PLANTATION HISTORY AND GROWTH OF OLD PINE STANDS IN KATHMANDU VALLEY: A DENDROCHRONOLOGICAL APPROACH

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Abstract

Pinus roxburghii Sarz. makes sub-tropical dry forest in the Himalaya and considered a potential species for dendrochronological studies. In Kathmandu valley, its distribution seems to be fluctuating from historical time. This study was carried out to disclose the plantation history of *P. roxburghii* inside Kathmandu valley as well as to extend understanding of its diameter, age and growth rate relationships. Tree core samples were collected from four locations in Kathmandu and one in Bhaktapur. The plantation history of Sallaghari (Bhaktapur), Singha Durbar Baraf Bag and Kumari temple, Thapathali (Kathmandu) was determined around 1870 AD, 1900AD and1875AD, respectively. The radial increment rate of this tree at Sallaghari (Bhaktapur) was 0.25±0.05cm/yr, Singh Durbar was 0.31±0.08 cm/yr, and Kumari temple was 0.32 ±0.03 cm/yr. The tree growth noticeably varied with location and topo-climatic conditions. Therefore, it is suggested that site selection is crucial for the suitability of this species to dendroclimatic study.

Introduction

Dendrochronology is a versatile discipline; tree rings have applications in multidisciplinary subjects *i.e.* to know past climate, occurrence of an earthquake, landslide, volcanic eruption, fire history, dating of old buildings or historic places (Fritts, 1976). Research scholars pointed that species such as *Pinus roxburghii, Pinus wallichiana, Tsuga dumosa, Picea smithiana, Juniperus recurva, Ulmus wallichiana, Cedrus deodara, Larix potanini* have potential for dendrochronological study in Nepal (Suzuki, 1990; Bhattacharya *et al.*, 1992; Schmidt, 1992; Cook *et al.*, 2003; Brauning, 2004). The tree ring calendar has already helped answer questions about an important time span of architectural and settlement history. Nepal is also rich in such archaeologically and historically significant places. Tree ring study of pine wood sample used in the monastery of Muktinath (Schmidt, 1992) found that the woods used in the construction of the monastery (the youngest tree ring before being chopped down) was felled in 1906 and a specimen from the foundations of the kings palace in Dzarkot (Jajarkot) was found to be harvested in 1512.

The chir pine (*Pinus roxburghii* Sarg.) is a native tree species of the Himalaya. It generally occurs up to 1200m, but at some sites it extends to over 2000m on exposed, dry south facing slopes, and well drained area. It is found in the west of Nepal on all aspects, but in the central and east, it tends to be confined to southern aspects and dry lower slopes of large river valley. It can be an excellent species to study the state of past climate with tree ring analysis (Bhattaracharya, 1992). Pines are popular timber since long time in Kathmandu valley. Most of the Malla period (1300 AD-1700 AD) temples and durbars were made from pine wood. Growth rate and age of trees are frequently used in silviculture, forestry, ecology and population dynamics studies. Despite the great importance of these estimates, there are a few published studies available for Nepali tree species.

Many palynological investigations in the Kathmandu basin were undertaken to investigate the past climate and paleo vegetation of the valley (e.g., Igarashi *et al*., 1988; Nakagawa *et al*., 1996; Fuji and Sakai, 2001; Paudayal, 2005, 2006; Bhandari *et al*., 2009). From palynological study of valley sediments, Fujii and Sakai (2001) found cyclic fluctuation of arboreal pollen of *Pinus* with frequency up to 75% i.e. dominant species in the lake sediments of 6-115m depth in different historical period, and *Pinus* species was associated with cold climate. Similarly, large sized old pine forest patch can still be found in some location of the Kathmandu valley. They can provide some historical as well as dendroclimatic information. In order to unravel the plantation history of pine inside Kathmandu valley as well as to extend understanding of the diameter, age and growth rate relationships and check suitability of these species for dendrochronological investigations, this study focused on *Pinus roxburghii* growing in the Kathmandu valley.

About the study area: The Kathmandu valley (Fig.1) is one of the large inter-montane basins formed within the Lesser Himalaya of Nepal and is located in warm temperate climatic zone (Fuji and Sakai, 2001). Presently vegetation of the valley floor is characterized by *Shima-Castanopsis* forest with some sub-tropical elements such as *Bombax*; however, on the slope area *Quercus* and *Rhododendron* forests are present (Stainton, 1972; Malla *et al.*, 1976). Old growth of pine trees are seen in the campuses of large residences or embassies and also in the outskirts of the city in Kathmandu. As they seem to be of the same age and size and that the wet valley

floor does not favour natural growth of pine trees, it is assumed that they were planted out of keen interest to have some greenery around a century ago. However, new plantations including that of pine trees are noted in several parts of Kathmandu, for example, in historical hillock of Swoyambhunath.

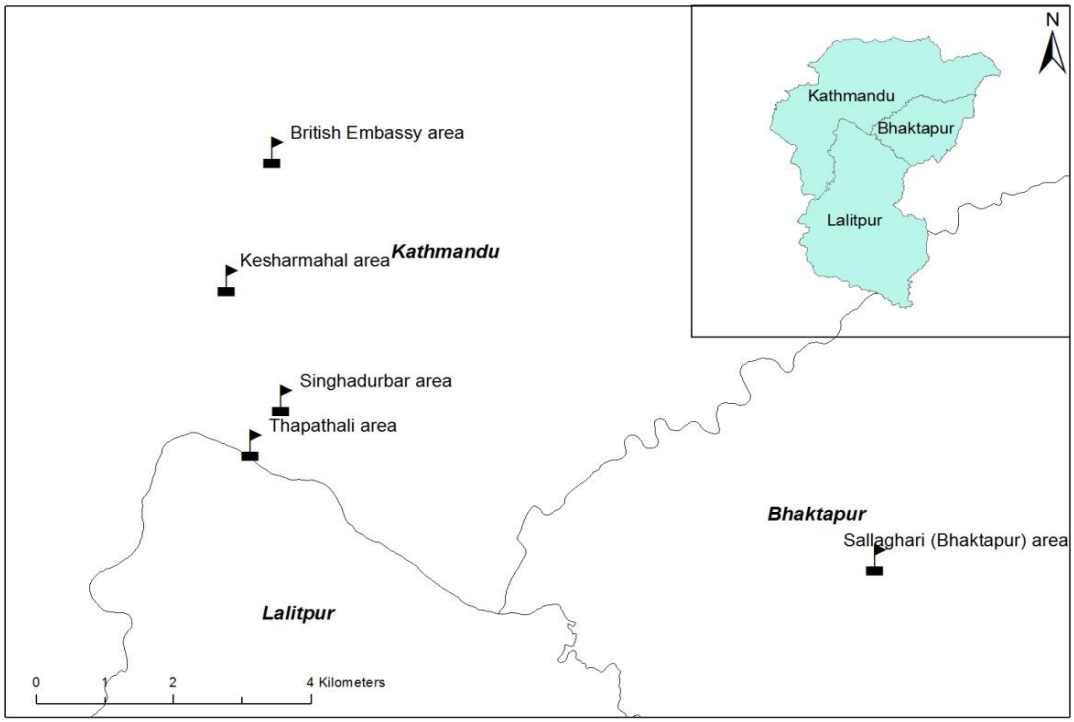

Fig.1. Location map of study area

Table 1. Descriptive statistics of *P. roxburghii* in sampling site.

Location	Mean DBH cm	Max DBH cm	Max age (yr)	Tree age corresponding to calendar yr	Ring density (yr/cm)	Radial Growth (cm/yr)
Sallaghari, Bhaktapur	75.68	104	140	1870	3.31±0.81	0.25±0.05
BarafBag, Singha Durbar	80.30	101	110	1900	3.19±0.95	0.31±0.08
Kumari temple, Thapathali	75.6	81	145-7	1873-5	4.36±0.52	0.32 ±0.03

Materials and Methods

Five old pine stands in Kathmandu valleys were selected and field sampling was carried out during Jan-Feb 2010 and Feb-March 2011. Swedish Increment Borer Haglof was used to obtain cores from living trees. Only healthy, sound trees with no sign of injury and of different sizes were selected. A total of 80 tree cores were collected from Chonga Ganesh Sallaghari of Bhaktapur (41 cores from 21 trees), Baraf–Bag in Singha Durbar (20 cores from 10 trees) and Dream Garden in Keshar Mahal (4 cores from 2 trees), Kumari temple at Thapathali (10 cores from 5 trees) and the British Embassy in Kathmandu (five cores of three trees). Tree cores were obtained from as close to ground as possible. Using GPS, locations, elevation and aspect of sampling sites were recorded. Collected tree core samples were handled, air dried, stored, glued and polished following the standard methods (Stokes and Smiley, 1968; Fritts, 1976).

The cores were subjected to visual cross-dating under a stereoscopic microscope to locate any missing and false (double) rings. Many cores did not pass through the center or pith. In these cores, missing radius and its years were calculated by observing the curvature of rings and its centre i.e. pith. Missing years and number of years of sampling height were added to the number of rings obtained from core samples to estimate the total age of the tree. Since our prime objective was to determine the oldest tree, sample having both pith and bark were given more importance. After the visual cross-matching under the microscope, rings of each core were measured to nearest 0.01 mm on computer-compatible measuring machine LINTAB at Nepal Academy of Science and Technology (NAST) Dendro-lab. To check quality of ring width characteristic and visual cross-dating, program COFECHA (Holmes, 1983) was used. Program ARSTAN was used to build ring width chronologies (Cook, 1985). Linear Regression was used to obtain relation between DBH and age.

Results and Discussion

A total of 80 tree cores were collected from 41 trees growing in different locations for the study. Tree cores from British Embassy area and Keshar Mahal area were discarded for final analysis due to the missing of pith and broken cores. It is notable that the pine trees in the British Embassy were very large (DBH 120 cm), but counted less than 65 years, indicating healthy growth under favorable condition. Cores from the other three locations, viz. Chonga Ganesh Sallaghari (Bhaktapur), Baraf Bag Singh Durbar (Kathmandu) and Kumari temple Thapathali (Kathmandu) were subjected to detailed analysis.

Table 1 presents descriptive statistics of pine trees of various locations. The mean diameter at breast height (DBH) of sample from Sallaghari, Bhaktapur was 75.68cm (max=104cm), Thapathali was 75.6cm (max= 81 cm) while that of Singha Durbar was found to be 80.3 cm (max=101cm). The oldest tree recorded in Sallaghari Bhaktpur was 140 years with 104 cm diameter. The site is at the end of Bhaktapur city in the west and near a Ganesh temple named Chonga and historical pond called Rani Pukhu aka Nhu Pukhu (Shrestha, 2010). The stand contains pine trees of almost the same size indicating that they were planted. Moreover, near the site is an army barrack established in 19th century during the Gorkha expansion. The age of the pine trees indicated that they were planted around 1870, the later period of Rana Prime Minister Jung Bahadur (1846-1877), the founder of Rana family rule.

The oldest pine tree at Baraf Bag of Singh Durbar was about 110 years old (sown year 1900 AD) which coincided almost with the construction of Singh Durbar. Singh Durbar was built in 1903 by the then Rana Prime Minister Chandra Shumsher (1901-1930) as a private residence (Shumsher, 1990). With 17 courts and 1700 rooms built in Victorian style, the palace was the largest in Asia. The building was later converted into Government Secretariat. Looking at the age of the pine trees growing there, it is assumed that the saplings were brought from the nursery and planted in the premises soon after the completion of the Durbar. Chandra Shumsher was a patient of tuberculosis; he must have savored the pine trees as there was a popular belief that the trees give fresh air good for health.

The oldest tree found at Kumari Mandir (temple) was more than 145 years (sown year 1873 AD). The Kumari Mandir is located nearby another Rana Residential Palace, Singha Mahal and near the bank of Bagamati river. The pine trees must have been planted in 1870s in the small hillock of Kumari Mandir along with the same other trees in the premises of the residential palace.

Tree growth differed in various locations. A pine tree having DBH 101 cm from Singha Durbar was estimated 99 years old while from the same place another tree had 100 rings with smaller DBH. Slight variation in the age of the tree was observed. This might be due to the presence of different cohort group in the population. According to Ahmed *et al* (2009), tree age varies from site to site, species to species, within a species and even in similar sized trees of the same species in an area. The average growth of tree (ring density) at Bhaktapur was found to be 3.31 year/cm (SD=0.81) and that for Singha Durbar was 3.19 yr/cm (SD=0.95). However, ring density of Thapathali (4.36±0.52) was slightly higher than other two sites which might be due to more aridity in the area. Similarly, per year radial increment was higher in Singh Durbar (0.31±0.08cm/yr) than that of Sallaghari, Bhaktpur (0.25±0.05cm/yr). However, growth rate of pine trees at Singh Durbar was compatible to that of Thapathali.

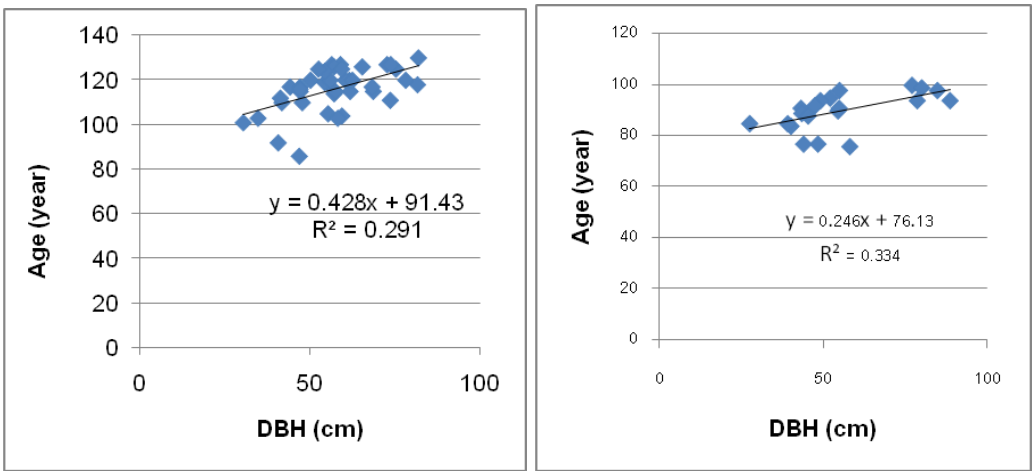

Fig.2. Diameter–age relationship of *Pinus roxburghi* from Kathmandu valley; Bhaktpur (a) and Singh Durbar (b)

Growth of tree species depends on various factors like soil condition, nutrient availability, water regime, light, etc. During the study, we measured some of the planted pine trees in the garden of the British Embassy in Kathmandu. Some of the pine trees there were over 110 cm in diameter, but the rings counted hardly 65 years. This could be because of the nutritional input and regular care taken by the gardeners. In a study in Pakistan, Ahmed *et al*. (2009) reported *P. roxburghii* having 78 cm DBH attained an age of 41 years, while smaller size (DBH 62.0 cm) tree showed 113 years of age. Ahmed *et al*. (1991) also reported age (112 years) of *Pinus wallichiana* from 20 to 65 cm DBH trees in Takht-e-Sulaiman of Pakistan.

Overall growth rates are based on all cores of individual species of a particular site. Similar sized tree of the same species from same site may grow with different rate. In a study in Pakistan, Ahmed *et al.* (2009) found growth rate of 1.7 years/cm for *P. wallichiana* at Shalthalo Bala, (Dir District) while *Abies pindrow* from Lalazar (Murree) produced most narrow (7.1 years/cm) rings. Aspect plays an important role in determining plant growth (Fritts, 1976). Ahmed *et al.* (2009) reported that *Cedrus deodara*, *P. wallichiana* and *Picea smithiana* grow faster on south facing slope while *A. pindrow* and *P. roxburghii* grow faster on North facing slopes. Ahmed and Sarangzai (1992) reported very slow growth (16 year/cm) in case of *Pinus gerardiana*.

Diameter–age relationship was also calculated (Fig. 2 a-b). There was significant positive relation between diameter and age in both sites: Bhaktpur ($r = 0.539$, $p = 0.001$) and Singh Durbar ($r = 0.578$, $p = 0.007$). In some place no linear relationship was found between radial growths with tree age. Ahmed (1988) reported significant relation between diameter and age from planted tree species and Ahmed *et al.* (2009) found significant relationship between DBH and age in *P. roxburghii* which is consistent to our study.

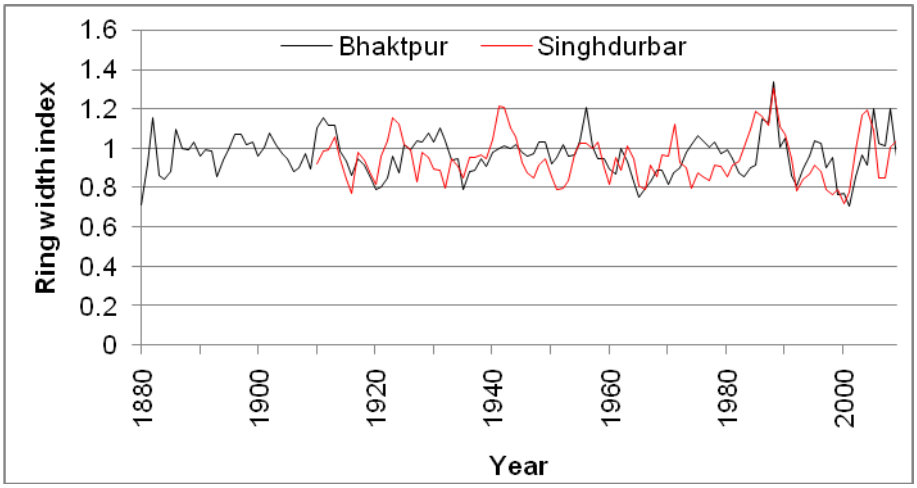

Fig.3. Standard chronology of *P. roxburghii* from Kathmandu valley

Fig. 3 presents tree ring chronologies of pine from Kathmandu valley. These chronologies showed oscillations in the growth of the tree. There is slight variation in the patterns of these two chronologies which might be due to the edaphic factors as well as due to anthropogenic disturbance in the area since both pine stands are planted. Though there is high sensitivity among tree cores, low series inter-correlation was observed which might be due to anthropogenic disturbance as well as site conditions. Bhattacharya et al. (1992) made a tree ring chronology extending from 1683 to 1979 AD using the same tree species growing at Tila Nala of western Nepal. That study also reported dendro-climatological potential of the *P. roxburghii* despite some observed missing and double (false rings) in some samples. However, appropriate site selection is crucial in any dendrochronological study (Fritts, 1976). Due to low value of important tree chronology statistics like expressed population signal, signal to noise ratio, these chronologies were not subjected to climate growth relationship.

The dendrochronological approach, thus, was found to be a useful tool to estimate the age of the old pine plantation in Kathmandu valley, which fairly coincided with the Rana regime, who might have favoured the trees for their evergreen nature and tall stature. The pine tree stand in Sallghari of Bhaktapur aged with the later years of founder of Rana family rule Jung Bahadur and that of the stands in Singha Durbar coincided with the construction of the Durbar in 1903. Similarly, the pine stand in Kumari Mandir coincided with the construction of Singh Mahal. Similar studies can be extended to assess the construction of historic temples in the valley, which are mainly built on the pine timber. As the growth is much influenced by several environmental factors, this study also emphasizes the need for appropriate site selection for the dendroclimatic study from pine species.

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