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RESEARCH ARTICLE

Influence of anthropogenic activities on the initial establishment and growth rate of introduced Senna siamea in Zomba-Malosa Forest Reserve, Malawi

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Abstract:

The study was conducted along the Nkanya-Lusewa rivers catchment as hot spot in Zomba-Malosa Forest Reserve in Domasi area in Malawi to determine the influence of anthropogenic activities on the growth of Senna siamea planted by the community using integrated indigenous-technocrat model. The study focused on 28 gardens along the rivers whose owners encroached the forest reserve and willed to participate in the study. In total we planted 101 S. siamea seedlings within a distance of 10 m on either side of the study rivers and we determined tree total height, canopy height, canopy base diameter and canopy base area in February, May, August, and November in 2014 using a ruler. We found that the average tree total height and canopy height slightly decreased from February to November from initial 34.7 cm to 31.1 cm and 16.8 cm to 12.1 cm respectively due to impact of transplanting shock and bushfires which led to loss of tree tops and some branches but those of canopy base diameter and canopy base area increased slightly following sprouting of burnt seedling stems. We further found that tree growth rates varied among the gardens due to transplanting shock, post-planting care differences, soil moisture variation, and incidence of bushfires.

Keywords: Growth Rate, Tree Total Height, Canopy Height, Canopy Base Diameter, Canopy Base Area

Introduction

Survival and growth rates of trees in a forestry ecosystem are influenced by a number of factors such as moisture content, mineral levels, pH, temperature, and exposure risks to herbivores and cutting by human beings. Emphasis is rarely put on determining the survival and growth rates of trees planted in natural forests in Malawi for better evaluating the forestation strategies employed. The people in Domasi area, in Zomba district in Malawi, cultivate in marginal land and have invaded Zomba-Malosa forest reserves for cultivation and charcoal production due to the scarcity of land which emanates from high human population growth and poverty level such that survivorship of indigenous trees is very low [1]. Trees planted along Nkanya and Lusewa rivers through Southern Region Water Board (SRWB) and Water Users Association (WUA) in Domasi area have been failing to survive since 2005 but those planted by the community through integrated indigenous-technocrat approach have shown great survivorship within the first 10 months. During all forest restoration interventions, the growth rates of these trees have not been determined in the study area. The study was therefore carried out to determine the initial growth rate of the trees planted through indigenous-technocrat model for better comparison of the initial establishments of the trees planted in various places in Malawi.

Studies have revealed that weed control, irrigation, and plants' biotic responses to physical factors such as water, light and nutrients are crucial in re-establishing native trees and shrubs along rivers in the initial years [2], [3]. Some studies in tropical forest restoration have recommended protection of forest areas from fire, seed and soil degradation; allowance of natural regeneration; and enrichment planting in degraded land because species richness recovers rapidly although with quite a different composition from original forest sites [4].

Trees such as *Albizia lebbeck*, *Faidherbia albida, Acacia polyacantha,* and *Senna siamea* or *Cassia siamea* are recommended for reforestation in many areas worldwide as well as in Malawi, especially in riparian systems and in agroforestry programmes because they have multipurpose characteristics, provide quick benefit to the ecosystem and human, and have no or little negative ecological effect on the riparian system [5],[6],[7]. However, the information on the initial establishment and growth rates of these tree species in Malawian conditions is not available but in Karnataka, India, a height increment of 2.5 m per year of *S. siamea* has been recorded, and in 3 years in West Bengal, trees were almost 8 m tall with a stem girth of 25 cm [8]. In Tanzania, during trial experiments, it was found to have grown 56.1 cm in 5 months [9].

Forest Research Institute of Malawi (FRIM) has only documented the growth rates of *K. anthotheca* but not of other viable quick growing trees which can best be used to restore the area where the majority of inhabitants depend on the forest for livelihood. The preliminary study in the determination of the initial growth and performance of a two-year old *K. anthotheca* under the plantation conditions in Zomba mountain forest reserve for the first two years indicates that it is a fast growing species during its early stages of establishment with mean crown diameter of 0.49 m and height of 0.8 m, and has revealed that trees growing on deeper soils grow taller than those growing on shallow soils [10]. This implies that the type of soil and plant pit depth are very important elements in affecting growth rates of trees planted by the community in the study site.

Some researchers have investigated the tree growth parameters and have discovered that various measures of tree size and corresponding measures of growth, each display a subtly different pattern with age and size, and that diameter and height increment generally peak early in life of a tree, whereas basal area and biomass increment peak later and are small when the tree is young [11]. These researchers have indicated 20 years as an interval for comparing the measured parameters and giving generalization, but small intervals such as 3 months have not been considered in determining increments of some tree growth parameters. The linear relationship, however, has been found in some tree species between tree height and diameter at breast height, canopy width and diameter at breast height, and between canopy width and tree height [12]. Studies have also shown that the amount of twig growth is closely related to the amount of the root system that is present except for the year following transplanting when the twig growth is influenced by buds formed the year before since the roots and the top of the tree are out of balance such that the roots cannot supply sufficient water and nutrients to the upper portions of the tree for vigorous growth [13]. Research has shown that plant reserves in root system young plants to survive total defoliation from fire or grazing [14], [15] thus why the species survived better.

The amount of woody increment produced each year has been found to be dependent on proper functioning and productivity of the leaves in a crown and that the overall growth represents specific crown vigour, general tree health, relative whole tree growth rates, and crown volume. In view of this, research has been done to determine percentage increase in xylem cross-sectional area per growth increment in a year, firstly by estimating the tree main stem diameter at four and a half feet (1.37 m) above the ground (height at the breast height) [16]. A generalized growth rate has then been determined based upon the number of annual increments present in the outside inch of xylem generated. This method, however, is not considering the young trees and as such, it cannot be effectively used to estimate the seedling growth rate within a year considering the short stem height of the seedlings.

Some researchers have determined a long-term tree and seedling growth and survivorship data from permanent sample plots in a neotropical dry forest in Jamaica and these were used to model periodic annual increment at the breast height and survivorship dynamics, cluster structural and functional types, and to estimate the age of selected tropical dry forest species so these can be applied elsewhere in Jamaican region or a place with the similar conditions [17]. The research in this study area also applied some related models, although the concentration is on the height, canopy volume, and survivorship of planted trees.

Study Area

Study site

The study area is located in Domasi area in Zomba district in Malawi at the elevation from 744 m to 954 m. Domasi area lies between latitude $15^{0}16'$ S and longitude $35^{0}30'$ E. This study site is located in Mtogolo Local Forest Management Block which is a part of Zomba-Malosa Forest Reserve. The main objective of conserving this Block is to protect and conserve natural resources in order to improve livelihoods of people found in Mtogolo group village. Under Local Forest Management system, the surrounding communities have been entrusted with the responsibility of taking care of the forest block under the guidance of Zomba District Forestry office [18].

Geology of the area

Domasi area and the rivers understudy, in particular, have sandy loam soils in general but they slightly vary in the proportion of sand and humus available making them also vary in texture. Domasi area has pre-karroo igneous rocks which are composed of three main mineral complexes namely Domasi granite, found in the Domasi river valley between Domasi and Mtwiche market; biotite-microtonalite, which has a little less Fe_2O_3, MgO and CaO and rather more than twice as much K_2O and P_2O_5 and is a basic contaminate of the Domasi granite and microgranites as evident in the Domasi river near Domasi prison [19].

Rainfall and Agriculture

The main crop cultivated in this encroached forest reserved is maize which is the staple food. The agrochemicals applied to maize may have an impact on the nutrient concentrations along the rivers and in off-river gardens. Several reports describe the climatic pattern experienced in Zomba [20], [21]. The reports point out that Zomba experiences a tropical climate with three main seasons: cold-dry, hot-dry and hot-wet with the mean annual temperature of 22.5^{o}C. The hottest months are September to November with the mean day temperatures of 28^{o}C to 30^{o}C while June and July are the coldest months with the mean day temperatures of 10^{o}C to 12^{o}C. The rainy season is from November to April with continuation in form of light cold showers from end-May to July while the dry season is from May to October. The average annual rainfall in Zomba ranges from 800 mm to 1,200 mm while in Domasi, in winter there is much less rainfall than in summer with an average of 1218 mm per annum and the day temperature averages 22.0 °C.

Methodology

Research Design

In this study, we used quantitative designs, block design, and natural snapshot experiments. The research was based on natural snapshot experiments coupled with plant growth observation and full community involvement in providing ideas and tree management. The block design was also used to compare variations in tree growth parameters within and amongst the blocks (garden part) along the rivers. Figure 1 below shows the villages and gardens (study plot) illegally opened in the forest reserve where the study took place. The green color in the figure indicates part of the forest reserve while the red points with letters indicate the study gardens.

Procedures

i) Tree planting

For effective implementation of the plants, we involved different stakeholders including garden owners who encroached the forest reserve in tree planting exercise where 101 *Senna siamea* seedlings were planted in 20 gardens (plots) along Nkanya-Lusewa rivers in February 2014, as shown in Figure 1 with alphabetical letters. The seedlings were planted within a width of 10 m on either side of the river bank taken as a buffer zone. The number of seedlings planted in each garden ranged from 3 to 9 depending on the size of the garden portion under study (block) and the choice of garden owners. Five (5) seedlings were planted in each of 9 gardens, 4 seedlings in 4 gardens, 6 seedlings in 1 garden, 7 seedlings in 2 gardens, 3 seedlings in 1 garden, and 8 seedlings in 1 garden.

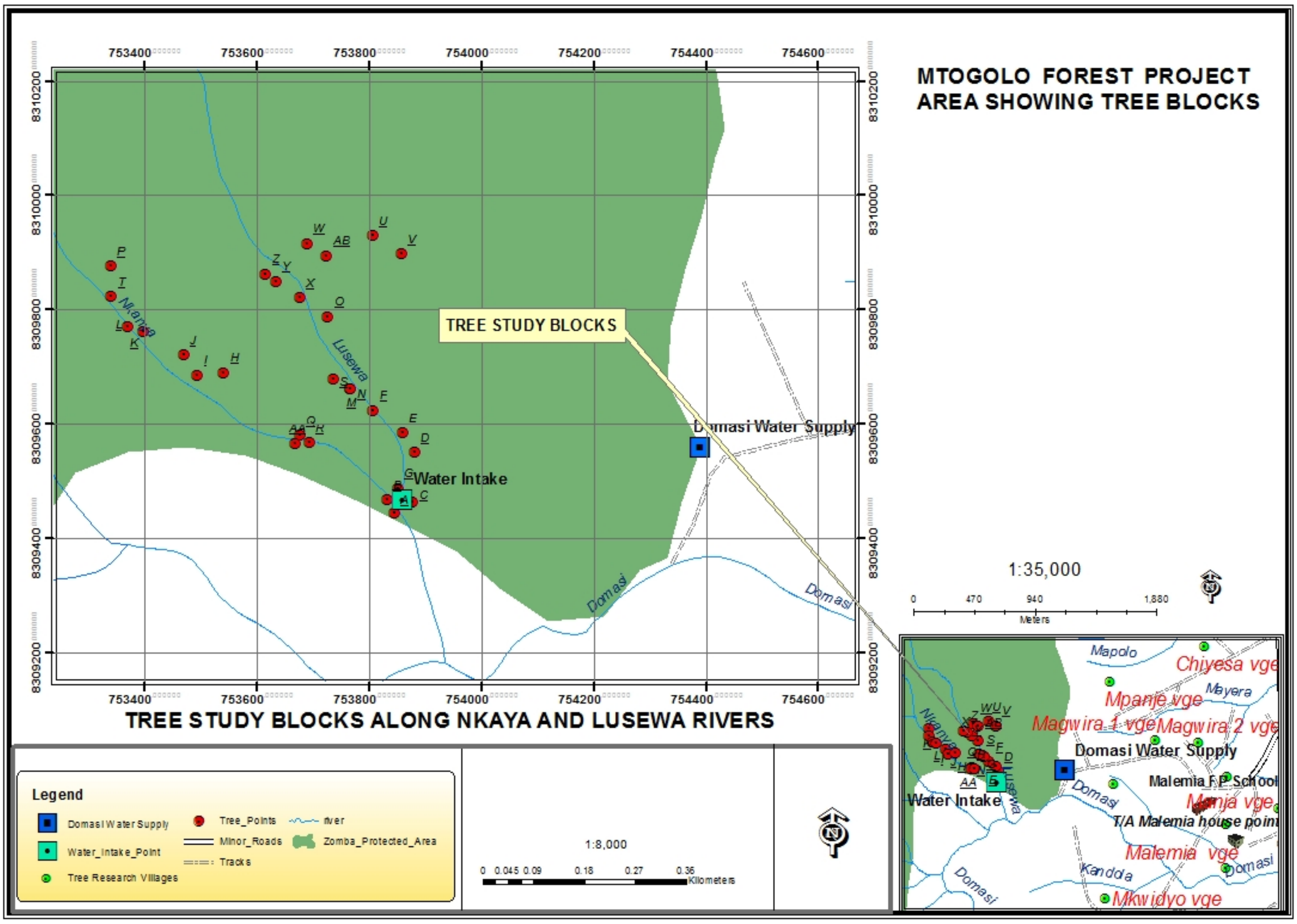

Figure 1: Drawing showing study blocks (part of garden) along Nkanya and Lusewa rivers(Source: Moyo G.G, Chikuni, M. andChiotha,S in International Journal of Environmental Science and Development)

ii) Determination of the growth rate of planted trees

We measured and calculated the tree total height, canopy height, canopy (crown) base diameter, and canopy (crown) base area of the tagged trees every three months for one year commencing on the fifth day after planting to allow time for the seedlings to adapt to the new conditions and develop initial structures. These quantitative measurements are needed as they provide useful insights into the biology of plants, and act as projectors of individual tree growth rate, timber production, and extent of ground cover. These parameters are of interest because they also determine plant physiognomy and nature of animal habitat in a forest. We further asked garden owners under study to state the type of fertilizer they applied in their gardens each year of the two consecutive years of the study because these agrochemicals may also contribute to the variations in growth rates of plants amongst the study blocks (gardens).

Tree total height and canopy height: We measured tree total height using a foldable 2 m-ruler from the stem base in contact with soil up to the last node at the stem apex (excluding the apical bud and leaf primordia). Apical bud and leaf primordia were excluded because they are easily broken by external environmental forces. In order to find canopy height, the same ruler was placed along the stem from lowest branch to the last node at the stem apex. In a seedling where the lowest branch was not available or any branch was not present, the lowest axillary bud was taken as the lowest branch.

Crown base area: We also used the ruler to measure the base diameter where both the Cross-method and Spoke-method were used to calculate crown base area depending on the shape of the crown. We firstly identified the crown shape, the longest spread and the longest cross-spread before taking measurements. The formula was subsequently used to calculate the assumed circular crown base area of each planted tree.

Cross-method: Firstly we measured the horizontal distance along the longest axis of the crown base from one edge to the opposite edge (the longest spread from edge to edge across the crown) and then we measured the longest spread perpendicular to the first cross-section through the central mass of the crown. The two values were then averaged to find the average crown base diameter (average crown spread) whose radius was then used to calculate the crown base area. This method was used where the trees had only a few, mostly opposite branches or the crown had elliptical base shape. Average crown spread= (longest spread + longest cross-spread)/2, Radius= Average crown spread/2.

Spoke-method: In this method, we took four or more measurements from the outer edge of the crown (branch tip) to the side edge of the trunk. The distance to the side edge of the trunk was for all practical purposes equal in length to the distance to the centre of the trunk. These individual spoke lengths were then averaged and were taken to be equal to the half the average crown spread (radius). We then used this radius to calculate the crown base area. Average crown spread =2 (Sum of spoke lengths/number of spokes). Radius = Average crown spread/2 = (Sum of spoke lengths/number of spokes).

Data Analysis

We analyzed data using SPSS and Excel computer packages to come up with the conclusion. Analysis of Variance (ANOVA) was used to calculate variations in growth parameters existing among study plots and within a year.

Results and Discussion

We found that in the 10 months study period, from February to November, *S. seamea* planted in the study site had the mean tree total height of 31.1 cm, canopy height of 14.7 cm, canopy base diameter of 30.0 cm, and the mean base area of 704.9 cm^2. The tree total heights, for instance, were relatively much below those recorded in India and Tanzania where plants were grown under optimum human care. We observed that the average tree total height increased from February to May by 1.3 cm indicating absence or insignificant presence of growth disturbance regimes but then it was observed to have dropped during third and fourth readings, that is 7 months after planting, in August and November respectively by 3.6 cm showing presence of artificial disturbance regimes such as bushfires which damaged the stem tips (Figures 2 and 6). The graphs for the species show that average total tree height dropped from initial 34.7 cm in February to 31.1 cm in November because the tree apex had withered thereby forming new shoot below whose tip was then taken as a new apex. The decrease in height between August and November was greater than that between May and August because severe fires were set in the forest in August and September. Despite the incidence of various disturbance regimes, we found that the general decrease in height for the whole period was insignificant. Similarly, average canopy height decreased between February and May by 4.7 cm from initial height of 16.8 cm to 12.1 cm but the canopy height started increasing up to November (Figures 3 and 6) because of the sprouting of the seedlings which had been burnt by bushfires although on overall the canopy height from February to November was reduced by 2.1 cm. This drop was mainly due to bushfire, and drastic reduction in both root generation and shoot growth following transplanting shock which resulted in the original tree apex withering and the original base branches or leaves dropping. Consequently, new tips sprouted below the original apex and new branches or leaves grew slightly above the original position on the stem.

The average canopy base diameter of seedlings on the other hand, had shown great increment by 22.0 cm from February to November and consequently the same growth pattern therefore followed for a canopy base area (Figures 4, 5 and 6) due to the spread of the sprouting seedling branches as a recovery phenomenon from fire stress although a significant drop was recorded in August. Variations in growth rates of different parameters were observed in different study plots (gardens) because of variations in exposure to bushfire intensities, plant care, soil moisture, and soil nutrient quantities. Weeding and irrigation are seldom done in public forests in Domasi area and other areas in Malawi thereby leading to great loss of seedlings. We observed that 12 farmers weeded around the planted seedlings before or soon after crop harvesting. In gardens where weeding was not done around the seedlings and in very bushy gardens with partial weeding, the severe fire was discovered to have heavily damaged the seedlings such that most trees instantly died while some sprouted again. These bushfires are yearly set in the forest reserve mainly by mice and hares hunters.

The highest mortality of *S. siamea* within three months was recorded in May mainly due to transplanting root shocks, seconded by that recorded in November. *S. siamea* seedlings cannot withstand prolonged drought and subjection to fire although it has been known to have the capability of growing under a wide variety of climatic conditions ranging from humid to arid [22]. In its natural habitat, its optimum mean annual temperature is within 20-28°C, and it prefers moist soils with good drainage and a soil pH of 5.5-7.5 [23], [24]. In our study, we also observed that seedlings planted in spots with high water content grew relatively taller than those planted in dry spots and that some trees dried up because they were planted relatively away from the water course in some gardens. We further observed that the majority of the farmers (26 out of 28) applied same type of fertilizers (a combination of 23:21:0+S and Urea in each garden) except 2 farmers who applied a combination of goat manure and urea to their maize as such, the agrochemicals may not have a significant effect on tree growth variations among and within the study gardens. Therefore based on the results, it implies that human beings have a great influence on the growth of the *S. siamea* planted in the public forest reserve through plant care, choice of planting station and avoidance malpractices such as bushfires.

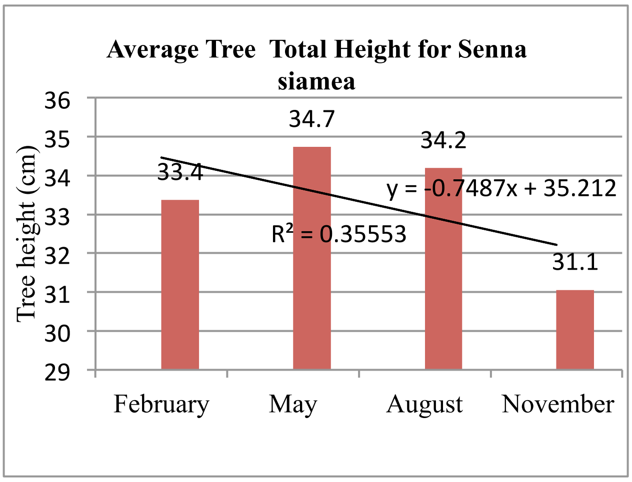

Figure 2: Average tree total height in 20 study plots

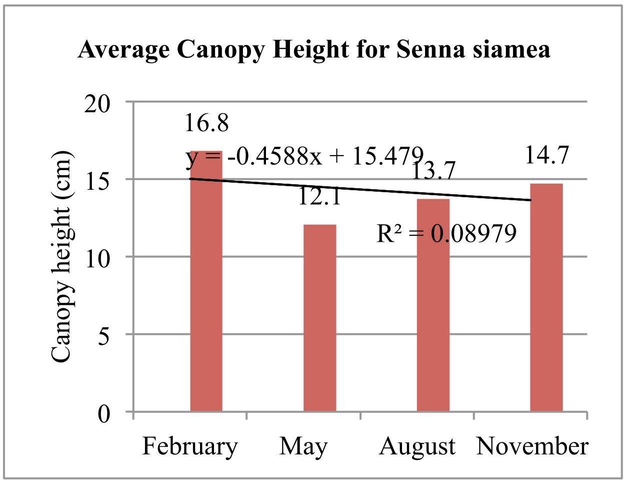

Figure 3: Average canopy height in 20 study plots

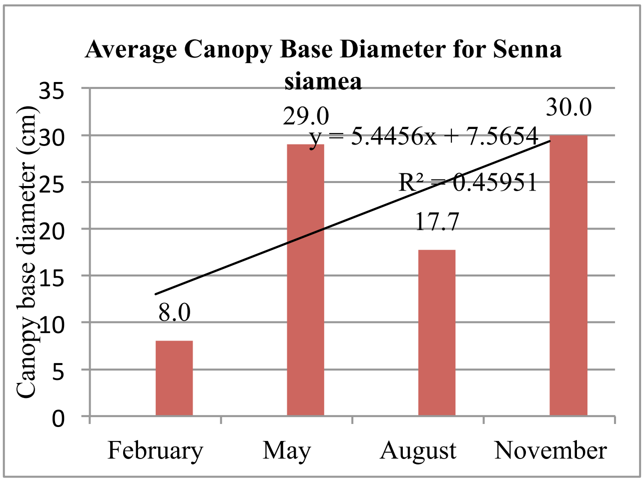

Figure 4: Average canopy base diameter in 20 study plots

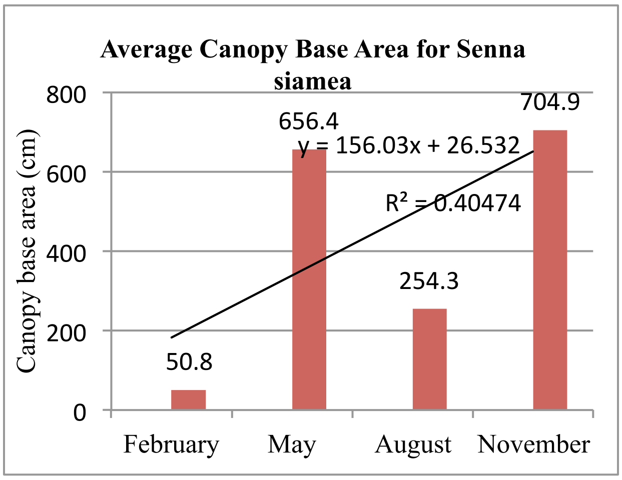

Figure 5: Average canopy base area in 20 study plots

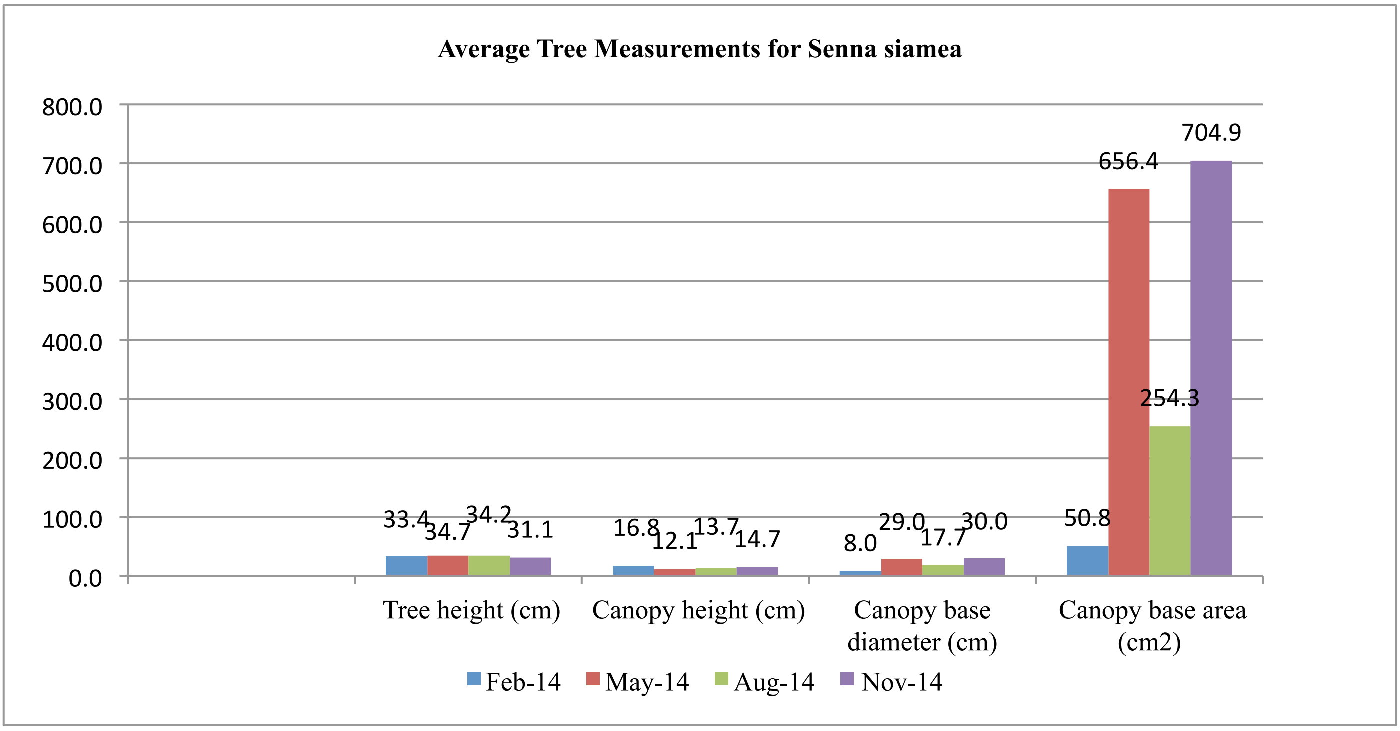

Figure 6: A summary of average tree height, canopy height, canopy base diameter and canopy base area in 20 study plots

Conclusion

We found that the average tree total height and canopy height slightly decreased from February to November but those of canopy base diameter and canopy base area increased slightly during 10 months of study period. The death of most seedlings were related to human activities such as harmful bushfires set to clear land for easy mice and hares hunting which was exacerbated by transplanting shock and failure of garden owners to properly take care of planted seedlings through weeding. We further found that tree growth rates varied among the gardens due to transplanting shock, post-planting care differences, soil moisture variation, and incidence of bushfires. Therefore human care is vital for the establishment and proper growth of *S. siamea* like other plant species planted or naturally growing in the public forest reserves.

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