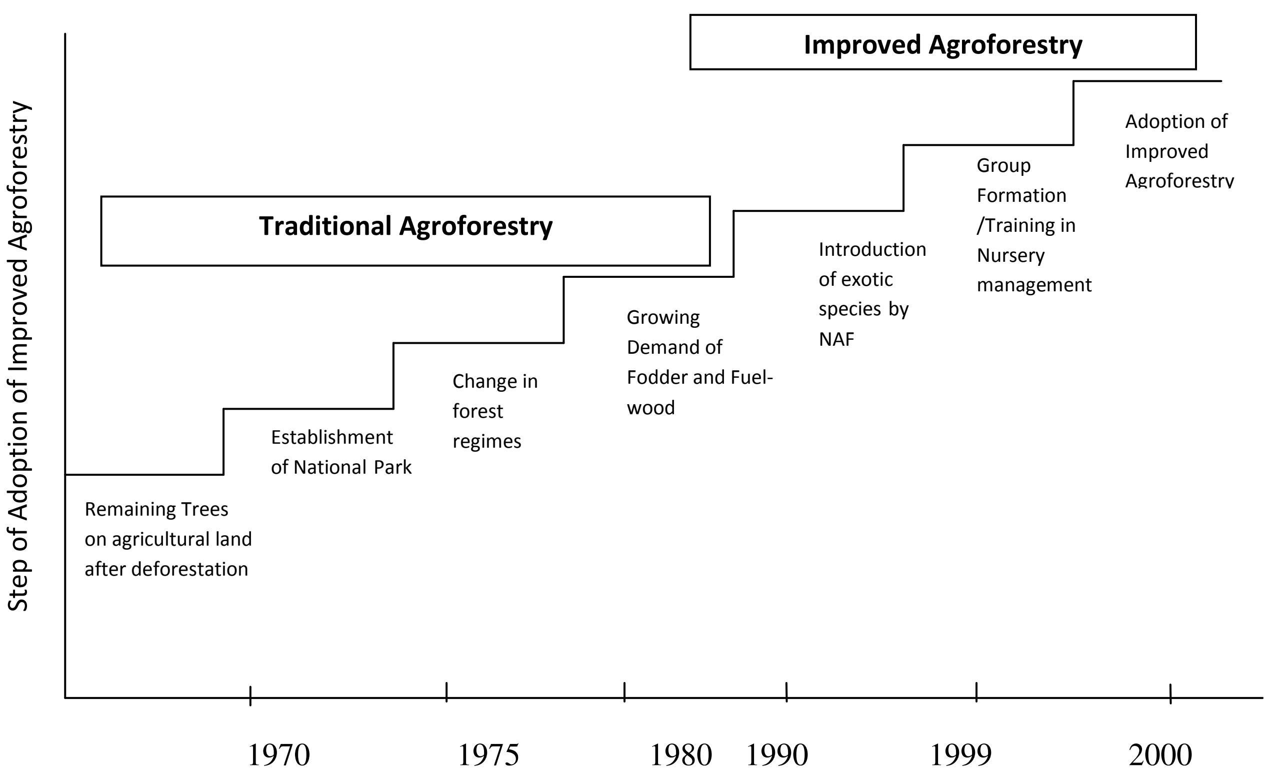


Fig 3: Steps of Adoptions of Improved Agroforestry (Modified from Raut *et al*., 2011)

Household size and number of females in household of project household was greater than without project household (Table 2). Similarly, in project household economically active population of age group between16 to 45 years of age was also higher.  The project household had significantly higher land holding size than without project household. Land holding under *bari* land was also significantly higher in the project households (Table 2). In the study area agroforestry species were mostly planted on the upland terraces (*bari* land) walls rather than *khet* land (Low land), because planting trees in walls (terrace raiser) of *khet* land would create a shadow for crop production. Due higher landholding size particularly *bari* land project households were actively practicing improved agroforestry for producing more fodder.

Table 2: Household Characteristics (Mean±SD)

| | With Project Households | Without Project Households | Significance |
|---|---|---|---|
| House hold size | 6±2.68 | 5±1.63 | 0.02** |
| Male in Household | 3±1.42 | 2±1.20 | 0.24 |
| Female in Household | 3±1.07 | 2±1.09 | 0.04** |
| Age group (0-15) | 1±1.5 | 2±1.14 | 0.29 |
| Age group (16-45) | 4±1.50 | 3±1.01 | 0.06*** |
| Age group (46-60) | 2±0.79 | 1±0.60 | 0.08*** |
| Age group (>60) | 1±0.62 | 1±0.65 | 0.88 |
| Total Land Holding Size(ha) | 0.79±0.38 | 0.55±0.35 | 0.01* |
| Bari Land (ha) | 0.40±0.20 | 0.25±0.25 | 0.45 |
| Khet (ha) | 0.35±0.21 | 0.30±0.16 | 0.03** |

*Significant at 1% level
**Significant at 5% level
*** Significant at 10% level

Seventy nine percent of households of both areas reported that they were practicing agroforestry for the purpose of livestock production (Table 3). Some of the responses from the without project area reported that they were practicing agroforestry because of less access to natural forest for collection of fodder and fuel wood. This is also one common reason of adoption of agroforestry in the Mid-hills of Nepal. However, no one from any of the project households cited this as a reason for adoption of agroforestry because people of project area were used to with the existing forest conservation rules and they believed that natural forest should be preserved for environmental protection. Farmers were also practicing agroforestry for soil conservation by reducing soil erosion and providing a continuous supply of organic matter from litter fall. The percent of households practicing agroforestry for the purpose of conserving soil nutrient content was double in project area (Table 3). Small numbers (7%) of households from project area were practicing agroforestry for the sole purpose of ecological benefit. It was observed that the households assigned to the project area had good knowledge about the myriad benefits of agroforestry such as increased self-sustenance by growing their own fodder, fuelwood and timber, soil conservation, and food production that they received during training from NAF.

Table 3: Reason for adoption of agroforestry

| Reason | With Project Households<br>N=28 | Without Project Households<br>N=58 |
|---|---|---|
| Less access to natural forest (%) | - | 14 |
| Increase livestock production providing fodder (%) | 79 | 79 |
| Maintaining soil nutrient (%) | 14 | 7 |
| Conserving forest for ecological benefit (%) | 7 | - |

### 3.2 Agroforestry Species

The number of agroforestry species and total number of the trees were significantly higher ($p<0.001$) in project households than those without project households (Table 4). This increase in the number of agroforestry species and in the total number of trees in the project area was not only due to the efforts of NAF, but also because of higher land area of the farmers. In the Mid-hill of Nepal, the number of agroforestry species depends upon the land's size due to the need of sufficient space for planting agroforestry (Acharya, 2006). In total 37 agroforestry species were recorded from the study area.

Table 4: Number of Agroforestry species and total trees (Mean±SD)

| | **With Project Household**<br><br>**N=28** | **Without Project Household**<br><br>**N=58** | **Significance** |
|---|---|---|---|
| Number of species Per household | 13±4 | 7±2 | 0.00* |
| Total number of Trees per household | 200±140 | 95±93 | 0.00* |

*Significant at 1% level
**Significant at 5% level
*** Significant at 10% level

The common fodder species mostly used in the Mid-hill area of Nepal, Kutmiro (*Litsea monopetala)* and Dar (*Boehmeria rugulosa*) were liberally and frequently distributed in more than 75% of households in both areas. This indicates that farmers were conscious of their future need for fodder to address the demand of an increasing livestock population. In 1999, NAF had introduced four fodder species; namely Ipil-lipil *(Leucanena leucocephala)*, Bhatmase *(Flemingia congesta)*, Kimbu *(Morus alba)*, Taki (*Bauhinia purpurea*) in the project area. Recently, NAF introduced one Non Timber Forest Product (NTFP) species namely Amriso (*Thysanolaena maxima*) in the area. These species, Bhatmase (*Flemingia congesta),* Ipil-lipil *(Leucanena leucocephala*, Kimbu *(Morus alba)*, and Taki *(Bauhinia purpurea)* and Amriso *(Thysanolaena maxima)* were also found in 7%, 33%, 76% and 81% in the without project households respectively (Table 5). It showed that the adoption of improved agroforestry is increasing. Neupane *et al*. (2001), reported 37% of NAF project household and 51% of without project households had adopted the exotic species introduced by NAF in Dhading district of the Mid-hill region of Nepal.

Table 5: Agroforestry species present in Household

| Local Name | Scientific name | Uses | With Project Households N=28 | Without Project Households N=58 |
|---|---|---|---|---|
| Kimbu | *Morus alba* | Fodder /Fuelwood | 96% | 76% |
| Amriso | *Thysanolaena maxima* | NTFP | 96% | 81% |
| Kutmiro | *Litsea monopetala* | Fodder | 93% | 95% |
| Dar | *Boehmeria rugulosa* | Fodder /Fuelwood | 86% | 76% |
| Amba | *Psidium guajava* | Fruit/Fuelwood | 82% | 45% |
| Bamboo | *Bambuseae* | Fuelwood | 75% | 36% |
| Sallo | *Pinus roxburghii* | Timber/ Fuelwood | 71% | 35% |
| Naspati | *Pyrus communis* | Fruit/Fuelwood | 71% | 28% |
| Ipil-lipil | *Leucanena leucocephala* | Fodder | 68% | 33% |
| Nibuwa | *Citrus aurantifolia* | Fruit/Fuelwood | 61% | 38% |
| Paiyun | *Prunus cerasoides* | Fodder /Fuelwood | 57% | 28% |
| Nimaro | *Ficus auriculata* | Fodder /Fuelwood | 54% | 12% |
| Gogan | *Saurauia napaulensis* | Fodder /Fuelwood | 39% | 10% |
| Khanayo | *Ficus cunia* | Fodder /Fuelwood | 36% | 35% |
| Bhatmase | *Flemingia congesta* | Fodder /Fuelwood | 32% | 7% |
| Khari | *Celtis australis* | Fodder /Fuelwood | 29% | 7% |
| Taki | *Bauhinia purpurea* | Fodder /Fuelwood | 29% | 9% |
| Kaiyo | *Ficus semicordata* | Fodder /Fuelwood | 21% | 7% |
| Katoos | *Castanopsis indica* | Fodder /Fuelwood | 21% | 2% |
| Karpro | *Ficus lacor* | Fodder /Fuelwood | 21% | 10% |
| Badhar | *Artocarpus lakoocha* | Fodder/ Fuelwood | 21% | 5% |
| Chilaune | *Schima wallichi* | Timber/ Fuelwood | 21% | 17% |
| Stylo | *Stylosanthes guianensis* | Timber/ Fuelwood | 18% | 5% |
| Kharseto | *Ficus hispida* | Timber/ Fuelwood | 18% | 5% |
| Dudhe | *Ficus hederacea* | Fodder/ Fuelwood | 11% | 0% |
| Gedule | *Ficus clavata* | Fodder/ Fuelwood | 11% | 7% |
| Kagati | *Phyllanthus emblica* | Fruit | 7% | 2% |
| Uttis | *Alnus nepalensis* | Timber/ Fuelwood | 7% | 3% |
| Siris | *Albizia procera* | Timber/ Fuelwood | 7% | 0% |
| Suntala | *Citrus nobilis* | Fruit | 4% | 2% |
| Siplikan | *Crataeva reliogiosa* | Fruit/Fuelwood | 4% | 0% |
| Sal | *Shorea robusta* | Fuelwood/ Timber | 4% | 0% |
| Nigalo | *Arundinaria intermedia* | Timber | 0% | 2% |
| Kathahar | *Artocarpus heterophyllus* | Fruit/Fuelwood | 0% | 2% |
| Chuletro | *Brassaiopsis hainla* | Fodder/ Fuelwood | 0% | 3% |
| Mango | *Mangifera indica* | Fruit/Fuelwood | 0% | 5% |

### 3.3 Agricultural Production

Eighty nine percent of project households and 68% of without project households reported an increase in agricultural income after adopting agroforestry. It was mainly due to increase in livestock production after adoption of agroforestry. In earlier times, farmers collected fodder from natural forest and allowed their livestock to graze in the forest. But after changes in forest regimes, these activities were limited which resulted in a reduced number of livestock. After the adoption of an agroforestry, the basic requirement for fodder was fulfilled and hence increased livestock production. Less than 5% of the households responded that the agricultural income was increased due to an increase in crop production through improving soil nutrient content by agroforestry (Table 6).

Table 6: Reason for increase in agricultural income

| | With Project<br>N=28 | Without Project<br>N=58 |
|---|---|---|
| Greater availability of forest product | - | 5% |
| Increased crop production | 4% | 2% |
| Increase in livestock production | 92% | 87% |
| Decrease in labour cost for forest product collection | 4% | 5% |

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#### 3.3.1. Crop Production

The cropping pattern of the *bari* land was Maize- Millet and in the *khet* was Rice-Maize in both project and without project areas. Millet and paddy yield was similar in both areas, but maize yield was significantly higher in project area than in the without project area (Table 7). Neupane *et al*. (2001) found that the crop yield of project households was more than without project households and most of the yield difference were in *bari* land. The farm yard manure made of green manure and animal dung was used more in agricultural land of project households than without project households (Table 7). Similarly, there was increased supply of organic matter from litter fall. Hence, the adoption of improved agroforestry practices provides green manure and maintains the nutrient cycle.

Table 7: Crop yield (kg/ha) per year and fertilizer use (Mean±SD)

| | **With Project Kg/Ha** | **Without Project (Kg/ha)** | **Significance** |
|---|---|---|---|
| Paddy | 2270±175 | 2210±113 | 0.22 |
| Maize | 2369±102 | 2206±97 | 0.06*** |
| Millet | 1661±152 | 1550±191 | 0.23 |
| **Use of fertilizer/household/year** | **Kg/ ha** | **Kg/ha** | **Significance** |
| DAP | 22±12 | 16±9 | 0.41 |
| Urea | 105±56 | 111±68 | 0.81 |
| Potash | 4±3 | 6±2 | 0.28 |
| Farm Yard Manure | 14750±845 | 10300±742 | 0.07*** |

*** Significant at 10% level

### 3.3.2 Livestock Production

The project and without project households were significantly different ($p<0.1$) in livestock units. The livestock unit of project households was 2.95 and without project households was 2.36. The higher value livestock units in project household was because the farmers were producing more fodder through practicing improved agroforestry as well as having more land. Moreover, there was higher household size, more females in household and more economically active people in project households. In the Mid-hills of Nepal, livestock population has positive correlation with the number of agroforestry species and number of trees (Acharya, 2006;

Neupane *et al*., 2002). The major livestock of the study area were buffalo, cow, oxen and goats. Buffalo and cow were used for milk production, ox for tilling of the land, and goat for their meat.

### 3.4 Fodder/ Fuel wood production

Fuel-wood and fodder requirement per household was similar in both project and without project areas. Mostly, the people of both project and without project area collected fuel-wood and fodder from their farm land, and if the amount was found to be insufficient, the difference was supplied from the community forest and by purchasing from households having surplus fodder and fuel-wood.

Table 8: Fodder and fuel wood requirement per household per day (Mean±SD)

| | With Project (Kg) | Without Project (Kg) |
|---|---|---|
| Fodder | 55±10 | 54±26 |
| Fuel wood | 21±10 | 24±11 |

Table 9 : Fodder and fuel-wood availability in household

| Available For | Fodder | | Fuel wood | |
|---|---|---|---|---|
| | With project N=28 (%) | Without Project N=58 (%) | With Project N=28 (%) | Without Project N=58 (%) |
| Surplus after consumption | 29 | 7 | 11 | 5 |
| 9 to 12 month | 50 | 36 | 68 | 40 |
| 6 to 9 month | 18 | 22 | 18 | 22 |
| 3 to 6 month | 4 | 22 | - | 22 |
| less than 3 month | - | 5 | 4 | 10 |
| Not Required | - | 7 | - | - |

Improved agroforestry had greater availability in fodder and fuel-wood supply. In the project area, more than 75 % of household had sufficient fodder and fuel-wood from their farmland but in without project area 43% of household had sufficient fodder and fuel-wood from their farm land. It shows that the agroforestry had a pronounced impact on fodder availability in project area. About 29 % of households in project area had surplus fodder after consumption. There were few (4%) households that have sufficient fodder and fuel-wood for less than a 6- month time frame in project area (Table 9). The farmers of the project area have been continuously planting exotic fodder species by which there were sufficient fodder and fuel-wood.

### 3.5 Household Income

In the study area, household income was generated through agricultural and non-agricultural activities. The average annual agricultural income of the project household's was significantly greater than the without project household's (Table 10). The major portion of agricultural income was produced from livestock production and was significantly higher in the project area. Income by selling fodder, fuel wood and timber contributed for 6 % and 3% of total income in project and without project area respectively. The contribution of crop production on total agricultural income was 3% in project area and 1% in without project area. It was significantly higher in the project area because of having higher land area and production rate. The household income from service was also significantly higher in the project area.

Table10: Household Income (Mean±SD)

| | With Project NRs /Yr | Without Project NRs/Yr | Significant |
|---|---|---|---|
| Total Agricultural income | 38732±15144 | 28685±16771 | 0.03** |
| Fodder | 536±1574 | 448±1667 | 0.81 |
| Timber | 214±1133 | - | 0.81 |
| Fuelwood | 1518±785 | 388±285 | 0.15 |
| Fruit | 2036±2138 | 638±2559 | 0.95 |
| Vegetable | 2536±4662 | 3690±6591 | 0.40 |
| Crop production | 1250±3996 | 155±874 | 0.04** |
| Livestock | 30643±10552 | 23366±14289 | 0.06*** |
| Total Non Agricultural Income | 149393±61767 | 83862±62010 | 0.01** |
| Service | 91714±19079 | 24034±47264 | 0.01** |
| Business | 1429±7559 | 2534±10101 | 0.60 |
| Remittance | 30357±68501 | 27931±68716 | 0.87 |

| | | | |
|---|---|---|---|
| Daily labour | 25893±28449 | 29362±28202 | 0.59 |

*Significant at 1% level
**Significant at 5% level
*** Significant at 10% level

## 4. Conclusion

Farmers have been practicing traditional agroforestry for millennia for providing themselves fodder and fuel-wood. The improved agroforestry with exotic fodder species was introduced by the NAF in 1999.  The total number of trees and species were significantly higher in the project household due to the efforts of NAF and circumstances in which a household had a higher land holding size. It was found that the agroforestry had a pronounced effect on the fodder availability in the area. The primary goal of the farmers practicing agroforestry was to increase livestock production, and thereby generating major economic activity in the study area, through producing more fodder from their farm land. Hence, the common fodder species were frequently distributed in both project and without project areas. Farmer's basic forest needs were efficiently collected from farm land and saved their time. The installation of improved agroforestry had a positive effect on the crop production, however crop production alone shares less than 3% of total agricultural income. The income gained from sale of forest product (fodder, fuel-wood and timber) also contributes to a tiny fraction of total household income. The famers were getting limited monetary benefits from agroforestry except by producing fodder for utilization of their livestock. Therefore, the livelihood of farmers in the Mid-hills of Nepal practicing subsistence agricultural with agroforestry could be improved greatly through introducing multipurpose tree species.

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