Article

Evaluating sustainability in community and collaborative forests for carbon stocks

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Abstract

The REDD+ is considered as effective mechanism to address the issues of climate change but it needs sufficient records of carbon stocks. Thus, research objectives are: to show the management options in community and collaborative forests, to compare the forest carbon stocks in these forests and to evaluate the principle of sustainability in practice of management in these forests. The primary data that includes social and biophysical information and secondary which comprises literatures related to scientific forest management were gathered. Here, 32, 33 and 31 samples from Banke- Maraha, Tuteshwarnath and Gadhanta -Bardibas collaborative forests (CFMs) and, 30, 25 and 22 samples from Chureparwati, Budha and Chyandanda community forests (CFs) respectively were collected using stratified random sampling. The social and biophysical data were analyzed using statistical analysis. The dry biomass was calculated applying equation of Chave et al. (2005), while sustainability of forest management was evaluated with Biolley's "Check Method" - Method du-Control and De Liocourt's law. It was found community forests were managed by nearest users while collaborative forests were managed by distant users as well. The highest value of carbon stock was found 197.1 ton ha^{-1} in Gadhanta- Bardibash collaborative forest and lowest about 92.081 ton ha^{-1} in Chyandanda community forest. Though, some management options are applied in community and collaborative forest, theses are not based on principles of sustainability.

Keywords carbon; community; collaborative forests; sustainability.

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1 Introduction

The climate change is global burning issues (Ferrarini, 2012; Zhang and Liu, 2012) and REDD+ is considered as effective and efficient mechanism to address it (Skutsch and Laake, 2009). Halting the deforestation and forest degradation can support to stop 18% of CO_2 emission (IPCC, 2009) and one of the important purpose of REDD+ is to enhance the forest (Wunder, 2008). Thus forest management activities should be shifted towards carbon enhancement so that local community will be able to get benefits from REDD+ mechanism (Luttrell et al., 2012). For this, sustainable management of forest is significantly important (Estrada and Joseph, 2012; Zhang et al., 2006; Zhang, 2007) since the issues of sustainable management of forest is already included in REDD+.

Every two seconds, an area of forest the size of a football field is clear-cut by illegal loggers around the globe consequences are release of CO_2 emission. Deforestation contributes about 5.9 $GtCO_2$ (giga tons or billion metric tons of CO_2) annually in the world (IPCC, 2007). The current rate of deforestation, clearing tropical forests could release an additional 87 to 130 GtC of CO_2 to the atmosphere by 2100 (Gorte and Sheikh, 2010). Net emissions of CO_2 in Nepal were estimated to be 9747 Gg for the base year 1994/95 and net emissions of CO_2 from the Land-use Change and Forestry sectors were about 8117 Gg in the base year 1994/95 (MoPE, 2004).

Worldwide, the community forest management is highly appreciated because of several successful and magical changes and most common ones are preventing deforestation and forest degradation, restoring and increasing in stocks, addition in yield, generating high incomes, supporting in poverty alleviation etc but there is a serious doubt to manage the forest through community forests in Tarai and inner Tarai due to expansion of infrastructure especially roads and jealous interest of users to trade the timber from the community forests(Pokharel et al., 2007).

The ITTO emphasis on the sustainable development theory in “sustainable forest management” is the basis for “sustainable forestry development”. Without sustainable forest management nothing could be discussed about sustainable forestry development ITTO (1992). The provision of inventory statistics, incorporation of growing stock, mean annual increment and annual allowable cut are the indication of scientific forest management in community forest which are also align with the task of REDD+ mechanism, match with the sustainable forest management (SFM) principles of ITTO (2009) like sustainability of production function, ecological function and economic and/or social function of forest resources and the target of Future’s of Nepal’s Forest 2020 to maintain the sustainability in forest management (MFSC, 2010) however uncertainty in sustainability and yield regulation stand still.

Statistically, About 305.11 million ha forest managed by community and indigenous peoples in 36 countries and in Asia-pacific it was about 146.00 million ha (ITTO, 2012). In Nepal, there are about 17900 community forests occupying 165265 ha and 17 collaborative forests having areas 43445 ha and forest management prescriptions based on statistics of inventory are included in operational plan and scheme. But there is a serious uncertainty to accept the statistics of inventory and management prescriptions. Thus several discourses in sustainability of community forest management and REDD+ is worthwhile (Barry et al., 2010). Are the forest management prescriptions in community and collaborative forests based on the scientific principle? Can applied prescriptions assure the future yield regulation? What are the effects of such forest management on forest carbon stock in community and collaborative forests? These are the principal questions in front of forest managers and thus this research paper try to find the answers of these questions. The objectives of this research are: to appraise the adapted management options in community forest and collaborative forests, to compare the forest carbon stocks in community and collaborative forests and to evaluate the principle of sustainability in practice of management in community and collaborative forests

2 Materials and Method

Three community forests and three collaborative forests of Mahottary district, Tarai were selected as research areas for this study because these all forests are natural and only management systems are different (Fig. 1). Selected community forests are Budhha, Chureparwati and Chyandanda while collaborative forests are Banke-

Maraha, Tuteshwarnath and Gadhanta- Bardibash. Mahottari district is situated at 26° 36' to 28° 10' N and 85° 41' to 85° 57' E. The average annual temperature ranges between 20-25^0 C and average annual rainfall recorded between 1100-3500 mm. The main species of these forests was Sal (*Shorea robusta*) and other species were Saj (*Terminalia tomentosa*), Botdhairo (*Lagerstroemia parviflora*), Harro (*Terminalia chebula*) and Barro (*Terminalia belerica*).

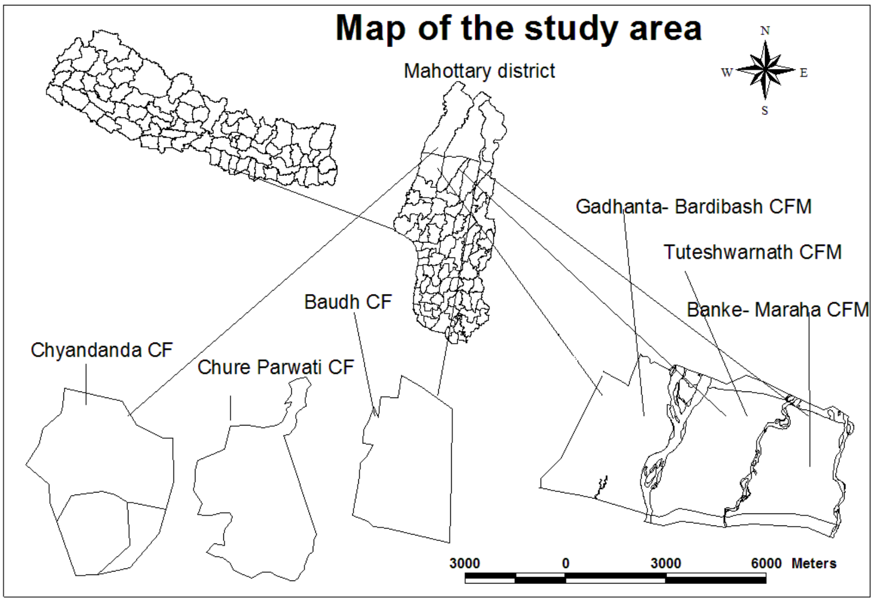

Fig. 1 Map of research site.

Biophysical data were collected from selected forests and community forest inventory guideline and management related documents like schemes of collaborative forests and operational plans of community forests were gathered in order to evaluate the forest management prescriptions.

2.1 Bio-physical data

Stratified random sampling was applied to gather the bio-physical data. So, three main strata namely regeneration, pole and tree based on stage of the forest were delineated on the map of the study areas.

The pilot sampling was carried out to calculate the number of sample plot (MacDicken, 1997). For this purpose at least 15 sample plots were taken from each stratum of collaborative and community forests. In this context, the diameter at breast height and height were measured to determine the minimum number of sample plots based on co-efficient of variance (Moore and McCabe, 2003). Hence, 32, 33 and 31 samples were collected from Banke- Maraha CFM, Tuteshwarnath and Gadhanta –Bardibas CFMs respectively. In case of community forests same process was followed to gather the data. Altogether, 80 samples were collected, out of this, 30 samples from Chureparwati community forest 25 samples from Budha community forest and 22 samples from Chyandanda community forest.

Firstly, forests were surveyed using the GPS receiver to prepare the maps. Then these were divided into three major strata like regeneration, pole and tree. Latter, sample plots were distributed on each stratum of the map. After, the coordinates of sample plots were uploaded in GPS.

Secondly, sample plots were established in the field by navigating the uploaded GPS coordinates. So, the plots were fixed according to the nature of the stratum. For, tree stratum 20m x 25m sample plot was established and nested plots for poles (10m x 10m), sapling (5m x 5m), seedling (5m x 2m) and litter, herbs and grasses (1m x 1m) were established simultaneously (DoF, 2003). Similarly, soil sample was fixed in the centre of plot.

2.2 Data generation

Height and diameter of sapling, poles and trees (dbh>5cm) were measured from determined sample plot. Then, sapling (dbh >1cm and <5cm), seedlings, herbs and shrubs were counted and their fresh weights were taken. Apart from that, soil samples were collected from three different depths 0-10, 10-30 and 30-60 cm in order to determine the soil carbon (IPCC, 2006; Chabbra, 2002).

The secondary data were analyzed applying the descriptive analysis. Similarly, the primary bio-physical data were analyzed to assess the variation in carbon of collaborative forests due to drivers of deforestation and forest degradation. The total carbon stocks variation was compared with one way ANOVA Tukey's test (Unger et al., 2012) by using software SPSS.

Collected operation plan of community forests, schemes of collaborative forests and community forest inventory guideline were reviewed to explore the planned silvicultural operations and scientific bases of these operations respectively. Moreover, the interaction with committee members was organized to know about the harvested products.

2.3 Calculation of forest carbon stock

It is essential to calculate the forest biomass before determining the carbon except soil. Therefore, the Above Ground Tree dry Biomass (AGTB) was calculated by using AGTB=0.0509$x\rho D^2H$ (Chave et al., 2005) for dbh (sapling, poles and tree)> 5cm. then, above ground sapling biomass having dbh<5cm was calculated by applying the formula compiled by Tamrakar and its sample was taken to get dry biomass as this allometric equation provide only the fresh weight. So, samples of sapling (dbh<5cm), seedling, leaf litter, herbs and grass (LHG) together were carried out to dry in the lab and their dry biomass was calculated using unitary method. Moreover, the root biomass was calculated by using root shoot ratio 0.125% (MacDicken, 1997). The biomass was converted into carbon by multiplying with 0.47% (IPCC, 2006)

Carbon content in the soil was analyzed by Walkley Black Method (Walkley and Black, 1958).

Bulk Density (BD g/cc) = (oven dry weight of soil)/ (volume of soil in the core)

SOC= Organic Carbon Content % x Soil Bulk Density (Kg/cc) x thickens of horizon, and total carbon= total biomass carbon + soil carbon

3 Results and Discussion

3.1 Practice of forest management in community and collaborative forests

Community forest is a patch of national forest managed by the community with the help of district forest office. The users are living around the forest. On the other hand, collaborative forest is block forest managed by three institutions like district forest office, local development institution and forest user. The distant users are also involved in the management of collaborative forest. Following are some differences in community and collaborative forests (Table.1).

3.2 Analysis of forest products collection from CF and CFM

The growing stock of collaborative and community forest was differed. The record showed that there was highest volume 239.33 m^3 ha^{-1} and lowest volume 57.35 m^3 ha^{-1} in Gadhanta- Bardibash collaborative forest and Chyandanda community forest (regeneration areas) respectively (Table 2).

The Forest resource of Nepal (1987-1998) showed that, the mean stem volume was 178m^3 ha-^{1} (DFRS, 1999). The study done by Mahato (2001) in Chitwan Tarai showed that average growing stock of Sal mixed forest was 180.3 m^3 ha^{-1} while it was 286.48 m^3 ha^{-1} in other site. The result of present research is quite similar to the mentioned research.

Table 1 Comparative activities in community and collaborative forests.

Operations	Community forest		Collaborative forest		Remarks
	Provision	Practice	Provision	Practice	
Protection Activities	Lauripalo: A daily rotation by household to protect the forest Prohibited to do deforested and degradation (D & D) Penalty and reward by users committee		Watcher/ staff of forest office Prohibited to do D & D Penalty for D & D	Watcher/ staff of forest office Prohibited to do D & D but difficult Penalty by district forest office	Community forest users involve in protection works
However sometime, users also request for the help of office staff in protection					
Development	Plantation, regeneration promotion. soil conservation work Fire line development		Plantation, regeneration promotion. soil conservation work Fire line development	Not implemented yet Fire lines are constructed and maintained	
Silvicultural operation	Thinning, pruning, cleaning, clearing and selection felling		Thinning, pruning and selection felling	Not implemented yet but illegally felled and deadwood are collected	
Utilization	Timber & firewood sell to users and market. Green trees harvested In case of *Shorea robusta* and *Acacia catechu* of Terai and Inner Terai (only 15 % revenue to the government)		Timber & firewood sell to users. Green trees harvested 50 % revenue goes to the government	Timber & firewood sell to users from dead logs	

Table 2 Growing stock of collaborative and community forests.

CFM/ CF	Area ha	Effective area ha	GS (m^3 ha^{-1})	Total AAC m^3	Total Collection (m^3) in 2011
Banke- Maraha CFM	2006	1455	198.21	940	122.86
Tuteshwarnath CFM	1334	1123	216.75	2920.92	31.43
Gadhanta- Bardibash CFM	1450	1185	239.33	3403.27	45.00
Budha CF	69.73	58.73	186.86	131.7	71.43
Chure Parwati CF	441.69	388.696	134.88	461.37	128.57
Chyandanda CF	41.35	35.91	57.35	24.71	

It was found that, prescribed volume of annual allowable cut (AAC) of collaborative and community forest was high but the collection was less. In case of Banke- Maraha collaborative forest only 122.86 m^3 timber was collected from dead wood and similar trend was found in other collaborative forests while there were less 128.57 and 71.43 m^3 timber collected from Chure Parwati and Budha CFs respectively.

The timber extraction from forest has been influencing effect on growing stock. The records of timber collection were less than the prescribed AAC but quantity of timber for their own uses was not recorded clearly. In fact, the community forest users only shared record of sold timber. Moreover, sometimes they intensely did not like to show the records. The reason behind it is the users are not fully agreed to pay the tax of *Shorea robusta* and *Acacia catechu* to the government.

Here the remarkable question is: can above harvestable practice assure the sustainable yield regulation and sustainable forest management for carbon enhancement? Some practices of silvicutureal operations like thinning, pruning, selection felling were adopted in community forest but it was not found in collaborative forest. These practices are not sufficient base to assure the sustainability in forest management (Bhandari, 2004). Thus, the participatory forest management system has to take serious concern about the scientific forest management.

The users have no knowledge about the sustainable management of forest. So, the support of forest technician is pertinent for yield regulation in community managed forest and ultimately for forest carbon stock enhancement. As some forest technicians have applied the Meyer's (1943) simplification of De Liocourt's law to check the diameter distribution in community forests but it is not applied in these community and collaborative forest.

Meyer’s (1943) simplification of De Liocourt’s law:

$$\text{Number of stems in Diameter interval } (Y) = Ke^{-ax}$$

where K = relative stand density based on site quality, e= 2.72 the base of Naperierian logarithms, x= diameter at breast height (Meyer, 1943; Prakash, 2001).

3.3 Comparison of C stocks in community and collaborative forests

3.3.1 Carbon stock in community and collaborative forest

Total carbon stock in collaborative forest is more than the community forest. It was fond that the highest quantity of carbon stock was 274.66 ton ha^{-1} in Gadhanta- Bardibash collaborative forest while it was lowest about 92.08 1ton ha^{-1} in Chyandanda community forest (Table 3).

Table 3 Carbon stocks in community and collaborative forests.

Collaborative & community forests	Area ha	Above ground C stock ton ha^{-1}		Below ground C stock ton ha^{-1}		Total ton ha^{-1}	Total C ton
		LHG	Regeneration + pole + tree	Root	Soil		
Banke- Maraha CFM	2006	4.21	116.72	15.12	61.06	197.10	395398.3
Tuteshwarnath CFM	1334	3.603	139.80	17.92	61.26	222.58	296927.3
Gadhanta Bardibash CFM	1450	6.325	178.88	23.15	66.31	274.66	398267.6
Budha CF	69.73	2.33	88.99	11.41	61.22	163.95	11432.47
Chure Parwati CF	441.69	2.11	95.52	12.20	62.22	172.05	75995.37
Chyandanda CF	41.35	3.11	26.99	3.76	58.22	92.08	3807.707

The pilot study done in Kayarkhola watershed in community forest showed that 276.5 ton C ha^{-1}, the inventory done in 2011 (Panta et al., 2011) while it was found different in studies done in Terai Arc Landscape that there was 206.15 ton C ha^{-1} in government managed forests, 240 ton C ha^{-1} in community forests and 274.58 ton C ha^{-1} in protected forests, the inventory was carried out in 2010 (Gurung and Kokh, 2011).

3.3.2 Statistical analysis of carbon stock in community and collaborative forest

The hypothesis whether average carbon stocks in community forest and collaborative forest varied was tested in ANOVA. The one-way ANOVA showed there was variation in mean carbon stocks in community and collaborative forest (Table 4).

Table 4 One-way Tukey's test.

Sources	Sum of squares	DF	MSS	F- ratio	F critical value	P -value
Between samples	502851.65	5	100570.3	3589.45	3.87	0.000
Within Samples (errors)	4791.13	171	28.02			
Total	507642.77	176				

3.4 Issues of sustainable forest management in community managed forests

3.4.1 Biolley’s “Check Method” - Method du-Control

Neither community forests nor collaborative forest showed performance based on Biolley’s “Check Method” - Method du-Control which has focused on the volume ratio of dbh<30cm: dbh =30-50cm: dbh >50 cm to 20:30:50 (Prakash, 2001; Lal, 2007). This has not included dbh <10 cm which has less significant contribution in stocks but it has high value in forest enhancement. It is worthy debate whether same principle can be used for carbon stocks based yield regulation (Wertz-Kanounnikoff and Kongphan-apirak, 2009).

It is noteworthy to compare the aspects of forest management applying the Biolley's sustainable principle in Nepal's community managed forests. The community forestry inventory guideline showed, the forest having volume> 250 m^3 ha^{-1} >10 cm diameter at breast height (dbh) is considered as good quality forest (DoF, 2003). Generally, in Tarai (plain area), high value *Shorea robusta* (Sal) is dominant species whose specific gravity is >0.88 g/cc. Allowing the same principle in carbon stock management indicated that, it will be essential matter of discussion to maintain C stocks about 20-25, 30-35 and >50 t ha^{-1} in dbh<30cm, dbh=30-50cm and dbh>50 cm respectively. Then, there will be enough evidences to assure of sustainability in irregular forest and address the issues of scientific forest management.

3.4.2 De Liocourt’s Law and diameter class distribution of CF and CFM

Comparing the diameter class distribution with De Liocourt’s law showed that there was more number of stems of 1-30 cm diameter class. It was found more that 623 to 992 of 0-10cm dbh class in five community and collaborative forests except Banke- Maraha CFM (511). Moreover, in case of 10-20cm diameter class, there was more number of stems in all forests. On the other hand, there was less Number of stems ha^{-1} in all forest except in Gadhanta- Bardibas and Tuteshwarnath CFMs of 20-30cm diameter class. In case of dbh>50cm, number of individuals ha-1 was more in collaborative forests and less in community forest. It was clearly seen thinning operations are lacking in both community and collaborative forests. The silvicultural operation should be concentrated to remove from overstocked and promote the under stocked carbon. In case of felling of larger dbh>50cm because green trees were selectively felled from community forests but not harvested from collaborative forests (Fig. 2).

Indeed, the users have no idea but forest technicians also not suggested to apply appropriate silvicultural operation. Here, it is essential to point that, as the second generation issues of community forest has focus on sustainable management of forest (Kanel, 2004), the De Liocourt's law explored appropriate diameter distribution of natural irregular forest which can help to plan what silvicultural operations are best suitable based on diameter class distribution and how it can be checked with Biolley’s “Check Method” (Sterba, 2004, Medarevic et al., 2010). The users of community and collaborative forests and forest technicians are not serious about this. Then, it is remarkable matter, what will be the goal of the Future’s of Nepal’s Forest 2020.

The values of carbon stocks of collaborative and community forests were varied according to dbh class and did not show the sustainable checking with values of carbon based on Biolley’s principle. The value of carbon stock of dbh<30cm was 24.89, 26.76 and 23.88 t ha^{-1} in Banke- Maraha CFM, Gadhanta- Bardibash CFM and

Chyandanda CF respectively, in case of 30-50cm dbh class, the value of carbon stock was 33.96 t ha^{-1} of Budha CF matching value with Biolley's modified value however values of carbon stocks of other dbh classes were extremely differed from Biolley's method based values of carbon stocks (Fig. 3).

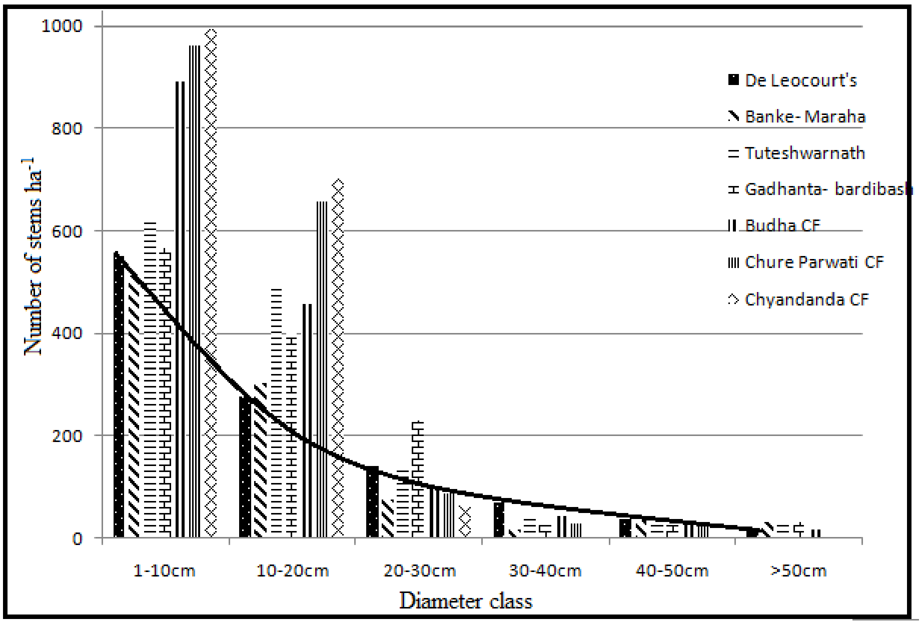

Fig. 2 Comparison of diameter distribution of community managed forest with De Liocourt's law.

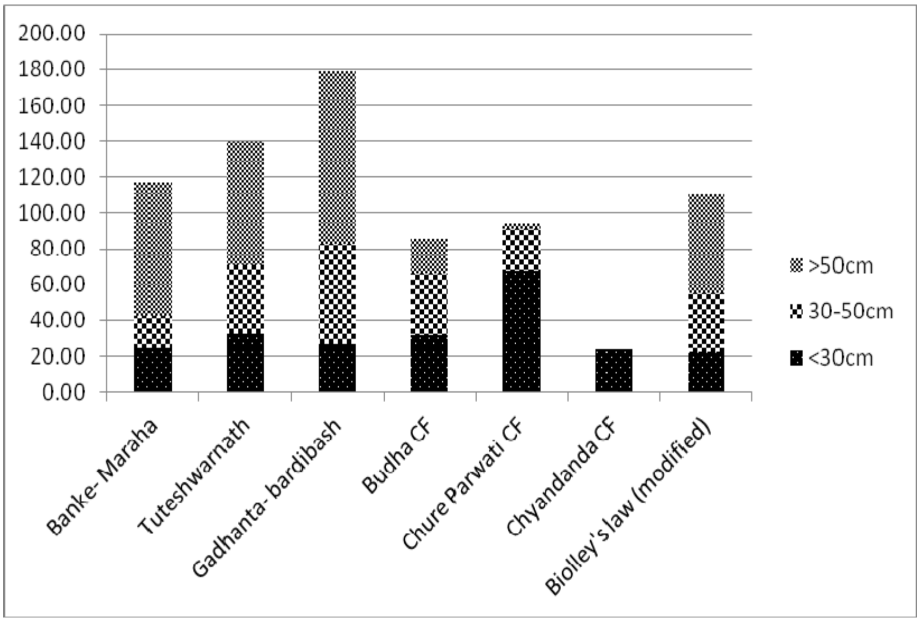

Fig. 3 Comparing Carbon stocks of community managed forests with value of Biolley's check.

4 Conclusion and Recommendation

Diameter distribution of community managed forest did not show the normality based on De Liocourt's law. Similarly, checking the values of carbon stock of these forests with Biolley's "Check Method" varied in in these forests according to dbh class. Thus, there is less chance of sustainable yield regulation from these forests without applying the scientific forest management.

The main objective of community based forest management is to regulate the yield in forest in order to maintain the normality. Volume based yield regulation based on Biolley's "Check Method" is most appropriate method of controlling the stocks in forest. So, if it is applied with some modification for carbon management it would be better to regulate yield for users and also to prepare for REDD+ mechanism.

Moreover, it will be better to check the diameter class based on Meyer's (1943) simplification of De Liocourt's law in order to know how much and from which diameter class should be removed to control the carbon stocks with Biolley's "Check Method".

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