Institute for Financial Management and Research:

Centre for Development Finance

Analysis of grazing exclusion policy through a climate change mitigation lens:
Case from Barsey rhododendron sanctuary, West Sikkim

November 2011

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The paper is submitted to the Government of Sikkim for inclusion in the forthcoming book on Climate Change aspects in Sikkim.

ABSTRACT

Forest ecosystems assume a significant role in climate change mitigation by the virtue of being one of the largest terrestrial carbon sinks. In India, Sikkim is one of the most pro-active states in leading the implementation of conservation policies and is recognised as a key conservation hub. Sikkim adopted a grazing exclusion policy in 1998 owing to the escalating anthropogenic pressure on the forest ecosystems and their consequent rapid degradation. This provided a chance for the revival of the health of the forest ecosystems. The main focus of this paper is to highlight the net positive impact on forest carbon stocks 12 years after the introduction of grazing exclusion policy in the State of Sikkim. We develop this case based on our field work in and around Barsey Rhododendron Sanctuary in the West District of Sikkim. The paper develops this case by comparing two alternative scenarios: (i) Forest carbon stocks in the absence of the grazing exclusion policy (ii) Forest carbon stocks with implementation of the grazing exclusion policy. We carried out extensive field surveys using FSI methodology for collecting vegetation data and conducted focused group discussions and household surveys to understand the resource consumption pattern of the herder community in the forests. The study adopted 1998 as the baseline year. The baseline growing stock was estimated based on earlier FSI surveys while the current growing stock was developed based on the current field work. The carbon losses were estimated based on resource consumption patterns. Our estimates show that the difference between with and without policy intervention scenarios amounts to about 585 thousand tonnes of carbon. Impact of this increase in sequestered carbon is not limited to the study site but is contributing to global carbon emissions abatement. Moreover, it is suggested to conduct similar study on a state-wide scale to develop a holistic picture for climate change impacts in the region.

Key words: grazing ban; grazing exclusion; Sikkim, forest carbon stock, growing stock

Kanchendzonga range from Phuktey top, BRS

INTRODUCTION

Forest ecosystems assume significance in addressing climate change associated challenges by playing a vital role in maintaining the carbon balance of the atmosphere. Interestingly, on one hand they form one of the largest terrestial carbon sinks and on the other, deforestation constitutes 20% of the anthropogenic GHG emissions worldwide (IPCC-WGI, 2007). Thus, their role in international climate mechanisms has been limited. Issues such as uncertainty of activities, non – permenenace1, leakage, establishing additionality and practical difficulties in measurement, reporting and verification were the leading cause for concern. (WWF Position Paper, 2009). However, recognizing the potential of forests and land use measures to reduce net carbon emissions by the equivalent of 10-20% of projected fossil fuel emissions through 2050 (UCS, 2005), Bali Action Plan inducted an international framework to halt deforestation. Reducing Emissions from Deforestation and Degradation (REDD), was inducted at the 13th Conference of Parties in 2007. Inclusion such as the REDD encourages and provides an opportunity to conservation-centric government policies, ultimately resulting in carbon abation and forest enhancement, to participate and benefit from the growing carbon market. Successful mitigation of climate change through REDD requires effective forest governance. (FAO and ITTO, 2009) Adaptive policies, developed through a bottom up approach, not only ensures stringent compliance to conservation centric policies,but also provides clarity on issues such as forest rights and access. (Bushley, 2010) Such forest management policies counter degradation of forest ecosystem and also enhance the capacity of stocking territorial carbon in them.

In India, Sikkim is one of the most pro-active states in leading the implementation of conservation policies. With over 80% of its geographic area notified as recorded forest area (FSI, 2009) and over 30% of its area under protected area networks, Sikkim is recognised as a key conservation hub. Furthermore, Sikkim plays an important role in biodiversity conservation at the global level as it is located in Eastern Himalayas, one of the 34 global biodiversity hotspots (DFEWM, Sikkim, 2011). It is home to a variety of flora (4500 species) and fauna (150 species of mammals & 550 species of birds & 600 types of butterflies) and also the magnificent peak Mt. Khangchendzonga, the highest peak in India. The rich diversity in a relatively small landmass puts forward considerable challenge in terms of governance. The issue is compounded by the fact that a high percentage of total population is forest dependent in the State[2]. For such a resource rich mountainous State, maintaining the health of natural resources also helps in minimizing the loss due to recurring natural disasters such as landslides and sinking areas. Realising the need for maintaining the balance between development and environment, Sikkim State government has launched a number of eco-friendly policies and initiatives in the last two decades to achieve the twin goals of conservation and sustainable development.

One of the challenging task was the implementation of the policy of banning grazing in the forest areas. Considering the high dependence of the local communities on the forest areas for subsistence needs such as fuelwood, fodder, timber and livelihood dependency on livestock rearing, policy implementation was a formidable task. With support from local communities, the successful implementation of the grazing exclusion policy provided a restoration chance to these degraded landscapes through undisturbed natural regeneration. Grazing exclusion leads to restoration of forest ecosystems and is recognised as a decisive policy measure

[1] Defines the risk of reversal of emissions removed by sinks through natural disasters
[2] As per the government records, each of the 907 villages in the State is a a forest fringe village. (DFEWM, Sikkim, 2011)

contributing to mitigating climate change. The main focus of this paper would be to highlight the net positive impact on forest carbon stocks by the introduction of grazing exclusion policy in the State of Sikkim. We develop this case based on our field work in Barsey Rhododendron Sanctuary (BRS) in the West District of Sikkim. We build this case by comparing two alternative scenarios: (i) Forest carbon stocks in the absence of the grazing exclusion policy (ii) Forest carbon stocks with implementation of the grazing exclusion policy.

Destroyed temporary cattle shed in BRS

STUDY SCENARIOS

The government of Sikkim introduced conservation policy banning open grazing of domestic livestock in reserved forests, plantations and water sources in 1998. Following the ban on grazing, the process of cow-shed removal was started in Barsey Rhododendron Sanctuary and by 2004; the policy was successfully implemented in the protected area. There was a reduction of about 93% in the livestock population units grazing in the study area. (Tambe, Bhutia, & Arrawatia, 2005) The decline in anthropogenic pressure on the forest resources is supposed to improve the condition of the degraded forest landscape and contribute in enhancing the forest carbon stock. The paper attempts to quantify this change in forest carbon stocks that can be attributed to the policy implementation. The paper develops two scenarios and compares them to highlight the change in forest carbon stocks due to the introduction of the grazing ban policy in BRS.

Scenario 1: Without Policy directive on grazing exclusion

In developing this scenario, we make projections for the forest carbon stocks in BRS for 2010, presuming that the grazing ban intervention had not been implemented for that area. The dynamics of livestock population variation over the last seven decades in BRS reveal that the livestock pressure was maximum around the late ninety's. Moreover around the same time, in 1998, there was detailed forest inventory survey conducted by Forest Survey of India in the West and South districts of Sikkim. BRS was one of the areas where plots where laid for the FSI inventory exercise. Around this time, the grazing pressure in BRS had also been established. Thus, looking at data availability, 1998 was chosen as the base year for developing this scenario. The projections are based on the assumption that in the absence of the policy directive on grazing exclusion, the grazing pressure would have remained constant over the next decade.

This scenario develops estimates for the growing stock in BRS for the year 2010, taking baseline growing stock from FSI 1998 survey. Change in forest carbon stocks from 1998 to 2010 is estimated as below:

$$C_t = C_{t-1} + C_i - C_l \quad \text{-- Equation 1}$$

Where, t varies from 1999 to 2010
C_t = forest carbon stock at time period t
C_i = increment in forest carbon stock due to mean annual increment
C_l = losses in forest carbon stock due to anthropogenic pressures
t = year

Scenario 2: With Policy directive on grazing exclusion

Following the Sikkim government notification on banning grazing in forest areas, the intervention was implemented in BRS by 2004 as discussed earlier. The baseline remains the same for both the scenarios. In this scenario, the estimates for the forest carbon stocks in BRS for the year 2010 are developed based on the primary data collected through intensive field survey during November- December 2010. The estimates generated from this scenario can be treated on the lower side as data has been collected from areas that were earlier subjected to grazing pressure. And undisturbed areas have not been covered in the survey.

The objective of constructing the two scenarios is to capture the policy impact of the grazing ban implementation in BRS. The first scenario captures the growing stock (2010) of degraded forests as it assumes that the disturbances do not cease to exist even after 1998. The second scenario captures the actual growing stock for 2010 based on field data, which reveals the removal of anthropogenic pressure from BRS after policy implementation in 1998. This difference in forest stocks in both the scenarios is emphasised by taking their respective carbon stocks into consideration. Thus, the potential and scope of forest cover to act as carbon sinks if conserved is also highlighted.

Bamboo, Tsuga demosa and Rhododendron regeneration in BRS post Policy directive

MATERIALS AND METHODS

Features of the study area

Barsey Rhododendron Sanctuary lies in the south-west corner of the West district of Sikkim with an area of 104sq. km. It is bounded by the Shingallilla Ridge which forms the natural international border with Nepal and in the south the Rammam river separates it from the West Bengal. The altitudinal gradient varies from 2200m – 4100m. The major significance of the sanctuary is the presence of a wide variety of rhododendron species and that it is home to some of the rare Schedule I species including Red Panda (Sikkim Forest Department, 2008).

BRS is surrounded by more than 30 fringe villages comprising of above 5000 households. (Sikkim Forest Department, 2008). In addition to stray cattle grazing in forest fringes, the sanctuary was home to 288 herders and 5,370 cows, 370 buffaloes, 506 yaks and 135 sheep. Prior to the ban, pattas (permits) were given to herders for grazing their livestock. Herders followed an agro-pastoralist lifestyle with establishing permanent goaths (cattle-sheds), in the forests and practicing mostly subsistence agriculture in the villages. In the forest, vegetation in and around the cattle-shed would be cleared to create kharka (open space for grazing). In the adjacent areas, trees would be heavily lopped for fodder and cut for firewood and timber. The movement of the herders depended upon availability of fodder, water, livestock type and was seasonal in nature. From mid of 1970s to late 1990's, there was an increase in the livestock population and rise in the number of heavy livestock types such as yak, and yak-cow hybrids. With livestock density as 61 livestock / km^2 and cattle shed of density of 4.5 / km^2, the sanctuary was immensely degraded due to the anthropogenic activities. (Tambe, Bhutia, & Arrawatia, 2005).

Field survey - Vegetation

We conducted extensive field surveys during Nov – Dec 2010. Data on vegetation and soil parameters was collected in the field while qualitative data was collected on hydrological and wildlife aspects. The study area was stratified into into 4 broad categories based on the forest type:

1. Upper Hill-Himalayan Wet Temperate Forest (Oak and dwarf bamboo dominated)
2. Moist temperate forest (Mixed coniferous)
3. Sub-alpine forest (Birch/Fir & Rhododendron forests)
4. Sub-Alpine scrub (Rhododendron & scrub thickets)

In each of the forest type zone, cow-shed spots were identified in high and low grazing intensity (disturbance) areas. The high and low disturbed areas were identified by consultations with local herders and forest officials. 10 plots were laid in each of the forest type zones within 1 ha radius of the cow-shed locations, except for the sub-alpine scrub forest where quadrants were laid. In all, 30 plots of 0.1 ha each and 20 1 m2 quadrants were laid. Also, 35 soil samples were collected. The methodology prescribed by the Forest Survey of India was followed for collecting vegetation data from the plots. In each of the plot, four 3 m X 3m sub-plots were laid to capture regeneration and shrubs data and four 1m X 1m quadrants were laid to capture data on herbs. (FSI, 2002). A detailed inventory on important vegetation attributes such as canopy cover, regeneration, girth at breast height, tree height etc was prepared. Also, details on forest disturbance such as lopping, cutting, fire, signs of domestic livestock grazing were also recorded. Noting of wild life was also recorded during the survey.

Upper Hill Himalayan Wet Temperate Forest

Moist Temperate Forest

Rhododendron Forest

Sub Alpine Forest

Field survey – Socio-economic

The data for average fuelwood, fodder and pole requirements were collected through Focused Group Discussions with Joint Forest Management Committee and Eco-Development Committee members, and Household Surveys of 60 herder households in the fringe villages of the sanctuary. Annual requirements of the herder population alone, was considered for this study.

Focused Group Discussions with JFMC and EDC members

Household survey of ex-herders

Secondary information

The average growing stock estimates were adopted from the FSI, Interim Report, (1998).

Area calculation

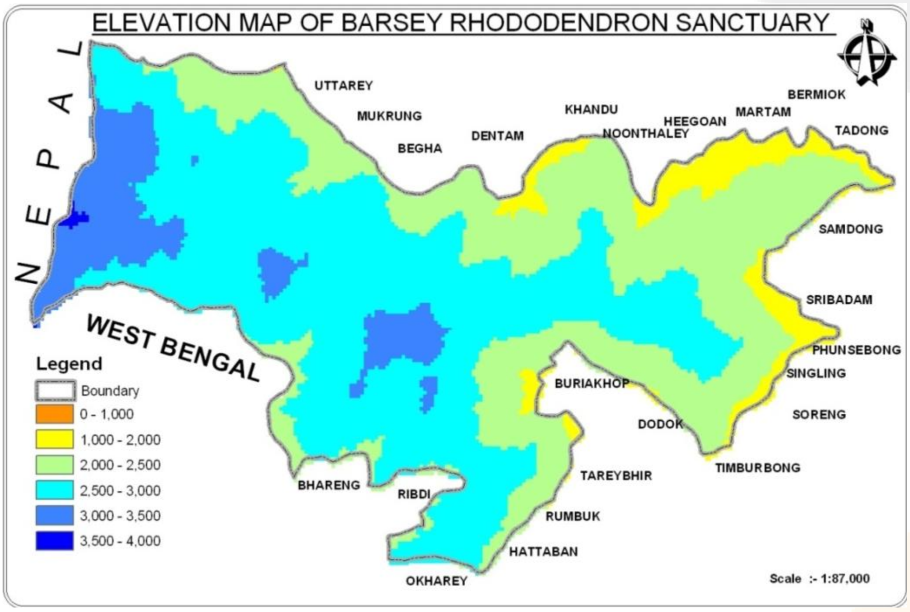

Figure1: Elevation map of Barsey Rhododendron Sanctuary ***(Source: FEWMD, Sikkim)***

We used a LISS III classified image for calculating area under each of the forest type. The image classified on the basis of altitude was taken from the Management Plan of the sanctuary as developed by the state forest department. The image was divided into six classes namely: 0-1000m, 1000-2000m, 2000-2500m, 2500-3000m, 3000-3500m and 3500-4000m. Arc GIS (version 9.2) was used to calculate the area under each altitude class, these area estimates were utilized for further estimation of carbon stock.

Methodology for estimation of growing stock

The study measures the impacts of grazing exclusion policy by considering four variables, i.e. Pre-ban growing stock, mean annual increment, anthropogenic pressures and post ban growing stock.

The baseline growing stock for the year 1998 is estimated based on average volume of growing stock values obtained from Forest Survey of India, Kolkata, interim report (1998). The growing stock in the year 2010 is estimated based on the plot level data obtained during the field surveys. Local allometric equations given in table 1 were utilized for calculating volumes of different tree species. Thus, the methodology for calculating the baseline and current growing stock are both based on FSI technique. State level Mean Annual Increment (MAI) estimate of 0.767 Mm3 (FAO 1998), as provided by the Food and Agriculture Organization report 1998, was adopted for this study. Activities causing loss of carbon stock, collectively taken as anthropogenic pressures, include lopping for fuelwood &fodder, poles for maintenance and construction of cow-sheds and free grazing of domestic livestock un forest areas. Field based primary data was used for calculating carbon loss due to anthropogenic pressure and post-ban growing stock as in 2011.

Table 1 : Allometric Volume Equations (FSI, 1998)

Form Class	Local Allometric Equation
I	V/D^2= 0.001559 +0.06674/D2 - 0.02039/D
II	V/D^2= 0.0012897 + 0.25564/D2 - 0.030418/D
III	V= 0.12652 - 0.018037 D + 0.000956D2
IV	V/D^2= 0.001184 + 0.1812/D2 - 0.02348/D
Estimation of Bamboo biomass (Hairiah K., Sitompul, Noordwijk, & Palm, 2001)	
W = .131 (D^ 2.28)	

Methodology for estimation of carbon equivalent

Methodology, prescribed by the Indian Council of Forestry Research and Education, was adopted to calculate carbon content of growing stock of trees and to estimate the loss in carbon stock due to anthropogenic pressures. As soil carbon estimates for the baseline are not available, the paper limits itself to biomass carbon, stored in forest vegetation, to highlight change in territorial carbon stock due to grazing ban.

Biomass carbon includes above-ground as well as below-ground biomass; where below-ground is a derived as a product of the root-to-shoot ratio [3] and above-ground biomass. For the baseline, average volume per hectare was considered from the FSI interim report. However, documented dbh at plot level was used in local allometric volume equations to estimate the above ground volume for estimating growing stock for 2010. These estimated growing stocks (in m3) were multiplied by the national biomass expansion factor to obtain above ground volume (AGV) and subsequently below ground volume (BGV). Conversion from biomass (in terms of volume) to biomass (in Tonnes) was done by assuming mean wood density as 0.7116. Even though the study doesn't include carbon stock assessment of forest litter and dead trees, carbon pool of other vegetation (on the forest floor biomass) was incorporated to calculate the Total Forest Biomass (TFB). Further carbon equivalent of biomass was estimated considering the dry weight of TFB.(Refer box 1 below)

Box 1: Methodology to estimate Carbon Content

Forest Carbon Stock = Biomass Carbon + Soil Carbon
(The paper assess only biomass carbon in order to highlight policy impact)
Biomass Carbon = Above Ground Biomass (AGV) + Below Ground Biomass (BGV)
Above Ground Volume (AGV) (Mm3) = Growing Stock (Mm3) * Biomass Expansion Factor (1.575)
Below Ground Biomass (BGV) (Mm3) = Above Ground Volume (AGV) * Root-Shoot Ratio (0.266)
Total Biomass (Volume) (Mm3) = ABV + BGV
Biomass of Trees (Million Tonnes) = Total Biomass*Wood Density (0.7116)
Other Vegetation (Million Tonnes) = Biomass*Ratio (0.015)
Total Forest Biomass (TFB) (Million Tonnes) = Biomass (Tree) + Other Vegetation
Dry Weight of Biomass (Million Tonnes) = TFB*0.8
Carbon Equivalent of Biomass (Million Tonnes) = Dry weight of Biomass*0.4

Source: (Kishwan, Pandey, & Dadhwal, 2009)

[3] ratio of belowground biomass to aboveground biomass of a tree species

RESULTS

Scenario 1: Without Policy directive on grazing exclusion

Estimation of baseline

The estimation of baseline growing stock is a prerequisite for the calculation of change in carbon stocks. Table 2 presents an overview of the growing stock assessment for the West district of Sikkim according to the FSI 1998 report. The FSI study had divided the forests into reserved and unreserved categories, which were further divided into 4 stratums based on the altitude. The paper has adopted the estimates developed for the reserved forests in West Sikkim. As most of the area in BRS lies above 2000m hence the values for stratum III and IV only were utilized for this paper. The area of BRS lying below 2500m was multiplied by growing stock estimates under stratum III while for area between 2500-3500m stratum IV estimates were used. Above 3500m, the tree line starts diminishing and subalpine thickets start dominating. In BRS 0.202 sq. km of area lies above 3500m and it has been excluded for the growing stock estimations.

Table 2 : Baseline volume estimates adopted for the study site (FSI, 1998)

Stratum	Altitude (m)	Volume (m^3/ha)	Stems per (ha)
I	≤ 900m	66.813	144.999
II	901 to 1800m	111.266	287.307
III	1801 to 2400m	130.196	190.811
IV	≥ 2400m	283.047	270.714

Source: FSI 1998 Report - Values for West district reserved forests

From the LISS image, the estimated area in BRS was 54.055 sq.km under stratum III and 85.14 sq.km under stratum IV. The total volume of growing stock was calculated by multiplying average volume per hectare by area. It was estimated as 0.704 Mm3 for stratum III and 2.410 Mm3 for stratum IV. The total forest biomass after converting the growing stock to biomass stood at 4.484Mt. From the above, the net accumulation of carbon in the forest stock was projected at 1.435Mt for the year 1998. Form the findings of the FSI report, it is observed that, the forests in stratum III were dominated by Quercus spp. that contributed the most (37.89 percent) while the stratum IV was predominated by Abies species (45.15 percent). In both the stratums, mature trees (over 60cm diameter) majorly contribute to the volume (63 to 65 %). The forests in stratum III correspond to the Upper Hill Himalayan wet temperate forests while, the forests in stratum IV cover the moist temperate and sub-alpine forest types. This estimated carbon stock is used as the reference level to detect change in carbon stock level.

Estimation of loss of carbon due to anthropogenic pressure

Forest ecosystem presents a unique case: when conserved or managed sustainably, they act as sink for carbon, while when degraded or destroyed they turn into sources of carbon dioxide emission. The rapid increase in anthropogenic pressure in BRS was a significant factor contributing to degradation. The livestock population in BRS increased from just over thousand in 1960's to over 6000 livestock units in 1990's[4], an increase of over 250%. This led to intensification of the human activities in the sanctuary, resulting in clearing up of the forested areas for constructing cattle-sheds and grazing areas. This human induced pressure in terms of extraction for fuelwood, construction and lopping for fodder was the main factor contributing to the forest degradation and resulting in diminishing the value of the forest carbon stock. Table 3 lists the livestock pressure in BRS for the year 2000. These values have been adopted in this paper for estimating the grazing pressure.

To estimate the carbon loss, a consumption based approach has been adopted. Information on activities contributing to extraction of the resource was documented through interviews with the herders. There were about 288 herders practicing pastoralism in BRS around the year 2000 (Tambe, Bhutia, & Arrawatia, 2005). The discussions with the herders revealed that the preferred species for fuelwood were *Arundinaria maling* (malingo), *Quercus spp* (bante), and *Viburnum cordifolium* (asare) in the temperate forests while *Abies densa* and *Rhododendron* spp were mostly used at the higher altitudes. The mean consumption of fuelwood by herder was 40kgs d^{-1} (1 head load)[5] for cooking and heating purposes. The average requirement of a herder was 21 metric tonnes $year^{-1}$.

Table 3: Livestock pressure in Barsey Rhododendron Sanctuary (Tambe, Bhutia, & Arrawatia, 2005)

Livestock	Population	Months grazed inside forest
Cow	5370	8
Buffalo	370	8
Yak	506	12
Sheep	135	12

Lopping of trees for fodder constituted another cause for loss in tree stock leading to loss in forest carbon. Lopping was mostly done for providing fodder to the young calves in the cattle sheds and to supplement the fodder requirements of livestock, especially in winter when ground availibaility of fodder declines. Some of the preferred species lopped for fodder were *Thamnocalamus Aristata* (Raat Ningale), *Arundinaria maling* (malingo), *Quercus spp* (bante), *Litsaea polyantha* (pahenley), *Ilex dipyrena* (lissey)and *Sorbus Cuspidata* (Teiga).The average fodder requirement of a herder was 90kgs d^{-1} (2.5 head loads) Net demand for fodder per herder was 33 metric tonnes $year^{-1}$. Herders also required poles for maintenance and construction of the cattle sheds. Species like *Viburnum cordifolium* (asare) and in higher altitudes *Abbies densa* (Silver Fir) and *Tsuga Dumosa* (hemlock) were utilized for this purpose. The herder on an average required 92 tonnes $year^{-1}$, for the purpose of constructing and repairing his cattle shed.

Table 4: Carbon losses due to various disturbances

Disturbance	Consumption (Tonnes p.a.)	Biomass Equivalent (Tonnes p.a.)	Carbon equivalent (Tonnes p.a.)
Fuelwood	6165.504	9710.669	3107.414
Fodder	9642.24	15186.528	4859.689
Timber (poles)	92.16	145.152	46.449
Grazing	100371.600	100371.600	17263.915

[4] Information from focussed group discussions with local communities
[5] For the purpose of calculations, 1HL has been taken as 40kgs and 1 Peel as 12HL.

Drivers of forest degradation in BRS

Besides lopping, another source of biomass loss to forests was in the form of livestock grazing freely in the forests. To estimate this loss, the average daily consumption of green fodder for a cow has been adopted as 60 kg. The other livestock such as yaks, sheep etc have been converted to equivalent cow units, which are multiples of this average cow consumption. For the purpose of calculation, they were taken as cattle/cow=1, buffalo=2, yak=1, and sheep=0.5 (Paljor, 1998).

The total average annual biomass extraction for a herder amounted to 33 metric tonnes of fuelwood, 52 metric tonnes of fodder, and 145 metric tonnes of poles. These annual estimates were then converted into their biomass equivalents using standard biomass expansion factors and further converted into their carbon equivalents by applying the carbon content conversion factor of 0.4 to them. Displayed in table 4 are the corresponding losses in the stocks of carbon due to lopping for fuelwood, fodder and grazing. The contribution of grazing to the loss of carbon stocks was estimated to be 68%[6] as compared to fuelwood and fodder which were at 12% and 19% respectively.

Projection of stock of carbon

As per methodology, the forest stocks in 2010 were estimated by taking the baseline stocks of 1998 and deducting the losses in carbon due to anthropogenic pressure from them and adding the natural regeneration of forest stocks every year. For this, the *MAI of 0.353 t/ha/yr* reported at the state level has been adopted. This was an addition of 4920.3963 tonnes of carbon per annum to the growing stock every year. By adopting equation 1, the carbon stock for 2010 for BRS was estimated to be 1.17 Million tonnes. The calculations indicate a reduction from 1.43 Million tonnes of carbon in 1998 (baseline year) at a rate of 22.054 thousand tonnes per annum. This continuous decline, over 12 years, suggests that the rate of removal of biomass to be higher than the associated natural regeneration and growth. Such projections with constant anthropogenic pressure eventually predict role reversal of trees- from carbon stocks to sinks. (Bhat & Ravindranath, 2010)

Scenario 2 - With Policy directive as government intervention

This scenario quantifies the effectiveness of grazing exclusion policy, in terms of carbon stocks. A positive change in sequestered territorial carbon levels points towards increase in forest biomass- a direct result of undisturbed natural regeneration. A negative change indicates continuation (or acceleration) of degradation activities resulting in higher carbon loss as compared to sequestration. Field based forestry inventory data is used to calculate the growing stock and its carbon equivalent for 2010, 12 years into the policy intervention. Based on the field inventory data, an average volume per hectare for each of the forest type- Upper Hill Himalayan wet temperate, moist temperate and sub alpine is estimated by taking an average of total volume in each of the ten plots laid.

[6] The loss of carbon due to grazing was estimated after considering the seasonality in grazing of the different types of livestock(Table 4)

Table 5: Volume, Biomass and Carbon Stock estimation in 2010

Forest type	Average Volume (m^3 per ha)	Forest Biomass Equivalent (Million Tonnes)
Upper Hill Himalayan Wet Temperate	189.462	1.474
Moist Temperate	233.659	2.317
Sub –Alpine	603.760	1.173

Most of the bamboo documented during the field survey had dbh in the range of 3-7cm, indicating rapid regeneration at the study site. The study adopted a diameter-dry weight relationship to estimate the growing stock for bamboo (Hairiah K., Sitompul, Noordwijk, & Palm, 2001). Carbon stored in bamboo forms 7% of the total carbon stock in the study site with maximum contribution of approximately 16 % in the wet temperate zone. In addition to bamboo species, *Quercus* species contribute upto half of the above ground volume in the wet temperate forests while *Litsaea polyantha* and *Rhododendron* species contribute 18.20% and 7.27% respectively. In the moist temperate zone there was a mix of broadleaved species with coniferous. There was dominance of coniferous (*Tsuga dumosa, Abies densa) and Rhodendron species,* adding upto 50% percent of the above ground volume. Some of the prominent broadleaved species were *Acer cambelli* (4.53%), *Osmanthus suavis* (6.79%), and *Quercus spp.* (9.73%). In the sub-alpine region, *Rhododendron spp.* was conspicuous owing to the luxuriant regeneration and contributed about 46.76% to the above ground volume. The regions had *Abies densa* (39.63%) is the other dominant species of the zone.

The stock of biomass of wet temperate, moist temperate and sub alpine forests was 1.474 Mt, 2.317 Mt and 1.173 Mt respectively (Table 5). Total Forest Biomass, inclusive of enumerated trees as well as other forest floor biomass, for the site is estimated as 5.059 Million tonnes while the carbon equivalent for same is 1.755 Million Tonnes. The estimates show that there was an increase of about 320 thousand tonnes of carbon over the baseline in the BRS. Table 6 presents the comparative scenario. The augmentation in the forest carbon stock can be attributed to the effective implementation of grazing exclusion policy in the BRS.

Table 6: Change in forest carbon stock between 1998 - 2010

Item with description	Factor	1998	2010
Growing Stock of Sanctuary (Mm^3)		3.114	3.513
Mean Biomass Expansion Factor (EF)	1.575		
Ration (Below to Above Ground Biomass) – RBA	0.266		
Above Ground Biomass (Volume) AGB=GS*EF		4.904	5.533
Below Ground Biomass - AGB*RBA		1.305	1.472
Total Biomass (TGB) AGB + BGB		6.209	7.005
Mean Density – MD	0.7116		
Biomass in Metric Tonnes = Growing Stock (Mm3) * MD		4.418	4.984
Ratio (Other Vegetation to Tree Biomass)	0.015		
Total Forest Biomass in Mt (Trees + Herbs + Shrubs) - TFB		4.484	5.059
Dry Weight in Mt (TFB*80%) - DW [7]		3.927	4.387
Stock of Carbon in Mt (DW*40%)		1.435	1.755

[7] DW(2010) is inclusive of the dry weight of bamboo species

DISCUSSION

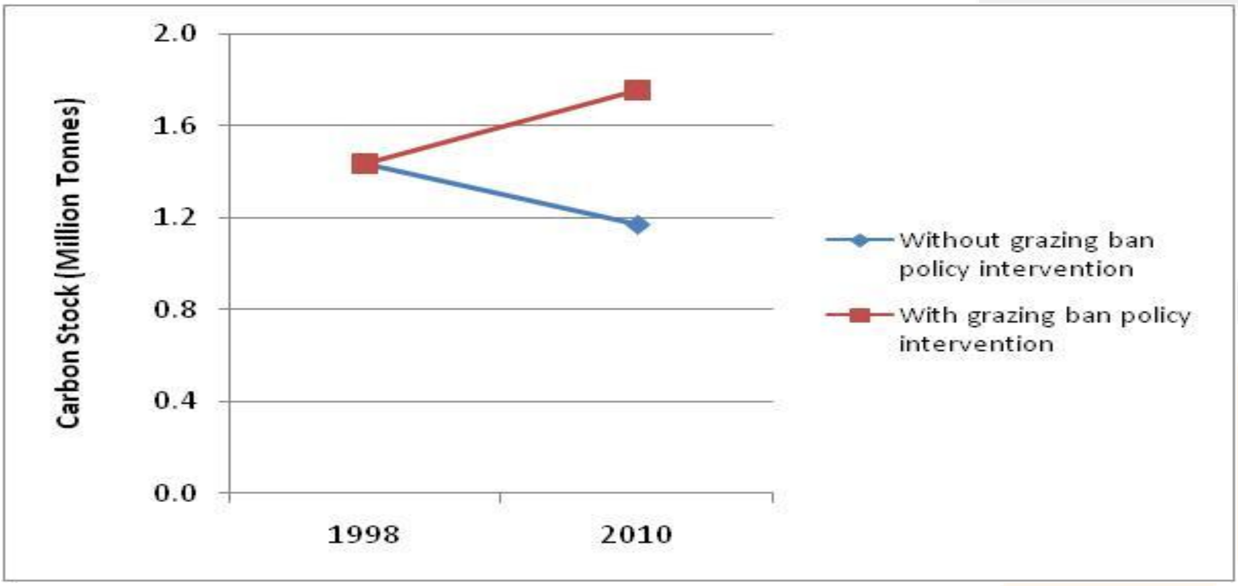

Figure 2: Comparison of scenarios - forest carbon stocks with and without grazing exclusion policy

This article reveals the impact of the grazing exclusion policy in terms of enhancement of the forest carbon stock on a relatively finer scale. Figure 2 presents a comparative account of the with and without policy intervention. It is observed that the difference between the with and without policy intervention scenarios amounts to about 585 thousand tonnes of carbon. This translates to 2142[8] thousand tonnes of carbon di-oxide equivalent. (Assuming an average price of the offsets in the forest carbon market scenario at \$4.6/tCO2e[9], it can be valued at Rs 45.33[10] crores.) This change indicates active role played by forests in enhancing carbon sink and sequestering carbon which would have been absent if grazing exclusion had not been implemented. This conservation promoting policy has improved carbon sequestration, considered as a low cost abatement option. Value of this carbon sequestrated is not limited to the geographic area of study site but rather is a contributor to global reduction in net carbon emissions. (Richards & Anderrson, 2001). Usually such studies are either designed at a broad regional scale based upon country or landscape level estimates or are micro-level site specific & data intensive studies, requiring time series data for longer time intervals. In either case data availability is a crucial factor. In the absence of the detailed longitudinal data, the case has been developed with limited information and scope. The estimates should be treated carefully and are indicative in nature. The intention behind developing this case using a available information was to highlight the significance of the impacts generated by the policy instrument and to showcase them by developing a case study.

Currently the working plan is being developed for the state of Sikkim for which intensive forest inventories are been conducted across all the districts. This data can be utilized along with the data from earlier forest inventories in the State (1988 or 1998) by Forest Survey of

[8] Based on the carbon dioxide to carbon ratio of 44 /12

[9] The average price for offsets across the primary forest carbon markets were \$3.8/tCO2e in 2008, \$4.5/tCO2e in 2009, and \$5.5/tCO2e in 2010 (Diaz, Hamilton, & Johnson, 2011)

[10] Conservative estimate taking 1\$ equivalent as Rs 46.

India to develop a picture of forest carbon stock change at the State level. Such an exercise will help in establishing the presenting a holistic picture of the policy measures and create a useful data repository for climate change related topics. Not only can such study contribute towards decision making on relevant policy issues, but by combining this data with socio-economic indicators, it is possible to establish program effectiveness and creating useful information for strengthening policy performance.

Sikkim with its effective implementation of conservation promoting policies has been able to reverse the trend of forest degradation. It has great potential in leading India's initiative on international conservation funding mechanisms. Efforts have to be made for creating linkages between its policy measures on conservation to the international mechanisms of climate funding by creating necessary frameworks This is great opportunity to utilize the State's internal institutional frameworks and prepare for playing a larger role by participating in global efforts of establishing market mechanisms to support initiatives on reducing forest loss and degradation.

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