EVALUATION OF GROWTH AND MANAGEMENT OF TEAK (*Tectona grandis* L.F.) ESTABLISHED IN FARMER WOODLOTS IN DRY AND INTERMEDIATE ZONES OF SRI LANKA

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Summary

*One of the main methods of establishing teak (*Tectona grandis *L. f.) plantations in Sri Lanka was through Farmer Woodlots. Therefore the present study was conducted with the objectives of identifying the growth of teak in different Farmer Woodlots in dry and intermediate zones of Sri Lanka, indentifying the management issues and measuring the availability and effects of selected soil nutrients on growth. 17 teak plantations of age ranging from 8 to 13 years managed through Farmer Woodlots were selected for this purpose. Those plantations were selected from Anuradhapura and Polonnaruwa Forest Divisions to represent the dry zone and from Kurunegala Forest Division to represent the intermediate zone. Three Farmer Woodlots from each plantation were randomly selected for the data collection and 10 farmers were interviewed from each plantation via a pre-tested questionnaire survey. Dbh and total height were measured from the trees in the sample plots and soil samples were collected to measure soil pH, bulk density, organic carbon, nitrates, phosphorus, potassium, magnesium and calcium. It was identified that the growth of the selected plantations were less than that of the height class II of teak yield tables published by the Sri Lanka Forest Department. A significant correlation was not identified between soil chemical parameters and the growth. Further, the tested nutrients were available in very low levels in the tested sites. The results of the questionnaire survey revealed that, 100% of farmers needed to extend the present 25 year lease agreement by 5 to 50 years to obtain more income. Moreover, 98% was willing to continue the programme for another cycle. However, they face problems such as poor site quality, wild elephant, fire and insect damage in managing their woodlots. In addition to that, lack of technical support was also highlighted.*

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INTRODUCTION

Less than 5% of total forest area supplies 20% of current world wood demand as natural forests are exhausted or come under the protection category (Larson, 2002). Therefore 90% of plantation forests have been established primarily to provide industrial wood and their relative global importance in this role is increasing rapidly. Most of the 10% of the remaining forest plantations were established to supply fuel or wood for non-industrial use (Fisher, 2000).

The expanding tropical plantation forests have tree species grown primarily as agricultural crops and now those forests also supply wood for forest industries. Significant amount of existing forest plantations were established in the past and those are managed as even-aged monocultures. Moreover, other types, such as uneven-aged and mixed plantations are also commonly available. While species and inter-species hybrids of a few new genera dominate plantation forestry worldwide (for example, *Acacia, Eucalyptus* and *Pinus*), plantation forests with those of a few others such as *Araucaria, Gmelina, Larix, Paraserianthus, Popules, Pseudotsuga* and *Tectona*, are of regional importance (Evans, 1992, Pandey and Brown, 2000, Kanowsky, 1997). Evans (1992) further emphasised that pioneers such as *Tectona, Pinus* and *Eucalyptus* account 85% of all forest plantations in the tropics.

Teak forest occurs normally in the Asia-Pacific region over an area of about 23 Mha. About one third (8.9 Mha) of the natural teak forests can be found in India. Teak is being grown as plantations in at least 36 countries across three tropical regions, i.e., Tropical Asia, Tropical Africa and South America (Fisher, 2000). Production of high quality wood in relatively long rotations of 50-70 years has been the usual practice ever since the world's first teak plantation was established in Nilambur in Kerala, India in 1842. However, shorter rotations of 20-30 years of both veneer and saw log production for relatively quick returns are now being employed in many countries (Niles *et al.*, 2002).

Forest plantations have had a mixed history in Sri Lanka. From small beginnings, it is now playing an important role in meeting the timber and fuel requirements of the nation. At the turn of the last century, plantation establishment was aimed at replacing forest lost through uncontrolled shifting cultivation. Those programmes used *Taungya* system during 1950 and 1970 while *Artocarpus heterophyllus* and *Swietenia macrophylla* were planted in the intermediate zone and some other hardwood species such as *Berrya cordifolia, Melia dubia*, and *Chloroxylon swietenia* were established in the dry zone with an increasing proportion of teak (Munaweera, 1998; Ariyadasa, 2003). After unfavourable and unjustified silvicultural reports, planting of teak was virtually stopped after 1926, but had been extensively resumed again by 1939 (Ariyadasa, 2002).

At present, over 45,000 ha of teak plantations are maintained by the Forest Department of Sri Lanka as homogenous plantations in the dry and intermediate zones. Apart from that, teak has been grown as mixtures with *Artocarpus heterophyllus*, *Azadirachta indica*, *Eucalyptus species* and *Swietenia macrophylla*. The popular methods of establishing teak plantations were *Taungya* systems under community forestry projects and later by participatory forestry projects.

Sri Lanka has a long history of participatory approaches to rural development dating back to the 1940s. The historical perspective of forest management since 1840 with the enhancement of Forest Ordinance 1907 No 12 shows that the prime objective of management of the forest plantations is to obtain timber. In 1980s policy makers decided to enhance the involvement of the rural community in forest management through social forestry programmes. A closer perusal of the implementation programmes indicates that the forestry sector is poised to centre around the participatory management principles. Along the lines of the overall forest policy and in keeping with the necessity to get local people in managing the forest sector, the government realised the need to draw up the community participation for forest conservation. Therefore several programmes were developed on the assumption that sustained forest development can only be achieved through the participation of the beneficiaries (FSMP, 1995).

Farmer's Woodlots were established in Anuradhapura, Kurunegala, Polonnaruwa, Matale, Monaragala and Badulla Districts of Sri Lanka. Most of the plantations are around 8 to 13 years old at present and therefore are suitable for commercial thinning. In another 10 to 15 years time, these plantations will be suitable for final felling, which would produce a considerable amount of timber from those woodlots.

Damage by wild elephants has been identified as a serious problem in the most of teak plantations established in the dry zone of Sri Lanka. Teak is susceptible to various kinds of pests and diseases. Generally, defoliators, skeletonisers and stem borers cause problems in teak plantations (Kandambi, 1993). Some social and political problems were also arisen during the teak establishment phases. In addition to those, there are many problems in the Farmer's Woodlot sector in Sri Lanka. The present rotation age is 25 years and therefore per tree average volume was found to be 38% lower than the Forest Department's provisional yield tables (Silva and Amarasekara, 2007) which indicates inadequate management practices of the woodlots, lack of soil fertility or mismatch of species-site combinations.

MATERIALS AND METHODS

Anuradhapura and Polonnaruwa Districts were selected to represent the dry zone and Kurunegala District was selected to represent the intermediate zone. Anuradhapura, Tambuttegama and Kekirawa were the selected Forest Ranges from Anuradhapura Division. Habarana was the only available Forest Range with Farmer Woodlots in Polonnaruwa Division. From Kurunegala Forest Division, Galgamuwa Forest Range was selected for the data collection. The selected plantations were established between 1994 and 1999 and therefore those were varying in the age. Altogether, 17 plantations were selected for the present study as shown in the table 1.

From each plantation, three Farmer Woodlots were randomly selected for the data collection and three samples were used for the tree measurements from each woodlot. Dbh and total height were measured from the trees of selected samples. In addition to that, soil samples were collected at each sampling point up to 30 cm from the surface.Bulk density, pH, total nitrates, phosphorus, potassium, calcium, magnesium and organic C of the soil samples were measured using standard methods.

A questionnaire survey was carried out to obtain information on farmers' life style and their view on participatory forestry programme. 10 farmers were selected from each plantation for this survey and thereby 170 famers were interviewed. Information on soil fertility and erosion, adequacy of the government support, intercropping, growth of timber etc were expected to be obtained from the questionnaire.

In order to examine the growth pattern with soil properties, a simple growth index was developed by dividing the height by age of trees (*gi=height/age*). Otherwise trees of different ages can provide misleading results with tested parameters.

Table 1: Description of the selected plantations

No.	Division	Range	Beat	Name	Planted year	Age (yrs)
1.	Anuradhapura	Anuradhapura	Galkulama	Kirikkulalma	1994	13
2.	Anuradhapura	Anuradhapura	Mihintale	Doramadalawa	1996	11
3.	Anuradhapura	Anuradhapura	Mihintale	Doramadalawa	1995	12
4.	Anuradhapura	Anuradhapura	Ratmale	Weerawewa	1998	9
5.	Anuradhapura	Anuradhapura	Ulukkulama	Ilupankadawala	1997	10
6.	Anuradhapura	Kekirawa	Kekirawa	Kaththankulama	1997	10
7.	Anuradhapura	Kekirawa	Kekirawa	Werunkulama	1999	8
8.	Anuradhapura	Kekirawa	Madatugama	Nelbegama	1996	11
9.	Anuradhapura	Tambuttegama	Eppawala	Batuwatta	1994	13
10.	Anuradhapura	Tambuttegama	Nochchyagama	Weliwewa	1997	10
11.	Anuradhapura	Tambuttegama	Thalawa	Karagahawewa	1998	9
12.	Anuradhapura	Tambuttegama	Thalawa	Karagahawewa	1996	11
13.	Kurunegala	Galgamuwa	Ambanpola	Getadivula	1999	8
14.	Kurunegala	Galgamuwa	Galgamuwa	Usgala	1994	13
15.	Kurunegala	Galgamuwa	Galgamuwa	Weeragolla	1996	11
16.	Kurunegala	Galgamuwa	Galgamuwa	Weeragolla	1995	12
17.	Polonnaruwa	Habarana	Habarana	Rambewewa	1997	10

RESULTS

Dbh and height of sampled teak trees were measured to compare the growth of different plantations and to establish relationship with soil parameters.

According to figures 1 and 2, the largest dbh and height values were recorded for the year 8 in Werunkulama plantation of Kekirawa Beat, Anuradhapura Division (14.3 cm and 13.4 m respectively); For age 9, in Weerawewa plantation of Ratmale Beat, Anuradhapura Division (12.1 cm and 11.7 m respectively); for age 10, in Rambewewa plantation of Habarana Beat, Polonnaruwa Division (17.5 cm and 13.3 m respectively); for age 11, in Karagahawewa plantation of Thalawa Beat, Anuradhapura Division (18.7 cm and 13.9 m); and for age 12, in Weeragolla plantation of Galgamuwa Beat, Kurunegala Division at age 12 (18.7 cm and 13.4 m). The largest dbh was recorded for age 13 in Batuwatte plantation of Eppawala Beat, Anuradhapura Division (18.3 cm) while the tallest height (14.8 m) for the same age was recorded in Usgala plantation of Galgamuwa Range, Kurunegala Division (14.8 m). Among all ages, the largest dbh was shown by Karagahawewa plantation of Thalawa Beat, Anuradhapura Division (18.7 cm at age 11) and the tallest height (14.8 m) was recorded in Usgala plantation of Galgamuwa Beat, Kurunegala Division at age 13.

Growth index values given in figure 3 indicated a different pattern from the total height as shown in figure 2. According to figure 3, the highest growth index (1.68) belonged to 8 year old Werunkulama plantation of Kekirawa Beat and the next highest growth index (1.33) was recorded in 10 year old Rambewewa plantation of Habarana Beat. The lowest growth index (0.67) was observed in 12 year old Doramadalawa plantation of Mihintale Beat.

When correlation values were observed, none of the parameters shown in figure 4 to 9 did not indicate significant relationships. Soil calcium values were not detectable and therefore a separate relationship between it and growth index could not be tested. Even a visual pattern of change of growth index with the tested soil parameters could not be established. However, it may not conclude here that there is no growth change due to changing soil nutrients. There may be other factors that affect more to the growth such as application of management prescriptions, damage due to fire and wild elephants etc.

Soil calcium was available in detectable form only in 12 year old Doramadalawa plantation (0.019 ppm) of Anuradhapura Range; Rambewewa plantation (0.311 ppm) in Habarana Range; 12 year old Weeragolla plantation (0.020 ppm) and Getadivula plantation (0.047 ppm) in Galgamuwa Range. In all other plantations, soil calcium was not detected. Teak is growing well in calcium rich soil and lack of soil calcium may have caused a low growth rate.

As shown in figure 4, soil bulk density of the selected plantations varied from 0.90 gcm^{-3} (12 year old Doramadalawa plantation of Anuradhapura Range) to 2.31 gcm^{-3} (Kaththankulama plantation of Kekirawa Range).

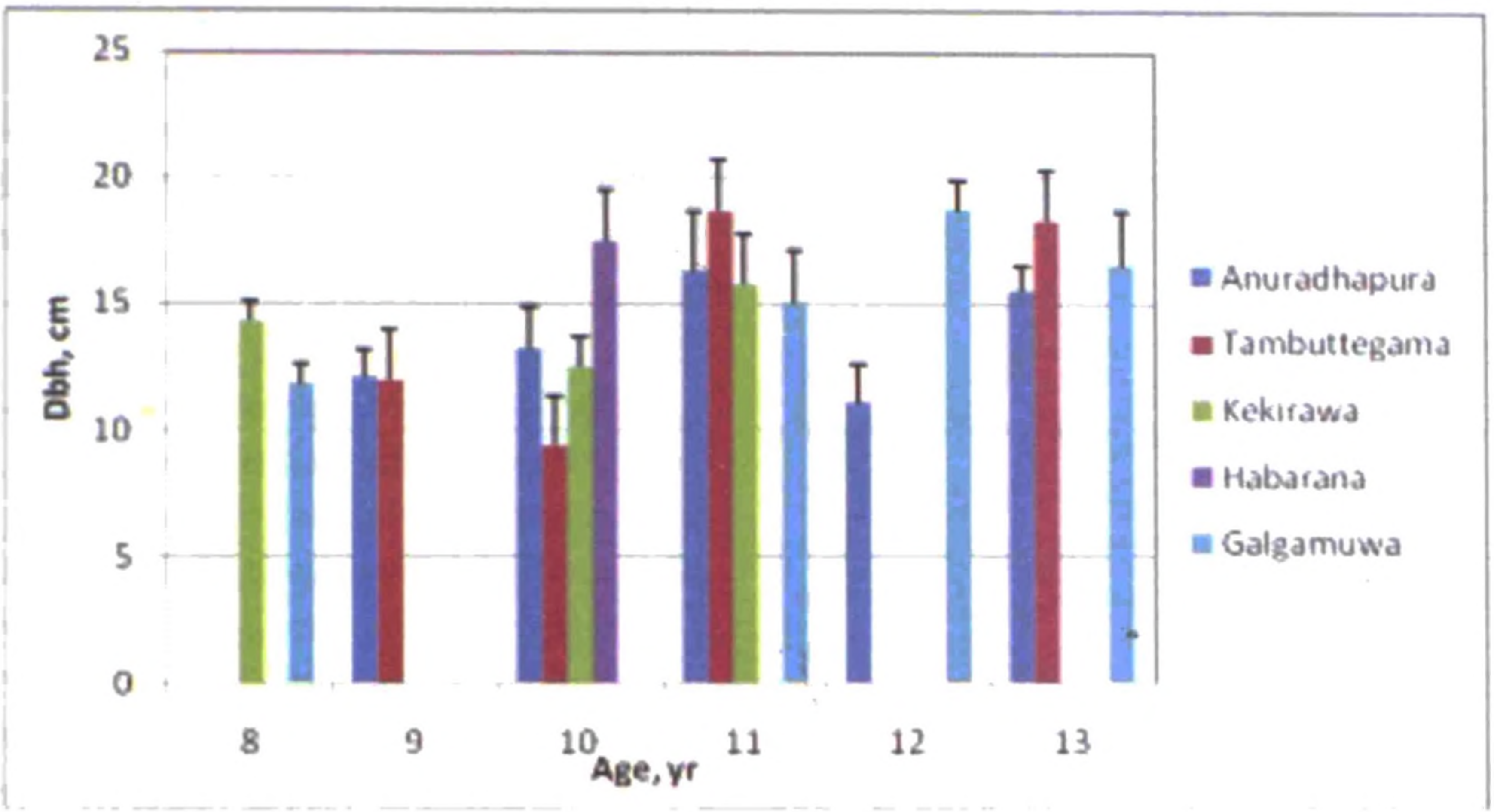

Figure 1: Average dbh values and the standard errors for each plantation at each age

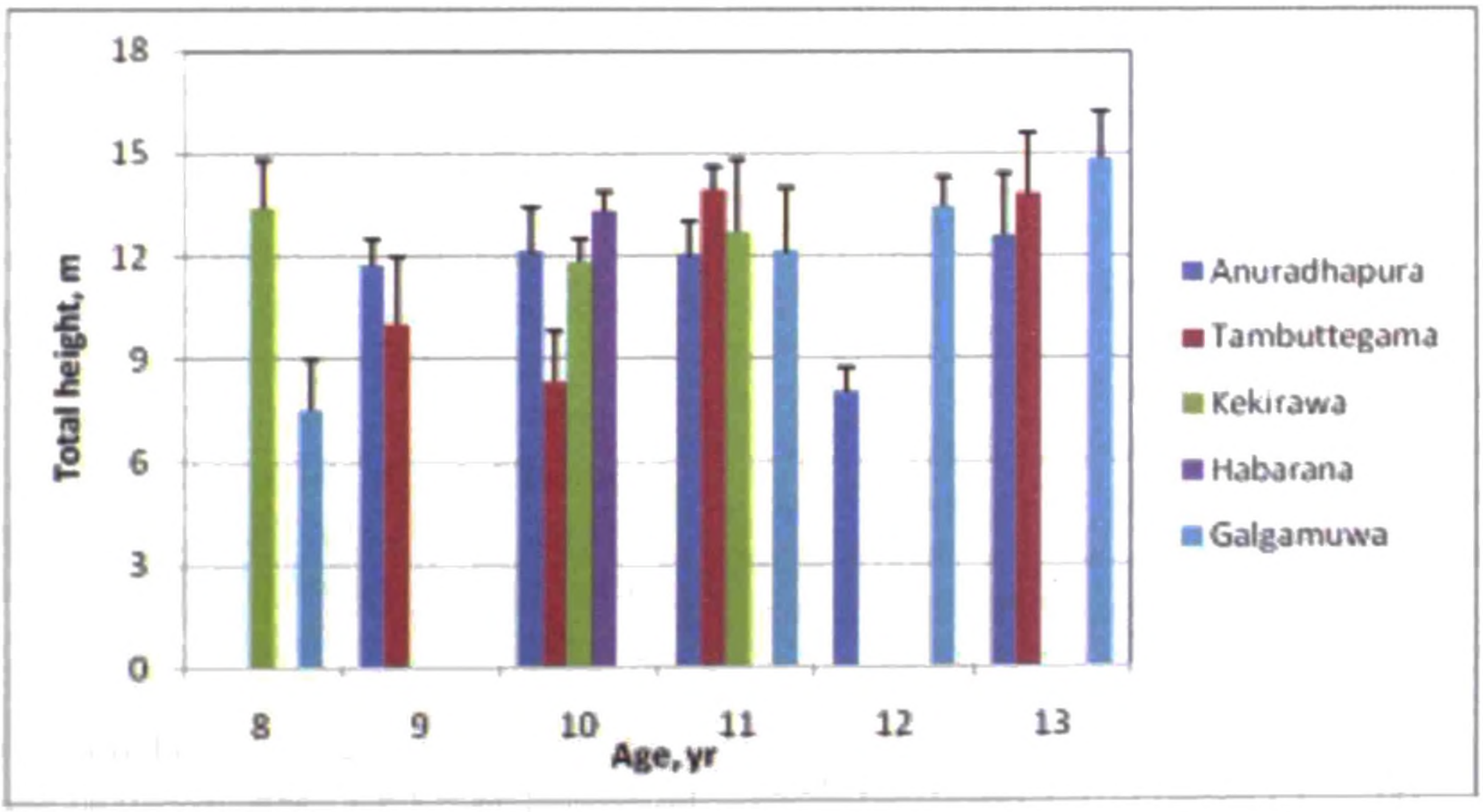

Figure 2: Average height values and the standard errors for each plantation at each age

Organic carbon indicated low values ranging from 1.2% to 4.9% for all plantations tested (figure 5). The reason for this could be due to the prevalence of frequent fires in most of the plantations. Among those plantations, the lowest values were indicated in the plantations of Kekirawa Range of Anuradhapura Division.

Other than Rambawewa plantation of Habarana Range, 9 year old Karagahawewa plantation of Tambuttegama Range, Weerawewa plantation of Anuradhapura Range and Werunkulama plantation of Kekirawa Range, nitrate content was less than 4.5 ppm for all other plantations (figure 6).

Only Weerawewa and Illupankadawala plantations of Anuradhapura Range had soil phosphorus closer to 250 ppm (figure 7). Rest of the plantations had that value between 56 to 200 ppm with the lowest value was recorded in 12 year old Doramadalawa and Kirikkulama plantations of Anuradhapura Range.

Weliwewa plantation of Tambuttegama Range and 11 year old Weeragolla plantation of Galgamuwa Range had the highest soil potassium values, i.e., 8.378 and 8.250 respectively (figure 8). All plantations in Anuradhapura Range and Habarana Range had comparatively lower potassium values.

The highest soil magnesium values were observed in all plantations of Galgamuwa Range (figure 9). That was the only range located in the intermediate zone of Sri Lanka. The values vary from 7.8 to 8.3 ppm. All the other selected plantations were located in the dry zone and the

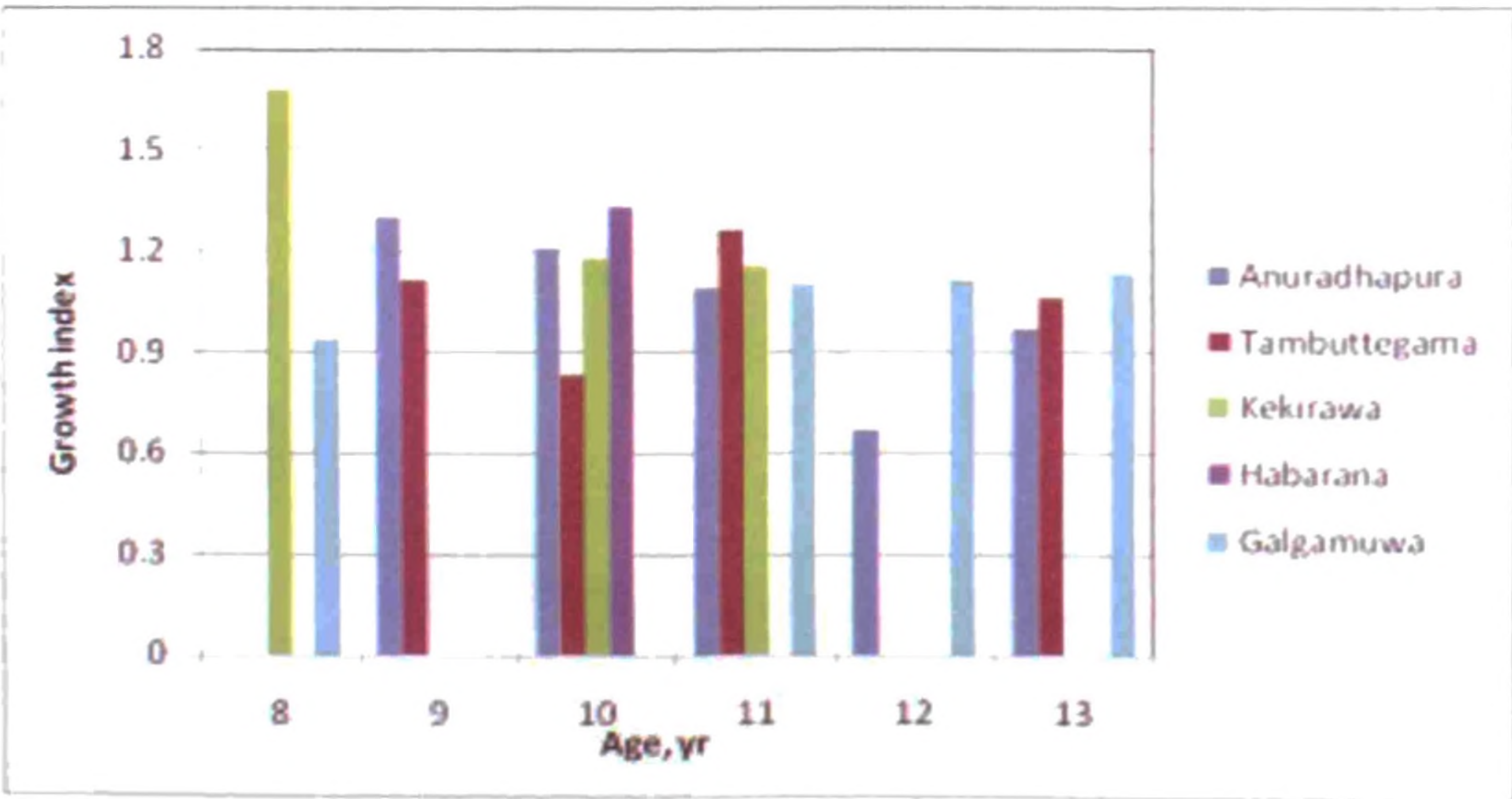

Figure 3: Height index calculated for each plantation at each age

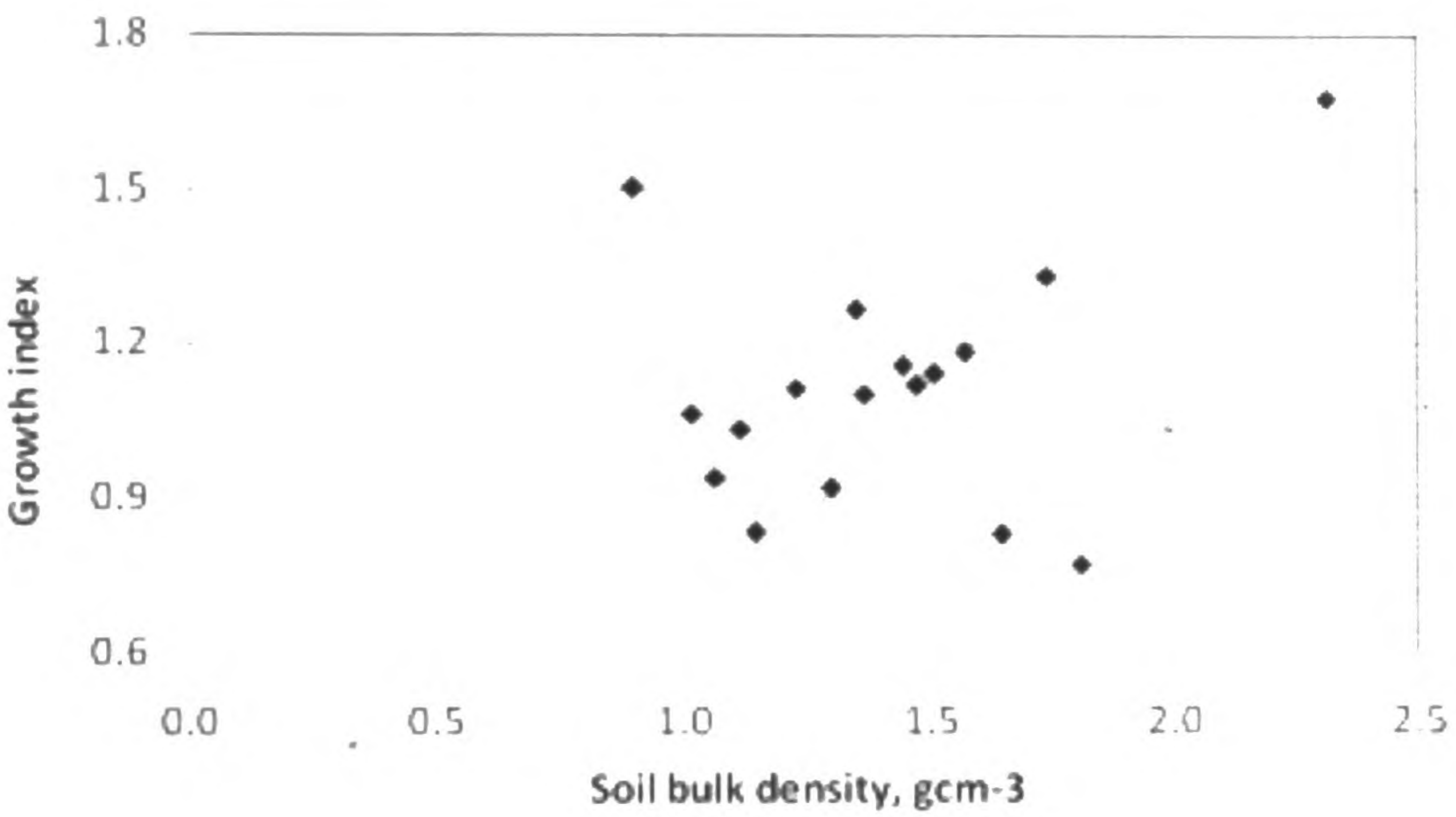

Figure 4: Growth index vs. soil bulk density

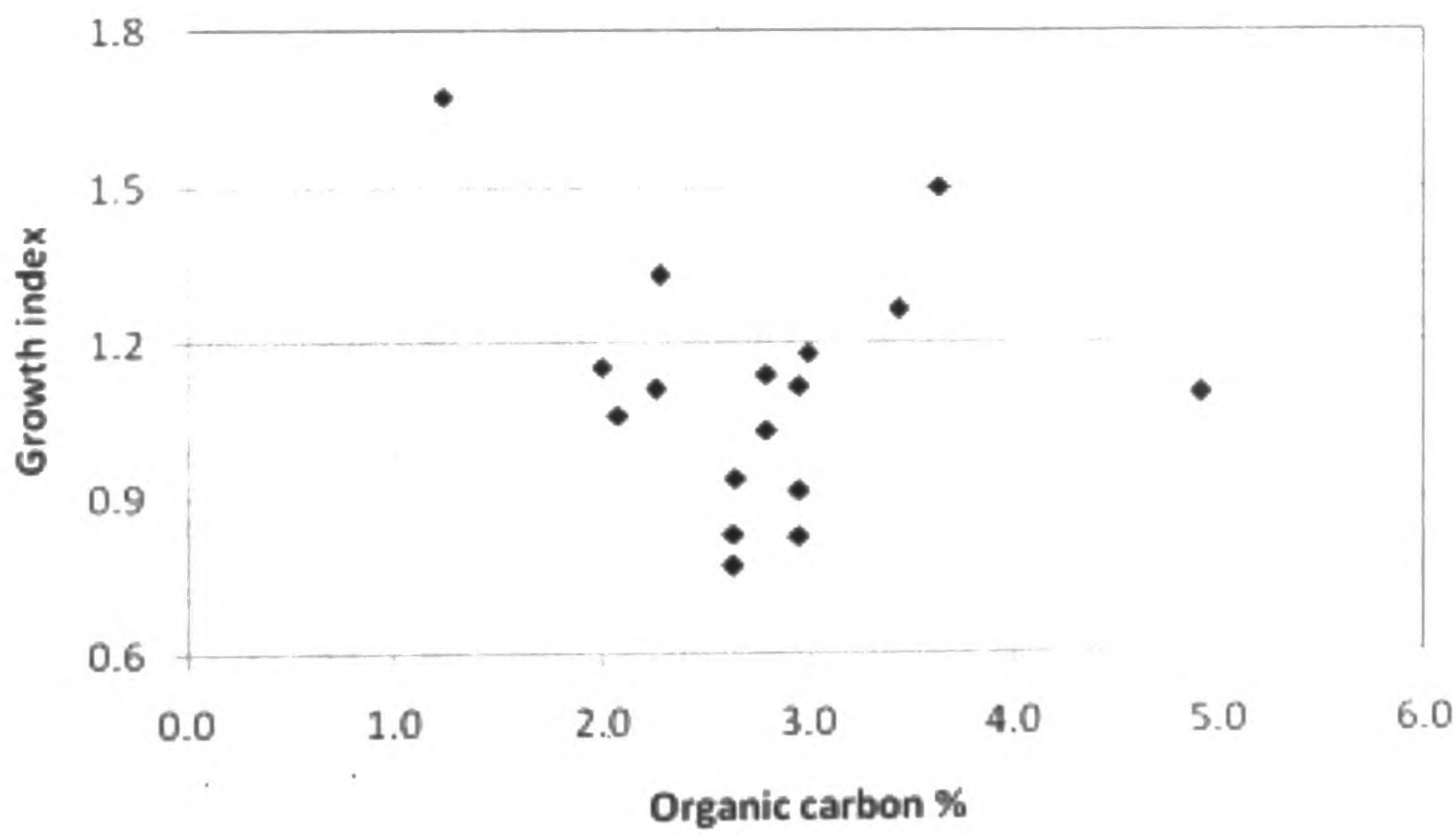

Figure 5: Growth index vs. soil organic carbon %

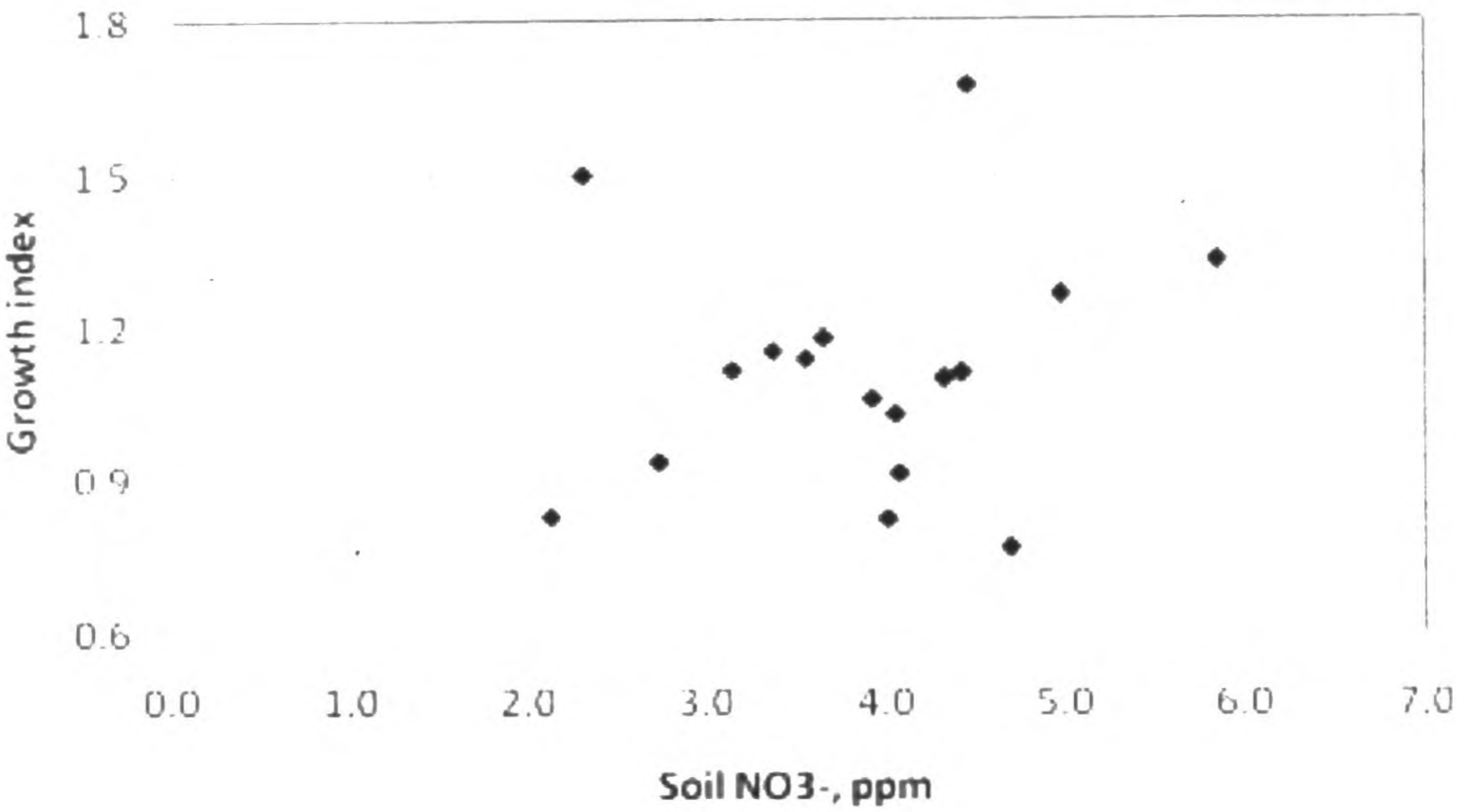

Figure 6: Growth index vs. soil nitrate

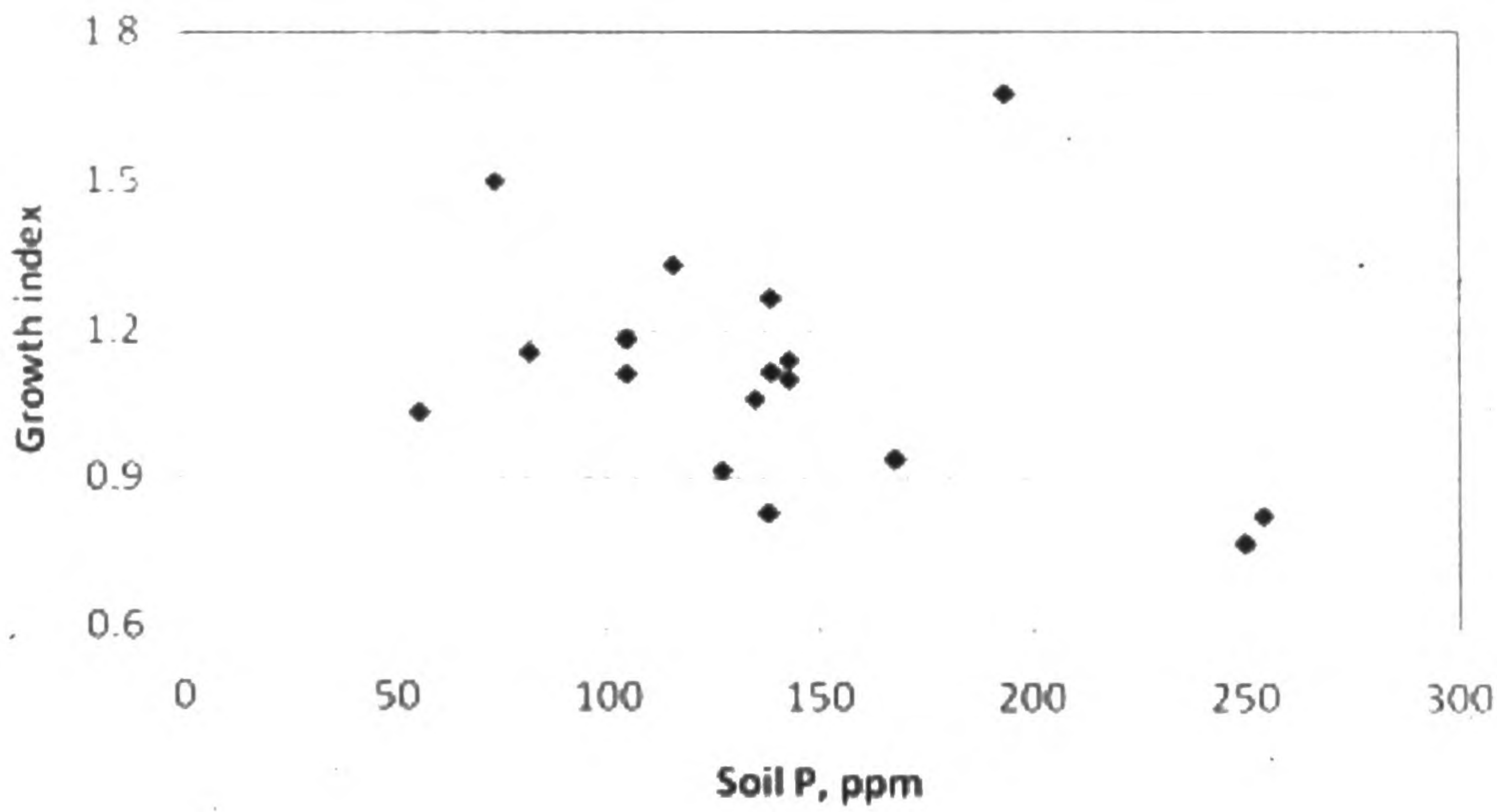

Figure 7: Growth index vs. soil phosphorus

magnesium values for those plantations were less than 5.5 ppm.

Altogether 170 famers responded to the questionnaire representing all plantations selected for the study. The current lease period of the Farmer Wood lots is 25 years. 100% of the respondents indicated that the given period is not adequate and requested to increase the period by 5 to 50 years. In addition to that, 98% of the farmers interviewed wanted to continue the Farmer Woodlot Programme for the second cycle. The reasons indicated by the rest of the 2% were lack of time to spare, less income generated by seasonal crops and need to migrate to the cities.

Frequent fire is one of the main problems in managing teak plantations under the Farmer Woodlot Programmes. The dry zone and the Galgamuwa Range of the Intermediate zone experience long dry periods and teak shed leaves at those periods. Other than 12 year old Doramadalawa plantation of Anuradhapura Range; all plantations in Kekirawa Range; Weliwewa and 9 year old Karagahawewa plantations in Tambuttegama Range; Getadivula in Kurunegala Range experienced frequent fires. The dry leaves lying on the ground catch fire easily and with the assistance of high winds, fire spread rapidly.

The most prevalent insect attacks for the teak plantations are the skeletoniser, defoliator and stem borer. Stem borer attack is common in the early ages of teak plants which may disappear with the maturity. However, skeletoniser was the commonest insect attack in the study areas. It starts spreading with the newly emerging leaves after rain periods. Although skeletoniser attack does not kill the plant, it retards the growth severely due to diminishing the ability of photosynthesis. Application of insecticides was not possible due to the height of the trees and lack of adequate finance to afford the chemicals and labour.

Lack of water for the irrigation activities was also a problem among the farmers especially for their seasonal crops. About 34 farmers had their own agro-wells or ones that can be used on shared basis. They used the water from those wells for the irrigation purposes using fuel-driven water pumps or manually. The others used only the rain water and therefore there was a risk of drying out their crops by droughts. However, none of the respondents irrigated teak plants even at the early stages.

18% of the respondents complained about wild elephant damage in their plantations. Elephant damage was common in Ulukkulama Beat of Anuradhapura Range, Kekirawa Beat of Kekirawa Range and Ambanpola Beat of Galgamuwa Range. However, there was no elephant damage when the plantations are naturalised with a thick undergrowth such as evidenced at Habarana Beat or established with a considerable amounts of neem (*Azadirachta indica*) as witnessed in Galgamuwa Beat of Galgamuwa Range.

62% of respondents indicated that they needed more technical support from the forest officers of the Sri Lanka Forest Department

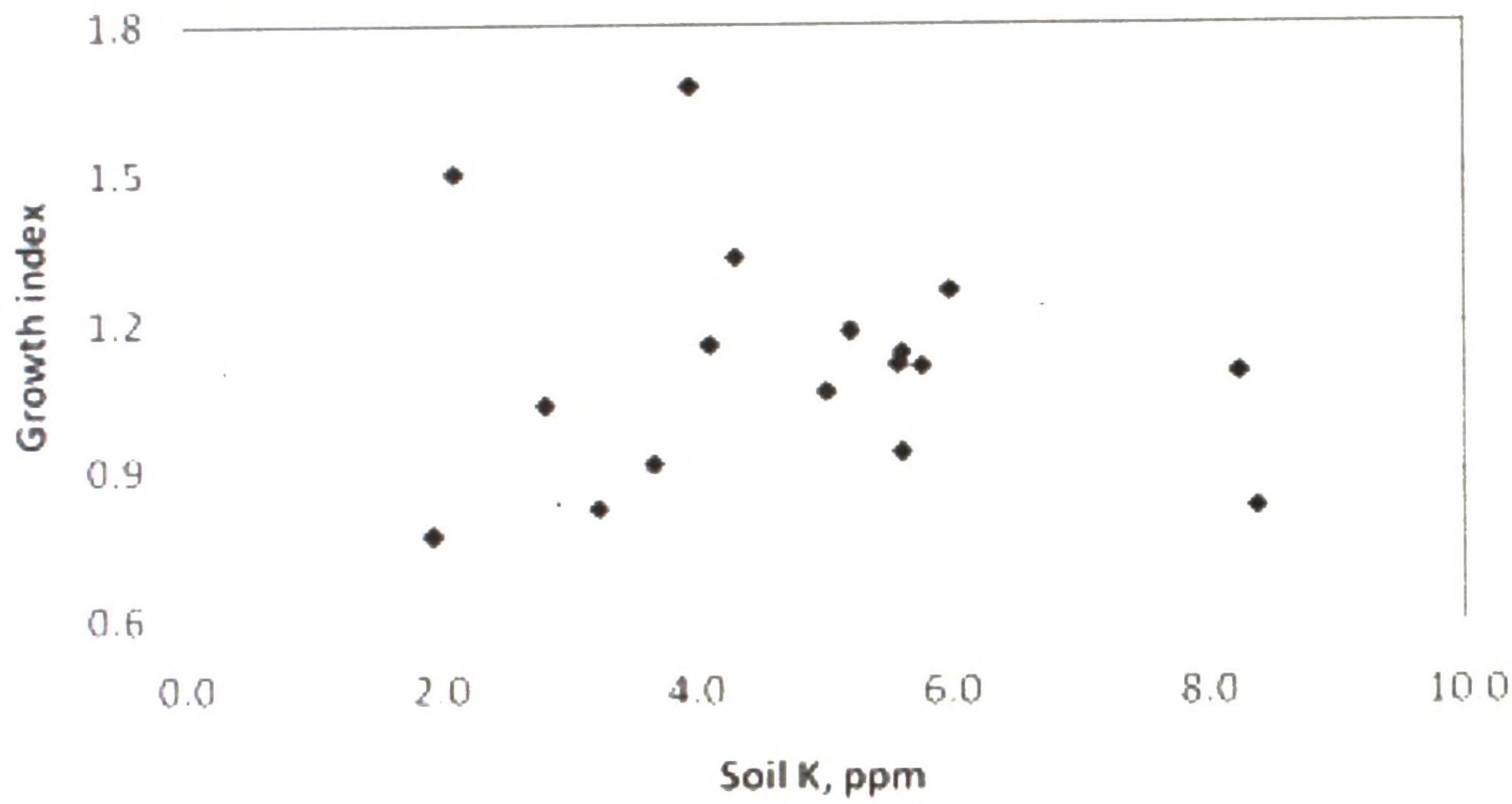

Figure 8: Growth index vs. soil potassium

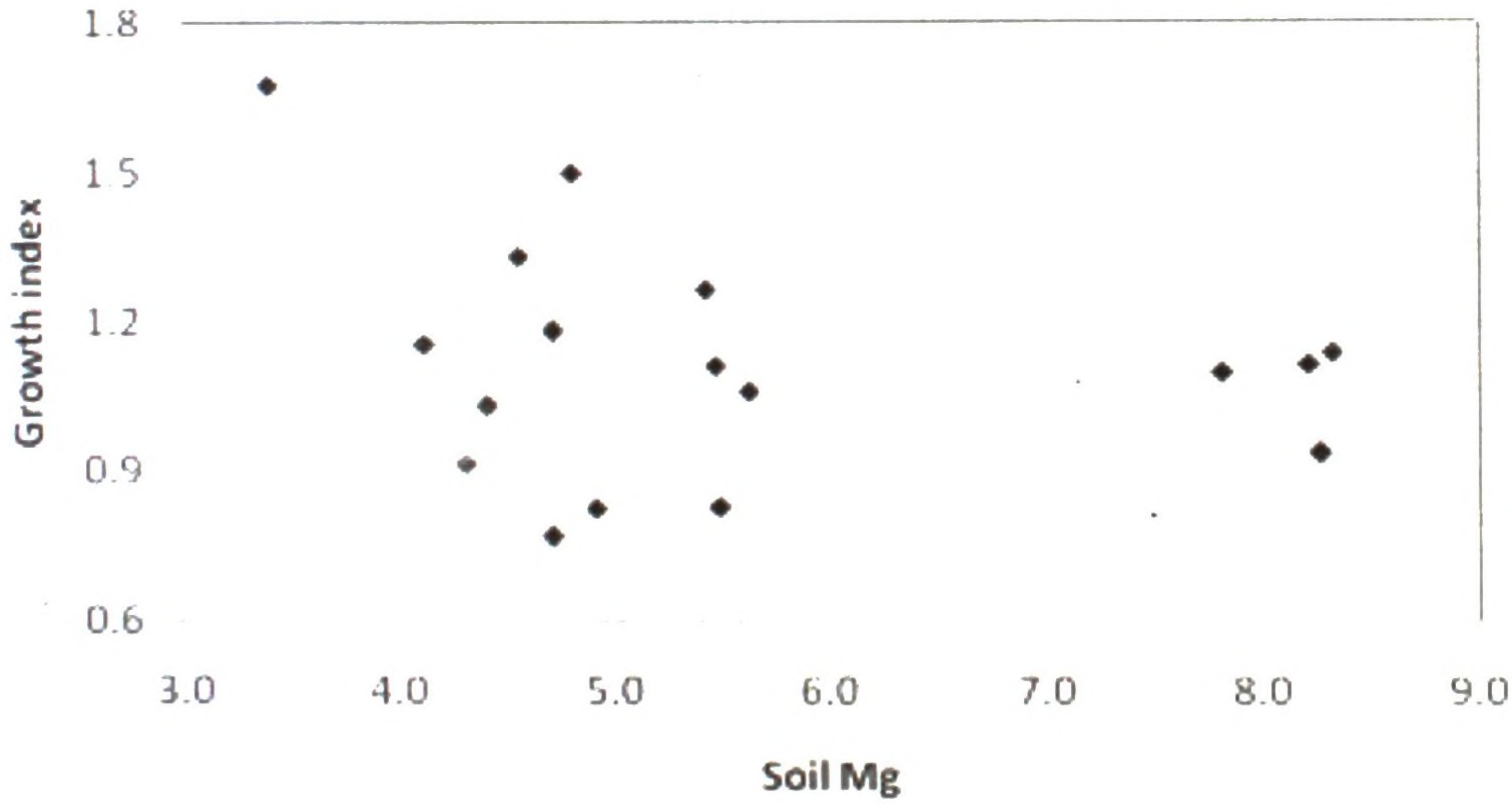

Figure 9: Growth index vs. soil magnesium

especially in the periods of pruning of teak. In the field visits, it was evidenced that improper pruning had caused stem damage. In addition to that, there were no specific plans prepared for Farmer Woodlot management. Teak yield tables are available for three classes managed as even-aged monocultures. However, the spacing and prescriptions are different in Farmer

Woodlot management and therefore it is necessary to have seperate plans for this purpose.

DISCUSSION

Growth parameters of trees such as dbh and height are correlated with the soil properties and management techniques used. According to Kubota and Hara (1996), growth dynamics of plant populations are determined not only by species specific properties, but also by biotic and abiotic factors such as neighbourhood, competition and environmental heterogeneity. Climate, physiography and soil comprise the abiotic factors that exert a significant influence on population development.

Climatic and physiographic factors can be held constant on similar geological regions and then soil properties become the major factor of the physical environment that has an appreciable bearing on the tree growth (Kubota and Hara, 1996). In accordance with this statement, some older plantations studied in this research project showed poor growth (e.g., 12 year old Doramadalawa plantation of Mihintale Beat) while some young plantations of this study showed comparatively a higher growth (e.g., 8 year old Werunkulama plantation of Kekirawa Beat). Soil nitrate was the highest in Werunkulama plantation although it was not significantly correlated with the growth index. However, that could be one reason of having a higher growth in this particular plantation. In addition to that, undisturbed plantations showed higher growths in the study sites than the sites where disturbances occurred due to fire, insects and elephant damages.

10 plantations out of 17 study sites were subjected to heavy fires. Surface fires significantly reduce carbon sequestration in forests (Tilman *et al.*, 2000). According to Reich *et al.* (2001), above ground net primary productivity of some forests is inversely correlated with the frequencies of surface fires. According to Hase and Foelster (1983), removal of teak wood during harvesting and after fire has severe impacts on soil calcium reserves. Moreover, removal of soil calcium is accompanied by decreasing soil pH and biological activities. The avoidance of mechanical site clearings and a permanent soil cover (mulch) during the site preparation and establishment of teak plantations could reduce nutrients losses caused by erosion and leaching.

If controlled burning is necessary, fires of low intensity may increase the quantities of N, P, K and Ca in the soil (Carter and Foster, 2004). However, Radke *et al.* (2001) stated that the use of controlled fire to meet the needs of forest managers is increasingly in collision with the air pollution and climate change issues. Most of Calcium absorbed by teak is stored in wood and bark and therefore it is recommended that the bark should be left in the plantation during teak harvest. The plantations where Calcium was not detected in the present study were undergone fire hazards frequently. According to farmers, most of those fires were deliberately set by them to eradicate weeds and caterpillars. They set fires after the periods in which the trees shed leaves so that, the ground fire setting becomes very easy. Otherwise the caterpillars that live on the stem would reach their homesteads and cause disturbances. However, the burning of litter may reduce the soil moisture. Under undisturbed conditions, annual litter decomposition and atmospheric nitrogen input can supply more than 70% of the nitrogen requirements of the stand. However, regular burning reduces this amount to less than 15% (Drechsel and Zech, 1994).

According to a study conducted in West Africa by Drechsel and Zech (1994) 6.4-7.4 of pH; 295-737 ppm of N; 150-160 ppm of P were required to classify a site as Class I for teak. That particular area reserves 1,200-2,400 mm annual precipitation with no more than 3 or 4 months with rainfall less than 50 mm. Climatic conditions of the above mentioned areas is much similar to that in the dry zone of Sri Lanka. The maximum nutrients recorded in the studies sites were 7.446 ppm of N; 254 ppm of P. The observed pH values were below 7.0 for all plantations. Therefore that could be one of the reasons for the sub-optimal growth recorded in the studied teak plantations managed as Farmer Woodlots.

Sri Lanka Forest Department has published three yield tables for three height classes. Only Werunkulama Plantation of Kekirawa Range recorded the total height in between height class I and II. However, most of the plantations measured had height growth between Class II and III. This indicated a poor quality soil or poor management practices. The direct observations at the field visits and the chemical analysis indicated that some lands which were given to establish Farmer Woodlots were marginal. Most of those lands indicated frequent fire and erosion for a long period of time and therefore suffer from nutrient loss.

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