Ecosystems & Development Journal 4(2): 20-27
April 2014 ISSN 2012-3612

Site Suitability for Bagras *(Eucalyptus deglupta* Blume*)* under Banana Plantation Boundary Planting in Northern Mindanao, Philippines

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ABSTRACT

The growth and development of bagras (Eucalyptus deglupta Blume) established along the boundary of banana plantations were measured and soil samples were collected to develop site index model and determine growth rate under banana-based boundary planting. Multiple linear regression analysis was used to develop growth prediction model using data from 24 temporary sample plots. Even though aspect is weakly and negatively correlated with total height (TH), this factor passed all the statistical tests and was included in the species' growth model expressed in the form LogTotal Height (TH) = -16.07 + 0.55(LogAge) + 0.92(LogpH) + 2.81(LogAspect) R^2=0.90. The model showed that N 44^0 59' W to due W (ASPC = 270) facing plantation, with soil pH = 4.30 attained a TH of 2.70 m at 1 year and 3.90 m when soil pH = 6.30. The predicted mean annual TH growth rate is 0.60 m, which ranged from 0.37 to 1.13 m. Plantations oriented due North to N 45^0 W (ASPC=315) reached a TH of 4.20 (pH = 4.30) to 6 m (pH = 6.30) at year 1. At year 21, TH was predicted to reach 31.90 m at pH = 6.30 but only 22.40 m at pH = 4.30. Results indicate that establishing boundary planting with bagras in banana plantation should be directed due W to N 45^0 W and in non-acidic soil.

Keywords: *Site suitability, boundary planting, bagras, agroforestry systems*

INTRODUCTION

In northern Mindanao, the use of agroforestry was spurred by the local people's growing awareness of the effect of soil erosion on farm productivity. The farmers of Claveria, Misamis Oriental, Philippines were aware of the reasons for declining crop yields in sloping areas. Both the Department of Agriculture (DA) and Department of Environment and Natural Resources (DENR) have been promoting selected agroforestry systems since the early 1980s to address unsustainable crop production in the uplands.

As a result of collaborative research and development projects among various research institutions, the academe, government agencies, private sector, and people's organizations (POs), different forms of agroforestry systems were established in upland farms of Northern Mindanao. Presently, the conversion of grassland areas into agroforestry is taking place at a fast rate, triggered by interacting factors of rapidly increasing population, system of landholdings, scarcity of jobs, and declining arable areas in the lowlands (Magcale-Macandog *et al.* n.d).

Bagras (Eucalyptus deglupta) has been used as an agroforestry tree species since 1983. Peñafiel and Bautista (1987) reported the successful establishment of bagras in grasslands dominated by wildcane (*Saccharum spontaneum)* and cogon (*Imperata cylindrica)* through the *Taungya* system, which is an agroforestry system with short food crop production phase along with a silvicultural method to ensure establishment of timber species. Among fast-growing exotic tree species, Eucalyptus is preferred by farmers due to its ability to grow successfully in a wide range of environments and its ability to coppice with rapid growth. Bagras is planted as a component of contour hedgerows or alley cropping, block planting, and boundary planting.

Tree-based agroforestry system using bagras appears to be an adequate smallholder plantations system that can meet local demand for food, wood, and wood-based products. In recent years, there has been an increasing number of smallholder timber plantations of fast-growing tree species in Claveria, Misamis Oriental, Mindanao (Magcale-Macandog *et al.* 1998). These preliminary findings indicate the future of timber production and the important role of agroforestry in the country.

In forestry, a site is usually defined by the location's potential to sustain tree growth, often with a view to site-specific silviculture (Skovsgaard and Vanclay 2007). Site classification may serve a range of management purposes, including ecological stratification for optimizing the estimation of forest site productivity.

Site quality is the potential productivity of a forestland area and is an expression of complex edaphic, climatic, and biotic factors that influence tree growth (Vendiola 1996). Generally, site quality is linked with productive capacity, and is expressed in unit of site index (Skovsgaard and Vanclay 2007).

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Using site index approach, the height of dominant trees of a given species and age is related to the capacity of a given site to produce wood of that species than any other measure (Spurr and Barnes 1980). Site index attempts to represent the relationship between height and age of overstory trees that are attributable to site rather than density effects. Site index is thus, the height of the dominant portion of the stand at a specified index age (Vendiola 1996).

Any site index curve is simply a family of height development patterns with quantitative symbols or numbers associated with the curves for referencing purposes. As a measure of site productivity, site index usually refers to the expected (or realized) stand height at a given reference age (Skovsgaard and Vanclay 2007). The reference age is referred to as the index age or base age. The true objective of site index curves is to select the height development pattern that a given stand would follow for the remainder of its life.

One limitation of the site index approach is that it can only estimate the productivity of an already forested site (Vendiola 1996). Brown and Loewenstein (1978), as cited by Vendiola (1996), contended that within sites that are not stocked or partially stocked, soil and other topographic characteristics would be useful in predicting potential site productivity.

Many tree-based agroforestry systems established in Northern Mindanao are not stocked at all or only partially stocked due to the farmers' management objectives and preferences. Many situations exist where the forest vegetation, whether trees or the understory plants, are not useful in providing an index of forest productivity (Spurr and Barnes 1980). According to Vendiola (1996), these pertain to non-forested lands to be reforested or converted from one type to another. Vendiola (1996) further stressed that the limitation of site-index approach can be addressed by using an environment-site index approach in estimating site productivity. The environment-site index approach is applicable to all forestlands including those that are not vegetated.

Generally, growth estimation of standing timber volume is crucial for successful operation especially in an agroforestry system. Accurate information is imperative as they constitute the basis for sustainable agroforestry timber production investment decisions, such as when to best sell and dispose present crops and start new ones (Eusebio 1988). Inventory information on stand growth is required for planning timber harvest rotations. Stumpage inventories are most likely to be used to determine the current value of timber in plantations (Jusoff 2008).

Site suitability assessment should be done to ensure successful establishment and management of smallholder tree-based agroforestry systems. Species-site matching is vital to ensure survival and growth. Lasco *et al.* (2006) found that the lack of species-site matching was one of the common problems in past reforestation (Forestry Sector Project Loan I & II amounting to USD 422.27 million) activities. This led to high mortality rate and poor performance of seedlings, particularly in Region XI in Mindanao.

Thus, Chokkalingam *et al.* (2006) recommended that POs, farmer groups, and the private sector should be conscious about species-site matching and use appropriate silvicultural techniques. Academic and research institutes are expected to provide training to government agencies, non-government organizations (NGOs), POs, and the private sector engaged in rehabilitation on species-site matching and silvicultural techniques (Chokkalingam *et al.*, 2006).

This study was done to develop site index model considering soil physical properties, physiographic characteristics, height, and age indicators to determine the growth of bagras in banana-based boundary planting agroforestry systems.

METHODOLOGY

Location

The study was conducted from August 2011 to March 2013 in selected banana-based agroforestry farms (boundary planting) approximately located between 124^0 34' and 125^0 58' East longitude and 7^0 52' and 8^0 54' North latitude in northern Mindanao, specifically in the provinces of Misamis Oriental and Bukidnon (Figure 1).

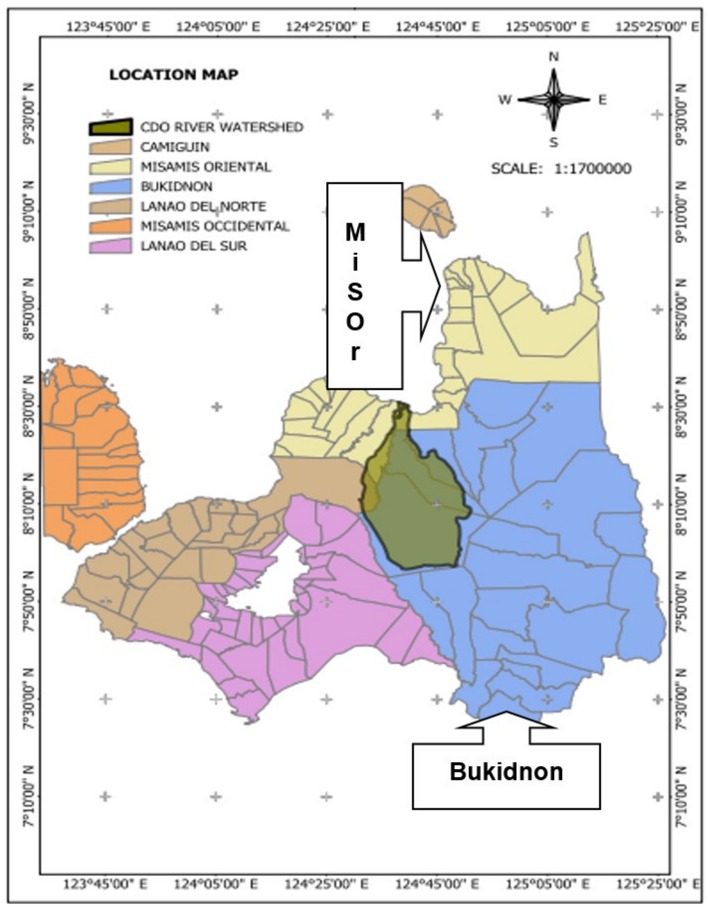

Figure 1. Digitized location map of Northern Mindanao (Source: Osio 2012)

Sample Plot Establishment

Thirty rectangular temporary sample plots (Figure 2) were established throughout the study area. The plots were identified such that various stand ages and prevailing environmental conditions were represented. Individual plots have an approximate size of 500 m^2.

Data Collection

Physiographic data

Elevation and aspect of each sample plot were determined using the geographic positioning system (GPSmap 76CSx GARMIN). The GPS was placed at the center of the plot for the elevation reading. Slope gradient was measured using a Clinometer (M5 SUUNTO) right at the center of the plot. *A*spect is better expressed by Brown and Loewenstein's formula (Palma 2012):

ASPC = (Aspect* x 45) – 45 (Eq. 1)

Where:

ASPC = the value considered as aspect to be inputted in the correlation/regression;

Aspect* = compass position of the slope exposure.

This is coded from 1 to 8 beginning with N 45^0 E and continuing in a clockwise direction using 45^0 increments to N.

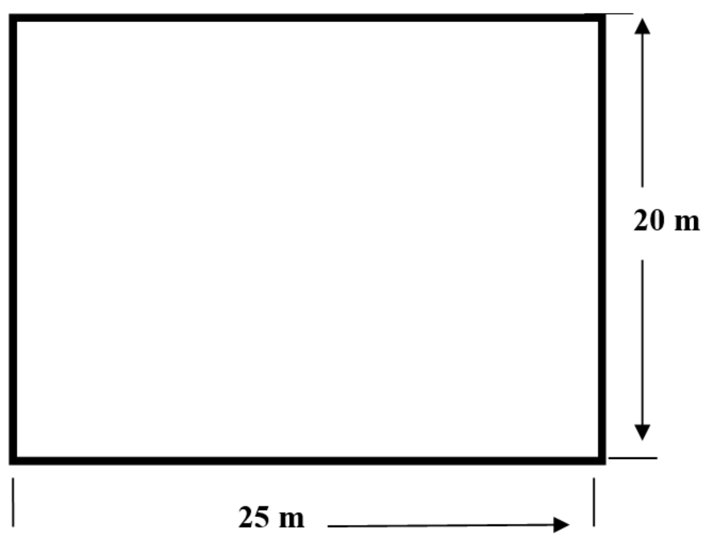

Figure 2. Lay-out of temporary sample plot (25 m x 20 m)

Soil chemical properties

Soil chemical properties were analyzed to determine fertility levels under agroforestry systems. Composite soil samples were gathered from each of the sample plots at 0-30 cm depth. The samples were air dried, pulverized, screened, and analyzed for pH, organic matter (OM), phosphorus (P), and potassium (K) content.

Stand characteristics

In each of the established plots, the total height (TH) of all the trees within the plot were measured. Tree age was reckoned from the year the trees were planted. Age was determined through interviews with the owners, caretakers or laborers, which was validated using the records of facilitators for plots belonging to Landcare members. Facilitators are extension workers from the World Agroforestry Centre (formerly International Centre for Research in Agroforestry) who facilitated the implementation of the Landcare Program. On the other hand, the age of trees from Dole® North Skyland plantations was validated from the records of so-called coaches, each one serving as the foreman of a designated Dole® plantation.

Regression Diagnostics

Data collected from the field was verified for the presence of potential problems such as unusual and influential data and collinearity. Furthermore, data verification to determine whether it met the assumptions of ordinary least square (OLS) regression was done. Verification involved checking the normality of residuals, homocedasticity of residuals, multicollinearity, linearity, and model specification.

Site Index Model Development

Data such as height, age, elevation, slope, aspect, pH, OM, phosphorus, and potassium were collated into a format amenable to computer processing. Correlation analysis was done using observations gathered from sample plots. Result from the correlation analyses determined the specific growth factors to be included in the construction of the site index guide equation and, ultimately, the site index model (Table 1).

To measure how strongly each independent variable was associated with total height, multiple linear regression analysis data using STATA v. 10 statistical analysis software. Numerous models were tested using different variables. The best model was selected based on the following criteria: 1) significant P-value; 2) high coefficient of determination (R^2); 3) least root mean square error (RMSE); and 4) passed independent test (validation).

RESULTS AND DISCUSSION

Climate

Areas where bagras was established are classified as Type 2 of the Corona Climatic Classification System, characterized by five to six wet months and two to three dry months. Mean annual rainfall within the span of growing years as recorded by the nearest Philippine Atmospheric Geophysical and Astronomical Service Administration (PAGASA) weather stations located in Lumbia, Upper Carmen, Cagayan de Oro City (8^0 26' Latitude 124^0 37' Longitude) and Malaybalay City (08^0 09' Latitude 125^0 05') were 1727 mm and 2607 mm, respectively. The mean annual rainfall recorded in the PAGASA station in Lumbia was well below the reported mean rainfall of 2500 mm (Bertomeu 2006). The mean annual temperature was 26.89 ^{0}C in Misamis Oriental and 24.07 ^{0}C in Bukidnon.

Table 1. Correlation coefficient (R) between total height (TH) and the predictor variables under banana-based boundary planting in Northern Mindanao, Philippines

	TH	Age	pH	OM	P	K	Elev	Slope	Aspect
TH	1.0000								
Age	0.7173	1.0000							
pH	0.1816	-0.2262	1.0000						
OM	0.0494	-0.0524	0.3281	1.0000					
P	-0.2784	-0.4278	0.1919	-0.2670	1.0000				
K	-0.0016	-0.0462	0.1807	0.1417	0.0760	1.0000			
Elev	**-0.3798**	-0.0668	-0.1259	0.2199	-0.1007	-0.0743	1.0000		
Slope	**-0.0140**	-0.0433	0.0701	-0.1263	-0.0138	-0.0397	**-0.0595**	1.0000	
Aspect	**-0.0595**	-0.6280	0.3984	0.0265	0.2424	-0.2092	**-0.4376**	**0.2110**	1.0000

In this study, rainfall and temperature were not included as independent variables in the formulation of site index for boundary planting. Rather, these data were considered as independent variables in the development of yield prediction equation.

Generally, studies by local and international researchers produced similar results in terms of the influence of rainfall and temperature on the growth of trees. Zou *et al.* (2007) explored the relationship of rainfall and temperature with various physiographic and edaphic factors. Pallardy (2008) showed how rainfall and temperature affect the availability and leaching of nutrients in the soil. Leaching of nutrients increased with an increase in rainfall and temperature.

Physiography

All plots sampled were facing toward the north-westerly direction. Slope ranged from 0^o to 10^o with mean slope of 3^o. Elevation ranged from 351 to 1248 meters above sea level (masl) with an average elevation at 709 masl, which is well within the biophysical limit range of 0 to 1800 masl stipulated by FAO (1983) as well as ICRAF and PROSEA (2009).

It is interesting to note that the maximum values observed for both slope and elevation were high although the minimum value was extremely low. Despite the wide gap between the minimum and maximum values, these physiographic properties failed to show definite influence on the growth variability of bagras planted in the boundary system. Both slope and elevation were not able to withstand the stringent elimination test of the multiple linear regression analysis.

Although correlation analysis showed that aspect (-0.06) has weak and negative linear relationship with TH, this variable however was able to withstand the stringent elimination procedure using ordinary least square. The result suggests that aspect is an important factor that influences growth of bagras planted in a boundary system. This can be partly explained in terms of how aspect influences the length of photosynthetic period (Tandug *et al.* 2003). Exposure to sunlight allows trees to produce carbohydrates through photosynthesis. Vendiola (1996) stated that best sites are on the northwest slopes while poorest sites are on the southwest slope, and that aspect is usually a very important site feature in hilly and mountainous areas. Exposure disrupts mountain temperature zones (Auslander *et al.* 2003). Since the maximum effectiveness of insolation comes only when solar radiation is at right angle to the surface, variation in exposures to radiation is modified. On the basis of these phenomena, south facing slopes receive more insolation per unit area than a flat surface, and about six times more than north facing slopes (Auslander *et al.* 2003). Slope aspects also influence soil chemical and biochemical properties that were found to differ significantly between north and south facing slopes (Sidari *et al.* 2008).

Soils

The range of values of the various soil chemical properties observed in the site is shown in Table 2. The mean OM content of the soil in the top 30 cm layer was 4.40% from samples collected in Misamis Oriental and Bukidnon (Table 2). The mean OM of 4.40% is considered high based on soil analysis rating (Badayos *et al.* 2007), just above the adequate level of 3-4%. This is higher than the earlier values reported by Magbanua and Garrity (1998) where soils have low to moderate OM content.

Table 2. Range of soil property values of top 30 cm layer of the boundary planting from northern Mindanao, Philippines

Soil Properties	Mean	Range
pH	5.17	4.33 – 6.32
OM (%)	4.40	2.66 – 6.23
P (ppm)	7.24	1.21 – 34.03
K (ppm)	115	36.00 – 500.00

The mean OM content of soils sampled was even higher than that of the bagras stand at PICOP, Bislig City, Surigao del Sur (Basada 1990).

Another factor with profound influence on plant growth is soil pH, which affects the quantity, activity, and types of microorganisms in soils. In turn, the latter influence decomposition of crop residues, manures, sludge, and other organic compounds in the soil. Soil pH also affects nutrient transformations and the solubility, or plant availability, of many essential nutrients. Phosphorus, for example, is most available in slightly acid to slightly alkaline soils. Soil pH can be altered by amendments. Increasing OM will decrease pH (increase acidity).

The pH values in the top 30 cm layer of the soil ranged from 4.33 to 6.32 (Table 2). The mean pH value at 5.17 indicates that the soil is strongly acidic (Badayos *et al.* 2007), which is below the estimated adequate levels of pH 5.50-6.50.

Phosphorus is one of the primary macronutrients supplied by the soil system. This element is required by plants and would most likely limit plant growth and development. Phosphorus is a constituent of nucleoproteins and phospholipids, and the high energy bonds associated with phosphate groups constitute the chief medium for energy transfer in plants. Phosphorus occurs in both organic and inorganic forms and is translocated readily, probably in both forms (Pallardy 2008).

The mean value of available P in the top 30 cm layer of soil in the boundary planting (7.24 ppm) was classified as medium based on Bray soil analysis rating (Badayos *et al*. 2007). Basada (1990) obtained high mean value (11.72 ppm) of available P in bagras plantation at PICOP. This value, however, was still inadequate for optimal plant growth set at 30 ppm and over. Dalmacio (1984) contended that a potentially good site for bagras should have available P in the topsoil of at least 25 ppm.

Enzyme activation, protein synthesis, osmoregulation, stomatal opening and closing, photosynthesis, and cell expansion are some of the important functions of exchangeable potassium (Pallardy 2008). It is required by plants in large amount and is highly mobile in the plants. The mean potassium value was considered medium low (80–120 ppm) based on soil analysis rating (Badayos *et al.* 2007).

Site Index Guide Model

Some soil chemical and physiographic properties, thought to be significantly associated with the variation in TH of trees in the study sites in northern Mindanao, were pre-selected based on findings in previous studies and available funds for the study. Grant *et al.* (2010) mentioned several authors who used site variables (*e.g*., measures of climate, geology, topography, as well as soil physical and chemical properties) to describe and assess site quality. These variables were subjected to ordinary least square regression using STATA v. 10 statistical analysis software.

The result of the tests on observations collected from the field showed no severe outliers indicating that observation is normally distributed. The variance of the residual was also found to be homogeneous. There was no case of multicollinearity detected using variance inflation factor (VIF) test. Lastly, the link test showed that the model was properly specified and that relevant variables were not omitted nor irrelevant variables included in the model.

Result of the analysis indicated that the highest coefficient of determination (R^2) of 0.90 with least root mean square error (root MSE) of 0.18 was attained after numerous iterations with only three variables declared by the model as important in collectively estimating the TH of bagras as shown in Equation 2. The variables entered into the model were: age, pH, and aspect (Table 3).

The equation is of the form:

(Eq. 2)

$$LnTH = -16.07 + 0.55(LgAge) + 0.92(LgpH) + 2.8\ (LgAspect)$$

Where:

LnTH = logarithm of TH in m;
LnAge = logarithm of age in yr;
LgpH = logarithm of pH;
LgAspect = logarithm of Aspect

The site index guide for bagras in banana-based boundary planting showed that 90% of the variance in TH was explained by age, pH, and aspect. The R^2 obtained in this study was analogous to the R^2 for corn-based boundary planting at northern Mindanao, which was 90.65% (Palma 2012) and higher than bagras at PICOP, Bislig City, Surigao del Sur (Basada 1990), which was 62%.

Table 3. Linear regression output for alley cropping using ordinary least square (OLS)

LNTH	Reg. Coef.	Std. Err	T	P>|T|
LgAge	0.55	0.04	12.51	0.00
LgpH	0.92	0.46	2.01	0.06
Lgaspect	2.81	0.83	3.40	0.00
Constant	- 16.07	4.51	-3.56	0.00

Figure 3 illustrates effect of age and pH on TH. A predicted mean increase of 0.60 m for every increase in age (for example, 1 yr to 2 yr) was observed (pH = 4.30; aspect = 270). The increase ranged from 0.37 (20-21 yr) to 1.13 m (1-2 yr). At pH = 6.30, the predicted mean increase of 0.80 m for every increase in age was also observed. This time, the increase in value ranged from 0.55 to 1.60 m for the same age. The slight difference in TH could be due to the changes in pH value from 4.30 to 6.30.

Bagras growth was predicted to attain a TH of 2.70 m at 1 yr and about 14.60 m at 21 yr when planted in soil with pH of 4.30 and facing W to N 44^0 59" W. However, bagras planted in an area with pH = 6.30, would yield a predicted TH of 3.90 m at 1 yr and 20.70 m at age 21 yrs.

Figure 4 on the other hand depicts the response of TH to age when aspect is facing N or N 45^0 W or 315 (ASPC value). It was observed that there was a predicted mean increase of 0.91 m for every increase in age (for example 1 yr to 2 yr) when pH = 4.30. The increase ranged from 0.60 (20-21 yr) to 1.75 m (1-2 yr). At pH = 6.30, the predicted mean increase of 0.80 m for every increase in age was also observed. This time the increase ranged from 0.86 to 2.48 m using the same age. As shown in Figure 4, bagras planted facing due N or N 45^0 W would attain a TH of 4.20 m (1 yr) and about 22.40 m (21 yr). A higher estimated TH was attained when planting bagras in an area with pH = 6.30. The estimated TH at 1 yr is 6 m and 31.90 m at 21 yrs.

Basada (1990) argues that potentially good site for bagras should have a pH of 7in the top soil. The values obtained were comparable to the values observed in the top soil of different plantations in Mindanao and Visayas planted to bagras, moluccan sau (*Paraserianthes falcataria*), and mangium (*Acacia mangium*) (Basada 1990; Dalmacio 1984; Vendiola 1996).

Black (1968) asserted that soil pH is generally considered as the single most important soil chemical property that affects soil fertility, the availability of many plant nutrients, and activity of soil microorganisms. The earlier study by Basada (1990) confirmed that soil pH value is a limiting variable affecting the TH attained by bagras. The results of the present study corroborate the findings of Vendiola (1996) who found that aspect exerted considerable influence on the differences in growth between stands of mangium.

Similarly, Tandug *et al.* (2003) inferred that aspect was significantly associated with height in moluccan sau (*Paraserianthes falcataria*), white lauan (*Shorea contorta*), and agoho (*Casuarina equisetifolia*). This can also be attributed to existing knowledge that exposure of slope determines the amount of sunlight received by the site, which in turn modifies moisture content as well as soil and air temperature.

A study on the effect of slope aspect on productivity and species composition of hilly grassland in the Xilin River Basin, Inner Mongolia, China showed that northern slope exhibited a higher productivity in terms of aboveground green biomass compared to south aspect areas. The available soil K, P, and N were shown not to limit plant productivity of south relative to north oriented slopes (Gong *et al.* 2008). Following similar procedures stipulated in deriving site index guide equation in alley cropping, the equation for final site index is in the form:

$$SI_{10} = -37.97 + 2.91(pH) + 0.13(ASPC) \quad \text{(Eq. 3)}$$
$$R^2 = 0.9964; \quad RMSE = 0.1926$$

Where:

SI_{10}= Site index at base age 10
pH = Soil reaction
ASPC = aspect

The paired comparison t-test using PROC MEANS (SAS version 8) was used to test the validity of the equations. Since the value of Prob>|t| is greater than 0.05, then the hypothesis that the difference between the predicted and observed value is equal to 0 or not significantly different from 0 is accepted. This implies that the site index equation can be used to predict the growth of bagras planted along the boundaries in Northern Mindanao.

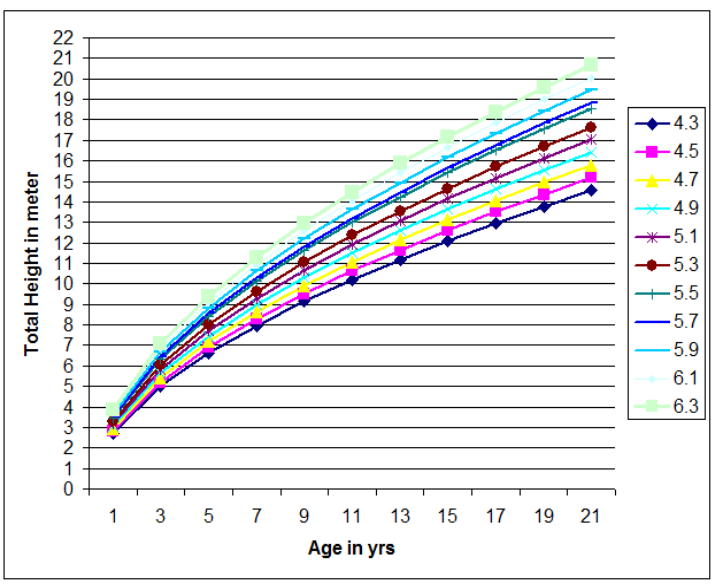

Figure 3. Response of total height to age and pH (aspect = 270)

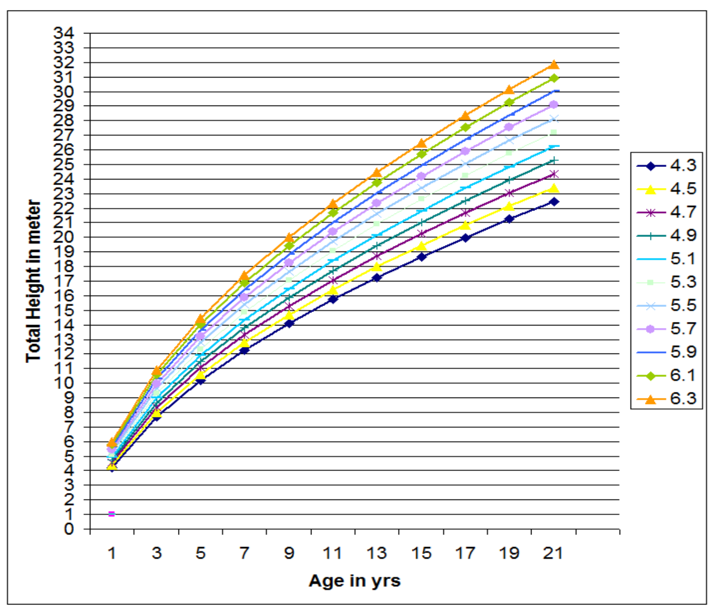

Figure 4. Response of total height to age and pH (aspect = 315)

CONCLUSION

Agroforestry system like boundary planting is widely practiced in the uplands and lowlands of northern Mindanao. Survey results confirmed that agroforestry is becoming an increasingly important land use system in Misamis Oriental and Bukidnon as majority of farmers have integrated trees in their farming systems.

The results from the study show that some relatively simple field assessment of soil information (*i.e.,* pH, OM, P, and K) when combined with physiographic (*i.e.,* elevation, slope and aspect) can be useful to predict the growth of bagras planted as an agroforest tree crop.

Variation in site index of bagras was associated with the change in age, pH, and aspect. These variables can account for 90% of the observed variation in site index. Also, based on the site index model developed, these variables were linearly related with TH as indicated by the positive sign of their coefficients. Thus, for every unit increase in age, pH, and aspect, there was an equivalent unit increase in TH of bagras and vice versa.

Both positive and negative relationships of pH with the selected site factors (*i.e*., OM, P, K, slope, and aspect) and its negative relationship with elevation support the general view that pH is the single most important soil chemical property affecting soil fertility.

RECOMMENDATIONS

Estimating growth is crucial for successful boundary planting establishment and management. The model can be used as basis in determining the best site for bagras, optimum rotation length, and in examining silvicultural options (*i.e.,* site preparation, nursery establishment, outplanting, fertilization, pruning, thinning, and harvesting). Changing soil pH is difficult because it entails additional cost; however, there are low-cost but effective ways of attending to this problem. Banana growers can segregate slashed stalks, blades, and stems after cleaning and then used as green manure or mulch. Some waste materials can also be converted into compost through vermicomposting. The site index models can only be safely used when the respective values for age, pH, and aspect are within the range indicated as follows: 1) age = 1-21 yr; 2) pH =4.33-6.32; and 3) aspect = Due W-N 44^0 59" W and N 45^0 W-Due N.

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ACKNOWLEDGMENT

The author is thankful to the DOLE North Skyland Inc., Mr. Ben Cadorniga of KASILAK Foundation, Agroforestry farmers from Palabrica, Simene, Gayunan, CTNI, PAGLAUM Inc, Sumido, Maputi, Quisumbing, PCC, Aure, MENZI, Dahan and Sulamin for providing access to their farm. The authors are also thankful to Dr. Leuvy Tandug for her advice on the statistical component of the study, and to Ms. Leila D. Landicho, for extending her expertise as professional copywriter and language editor. Last but not the least, the main author thanks the Science Education Institute-Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department of Science and Technology (SEI-PCAARRD-DOST), Commission of Higher Education (CHED) for the financial support.