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Reducing Emission from Community Forest Managements: A Feasible Study from Almora, Uttarakhand

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Abstract The present study highlights the significance of community forests in relation to forest degradation. This article argues that community can benefit from the REDD+ mechanism by proactively acting to curb the rate of forest degradation. Successful participation can bring biodiversity, ecological and economic benefits to the community as well as to the country. Of the total biomass in Anriyakot Van Panchayat the contribution of above ground and below ground parts was 73.95% and 26.05%, respectively. The contribution of shrub, herb and litter was 3.90%, 1.25% and 2.68%, respectively. Beside this in Bhatkholi Van Panchayat of the total biomass the contribution of above ground and below ground parts was 74.39% and 25.61%, respectively. The contribution of shrub, herb and litter was 5.72%, 3.50% and 6.11%, respectively. The mean carbon sequestration rate in Anriyakot and Bhatkholi Van Panchayats was 3.90±0.52 t ha^{-1} yr^{-1} and 3.41±0.69 t ha^{-1} yr^{-1}, respectively. The soil organic carbon percent varied from 1.00±0.29 to 2.73±0.51 in Anriyakot, while 1.41±0.54 to 2.97±0.46 in Bhatkholi Van Panchayat. The finding indicates that the community managed forests may act as role model in mitigating climate changes. Determining the level of carbon stock pools in different components has become a concern of governments, businesses and many organizations. It is must to incorporate climate change consideration in forest sector especially Van Panchayat forests for long-term planning process.

Keywords Community Managed Forest, Van Panchayat, Carbon Sequestration Rate, REDD

1. Introduction

Increased greenhouse-gases are attributable mostly to fossil fuel combustion and deforestation worldwide[1]. Increasing scientific evidence suggests that the impacts of warming will be more serious and will occur sooner than had previously been believed. The alarming carbon dioxide rise in the atmosphere would raise the global atmospheric temperature by approximately 1℃ but its impacts on the Himalayan region would be more where the temperature are expected to increase by upto 2℃ [2]. The removal of atmospheric GHGs by terrestrial ecosystem through carbon sequestration has provided a great opportunity for shifting GHGs emission to mitigate climate change. Under the Kyoto protocol only afforestation and reforestation activities has been considered. However, with regard to and reducing emissions[3]. Carbon sequestration activitiesmust be coupled with streams of long-term positive benefits to local community, to ensure that potentially negative social impacts are averted and that avoided emissions are sustainable. Under the proposed REDD policy, proposed in Bali conference there is a strong move to reduce CO_2 emissions from terrestrial ecosystems by reducing deforestation rates in the tropics[4]. However, in Copenhagen conference REDD policy was extended to REDD+ to include forest enhancement, sustainable forest management, conservation and reduced forest degradation[5]. In the present scenario measuring forest degradation is problematic and require many trained professionals. A potentially cheaper alternative monitoring approach at the local implementation scale of REDD+ is to engage local people in monitoring [6] a local based forest monitoring approach therefore hold promise for REDD+. In the present scenario the role of community forests cannot be neglected, as they have vast reserves of carbon stored in their woody biomass and in the soil carbon pool where carbon remains sequestered for long durations in the deeper layers[7]. The present study highlights the significance of community forests in relation to forest degradation and deforestation. This article argues that community can benefit from the REDD+ mechanism by proactively acting to curb the rate of forest degradation. Successful participation can bring biodiversity, ecological and economic benefits to the community as well as to the Nation.

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2. Material and Methods

2.1. Study Site

The study sites are located in the Van Panchayats of Anriyakot and Bhatkholi in Lamgara block of Almora districts of Uttarakhand. These Van Panchayat forests lie between 29º 32′ 98″ to 29º 34′ 42″ N latitudes and 79º 41′ 45″ to 79º 43' 2" E longitudes. The elevation of these Van Panchayats varied from 1800 to 2000m. The basic climate pattern is governed by the monsoon rhythm. The average annual rainfall varied from 329.3 to 515.9 mm. The mean maximum temperature varied from 17.31℃ (December) to 28.90°C (June), while the mean minimum temperature varied from 2.18°C (January) to 14.87℃ (June). The parent material forming the soils in the study area mainly comprises of schist, micaceous quartizimeta morphism, plutonic bodies of granodiorites and granites[8]. Altitudinally the study areas are located in temperate environment but latitudinally it comes within subtropical belt. Majority of forest soils belong to the brown forest soil category[9]. The soil is residual and shallow. The soil of all the forest types is slightly acidic in reaction and the texture is more or less clay loam. The vegetation type mainly comprises Himalayan moist temperate oak forest and subtropical pine forest. The dominated tree species of both the Van Panchayats are *Quercus leucotrichophora*, *Pinus roxburghii*, *Rhododendron arboreum*, and *Myrica esculenta*.

2.2. Methodology

Information on socio-economic parameters was collected by questionnaires which were distributed to 30% of the households in the Van Panchayat. The house holds were selected randomly on the basis of number of family members and categorized in to small (<4), medium (5-9) and larger (>10). Four aspects at both the Van Panchayats were identified. At each aspect, trees were analyzed by placing randomly 10, 100 m^2 circular quadrats. However, saplings, seedlings and shrubs were studied by using 10, 5×5 m^2 quadrats[10]. Herbs and litter were studied in 10, 50× 50 cm^2 quadrats placed randomly[11]. Tree layer biomass was estimated on the basis of allometric equations previously developed[11 12]). Carbon stock and sequestration rate were estimated as 50% of the dry weight of biomass and 50% of net primary productivity[13 14]. Soil samples were collected from 5-6 pits dug up to 100 cm depth in different locations within each aspect. From each pit 300 to 500 gm soil samples were collected from 0-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-60 cm, 60-70 cm, 70-80 cm, 80-90 cm, 90-100 cm soil depths from both Van Panchayats, packed in to polythenebags and brought to the laboratory. Soil carbon estimation was based on rapid titration method of Walkey and Black[15]. To determine soil bulk density, soil samples were collected by means of a special metal core sampling cylinder of known volume from different soil depths considered for soil carbon estimation. Samples of soil were brought to the laboratory and oven dried at 60℃ till constant weight and soil bulk density was calculated[16]. The pH of each soil sample was determined using a digital pH meter. Fine roots (< 1mm in diameter) were estimated following the ingrowth core method. The soil cores were obtained by driving a sharp edged steel tube (8.5 cm internal diameter) in to the soil up to a depth of 1m (0-20, 20-40, 40-60, 60-80, 80-100 cm soil depth). In this modified ingrowth process, fine roots were excavated from the soil core with the help of a steel tube and hole was refilled with root free mineral soil. Root samples were collected from different directions, kept in polyethylene bags depth wise and brought to the laboratory. Soil moisture was determined on fresh weight basis[15]. For total Nitrogen (N), available Phosphorus (P) and available Potassium (K), three composite samples at different soil depths (0-30, 30-60, 60-100 cm) were taken. The total nitrogen content (%) was determined by micro-Kjeldahl assembly[17]. Soil phosphorous and potassium were extracted by wet ashing of 1 g soil material in acid mixture consisting of 10 ml H_2SO_4 +3 ml HNO_3 + ml $HClO_4$[15]). Soil potassium was determined using a flame Photometer, and phosphorous was determined using spectrophotometer[15]. Analysis of variance (ANOVA) and Standard errors were calculated by using SPSS version 16 software.

3. Results

3.1. Forest Management and Socioeconomic Status

The total household number in the present study ranged from 58 to 129. The area under both Van Panchayats varied from 30-50 ha. Every household has livestock number below 5. All the families are using fuelwood for cooking and heating purposes, only 3-5 families are using LPG, occasionally. The daily requirements of fuelwood ranged from 5-7 kg of dry fuelwood per family. The condition of the forests is quite satisfactory because trees are in healthy condition without lopping and are relatively undisturbed. The regeneration pattern is good, because the conversion of seedlings to saplings and saplings to trees is satisfactory. After the formation of the Van Panchayat the villagers believe that the condition of forest has improved substantially. Reforestation and afforestation emerged as a direct response to the ever-growing demands for fodder, fuel wood, and water in the village. The plantation of the *Myrica esculenta* and *Alnus nepalensis* was done in 2009 in about 5 ha area. The villager's clear fire lines for the protection of forest during the summer season. According to recent estimates, there are about 12,089 Van Panchayats in Uttarakhand managing an area of 5,44,965 ha. Handing over forests to communities for management has gradually improved the forest condition with positive impacts on biodiversity conservation, increased production of fodder, firewood, litter and other non-timber forest products (NTFPs) which support subsistence livelihoods. The impact of this policy in the forestry sector has undoubtedly been positive in reducing deforestation and forest degradation in Uttarakhand Himalaya.

3.2. Phytosociological Attributes

The total tree density of the Anriyakot and Bhatkholi Van Panchayat ranged from 150 to 490 ind/ha and 193 to 324.3 ind/ha, respectively (Table 1). The forest of both site were dominated by *Quercus leucotrichophora* and *Pinus roxburghii*. The total tree basal area in the present study varied from 5.26- 13.62 m^2 ha^{-1}. In the present study the conversion of seedlings to saplings and saplings to trees of *Quercus leucotrichophora* was satisfactory indicating an expanding type of population. Similarly, *Rhododendron arboretum* seedlings and saplings were in good conditions, while the *Pinus roxburghii* regenerating poorly. The higher density of seedling, sapling and trees was because of the efforts of community members and proper forest management practices deployed by the community.

3.3. Forest Biomass

The total forest biomass of Anriyakot Van Panchayat in year 1st was 453.22 t ha^{-1} and it increased to 485.61 t ha^{-1} in 2nd year. The percent contribution of the tree layer in total forest biomass was maximum (98.82%). The biomass of the shrub and herb layer was close to 1.18%. While, the total forest biomass of Bhatkholi Van Panchayat in year 1st was 179.36 t ha^{-1} and it increased to 208.61 t ha^{-1} in 2nd year. Of the total forest, biomass contribution of the tree layer was maximum (98.1%). The biomass of the shrub and herb layer was close to 3.9%. Of the total biomass contribution of above ground part was 73.4% and belowground part 26.6% (Table 2)

Table 1. Site characteristics of the Anriyakot and Bhatkholi Van Panchayat forests

Parameters	Anriyakot Van Panchayat	Bhatkholi Van Panchayat
Altitude (m)	1500-1800	1500-1700
Year of formation	1978	1976
Area (ha)	36.12	50
Dominant Vegetation	*Quercus leucotrichophora, Pinus roxburghii*	*Quercus leucotrichophora, Pinus roxburghii*
Total Tree density (in/ha)	150 to 490	193 to 324.3
Livestock population under each household	2-5	3-5
Daily requirements of fuelwood (Kg/family)	5-7	5-7
Total household number residing around the Van Panchayat forest	12	15
Soil bulk density gcm^{-3} (0-100cm)	1.09±0.007 to 1.36±0.03	0.82±0.06 to 1.36±0.005
Soil carbon% (0-100cm)	1.00±0.29 to 2.73±0.51	1.41±0.54 to 2.97±0.46
Annual range of soil moisture (%) (0-100cm)	7.53±1.06 to 29.72±1.15	6.52±1.09 to14.50±1.15

Table 2. Average forest biomass of tree, shrub and herb layers of Bhatkholi and Anriyakot Van Panchayat

	Biomass Year 1 (t ha^{-1} yr^{-1}) B1	Biomass Year 2 (t ha^{-1} yr^{-1}) B2	Biomass Year 1 (t ha^{-1} yr^{-1}) B1	Biomass Year 2 (t ha^{-1} yr^{-1}) B2
	Bhatkholi Van Panchayat		Anriyakot Van Panchayat	
Boles	18.57±1.45	20.54±1.47	42.30±7.70	45.28±7.82
Branches	8.00±2.40	10.03±2.47	22.92±6.68	25.64±6.97
Twigs	3.51±1.23	4.52±1.39	11.61±4.12	12.09±3.88
Foliage	1.82±0.41	2.04±0.52	5.39±1.71	5.54±1.76
Total above ground	31.90±1.37	37.13±1.46	82.22±5.05	88.55±5.11
Stump root	9.12±2.68	10.08±2.88	24.22±7.02	25.15±7.42
Lateral roots	1.84±0.38	2.30±0.42	4.86±1.30	5.05±1.40
Fine roots	0.24±0.05	0.40±0.08	0.68±0.19	0.99±0.07
Total below ground	11.20±1.04	12.78±1.13	29.76±2.84	31.19±2.96
Shrubs	1.51±0.57	3.37±0.91	2.89±0.98	5.07±1.11
Herbs	1.39±0.16	2.06±0.45	1.47±0.66	1.62±0.77
Total	46	55.34	116.34	126.43

3.4. Soil Characteristics

The total organic soil carbon upto 100 cm soil depth varied from 13.39±0.36 t ha $^{-1}$ to 30.08±0.30 t ha $^{-1}$ across different soil layers of both Van Panchayats. The soil organic carbon percentage of the Anriyakot Van Panchayat ranged from 1.00±0.29% to 2.73±0.51%, whereas on Bhatkholi Van Panchayat it ranged from 1.41±0.54% to 2.97±0.46% (Figure 1 and 2). The maximum soil organic carbon percent being in top soil layer upto10 cm and thereafter it decreased with increasing soil depth. Contrary to this, the soil bulk density followed a reverse trend and varied from 1.09±0.07 g cc $^{-1}$ to 1.44±0.22 g cc $^{-1}$

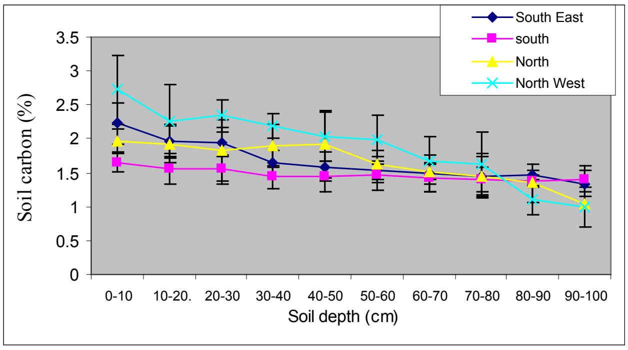

Figure 1. Soil carbon of Anriyakot Van Panchayat along different soil depths and aspects

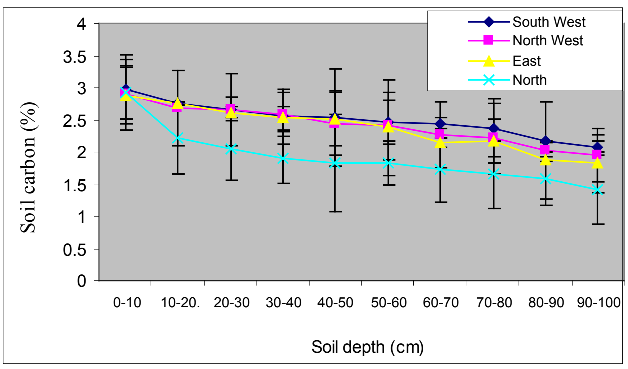

Figure 2. Soil carbon of Bhatkholi Van Panchayat along different soil depths and aspects

across different soil depths on Anriyakot Van Panchayat and 0.97±0.06 g cc $^{-1}$ to 1.36±0.004 g cc $^{-1}$ on Bhatkholi Van Panchayat (Table 1). The ANOVA test showed that the soil organic carbon, site, depth varied significantly at $P<0.05$. The combined effects of site x aspect also showed significant variation at $P<0.05$. However, the combined effects of site x depth aspect x depth did not varied significantly.

3.5. Carbon sequestration rates

The average carbon sequestration rate in the present study in Anriyakot Van Panchayat forest was 3.90±0.52 t ha $^{-1}$ yr $^{-1}$, while in Bhatkholi Van Panchayat forest it was 3.41±0.69 t ha $^{-1}$ yr $^{-1}$. The maximum sequestration rate was on south facing aspect (5.44 t ha $^{-1}$ yr $^{-1}$) of the Anriyakot Van Panchayat forest and the minimum sequestration rate was on east facing aspect (2.03 t ha $^{-1}$ yr $^{-1}$) of the Bhatkholi Van Panchayat forest (Figure 3).

Data showed that in both the Van Panchayats, the highest amount of carbon was stored in the biomass of *Quercus leucotrichophora* trees (91.55 %).

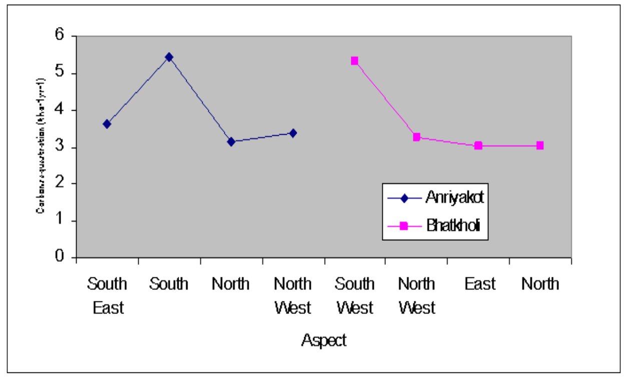

Figure 3. Carbon sequestration rates (t ha $^{-1}$ yr $^{-1}$) in Anriyakot and Bhatkholi Van Panchayat (Carbon sequestration rate is on Y-axis and Aspect on X-axis)

Analysis of statistics (T-Test, paired sample) between aboveground carbon sequestration rate and belowground carbon sequestration rate showed significant variation at $P<0.005$.

3.6. Litter Fall

The mean annual litter fall in Anriyakot Van Panchayat forest was 6.25±0.26 t ha $^{-1}$ (mean of four aspects). The mean litter fall value was higher in summer season (2.86±0.39 t ha $^{-1}$) followed by rainy (1.87±0.27 t ha $^{-1}$) and winter season (1.53±0.04 t ha $^{-1}$). While the mean annual litter fall in Bhatkholi Van Panchayat forest was 6.08±0.50 t ha $^{-1}$ (mean of four aspects). The mean litter fall value was higher in summer season (2.55±0.32 t ha $^{-1}$) followed by rainy (1.84±0.24 t ha $^{-1}$) and winter season (1.68±0.26 t ha $^{-1}$) (Table 3). The ANOVA test showed significant variation at $P<0.05$ across aspects, seasons and types of litter. The combined effects of seasons x types of litter, seasons x aspects also varied significantly ($P<0.05$). However, in case of site x aspects, sites x seasons, sites x litter types and aspects x litter types did not show significant variation.

Table 3. Average seasonal litter fall (t/ha) in Anriyakot and Bhatkholi Van Panchayat

Season	Anriyakot Van Panchayat				
	Wood	Fresh leaf litter	Partially decomposed	Miscellaneous	Total
Summer	0.89	1.66	0.22	0.05	2.82
Rainy	0.41	0.89	0.52	0.05	1.87
Winter	0.59	0.69	0.24	0.00	1.52
Total	1.89	3.24	0.98	0.10	6.21
Bhatkholi Van Panchayat					
Summer	0.78	1.68	0.09	-	2.55
Rainy	0.40	1.06	0.37	0.02	1.84
Winter	0.85	0.70	0.13	-	1.68
Total	2.03	3.44	0.59	0.02	6.08

3.7. Fine Root Biomass

The total fine root biomass in Anriyakot Van Panchayat forest varied from 4.33 t ha $^{-1}$ to 6.65 t ha $^{-1}$ (Four aspects). The average fine root biomass of the three seasons was 7.41±2.89 t ha $^{-1}$. The total fine root biomass in Bhatkholi Van Panchayat ranged from 4.28 t ha $^{-1}$ to 5.74 t ha $^{-1}$. The average fine root biomass was 6.56±2.68 t ha $^{-1}$. The fine root biomass across all seasons declined with depth increasing soil depths.

The ANOVA test showed that fine roots biomass varied significantly ($P<0.05$) between seasons, forest site, aspects, soil depths and to the combined effects of season x forest site and season x soil depths.

4. Discussion

As deforestation was acknowledged as a source of anthropogenic emissions at the 13th CoP meeting, interest is growing in finding ways to include the reduction in forest degradation in developing countries beyond the first commitment period of the Kyoto Protocol[18]. Therefore, it is important for the authorities in the regions concerned to take early cognizance of the potential that forest conservation offers and lobby for a mechanism that brings benefits to local communities, which will conserve forests locally and extending the benefits globally. The present study illustrate that community forest management can be a viable strategy for reducing emissions from deforestation, as the data reveal that the mean carbon sequestration rate for India (3.7 t ha $^{-1}$ yr^{-1}) and Nepal (1.88 t ha $^{-1}$ yr^{-1}), are close to 2.79 t ha $^{-1}$ yr^{-1} or 10.23 CO_2 t ha $^{-1}$ yr^{-1} under normal management conditions, this is the condition when local people have extracted various forest products to meet their sustenance needs[19]. The Van Panchayat forests in Uttarakhand are sequestering carbon at the average rate of around 3.3 t ha $^{-1}$ yr^{-1}. However, these values varied from place to place. In least disturbed forests of various types, such as sal, pine and oak forests generally carbon sequestration rates ranged between 4.0-5.6 t ha^{-1} yr^{-1}. These are more or less similar to values reported for tropical forests. However, due to forest degradation these high rates are not found everywhere at regional scale. A range of values between 2.52-3.53 t ha^{-1} yr^{-1} is common[20]. The carbon sequestration values observed from the present study varied from 2.03 to 5.44 t ha^{-1} yr^{-1}. The carbon sequestration values observed from the present study are in agreement with the values reported earlier for different central Himalayan forests[21, 22, 23]. A study carried out in the inner Terai region in Nepal shows carbon sequestration rates of 2 t C ha $^{-1}$ yr^{-1} from aboveground biomass, including understory biomass, and SOC of upto 20 cm depth[25]. In the present study the number of trees was more in the younger size girth classes (30 to 60cm), therefore calculated carbon sequestration rate values are towards higher side. Almost trees of medium size girth class had a greater potential for carbon sequestering than mature trees because the growth rate was slow in bigger size girth classes. Therefore, to conserve and manage the small trees of 10- 60cm girth class can considerably increase carbon sequestration potential in the near future if appropriate management practices are applied. [26, 27] reported that carbon sequestration depended not only forest types and rates of productivity but also on the size classes of trees. As the average prices of carbon offsets range between US$ 5 to US$ 28 per tones. Using the nominal rate of US$ 10 per tones, the carbon stored in Anriyakot and Bhatkholi Van Panchayat forests was US$ 1690.44 and US$ 2046, respectively. The situation in other Van Panchayats in Uttarakhand is more or less similar. It was assumed that at least 2-5 ha of forest are required per household to meet their daily needs of fodder and fuelwood. A major transfer of forest from government to Van Panchayat would be required to give adequate forest support to most villages. This comes to over 100,000 ha of government forest; that is, nearly 40% of the existing forests[28]. Once each Van Panchayat is assured of an adequate forest area, regulations about the protection of government forests can be enforced effectively. This can be used to address the problem of leakage. Thus it would help to ensure improvement in the remaining government forest. Once assured of rights, villagers would be encouraged to take up measures to reduce their day to day dependency on forests. Selling of carbon from their forests can provide a considerable income for the Van Panchayats. The inclusion of forest conservation activities in international agreements and protocols will give incentives to the local population to get certified emission reductions for their efforts to conserve the forest. This would not only provide resources for sustainable livelihoods and improved lifestyles, but also encourage the marginalized people of the Himalaya to make a meaningful contribution to reducing global emissions and forest conservation[29]. On the basis of review of past studies, there appear to be high potential for enhancing the carbon sequestration in the vegetation and soils of the Central Himalayan region through improved management of degraded lands. Soil carbon sequestration could meet at most about one-third of the current yearly increase in atmospheric CO_2 however, the duration of the effect would be limited, with significant impacts lasting only 20-50 years[30]**.** Soil organic carbon values of the present study varied from 0.38 to 2.73%. These values are generally comparable with the values reported earlier for different Central Himalayan forests (0.97% to 4.1%[23]).The organic soil carbon percent in the present study was higher on the top soil layers and declines as the soil depth increases. The vertical distribution of roots and soil carbon are correlated but soil carbon goes deeper than roots. Soil carbon turnover decreases with soil depth resulting in higher soil accumulation per units of carbon input in deeper layer soil organism mixes carbon vertically. The tree species which have a deeper root allocation hold a great potential and various species of given area need to be examined in view of soil carbon accumulation. On an average most of the soil texture of both the Van Panchayats were clay resulting in the higher value of soil organic carbon percent.

The estimates for sequestrating atmospheric CO_2 indicate that maintaining existing forests may be one of the least cost options for offsetting carbon, based on the breakeven price of $ 0.55 to $ 3.70 per t CO_2. It is assumed that if the rates for credits are considerable higher than their cost, then it may be a real incentive to strengthen and promote sustainable forest management, which will be attractive to local communities as well as governments in developing countries. It also clearly shows REDD policy must be built upon the existing CFM policy where communities are recognized with their forest use rights. Successful participation can bring ecological and economic benefits to the community as well as the country.

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