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# Effects of Hilly Aspects on Carbon Stock of *Pinus roxburghii* Plantations in Kaleri, Salyan Salleri and Barahpakho Community Forests, Nepal

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## ABSTRACT

Hilly aspects are prominently affecting carbon stock but such research has not done yet in Nepal. Therefore, this study was objectively conducted to assess effect of aspects on carbon stock of *Pinus roxburghii* plantations. Three community forests (CFs) were selected for this study. Then, 11, 26 and 34 samples representing the four aspects were collected from Barahpakho, Salyan Salleri and Kaleri community forests respectively. Additional 183 soil samples were gathered from 0 to 0.1, 0.1 to 0.2 and 0.2 to 0.3 m depths. The diameter and height of plants were measured. Data were analyzed to calculate biomass carbon and soil samples were analyzed using Walkley and Black method. The result showed the carbon stock was 90.57±4.32 and 70.10±2.43 t $ha^{-1}$ in North and South aspects correspondingly in Salyan Saleri CF. Moreover, mean annual carbon increment (MACI) was the highest 3.95 t $ha^{-1}$ in North aspect of Salyan Saleri CF. The ANOVA and Kruskal Wallish tests showed, there was significant difference in MACI among four aspects at 5% level of significant.

Key words: annual, aspects, carbon, forest, increment, mean

## 1. BACKGROUND

There is intrinsic relationship between vegetation growth and landscape features (DIXON et al. 1994). Specifically, hilly terrain is characterized by the aspects which are playing a relevant role in vegetation growth (IPCC 2010; GRACE et al. 1995; HUDIBURG et al. 2011; RAM ASHESHWAR MANDAL et al. 2016; MANGALA DE ZOYSA & MAKOTO INOUE, 2017). The south aspect is generally dry and it possesses poor soil in comparison to other aspect (PETRESCU et al. 2012; ACHARD 2002; SCHIERMEIER 2008; KLANDERUD, BIRKS; 2003). Thus the forest carbon growth is affected. In fact, carbon change is the global concern (PAN et al. 2011) under the Reducing Emission from Deforestation and Forest Degradation (REDD+) mechanism which has been offering the reward for carbon credit.

The carbon credit and its precise monitoring are fundamentally interrelated components (TIMOTHY; PEARSON et al. 2007) under REDD+ mechanism. The higher the precision of carbon measurement the higher will be price of carbon credit. The consequence will be supplementary benefit to local community and government. Therefore, developing countries like India, Indonesia, Vietnam, Congo, Thailand and others are demonstrating carbon credit maintaining high precision (JONAH et al. 2015). Some of them are capable to approach the tier three because of practicing the very precise methodology of forest carbon estimation and rigorous statistics. They have well managed data set of forest carbon according to species, aspect, slope, soil type and landscape which are helpful instruments to develop reference emission level and design monitoring reporting and verification precisely. Therefore, it is remarkable issue whether there is enough statistics of carbon stock in Nepal. The direct answer is not sure, it is very limited

Nepal is showing impressive progress in REDD+ mechanism however the methodological approach is very poor. Nepal is committed to approach for tier two, but she has been lacking reliable data set and practice of precise carbon quantification. Typically, carbon dynamic is affected due to aspects (NEUPANE, SHARMA et al. 2014). Midhill is very suitable regions for *Pinus roxburghii* (JACKSON 1994; GURARNI et al. 2010). Therefore, this species have been massively planted in lower altitude between 500 to 1200 m. Carbon density of this species is national important but there are very few research works regarding this. Particularly, whether there is any effect of aspects on carbon stock and mean annual carbon increment are not assessed yet. Therefore, this research is important.

## 2. MATERIALS AND METHODS

### 2.1. Site selection

Three community forests specifically Barahpakho, Salyan Salleri CFs from Myagdi district and Kaleri CF from Sindhupalchowk district of Nepal were selected for this study because *Pinus roxburghii* is dominant species in these forests. Barahpakho CF is located in Athunge village development committee (VDC) - 1,2 while Salyan Saleri CF is situated at Babiyachaur VDC-6 and Kaleri CF lies at Sanosirubari VDC -6,7,8. Moreover, the areas of Barahpakho, Salyan Saleri and Kaleri CFs were 16.16, 49.25 and 97.44 ha respectively.

Myagdi and Sindhupalchowk districts are geographically located in hilly areas so their general climates and vegetation types are also similar. In fact, Myagdi district is located at 28º 20' to 28º 47' N and 83º 08' to 83º 53' E and altitude ranges from 792 to 8167 m. The temperature record showed between 3 to 36 ºC while estimated annual rainfall was about 407 to 2960 mm. Forest is the dominant land cover occupying 36.8% of the total area of the district. Altogether, there are 288 community forests in this district including Barahpakho and Salyan Saleri CFs where *Pinus roxburghii* was planted in 1984 and 1985 respectively (DDC, 2015). Sindhupalchowk district lies between $27.27^0$ to $28.13^0$ N and $85.06^0$ to $86.06^0$ E while the elevation ranges from 747 to 7085 m.

Moreover, average annual rainfall is about 2,500 mm and temperatures vary from 7.5 ºC to 32 ºC. The total forest covers 30.51 % of total area of the district. Mainly *Pinus roxburghii, Pinus wallichiana, Alnus nepalensis, Schima wallichii, Castonopsis indica, Quercus spp and Rhododnedron arborium* are common vegetation species in this district (DDC, 2016). In total there are 509 community forests in this district including Kaleri CF just near to Chautara municipality, district headquarter. The plantation of *Pinus roxburghii* was done in 2001 in this CF.

### 2.2. Experimental design and sampling

The experimental design and sampling are the soul of any study. The maps of the forests were prepared using coordinates of Geographical Positioning System. Simple random sampling was done setting the complete random design. Altogether 61 biophysical and additional 183 soil samples were collected for this study. Particularly eleven, twenty six, and thirty four samples were collected from Barahpakho, Salyan Saleri and Kaleri community forests respectively. The samples were randomly distributed on the map and their coordinates were uploaded in the GPS receiver. Next, the coordinates were navigated to establish the sample plot in the field. The nested plots having 20 × 25, 10 × 10, 5 × 5 and 2 × 5 $m^2$ were laid down for the sampling tree, pole, sapling and seedling respectively.

### 2.3. Data collection

Both primary and secondary data were needed to conduct this study. So, the primary data were collected from direct measurements and samples collection. Especially, measurement of diameter and height of tree, pole and sapling were recorded of each sample plot. In addition, samples of sapling and seedling were collected and packed. Besides, soil samples were collected from three depths particularly of 0-0.1, 0.1 to 0.2 and 0.2 to 0.3 m. Meanwhile, the secondary data like records of plantation and detail information of community forests were collected from district forest office and community forest users.

### 2.4. Data Analysis

The biomass is the main base to calculate the forest carbon and hence, biomass was estimated using the following formula and then carbon stock was estimated simultaneously.

*Above ground carbon estimation*: The above ground biomass of plants having DBH>5cm was quantified using allometric equation developed by CHAVE et al. (2005).

AGTB= $0.0509 \times \rho D^2 H$; Whereas, AGTB = above ground tree biomass (Kg);

$\rho$ = dry wood density ($gm/cm^3$); D = tree diameter at breast height (cm) and H = total height (m) of plant

On the other hand, the biomass of plants with DBH<5cm was calculated differently because of use limitation of above equation. So, firstly, the volume of main stem was calculated using following equation then that value was converted into biomass multiplying with wood density. Besides, biomass of branch and leaves were calculated using multiplying factor individually 44% and 11% of stem biomass correspondingly (SHARMA, PUKKALA 1990).

Stem volume= $\pi D^2 \times h \times ff/4$

Biomass = Volume × dry wood density ($gm/cm^3$) where 0.327 $gm/cm^3$ was used for *Pinus roxburghii*. Where, D is diameter, h is height of the plants and ff is form factor, it is 0.5 (DOF, 2004).

Moreover, the biomass of litter, herbs and grass was calculated by:

$$\mathrm{LHG} = \frac{w_{\mathrm{field}}}{A} \cdot \frac{w_{\mathrm{subsample,dry}}}{w_{\mathrm{subsample,wet}}} \times \frac{1}{10000}$$

Where, LHG = biomass of leaf litter, herbs and grass in t $ha^{-1}$
$W_{field}$ = weight of the fresh sample of leaf litter herbs, and grass were destructively sampled within an area in gm
A = area in which leaf litter, herbs and grass were collected in ha
W (dry subsample) = weight of the oven dry sub sample of leaf litter, herbs, and grass were taken to the lab to determine moisture content in gm
W (wet subsample) = weight of the fresh sub sample of leaf litter, herbs, and grass were taken to the lab to determine moisture content in gm (PALADINI et al. 2009).

Estimated biomass was converted into carbon multiplying by 0.47 (MACDICKEN 1997).

*Belowground biomass carbon stock (BC)* **:** The below ground biomass carbon was estimated assuming 15 % of above ground biomass carbon (MACDICKEN 1997; MOKANY et al. 2006).

## 2.5. Soil organic carbon

The soil organic carbon was calculated using the following method (PEARSON et al. 2007).

SOC = ρ ×d × % C
Where, SOC = soil organic carbon stock per unit area (t $ha^{-1}$); p = soil bulk density (gm $cm^{-3}$);
d = total depth at which the sample was taken (cm) and % C = carbon concentration
Moreover,
Soil bulk density (gm $cm^{-3}$) = (oven dry weight of soil) / (volume of soil in corer)
Organic matter in soil samples was determined by Walkley and Black method in the lab (WALKLEY, BLACK 1958).

## 2.6. Total Carbon stock

C (T) = C (AGTB) + C (AGPB) + C (AGSB) + C (BB) + C(S) + C (LHG) + SOC

Where,
C (ABTB) = carbon in above ground tree biomass (t C/ha)
C (ABPB) = carbon in above ground tree biomass (t C/ha)
C (AGSB) = carbon in above ground sapling biomass (t C/ha)
C (BB) = carbon in below ground biomass (t C/ha)
C (LHG) = carbon in litter, herb and grass (t C/ha)
C(S) = carbon in seedling (t C/ha)
SOC = soil organic carbon (t C/ha)

# 3. RESULTS

## 3.1. Carbon stock in different aspects in Kaleri community forest

The total carbon stock in *Pinus roxburghii* was varied in different aspects. Specifically, the maximum and minimum above ground carbon stock were in Kaleri community forest was 16.72 t $ha^{-1}$ with the highest 53.58 ±3.21 t $ha^{-1}$ in North aspect and the lowest 36.86 ±2.1 t $ha^{-1}$ in West aspect. This difference was about 20.47 t $ha^{-1}$ in Salyan Saleri community forest because the highest quantity was 90.57±4.32 t $ha^{-1}$ and that was the lowest about 70.10±2.43 t $ha^{-1}$. In case of Barahpakho CF, the difference was only 8.50 t $ha^{-1}$ (Table 1). Similar type of variation was estimated in case of below ground carbon stock in different aspects of the community forests. The main reason can be due to variation in soil nutrients.

**Table 1** Total carbon stock according to aspects in community forests

| Community forests | Above ground carbon t $ha^{-1}$ | | | | Below ground carbon (root only) t $ha^{-1}$ | | | |
|---|---|---|---|---|---|---|---|---|
| | N | S | W | E | N | S | W | E |
| Kaleri CF | 55.33 | 38.72 | 36.86 | 53.58 | 6.92 | 4.84 | 4.61 | 6.7 |
| Salyan Saleri CF | 90.57 | 70.10 | 72.60 | 81.11 | 11.32 | 8.76 | 9.07 | 10.14 |
| Barahpakho CF | 85.11 | 82.60 | 76.61 | 80.67 | 10.64 | 10.32 | 9.57 | 10.08 |

### 3.2. Soil carbon stock at different soil layers in different aspects

The soil organic carbon stock was decreased with increase depth. The soil organic carbon was maximum 36.33 t $ha^{-1}$ at 0 -10 cm depth in soil and minimum 9.32 t $ha^{-1}$ in North aspect at 20-30 cm depth in soil Barahpakho community forest (fig. 1). Same trend was found in other community forests as well. The remarkable fact was, the soil carbon was also highest in North aspect in comparison to other aspects in all community forests. The high carbon in upper layer is due to high microbial activities and high decomposition of litter in comparison to other layers.

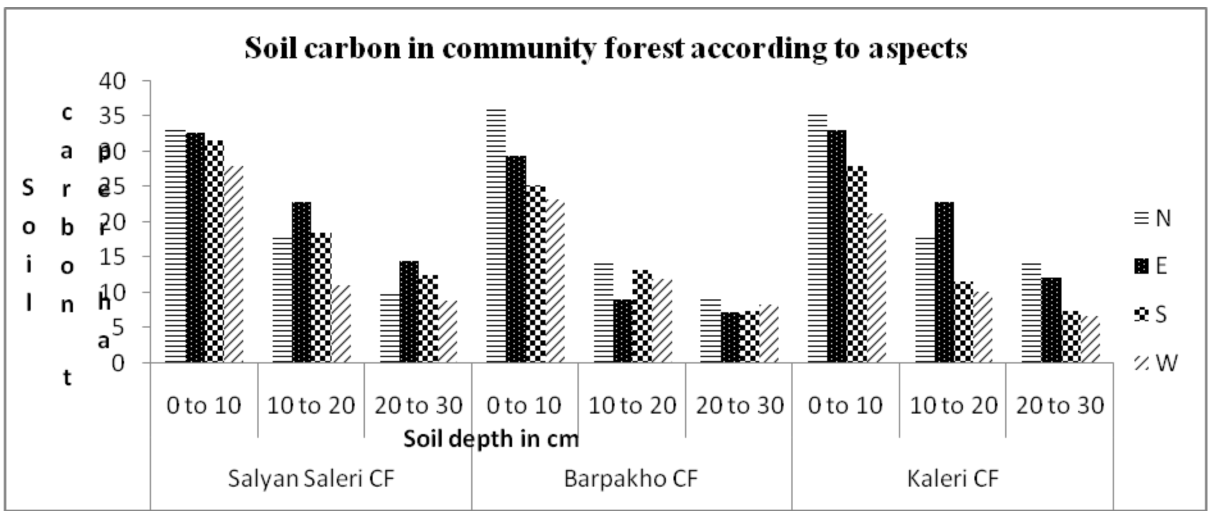


**Figure 1** Soil carbon in different community forests

### 3.3. Mean annual carbon increment

The mean annual carbon increment was the highest in North aspect in all community forests and they varied in other aspects (Table 2). The records of increment were 3.95, 2.70 and 2.62 t $ha^{-1}$ in Kaleri , Salyan Saleri and Barahpakho CFs respectively. The reason of low carbon growth in Barahpakho CF was dominance of over mature tree while it was just opposite like high carbon increment in Kaleri community forest due to presence of young plants. Principally there is high growth at young aged plants than other staged plant.

**Table 2** Aspect wise mean annual carbon increment

| **Community forests** | **Mean annual carbon increment (t $ha^{-1}$)** | | | |
|---|---|---|---|---|
| | N | S | W | E |
| Kaleri CF | 3.95 | 2.77 | 2.63 | 3.83 |
| Salyan Saleri CF | 2.70 | 2.09 | 2.17 | 2.42 |



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| | | | | |
|---|---|---|---|---|
| Barahpakho CF | 2.62 | 2.36 | 2.54 | 2.48 |

### 3.4. Statistical comparison of MACI in different aspects

The mean annual carbon increment was significantly differed according to the aspects (Table 3). For this, the data were evaluated using Shapiro-Wilk test to check the normality of data set of mean annual carbon increment (MACI) of CFs. This statistical test showed that data set were normal in Kaleri and Salyan Saleri CFs therefore one way ANOVA was applied to compare the MACI among the aspects which showed there was significant differences at 5% level of significance in Kaleri CF while it was not significant in Salyan Saleri CFs.

**Table 3** Shapiro-Wilk test for normality in MACI according to aspects

| **Kalleri CF** | | Salyan Saleri CF | Barahpakho CF |
|---|---|---|---|
| Aspects | P- value | P- value | P- value |
| N | 0.084 | 0.409 | 0.015 |
| S | 0.067 | 0.569 | 0.014 |
| W | 0.372 | 0.280 | 0.518 |
| E | 0.131 | 0.263 | 0.006 |
| Decision for test | Parametric test ANOVA | Parametric test ANOVA | Non parametric test Kruskal Walis |

Further Tukey's test also showed significant differences in MACI of N and S but there was no significant differences in MACI of W and E aspects.

On the other hand, the plot wise MACI was not normal in Barahpakho CF so the Kruskal Walis test was used which showed there was significant difference in MACI of N and S aspects at 5% level of significant but it was not significant in other two aspects (Table 4). In addition, Mann-Whitney U test also showed there was significant difference mean annual carbon increment between N and S aspects.

**Table 4** Statistical comparison of mean annual carbon increment in community forests

| Community Forests | Statistical tests | P- Value | Further Statistical tests | P- Value |
|---|---|---|---|---|
| Kalleri | Parametric test ANOVA | 0.000 | Tukey | 0.001 between N and S aspects but 0.065 between E and W aspects |
| Salyan Saleri | | 0.268 | NA | |
| Barahpakho | Kruskal Wallis | 0.010 | Mann–Whitney U test | 0.000 between N and S aspects but 0.175 between E and W aspects |

## 4. DISCUSSION

### 4.1. Variation in total carbon stock according to aspects in community forest

The carbon stock was varied in different aspects (STEPHENS et al. 2007). It was highest in north aspect and lowest in South aspect in the community forest. The reason behind it is generally the south aspect is dry and less fertile than the north aspect (JACKSON 1994; LUA et al. 2010). The study done by NEUPANE, SHARMA (2014) showed above ground carbon was 50.40 t $ha^{-1}$ in Laxmi Mahila CF, this value was nearly equal to the value of carbon stock of East aspect of Kaleri CF, this may be due to the similar species, topographical region, same staged plants and density. Another study done by SHEKH, KUMAR (2010) demonstrated that carbon stock of *Pinus roxburghii* in northern aspect was nearly 62.49 t $ha^{-1}$, this value was less than the value of North aspect of Kaleri CF.

The forest resource assessment (DFRS 2015) of Midhill showed the above ground carbon in *Pinus roxburghii* was 87.99 t ha$^{-1}$, this value was the lower than the carbon of Northern aspect of Salyan Saleri CF and higher than the carbon of Barahpakho CF. The below ground carbon stock (root carbon) was estimated using the default value so the variation was similar like above ground carbon stock.

### 4.2. Soil organic carbon

The soil carbon was the highest in Barahpakho community forest at 0-10 cm and lowest at 20 to 30 cm. This trend was found in all aspects in all community forests. The reason behind it is the soil organic carbon is more at top layer of soil because of the high decomposition of leaf litter which accumulated at the top layer (GRIGAL, 1992). Top soil shows higher $CO_2$ flux than subsoil as it is the zone of maximum root and soil flora and fauna activities (LAMANDER et al. 1998). Another important fact is, the soil carbon was also high in Northern aspect, the reason behind this is Northern aspect is more moist and fertile than others (INGER et al. 2015) The study done by PANT, BARGALI (2009) showed that, the soil organic carbon at Khurpatal site varied between 62.62 to 79.07 t ha$^{-1}$ upto 40 cm, the minimum value was similar to the value of soil carbon in Northern aspect of Salyan Saleri CF but the maximum value was higher. Forest resource assessment done by DFRS (2015) showed that the average soil organic carbon was 54.33 ±1.29 t ha$^{-1}$ which was lower than total soil carbon of the Northern aspects but higher than that of Western aspect. Moreover, study conducted by CHHETRI (2007) showed the soil carbon was higher in the Northern aspect (71.2 t ha$^{-1}$) than the soil carbon of Southern aspect (61 t ha$^{-1}$), the first value was higher but the next value was quite similar to the soil carbon of Northern aspect of Salyan Saleri CF.

The present study is contrary to the following study conducted in different community forests of Nepal. According to the study conducted by SHARMA et al. (2011) in Shree Salumbudevi community forest of Pukhulachhi VDC, Kathmandu, maximum amount of carbon was estimated for forest (51.24 t ha$^{-1}$) and forest soil ranked second largest carbon pool (46.2 t ha$^{-1}$) in studied community forest. According to SHRESTHA (2010) the maximum carbon pools were stored in above ground live tree (138±6 t ha$^{-1}$) followed by soil organic carbon (90±2 t ha$^{-1}$) in community managed forest of Nawalparasi district.

### 4.3. Mean Annual carbon increment

The mean annual carbon increment depends up on the age of the plant, soil nutrients availability, aspects and climate. Net annual biomass accumulation was about 17.2 t ha$^{-1}$ in *Pinus roxburghii* forest which was estimated 8.04 t ha$^{-1}$ (RANA et al. 1988). The estimated value was higher than mean annual carbon increment of this research. The mean annual carbon increment was the highest in Northern aspect and lowest in Southern aspect. The carbon increment based on the forest inventory guideline may be 3% if the forest is medium stocked which would be 2 to 3 t ha$^{-1}$ in case of medium growing species (DOF, 2004) and *Pinus roxburghii* is medium growing species.

## 5. CONCLUSION AND RECOMMENDATION

Both above and below ground carbon stock were the highest in North aspect in *Pinus roxburghii* while it was generally the lowest in west aspect. The soil carbon differed according to aspects and it indicated the highest record in North aspect. Obviously, the carbon growth was the highest in North aspects.

Further research is needed to find the carbon status and growth according to different forest types, species, climatic zones, different aspects, and soil types.

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