Soil carbon, nitrogen and texture dynamics at root zone and between plants in Riverine plantation of *Acacia catechu*, *Dalbergia sissoo*, *Phyllanthus emblica* and *Eucalyptus camaldulensis*

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Abstract
This research was objectively carried out to assess the dynamic of carbon, nitrogen and texture at root zone and location between plants. The plantation of *Acacia catechu*, *Dalbergia sissoo*, *Phyllanthus emblica* and *Eucalyptus camaldulensis* of Pragati community forest, Mahottari district, Nepal was selected for this study which was done in 2011. The stratified random sampling was applied to collect soil samples. Altogether 320 soil samples were collected from 0-10, 10-30, 30-60 and 60-90 cm depths. The result showed that soil carbon was about 8.16 t ha⁻¹ at root zone which was only 7.56 t ha⁻¹ at location between plants at 0-10 cm depth in *Phyllanthus emblica* stratum. The soil carbon was the least nearly 2.08 t ha⁻¹ at root zone which was 1.59 t ha⁻¹ at location between plants in *Eucalyptus camaldulensis* stratum. The carbon percentage was the highest about 1.35% at root zone of *Phyllanthus emblica* stratum. However, the C/N ratio was the highest about 69:1 at location between plants of *Dalbergia sissoo* stratum. The texture of soil was loamy sand at root zone in *Phyllanthus emblica*, *Acacia catechu* and *Dalbergia sissoo* plantations while it was sandy at both root zone and between plants of *Eucalyptus* plantation. Plantations have significant effect on soil carbon and nitrogen at 95% confidence level.

Keywords: Root zone, plants carbon, nitrogen, soil texture.

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Introduction

The plant is the most capable living component to conserve and restore the soil, reduce the erosion and retain the fertility (Durán Zuazo and Rodríguez Pleguezuelo, 2008; Stokes et al., 2009). The canopy and crown of plants slow down the speed of the rainfall to reach the land surface (Holder and Gibbes, 2017). Plants like grass, ground covers, shrubs, and trees can help to stabilize river embankments through root system to hold the soil minerals (Preti and Giadrossich, 2009). The vegetations absorb rain water to reduce the surface runoff rate. In addition, the plants importantly stop to wash out the soil particles (Doran and Zeiss, 2000; Karlen et al., 2001). So, the plantations play a vital role to reduce hazards due to flood, land slide and bank cutting due to river (De Baets et al., 2007; Karoshi and Nadagoudar, 2012). Meanwhile plants play a key role to sequestrate the carbon and maintain soil fertility enhancing Nitrogen. Especially the natural hazardous is severe at exposed land area in comparison to vegetated land. Therefore, plantation especially at the bank of the river and surrounding has great importance to conserve the soil.

Globally, climate change is serious issue and one of the extreme effects is river flood (van den Honert and McAneney, 2011; Kundzewicz et al., 2013). The evidences are the severe flood in 2000 in Mozambique that
killed thousands of citizens (Aderogba et al., 2012). One of the most devastating floods occurred in southern Alberta, Canada in 2004 (Buttle et al., 2016) which damaged many health and wealth. The heavy torrential rains caused floods in Kyushu, Japan, killed 32 people (Takezawa et al., 2014). The Cyclone Ita flood killed 21 people in Solomon Islands (Davidson, 2014). The heavy rainfall in Visakhapatnam, India in 2014 destroyed many things and made thousands more homeless (Ramuje and Rao, 2014). The mass slide killed two dozen citizens in Sindupalchok, Nepal in 2014 (MoI, 2014; MoHA, 2015). The best option is restoration of soil through plantation and river training to protect the land and lives (Aston, 1979) on the earth.

The plantation of Acacia catechu, Dalbergia sissoo, Eucalyptus camaldulensis and Phyllanthus emblica was carried out targeting to control the soil erosion and minimize the effects of flood at Pragati community forest, Mahottary district Nepal. On the other hand, the plantation has high positive effect on soil carbon (C), nitrogen (N) and texture formation (Hofstede et al., 2002; Kooch and Zoghi, 2015; Li et al., 2017) but the research regarding the contribution of plantation was not done yet. Moreover, it is more interesting fact that the soil carbon, nitrogen and texture are so sensitive to the vegetation that these were differed even at “root zone” and “location between the plants (about 1-1.25m away from root zone)” as well. Therefore, this study was objectively carried to assess the soil carbon, nitrogen and texture dynamics at root zone and location between plants of riverine plantation of Acacia catechu, Dalbergia sissoo, Phyllanthus emblica and Eucalyptus camaldulensis.

Material and Methods

Pragati community forest of Mahottary district, Nepal was selected for this study because the community forest was established at bank of the Ratu river where plantation of four species specifically Acacia catechu, Dalbergia sissoo, Phyllanthus emblica and Eucalyptus camaldulensis were done in 2011. The plantation is about five years old. The purpose of the plantation was to control soil erosion and bank cutting caused by Ratu river. Geographically, Mahottary district is located at 26° 36' to 28° 10' N and 85° 41' to 85° 57' E (Figure 1). The temperature of this district ranges between 20-45 °C and average annual rainfall has been recorded between 1100-3500 mm.

Experimental design and sampling method

The whole plantation area was considered as one block. The block was categorized into four strata according to species. Hence stratified random sampling was applied setting randomized block design (Kothari, 2004). The map of whole plantation area was prepared and stratified. Altogether 320 points for soil samples were marked on the map in such way that 160 points laid close to the root of the plant called “root zone” and same number of points were laid at the midpoint of two plants named as “location between plants”. The spacing was maintained 2-2.5m between plants. In fact, 20 samples were collected from each species strata specifically 10 samples from root zone and same number of samples from location between plants (Winner, 2009).

Soil Analyses

Collected soil samples were analyzed in the lab. Soil carbon, nitrogen, and C/N were analyzed. The soil texture (sand, silt and clay) was estimated using feel analysis (Thien, 1979). Field-moist samples from both sampling batches were gently and manually crumbled and sieved (<8 mm) in order to remove the root material. Each sample was thoroughly mixed and stored at field humidity in polyethylene bags until
analyses. Soil analyses were conducted on air-dried samples from which crop residues, root fragments and rock larger than 2 mm had been removed and stored at room temperature. Some soil analyses were determined by the following methods: soil texture by the Bouyoucos hydrometer method (Anderson and Ingram, 1993), total Nitrogen by digestion and subsequent measurement conducted by the Kjeldahl method (Kjeldahl, 1883). All soil samples were sieved through a 150 μm mesh to determine the total organic carbon content by the wet oxidation method (Walkley-Black) with K₂Cr₂O₇ (Walkley and Black, 1958). C/N ratio in soils were calculated as total organic carbon / total nitrogen.

### Statistical Analysis

The descriptive analysis was carried out to find the mean, standard deviation and standard error of the soil carbon of different stratum. At the same time, distributions of data were examined using Kolmogorov-Smirnov and Shapiro-Wilk tests to evaluate the normality of the data. Next, the t-test was applied to compare the carbon in total and at different depth at the location root zone and between the plants (Kothari, 2004).

### Results and Discussion

#### Soil carbon dynamics at root zone and between plants

The soil carbon was differed at root zone and location between plants according to species. In case of *Phyllanthus emblica*, this was more about 8.16 t ha⁻¹ at root zone which was 7.56 t ha⁻¹ at location between plants at 0-10cm depth. This was decreased according to increasing soil depths. In addition, soil carbon was the least nearly 2.08 t ha⁻¹ at the root zone which was 1.59 t ha⁻¹ at location between plants in *Eucalyptus camaldulensis* stratum. This indicates that the capacity of soil carbon formation was the highest of *Phyllanthus emblica* while it was the least of *Eucalyptus camaldulensis*. The reason behind this was leaf decomposition of leaf litter of *Phyllanthus emblica* was faster than the leaves of *Eucalyptus camaldulensis*. At the same time values of soil carbon were also high about 7.85 and 5.83 t ha⁻¹ at root zone of *Acacia catechu* and *Dalbergia sissoo*. The study importantly showed that *Phyllanthus emblica*, *Acacia catechu* and *Dalbergia sissoo* are favorable species for soil formation in comparison to *Eucalyptus camaldulensis*. Moreover, there were significant differences in soil carbon between the location root zone and between plants at 95% confidence interval at different soil depth. This showed that the soil carbon formation in riverine areas was higher at the root zone than other place, since the microbial activities are high in soil near the root (Table 1).

| Species                  | Details             | Soil carbon t ha⁻¹ according to soil depth |
|-------------------------|---------------------|------------------------------------------|
|                         | 0-10 cm | 10-30 cm | 30-60 cm | 60-90 cm |
| *Phyllanthus emblica*   | Root zone | 8.16     | 6.84     | 4.93     | 3.69     |
|                         | Between Plant | 7.56     | 6.43     | 3.28     | 3.02     |
|                         | Difference/p-value (t-test) | 0.50/0.01 | 0.41/0.02 | 1.65/0.00 | 0.67/0.01 |
| *Acacia catechu*        | Root zone | 7.85     | 6.35     | 3.04     | 3.02     |
|                         | Between Plant | 3.69     | 3.02     | 2.9      | 2.64     |
|                         | Difference/p-value (t-test) | 4.16/0.00 | 3.33/0.00 | 0.14/0.00 | 0.38/0.00 |
| *Dalbergia sissoo*      | Root zone | 5.83     | 4.58     | 4.29     | 1.89     |
|                         | Between Plant | 2.64     | 1.84     | 1.84     | 1.78     |
|                         | Difference/p-value (t-test) | 3.19/0.01 | 2.74/0.00 | 2.45/0.00 | 0.11/0.40 |
| *Eucalyptus camaldulensis* | Root zone | 2.08     | 1.62     | 1.22     | 0.72     |
|                         | Between Plant | 1.59     | 1.12     | 0.74     | 0.25     |
|                         | Difference/p-value (t-test) | 0.49/0.00 | 0.5/0.01 | 0.48/0.00 | 0.47/0.00 |

The mean carbon of soil was the highest nearly 23.62 t ha⁻¹ at root zone of *Phyllanthus emblica* stratum while this was the lowest 3.7 t ha⁻¹ at location between plants of *Eucalyptus camaldulensis*. There were significant differences in soil carbon at the root zone and location between plants in different plantation strata at 95% confidence level. The maximum and minimum records of soil carbon were 25.86 and 22.21 t ha⁻¹ respectively at the root zone of *Phyllanthus emblica* stratum (Table 2). The soil carbon in *Eucalyptus camaldulensis* stand was about 9.2 t ha⁻¹ in Southern China (Du et al., 2015) which value was about to similar with this study.

#### Carbon and nitrogen ratio at root zone and between plants

The carbon percentage was the highest about 1.35% at the root zone of *Phyllanthus emblica* stratum but this was the least only 0.47% at location between plants in *Eucalyptus camaldulensis* stratum. However, the C/N ratio was the highest about 69:1 at location between plants of *Dalbergia sissoo* stratum.
The soil fertility is improving high at root zone of *Acacia catechu* stratum since the C/N ratio was found to be the lowest here while it was the lowest rate of soil improving at location between plants of *Eucalyptus camaldulensis* stratum because C/N ratio was nearly 61.00:1 (Table 3). High C/N ratio can slow down the decomposition rate of organic matter and nitrogen depends up on the C/N ratio (Swangjang, 2015). The higher the soil C/N ratio the lower the decomposition process of organic matter and nitrogen because it can limit the ability of soil microbial activity (Wu et al., 2001). The C/N ratio ranges 0.2:1 to 27.4:1 in plantation area in Northeastern United States Watersheds (Ross et al., 2011) and the highest ratio of this research was about similar to the C/N ratio of at the location between plants in *Acacia catechu* stratum. Soil materials are affected due to C/N ratio (Swangjang, 2015). The soil having very less N % is considered as the very low fertile soil (Dawud et al., 2017).

Table 3. C/N ratio in soil

| Species            | Zone            | Mean C t ha⁻¹ | C difference t ha⁻¹ | p-value (t-test) | Min. | Max. | Standard deviation | Standard error | Soil Fertility Improvement |
|--------------------|-----------------|---------------|---------------------|-----------------|------|------|-------------------|-----------------|-----------------------------|
| *Phyllanthus emblica* | Root zone       | 2.36          | 3.33                | 0.01            | 22.21| 25.86| 1.03              | 1.06            | High                        |
|                    | Between Plants  | 20.29         | 0.01                | 18.92           | 21.60| 0.94 | 0.88              |                 | High                        |
| *Acacia catechu*   | Root zone       | 20.26         | 8.01                | 0.00            | 20.26| 20.51| 0.08              | 0.03            | Low                         |
|                    | Between Plants  | 12.25         | 0.00                | 11.22           | 13.32| 0.66 | 0.43              |                 | Low                         |
| *Dalbergia sissoo* | Root zone       | 16.59         | 8.49                | 0.00            | 14.26| 19.71| 1.99              | 0.63            | Low                         |
|                    | Between Plants  | 8.10          | 0.00                | 5.90            | 10.77| 1.25 | 0.39              |                 | Low                         |
| *Eucalyptus camaldulensis* | Root zone     | 5.64          | 1.94                | 0.00            | 3.34 | 4.11 | 0.08              | 0.25            | Low                         |
|                    | Between Plants  | 3.70          | 0.00                | 4.64            | 7.69 | 0.25 | 0.80              |                 | Low                         |
|                     |                 |               |                     |                 |      |      |                   |                 |                             |

Soil texture dynamics at root zone and location between plants

The soil texture consists of proportion of sand, clay and silt. These were differed at root zone and location between plants. The texture of soil was loamy sand at root zone in *Phyllanthus emblica, Acacia catechu* and *Dalbergia sissoo* plantations while it was sandy at both root zone and between plants in *Eucalyptus camaldulensis*. The finding showed that the *Eucalyptus camaldulensis* has very poor capacity to form the soil in riverine site (Table 4). The percentage of sand, silt and clay was significantly differed at root zone and between plants at 95% level of confidence. The soil texture at the bank of the river and ocean is dominated by sandy soil (Matsui et al., 2015).

Table 4. Soil Texture Dynamics at Root zone and Location between plants in different stratum

| Species                      | Sites            | Sand % | Clay % | Silt % | Texture   |
|------------------------------|------------------|--------|--------|--------|-----------|
| *Phyllanthus emblica*        | Root zone        | 82.50  | 5.50   | 12.00  | Loamy sand|
|                              | Between Plants   | 89.00  | 4.25   | 6.75   | Loamy sand|
|                              | Difference/p-value | 6.50/0.00 | 1.25/0.00 | 5.25/0.00 | Sandy   |
| *Acacia catechu*             | Root zone        | 89.00  | 4.25   | 6.75   | Loamy sand|
|                              | Between Plants   | 96.50  | 2.25   | 1.25   | Sandy     |
|                              | Difference/p-value | 7.50/0.00 | 2.00/0.00 | 5.50/0.00 | Sandy   |
| *Dalbergia sissoo*           | Root zone        | 89.80  | 3.5    | 6.70   | Loamy sand|
|                              | Between Plants   | 95.25  | 3      | 1.75   | Sandy     |
|                              | Difference/p-value | 5.45/0.00 | 0.50/0.00 | 4.95/0.00 | Sandy   |
| *Eucalyptus camaldulensis*   | Root zone        | 93.50  | 4.00   | 2.50   | Sandy     |
|                              | Between Plants   | 95.50  | 3.50   | 1.00   | Sandy     |
|                              | Difference/p-value | 2.00/0.00 | 1.00/0.00 | 1.50/0.03 | Sandy   |
Conclusion
The carbon and nitrogen were significantly varied at root zone and location between plants according to soil depths and species. The carbon and nitrogen were higher at root zone in comparison to between plants. The soil texture was recorded sandy loam in Phyllanthus emblica, Acacia catechu and Dalbergia sissoo strata but it was sandy in Eucalyptus camaldulensis stratum. The C/N ratio was higher at location between plants than root zone. Mean soil carbon was the highest at root zone of Phyllanthus emblica but this was the lowest at the location between plants of Eucalyptus camaldulensis stratum. The research can be applied to choose the appropriate species for plantation in river reclaimed area. Further studies are essential to examine soil carbon formation in different sites according to the plants species.

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