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Assessing the roles of community forestry in climate change mitigation and adaptation: A case study from Nepal

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ABSTRACT

Integration of the mitigation and adaptation roles of forests is important in addressing climate change issues. Community forests (CFs) have capacity to contribute in both roles as local communities are collectively working to improve forests and to fulfil their own basic forest product needs. Nowadays, an incentive mechanism for Reduced Emissions from Deforestation and forest Degradation, conservation of forests, sustainable management of forests and enhancement of carbon stocks in forests (REDD+) is emerging and already has received considerable attention in achieving climate change mitigation whereas there has been little analysis of its potential contribution to adaptation objectives, particularly at the community level. Therefore the overarching goal of this study was to analyse CFs from a mitigation and adaptation perspective. This study assesses 105 CFs covering a range of forest types managed by socially diverse communities of Nepal. Two point carbon data (2010 and 2013) was analysed to investigate differences in carbon stocks in these forests following the introduction of a REDD+ pilot program in Nepal. Similarly, a document review and focused group discussions were organised to evaluate the livelihood support and adaptation potential of pilot REDD+ CFs. This study found that community forest user groups (CFUGs) have increased forest carbon stocks and that the pilot REDD+ projects are also delivering livelihood benefits which ultimately will help adaptation to adverse climatic conditions. However, the motivation for communities to realise REDD+ carbon incentives may reduce the food supplement capacity of forests by limiting vegetation diversity.

1. Background

The IPCC fifth assessment report (2014) clearly identifies the forestry sector as one of the key sectors responsible for Greenhouse Gas (GHG) emissions (Victor et al., 2014), while conserving and reducing forest biomass loss can provide a relatively cheap option for climate change mitigation (Stern, 2007). Forests in developing countries are highly important in supporting the livelihoods of surrounding forest dependent communities and particularly the local poor (Wunder, 2001; Sunderlin et al., 2005). Local people collect herbs such as shoots of *Asparagus racemosus*, tubers of *Dioscorea bulbifera* L. and fruits of *Phyllanthus emblica* L from forests to use as food. A study found that Chepang (an indigenous group living in Nepal) communities use these wild food for more than 3.5 months per year (Aryal et al., 2009). This shows the capacity of forests to provide food supplements during times of food scarcity but, to do so, the diversity of species in forests must be maintained (Shrestha and Dhillion, 2006). If there has been a reduction in the diversity of plants and a shift to stands dominated by only a few species with high biomass stock, a forest may not provide adequate food supplements to enable poor people to survive during adverse climatic conditions (Aryal et al., 2009; Pandey et al., 2014b; Subedi, 2006).

Forest resources are vital for both climate change mitigation and in providing livelihood options for local communities in developing countries, but these are compromised by the over exploitation of resources and degradation of forest health (Hosonuma et al., 2012). This affects both the livelihood of forest dependent communities and the carbon sequestration capacity of forests. REDD+ has been trialled in developing countries (Olander et al., 2012; Streck, 2012) to encourage communities in incentive based climate change mitigation. However, there is a need to identify how existing forest management systems contribute in developing countries. At present, global forests are under different forms of ownership—namely, government, industry, private (individual) and community (FAO, 2011). Among these, community forests (CFs) are considered an important system in developing countries (Nurse and Malla, 2006). Particularly in Nepal, people have been

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engaged in forest improvement and sustainable use under this system for more than 30 years. Forest dependent communities in most developing countries use forest resources to feed their livestock and obtain building materials, wild food, medicines and raw materials for cottage industries (Subedi, 2006). Some studies have found that the REDD+ pilot project in CFs has increased carbon sequestration capacity in forests (Pandey et al., 2014a) but there are limited studies which aim to analyse both mitigation and adaption potential in these forests. This knowledge is important in developing a mechanism that delivers both environmental and social benefit. As over 22% of total forest cover in developing countries is under community management (compared with 3% in developed countries) (White and Martin, 2002), the CF system should be considered while developing programs and activities to address climate change issues. To analyse the roles of community forests, we have assessed carbon stock changes and the socio-economic benefits to local communities in a pilot REDD+ project in Nepal.

2. Methodology

2.1. Description of study area

This study selected 105 CFs with different dominant species (i.e. different forest types), located at a range of altitudes, 271–3238 m asl, in the Himalayan country of Nepal. These forests are located in three watersheds—namely, Kayerkhola (271–1618 m asl), Ludikhola (418–1401 m asl) and Charnawati (652–3238 m asl) (Fig. 1)—and represent four major vegetation types in the region. Mixed *Shorea* broadleaf forests include large, deciduous, light demanding, slow to moderate growth-rate trees (e.g. *Shorea robusta*, *Lagerestroemia parviflora, Mallatus phillipinensi* and *Terminelia tomentose*). The *Schima–Castanopsis* forests are moderately shade-tolerant, have moderate-growth habits and are palatable and used as fodder (Jackson, 1994). *Pine* forests are light demanding and predominantly fast growing trees which are useful for timber. Finally, *Rhododendron–Quercus* are slow growing by nature (Jackson, 1994).

Nepal is a diverse country, not only in terms of vegetation types but also the diverse socio-cultural practices of the people with 125 caste/ethnic groups (CBS, 2011). These groups have different economic and cultural practices and different use and management relationships with forest resources (Neupane et al., 2002). The study area represents these variations, covering 15,380 households including Dalit, Ethnic group and Brahmin and Kshetri. According to Gellner (2007): Dalits are the 'untouchable' group; Ethnic groups are those who have historically maintained a separate culture, language and customs; and Brahmin and Kshetri are considered as upper caste in Nepal.

In this area, a pilot REDD+ project was implemented jointly by the International Centre for Integrated Mountain Development (ICIMOD), Asia Network for Sustainable Agriculture and Bioresources (ANSAB) and Federation of Community Forestry Users Nepal (FECOFUN) with financial support from the Norwegian Agency for Development Cooperation (NORAD).

The project supported to CFUGs for reducing extraction of forest resources by promoting alternative energy means, carrying out plantation activities in sparse forest areas and uncultivated private land, raising awareness on sustainable harvesting practices, guarding to control illegal harvesting and implementing income generating activities at poor households (ANSAB/ICIMOD/FECOFUN, 2013). Although, some of those activities were operating by CFUGs before REDD+ project (Yadav et al., 2003), additional distribution of alternative energy sources (improved cooking stoves and biogas plant as alternative of household energy), increased supply of forest resources from plantation, reduced biomass damages from forest fires and illegal harvesting might have played roles to change biomass carbon in CFs under the REDD+ project.

2.2. Carbon sock estimation

2.2.1. Carbon pool inventory

This study collected carbon pool data from February to May in 2010 and 2013. These repeated measurement in same plots over the three years were done to analyse carbon stock changes with the introduction of REDD+ activities in CFs. For the analysis, all forest areas were stratified on the basis of canopy cover into two strata (sparse with <70% vegetation cover and dense with $\geqslant$70% canopy cover) using Geographic Information System (GIS) applications. Satellite images (Geoeye, captured on November 2009) of the study sites were taken and analysed using ERDAS IMAGINE to identify CF boundaries and canopy covers as suggested in the literature (Pandey et al., 2014a). There were 7436.0 hectares of dense canopy and 2829.5 hectares of sparse canopy forests. A total of 490 composite plots were established in 2010; of these, 395 were 'dense canopy' and 95 were 'sparse canopy'. The plots were randomly selected within CFs to cover all five dominant vegetation types, using Hawth's analysis tool which was developed for ArcGIS to distribute sample plots on the map randomly (Beyer, 2004). From the central point of a sample plot, a composite plot with sub-plots of radius 0.56 m, 5.64 m and 8.92 m were established to measure litter (dry fallen leaves and twigs), herbs (living plants including grasses), saplings (woody plants with 1–5 cm DBH) and trees (plants with $\geqslant$5 cm DBH), respectively.

2.2.2. Tree biomass estimation

The quantity of aboveground tree biomass (AGTB) was estimated using the most relevant equation for moist forest type (Eq. (1)) (Chave et al., 2005). This equation was used because (1) it was developed by using a large set of data (with >5 cm DBH trees); (2) it uses three variables: namely, wood specific gravity, tree height and DBH; and (3) rainfall pattern of the study sites (>1700 mm) and the proposed rainfall pattern for the equation are similar. Wood-specific gravity relevant to Nepal was used in the analysis of biomass but these data were missing for some species within a forest type and a general value was derived from the average specific gravity of species from the same taxonomic class (MPFS, 1988).

$$\mathrm{AGTB} = 0.0509 * \rho D^2 H \tag{1}$$

where

AGTB	=	aboveground tree biomass (kg);
ρ	=	wood specific gravity (kg m^{-3});
D	=	tree Diameter at Breast Height (DBH) (m); and
H	=	tree height (m).

2.2.3. Sapling biomass estimation

Nepal-specific biomass tables were used to estimate aboveground sapling biomass (AGSB) (1–5 cm DBH). These tables were developed by Tamrakar (2000) to estimate green biomass; using these tables, green biomass was converted into dry biomass by multiplying by species-wise fractions taken from the literature: specifically, 0.627 for *Quercus* spp., 0.613 for *Lyonia ovalifolia,* 0.58 for *Pinus roxburghii,* 0.57 for *Alnus nepalensis,* 0.545 for *Schima wallichii,* 0.537 for *Albizzia lebbeck,* 0.517 for *S. robusta,* 0.5 for *T. tomentose* and 0.45 for *Pinus wallichiana* (Bhatt and Tomar, 2002; Jain and Singh, 1999; Kataki and Konwer, 2002; Shrestha et al., 2006; Wihersaari, 2005). Where the fraction was not available,

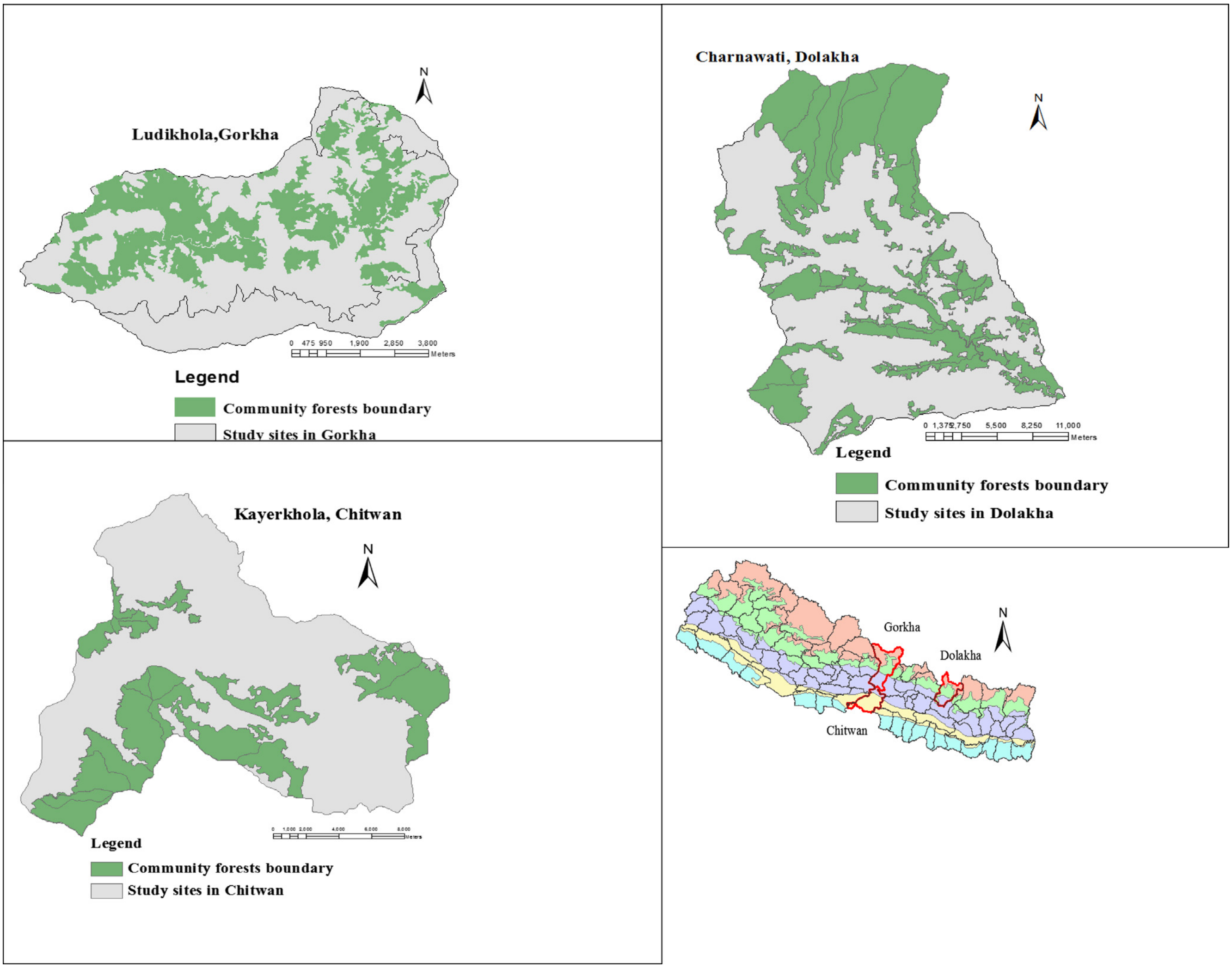

Fig. 1. Map showing the study area with three watersheds: Kayerkhola watershed (271–1618 m asl) in Chitwan district; Ludikhola watershed (418–1401 m asl) in Gorkha district; and Charnawati watershed (652–3238 m asl) in Dolakha district.

mean fractions of closely related species were used (Baker et al., 2004; Ngugi et al., 2011; Pandey et al., 2014a).

2.2.4. Litter biomass estimation

The biomass of litter and herbs were obtained from the relationship between total fresh weight in the plots, plot area and biomass fraction (ratio of the dry to fresh weight). For this ratio, about 100 g of a well-mixed sample from each plot was sent to the national laboratory of Nepal. In the laboratory, the constant weight was measured after oven drying. The dry-weight (biomass) of litter and herbs per hectare was calculated with the help of: (1) fresh weight of samples in a plot; (2) dry-weight and fresh-weight ratio of samples; and (3) the sample plot area to hectare expansion factor (area of a hectare/area of a sample plot).

2.2.5. Below ground biomass estimation

For the belowground biomass estimation, root to shoot ratio (0.27 for tropical and sub-tropical forests and 0.3 for temperate forests) was used (Mokany et al., 2006). All biomass estimates were converted into carbon stock by multiplying by 0.47 as recommended by the IPCCC Good Practice Guidelines (2006). The plot data were analysed by vegetation type and canopy cover for the reference year 2010 and changes in carbon stock between 2010 and 2013 were calculated.

2.2.6. Soil carbon estimation

Soil organic carbon does not usually change in forests over short time periods (Houghton et al., 2000). In addition, CFUGs allow local communities to collect fallen dry litter for cattle bedding material (Adhikari et al., 2007), so there is little chance for litter debris to accumulate and decompose to form soil organic matter in CFs compared to forests in which regular collection practices do not occur. Therefore soil carbon was not considered in this study.

2.3. Social data

Data about socio-economic and institutional changes were collected from November 2011 to March 2012 from Focus Group Discussions (FGDs) and the review of documents which mainly included meeting decisions, operation plans and the constitutions of community forest user groups. A check list (Appendix I) was used to review the documents of 36 CFUGs including nine randomly selected CFUGs for each vegetation type. Change in practices and benefits associated with forests management practices were analysed while taking into account the possible effects from, and response to, climate change risks and vulnerable situations.

FGD is considered an active and dynamic social exchange which provides opportunities to build a cumulative understanding of an identified problem (Kitzinger, 1994; Tashakkori and Teddlie,

Table 1
Biomass carbon (above and below ground) in study area community forest types, 2010–2013.

Dominant vegetation type	Type of strata	No of plots	Biomass carbon in 2010 (MgC/ha)			Biomass carbon in 2013 (MgC/ha)			Change in biomass C (MgC/ha/year)		
			Avg biomass C	Range	SD	Avg biomass C	Range	SD	Avg change C	Range	SD
Mixed *Shorea* broadleaved	Dense	207	126.8	2.9–345.1	83.7	144.3	1.3–364.3	80.7	5.8	−9.6 to 16.2	6.9
	Sparse	52	85.4	2.3–198.9	85.4	94.2	6.3–203.8	54.9	2.9	−8.8 to 15.0	6.3
	Total	259	118.5	2.3–345.1	81.0	134.2	1.3–364.3	78.8	5.2	−9.6 to 16.2	6.8
Schima–Castanopsis	Dense	98	95.2	10.8–277.7	61.1	116.0	30.4–300.3	62.3	6.9	−5.8 to 16.4	5.5
	Sparse	18	48.3	8.8–126.3	35.1	54.1	9.9–110.9	35.2	1.9	−5.1 to 9.2	3.8
	Total	116	87.9	8.8–277.7	60.2	106.4	9.9–300.3	62.9	6.2	−5.8 to 16.4	5.6
Pine	Dense	30	103.0	11.3–230.6	56.7	127.0	18.4–225.3	54.3	8.0	−7.3 to 16.5	5.8
	Sparse	12	62.4	0.6–185.6	48.3	70.5	3.3–185.9	46.5	2.7	−1.1 to 9.1	3.2
	Total	42	91.4	0.6–230.6	57.0	110.8	3.3–225.3	57.7	6.5	−7.3 to 16.5	5.7
Rhododendron–Quercus	Dense	60	114.7	21.1–254.8	68.4	121.7	18.8–254.5	66.3	2.3	−9.3 to 13.2	5.5
	Sparse	13	48.2	3.7–151.7	48.5	54.2	6.4–174.4	50.8	2.0	−5.6 to 7.6	3.3
	Total	73	102.9	3.7–254.8	69.9	109.7	6.4–254.5	68.6	2.3	−9.3 to 13.2	5.2
Total	Dense	395	115.3	2.9–345.1	75.5	132.5	1.3–364.3	73.5	5.7	−9.6 to 16.5	6.5
	Sparse	95	70.4	0.6–198.9	54.4	78.1	3.3–203.8	52.7	2.6	−8.8 to 15.0	5.2
	Total	490	106.6	0.6–345.1	74.0	122.0	1.3–364.3	73.1	5.1	−9.6 to 16.5	6.4

2003). Therefore, as in Kitzinger (1994) and Stewart et al. (2007), 12 FGDs, including three representative groups for each vegetation type, were organised to identify social, institutional and economic changes in the CFUGs due to the REDD+ project activities. For each discussion, 10–15 individuals were randomly invited from the local community and asked about existing and changed practices. A check list (Appendix II) was used to guide the FGDs.

Changes in social dynamics due to the REDD+ project were analysed by comparing activities associated with forest management and use practices in the three years before and three years following the start of the REDD+ project.

3. Results

3.1. Changes in forest carbon stocks

Among the four forest types, mixed *S. robusta* broadleaved forests had the highest biomass carbon stock in 2010 followed by *Rhododendron–Quercus* dominated forests, *Pine* forests and *Schima–Castanopsis* forests (Table 1). While analysing carbon stock by strata, all dense forests had higher biomass carbon levels than did sparse forests, confirming the higher carbon sequestration potential of dense strata forests. Since local communities protect forests from illegal harvesting and forest fire, we can assume that sparse forests could become more dense and carbon stocks increase. We found significant variations in average estimated carbon stock (from 48.2 to 126.8 MgC/ha) across the CFs in the study. The highest average carbon quantity was recorded in dense mixed *Shorea* broadleaved forests (126.8 MgC/ha) while the lowest was in sparse *Rhododendron–Quercus* forests (48.2 MgC/ha).

Following the instigation of REDD+ project activities, carbon stocks in the majority of sampling plots increased (average 5.1 MgC/ha/yr). This increment was highest in dense *Pine* forests (8.0 MgC/ha/yr) and lower in sparse *Schima–Castanopsis* forests (1.9 MgC/ha/yr). This indicates the potential for REDD+ project activities to increase carbon stocks in CFs. However, carbon stock decreased in some plots in this study; this was most evident in dense stratum mixed Shorea broadleaved forests (−9.6 MgC/ha) and least in sparse stratum of Pine forests (−1.1 MgC/ha). According to local communities, these negative changes in carbon stock were mainly due to illegal activities, road construction inside forest areas, illegal logging and over harvesting (where biomass extraction exceeded annual biomass increment) mostly in plots close to walking paths. They suggested that increased awareness of the impacts of deforestation and forest degradation, mechanisms for providing economic incentives for improved CFs and providing alternatives to fulfil demand for forest products or developing accessible technology to reduce or replace consumption of forest products could help to reduce such negative changes (Table 2). Since community forestry have provisions for sustainable harvesting practices to fulfil their basic forest products needs and doing silviculture operations to improve forest structures, this might also be a reason to decrease biomass in some plots. But both of these latter reasons could have a positive role to improve forests and support local livelihoods in the long run.

3.2. Adaptation roles of community forests

Document review and FGDs showed that the CF system has increased social capital and livelihood opportunities in local communities. As a local institution, most of CFUGs have provided a platform for collective action and enhanced coping and support for community members during adverse vulnerable situations. Besides this increased social capital, income from forest based cottage industries and the sale of non-timber forest products, as well

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Table 2
Summary of the contribution of CFs to local communities' adaptation to climatic hazards.

Social capital	Livelihood benefits
Before REDD+	
CFUGs were established as an institution and members acted collectively CFUGs had good relations with relevant institutions including FECOFUN, DoF, which helped to improve their capacity and build social resilience Mixed *Shorea* broadleaved, *Schima–Castanopsis* and *Pine* dominated CFs were more connected with other organizations and gaining benefits which improved livelihoods and capacity to cope with climatic and other risk	CFs were an integral part of local forest dependent communities. Local communities extracted fodder and grass for livestock, timber to build houses, fuel wood for household energy, wild food (both vegetable and meat) as supplementary food sources and generated income by collecting and selling non-timber forest products from CFs All CFs provided forest resources to local communities. Local people were aware of the potential of CFs to generate income through the selling of forest products. Key marketable products included Churi (*Diploknema butyracea*) from mixed *Shorea* broadleaved forest types and Lokta (*Daphne bholua*) and Wintergreen (*Gaultheria fragrantissima*) from *Schima–Castanopsis* and *Rhododendron–Quercus* forests Traditionally, people from the poorer Chepang, Tamang and Dalit communities collected wild food (e.g. yams, tubers, fruits, vegetables) from forests as a supplementary source of food. Under adverse climatic conditions and times of reduced agricultural production, most CFUGs also collected wild food from the CFs
After REDD+	
REDD+ is new global mechanism. For the pilot project activities in Nepal, new institutions have been set up at government level (i.e. REDD+ Forestry and Climate Change Cell); REDD+ networks have also been established representing all CFUGs at the watershed level. Linkages have been established between networks, district forest offices and project implementing organisations and capacity building training carried out. Regular decision making meetings are organised which has increased cohesiveness among these groups. According to the local people, these activities have increased their level of confidence that their social resilience to face climate risk has improved	REDD+ projects facilitate the making of pro-poor decisions in CFs through increased focus on the livelihoods of poor members and enhanced benefit sharing. REDD+ projects provide improved cooking stoves and biogas plants to poor households, encourage CFUGs to implement income generating activities and provide alternative supply sources for forest products by providing seedlings and support to local communities for plantation projects
Community perceptions of the potential benefits of the REDD+ mechanism	
Better connection with relevant institutions and new collective actions will help communities access support under future risk including climate change	More systematic benefit sharing mechanisms could be developed REDD+ carbon benefits may help in implementing income generating activities and provide a common fund for use during high risk situations linked to climate change

as enhanced access to and sharing of food supplements such as roots, tubers, fruits, flowers, and shoots were reported. Low income people such as Chepang in Kayerkhola watershed and Dalit and Tamang in both Ludikhola and Charnawati watersheds tend to be more vulnerable. CFUGs have income generating activities for local vulnerable poor members such as free distribution of young goat and buffalo. These people can then generate income by selling baby goats to other members to grow and mature goats for meat, producing buffalo milk and selling at local market. They collect grass and other fodder to feed their livestock without harming the forests and also collect non-wood forest products for food supplements to feed their family members (Table 2).

4. Discussion

4.1. Importance of CF in addressing climate change

Climate change can be addressed through two different approaches, namely mitigation and adaptation (Klein et al., 2005; Verchot et al., 2007). Importantly, forests can contribute to both (Klein et al., 2005). The REDD+ program may provide up to 30% of the cost-effective global mitigation potential (Stern, 2007) and there are many initiatives under implementation in developing countries (Caplow et al., 2011). This study found that CFs have sequestered huge amounts of carbon stock (48.2–129.9 MgC/ha) depending on vegetation type. Further, this study indicates that there is a significant range in the estimated quantity of carbon stored in CFs which shows potential to increase carbon stock. This is indicated in other literature as well (Maraseni et al., 2005; Pandey et al., 2014a). After REDD+ project activities were instigated in the study area, average carbon stocks increased by 5.1 MgC/ha/yr (1.9–8.0 MgC/ha/yr). As also indicated in the literature, local communities are managing forests to restore degraded and deforested areas in developing countries (Agrawal and Angelsen, 2009). Local communities have put additional efforts into existing forest management practices to increase carbon stock in REDD+ CFs. The REDD+ pilot project has encouraged forest user groups to reduce extraction of biomass from forests, control damage due to forest fires, use improved cooking stoves (ICSs) which consume less quantity of firewood than traditional ones and use biogas as a fuel. The project distributed ICS to 6% households and biogas plants to 3% of households in mixed *S. robusta* broadleaf CFs. Similarly, there were distributions of: ICS to 11% and biogas to 1% of households of *Schima–Castanopsis* dominated CFs; ICS to 10% and biogas to 1% of households of *Pine* dominated forests; and ICS to 15% and Biogas to 1% of households of *Rhododendron–Quercus* dominated CFs (ICIMOD, 2014). Traditional cooking stoves consume 30–40% more firewood consumptions than ICSs (Bhattacharya et al., 2000; Dhakal and Raut, 2010); therefore, we can assume that these communities' efforts to change household energy pattern has contributed to increased carbon stocks in forests.

Improved forest condition and added carbon stock help to mitigate global climate change. The study found loss of carbon stock in some plots which was CFUGs perceived to be due to illegal activities involving outsiders. As the livelihoods of local communities are dependent on forest resources (Yadav et al., 2003; Subedi, 2006), this study found that most of community members used one or more forest products from CFs such as fodder, grasses, fuelwood, timber and NTFPs. Local communities were confident that they were still able to use forest resources if necessary during adverse situations when agriculture production was affected and members were unable to buy food for their families. However, the maintenance of these resources needs to be addressed in the REDD+ project mechanism and activities.

Besides food supplements and climate change mitigation, local communities perceive that improved CFs have helped to regulate weather patterns, mainly temperature and rainfall, at the local level. These perceptions of local communities of positive changes in microclimatic conditions after forest condition improved are similar to findings reported in the literature that deforestation affecting microclimatic conditions and leads to increasing levels of unwanted species (pests) and diseases (Larsen, 2012). This shows the potential contribution of CFs in regulating microclimates.

This study found CFs to be a source of food, fodder, fibre and income to local forest dependent communities. As stated in other studies, uncultivated food can be a significant potential source of food supply in rural areas (Aryal et al., 2013) and the wild food of CFs can provide social security to local communities. Local communities reported that, when food availability was limited (due to limited land area or agricultural crop failure due to natural disasters), they go and collect food supplements from CFs to feed their family members. This shows CFs have potential to support communities during adverse climatic conditions if there is enough product in the forests. It will only be possible to provide food supplements during scarce times if the diversity of species in forests is maintained (Shrestha and Dhillion, 2006).

4.2. Possible activities to achieve both adaptation and mitigation in CFs

Community-based management approaches are considered to be the most successful approach in climate change adaptation because local people bring indigenous knowledge and management need in making decisions on climate change adaptation (Keenan, 2015). Therefore promotion of community forestry may increase local adaptive capacity which was also found in other literatures (Keenan, 2015).

Increased biomass in forests is a key focus of climate change mitigation (Olander et al., 2012) and fundamental to the present additionally criteria for payment in REDD+ mechanism (Angelsen et al., 2012) and project developers may choose to focus on carbon increment activities in developing countries. Similarly, there are possibilities of changes in existing community practices towards promoting trees capable of producing higher carbon stock to maximise REDD+ payments. However, compared to practices which support more diverse forests, carbon focused forestry practices are less likely to contribute to the overall livelihood of local communities, especially as they adapt to changing climatic conditions. They also contravene the social and environmental safeguard principle (UNFCCC, 2011). Only forests with diverse species can provide multiple livelihood benefits to rural communities (Arnold et al., 2011) and such forests are likely to play an important role in the resilience of local rural communities in countries such as Nepal.

The REDD+ mechanism is currently being developed with many pilot projects in many developing countries. It is therefore important to consider the adaptation support roles of forests while designing the strategies and projects at local, national and international levels. Community-based forest management approaches are considered to be the most successful approach in climate change adaptation and promotion of community forestry may increase local adaptive capacity (Keenan, 2015). However, incorporating an adaptation component on the REDD+ program may add some complexity (Long, 2013). To develop the REDD+ mechanism to deliver carbon benefits in the context of the adaptation role of forests, the following considerations would be helpful:

- *Encourage communities to maintain multiple species in REDD+ project* – Forests with multiple species provide various products and services to local communities and are important to the social security of local rural communities (Shrestha and Dhillion, 2006; Aryal et al., 2013). Local forest dependent people are poor and depend on forests to generate additional income (Adhikari et al., 2007); therefore, REDD+ projects can motivate them to enhance their management practices to deliver multiple benefits. The forest management practices of communities are likely to change the status of forests (Smith et al., 1997). Changed practices aimed at deriving maximum benefit from carbon storage may limit species richness; however, this is unlikely to provide livelihood benefits to people in the long run. Local communities may not have prior knowledge about possible changes in the supply situation of wild food in the future due to their carbon oriented forestry practices. Losing a source of food supply may create a more vulnerable situation for them during periods of food scarcity. Therefore providing premium prices from REDD+ incentives mechanism to CFs with high levels of species diversity could encourage local communities to manage to maintain multiple species in forests. Similarly, awareness raising activities about the possible risk of climatic hazards, possible roles of forests and possible adaptation strategies for local communities needs to be carried out to prepare local people and develop strategies.
- *Plant multipurpose trees in barren areas* – According to community forest user groups, seedlings and technical guidance were delivered through the REDD+ project to enable the planting of trees on unproductive private lands and in degraded forest areas. This could be useful for both climate change adaptation and mitigation as plantations of multipurpose trees on fallow land and an appropriate agroforestry system will contribute to both sequestering atmospheric carbon and supporting livelihood options at the local community level (Smith and Scherr, 2003). Facilitation of plantation activities on barren lands could be one strategy of the REDD+ project in developing countries which will provide alternative options to supply forest products.
- *Policy intervention* – Governments policy is important in designing programs and projects (Angelsen, 2009). Government policies need to be conducive to better incentives for forests which contribute to both mitigation aims at the global level and adaption aims at local levels. The original aim of CFs was to provide subsistence forest product benefits to local communities by improving forests status (Gilmour and Fisher, 1991) and government policies supported that aim (MPFS, 1988; GoN, 1993). Now governments in developing countries are shaping policy and practices around the REDD+ mechanism. Provisions to encourage project development agencies and local communities to promote both mitigation and adaptation roles of forests to address climate change should be considered.

5. Conclusion

Community forests have potential to contribute in both mitigation and adaption roles to address climate change. However, communities are likely to be motivated to increase carbon stock only for possible REDD+ payments and there are high possibilities that this will undermine the significant benefits of diverse vegetation forests. Management to maximise carbon stocks may contribute carbon sequestration and bring carbon payments at the local level but such forest management practices may limit the vegetation richness. As a result, forests may not supply enough food, fibre and other livelihood support to maintain community wellbeing during situations of low agricultural production. This may create a less resilient society particularly during adverse climatic conditions. Although this study was conducted in Nepal, the learnings are applicable to most developing countries because most countries with significant areas of forest under community ownership are demonstrating a strong willingness to be involved in the

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REDD+ mechanism. Therefore both species richness and carbon stocks need to be considered while designing REDD+ projects and developing payment mechanisms. For this, a linkage needs to be established between carbon payments and species richness in CFs.

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Appendix I. Checklist used to collect information related to socio-economic and instructional practice in REDD+ CFUGs from available documents

Descriptions
1. General assembly and meeting of executive committee (number of events/year, number of participants)
2. Silviculture operation (what and how?)
3. Local institutions and social support mechanisms (if any)
4. Forest products use practices (what and how?)
5. Forest contributions to supplementary food supply (if any)
6. Economic activities associated with forests
7. Sources of forest products supply other than the CF
8. Alternative energy use (type of energy and number of adopting households) in the CFUG

Appendix II. Checklist of questions asked in group discussions

Key questions
1. What was the status of your forest? (before CF, after REDD+ project and in future)
2. Do you want to improve the present status of your forest? (if yes, why?)
3. Does your group generate income from your forest? What do you do with forest incomes?
4. What benefits are you getting from your forests?
5. What are the major sources of income of community members?
6. How do you make forest management related decisions?
7. Which are the timber tree species and preferred timber tree species available in your forests?
8. How do members of your community fulfil their forest product needs? (supply sources of forest resources)
9. What do you know about the REDD+?
10. What changes have been made with the REDD+ project activities? Particularly forest product use practices (timber, fire wood, fodder, grass, fodder and NTFPs), decision making processes (meeting frequency and participation), forest improvement activities (guarding, plantation and silviculture operation) and forest degradation activities (fire, grazing, illegal harvesting)
11. What have you done to increase carbon stocks in your CFs?
12. What are the benefits of the REDD+?
13. What can be done to make the REDD+ incentive mechanism more beneficial at the community level for long term benefit?
14. What is the observed age of the forests? (based on dominant trees)
15. In your opinion, which forests (i.e. near a motor-able road or far from the road; nearby settlement or far from settlement) are better (in terms of stocks and bigger trees per unit area).
16. What was the production rate of agriculture crops in the last 15 years and now?
17. Climate change risks and hazards (observations, potential in future)
18. Potential contribution of forests to adaptation under adverse climatic conditions (if any)
19. How can communities maintain forests that are able to contribute to climate change adaptation and mitigation?
20. Social practices and local institutions which could help in coping with adverse climate scenarios

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