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Potential Carbon Offset in Public Plantation: Offering Opportunity for REDD+ and Soil Fertility

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Abstract: *This work is aligned with the main purpose of REDD+ reward but it needs sufficient records of carbon to develop the Monitoring Reporting and Verification (MRV) system and reference emission level. Hence, the objectives of the study are to compare the carbon stocks of different aged public plantations with respect to neighboring sites, to see the variation in mean annual increment carbon (MAIC) and to assess the variation in amount of nitrogen (N), phosphorous (P) and potassium (K) in soil. Three public plantations in Mahottari district, Tarai were selected for study. Then, random sampling was applied to collect the data from control and plantation sites. Altogether 28 sample plots were distributed on the study site. The sample plots were established navigating the coordinates in the field of 10 m × 10 m for pole and 1 m × 1 m for litter and grasses. Height and diameter at breast height were measured of pole, and samples of litter and grasses were collected. Meanwhile, the soil samples were collected from the centre of the plot from 0-0.1 m, 0.1-0.3 m and 0.3-0.6 m depths. The biomass was calculated using standard equations and soil C, N, P and K contents were estimated in the lab. The result showed there were significant differences in carbon (C) stocks, it was 140.32 t/ha in treatment site 68.39 t/ha in control site of Shreepur public plantation while MAIC was found to be highest 10.19 t/ha in same site and lowest 3.39 t/ha in Bisbitty public plantation. Moreover, nitrogen was highest 98.41 kg/ha in 0-0.1m and it was decreased according to soil depths in Shreepur public plantation and same trend was found in soil P and K. Hence, such type of intensive research is recommended in order to secure the candidacy for REDD+ reward.*

Key words: *Public plantation, mean annual increment carbon, REDD+.*

Introduction

Managing the carbon either by reducing deforestation and forest degradation or by enhancing the forest through plantation has significant value (Shively, 2004) in REDD+ and it can add high value if such plantations are managed by the landless poor communities (Smith *et al.*, 2003). The ultimate goals of REDD+ is to cut off pressure on the forest either by establishing the plantation, enhancing regeneration or reducing the deforestation and forest degradation and it offers to improve the livelihood of the poor communities (Campbell, 2009; Hett *et al.*, 2011). The plantations also create the opportunity of increasing soil fertility which enables degraded lands reclaim to yield more from intercrops and generate income for landless communities through agro-forestry practices; this is a new innovation in forest expansion as public plantation in Tarai (plain), Nepal. Such afforestation activities significantly contribute to sequester the CO_2 (Jackson *et al.*, 2002).

Annually, there is decline in world's forest areas due to heavy pressure of increasing populations. The global net change in forest area in the period of 2000–2010 was estimated to be 5.2 million ha annually but plantation was accounting for 130 million ha by area and 3% of world's forest (Mini *et al.*, 2011). Southeast Asia experienced the largest shrink in forest area in the region since last ten years, with an annual net loss of more than 0.9 million ha. In Nepal, about 84,000 ha of forest became deforested annually between 1991 and 2001. Out of this, the annual deforestation was nearly 10000 ha in Tarai. However, there was positive change in forest cover about 0.25% in Mahottary district in between 1991 to 2001 (DoF, 2005), improving the forests through plantation and community based forest management but presently, people realized that there is still escalating deforestation and forest degradation activities.

More than one billion people – one seventh of the world population live on less than US $ 1 a day. South Asia has about 423 million people, the highest number of people living in absolute poverty (FAO, 2011). About 25% of population lives under the poverty line and out of that 80% people are dependent on forest products in Nepal (Pokharel, 2011). The main reason of deforestation and forest degradation is poverty because of the people's dependency on forest for subsistence livelihood (Laurance, 1991; Bradford *et al.*, 2012), so it is essential to first manage the forest dependant poor people to kick out the key causes of deforestation and forest degradation (Willium, 1999). In this circumstance, the REDD+ has also focused to manage the factors like local poverty for enhancing the forest stock in order to reduce emission to meet the global target of keeping the temperature below 2^0C in this century (UNFCCC, 2010).

The public plantation in Nepal is one of the best example of forest enhancement where landless Dalit (untouchable casts) communities are adopting agro-forestry practice to manage degraded lands for income generation and collection of forest products like grasses, leaf litter and small twigs and ultimately hoping to gain the high income from pole. The immediate resultant impact of this is pressure off on the natural forests. One more attractive future motivation will be REDD+ reward for forest enhancement but it needs intensive database of carbon stocks for designing the appropriate monitoring reporting and verification (MRV) system and developing reference emission level (REL). Thus, database requires evaluations like, are there significant differences in carbon stocks of afforested and non-afforested areas? What is the mean annual increment of carbon (MAIC) in the public plantations and how much CO_2 can be removed from the atmosphere through such plantations? What is the quantity of accumulation of N, P and K in soil of public plantation? This research paper tries to answer these questions so that such plantations can secure the candidacy to be eligible under REDD+ reward.

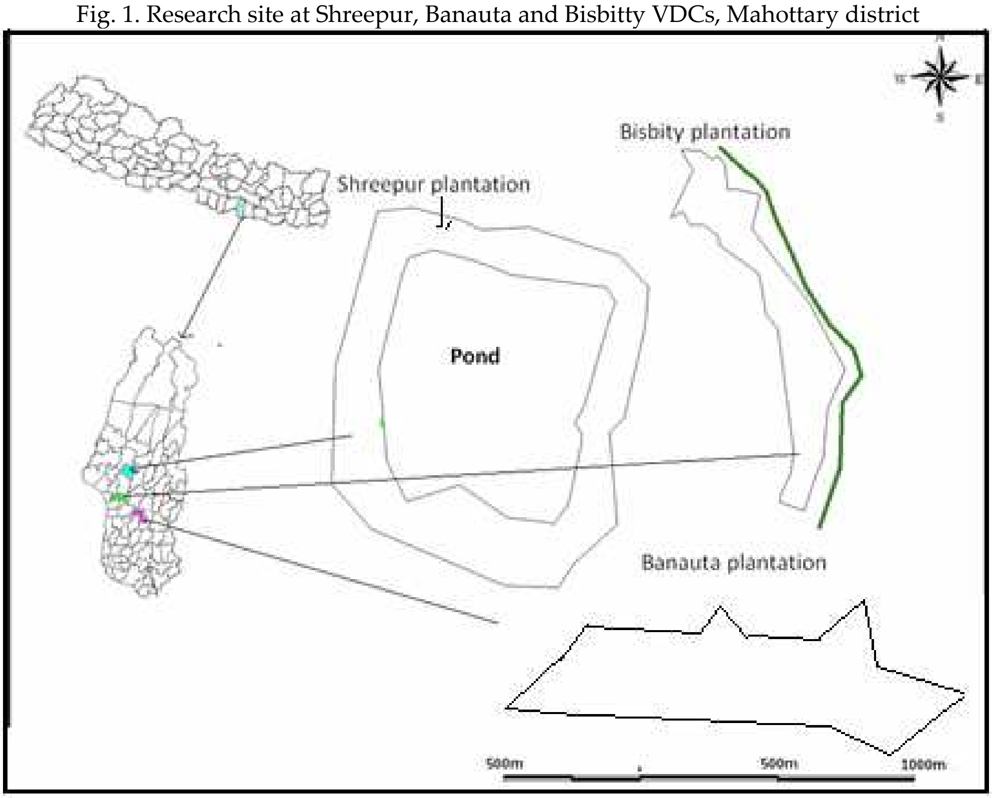
Materials and method

Research site: Three public plantations of Bisbitty, Banauta and Shreepur village development committees of Mahottary district in the central Tarai, Nepal were selected for study (Fig. 1). These sites are planted with pure *Eucalyptus camaldulensis.* The existing natural plant species are *Cynodon dactylon* and *Mimosa pudica*.

Mahottary district is situated in 26° 36' to 28° 10' North and 85° 41' to 85° 57' East. The annual average temperature ranges between 20-25^0 C and annual average rain fall recorded ranges between 1100-3500 mm.

Three public plantations were established in three different years and managed by three different types of landless poor marginalized untouchable communities adopting diverse traditional jobs. The plantations were carried out in 2006, 2007 and 2008 at Shreepur, Bisbitty and Banauta sites, respectively. The plantation in Shreepur was managed by Khatave- Mandal (sheep keeping community), plantation in Banauta was managed by Chamar community (shoe makers) and plantation of Bisbitty was managed by Mushar community (soil worker). The inter-crops were *Lathyrus sativus*, *Aloe vera* and green vegetables like ladiesfinger, cauliflower, brinjal in Bisbitty, Banauta and Shreepur public plantations, respectively.

Fig. 1. Research site at Shreepur, Banauta and Bisbitty VDCs, Mahottary district



Bio-physical data collection: The maps of these plantation areas were prepared using the coordinates taken by Geographical Positioning System (GPS) with the help of ArcGIS software. Simple random sampling was used maintaining 1% sample intensity (DoF, 2003). Altogether 28 sample plots were randomly identified (9, 11 and 8 sample plots were fixed to collect the data from Banauta, Shreepur and Bisbitty plantation sites, respectively). After that, the centre point coordinates of each sample plots were recorded from the map and uploaded in GPS. Then, the nested sample plots were established in the field by navigating the GPS coordinates. The plantations are generally pole sized so nested sample plots of 10 m × 10 m for this and 1 m × 1 m for litter and grasses were established while soil samples were taken from the centre. Height and diameter (at breast height) of poles and sapling (greater than 5 cm dbh) were measured but the samples of sapling (less than 5 cm dbh), grasses, litter and soil were packed to carry to the lab for analysis. Soil samples were collected from three different layers (0-0.1 m, 0.1-0.3 m and 0.3-0.6 m) using soil auger (Wang *et al.,* 1996). The sampling of control sites were conducted to neighboring areas of the plantation site. Thus, five samples of grasses and soil were taken from each site following the same sample size. The control site is only covered by *Themeda triandra*, *Cynodon dactylon, Mimosa pudica,* etc.

*Data generation***:** The biophysical data were analyzed applying the simple statistics using SPSS software, statistical software. The biomass was calculated using biomass equation of Chave *et al*. (2005) for larger than 5cm diameter at breast height (dbh) and biomass equation of Tamrakar (2000) but this biomass equation provides only the fresh weight so collected samples were dried. Moreover, samples of litter and grasses were also dried to calculate the dry biomass. Meanwhile, the root biomass was calculated multiplying by conversion factor 0.125 of shoot biomass. Then, the biomass was changed into carbon multiplying by 0.47 (MacDicken, 1997).

At the same time soil bulk density and carbon content were calculated by using Walkley and Black method. Meanwhile, Nitrogen (N) and Phosphorous (P) were analyzed by Kjeldahl digestion and colorimetry method (Wang *et al.,* 1996), respectively while Potassium (K) was analyzed by using Ammonium acetate extraction method (Knudsen *et al.,* 1982).

The mean annual carbon was calculated using following equation. Then, the value was changed into CO_2 multiplying conversion factor 44/12 in order to show the CO_2 removal from atmosphere.

$$\text{Mean annual increment of C (MAIC)} = \frac{\sum \text{Total C stock of pole \& sapling}}{\text{Age of plantation}} \qquad \text{(Source: Lal, 2007)}$$

Data preparation for statistical analysis: The identified outlier in biomass of Banauta plantation was removed testing under the normality for further statistical analysis using SPSS software. Then homogeneity test was carried out to apply the one way ANOVA test to compare whether MAICs in these three public plantations differ.

Same ways, collected data from control sample plot, neighboring to each public plantation were also analyzed in order to assess the C stock. Finally, the C stock of plantation site and control sites were compared by applying t-test.

Results and discussion

Carbon stock in public plantation: The carbon stock varied in public plantation according to its age. The public plantation of Shreepur site was oldest one so the value of total C stock was highest (140.26 t/ha) and the public plantation of Bisbitty site was the youngest one thus this vale was lowest (30.19 t/ha). Same trend was found in soil carbon and carbon stock of pole as well as sapling. As the area of Shreepur public plantation was 10.5 ha, Banauta was 8.8 ha and Bisbitty was 7.6 ha, the grand total C stock were 1473.33, 622.29 and 230.60 t, respectively (Table 1).

Table 1. Quantity of carbon stocks in different public plantations

Public plantation	Area (ha)	No of trees	Pole and sapling C (t/ha)	Root carbon	Grass and litter (t/ha)	Soil carbon (t/ha)	Total C (t/ha)	Total C (t)
Shreepur	10.5	3618	54.34	6.79	0.06	79.13	140.32	1473.33
Banauta	8.8	2013	29.90	3.74	0.07	37.00	70.71	622.29
Bisbitty	7.6	1756	12.03	1.50	0.065	16.74	30.34	230.60

Comparison of C stocks in public plantation and control sites: Two- sample t-test showed that there were significant differences in C stocks in plantation and control sites of all public plantations at 95% of confidence interval. The mean differences in C stock varied from 51.26% to 66.11% between plantation and control site (Table 2).

Table 2. Comparison of C stocks in public plantation

Public plantation	Category	Mean (ton/ha)	% mean difference	Standard error	Standard deviation	t_{cal}	t_{tab} (α=5%)	P value
Shreepur	Plantation	140.32		0.71	2.36	96.2	2.1	0.00
	Control	68.39	51.26	0.23	0.52			
Banauta	Plantation	70.71	66.11	0.38	1.08	20.5	2.2	0.00
	Control	23.96		0.21	0.47			
Bisbitty	Plantation	30.34	61.24	0.36	1.03	50.5	2.2	0.00
	Control	11.76		0.07	0.15			

Mean annual increment carbon (MAIC) in public plantations

Annual removal of CO_2 by public plantation: Total CO_2 removal also varied in different public plantations. Annually, these three public plantations can remove 775.22 t of CO_2 from the atmosphere. Mean annual CO_2 removal was lowest (12.41 t/ha) by Bisbitty public plantation while it was highest (37.36 t/ha) by Shreepur public plantation. Similarly, the MAIC was highest (10.19 t/ha) in Shreepur and lowest (3.39 t/ha) in Bisbitty public plantation (Table 3).

Table 3. Annual removal of CO_2 from public plantation

Public plantation	Annual removal of CO_2 (sapling+ poles)			
	MAIC ton/ha	MAIC%	CO_2 removal ton/ha	Total annual CO_2 removal ton
Shreepur	10.19	20.00	37.36	392.25
Banauta	6.56	16.67	24.06	252.65
Bisbitty	3.39	25.00	12.41	130.32
Total				775.22

Analysis of mean annual increment C: Tukey's HSD Post Hoc Test, the one way ANOVA showed that the values of the mean annual increment of C of these public plantation were varied at 95% significant interval (Table 4).

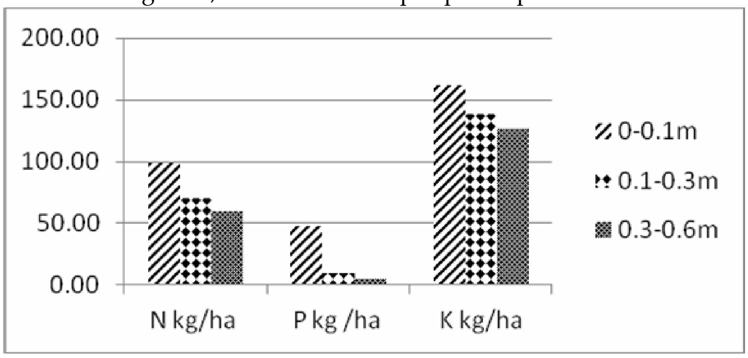
Table 4. ANOVA analysis of mean annual increment carbon

Plantation site	N	Subset for α= 0.05		
		Category 1	Category 2	Category 3
Bisbitty	8	3.38		
Banauta	8		6.56	
Shreepur	11			10.19
Sig.		1.000	1.000	1.000

Quantity of nitrogen, phosphorous and potassium in soil of public plantation: The quantity of N, P and K varied according to soil depth. It was found to be highest in 0-0.1 m and decreased respective to soil depth 0.1-0.3 m and 0.3-0.6 m. The quantity of accumulation of N, P and K in different public plantation is described below.

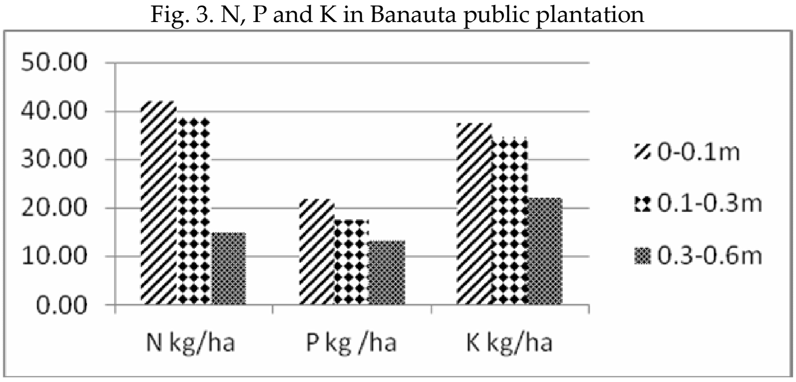
Nitrogen, phosphorous and potash in Shreepur public plantation: It was found to be the highest N, P and K in 0-0.1 m depth and followed by 0.1-0.3 m and 0.3-0.6 m. Thus, the values of N were 98.41, 69.94 and 58.88 kg/ha in 0-0.1 m, 0.1-0.3 m and 0.3-0.6 m soil depths, respectively. Same trend was seen in quantity of P and K as well (Fig. 2).

Fig. 2. N, P and K in Shreepur public plantation



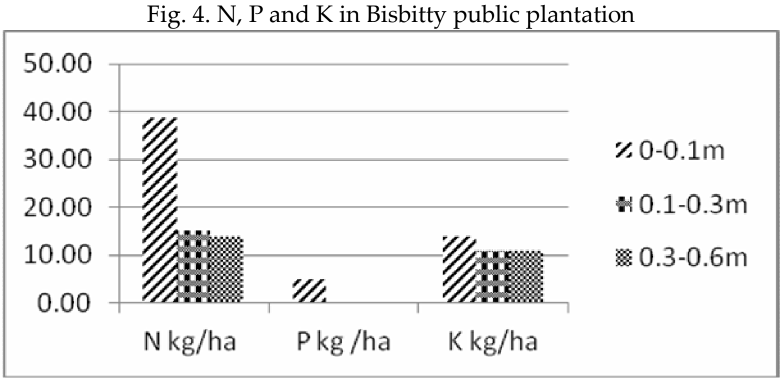
Nitrogen, phosphorous and potash in Banauta public plantation: In case of Banauta public plantation, it was found to be highest quantity of N in 0-0.1 m and followed by values at 0.1-0.3 m and 0.3-0.6 m with 42.00 kg/ha, 38.52 kg/ha and 14.96 kg/ha, respectively. Similar trend was found in the accumulation of P and K (Fig. 3).

Fig. 3. N, P and K in Banauta public plantation



Nitrogen, phosphorous and potash in Bisbitty public plantation: The quantity of N in Bisbitty public plantation was found to be highest in 0-0.1 m depth with value 38.52 kg/ha and it was followed in 0.1-0.3 m and 0.3-0.6 m with the values of 14.95 and 14.00 kg/ha, respectively. This trend was also seen in accumulation of P and K (Fig. 4).

Fig. 4. N, P and K in Bisbitty public plantation



Difference in N, P and K in soil of public plantation and of control site: The results showed that there were differences in values of N, P and K between plantation and control site. The highest differences in values of N, P and K were found with 192.90, 40.85 and 303.26 kg/ha in Shreepur public plantation but lowest differences in Bisbitty public plantation with values 48.25, 3.19 and 24.77 kg/ha (Table 5).

Table 5. N, P and K in soil (kg/ha) in soil of public plantation and control site

Site	Category	N	P	K
Shreepur	Public plantation	227.23	61.27	426.37
	Control site	34.33	20.42	123.11
	Differences	192.90	40.85	303.26
Banauta	Public plantation	95.48	52.60	94.07
	Control site	30.22	15.91	28.21
	Differences	65.26	36.69	65.86
Bisbitty	Public plantation	67.47	5.20	35.78
	Control site	19.22	2.01	11.01
	Differences	48.25	3.19	24.77

Discussion

The C stocks in biomass and soil of public plantation (*Eucalyptus camaldulensis*) varied according to age, site and number of plants/ha (density). As, there was the highest individuals per ha in Shreepur public plantation, the C stock per ha was also highest. Similarly, the carbon stock per tree was more nearly 0.017 t C per tree in Bisbity public plantation than that 0.035 t C per tree of Banauta public plantation. Other reasons were site quality, effect of intercrops, and activeness of users to carry out the management operations like weeding, cleaning and pruning (Shrestha *et al.*, 2008). The values of soil C was highest in Shreepur public plantation and lowest in Bisbitty public plantation because of more loamy soil in Shreepur public plantation and sandy loam soil in other sites. In fact, the Banauta and Bisbitty public plantations were situated on the bank of the river while another site, Shreepur was situated on the Bank of pond. Soil C dynamics depends upon various biotic and abiotic factors such as micro-climate, faunal diversity, land use, land management and crops (Sthapit *et al.*, 2004).

The present study, when compared with the research done by Dutta *et al.* (2010), showed about 84.07 t/ha and 87.42 t/ha C of biomass of 10 and 11 years of *Eucalyptus camaldulensis* in Indrakali community forest and in Newardanda Kamidanda community forest of Mahottary district, respectively. Meanwhile, the values of soil C were 76.27 t/ha in Indrakali community forest which is near to the value of Shreepur public plantation and 41.24 t/ha in Newardanda and Kamidanda community forest, the values were different from this research.

The values of MAIC was the highest in Shreepur public plantation and lowest in Bisbitty public plantation. Amatya *et al*. (2002) showed that the values of MAI of 4 years plantations of poor site was 5.8 m^3/ha and 6 years plantation of fair site was 19.4 m^3/ha, it means estimated values of MAIC which is equal to MAI (m^3) $\times$ wood density $\times$ 0.47 (wood density of *Eucalyptus camaldulensis* is 0.96 kg/m^3), were 2.63 t/ha and 8.75 t/ha, respectively. These values were nearly close to the MAIC values of the research site. Moreover, Hawkin (1987) stated that the mean annual increment (MAI) of 5 years *Eucalyptus camaldulensis* was 25.4 m^3/ha, consequently estimated values of MAIC was 11.46 t/ha, this value was very close to 6 years plantation of Shreepur site. Generally, the MAIC values of this research were lower than the other; the reason behind it may be due to inferior soil quality of the present research sites. Growth performance of *Eucalyptus camaldulensis* is better on non-saline soil than on moderately saline soil (Dhakal, 2008).

Additional benefit of the plantation was increase in soil fertility as increase in N, P and K because of the intercropping and decaying of humus. Generally, 7 years rotation was fixed for pole production from *Eucalyptus camalduensis* plantation. As *Eucalyptus camaldulensis* is good coppice, the next rotation will be started after harvesting and again the intercropping can be carried out in these public plantations so the farmers will have more yields. The present values of N, P and K in soil were found to be highest in Shreepur public plantation while the lowest values were found in Bisbitty public plantation. The results compared to the study done by Yadav *et al*. (2007) in riverside on *Leucaena leucocephala* of 5 year plantation showed values of N, P and K 453.24, 25.46 and 340.62 kg/ha, respectively, the present values were less. Moreover, the study done by Baral (2008) showed that the values of N, P and K were 843, 61 and 310 kg/ha, respectively in mixed *Schima- Castonopsis* forest of Gaukhureshwar Community Forest. Other study done by Paudel *et al*. (2003) in sandy loam soil of values of available P and K in the soil of the pure *Shorea robusta* forest were 76.64 and 267.73 kg/ha respectively. Comparing with the present research, these values were different.

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