

EFFECT OF ELEVATION, SLOPE AND ASPECT ON THE HEIGHT AND DIAMETER GROWTH OF *ACACIA AURICULIFORMIS* IN A DEGRADED HILLY AREA OF BANGLADESH

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Abstract: *Acacia auriculiformis*, a fast growing and hardy leguminous tree species, has widely been planted to rehabilitate degraded hills in Bangladesh. In this study the effect of elevation, slope and aspect on the growth of *A. auriculiformis* is evaluated. Data were collected from the plantations on the hills in Chittagong University campus. It was observed that height and diameter growth diminished significantly with the increase in elevation and slope. However, variation in aspect did not have significant impact on growth. Simple linear and logarithmic models were developed to predict the height and diameter growth against elevation and slope.

Keywords: *Acacia auriculiformis*; Elevation; Slope; Aspect; Growth; Rehabilitation; Degraded hill; Multipurpose tree.

Introduction

Acacia auriculiformis is a fast growing, multi-purpose and leguminous tree species. Because of its ability to grow on a wide range of soil, tolerance to environmental stresses (Davidson, 1985) and ease of propagation (Davidson, 1985; Das, 1986; Kamaluddin *et al.*, 1998), the species has widely been cultivated to rehabilitate degraded land (Davidson, 1985), mine spoiled area (Rodrigues, 1997; Bhowmik *et al.*, 1996), *Imperata cylindrica* grasslands (Otsamo *et al.*, 1997), fly ash dump-yards (Shyam and Lal, 1996), usar soils (Chaturvedi and Behl, 1996) and saline vertisols (Patil *et al.*, 1996). Nitrogen fixing ability and comparatively rapid decomposition of its litter made the species suitable for various agroforestry systems (Zakra *et al.*, 1996; Masutha *et al.*, 1997; Nayak and Senapati, 1997) and to regenerate exhausted soils (Versteeg *et al.*, 1998). As a source of timber, pulpwood, high quality fuelwood and fodder (Davidson, 1985) this fast growing species has become a very important component of afforestation programmes in many countries. Exploiting its potential for lac culture (Remadevi *et al.*, 1997) can further enhance the contribution of the species in the rural economy.

The species has widely been planted through out Bangladesh. It has been planted both in social forestry programmes on marginal lands (e.g., roadsides) and in large commercial plantations in the hilly regions of Chittagong and Sylhet civil divisions. However, for commercial success and sustained yield management of the species, it is important to develop successful growth models for

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different site conditions. In India Anil *et al.* (1998), Datta (1997) and Sahoo *et al.* (1996) have developed biomass production model for *A. auriculiformis* considering the growth contributing characteristics (height, diameter, girth, etc.) as independent variables. In Thailand, Janmahasatien *et al.* (1996) incorporated soil and climate data in their model for *A. auriculiformis* to provide information on site-species suitability and productivity of the species in a particular site condition.

It is recognized that topographic factors (elevation, slope and aspect) have significant influence on the growth of plants (Monserud and Sterba, 1996; Fonweban and Houllier, 1995; Chen and Wang, 1987). Thus, this study was undertaken to investigate the effect of elevation, slope and aspect on the growth of *A. auriculiformis* and develop regression models for height and diameter growth for those topographic factors.

Materials and Methods

Study area: Chittagong University campus (20°30' N and 90°50' E approximately) is a 515.58 ha hilly area in Chittagong district. The hills are 20 - 25 m tall (from their bases) with slopes ranging between 35% and 62% (Temu *et al.*, 1989). Soil in this area is inceptisols, well-drained and moderately textured sandy loam and acidic in reaction (Anon, 1979). The general climate is of tropical monsoon type with a short and dry winter. Mean annual rainfall is about 3000 mm but due to uneven distribution, a 3 - 4 months drought period is experienced (Fig. 1.). Due to proximity to the human habitation, the area has been subjected to severe human interference. Original dipterocarp vegetation had been completely replaced by secondary vegetation mostly of thatching grasses, bushes of herbs and a few scattered trees. Local people utilize this land for pasture and collection of fuelwood. Block plantations of *A. auriculiformis* along with another 28 species have been established in Chittagong University campus since 1973.

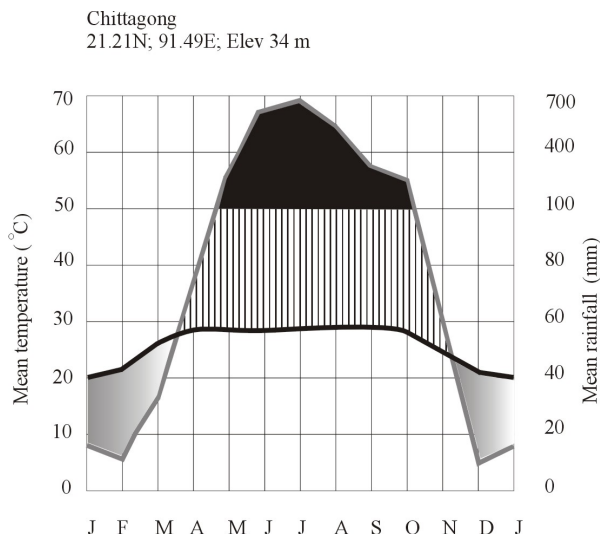


Fig. 1. Climate map for Chittagong region (based on FAO, 1987).

Method of Sampling and Tree Measurement: Data were collected from one to nine year old, randomly selected pure *A. auriculiformis* stands on four sites (i.e., four replications). In each selected stand line sampling (across the contour) was carried out. Total height and diameter at

breast height (DBH; to the nearest cm) of all trees in a sample line were measured. Graduated poles and Spigel Relascope were used to measure the height of smaller and taller trees respectively. DBH was measured with a diameter tape. While measuring a tree, its elevation (vertical distance from the base of the hill), slope (%) and aspect were recorded. For determining slope and aspect Suunto Clinometer and Compass were used.

Data Collation: Data from all the rows were pooled together and trees were classified according to three elevation and slope (%) categories and aspects. Elevation categories were bottom hill (up to 5 m), middle hill (5 - 15 m), and top hill (15 - 25 m). Slope categories were Level one (25% - 34%), Level two (35% - 44%), and Level three (45% - 54%). Aspects considered were North (N), South (S), East (E) and West (W). Age of the stands was recorded from plantation journals. The Mean Annual Height Increment (MAHI in m) and Mean Annual Diameter Increment (MADI in cm) were calculated. Variance analysis (ANOVA) was carried out for MAHI and MADI against elevation and slope. Simple linear and logarithmic regression models were developed to predict height and diameter growth at various elevations and slopes.

Results and Discussions

Effect of Elevation on Height and Diameter Increment: Data revealed a significant negative impact of elevation on height and diameter growth ($F_{2,9} = 493.88, P < 0.05$ and $F_{2,9} = 232.12, P < 0.05$ respectively; Fig. 2).

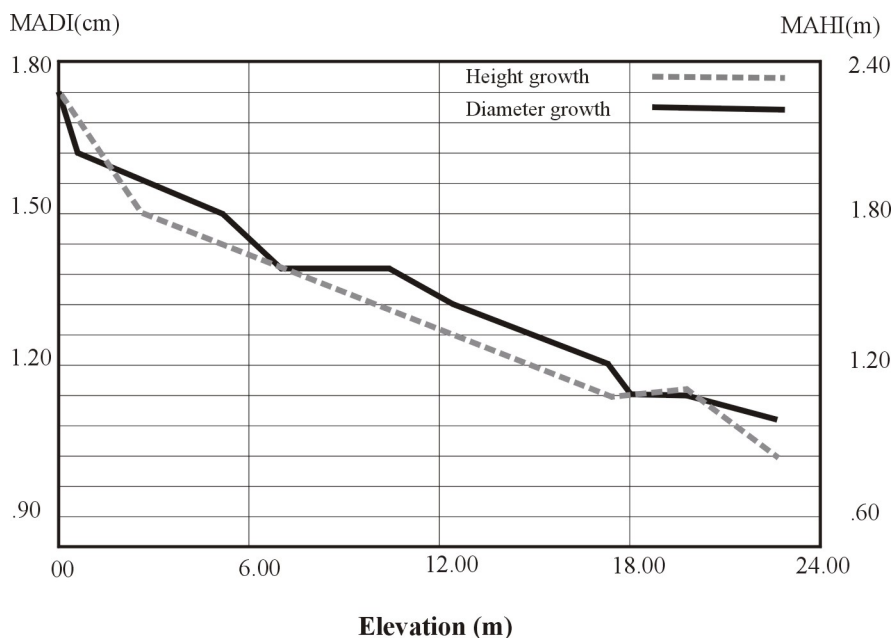


Fig. 2. Effect of elevation on height and diameter growth of *A. auriculiformis*.

Similar studies for *A. auriculiformis* for a comparison could not be traced. However, a significant effect of elevation on the growth of other tree has been reported by Chen and Wang (1987), Temu *et al.* (1989), Hairston and Grigal (1994), Fonweban and Houllier (1995), Garkoti (1995) and Monserud and Sterba (1996). Joshi (1984) had similar observation with bamboo. In the same study

area Temu *et al.* (1989) had similar observation with *Dipterocarpus turbinatus*, *Artocarpus chaplasha* and *Cassia siamea*. They opined that lowering of water table and nutrient leaching could be the causes for such reduced growth at higher elevations. A significant negative relationship between elevation and the availability of soil water (Hairston and Grigal, 1994) and lower humus biological activity (Bernier, 1996) is reported. Mudrick *et al.* (1994) observed a variation in the rate of leaf litter decomposition with elevation which was lowest on the mid slope. Hees *et al.* (1984) opined that an increasing elevation could cause decrease in soil quality and Bernier (1996) maintained that this indicates a decrease in soil productivity.

Effect of Slope on Height and Diameter Increment: Data revealed a significant negative impact of slope on the height and diameter increment ($F_{2,9} = 592.33$, $P < 0.05$ and $F_{2,9} = 133.97$, $P < 0.05$ respectively; Fig. 3). Slope has been recognized as a major determinant of plant growth by Keenan and Candy (1983), Shao (1983), Chen and Wang (1987), Soerianegara and Mansuri (1994), Fonweban and Houllier (1995), and Monserud and Sterba (1996). Joshi (1984) observed a significant negative co-relation between slope and the growth of bamboo. Hees *et al.* (1984) opine that as the soil drainage increases with increasing slope, the climate (microclimate) become harsher and soils become thinner.

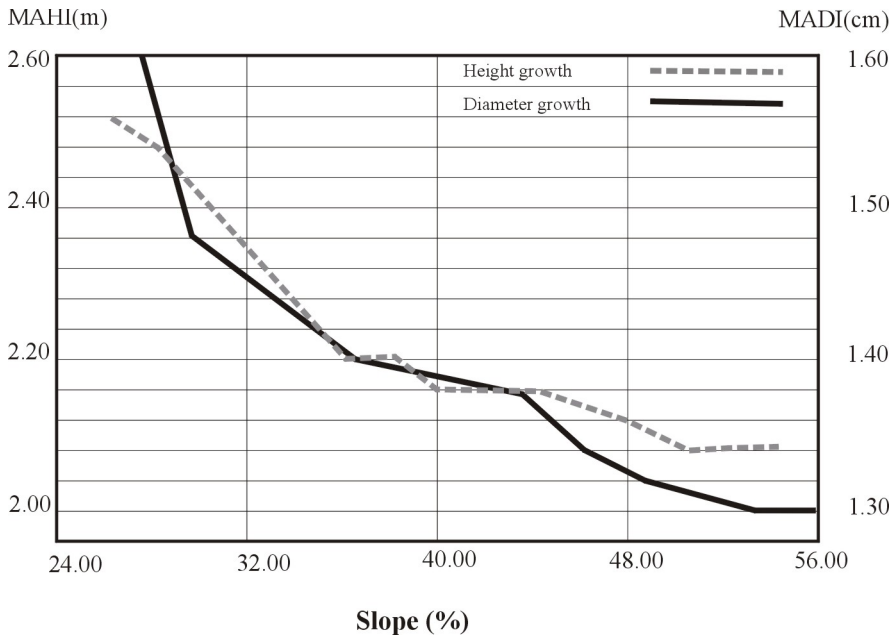


Fig. 3. Effect of slope on height and diameter growth of *A. auriculiformis*.

Effect of Aspect on Height and Diameter Increment: Data revealed a very weak relationship between aspect and growth (Fig. 4). The impact of aspect on height was significant ($F_{3,12} = 11.99$, $P < 0.05$) but it was insignificant for diameter increment ($F_{3,12} = 3.82$, $P < 0.05$). Aspect is considered as a significant determinant of growth by Shao (1983), Joshi (1984), Sarma *et al.* (1985), Chen and Wang (1987), Verbyla and Fisher (1989), Saseendran *et al.* (1993), Hairston and Grigal (1994), Brunori *et al.* (1995), Fonweban and Houllier (1995), Rolland *et al.* (1995) and Monserud and Sterba (1996). It also affects species distribution (Rajwar, 1988; Rolland *et al.*, 1995).

Most site quality models assume N-E facing slopes as the optimal aspect for forest growth in the northern hemisphere but it might vary with elevation and/or season of growth (Verbyla and Fisher, 1989). It is observed that in hilly areas the distribution of organic matter and nitrogen is strongly related with aspect (Hairston and Grigal, 1994). Probably due to the occurrence of warmer air and soil temperature (Sarma *et al.*, 1985; Verbyla and Fisher, 1989; Saseendran *et al.*, 1993) and a prolonged growing season on northern aspect slopes (Verbyla and Fisher, 1989) there are greater biological activities and faster leaf litter decomposition (Mudrick *et al.*, 1994) and more developed (Sarma *et al.*, 1985) and richer (Baduni and Sharma, 1996) soil. Thus, plant growth is usually higher on the northern aspect (Joshi, 1984; Sarma *et al.*, 1985; Saseendran *et al.*, 1993; Brunori *et al.*, 1995). A weak relationship between the growth of *A. auriculiformis* and aspect observed in this study is probably due to the fact that smaller height of the hills (20-25 m) and gentle slope (35%-62%) minimized the effect of aspect.

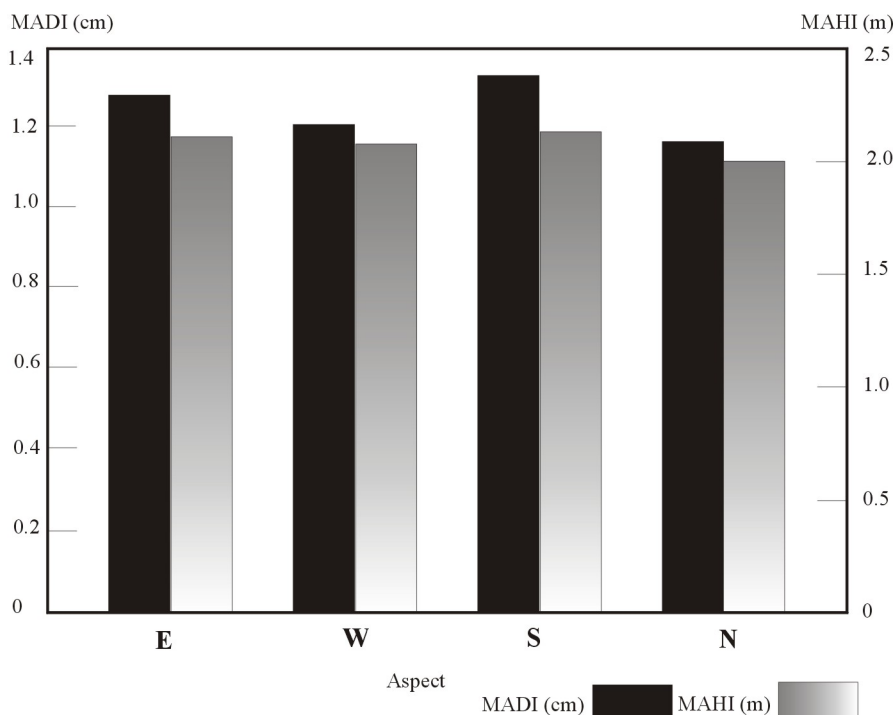


Fig. 4. Effect of aspect on the height and diameter growth of *A. auriculiformis*.

Regression Models: (I) Regression model for estimating height and diameter growth against elevation:

- ❑ Simple Linear models:
 - MAHI = 2.03 - 0.0515 * el; S = 0.1365; R² = 90.5%
 - MADI = 1.65 - 0.0262 * el; S = 0.0455; R² = 95.7%
- ❑ Logarithmic models:
 - LogH = 0.665 - 0.176 * Log el; S = 0.0832; R² = 91.6%
 - LogD = 0.469 - 0.0942 * Log el; S = 0.0577; R² = 86.6%

(ii) Regression models for height and diameter growth against slope:

- Simple Linear models:
MAHI = $3.34 - 0.024 * sl$ (%); S = 0.0839; $R^2 = 91.3\%$
MADI = $1.79 - 0.0093 * sl$ (%); S = 0.041; $R^2 = 86.8\%$
- Logarithmic models:
LogH = $2.35 - 0.0408 * \text{Log } sl$; S = 0.3126; $R^2 = 93.2\%$
LogD = $1.33 - 0.268 * \text{Log } sl$; S = 0.02081; $R^2 = 93.1\%$

Where, MAHI = Mean Annual Height Increment (in m)
MADI = Mean Annual Diameter Increment (in cm)
S = Standard error of estimates
 R^2 = Coefficient of determination
el = Elevation (in m) and
sl = Slope (%)

In this study the values of R^2 reveal that elevation and slope, independent variables of the models explain almost the total variation. It is also evident that, height and diameter growth of *A. auriculiformis* varied predictably with elevation and slope.

For predicting height growth of *A. auriculiformis* against varying elevation, logarithmic regression model appears to be better suited since the value of R^2 is higher and standard error of estimate is smaller than those in simple linear model. For predicting diameter growth simple linear model appears to be better on the same ground. For predicting height growth of *A. auriculiformis* against varying slope, simple linear model appears to be better suited. Though in logarithmic regression model the effect of slope was better represented, standard error of estimate was almost four folds of that in simple linear model. The diameter growth against varying slope could be better predicted with logarithmic model since it better represented the effect of slope and standard error of estimate was lower than that in simple linear model.

Similar study on *A. auriculiformis* for a comparison could not be traced. However, Sahoo *et al.* (1996) observed that biomass production of the species was best predicted by equations based on non-logarithmic function of height. Simple Linear Regression models based on only one independent variable, are effective in predicting height and diameter increment and biomass production. However, to make a model more effective in selecting appropriate species for particular areas and to predict performance of the species data on climate, soil, etc. need to be incorporated (as in Janmahasatien *et al.*, 1996). Thus, a Multiple Linear Regression model would be more appropriate.

Conclusion

In this study the effect of elevation, slope and aspect on the growth of *A. auriculiformis* was evaluated. It was observed that elevation and slope had highly significant negative impact on height and diameter growth of the species. The equations developed for the prediction of height and diameter growth based on elevation and slope revealed that these independent variable were representing almost total variation in growth. Findings of this study might be extrapolated for similar site condition with caution. This study may supplement other experiments regarding the growth of *A. auriculiformis* and benefit people who are engaged in the management of the species.

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