

Analysis of carbon stock and radial growth of trees through tree ring analysis in pine forest of linga guthi in Bhaktapur, Nepal

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ABSTRACT

Forests are the integral to the global carbon cycle. These ecosystems sequester carbon in the plant biomass and in the soil. The study was carried out in Linga Guthi Community Forest of Bhaktapur to estimate carbon Stock and radial growth of *Pinus roxburghii* through tree ring analysis. A total of 32 circular plots of 250 m² area were laid down randomly. Subplots were made for study of saplings, Litter, herbs and soil. For tree ring analysis, tree core samples were collected from different blocks of forest. Ring widths were measured using TSAP-Win Software attached to a LINTAB measuring system. For tree ring analysis, COFECHA and ARSTAN program were used. The average carbon stock of Linga Guthi Community Forest was 272.22±17.36 t/ha. Similarly, it has storage of 206.87± 4.47 t/ha AGTC, 41.37±2.19 t/ha BGTC, 23.814±1.00 t/ha SOC. The carbon sequestration rate of the forest was 2.22 Ct/ha/year. The average radial growth of pine trees in the forest was found to be 2.06 ± 0.13 mm/year. The maximum radial growth was 4.47 mm/yr. The oldest tree recorded in this forest was 158 years with 58 cm diameter. However the average age of the forest was 98 years. The ring width chronology of 158 years was prepared for pine tree extending from 1854 to 2013 A.D.

Keywords: carbon sequestration, dendrochronology, growth rate, ring width

INTRODUCTION

Globally, forests act as a natural storage for carbon, contributing approximately 80% of terrestrial above-ground, and 40% of terrestrial below-ground biomass carbon storage (Krischbaum, 1996). They play a critical role in reducing ambient CO₂ levels, by sequestering atmospheric carbon into the growth of woody biomass through the process of photosynthesis and also by increasing the soil organic carbon (SOC) content (Brown & Pearce, 1994). Carbon sequestration from atmosphere can be advantageous from both environmental and socioeconomic perspectives.

Forest ecosystems play a crucial role in regional and global terrestrial carbon (C) cycles because they store large quantities of C in vegetation, detritus, and soil, and exchange large amounts of C with the atmosphere through photosynthesis and respiration (Dixon *et al.*, 1994). The major carbon pools to be measured in forest carbon estimation are plant biomass (Above and below ground), above ground sapling biomass (AGSB), soil organic carbon (SOC), and litter, herbs, and grass (LHG) (IPCC, 2006). As the tree biomass experience growth, the carbon held by the plant also increases the carbon stock (Jana *et al.*, 2009). The rate of carbon storage increases

in young stands, but then declines as the stand ages (Jana *et al.*, 2009). Tree ring records can go back hundreds to thousands of years, depending on when the tree lived and how old it was and also helps to know past climate condition (Fritts, 1976). The tree ring produced in any year can be influenced directly by the climate of the year of formation, and indirectly by the climate of prior years. Dendrochronology gives baseline information about the forest structure, total Carbon Stock, sequestration rate and its Radial Growth in forest (Fritts, 1976).

To mitigate climate change and control of global warming, community-based forest management has an significant role to play in sequestering carbon, reversing processes of deforestation, and promoting rural development (Klooster & Masera, 2000). The role of community forest is well known in sequestration of carbon, and more information is needed about functioning as source and sink of GHGs.

In Nepal, most studies has been conducted in forest for their tangible economic benefits where as very few studies have been done on intangible benefits like carbon sequestration (Shrestha & Singh, 2008). Forests exchange large amounts of CO₂ with the atmosphere and are able to sequester large amounts of CO₂ into biomass (Moroni, 2012).The role of community forest is well known in sequestration of carbon, and more information is needed about functioning as source and sink of GHGs. Through the tree ring analysis, the annual growth of the community forest and age of the tree can be estimated. Tree rings have been widely used in dating the past environmental events such as climate (Cook & Kairiukstis, 1990; Fritts, 1976), fire, forest structure and dynamics, landslide, earthquake also.

MATERIALS AND METHODS

The study was carried out in Linga Guthi Community Forest (LGCF) of Bhaktapur, at Chittapol VDC. The forest constitutes a natural chir pine (*Pinus roxburghii*) forest along with few patches of other species.

Stratified random sampling was done in the forest area for estimation of forest carbon. 32 Circular plots of 250 m² area were sampled in the forest. The circular plot of 8,92 m was established to measured Above ground tree biomass (AGTB). For estimating the tree biomass, equation developed by (Chave *et al.*, 2005) for moist climate was used according to the carbon inventory guidelines given by Subedi *et al.* (2005).

Above Ground Tree Biomass (AGTB)=0.0509 X ρD²H

Where, AGTB= Above ground tree biomass (kg), ρ= wood specific gravity (gm/cm³), D= tree diameter(cm) and H= tree height(m)

Sub plots were established within each plot for estimating carbon in saplings, litter/herbs and soil. Sub plots with a 5.64 m radius were established for saplings; and subplots with 0.56 m radius was established for sampling leaf litter, herbs, grass, and soil.

The following regression model developed by Tamrakar (2000) was used to calculate sapling biomass.

$\ln(\text{AGSB}) = a + b \ln(D)$

where AGSB = Above ground sapling biomass

For calculating below ground biomass of trees, root to shoot ratio value of 1:5 was used ie 20% of above ground tree biomass as recommended by (Mac Dicken, 1997). Similarly the biomass stock was converted into carbon stock after multiplication with the IPCC (2006) default carbon fraction of 0.47.

For determining soil organic carbon Walkely and Black Method (1934) was used. Soil samples were collected from each sub plots of 0.56 m up to 30 cm depth.

Standard increment borer (Swedish Haglöf 16", 3-Thread, 0.200" (5.15 mm) diameter was used to extract the core samples from selected trees from each quadrat samples. Two cores were collected from 36 sample trees. Core samples were labeled, mounted and core surfaces were sanded manually through grades of progressively finer grit sand paper such as 120, 320, 400, 600, 800 and 100 sand papers until the ring boundaries are visible under binocular microscope. The LINTAB measurement system with a LINTAB moving stage and stereomicroscope, attached to PC having TSAP-Win program was used to measure the ring-widths of each series at dendrochronological laboratory of Department of Forest research and survey (DFRS) in Babarmahal, Kathmandu. The age of trees was determined using dendrochronological techniques (1 annual ring=1 year). For determining the radial growth and preparing the chronology, COFECHA and ARSTAN Program was used.

RESULTS AND DISCUSSION

The average carbon stock of the LGCF was 272.229±17.316 t/ha including soil organic carbon, tree biomass carbon, litter/herbs/grass (LHG) and saplings. The distribution of carbon in different pools is shown in fig 1. The total carbon stock of the studied forest with area 19.48 ha area was found to be 5303.02t. Comparatively less carbon was present in sapling and LHG in the forest. The average carbon stock estimated for chirpine in Bhaiyadevi CF, Salyan was 72.86 t/ha with an annual carbon sequestration rate of 2.21t/ha/yr. Baral *et al.* (2009) have estimated above-ground carbon stock of 34.30- 97.86 dry wt. ton ha⁻¹ and rate of carbon sequestration (1.30-3.21 t/ha/yr), in different forest types. Hence the present findings show that the forest is well stocked with higher value of carbon stock and sequestration rate.

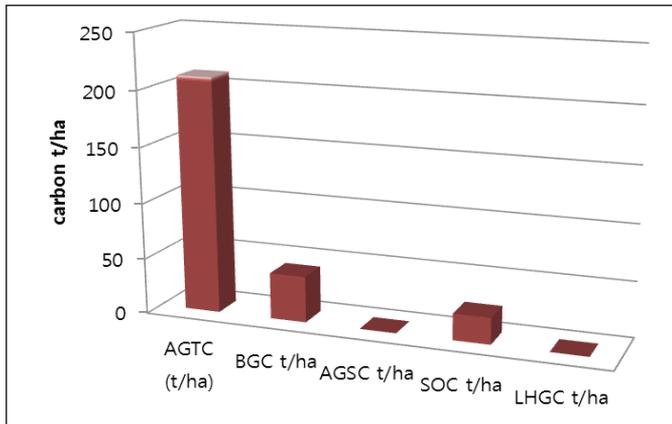


FIG. 1. Total carbon stock of forest.

Radial growth of pine trees

Similar sized tree of the same species from same sites may grow with different rate. The overall growth of pine tree in LGCF was found to be 2.0619 ± 0.139 mm/year whereas maximum radial growth was 4.472 mm/yr.

After the visual cross dating under the LINTAB microscope, ring of each core were measured and counted the ring number that gave age of tree. The tree rings numbers were plotted against diameter to see the relationship between diameter and age. There was significant positive relation between diameter and age in linear growth. The relation between radial growth, age and DBH are also shown in fig. 3 and 4. This chronology shows the negative correlation between radial growth rate and age and relation between growth rate and DBH. Ring width often decrease with increasing tree age. There was negative correlation between radial growth rate and age and relation between growth rate and DBH. Ring-widths often decrease with increasing tree age. The cumulative growth rate was also in negative correlation as shown in fig. 5. This biological growth trend is usually independent of other factors influencing tree growth (e.g. climate) and it is often helpful to remove it by a curve-fitting procedure prior to further analysis (Fritts, 1976).

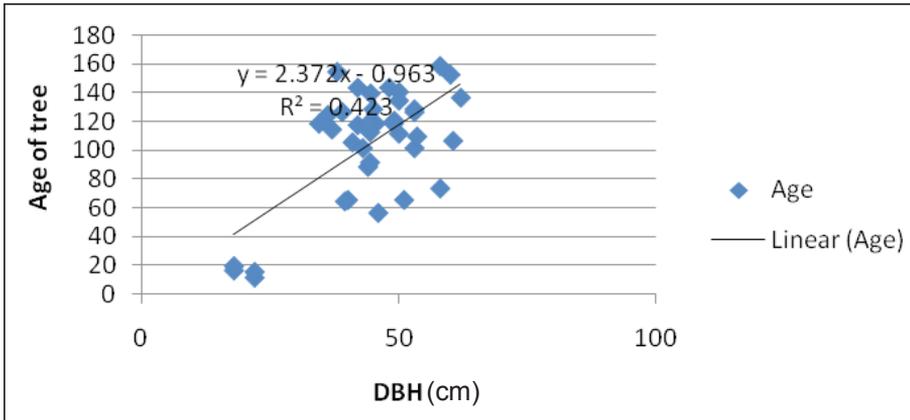


FIG. 2. Diameter-age relationship of *Pinus roxburghii* in Linga Guthi CF.

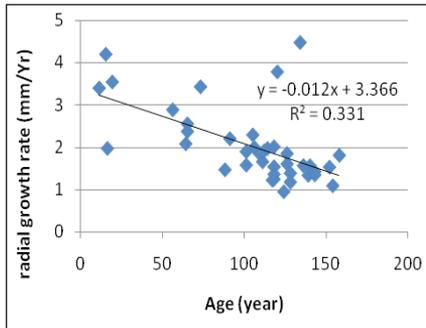


FIG. 3 Radial growth–age relationship.

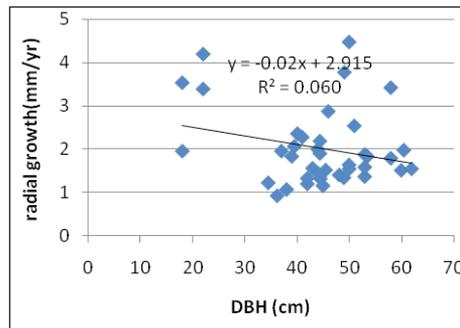


FIG. 4. Radial growth – DBH relationship.

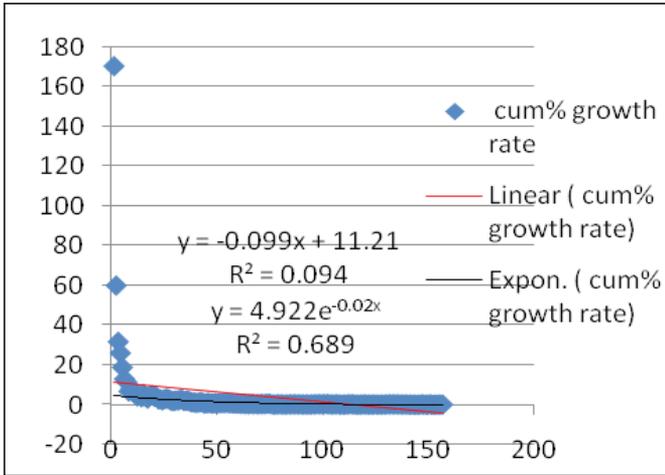


FIG. 5. Cumulative growth rate (%).

Age of pine forest

The oldest tree recorded in this forest was 158 years with 58 cm diameter. However the average age of the forest was 98 years. The tree age corresponding calendar started from 1854 to 2013 A.D. (table 1).

TABLE 1. Descriptive statistics of the radial growth and age of *Pinus roxburghii* in Linga Guthi Community Forestry, Bhaktapur.

Mean DBH(cm)	Max DBH (cm)	Max age (year)	Min age (year)	Tree age corresponding calendar (year)	Radial growth (mm/yr)
39.74	62	158	11	1854-2013	2.0619 ±0.139

Annual rate of carbon sequestration in aboveground tree biomass

It was found that 2.22 t of carbon/ha was sequestered in aboveground tree biomass each year. In young trees, there is increased annual net productivity which directly indicates increase in forest biomass and hence higher carbon sequestration potential (Adhikari, 2011). Jina *et al.* (2008) studied same species at Kumaun, Central Himalaya of India and found carbon sequestration rate of 5.06 - 6.66 t/ha/yr in non-degraded forest and 1.07 - 1.27 t/ha/yr in degraded sites. The lower carbon sequestration rate in the forest may be due to the degradation by logging for religious purposes or soil nutrients and other climatic factors.

Ring width chronology

A 158 year long ring-width chronology of *Pinus roxburghii* was developed extending from 1854 to 2013 AD. The chronological statistics for the entire period as well as for the common period are given in table 2. The ring width standard chronologies were prepared and shown in fig. 6, 7 and 8.

TABLE 2. Chronological statistics of *Pinus roxburghii*.

Statistics	Standard chronology	Residual chronology
Chronology span	1854-2013 AD	1854-2013 AD
No. of radii	75	75
Mean sensitivity	0.089	0.098
Std. deviation	0.129	0.101
1 st order correlation	0.502	-0.003
Common period	1939-2013 AD	1939-2013 AD
Correlation between radii(r_a)	0.034	0.024
Correlation between tree(r_b)	0.031	0.023
Correlation within tree(r_w)	0.223	0.122
SNR	1.923	1.345
EPS	0.658	0.573

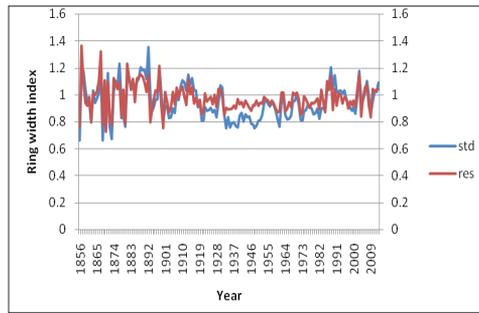
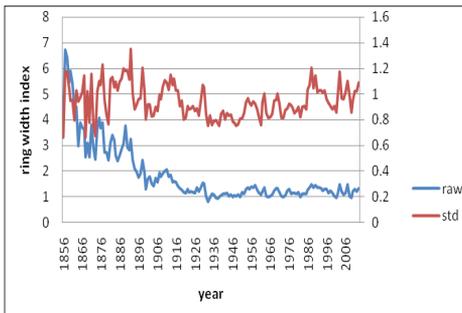


FIG. 6. Standard and residual chronology of ring width index and age.

FIG. 7. Standard and raw chronology.

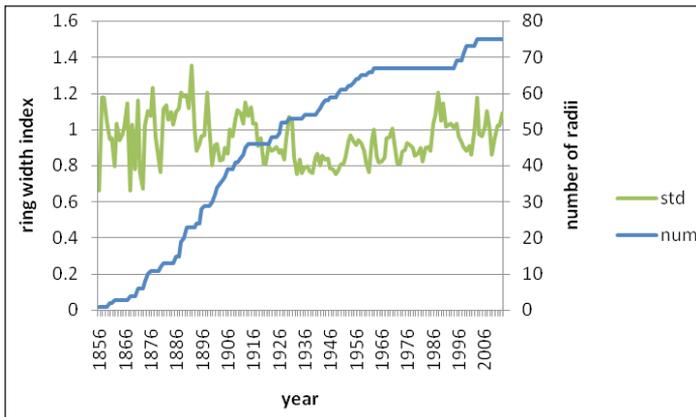


FIG. 8. Standard chronology and sample depth of *Pinus roxburghii*.

For common period of (AD 1939-2013) various statistics like correlation, EPS, SNR and variance explained were computed. The mean sensitivity of standard and residual chronology was found to be 0.089 and 0.098 respectively. The first order correlation was 0.502. Here First order autocorrelation decreased to -0.003 in residual chronology because autocorrelation is removed from standard chronology to get residual chronology. The mean correlation within tree, between trees and among all radii was estimated. The mean correlation within tree was greater than 0.122 than correlation between tree and among all radii. Lower value of correlation coefficient has been recorded for both the chronologies however the coefficient was less for between trees and among all radii. The EPS for standard and residual chronology was 0.658 and 0.573 respectively. Both chronologies did not exceed the EPS limit of 0.85 indicating that the site chronology does not represent the well population chronology.

Above ground tree biomass and carbon in the forest is higher compared to other studies. Carbon sequestration rate of 2.22 t C/ha was found in aboveground tree biomass each year. Linga Guthi CF is one of the old forests in the valley as 158 years old pine with 58 cm DBH was recorded. The tree age corresponding calendar was started from 1854 to 2013 A.D. The average radial growth of pine tree was found to be 2.0619 ± 0.139 mm/year. The age and DBH relationship show positive correlation. The radial growth rate of tree show negative correlation with age and DBH of trees. This biological growth trend is usually independent of other factors influencing tree growth (e.g. climate).

Thus, Linga Guthi CF has higher potential of carbon sequestration and pine trees stored large amount of carbon. The forest is being degraded by logging of mature trees for traditional and religious festivals of Kathmandu and Bhaktapur. As old pine trees in this forest preserve records of past environmental histories, other alternatives seem necessary to control logging and to conserve the forest.

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