prospects of livelihood and carbon benefits as influenced by community forestry in nepal

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PROSPECTS OF LIVELIHOOD AND CARBON BENEFITS AS INFLUENCED BY COMMUNITY FORESTRY IN NEPAL

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Credit

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Declaration

I, Nirmal Mani Dahal, 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 to any other university for award of any type of academic degree.

Signature……………………….

Date……………………………….

DEDICATED TO MY LATE GRANDPARENTS YAGYA PRASAD DAHAL AND MANJUKUMARI DAHAL

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PART ONE: EXTENDED SUMMARY

Abstract

This thesis examines the forest based livelihood strategy of the forest user groups and the prospects and potential benefits of soil carbon sequestration through REDD (Reducing emissions from deforestation and forest degradation) program in two watersheds of Nepal. User groups in the community forests are managing forests for the sustainability and better achievement of livelihood assets. Community-based forest management has also been perceived as a platform for gender equity and empowerment. Along with the social benefits, community forestry has increased the potential of soil carbon sequestration. However, the REDD mechanism is still an international agenda between the countries for implementation. Therefore, our preparedness and position should be adequate for the possible beneficial implementation of REDD in Nepal. On this ground, a study was carried out in Kayarkhola and Ludhikhola watersheds of Chitwan and Gorkha districts of Nepal respectively during October & November 2011. The objectives of this study were to (a) understand the assets of forest based livelihood strategy in the community-based forest management system and (b) assess the prospects of enhancing soil organic carbon stocks in the community forests with potential implication for REDD. Data collections were conducted using questionnaire survey, focus group discussions, laboratory experiments and study of relevant literatures.

The study revealed that both men, women were important elements in the community forestry sector. Notably the women and other disadvantageous groups were being empowered through programs organized by the community forestry users groups such as adult literacy class, trainings in forest inventory, carbon measurements, livestock management and other skills such as tailoring, mason, carpentry, etc. Our findings showed that the crop productivity has increased from the past to present that is production has increased after establishment of community forest. The opportunities of improved livelihood through the identification of social roles, responsibility and other managerial aspect in community forestry appears to empower community and enables the development of institution for better management and governance of resources. The other potential benefits are the prospects of enhancing carbon sequestration.

Our study revealed that forest soil has a high potential to sequester carbon, potential REDD benefits and some MRV(Monitoring, Reporting and Verification) issues related to it. Based on the measurements of required soil parameters we calculated the soil organic carbon (SOC) stock in the community forests and compared with other studies. The comparison showed the similar trend of carbon storage within one-meter soil profile. We also calculated SOC stock within the community forests in watersheds and of other degraded sites. The result showed that well managed site (community forest) had three to four times higher soil carbon stock than degraded site. The estimation of potential carbon gained indicated the potential future benefits of enhancing soil carbon stock through community forests as a part of REDD program.

Keywords: Community forests, sustainable forest based livelihood, Soil organic carbon and REDD benefit.

Introduction

The long-term goal of the community forest program is to restore the degraded forest and afforestation. However, it is also important for livelihood management, ecosystem services and rural development (Baral 1993). Hence, to address this issue of forest management, rural development and livelihood, community forestry has become the efficient tool in Nepal (Pokharel et al. 2005a; Sharma 2002). Rural livelihood in Nepal depends on forest sources, mainly for the timber and non timber forest products. Varughese (2000) stated that more than 80% of total population in Nepal depends on these sources for livelihood. The assets of sustainable livelihood such as human, physical, natural, social and economic are positively improving in the forest user groups. Improved ecosystem services, opportunities for generating household incomes, development of community infrastructures, social participation, planning, decision making, making, etc. are the positive changes observed in the users groups (Dev et al. 2003). Pokharel & Nurse (2004) also mentioned that users groups were able to manage thousands of hectares of forest land. The good forest governance and sustainable forest management have been achieved and is the way to improve the people's livelihood.

Improved forest management provides better environmental services such as biogeochemical cycles, flow of forest products. These services are different functions of ecosystem (Sarukhan et al. 2005). Climate regulations can be maintained by avoiding deforestation and degradation of forest-land. This activity also reduces the greenhouse gases emissions in the atmosphere along with increasing carbon sequestration. Managing, conserving and expanding the forest area increases the biomass, flourished on the soil quality hence sequestrate more carbon or reduce the GHGs emissions by (Metz & Davidson 2007). Recently such strategy has been considered as one of the options to reduce emission, notably the REDD program. Under the REDD program, the estimation of soil organic carbon stocks are also needed. Soil can act as sources as well as sink for carbondioxide emissions.

On this background a study was conducted in Kayarkhola and Ludhikhola watershed of Chitwan and Gorkha districts of Nepal respectively. The study has the following objectives:

Objective 1:

To understand the assets of forest based livelihood strategy in the community-based forest management system.

The research questions/hypothesis include:

a. How are the status of livelihood assets and other socioeconomic features of forest users groups?

b. Is there any relationship between the variables of livelihood assets with the users groups?

Objective 2:

To assess the prospects of enhancing soil organic carbon stocks in the community forests and its relevance to REDD.

The research questions/hypothesis include:

a. How are the soil properties and SOC distributed in different soil depth?

b. Does the quantified SOC stock reflect consistency with other published work?

c. Does the soil carbon storage implicit the potential benefit from REDD ?

The outputs of this study are presented in two papers. Each paper respectively addresses the research questions based on objectives mentioned above. The first paper deals with the understanding of livelihood assets' status in the forest users groups of community forests. Similarly, the second paper deals with the estimation of soil carbon stocks in the community managed forests and its prospects with REDD. The study areas for this study are the community forests of Kayarkhola and Ludhikhola watersheds of Chitwan and Gorkha districts of Nepal respectively.

State of the Art

This section provides the brief summary of literatures relevant to the objectives of study related to community forestry; forest based livelihood and soil organic carbon with its implication for the REDD.

Community forestry (CF) and Livelihood

Before 1957, Nepalese government focused on conversion of forest area to agricultural land (Gautam et al. 2004). From 1957 until 1976, nation controlled forest governance failed and rapid deforestation and degradation spread all over the country. According to Wallace (1988) community-based forest management started in Nepal after 1977. After 1977, there were several changes in the forest legislation which transferred the forest management from government to local community. Forest Act 1993 of Nepal, provided the legal base for locals to manage forest with getting benefits and opportunities to them (Acharya 2002). The restoration and management practices of forest by the community forest users' groups (CFUGs) in a community has led them to get livelihood benefits such as improved social, economic, human, physical and natural assets (Pokharel 2002).

At least one-third of the total Nepalese population were participating in forest management by the year 2009. This includes more than 70 percent of total population who depends on agriculture for their livelihood (Ojha et al. 2009). Agriculture is directly supported by forest. Farmers collect fodder from forests. This fodder used by livestock provide manure, which is used in agriculture land. Rasaily (2006), from the study in Dhading and Lalitpur district also showed the benefits such as bedding material, availabilities of water for crops are being obtained from forests and are enhancing their crop productivity. Similarly direct benefits of forest to livelihood include the flow of forest services such as non timber and timber forest products. Likewise, indirect benefits include watershed protection, soil erosion and gully formation, water sources, soil fertility, etc. (Thoms 2008).

A study by Gautam et al. (2008), in the forest user groups of Kavrepalanchowk district of Nepal showed the benefits of community forestry through improvement of livelihood assets. People are using the forest resources in a sustainable manner which promotes biodiversity and other natural assets. Economic benefits from forests are being used for the road construction (physical assets).

Community forestry, Soil Organic Carbon (SOC), REDD

Forests in the world contribute about 18% of total greenhouse gas (GHGs) emission if they are cleared up or degraded. Nevertheless, if they are managed properly, then about one-tenth of the global carbon emissions can be sequestered through biomass and soil (FAO 2012). Soil in the biosphere is the largest carbon pool. About 60 percent of the world's terrestrial carbon is covered by the forest vegetation and soil (Winjum et al. 1992). Kirschbaum (2000) stated that soil contained about 2400 Gigatons of carbon upto 2m depth. Therefore, carbon sequestration in soil is reliable.

Lal (2004), argued that restoration of degraded land and afforestation can increase the potential of soil carbon sequestration. The restoration of degraded agriculture land reduces the loss of carbon thus has a positive impact on productivity. However, rate of soil carbon storage in forest depends on the climate variability, dominant tree species with other species, litter composition, management practices, etc. (Lal 2005). Community forestry in Nepal is the effective management practice and restore the forest (Pokharel et al. 2005b). Pokharel et al. (2007) indicated that the density of community forest in the mid hill region of Nepal has increased maximum by 21 percent per annum with an average size of 85 hectares per user groups. More than 14,000 user groups are managing about 1.20 million hectare of forest.

REDD mechanism introduced from Bali conference, 2007 might be the potential mitigating tool to address global environment change. Integrating community forests under this mechanism in developing countries such as Nepal might be a good initiative to enhance environmental security (Dahal & Banskota 2009). This integration will provide new aspect to the forest use. The potential benefits from carbon sequestration increase the value of forest sector. Acharya et al. (2009), studied carbon quantity in three community forest over a three-year period in mid hills of Nepal and found mean carbon pool size (including tree biomass, root system and SOC under 1m) to be 504.31 ton CO_2 per hectare. The rate of carbon sequestration excluding SOC per annum was 7.04 ton CO_2. A study of carbon potential for different types of land related to community forestry in Dolakha district of Nepal showed that about 65000 hectare land over thirty years could sequester about 5.4million ton CO_2 equivalent (De Gryz & Durschinger 2009).

Although the forestry sector has potential REDD benefits, it is also important to address the different issues related. Acharya et al. (2009) in detail discussed the benefits and risk of REDD program. Besides the climate, biodiversity, social and livelihood benefits of REDD, social and environmental risks were also discussed. Likewise, there are also methodological issues and challenges, issues on measurement, monitoring, reporting and verification of REDD (discussed detailed in paper II).

Materials and Methods

Both qualitative and quantitative methods were used for the study. The study was conducted in community forests of two watersheds in Chitwan and Gorkha district of Nepal. Kayarkhola watershed of Chitwan district (Central Development Region) ranges from 245m-1944m altitudes. There are 16 community forests in this watershed, and the user groups are managing about 2382 hectares of area under forestry. Chelibeti and Jamuna community forest was selected for the study. Similarly, Ludhikhola watershed of Gorkha district (Western Development Region) ranges from 318m-1714m altitude. It includes 31 community forests within which Laxmimahila and Kuwadi were selected for the study. About 1887.5 ha of land has been managed by forest users groups in this watershed.

For the livelihood study, a total of 156 households in four selected community forests was surveyed including six focus group discussions. This sample size of household represents more than 30% of entire household involved in CF. A structured questionnaire was developed in seven sections with both close and open-ended questions in order to collect information on availability of assets and peoples' perceptions on it. It included five sustainable livelihood assets (natural, social, economic, human and physical), the socioeconomic and demographic information about the households. Likewise, correlation was also performed to understand the relation of studied variables within the livelihood assets.

For the biophysical study (focused on soil carbon), 3 sample plots (size = 20m×25m) were randomly selected from each community forest. Soil samples were collected from 0-15cm, 15-30cm,30-60cm and 60-100cm. Bulk density, soil texture and soil organic carbon contents were determined. Dry combustion method was used to determine the soil organic carbon (Nelson & Sommers 1982). Similarly, hydrometer method was used to determine the soil texture (Wairiu & Lal 2003). Likewise, core method was used to determine the bulk density (Blake & Hartge 1986). The total carbon stock in the one-meter depth was gained by adding the stocks in simultaneous depth. More details are given in paper II.

The data on livelihood was computed using SPSS 17.0 and Sigma plot 11.0 software. Different analysis was conducted to understand the differences of livelihood assets between the community forests. For the soil study, the data were analyzed using Excel 2007 and Sigma plot

11 software. Descriptive statistics (mean, standard deviation) and tools such as Pearson's correlation, one-way ANOVA was used to analyze the data.

Results and Discussion

I. Understanding assets of forest based livelihood strategy

a. Demographic information

The family size and average number of literate members within Chelibeti CFUG and Jamuna CFUG were similar. Family size and literate members in Laxmimahila were significantly higher than Kuwadi ($p<0.05$). In both the watershed low percentage of respondents had higher education, and the majority of the respondents in all four CFUGs were found to be illiterate, and most of them were female. However, in the study area adult literacy classes had been started before so the literacy rate might increase in the future.

b. Socioeconomic condition

The study showed that all the members of forest users groups in both the watersheds have agriculture as main income sources. The members of these user groups perceived that role of forest, and its services are very important to their income sources. People are actively associated with different institutions of society. All the members in Chelibeti, Jamuna, Laxmimahila and about 80% of Kuwadi CFUGs are members in different institutions. Community forests have provided an opportunity for people to improve their social and economic status. Besides the agriculture other income generating activities are being initiated by the people. Likewise, people participation in social organizations are also being observed.

c. Livelihood assets

Table 1 shows the status of livelihood assets' indicators in the study area. The status on the indicators are the benefits from the community forestry. The quality of status might increase in the future. Access to health services, development of skills, trainings, utilization of ideas, knowledge, etc. are some of the indicators of human assets. These assets are the means of achieving sustainable livelihood outcomes (DFID 1999). Non timber forest products' (NTFPs) use needs high level knowledge (Pandit & Thapa 2003). Therefore, these product use was lower than other forest products such as leaflitter in the community forests of both the watershed. However, members in community forests derived economy from different sources and are then used for business, vegetable farming, education, livestock production, etc. Forest has a positive role in their farming. Physical infrastructures such as schools, roads, buildings, electricity, etc. are important for improvement and establishment of community (Brabben et al. 2004). Giri et al. (2008) revealed that women's participation in community forestry, forming and participating in forest users' group is increasing by these days. They are focusing their active participation and roles in widening the structures and decision-making process.

Table 1: Status of livelihood assets' indicators in the forest user groups of study area

Watershed/District		Kayarkhola/Chitwan		Ludhikhola/Gorkha	
Forest User Groups		Chelibeti	Jamuna	Kuwadi	Laxmimahila
Natural Assets	Forest quality enhanced	Yes	Yes	Yes	Yes
	Land types (%[a])	*Khet land*[b] only(57) Both *Khet land* and *Bari land*[c](43)	*Khet land* only(62.5) Both *Khet land* and *Bari land* (37.5)	Both *Khet land* and *Bari land* (50) *Bari land* only (44) None (6)	*Bari land* only (53) Both *Khet land* and *Bari land* (40) None (7)
	Total land quantity (hectare/household)	0.17	0.25	0.40	0.20
	Major crop production	Rice and maize	Rice, maize and wheat	Rice and maize	Rice, maize, millet
	Quantity of production changed overtime	Increased	Increased	Increased	Increased
Economic Assets	Use of leaflitter, fuelwood	Yes	Yes	Yes	Yes
	Use of fodder	Yes (only 3%)	No	No	No
	NTFPs users (%)	42	7	20.5	50
	Main occupation	Agriculture	Agriculture	Agriculture	Agriculture
	Extra financial sources (type)	Social groups (credit)	Neighbors (credit)	Finance (loan)	Social groups (credit)
	Major expenses	Household activities	Household activities	Household activities	Household activities
Physical assets	Access to physical infrastructures (%)	82	97	88	47
	More access to	School and road	School and road	School and road	School and road
	Access to communication facilities (%)	80	80	91	100
	Alternative energy users (%)	28	4	18	27
	Access to physical	63	100	7	17

	infrastructures (%)				
	Drinking water facilities	Tap and springs	Tap water	Tap water	Tap water
Social Assets	Social participation	Yes	Yes	Yes	Yes
	Gender equity perception	Yes	Yes	Yes	Yes
	Perception on equity areas	Home/ social groups	Home/ occupation	Education/health/ social groups	Home/social groups
	Adult literacy class	Yes	No	Yes	Yes
	Female decision making power	Yes	Yes	Yes	Yes
Human assets	Access to health facilities	Health post	Health post	Hospital/ medical	Health post
	Skill and trainings	Yes	Yes	Yes	Yes
	Skill and trainings on	Tailoring, mason, farming	Tailoring	Tailoring, farming	Tailoring
	Assets ownership (%)	100	7	15	3
	Health awareness	92	100	44	50

[a] percentage of total respondents in each forest users groups [b] irrigated land [c] non-irrigated land

Correlation between the livelihood assets' variables in the study sites

In this section, we studied the correlation between the different independent variables of livelihood assets in all the four community forests. Variables such as leaflitter, fuelwood, fodder, economic indicator (loan), major income, communication, alternative energy, decision making, skill and trainings, agriculture production, gender, drinking water sources, irrigation facility, literacy, NTFPs and institutional membership are considered and studied the association between them. In Jamuna CF, among the studied variables, all were moderately associated. The association was both positive and negative. The positive association was observed between fuelwood and leaflitter as well as between wheat production and leaflitter collection. In Chelibeti community forest, besides few weakly correlated, most of the variables were moderately correlated. These associations were both positive and negative. Irrigation and loans, skill & training and adult literacy have positive weak associations. Likewise, skill & training and NTFPs, irrigation and NTFPs, etc. have negative association. Moderate positive association was observed between skill & training and decision making in Laxmimahila CF. Similarly, the negative association was also observed between skill & training and NTFPs and perfect negative association was observed between decision making and NTFPs. In Kuwadi community forest, there was also observed both positive and negative moderate correlations between the variables. NTFP and rice production accounted for 20% association in the forest users groups. The association of these variables was positive.

II. Prospects of enhancing soil carbon stock into community forests

Soil description

Soil from Chelibeti and Jamuna community forests in Kayarkhola watershed had silt loam texture. Similarly, in Ludhikhola watershed, Kuwadi CF had silty-clay loam texture whereas in Laxmimahila CF, silty loam was observed as dominant soil texture.

Bulk density and Soil Organic Carbon

Bulk density significantly increases with the soil depth. In the subsurface layer of soil, there generally contains less pore space than in the surface. This is likely to be caused by the soil organic matter, aggregation and root penetration decreases with increased soil depth hence, increase the bulk density (Davidson & Ackerman 1993; USDA 2008). Cultivated land possesses a higher bulk density due to the lower organic matter and vice versa with forest lands.

Decreasing trend of the SOC with increased depth was observed in the study sites. In the top soil (0-15cm) in CFs of Kayarkhola and Ludhikhola watersheds revealed SOC content 2.0 % in Chelibeti and 2.39 % in Jamuna, 1.99 % in Kuwadi and 2.02 % in Laxmimahila. Comparing the results from this study with the degraded sites studied by Shah et al. (2000) in central hills, Brown et.al (1999) in Dhulikhel and Baral et.al (1999) in Kavre district of Nepal revealed SOC content (%) 0.5, 0.68 and 0.1 respectively. It signified that the improvement in landuse management has potential to increase the carbon content. The good management of forest indicates dense crown cover resulting in high SOC content in surface layer than degraded sites (Sitaula et al. 2005).

Correlation between soil parameters

The soil organic carbon was negatively correlated with bulk density (r = -0.57). A gradual decrease in the SOC with depth was observed. The decreasing trend of SOC with increasing depth in the different forests of himalaya was also observed by Mehraj et al. (2009). The high soil carbon content in the top layer might be due to the high rate of decomposition of leaflitter. So in dense forest with high canopy cover can result more leaflitter fall than the sparse low canopy cover forests. Our study in one meter depth soil profile in Kayarkhola watershed had higher gravel content than in Ludhikhola watershed ($p<0.01$). Considering all the parameters for SOC stock estimation; we estimated 3517 metric tons of carbon (MTC) for Jamuna, 6697 for Chelibeti MTC, 1044 MTC for Laxmimahila and 13374 MTC for Kuwadi CF.

Estimation of SOC stock between community forests of watersheds and comparing with other studies

SOC estimated for Jamuna was 101.85 ton per hectare (ha). Likewise, for Chelibeti it was 103.35 ton/ha, Laxmimahila was 119.7 ton/ha and Kuwadi was 144.94ton/ha. In comparison, Chelibeti CF has higher carbon stock per hectare than Jamuna CF, and Kuwadi has higher stock per hectare than Laxmimahila CF in two different watersheds. Shrestha et al. (2004), Mehraj et al. (2009) discussed about the possibility of lower carbon stock due to the human interference as well as lower collection of leaflitter due to wider space of tree species in forest. Soil physical parameters such as high gravel content, low bulk density and SOC content might lower the SOC stock estimation. We compared our SOC stock estimation of one meter soil profile with other studies performed by different researchers in various districts and watersheds having close climatic regions. Almost all the experiment shows the similar trend of carbon storage within one meter soil profile.

Prospects of carbon storage in community managed forest soil and its implication for REDD

We estimated carbon stock of degraded sites from earlier published work from similar geographical region and forest of Nepal. The analysis was made only for the top soil (0-15cm) due to limited data availability. The SOC stock of CF managed site (Kuwadi and Laxmimahila CF) were significantly higher compared to degraded sites. From the comparison; Kuwadi would get the benefit of 25.51 MTC (93.62 ton CO_2e/ha) and Laxmimahila would get 17.70 MTC (64.96 ton CO_2e/ha). This amount of carbon in the voluntary carbon market for US$ 12 per ton of CO_2 (Dhital 2009) provides an amount of US$ 1123 to Kuwadi CF and US$ 779.5 to Laxmimahila CF. This benefit of carbon sequestration from degraded to the managed land system could be possible option for mitigating the global environment change with providing incentives for CF. Hence forest's conservation for the REDD may be a relevant mechanism projected by United Nations Framework Convention on Climate Change (UNFCCC) that has encouraged developing countries like Nepal to consider.

Conclusion

The two research papers included in this thesis provide an better understanding of status of assets in sustainable forest based livelihood strategy, community empowerment through forestry, forest as carbon sink and its prospects to mitigate global environment change through REDD program. Community forestry has a vital role in conserving the forest resources with providing equal opportunity to all the forest users groups to uplift the livelihood status. Gender empowerment, participation, capacity buildings, etc. are some of the key benefits of community forest.

On prospects of global environment change, community forest can act as a good source of carbon sequestration in soil. Significant amount of soil carbon can be sequestered if a highly degraded site is converted to community forest. The economics of this carbon benefits from a degraded to a well-managed site could be relevant to REDD program. The improvement in forest and soil provides other benefits, which directly or indirectly impacts on people livelihood.

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PART TWO: RESEARCH PAPERS

PAPER 1: UNDERSTANDING THE ASSETS OF FOREST BASED LIVELIHOOD STRATEGY IN THE COMMUNITY-BASED FOREST MANAGEMENT SYSTEM IN NEPAL

Understanding the assets of forest based livelihood strategy in the community-based forest management system in Nepal

Abstract

Community-based forest management practices are effective tools for restoration of degraded forest resources, income generation and livelihood asset improvement. Two watersheds: Kayarkhola and Ludhikhola and two community forests in each watershed were chosen for this study. Household surveys in 156 households and six focus group discussions were conducted in order to obtain information on livelihood status of the households. Results showed that alike men, women are also capable of managing forestry sector to enhance better livelihood. Different organizations are empowering people through literacy program, trainings in forest inventory, carbon measurements, livestock management and other skills such as tailoring, mason, carpentry, etc. Analysis of all five livelihood assets' indicators in the study sites reveal that agriculture is the main income source, and productivity has increased overtime. People use fuelwood and leaflitter in significant quantities for domestic purposes. More than 70 percent of the respondents have access to the communicating means. Tap water and springs are the major sources of drinking water. Community forest users´ groups in Kayarkhola watershed have high irrigation facility than Ludhikhola. However, both watersheds have low use of alternative energy. The social participation, gender equity, decision-making powers are some of the social assets, which are improving in the study area. Similarly, access to health facilities, and related individual awareness among people are also improving. Correlation between variables of livelihood assets in the study sites showed mostly moderate relationship. However, this relationship is both positive and negative. The overall results from this study suggest that opportunities of improved livelihood through the identification of social roles, responsibility and other managerial aspect in community forestry empower the community (along with women) and hence could establish an institution for better management and governance of resources.

Keywords: Forest restoration, community forest, women's participation, resources management and livelihood assets

Introduction

Consumption of goods and services from the forests are the basis of rural forest based livelihood. In developing countries such as Nepal, the uses of forest services are subsistence which are linked with cultural importance, agricultural inputs and other characteristics of livelihood (Arnold 2001). Forest as a common pool resource is accessible to all, which in turn gets degraded due to over consumption. Community forestry program had started in Nepal after the late 70s which then regarded as a tool for forest restoration in Nepalese context to prevent this degradation (Pokharel et al. 2005). This restoration process established different livelihood assets changing the livelihoods which are based on forest (Pokharel 2003).

Forests have ensured the sustainability of livelihoods of communities with an enhancement of the natural and physical assets (Gautam et al. 2008). The sustainable use of resources is promoting natural assets as well as physical assets such as road construction from the economic benefits of the community forestry (Gautam et al. 2008). For example, forest in the Koshi region in the mid-hills of Nepal showed improving social assets such as group formation, community participation and decision making in local welfare (Dev et al. 2003a). The formation of credit and micro credit schemes for different alternative livelihood programs has enhanced the financial assets of communities. Similarly, the literacy program, personal hygiene, sanitation program and social network have improved the human assets (Dev et al. 2003b).

Forest provides benefits for the crop production by supplying bedding materials which after composting is used as farm yard manure (Rasaily 2005). Water sources for irrigation are also improved due to the restoration through the forestry program that improved the crop production (Rasaily 2005).

During the early period, forest degradation and deforestation were the major environmental problems in Nepal. Nepal lost about 9% of its total forests (about 570,000 ha) within 21 years from 1964 to 1985 (Pokharel et al. 2005). Shrub lands increased from 4.8% to 10.6% during 1980s to 1990s.   Study showed that during 1979 to 1994, the forest area decreased by 24% and shrub land increased by 126% (Ojha et al. 2008). Hence, to address the issues of degradation, forest restoration emerged in Nepal through the community forestry programs (Pokharel et al. 2005).

Community-based forest management has then established as a resource management institution in this sector for the restoration, conservation and livelihood improvement (Gautam 2009). A survey showed that about one-third of the total population of Nepal are involved in managing the forest resource by the year 2009 (Ojha et al. 2009). Therefore, people are together in establishing a development pathway through sustainable use of the resources (Gautam et al. 2003). Forest resource management in Nepal is based on people's participation and decision of the user's group. Women are the key forest users, and their involvement in the sustainable management revealed success in management practices (Agarwal 2009). Community forestry program tried to empower women's status through participation since 1980s (Giri et al. 2008). Hence, this study tried to focus the following objectives:

a. to understand the livelihood assets (social, physical, economic, natural and human) and other socio-economic features of community forest users groups handled by both men and women;

b. to identify the relationship between the variables of livelihood assets in the user groups.

Materials and Methods

Study Area

The study was conducted in Kayarkhola and Ludhikhola watershed. Kayarkhola watershed is located in Chitwan district of the Central Development Region of Nepal. It ranges from 245m to 1944m altitude covering the area of 8002 hectares. Altogether, there are 16 community forest user groups in the watershed covering 2381.97 ha of forest land. *Chepangs* and *Tamangs* are the major inhabitants of the watershed. Likewise, Ludhikhola watershed is located within the Gorkha district of Western Development Region of Nepal. It ranges from 318m to 1714m covering the area of 5750ha. There are 31 community forest user groups managing the 1887.5 ha forest land. *Brahmin, Chhetri, Magar, Gurung, Tamangs,* etc. are the major inhabitants within the area.

Study Sites

Two community forests (CF) from each watershed were selected. These CFs was selected based on who managed the forest. Therefore, we included forests, managed by both women and men. The details of the CFs are given below (Table 1).

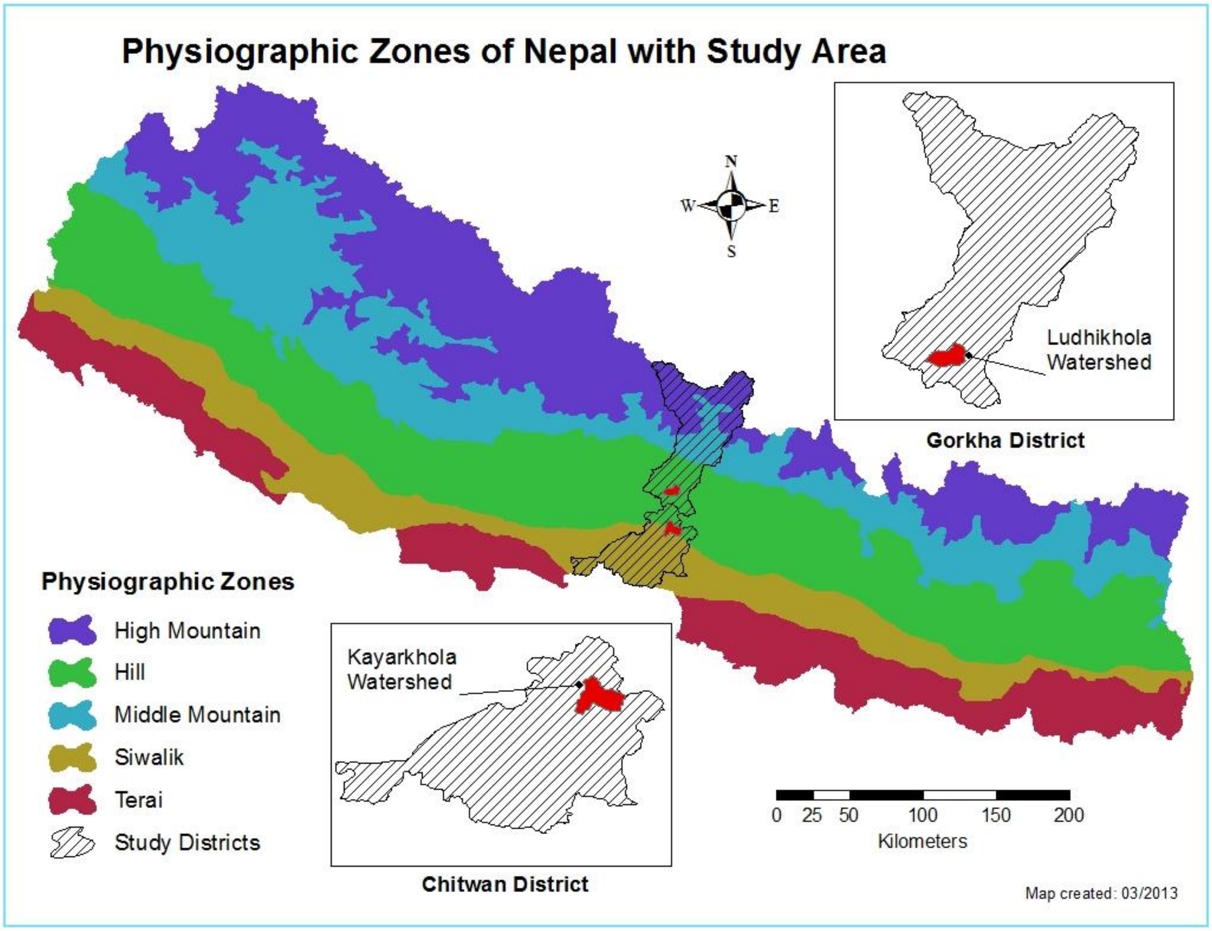


Figure 1: Map showing the Chitwan and Gorkha districts and the watersheds' area

Table 1: Details of study sites in Kayarkhola and Ludhikhola Watershed

CF Name	Total Involved HH in CF	CF area (ha) -Average/HH	Total CF area (ha)	Area in strata (ha)		Management group	Watershed
				Dense	Sparse		
Chelibeti	170	0.38	64.9	59.6	6.2	Women	Kayarkhola
Jamuna	32	1.15	34.5	10.9	23.7	Men	Kayarkhola
Laxmimahila	75	0.12	8.72	8.09	0.63	Women	Ludhikhola
Kuwadi	104	0.89	92.27	83.75	8.52	Men	Ludhikhola

HH- Households

Data Collection and Analysis

A household questionnaire survey was conducted during October- November 2011. The survey was conducted in 156 selected households with six focus group discussions. The chosen household represents more than 30% of entire household involved in CF. Of total 156 households; 92 were from Kayarkhola watershed (60 from Chelibeti CF, 32 from Jamuna CF) and 64 from Ludhikhola watershed (30 from Laxmimahila CF and 34 from Kuwadi CF). Purposive selection was carried out in order to choose CFs in both the watersheds whereas random sampling was performed to select the households in each CF. Head member of a household was interviewed and in the absence of the head member, another member who showed willingness to be interviewed, was interviewed. A structured questionnaire was developed in seven sections with both close and open-ended questions in order to collect information on availability of assets and peoples' perceptions on it. It included five sustainable livelihood assets (natural, social, economic, human and physical), the socioeconomic and demographic information of the households.

Statistical Analysis

In order to compute statistical analysis, SPSS version 17 and Sigma plot versions 11 were used. The normality test (Shapiro-Wilk) of the data was performed through the sigma plot and then required test for the parametric data, and non-parametric data were used. Descriptive statistics (mean, standard deviation, standard error of mean) and tools such as t test, chi-square test, Z test, Man Whitney U test, Fisher Exact tests were used to analyze the data. The mean and frequencies were calculated and presented in graphs and tables.

Result and Discussion

A. Demographic information

The average age of the respondents in the Chelibeti community forest user group (CFUG) was 35 and Jamuna CFUG was 36. The family size within these two CFUGs was alike (Table 2). The average number of literate members in Chelibeti CFUG and Jamuna CFUG were similar. The majority of the respondents in all four CFUGs were found to be illiterate, most of which were female.

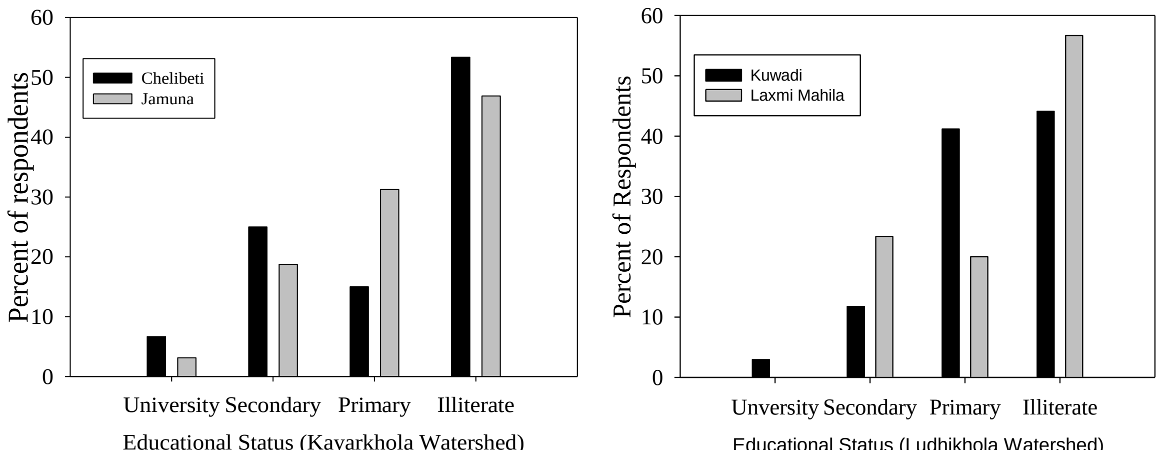


Figure 2: Frequency distribution of educational status within CFUGs of watersheds

Alike the CFUGs in Kayarkhola, the respondents' average age of Kuwadi CFUG and Laxmimahila were not significantly different. Family size in Laxmimahila was significantly higher than Kuwadi ($p<0.05$). The average literate members in a family of Laxmimahila was also higher than Kuwadi ($p<0.05$). In both the watershed low percentage of respondents had higher education.

Table 2: Comparison of demographic information within CFUGs of Kayarkhola and Ludhikhola watersheds

Indicators	Kayarkhola Watershed			Ludhikhola Watershed		
	Chelibeti	Jamuna	P -value	Kuwadi	Laxmimahila	P-Value
Age	35	36	0.91	41.5	43	0.63
Family size	5	5	0.76	5	6	0.04
Literate family members	3	4	0.23	3	5	0.01

B. Socioeconomic condition

Income sources within CFUGs are presented in figure 2. The result showed that agriculture was the major source of income for both CFUGs. For Chelibeti CFUG, there were other sources of income such as, private jobs, business. For Jamuna CFUG, the majority of respondents (more than 90%) agreed agriculture as the main source with private jobs and other sources to some extent. More than 90% of the respondents in Chelibeti and 73% respondents in Jamuna perceived that the forest had a medium role in their total household income. All the respondents of Chelibeti and Jamuna CFUGs have participation and institutional membership.

As illustrated in figure 3, majorities of the respondents in the Kuwadi and Laxmimahila CFUGs had agriculture as the main occupation. In Laxmimahila CFUG, about 7% of the respondents agreed that government service was also contributing to the income source. Likewise, business (23%) and remittance (17%) was also contributing to the income source. In Laxmimahila CFUG 50 % of the respondents had perceived that forest had either medium or low role in total income whereas in Kuwadi CFUG 48% had the medium role, 3% had the low role, and others do feel no role in their income sources. All the respondents of Laxmimahila and 80% of Kuwadi CFUGs had social participation and institutional memberships.

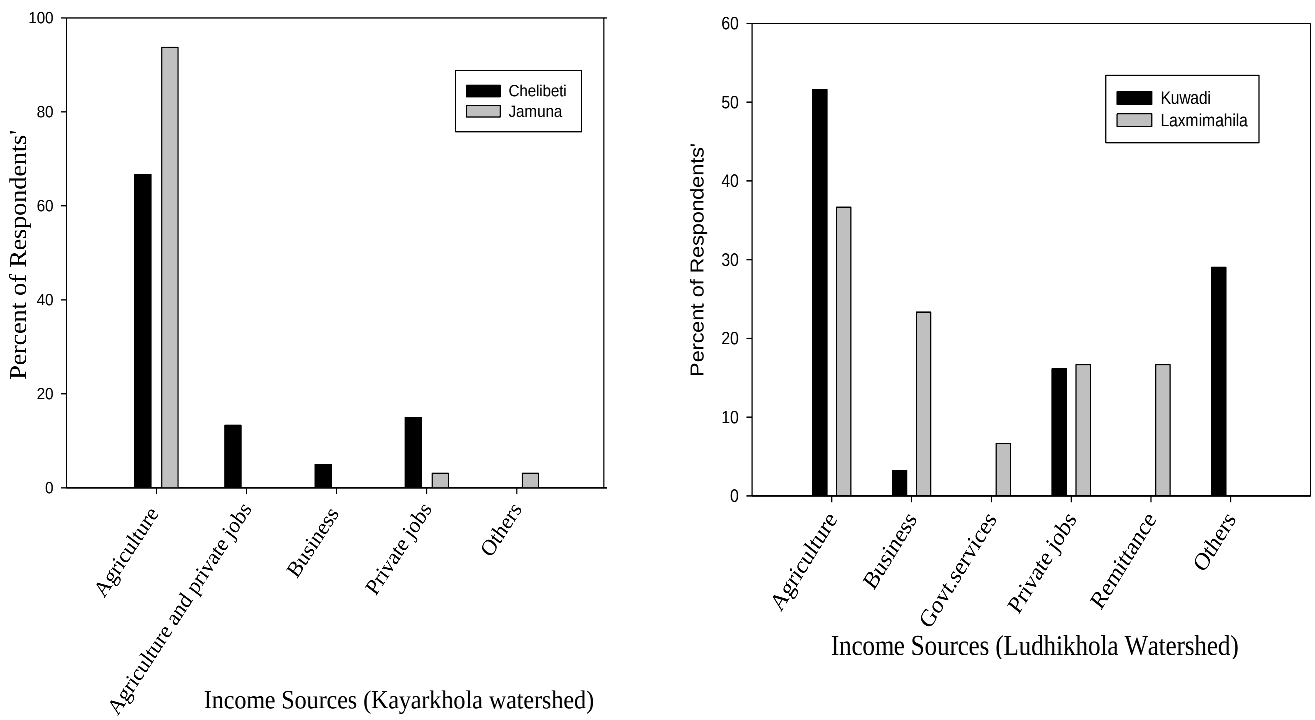
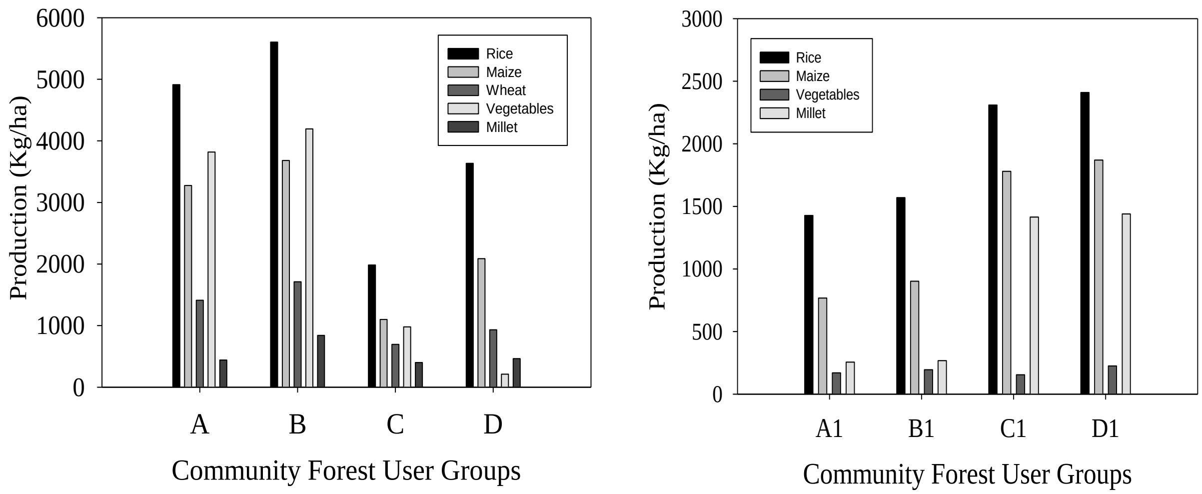


Figure 3: Frequency distribution of income sources within CFUGs of Kayarkhola and Ludhikhola Watersheds.

C. Livelihood Assets

a. Natural assets

The natural assets in both watersheds have been defined by the forest quality, land holdings and productivity. 97% of respondents' in Chelibeti and 81% in Laxmimahila perceived higher forest quality status. The results showed that the average landholdings in Jamuna CFUG was 0. 25ha and in Chelibeti, CFUG was 0. 17ha. Although the land use types were similar between these CFUGs, the type of production was found to be significantly different ($p<0.001$). According to the survey data, the major crops' production within Chelibeti was higher after the forest restoration ($p<0.001$) as shown in figure 4. Similarly, Jamuna had also the higher productivity after restoration ($p<0.001$).



A- Chelibeti before FR, B-Chelibeti after FR, C-Jamuna before FR, D-Jamuna after FR, A1- Kuwadi before FR, B1-Kuwadi after FR, C1-Laxmimahila before FR, D1-Laxmimahila after FR

Figure 4: Major Crop production (Kg/ha) within CFUGs of Kayarkhola and Ludhikhola watersheds before and after forest restoration (FR)

80% of respondents' in Kuwadi and 67% in Laxmimahila CFUGs perceived that their forest had high quality. Similarly, average landholding per household in Laxmimahila CFUG was 0. 20ha and Kuwadi were 0. 40ha. Though the land holding size in Laxmimahila was relatively lower, the production of cereals and vegetables were significantly higher than Kuwadi ($p<0.001$). People in Laxmimahila might be getting proper irrigation and seed quality, which enhanced their productivity. Alike CFUGs in Kayarkhola, Kuwadi had also higher production after restoration ($p<0.001$). In the same way Laxmimahila had also high production as of Kuwadi after restoration ($p<0.001$).

The forest quality is increasing in both study sites. The community forestry practices have positively influenced the hydrological cycle, ecosystem services and in agriculture practices. The forest resource use is sustainable and degradation is lowered. The efforts of making barren land to greenery and other potential efforts to make forest and land, more productive was observed at the study sites. The seasonal crop production of different varieties in different land holdings is common in practice.

b. Economic assets

The use of fuelwood and leaflitter was higher than non timber forest products (NTFPs) in both the study sites. The use of NTFPs needs more knowledge regarding its identification and proper use (Pandit & Thapa 2003). Very few people might know about it. So its use is comparatively low. This also indicates the diversification of economic activities from the forest. The fuelwood and leaflitter are widely used in the domestic purposes. The fuelwood is used for cooking and other heating purposes. Similarly, the green part of the leaflitter is used for livestocks, and the dried litter part is used in heating. In Ludhikhola watershed, there is no fodder use. In Kayarkhola watershed, only two households of Chelibeti CFUG use the fodder from forests. It might be due to the use of local agricultural residue as fodder. In comparison to study sites of Kayarkhola watershed, the study sites of Ludhikhola are much closer to the local market. So this can be the reason for not going into the forest for fodder collection. The other indicators of economic assets discussed with the respondents are about the financial flows. For the better economic condition, respondents have received loans, credits from the financial institutions and other sources such as neighbor, relatives. These assets are then used for business, vegetable farming, education, livestock production, etc., which will give high economic benefits in the future. The role of community forestry and people participating in it has made them active in uplifting the economic status which is very fruitful to them.

Economic assets such as credit, loan facilities have contributed for income generation. The uses of forest products leaflitter; fuelwood were also beneficial for the household. Table 3 showed that there was no significant difference between Chelibeti and Jamuna CFUG on the use of leaflitter and fuelwood. These resources were used mainly for household purposes. Besides the timber products, the community also got NTFPs. The use of these NTFPs in Chelibeti was higher than Jamuna ($p<0.001$). People in Chelibeti, especially, the old generations might have more knowledge of the products. So they might use it as alternative medicine. The flow of financial activities such as loans, credit was significantly higher in Chelibeti than in Jamuna ($p<0.05$). They mainly invested the money for education, business. Some respondents also invest in vegetable farming and livestocks. However, the perception on the contribution of forest for achieving the economic assets was not different between the communities.

Table 3: Summary of average use of forest product (Kg/month) within CFUGs of Chitwan and Gorkha District

Forest products	**Kayarkhola Watershed**			**Ludhikhola Watershed**		
	Chelibeti	Jamuna	P value	Kuwadi	Laxmimahila	P value
Leaf-litter	528	622	0.139	235	310	0.83
Fuelwood	348	606	0.635	184	38	<0.001
Fodder	-	488	-	-	-	-
NTFPs	1.5	2	<0.001	1.8	1.50	<0.05

Unlike CFUGs in Kayarkhola watershed, there was a significant difference between the Kuwadi and Laxmimahila CFUG in the use of fuelwood. Kuwadi used higher quantity than Laxmimahila ($p<0.001$). However, there was a similarity to the use of leaflitter as shown in table 3. These resources were also mainly for the household activities. The use of NTFPs in Laxmimahila was more than Laxmimahila ($p<0.05$). In comparison to Kuwadi; Laxmimahila people might have enough knowledge regarding the use of these resources in the daily life. Basically, these resources are aromatic and medicinal plants can be used as medicines. The financial activities in Kuwadi had higher flows ($p<0.05$). The sources of these activities in Kuwadi were also highly diverse than Laxmimahila. They got the money, mainly from the finance and their social groups. The use of these financial activities in CFUGs of Gorkha was significantly different ($p<0.05$). These finances were mainly used in education, business, livestock and vegetable farming, etc. As they produce vegetables, livestocks in their farm, they are quite dependent in forest resources hence perceived the more contribution of forest for achieving the economic assets.

c. Physical assets

Physical assets have a supportive role for the development of infrastructures. These infrastructures such as schools, bridges, community buildings, drinking water, electricity, alternative energy, etc. are important for improvement and establishment of community (Brabben et al. 2004). In both the CFUGs in Kayarkhola, overall accesses to the physical infrastructures were similar. The communities had the infrastructures such as school, bridge, roads, community buildings, etc. Respondents had access to the communicating means such as television, radio, phone, etc. shown in figure 5. Taps and springs were the main infrastructures for drinking water in the community. More than 60% of the Chelibeti and all respondents of Jamuna CFUG had the irrigation facility for agriculture. Similarly, about 28% of Chelibeti CFUG and only about 4% of the Jamuna CFUG were using the alternative energy such as biogas.

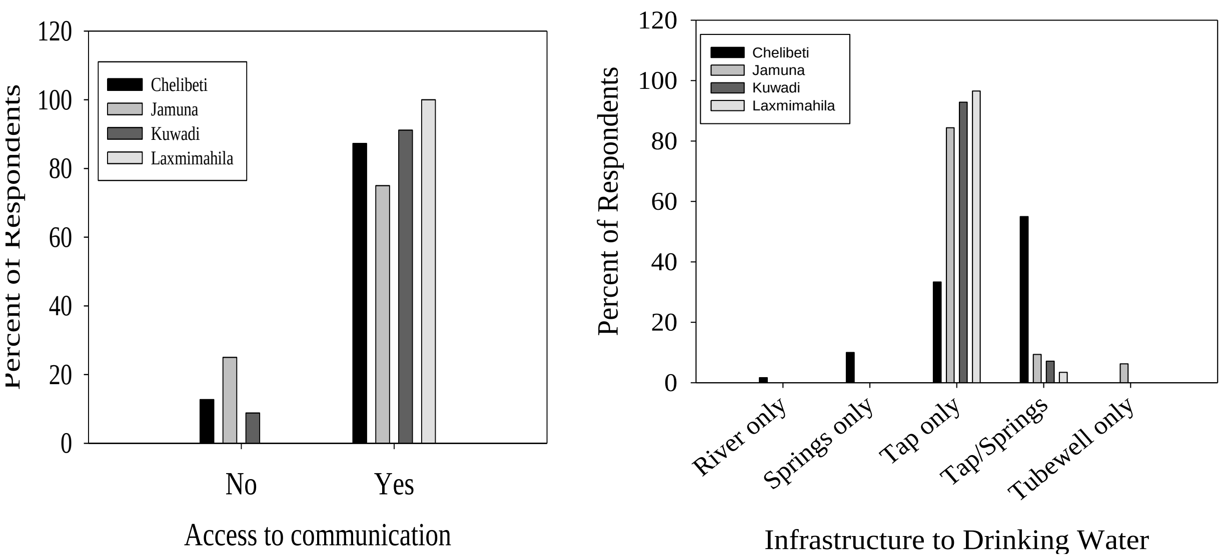


Figure 5: Frequency distribution of access to communication and infrastructure to drinking water within CFUGs of Kayarkhola and Ludhikhola watersheds

In Ludhikhola watershed, Kuwadi has higher accessibility to physical infrastructures ($p<0.05$). CFUGs had access to the road, school, etc. with the drainage system in Laxmimahila CFUG. Each respondent's family was beneficiaries of these infrastructures. People from Laxmimahila CFUG had access to computer and the internet besides other communication means such as radio, television, phones, etc. As of Kayarkhola, taps; springs were the major infrastructures for drinking water. More than 80% of the respondents' in both the CFUG didn't have irrigation facilities for their land. Similarly, only about 20% of respondents used biogas as an alternative energy.

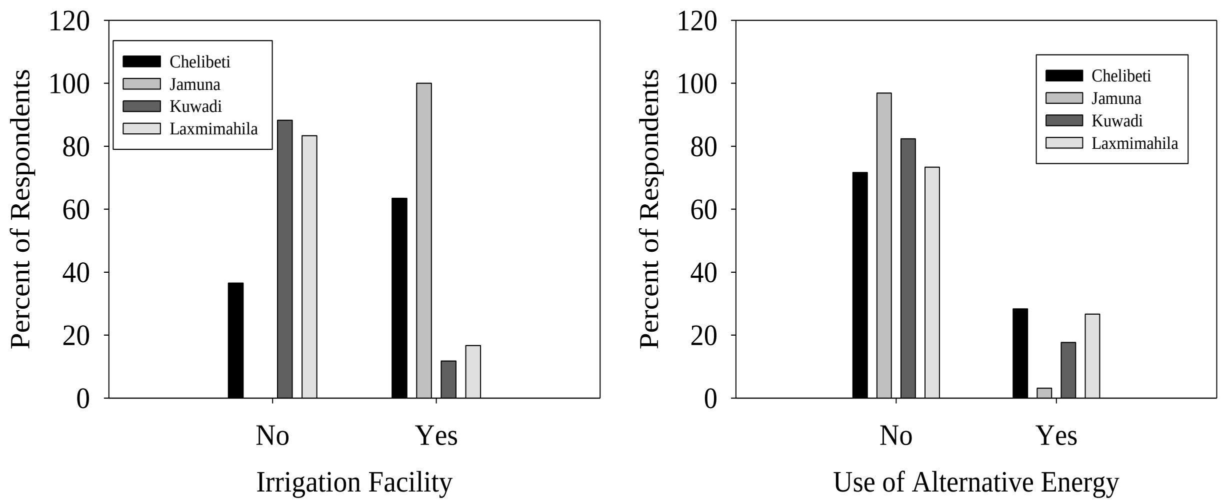


Figure 6: Frequency distribution of irrigation facility and use of alternative energy within CFUGs of Kayarkhola and Ludhikhola Watersheds

The extensive access to the physical infrastructures in the study sites led them to live in a quality life. Disadvantages group people were being helped by the forest users groups in access to education, health and sanitation. These group people are far behind to the access of resources, education and overall empowerment in society (Gurung 2006). The community groups were involved in increasing and managing the available facilities. The forest user group in the Jamuna community forest was constructing the hotels for the visitors to the study sites. This effort has increased the potentiality of developing the area in ecotourism. Moreover, the user groups in Chelibeti were planning to construct a bridge over the river named Kayarkhola to get short and fast access to the market. These efforts in the long term have positive implication to the livelihood.

d. Social assets

According to Timsina (2002), social inclusion, especially for women is still challenging in the forestry sector of Nepal. However, Giri et al. (2008) revealed that women's participation in community forestry, forming and participating in forest users' group is increasing by these days.

They are focusing their active participation and roles in widening the structures and decision-making process. Our study also illustrated that the active participation of respondents in societal activities in Jamuna CFUGs of Kayarkhola was significantly higher than Chelibeti ($p<0.05$). The respondents' participation was on community forestry, social and community-based organization such as cooperatives, forest users groups, women groups, etc. However, respondents from both the CFUGs perceived that they had gender equity in education, home, occupation, etc. About 53% of the female respondents' in Chelibeti and 66% in Jamuna CFUGs had decision-making power in household activities, occupation, business, etc. About 18% of uneducated respondents in Chelibeti FUG had attended the adult literacy class.

The social participation of respondents in Laxmimahila CFUG was significantly higher than Kuwadi ($p<0.05$). They participated in social organization, community forestry, etc. Respondents perceived that they had gender equity in education, occupation. About 50% of female respondents in Laxmimahila and 74% in Kuwadi had the decision making capacity in their household levels. Among the illiterate respondents, 15% of them in Kuwadi and only 4% in Laxmimahila attended the adult literacy classes.

These findings suggest that social assets such as participatory management, collective plans and policies, decision making, gender empowerment has been increased through community forestry. However, the benefits of assets can only be grasped when people participate and actively involved in the social organization, institution. In our study, these opportunities are enhanced by the community forestry. Community forestry has created a platform for all types of social inclusiveness. The advocacy, training, literacy classes, assessing internal governance capacity defines the base for the inclusion of women and marginalized people in the decision-making process which later contribute to the peace development, conflict management, sustainable resource management and poverty reduction (Acharya & Gentle 2006). The beneficiary groups then could draft the roadmap to get sustainable social welfare. At the individual level, these opportunities have made aware about their rights and duties, securing the livelihood potentially through economic development.

e. Human assets

Access to health services, development of skills, trainings, utilization of ideas, knowledge, etc. are some of the indicators of human assets. These assets are the means of achieving sustainable livelihood outcomes (DFID 1999). In Nepal, department of forests along with other bilateral donors, and local NGOs are involved in improving human assets (Thoms 2008). The investment on human assets creates awareness among individuals and whole community. They are aware of resource conservation and utilization, forest fires, NTFPs collection, etc. Individual awareness about health issues, identification of skills and trainings, ownership of properties and its proper investment are also some of the awareness created by improved human assets (Gnyawali 2007).

Our study on this asset showed that the access to the health facilities, identification of skills and trainings, personal hygiene and other health sanitation were improving in the study area. All the respondents in Chelibeti and Jamuna CFUG had access to the health post, private clinics, medical, etc. About 75% of total respondents in Chelibeti and 12.5% in Jamuna had been training in technical fields such as farming, tailoring, mason, etc. Similarly, all the respondents of Laxmimahila and about 70% of Kuwadi had access to the health post, clinics and medical. About 12% of total respondents in Kuwadi and 50% in Laxmimahila CFUGs had acquired skills and trainings. Likewise, 44% of respondents in Kuwadi, all in Chelibeti, only 7 % in Jamuna and 50% in Laxmimahila were aware about personal hygiene, health sanitation . The lower percentage in Jamuna might be due to the lack of family education.

In the study areas, different organizations like International Centre for Integrated Mountain Development (ICIMOD), Asia Network for Sustainable Agriculture and Bioresources (ANSAB), Federation of Community Forestry Users Nepal (FECOFUN), are directly involved with the community. These organizations are involved in forest management, collection and utilization of NTFPs, etc. Forest users' groups are getting training on forest inventory, carbon measurement and its potential benefits from REDD program. This opportunity has also made them aware of the conservation of forest resources. Students have been trained as Local Resource Person (LRP) who helped the university-level student, educational institution conducting their research and workshop in the sites. This opportunity has increased their creativity and knowledge. During 2010 to 2011, Heifer International provided trainings to the women of Kayarkhola watershed about the livestock management. It also organized the adult literacy class and other health programs to the communities.

Correlation between the livelihood assets' variables in the study sites

The correlation between the variables studied in the Jamuna community forest is illustrated in table 4. All the variables were moderately associated. The association was both positive and negative. The positive association between the variables was observed high between fuelwood and leaflitter and low in between the wheat production and leaflitter collection. The coefficient of determination (r^2) showed about 43% of fuelwood collection of Jamuna community forest was directly accounted with leaflitter collection and vice versa. In rural livelihood, these fuelwood and leaflitter are basic materials in household consumption. So the collection of one is always associated with other. The sources of these materials are the forests and sometimes also the agricultural land. Similarly, 15% of wheat production was directly accounted with the leaflitter collection and vice versa. As discussed earlier, the residue, from the farms are also the sources of leaflitter in the study sites. In negative association, the maximum was observed between skill and training and NTFP. It accounted about 23%. When people obtain the skills and training in a particular field such as tailoring, carpentry, etc. then their dependency on forest products, especially NTFPs might get reduce for economy.

In the Chelibeti community forest also most of the variables were moderately correlated (table 6). However, some were also weakly correlated. These associations were both positive and negative. Irrigation and loans, skill & training and adult literacy have positive weak associations. Skill & training with communication was positively associated and accounted for about 45%. It says that more access to the communication gives more opportunities for the skills development and trainings. Similarly, NTFPs and irrigation were negatively associated. It accounted about 43%. This association revealed that if the irrigation facility is accessible to the farmers, then the agriculture productivity will be regular and high. This makes less depend on forest product such as NTFPs for the economy. Likewise, skill & training and irrigation were also positively associated. It accounted about 31%. It can be summarized as the training and skill gained as mason can help in constructing the irrigation canal for agriculture. In Chelibeti community forest, there was some negative association between the skill & training and NTFPs, irrigation and NTFPs, etc.

In the Laxmimahila community, forest perfect negative association was observed between decision making and NTFPs (table 5). Besides this relation, both moderately positive and negative correlations were observed. The moderate positive association was observed between skill & training and decision making. About 45% of skill and training was directly accounted with decision making and vice versa. Similarly, the negative association was also observed between skill & training and NTFPs. It was also accounted to be 45%. In Laxmimahila, it can be predicted that the development of skills and training enhance the decision-making power among the people. The decision can be taken in their household perspectives and in occupation, business. Likewise, more the people who have skills in various fields depend less on non-timber forest products.

In the Kuwadi community forest, there was also observed both positive and negative moderate correlations between the variables (table 8). NTFP and rice production accounted for 20% association in the forest users groups. The association of these variables was positive. The results can be explained in a way that people who were more active in rice production also involved in the NTFPs collection. Similarly, the data showed that the farmers producing rice were also producing maize as well. About 31% of the rice production in Kuwadi community forest accounted with maize production and vice versa. Likewise, positive association (30%) was accounted with alternative energy and skill & training. Some negative association was also observed. For example, loan taken by people was negatively associated with sex (21%) and institutional membership. Less involved in community works, organization had more loans and vice versa. Also, more discussion and equity in gender had fewer loans and vice versa.

Table 4: Correlation Matrix of Jamuna Community Forest

Correlation Matrix Jamuna Community Forest															
Variables		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**
Leaflitter/month in kg (a)	Pearson Correlation	1													
Fuelwood/month in kg (b)	Pearson Correlation	.655**	1												
Fodder/month in kg (c)	Pearson Correlation	.483**	.495**	1											
NTFP forest (d)	Pearson Correlation	.169	.144	.095	1										
Indicators - loan (e)	Pearson Correlation	-.182	-.189	-.162	-.046	1									
Major Income present (f)	Pearson Correlation	-.334	-.192	-.174	0.000	0.000	1								
Communication (g)	Pearson Correlation	-.420*	-.194	-.101	-.104	-.149	.289	1							
Alternative energy (h)	Pearson Correlation	-.201	-.133	-.137	.032	.046	0.000	.104	1						
Decision making (i)	Pearson Correlation	.225	-.132	-.113	-.032	-.046	0.000	-.104	.032	1					
Skill and Training (j)	Pearson Correlation	-.297	-.168	-.131	-.475**	.098	0.000	.218	.475**	.068	1				
Rice/ha/yr in kg (k)	Pearson Correlation	.051	-.023	-.027	-.077	-.227	.169	.112	.131	.139	.104	1			
Maize/ha/yr in kg (l)	Pearson Correlation	-.052	.044	.092	-.039	.177	-.076	-.217	-.286	-.203	-.026	-.128	1		
Wheat/ha/yr in kg (m)	Pearson Correlation	.388*	.292	.039	.134	.227	-.163	-.334	-.251	.017	-.324	.122	.262	1	
Gender (n)	Pearson Correlation	-.050	-.042	-.027	.121	-.383*	-.270	.078	-.121	-.266	-.255	.034	.013	-.324	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 5: Correlation Matrix of Laxmimahila Community Forest

Correlation Matrix- Laxmimahila Community Forest													
Variables		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**
Major Income present (a)	Pearson Correlation	1											
Fuelwood/rmonth/kg (b)	Pearson Correlation	.261	1										
NTFP (c)	Pearson Correlation	-.444*	-.496**	1									
Indicators-loan (d)	Pearson Correlation	.154	.285	-.509**	1								
Drinking water (e)	Pearson Correlation	.115	.133	-.267	.117	1							
Irrigation (f)	Pearson Correlation	.140	.054	-.268	.098	.120	1						
Alternative energy (g)	Pearson Correlation	-.230	-.299	.603**	-.099	.161	-.067	1					
Decision making (h)	Pearson Correlation	.444*	.496**	-1.000**	.509**	.267	.268	-.603**	1				
Adult Literacy (i)	Pearson Correlation	.227	.350	-.333	.218	.089	.149	-.201	.333	1			
Skill and Training (j)	Pearson Correlation	.168	.201	-.668**	.262	.018	.418*	-.342	.668**	.089	1		
Rice/ha/yr in kg (k)	Pearson Correlation	-.074	-.097	-.044	-.011	.071	.489**	-.028	.044	.095	.354	1	
Maize/ha/yr in kg (m)	Pearson Correlation	.085	-.046	.115	-.084	.339	.149	.223	-.115	-.504**	-.164	.019	1

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

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

Table 6: Correlation Matrix of Chelibeti Community Forest

Correlation Matrix - Chelibeti Community Forest															
Variables		**a**	**b**	**c**	**d**	**E**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**
Leaflitter/month in kg (a)	Pearson Correlation	1													
Fuelwood/month in kg (b)	Pearson Correlation	.631**	1												
NTFP (c)	Pearson Correlation	.226	-.025	1											
Indicators - loan (d)	Pearson Correlation	-.046	-.128	-.206	1										
Major Income present (e)	Pearson Correlation	.092	-.010	.131	-.136	1									
Communication (f)	Pearson Correlation	-.102	-.070	-.437**	.309*	-.380**	1								
Irrigation (g)	Pearson Correlation	-.338**	-.133	-.656**	.285*	-.189	.469**	1							
Alternative energy (h)	Pearson Correlation	-.121	.027	-.420**	.250	-.078	.314*	.494**	1						
Decision making (i)	Pearson Correlation	.028	-.073	.034	.196	.171	-.175	-.043	-.024	1					
Adult Literacy (j)	Pearson Correlation	-.164	-.087	-.455**	.122	.078	.237	.429**	.180	-.018	1				
Skill and Training (k)	Pearson Correlation	-.381**	-.218	-.505**	.210	-.234	.674**	.561**	.363**	-.157	.274*	1			
Rice/ha/yr in kg (l)	Pearson Correlation	.017	.080	-.004	.189	.027	.001	.143	.213	-.206	.148	.004	1		
Maize/ha/yr in kg (m)	Pearson Correlation	.200	.112	.031	-.044	-.323*	.195	.058	.042	-.446**	.076	.050	.119	1	
Gender (n)	Pearson Correlation	.093	.040	-.020	-.212	-.107	.117	-.057	-.048	.121	-.342**	-.019	-.158	-.218	1

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Table 7: Correlation Matrix of Kuwadi Community Forest

Correlation matrix -Kuwadi Community Forest																	
Column1	**Column2**	**A**	**b**	**c**	**d**	**e**	**F**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**
Major income present (a)	Pearson Correlation	1															
Institutional membership (b)	Pearson Correlation	-.032	1														
Leaflitter/month in kg (c)	Pearson Correlation	-.023	-.116	1													
Fuelwood/month in kg (d)	Pearson Correlation	.098	-.348*	.350*	1												
Indicators- loan (e)	Pearson Correlation	-.109	-.471**	.299	.373*	1											
Communication (f)	Pearson Correlation	-.012	-.128	-.320	.234	.316	1										
Drinking water (g)	Pearson Correlation	.081	-.190	-.141	.337	.107	.128	1									
Irrigation (h)	Pearson Correlation	.014	.310	.233	.093	-.013	.114	-.070	1								
Alternative energy (i)	Pearson Correlation	.263	-.214	-.164	.094	.257	.144	.214	-.169	1							
Decision making (j)	Pearson Correlation	.190	.103	-.016	.368*	-.018	.283	.597**	.012	.278	1						
Literacy (k)	Pearson Correlation	.012	.400*	.017	-.006	-.316	-.269	-.128	.208	-.144	.187	1					
Skill and Training (l)	Pearson Correlation	.072	.070	-.182	-.287	-.013	.114	.169	-.133	.549**	.219	-.114	1				
NTFP (m)	Pearson Correlation	.074	.236	-.149	.079	-.282	-.158	.337	-.040	.236	.354*	-.098	.186	1			
Rice/ha/yr in yr (n)	Pearson Correlation	-.102	-.059	-.131	.308	-.134	.003	.221	.118	-.001	.249	.158	-.187	.444**	1		
Maize/ha/yr in yr (o)	Pearson Correlation	.091	-.391*	.075	.293	-.007	-.074	-.046	.033	-.015	-.058	.078	-.452**	-.022	.559**	1	
Gender (p)	Pearson Correlation	-.051	.304	.087	-.166	-.461**	-.204	-.142	-.079	-.180	-.115	-.013	-.079	.224	-.176	-.164	1

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

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

Discussion summary

The basis of livelihood assets has been directly influenced by the community forest in the study sites. Improved levels in the managerial aspect of forest, high security of forest products, secured and good flow of environmental services has an important role for the livelihood basis. These roles in management aspect of the community forest in the study area, then there are many similarities and dissimilarities. However, people in all the community forests have favorable attitudes and determination for the forest protection and its use for livelihood improvement. The findings and its analysis collected from all the community forests are based on the assets, demographic information and socioeconomic circumstances.

The research outcomes indicated that forest restoration through the community forestry program has improved the livelihood of people. The program has helped in enhancing the livelihoods of the people not only by fulfilling basic needs of the forest users but also fortifying the resource management, equitable benefits sharing and decision making. The responsibility in managing the forest by women as a part of forest user group have empowered them ahead with the sustainable use of resources. This responsibility that women are handling and managing the resources is significant in good forest governance. The poor and the marginalized people within the forest user groups are more beneficial for the implementation of income-generating activities, adult literacy class, personal hygiene, health and sanitation programs. Besides resource management such as biodiversity conservation, soil conservation and water resource conservation, carbon sequestration is also one of the benefits of community-based forest management (Lasco & Pulhin 2006). The study area is the pilot project area of the REDD program, people's participation and support on it have definitely conserved and restored the forest resources along with their livelihood improvement. There has been more productive and sustainable access to the resources. The improvement in livelihood has helped better resource management thus creating opportunities for huge carbon stocks along with other assets such as fuel, fodder, NTFPs, timber forest products, agricultural productivity, etc.

A study by Adhikari (2001) on a gender analysis in community forests of Ramechhap and Dolakha district of Nepal illustrated the gender biased roles in all areas of society from household to government. Sunam & McCarthy (2010) state that due to lack of confrontation in a public sphere, the marginalised people are being excluded from a decision-making process and more powerless.The opportunity for women and socially marginalized people to participate and take decisions in communal activities or resource management is a great issue then in community forestry. However, these issues were raised in the study sites. There have been comparisons between women handled community forest with the other in both the study area. Therefore, it could be said that the livelihood assets in both were good and could be better in the future. The limitations from conservative policies of user groups on resource access as indicated by Branney et al. (2000) and Arnold (1998) (cited by Gautam 2009) were not observed in the study sites as the user groups are benefiting from the REDD program and are more involved in managing the resources.

Limitations of study

In this study, we tried to understand the status of assets of sustainable livelihood in the forest users groups of two different watersheds. The livelihood index was not derived from the indicators to compare. We only analyzed the data and tried to understand the differences between the user groups in a watershed. Our data totally rely on the respondents' views and understanding. We tried one of the ways in this study and other more methods can be used to understand the people's livelihood influenced by the community forestry.

Conclusion

The community-based forest management in Nepal has been largely successful in terms of fulfilling basic livelihood requirements, restoring forest degradation and conditions. It is also affluent in empowering women and creating opportunities for the gender equity. The findings suggest that women could empower themselves if given responsibility which on later can establish as an institution. The best management and governance (despite of gender) of the resources can create better livelihood assets and welfare of the people. The forest livelihood can only be a livelihood strategy if managed, conserves properly with equity and equality among the stakeholders. The findings of the study also revealed that if the managerial aspect of the resources is converted in terms of resource economics, then it goes in the best way. Therefore, it gives more energy, effectiveness, and strength among the users whom they utilize for the resource management and push up their livelihood strategy.

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PAPER 2: SOIL CARBON STOCK AS INFLUENCED BY COMMUNITY FORESTRY IN NEPAL AND ITS IMPLICATION FOR REDD (REDUCING EMISSIONS FROM DEFORESTATION AND FOREST DEGRADATION)

Soil carbon stock as influenced by community forestry in Nepal and its implication for REDD (Reducing emissions from deforestation and forest degradation)

Abstract

Soil is the potential sink for atmospheric carbon, which has a significant role in mitigating global climate change. Soil organic carbon (SOC) content, including other soil parameters varies within a soil profile in response to management that regulate soil carbon stock. Studied was performed on Jamuna and Chelibeti community forests (CF) in Kayarkhola watershed of Chitwan district and Laxmimahila and Kuwadi community forests in Ludhikhola watershed of Gorkha district in Nepal. This study was focused on three specific objectives. Firstly, it focused on investigating the forest soil properties with SOC distribution in different soil depth (up to 1m). Secondly, we estimated the SOC stock in each CF of both watersheds and compared within and with the other similar published works. In third part, we assessed the prospects of carbon storage in well managed sites (CF) in comparison with degraded sites and its implication to REDD (Reducing emissions from deforestation and forest degradation). This study also tried to cover the MRV (Monitoring, Reporting and Verification) issues in REDD regarding the measurement and updating the carbon data from different physiographic zones of Nepal. Soil samples were collected from the study sites using a core sampler from four soil depths (0-15cm, 15-30cm, 30-60cm and 60-100cm). We collected samples from three plots in each CF. Dry combustion and hydrometer method were used to determine SOC and soil texture respectively. Likewise, core method was used to determine soil bulk density. The result showed SOC content decreased with soil depth. SOC content and bulk density between the CFs in the watershed were similar and gravel contents were different. The result showed differences in the SOC stock within the community forests in watersheds and between the degraded and well managed sites. The estimation of potential carbon gained from conversion of degraded sites to well managed sites indicated the potential benefits of enhancing soil carbon stock through community forests as a part of REDD program.

Keywords: Soil organic carbon, community forest, REDD, carbon price

Introduction

In a terrestrial ecosystem, vegetation and soil contain the different amount of carbon storage. Soil acts as the largest carbon store in the biosphere. Soil can hold carbon twice as much as it is present in the atmosphere (Dey 2005). Soil contains carbon about three times more than vegetation. Carbon storage below the ground surface is greater than aboveground surface (Post & Kwon 2008). Carbon storage below the ground surface is related with the input from the above ground biomass. In case of forest ecosystem, leaf litter, fine root decomposition, the canopy cover, etc. can have a positive impact on soil carbon (Johnson 1992). Hence forest's ecosystem has the higher potentiality of capturing and storing the carbon (Gibbs et al. 2007).

The potentiality of carbon capturing through forest is diminished by land degradation and clearing the forest area for agriculture. Hence forest's restoration and protection are essential for efficient sequestration. Forest's restoration through community-based forest management has been considered as one of the successful forest management and effective reforestation practices in degraded land (Pokharel et al. 2005). Nepalese forest covers during the 1970s were in the declining phase. Only after the 1990s forest cover started increasing due to the community-based management system. Community forestry has been capable in establishing good forest governance for restoring the degraded forest land. Pokharel et.al (2005) also mentioned that restoration has improved the forest agriculture interface, controlled degradation and improved forest conditions. The forest's improvement established the greenery in the hills, regeneration of species, basal area, growing stocks and soil quality (Pokharel et al. 2007). The forest fires, over gazing, and other illegal activities in forest have been reduced. Similarly, forest patrolling, sustainable collection in fuel, fodder, timber, leaflitter, etc. have increased the forest biomass. Some examples like the grasslands and shrublands in Kavre and sindhupalchowk districts of Nepal were converted to forest land increasing its area from 7677 ha to 9679 ha (Jackson et al. 1998). As mentioned by Pokharel & Nurse (2004), community forest canopy cover in Dhaulagiri hills between 1996 -2001 increased more than double (11% to 23%). A study by Livelihood and forestry programs in 2008 (unpublished data) mentioned by Luintel et al. (2009) in the Koshi hills of Nepal revealed that the basal area and biomass were increasing respectively by 2% and 1.5% per annum during the 14-year period. In the same period, the growing stock increased by $2m^3$/ha/year in average. In terms of area, study by Karky (2008) in Ilam (383 ha), Lamatar (96 ha) and Manang (240 ha), the average total biomass increased from 115 to 128, 102 to 108, 62 to 66 ton/ha respectively in three consecutive years. These examples show the success of community forestry in increasing the forest biomass and soil quality. However, Karky (2008) also argued about the forest types, and altitude differs on the biomass. He discussed that the sub tropical and lower temperate broad-leaved forests in lower altitude have higher biomass per hectare than the higher temperate conifer. The higher biomass reveals the larger carbon pools. The increased forest biomass has the potential to increase soil quality and its productivity despite factors like geography, climate, landuse history, etc.

In 2005, Conference of Parties, COP 11 (Montreal Climate Change Conference) introduced the RED (Reducing emissions from deforestation). It included the forests to non forests change. In 2007, the 13th COP meeting at Bali introduced reducing emissions from deforestation and forest degradation (REDD) program as a potential tool for mitigating global environment change. Besides deforestation, it included forest degradation. It values the carbon stock in the forest and provides incentives for the developing countries to reduce forest emissions. UNFCCC meeting in Accra, 2008 introduced REDD+ with addition of sustainable forest management (SFM), forest conservation and enhancement of carbon stocks (Dahal & Banskota 2009). This concept is to ensure forest conservation linking the sustainability, biodiversity protection and increasing the carbon stocks. Due to this, community forests in developing countries like Nepal might be the beneficiary of implementing REDD program and compensating the forest managing groups. The compensation to forest managers includes from the prices of total carbon sequestered. Hence the carbon storage from the forest could benefit from the local to the global by promoting carbon sequestration and ecosystem services.

Although the potential benefits could be higher, REDD/REDD+ program appears just as an international agenda between the parties for its possibilities of implementation. Therefore, the preparedness for the better bargaining capacities, stronger position to implement REDD in the most beneficial way for the countries like Nepal is essential (Dahal & Banskota 2009). In order of implementing full phase REDD program, the UNFCCC- Conference of Parties (COPs) has established pilot phase in 2012. This phase measures the emissions from the forest degradation and establishes guidance. Besides these, the issues of conservation, livelihood benefits through the forests are also covered (Miles & Kapos 2008).

Community forestry is associated to the carbon sequestration and its pricing from REDD program. The pricing benefits from REDD require monitoring of forest cover, i.e. the change in forest area and measurement, reporting and verification (MRV) of forest carbon stocks. Carbon stock measurement and analysis determine the net forest emissions and is based on five carbon pools, which are soil organic carbon, litter, dead wood, above and below ground biomass (Penman, Jim et al. 2003). The emissions can occur due to the land-use changes, and moreover; the specific land-use changes differ on the emission of the carbon amount (Miles et al. 2008). For example, Miles et al. 2008 illustrated that conversion of forests to agriculture land (rice or maize or soyabean) than the oil palm emits 60 percent more emission. Therefore, forest monitoring is important to identify the anthropogenic sources of emissions and potential sources of removal by sinks (Maniatis & Mollicone 2010) as shown in figure 1.

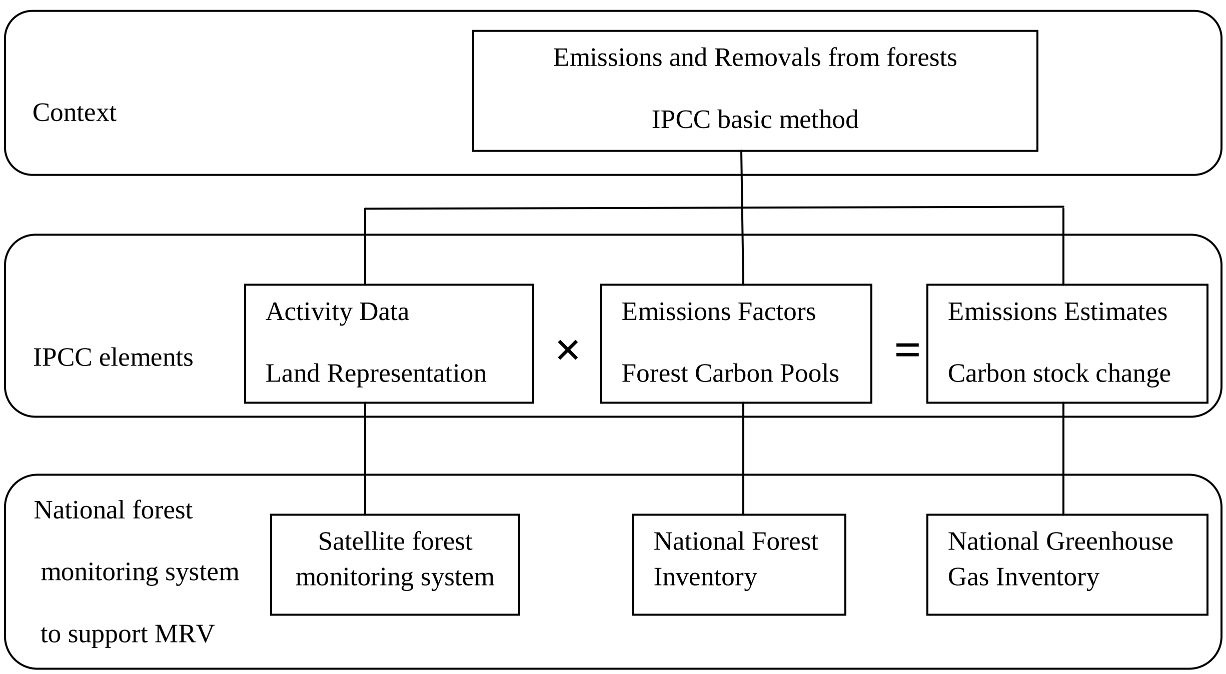

Figure 1: MRV framework showing the elements' interaction in a national forestry monitoring system. Adapted from (Maniatis & Mollicone 2010).

Figure 1 illustrates that the emission estimates can be calculated from the extent of human activity (Activity Data) and quantification of emissions per unit of activity (Emissions Factors). Activity data represents the default 20-year data on the land-use change, and the emission factors represent the forest area conversion that is the fluctuation in carbon stock (Penman, J et al. 2003). The figure also mentions the national-level monitoring system to support the MRV.

IPCC has established requirements for MRV in REDD program, in which Nepal has many gaps and issues to meet these necessities under MRV. Jha & Paudel (2010) discussed about the methodological and capacity gaps. Nepal has adopted tier 2 and is building capacity to shift to tier 3 (Tier is the optional measures provided by the IPCC guidelines for measuring, monitoring and recording of degradation and deforestation). Based on National forest inventory, Jha and Paudel (2010) identify methodological gaps in four areas of monitoring, which are deforestation, forest degradation, carbon stock and co-benefits. Similarly, Nepal's capacity on MRV has also been discussed by Jha & Paudel (2010) based on study by Herold (2009) on capacity indicators. They discussed about the indicators such as consistency, transparency, comparability, completeness, accuracy, human resources and sources of data with Nepal's existing forest monitoring system. Besides these gaps in forest monitoring mechanism, there are still other various issues and challenges for the MRV designing in Nepal. Some of these are: adopting forest definition, scale of accounting, methods and approaches for MRV mechanism. Likewise, Ojha et al. (2008) raised the issues of technical capacity, institutional mechanism with transaction costs in MRV. They also argued that project specific baseline, and its monitoring methods should also be addressed in necessities. Based on the discussion on these issues, there is a need of generating updated data in Nepal from all physiographic regions, forest types and its monitoring. For this, concerned government, non government bodies and academic institutions should work together. These work then promotes the Nepalese forest in the voluntary market for carbon through REDD process. There are number of reports available on estimating above ground biomass from Nepal. However, estimation of below ground carbon stock is rarely available. In this study, therefore, we tried to study the soil carbon; its potential REDD benefits from pricing in two different watersheds of Nepal. The specific objectives of study are:

i. To investigate the soil properties and SOC distribution in different soil depth

ii. To quantify carbon stock and compare with other published works from Himalayan region.

iii. To assess the prospects of carbon storage in soil and its implication for REDD

Materials and Methods

Study Area

The study was conducted in two watersheds in different regions of Nepal. Kayarkhola and Ludhikhola watersheds are located in the Chitwan district (Central Development Region) and Gorkha district (Western Development Region) of Nepal. Kayarkhola watershed ranges from 245m to 1944m, and Ludhikhola ranges from 318m to 1714m from the sea level. Kayarkhola and Ludhikhola cover the area of 8002 ha and 5750 ha respectively. There are 16 community forest user groups in Kayarkhola watershed and 31 in Ludhikhola. The community forest user group is managing the area of 2381.97 ha in Kayarkhola watershed and 1887.5 ha in Ludhikhola watershed. From each watershed, two community forests were selected. Chelibeti and Laxmimahila community forests are managed by female. The details of the study sites are illustrated in table 1.

Table 1: Details of study sites in Kayarkhola and Ludhikhola Watershed

Community Forest	**Watershed**	**Total CF area (ha)**	**Area in strata (ha)**	
			Dense	**Sparse**
Chelibeti	Kayarkhola	64.8	59.61	6.17
Jamuna	Kayarkhola	34.53	10.86	23.67
Laxmimahila	Ludhikhola	8.72	8.09	0.63
Kuwadi	Ludhikhola	92.27	83.75	8.52

Shorea robusta (Sal) is the dominant species in the study sites of both Kayarkhola and Ludhikhola watershed. Besides the *Shorea robusta,* other species *Lagerstroemia indica* (Crape - myrtle/Ashare), *Lagerstroemia parviflora* (Botdhangero), *Nyctanthes arbor-tristis* (Night-flowering jasmine/Parijat), *Casearia graveolens* (Badkaule) are found in Jamuna CFUG. In Chelibeti CFUG, *Lagerstroemia parviflora* (Botdhangero), *Rhus wallichii* (Bhalayo), *Cassia fistula* (Golden shower tree/Rajbrikshya), *Quercus floribunda (Green Oak/*Thinke), *Careya arborea* (Slow Match Tree/Kumbi), *Syzygium cumini* (Black Plum Tree/Jamuno), *Mallotus philippinensis* (Monkey face tree/ Sindure), *Casearia graveolens* (Barkamle), *Talama hodgsinni* (Bhalukath), *Woodfordia fruticosa* (Fire flame bush/Dhangero), *Terminalia alata* (Indian laurel/Saj), *Phyllanthus embilica* (Indian gooseberry/Aamala), *Cornus oblonga* (Latikath), *Lagerstroemia indica;* species are found. Likewise, in Kuwadi CFUG, Kyamuno, *Lagerstroemia parviflora*, *Rhus wallichii*, *Syzygium cumini*, *Schima wallichii* (needle wood/ Chilaune) species are found and in Laxmimahila CFUG, *Schima wallichii*, *Rhus wallichii* species are found. The soil of Chelibeti and Jamuna CFUG has silt loam texture. Similarly, Kuwadi CFUG has silty-clay loam texture, and Laxmimahila has both silt loam and silty clay texture.

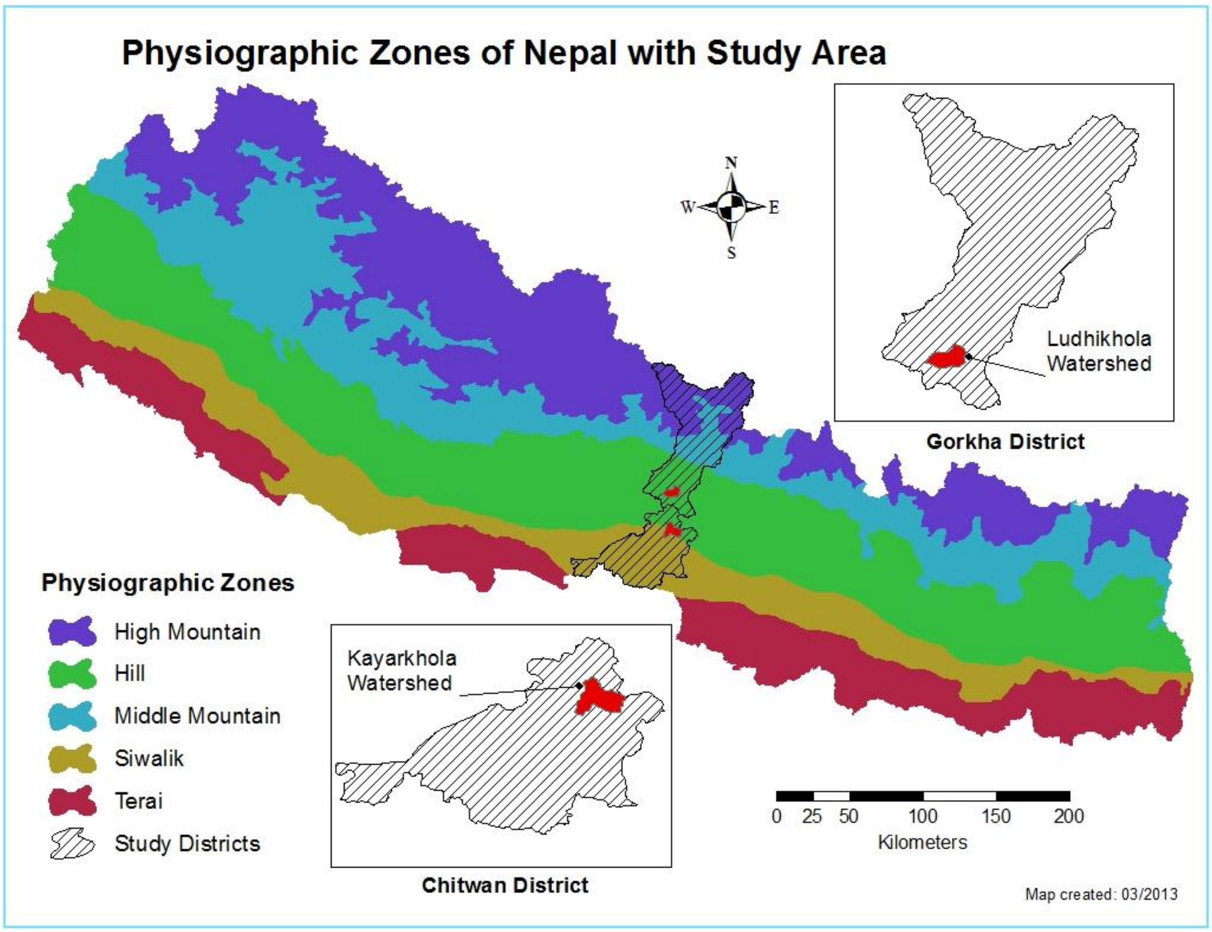

Figure 2: Map showing the Chitwan and Gorkha districts and the watersheds' area

Soil sampling, Analysis and Calculations

Soil sample was collected in November 2011. Three sample plots (size = 20m×25m) were randomly selected from each community forest. A core sampler size of diameter 5cm and height 6cm (volume 117.75 cubic centimeters) was used to collect the soil samples for determining the bulk density. The samples were taken from the four soil depths (0-15cm,15-30cm, 30-60cm and 60-100cm). While taking the soil sample from different depths up to 1 m, in some cases bedrock was found within 30 to 60cm and 60-100cm. In such a cases' sample was not collected beyond the rock. Dry combustion method was used to determine the soil organic carbon (Nelson & Sommers 1982). Similarly, hydrometer method was used to determine the soil texture (Wairiu & Lal 2003). Likewise, core method was used to determine the bulk density (Blake & Hartge 1986). Based on the parameters, soil depth (sample taken) the bulk density of the soil in the depth, and organic carbon content in the depth, soil carbon stock was calculated. The total carbon stock in the one-meter depth was gained by adding the stocks in simultaneous depth. Then by the unitary method, the stock in per hectare with its reflection in the whole community forest area was estimated.

The soil organic carbon stock was calculated by using the following equation (Wairiu & Lal 2003):

Soil carbon stock (Kg/m^2) = Bulk density (Kg/m^3) × SOC content% × depth of the horizon (m) × CF_{st}

Where CF_{st} is the correction factor for stone and gravel content in soil.

CF_{st} = 1- (%stone+%gravel)/100

SOC stock in selected community forests was estimated by multiplying the carbon stock (Kg/m^2) with the total area in each horizon. The total C stock from each horizon was then summed up to estimate carbon stock from soil profile located in each community forest. To assess the possible carbon gain through CF intervention, we reviewed the estimates of other work and compared with our data.

The carbon stocks (Kg/m^2) of three degraded sites of mid hill watershed (Dhulikhel, Kavre and central hills) were estimated of the top soil (0-15cm) (Brown et al. 1999), (Baral et al. 1999), (Shah et al. 2000) reviewed by (Sitaula et al. 2004). For this estimation, bulk density and CF_{st} were assumed similar as that of community forests of Ludhikhola watershed. Then the difference of carbon stocks between degraded and community forest sites (Ludhikhola watershed) were compared to assess the prospects of soil carbon storage (in economic terms) in community managed land.

The data were analyzed using Excel 2007 and Sigma plot 11 software. Descriptive statistics (mean, standard deviation) and tools such as Pearson's correlation, one way ANOVA was used to analyze the data.

Result and Discussion

Soil Description

Table 2 shows the description of soil in the study sites in Kayarkhola and Ludhikhola watershed. In Kayarkhola watershed, both the soils of Chelibeti and Jamuna community forests had silt loam texture. Similarly, in Ludhikhola watershed, Kuwadi CF had silty-clay loam texture whereas in Laxmimahila CF, silty loam was observed as dominant soil texture. The texture of soil along with soil mineral (clay, silt and sand) densities, soil organic matter and the particle arrangement determine the bulk density of soil. The comparison of SOC content, bulk density of the soil in Jamuna and Chelibeti as well as Kuwadi and Laxmimahila didn't show any significant differences.

Bulk density

Bulk density significantly increases with the soil depth. In the subsurface layer of soil, there generally contains less pore space than in the surface. This is likely to be caused by the soil organic matter, aggregation and root penetration decreases with increased soil depth hence, increase the bulk density (Davidson & Ackerman 1993; USDA 2008). Compact, low porous soil, poor organic matter containing soil has a high bulk density. Therefore, sandy soil has relatively high bulk density than clay and silt soil. Silt and clay, loam soils have high porosity, finer texture and low bulk density. The depth distribution of these soil parameters may explain the trend in observed bulk density with soil depth.

Land use has greater impacts on bulk density. Therefore, it changes accordingly. Cultivated land possesses a higher bulk density due to the lower organic matter and vice versa with forest lands. It may be due to the SOC loss during conversion of natural forest. This shift of forest land to cultivated land also changes the physical-chemical and enzymatic characteristics of soil (Kizilkaya & Dengiz 2010).

Table 2: Soil properties in the study area

		Mean±SD			
Watershed (District)	**Community Forest**	**Soil Organic Carbon%**	**Bulk Density (gm/cc)**	**Gravel Content (cc)**	**Soil texture**
	Jamuna	1.61±0.15	1.31±0.19	34.77±10.34	Silt Loam
	Jamuna	2.03±1.05	1.18±0.16	17.34±10.49	Silt Loam
	Jamuna	1.32±0.70	1.22±0.16	31.55±9.15	Silt Loam
Kayarkhola	Chelibeti	1.19±0.13	1.29±0.23	21.76±11.90	Silt Loam
(Chitwan)	Chelibeti	1.87±0.35	1.34±0.22	21.74±6.45	Silt Loam
	Chelibeti	1.60±0.86	1.19±0.27	20.52±7.14	Silt Loam
	Kuwadi	1.78±0.67	1.32±0.17	7.91±4.26	Silty Clay Loam
	Kuwadi	1.10±0.21	1.29±0.21	7.13±5.67	Silty Clay Loam
	Kuwadi	1.18±0.48	1.36±0.15	1.10±1.59	Silty Clay Loam
Ludhikhola	Laxmimahila	0.87±0.44	1.53±0.19	6.26±2.28	Silt Loam
(Gorkha)	Laxmimahila	1.87±0.58	1.01±0.16	18.66±8.58	Silty Clay
	Laxmimahila	1.42±0.50	1.29±0.15	4.59±5.14	Silt Loam

Soil organic carbon

A gradual decrease in the SOC with depth was observed (figure 3). The physical and chemical properties of SOC in the subsoil are stabilized as mentioned by Lorenz et al. (2011) and the SOC turnover time rises with the increased soil depth. The vertical distribution of SOC in the soil depth is associated with plant functional types as well. In forest land, there is 50 percent

SOC content compared to shrub's land (33%) and grassland (42%) in the top 20cm relative to first meter and changes with the second and third meter. Climate and vegetation are highly related to the SOC with depth. The subsurface SOC content could be more stable and contribute to carbon sequestration.

The subsurface carbon sequestration can be achieved by the input of organic matter in soil depth profile. This can be possible by the deep and thick root plant species containing high contents of chemical. Similarly, the dissolved organic carbon (carbon contained in a solution of less than 0.45 µm in size) from high input of organic matter in the surface layer when moved to deep soil profile contribute to the soil carbon storage (Lorenz & Lal 2005). Likewise, higher steep slopes also lower the carbon content (Awasthi et al. 2005). As discussed Awasthi et al. (2005) there is shallow soil with sparse vegetation and in high rainfall, the top soil gets eroded causing loss of organic matter. Besides steepness, he also indicated the relation of SOC with aspect, nutrient stocks, soil loss, elevation, etc. Although the soil characteristics and other topographical features have the impact on soil carbon and overall stock, better land use management reveals the significant carbon storage capacity. Shrestha et.al (2004) found top layer (0-10cm) SOC content (%) in community managed forest in Mardi watershed of Kaski district in Nepal to be 4 to 6. Similarly, Awasthi et al. (2005) also found SOC content (%) to be 3.17 in the same watershed at 0-15 cm soil profile. Likewise, our study in top soil (0-15cm) in CFs of Kayarkhola watershed revealed SOC content (%) 2.0 in Chelibeti CF and 2.39 in Jamuna CF. In CFs of Ludhikhola watershed SOC content (%) 1.99 in Kuwadi CF and 2.02 in Laxmimahila CF. In comparing these study with the degraded site studied by Shah et.al (1999) in central hills, Brown et.al (1999) in Dhulikhel and Baral et.al (1999) in Kavre district of Nepal revealed SOC content (%) 0.5, 0.68 and 0.1 respectively. This showed the improvement in management has potential to increase the carbon content. These data also showed that the variation in SOC content indicates the management and condition of sites. The good management of forest indicates dense crown cover resulting high SOC content in surface layer than degraded sites (Sitaula et al. 2005).

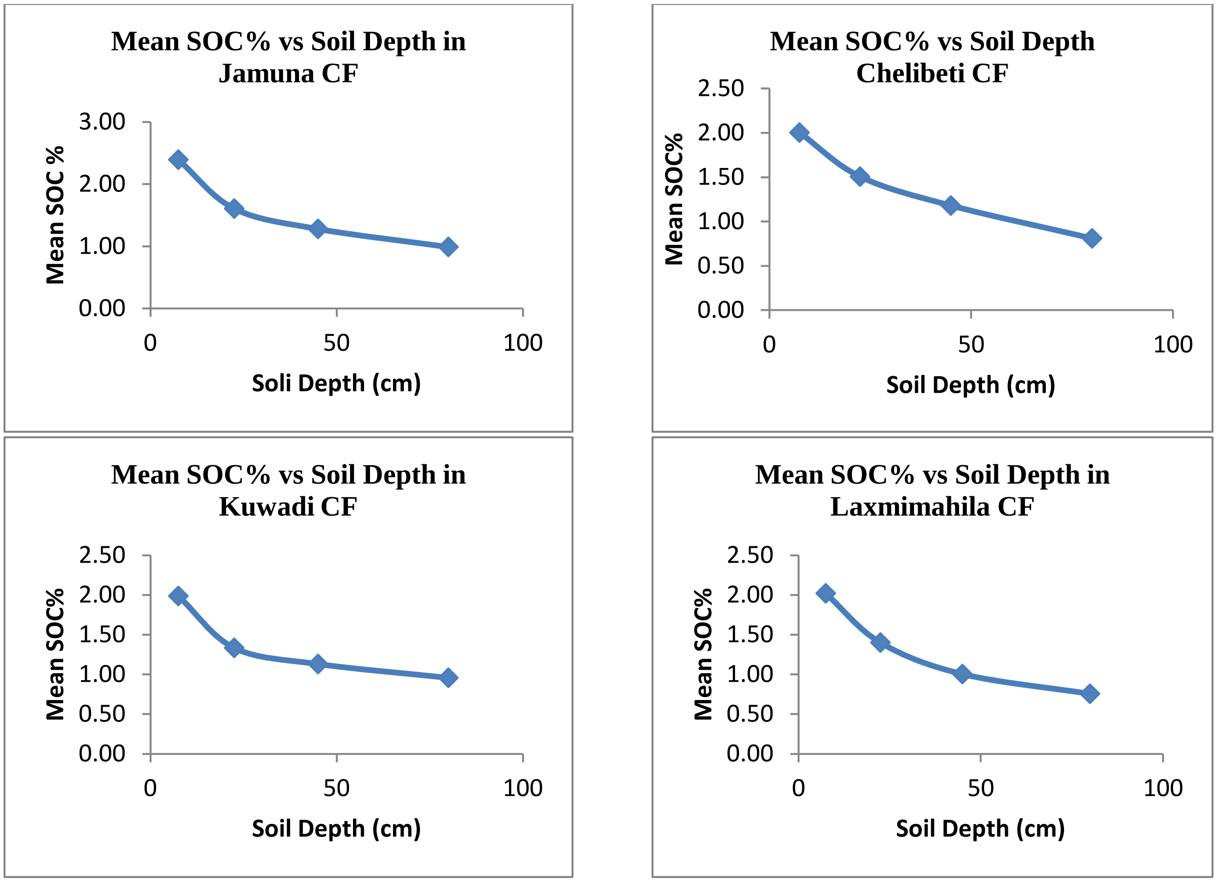

Figure 3: Variation in Soil organic carbon with soil depth in the different community forests of the study area

Correlation among soil parameters

The soil organic carbon was negatively correlated with bulk density (r = -0.57). The lower bulk density due to high SOC contents in soil could be from better macro aggregation and high mean weight diameter of soil aggregates (Akala & Lal ; BoniniA & AlvesB 2010). A comparative data in six plots at Kayarkhola watershed and six at Ludhikhola watershed showed the SOC decreasing trend with the increasing depth (fig 1). Trujillo et al. (1997) in Shrestha et al. (2004) also discussed that the SOC content decreases with the soil depth in spite of vegetation cover and soil texture. Similarly, Mehraj et al. (2009) furthermore, found the decreasing trend of SOC with increasing depth in the different forests of himalaya. The high-carbon content in the upper layer of soil might be due to the high rate of decomposition of leaf and litter. So comparatively the dense forest can have high canopy cover resulting more leaflitter fall than the sparse low canopy cover forests.

Measurement of gravel and stone content is also the important soil parameter in estimating carbon stock in forest soil apart from the bulk density and SOC content. This parameter is highly present in the mid hill soils, and its increment in soil lowers the carbon stock estimation (Shrestha et al. 2004). Our study in one metre depth soil profile in Kayarkhola watershed had higher gravel content than in Ludhikhola watershed ($p<0.01$). Their respective SOC stocks were 3517 MTC for Jamuna, 6697 for Chelibeti MTC, 1044 MTC for Laxmimahila and 13374 MTC for Kuwadi CF.

Estimation of SOC stock between community forests of watersheds and comparing with other studies

As indicated earlier, in Jamuna and Chelibeti, the SOC stock was 3517MTC (101.85 ton/ha) and 6697MTC (103.35 ton/ha) respectively. Similarly, in Laxmimahila, it was 1044 MTC (119.7 ton/ha) and in Kuwadi, it was 13374 MTC (144.94 ton/ha) (Table 3). Comparatively, in Kayarkhola watershed, Chelibeti CF has higher carbon stock per hectare than Jamuna CF. Similarly, in Ludhikhola watershed Kuwadi has higher stock per hectare than Laxmimahila CF. The lower carbon amount could be due to relatively high human population influences in the community forestry (Shrestha et al. 2004). Mehraj et. al (2009) also discussed that lower carbon could also be due to the lower litter collection and accumulation from wider space of tree species in forest. The role of soil physical parameters such as high gravel content, low bulk density and SOC content might lower the SOC stock estimation. Furthermore, these fluctuations in quantity of soil parmaters can be due to the soil type, altitudinal variation, slope, drainage classes, etc. (Gibbs et al. 2007).

The studied area includes the community forests in Kayarkhola and Ludhikhola watershed. These watersheds are located in Chitwan and Gorkha districts. Similar, studies were performed by different researchers in various districts and watersheds having close climatic regions. Some of their findings are illustrated in table 3. Almost all the experiment shows the similar trend of carbon storage within one-meter soil profile. The maximum and minimum have been observed in Kuwadi and Lipindevi Thulopakha community forests respectively. The carbon storage in profile range less than one meter is also acceptable. Bajracharya et al. (2004), estimated the mean SOC pool of about 89.1 ton/ha in one-meter soil depth in middle hill forest. This comparison shows the potentiality of community forests to store the carbon in the soil beneath. In the soil beneath, SOC get concentrate in micro-aggregates, less than 1mm. These micro-aggregates are highly stable resulting less decomposition of organic carbon (Shrestha et al. 2004) and the stability of aggregates is influenced by the soil organisms such as earthworms (Ketterings et al. 1997).

Factors such as land use, organic matter content, soil types have influenced on the soil organic carbon. Besides these factors, forest vegetation types, management practices, geographical locations, climate, moisture also influence the carbon (Jandl et al. 2007). A study by Ranabhat et. al. 2008 revealed that *Alnus nepalensis* had higher aboveground and root carbon sequestration and lower soil carbon sequestration than Pinus species. Similar study was carried out by Shrestha 2009, in two community forests, Bajha and Bharkes (Table 3) of Palpa district having dominant species *Schima castonopsis and Shorea robusta.* The sequestration was high in *Schima castonopsis* forest. A comparison of Chelibeti and Jamuna with Pragati community forest of kayarkhola watershed in Chitwan district showed that Pragati CF has higher carbon sequestration. Bhattrai et.al (2012) identified two dominant species in the Pragati CF. Presence of more than one dominating species in the community forest can differ on the canopy cover, leaflitter quantity, etc., which can also influence the soil carbon (Mehraj et al. 2009).

Pragati had *Shorea robusta* and *Lagerstroemia parviflora* and Jamuna;Chelilibeti had *Shorea robusta* as dominant species. Similarly, other community forests having one or more dominating species and their soil carbon stock has been mentioned in table 3.

A study was performed by Banskota et al. (2007), in community managed forest in Lamatar (Lalitpur), Manang, and Illam also showed the increment of carbon stock. In the three successive years, the rate of carbon is increased by 1.41, 1.13, 3.1ton/ha/yr respectively. In these managed forests, the average increment is 1.88 ton/ha/yr. Similarly, Van panchayat forests (Dhaili, Toli, Guna) in Uttarakhanda, India studied by Banskota et al. (2007) showed the total carbon (excluding SOC) increased by 3.7 ton/ha/yr in average. It was higher than community forest in Nepal. The differences in the carbon stock can be due to the tree age and users' intervention to the forest for subsistence needs (Dhital 2009). Likewise, a study was made by Bhattrai et.al (2012), regarding the potentiality carbon sequestration in community forest in Nepal. The experiment was performed for two successive years. It revealed that yearly one to three tons/ha carbon (total stock, including vegetation and soil) increased continuously. He also argued that the forest management system could influence the carbon sequestration. In a total area of 630ha forest, about 478,000 tons of carbon dioxide equivalent stocks were collected within the period of two successive years and through the community forest, it can sequester 4700 tons of carbon dioxide equivalent every year. Therefore, best management practices can be the reason for the high-carbon stock and its economic benefits.

Table 3: Soil carbon stocks in soil profile depths of different community forests in Nepal

CF/Watershed/Location	**Dominant Species**	**SOC measured depth (m)**	**SOC Stock (tonha^{-1})**	**Source**
Jamuna/Chitwan	*Shorea robusta*	1	101.85	Our work
Chelibeti /Chitwan	*Shorea robusta*	1	103.35	Our work
Laxmimahila/Gorkha	*Shorea robusta*	1	119.7	Our work
Kuwadi/Gorkha	*Shorea robusta*	1	144.94	Our work
Jarneldhara/Palpa	*Schima castonopsis*	1	121.4	(Khanal et al. 2010)
Lipindevi Thulopakha/Palpa	*Schima castonopsis,*	1	94.6	(Khanal et al. 2010)
Pokharekhola watershed/Dhading	*Shorea robusta*	0.4	66	(Shrestha & Singh 2008)
Pokharekhola watershed/Dhading	*Schima castonopsis*	0.7	103	(Shrestha & Singh 2008)
Pokharekhola watershed/Dhading	*Shorea robusta, Schima castonopsis, Pinus roxburghii*	0.3	32.5	(Tiwari et al. 2006)
Bajha/Palpa	*Schima castonopsis*	1	130.76	(Shrestha 2009)
Bharkes/Palpa	*Shorea robusta*	1	126.07	(Shrestha 2009)
Pragati/Chitwan	*Shorea robusta, Lagerstroemia parviflora*	1	119.3	(Bhattarai et al. 2012)
Borrow pit/Makwanpur	*Pinus wallichii,Alnus nepalensis*	1	119.3	(Bhattarai et al. 2012)
Thanksa Deurali/Dolakha	*Pinus petula, Pinus wallichiana*	1	119.4	(Bhattarai et al. 2012)
Ludhi Damgade/Gorkha	*Pinus roxburghii, Schima wallichii*	1	106.6	(Bhattarai et al. 2012)

Prospects of carbon storage in community managed forest soil and its implication for REDD

Carbon stock data for degraded sites were collected from earlier published work from similar geographical region and forest of Nepal and analysed only for the top soil (0-15cm). Multiple comparisons of means (SNK, $\alpha = 0.05$) showed that SOC stock in degraded, and a well managed site varies significantly ($p<0.05$). The degraded sites' carbon stock compared to community forest (Kuwadi and Laxmimahila) were substantially lower ($p<0.05$). Table 4 shows the carbon stock of degraded sites (from review) compared with other two community forests (our work). This indicates a significant gain in the carbon could be made if the degraded sites could be managed through the community forestry intervention. As the degraded land is restored the vegetation grows well and along with the soil become a net carbon sink (Lal 2004). In the table 4, the average carbon stock is more than four times higher for Kuwadi and three times for Laxmimahila community forest compared to degraded forest. Although this stock comparison is dynamic and changed according to the spatial and temporal factors, it only serves a hypothetical indication for carbon gain by managing degraded forest land in Nepal.

Table 4: Differences in soil carbon stock (top soil 0-15cm) between community managed forest land and degraded land in different sites in Mid hills of Nepal.

	Soil organic Carbon ($KgCm^{-2}$) in 0-15cm			
	Kuwadi CF	**Degraded sites**	**Differences**	**MTC[a]**
Site 1	4.00	0.70*	3.30	33.01
Site 2	2.31	0.95**	1.36	13.58
Site 3	3.13	0.14***	2.99	29.94
Average	**3.15**	**0.60**	**2.55**	**25.51**
	Soil organic Carbon ($KgCm^{-2}$) in 0-15cm			
	Laxmimahila CF	**Degraded sites**	**Differences**	**MTC**
Site 1	2.44	0.70	1.74	17.39
Site 1	1.52	0.95	0.56	5.64
Site 2	3.15	0.14	3.01	30.06
Average	**2.37**	**0.60**	**1.77**	**17.70**

MTC[a]- Metric tons of carbon, *Shah et.al (1999), **Brown et.al (1999), ***Baral et.al (1999)

1 MTC= 3.67 $MTCO_2e$ (Metric ton carbondioxide eqvt.)

This benefit of carbon sequestration from degraded to the managed land system could be possible option for mitigating the global climate change. Hence forest's conservation for the REDD mechanism projected by UNFCCC has encouraged developing countries like Nepal to adopt it at the intensive scale. Community forestry, in context has been considered as the beneficiary of REDD. There can be three best scenarios as discussed by Karky & Skutsch (2010) for the forest conservation. The first is protection for the fulfillment of subsistence needs such as timber, fuel wood, fodder, etc. The second is protection for subsistence needs including the carbon value. The carbon value could be called the revenue of the forest conservation and protection. The third scenario is only for the carbon value (exclude the use of forest resources). There are several rules and policy for the implementation of use of forest resources, and REDD carbon project is in association for the carbon value estimation. The voluntary carbon value in the market starts from about US$ 5 per ton of CO_2 on average, which can rise up to US$ 20 and above in the international market. Considering US$ 12 per ton of CO_2 (Dhital 2009), there would be gained from the upgrading of a degraded land to a well managed community forest (Kuwadi CF= 93.62 ton CO_2e/ha = US$ 1123 and Laxmimahila CF=64.96 ton CO_2e/ha= US$ 779.5). A report from (UNEP 2001) as indicated by (Upadhyay et al. 2005) out of total 14.7×10^6 hectare land of Nepal, about 11 percent land considered as shrubland/degraded land/degraded forests and about seven percent is non cultivated land. If this land could be managed in for better land use, then significant carbon could be sequestered with additional economic benefits under REDD.

Limitations of study

In this study, we only attempted to discourse, the soil carbon potential in the community forests of two watershed. The aboveground biomass and its carbon potentiality could not be addressed in this study. For the prospects of carbon economic value, we rely on other secondary sources of the similar region. We collected SOC data of the degraded site from past studies, and very few data were available. Likewise, the SOC stock, content and other soil parameters discussed in this study is influenced by numerous factors which all may not have been addressed. Therefore, more studies covering both spatial and temporal variabilities will be required before generalizing the results.

Conclusion

Community forests in Kayarkhola and Ludhikhola watersheds are the good example forest in the community-based management system for soil carbon sequestration. Soil bulk density and SOC content decreases with soil depth in spite of vegetation cover and soil texture. The study sites had *Shorea robusta* as dominating tree species. Except Kuwadi CF, all other community forests had silt loam soil texture. Kuwadi CF had silty-clay loam as dominant soil texture. Similarity in SOC content and bulk density with varied gravel content on forest soil influences the carbon sequestration. Likewise, presence of more than one dominating tree species in forest also influences the carbon sequestration. Significant carbon can be sequestered from improvement of a degraded site to community forestry. The cost of improvement might be gained from economic benefits of carbon through REDD program. The improved soil features through community forestry contribute to the benefits of environmental services such as carbon sequestration, which helps to mitigate the global environment changes.

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