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Carbon Sequestration and Climate Change Impact on the Yield of Bagras (*Eucalyptus deglupta* Blume) in Bagras-Corn Boundary Planting Agroforestry System in Misamis Oriental and Bukidnon, Philippines

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ABSTRACT

Bagras-corn boundary planting agroforestry system for biomass production and climate change mitigation is essential options for smallholder agroforestry farms in Misamis Oriental and Bukidnon, Philippines. In this study, the multiple linear regression analysis was used to develop an appropriate prediction models for yield and biomass expansion factor from soil chemical properties, physiographic characteristics, stand attributes, rainfall and temperature. Results showed strong association of age, site index, temperature and spacing with yield (88.7 %). Based on the model, the predicted biomass accumulation at 52 trees per hectare was 24.44, 73.07 and 78.67 Mg ha^{-1}. The mean annual aboveground biomass accumulation was 24.44, 7.31 and 3.93 Mg ha^{-1} y^{-1} at ages 1, 10 and 20 years. The equation developed had shown the predicted positive response of bagras to future changes in seasonal mean temperature. Establishing bagras at a distance of 2 m, site index equal to 19 m, age set at 10 y was predicted to yield 0.1974 m^3 per tree in 2020. At 2050, yield was predicted to balloon to approximately 3.1182 m^3 per tree. Yield and biomass production in boundary plantings can be highly variable – dependent on environmental and soil characteristics and tree spacing.

Key words: *agroforestry, boundary, climate change, yield, carbon sequestration*

INTRODUCTION

Eucalyptus deglupta Blume become one of the most common fast-wood plantation tree species in many continents around the world. A member of the Myrtaceae family, the genus dominated the tree flora of Australia. It is locally known as bagras or Mindanao gum (English name); amamanit, bagras, banikag, dinglas (Filipino); bagalangit (Indigenous Peoples in Northern Mindanao). There are more than 700 species (*International Centre for Research in Agroforestry and PROSEA 2009*) of *Eucalyptus*, mostly native to Australia, and a very small number are found in adjacent parts of New Guinea and Indonesia and one as far north as the Philippine archipelago.

The International Centre for Research in Agroforestry (ICRAF) defines live fencing as "a way of establishing boundary by planting trees and/or shrubs at relative close spacing and by fixing wire to them (*Lasco and Visco 2003*). Planting multiple – use tree species around the farm is a very common practice. They provide protection, privacy, and valuable products (i.e. log, lumber, posts) to the farmers. Trees are planted within property line as fence, or as demarcation of farm lots.

Generally, growth and yield estimation of standing timber is crucial for a successful agroforestry enterprise. Accurate information on growth and yield is imperative as they constitute the basis for sustainable agroforestry timber production investment decisions. It helps to determine when it is best to sell and dispose the present crop of trees and start new ones (*Palma 2012*). Recently, growth and yield information is used to estimate carbon stock using various biomass equations (*Zianis et al. 2005; Somogyi 2008*).

Studies on growth and yield of Eucalyptus spp. were conducted mostly in plantation (*Eldridge et al. 1993*; *Harrison et al. 2003*) and have used global allometric equations (*AKECOP nd*). However, accuracy in estimating growth and yield for carbon using global allometric equations, remains a problem because of the uncertain biomass and carbon estimates in forest ecosystems (*AKECOP nd*). Thus, growth and yield studies should be undertaken to effectively demonstrate the economic feasibility of growing bagras in an agroforestry system.

Tree-based agroforestry system using bagras could be an alternative to smallholder plantations, which could meet local demands for wood and other wood products if integrated with timber and food production. It. In recent years, there has been an increase in the number of smallholder timber plantations of fast-growing tree species in Claveria, Misamis Oriental, Mindanao (*Magcale-Macandog et al. 1998*). *Kleinn and Morales* (*2002*) supported this observation

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with their global inventories of trees on farm or "trees outside forests". They found out that in Punjab, India, farm trees account for 86% of the provinces growing stock, and in Sri Lanka over 70% of industrial wood come from trees outside forest. Even though these were preliminary findings, it provides an overview on timber production and the role of agroforestry in the future.

Limited information is available for use by prospective tree farmers and investors on the preparation of feasibility studies which is important for sourcing funds. Similarly, little emphasis was devoted on finding best management practices for the tree components, and the suitable site for the chosen tree species. As a result, low productivity of the tree components resulted from poor growth and eventual yield. Thus, the questions of many potential adopters of agroforestry systems and technology remained unresolved and essential information to answer these problems is still wanting.

Quantifying the impacts of climate change on bagras-corn agroforestry systems tree species growth and yield is required by tree farmers. Tree farmers know the tree species growth characteristics in bagras-corn boundary planting agroforestry systems have the growth characteristics to compete in a future climate. With this, tree farmers will be better able to design stand prescriptions tailored to promote these species.

The objectives of this paper were to determine the carbon sequestration potential of bagras-corn boundary planting agroforestry system and to assess the impact of future climate change on the yield of bagras in an agroforestry systems in Misamis Oriental and Bukidnon.

MATERIALS AND METHODS

Geographical Location of Study Site

Using GPS the geographic location of each sample plots were collected. The locations of different agroforestry systems were within the longitude of East 1240 05' 00" to 1250 25'00" for Misamis Oriental and Bukidnon, respectively. On the other hand, the latitudinal gradient for Misamis Oriental and Bukidnon were within North 70 30'00" to 90 10'00". The province of Misamis Oriental is composed of 27 municipalities mostly located along the shore except for the municipality of Claveria which is landlocked. Meanwhile, the province of Bukidnon is made up of 23 municipalities located in the upland.

Bagras-corn boundary plantings in the study area were located between 250 to 980 masl. The mean elevation was 738 masl. The bulk of the sample plots are facing northwesterly direction. Slope ranged from 00 to 140 with an average of 4^o.

Table 1. Geographic distribution of sample plots by provinces and municipalities.

Location	Boundary
Misamis Oriental	
Claveria	34
Villanueva	2
Bukidnon	
Manolo Fortich	2
Impasug-ong	3
Malaybalay City	15
Maramag	1
Lantapan	1
Total	58

Table 2. Range of soil property values of top 30 cm of bagras-corn boundary planting agroforestry systems from Misamis Oriental and Bukidnon, Philippines.

Soil Properties	Boundary	Rating
pH	4.23 – 6.34	Very strongly acidic
Organic Matter (%)	1.77 – 6.06	Medium
P (ppm)	1.54 – 143.23	High
K (ppm)	45.00 – 339.0	Medium

*Based on *Badayos et al.* (*2007*) soil analysis rating of the mean values

Weather Data Collection

The historical and observed monthly normal weather data were obtained from the Climatology and Agrometeorology Division, of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). The study areas are classified as Type 2 of the Corona Climatic Classification System which is characterized by wet (5 to 6) and dry (2 to 3) months. Average annual rainfall within the span of growing years of bagras, as recorded by the nearest PAGASA weather stations located in Lumbia, Upper Carmen, Cagayan de Oro City (8^o 26' Latitude 124^o 37' Longitude) and Malaybalay City (08^o 09' Latitude 125^o 05'), were 1727 mm and 2607 mm for Misamis Oriental and Bukidnon, respectively. The mean annual rainfall recorded from PAGASA station in Lumbia was well below the reported average rainfall of 2500 mm (*Bertomeu 2006*). The average annual temperature was 26.89 ^oC in Misamis Oriental and 24.07 ^oC in Bukidnon.

Growth measurements

In each of the established plots, all dominant and codominant trees were selected for the measurement of merchantable height (MH) and total height (TH). Measurement of MH was based on the first large branch of the trees. Similarly, the TH was measured from the base of the tree to the tip. The collection of data utilized Clinometer (PM-5, SUUNTO) in good condition.

Site Index Guide Equations

Based on the results of the previous studies conducted in the country, some soil chemical and physiographic properties thought of being significantly associated with the variation in total height of trees in the study sites in Misamis Oriental and Bukidnon were pre-selected. The site index used in this study was:

$$SI_{10} = 1.613206 + 0.0307033(LnP) + 0.0039026(ASPC) \quad (1)$$

$$R_2 = 0.9065; \qquad RMSE = 0.08038$$

Where:
SI_{10}= site index at base age 10 years;
LnP = natural logarithm of available phosphorus in ppm;
ASPC = aspect

Yield Model

The development of these models requires different expressions representing the relationships among stand variables. The variables used in this study were age, soil-site index, spacing, basal area, provenance, rainfall and temperature. These variables thought of being significantly associated with the variation in yield of trees in the study sites in Misamis Oriental and Bukidnon were pre-selected relative to the results of the previous studies conducted in the country.

Relationships between measures of yield obtained from 58 sample plots (with 13 age classes between 1 to 21 years) were used to model yield, using the combined stepwise, forward and backward procedure in the regression analysis method. The parameters of the model for the data were determined using multiple linear regression analysis using regress command (STATA 10.0). Only variables with high coefficient of determination (R^2), least root mean square error (RMSE) and significant P>|t| value were included in the yield models. The assumption was tested using available regression diagnostics. The model was validated using a separate set of data from bagras-corn boundary planting agroforestry systems in Misamis Oriental and Bukidnon.

Assessing Future Climate Change Impact

The impact of future climate change on the growth and yield of bagras was assessed based on the projected change in seasonal mean rainfall and temperature of the Province of Bukidnon. The data was extracted from the completed study of PAGASA to generate climate change scenario for the 43++ provinces using PRECIS Regional Climate Model for the main dynamical downscaling technique. The PRECIS stands for Providing Regional Climate Model for Impact Studies. The data were inputted to the yield prediction model to determine the impact of changes in rainfall, temperature and other variables on the yield of bagras.

Carbon Density and CO_2 Sequestration

The above ground carbon density of bagras was determined using the formula (*Brown and Lugo 1992*)

Above Ground Biomass (ton per tree) = volume over bark (cubic meter per tree) * wood density (kg m^3) * biomass expansion factor (BEF) (2)

Volume over bark (VOB) was derived using the volume equation developed by *Lanting et al.* (*2008*). On the other hand, the wood density was taken from the study of *Alipon and Floresca* (*1990*). In this study, the biomass inventoried volume (BV) was the product of VOB (cubic meter per tree) and wood density. Then, the BV value was designated as independent variable and the preliminary BEF variable as the dependent. Using the two parameters, the BEF for bagras was constructed.

The total carbon dioxide was calculated using *Butthep et al.* (*2008*) procedure, that is, multiplying total carbon stock by a simple ratio (44/12 = 3.66 is ratio of CO_2 to C, derived from atomic weight of carbon {12.011} and oxygen {15.9994}).

RESULTS AND DISCUSSION

Bagras-Corn Boundary Planting Agroforestry System

Another common agroforestry system in Misamis Oriental and Bukidnon is the planting of trees along boundary or boundary planting (**Figure 1**). Based on the interviews, the farmers vary in choosing and planting bagras depending on the crop raised, and what exist between farm lots or between crops within one large farm lot. Another reason was for economic and domestic uses like lumber production for home uses. One quite different intention in the banana plantations in Luna, Claveria and the DOLE North Skyland Inc. banana plantations in Malaybalay City and Impasugong, Bukidnon. Wherein bagras were planted to protect the adjacent community during scheduled spraying.

Mainstream agricultural crop planted in this type of agroforestry system is corn. Other important crops planted in small plots were banana, rice, beans, tomato, cabbage, watermelon and rose. There were also fruit trees like mango, durian, rambutan, lanzones and cacao (*Theobroma cacao*). Bagras planting materials used in DOLE North Skyland Inc. plantation were taken from Tandag, Surigao del Sur through the KASILAK Development Foundation Incorporated their partner NGO (*Cadorniga 2012 Personal Communication*). Meanwhile, the seeds used in Claveria were sourced out from

Figure 1. Boundary planting located at Barangay Kalingagan, Villanueva, Misamis Oriental.

PICOP and raised in their respective Landcare Association nurseries (*Bertomeu and Sungkit 1999*).

Yield Prediction Equation

The independent variables for the boundary yield prediction model were age, site index, natural logarithm basal area and natural logarithm of mean annual rainfall. The dependent variable was the natural logarithm of volume. Generally, studies by local and international researchers had bared similar results in terms of the influences of rainfall and temperature on the growth of trees. *Zou et al.* (*2007*) explored the relationship among various physiographic and edaphic factors. *Pallardy* (*2008*) showed the importance of rainfall and temperature on the availability and leaching of nutrients in the soil. Leaching of nutrients increased with an increase in rainfall and temperature. Transformation of the different independent variables was in the form of natural logarithm transformation.

On this study, a number of probable combinations of independent variables were tested, however most of these combinations failed to satisfy the statistical, biological and independent tests except for one equation that passed all tests, so it was accepted. The yield prediction model that satisfied all statistical and independent tests was in the form of:

$$lnYield = -a + b1*nSI + b2*nA + b3*Temp + b4*SP \quad (3)$$

Where:

lnYield = natural logarithm of yield in m^3
nSI = natural logarithm of site index in meter
lnA = natural logarithm of age in years
Temp = mean annual temperature in degree centigrade (^oC)
-a = constant
b1, b2, b3, b4 = regression coefficients

Table 3 shows the coefficients and the corresponding P value. The coefficients for natural logarithm of site index and age were significantly different from 0 using alpha of 0.05 because its P value of 0.000 and 0.002 was definitely smaller than 0.05 and even 0.01. Both the coefficients for temperature and constant were significantly different (P value of 0.047). The coefficient for spacing was not significantly different from 0 using alpha of 0.05 because its P value of 0.099 was greater than 0.05. The P value was the probability of seeing a result as extreme as the one you are getting in a collection of random data in which the variable had no effect. With a value of 5 %, it indicated that 95 % probability of being correct that the variables were having some effect. However, the size of the P value for a coefficient says nothing about the size of the effect that site index, age, temperature and spacing on yield because it is possible to have a highly significant result (very small P) for a diminutive effect.

Again, the beta coefficients can be used to compare the relative strength of the various predictors within the model. In this study, site index has the largest beta coefficient, 0.6772, and spacing has the smallest beta, 0.1402. Thus, a one standard deviation increase in site index leads to a 0.6772 standard deviation increase in predicted yield, with the other variables held constant. And, a one standard deviation increase in spacing, in turn, leads to a 0.1402 standard deviation increase in yield with the other variables in the model held constant.

$$lnYield = -78.55512 + 2.147243(lnSI) + 0.7052028(lnA) + 2.555336(Temp) + 0.0747424(SP) \quad (4)$$

R2 = 0.8870 RMSE = 0.29927

A change in values of the independent variables in the model causes changes in the yield curve inversely as shown by the negative value of the constant. The coefficient of determination showed that 88.70 % of the variance of yield can be explained by site index, age, temperature and spacing. This entails that only 11.3 % were left unexplained by the yield equation. All of these coefficients of determination are high enough so the yield equation can be used to predict volume of bagras in a boundary system in Misamis Oriental and Bukidnon.

The equation 4 selected four variables, namely: site index, age, spacing and temperature. These variables have different degree of contribution to the changes in yield. All independent variables have linear relationship with yield. Based on the model, for every unit increase in site index, there is a 2.15 unit increase in the predicted yield. The yield is predicted to be 0.70 units higher for every unit increase in age. For every unit increase in temperature, yield is predicted

Table 3. Regression Coefficients of variables from boundary agroforestry system.

lnYield	Coeficients	P > [t]	STD. ERR	T	Beta
lnSI	2.147243	0.000	0.3173046	6.77	0.6772066
lnA	0.7052028	0.002	0.1994444	3.54	0.5528596
Temp	2.555336	0.047	1.201945	2.13	0.3087424
Spacing	0.0747424	0.099	0.043028	1.74	0.1401542
Constant	-78.55512	0.028	32.92434	-2.39	-

to be 2.56 units higher. While unit increase in spacing, there is a 0.07 unit increase in the predicted yield.

The relationship between yield and temperature in this study supported the general knowledge of the importance of temperature on the growth and yield of tropical trees. It is common knowledge that temperature had positive and negative effect on tree growth through its physiological processes (i.e. photosynthesis, respiration, absorption, translocation and transpiration). The effect of air temperature usually is modified by light intensity, CO_2 availability, soil temperature, water supply, and preconditioning effects of environmental factors. Temperature has a significant influence on many of the plant physiological and biochemical systems. Many investigators have found various responses of different species to root and air temperature treatments. Increase in soil temperature promoted vegetative growth and increased yield, and enhanced absorption of water and nutrients (*Pallardy 2008*). In this study, an increase in temperature from 27 ^oC to 27.1 ^oC will increase yield by about 29.1 %.

The mean annual rainfall (mm), provenance and basal area were not included (dropped) from list of independent variables in the final equation. Both rainfall and basal area were not able to withstand the stringent elimination test of linear regression. On the other hand, provenance was dropped due to limited variation of seed sources.

The yield prediction model is applicable in bagras trees planted in the boundary with ages from 1-21 years; site index ranging from 5-19 m; mean annual temperature ranging from 26.88-27.37 ^oC; spacing ranging from 1-8 m^2. These ranges were established based on the available data gathered.

Validation of the model developed for bagras was made using five separate plots (**Table 4**). The actual volume computed using the volume equation constructed by *Lanting et al.* (*2009*) was compared to the predicted volume derived from the yield prediction equation. The paired samples t-test using PROC MEANS (SAS system, version 8) was used to determine the significant difference between these values.

Timber Yield in Bagras-Corn Based Boundary Planting Agroforestry Systems

The volume of bagras planted in the boundary was derived from four independent variables (i.e. age, site index, spacing and mean annual temperature) . All these variables entered into the equation. Relative to the constructed yield prediction equation, the mean annual increment (MAI) of bagras differed with site index, basal area and mean annual rainfall. When temperature was set at 27.1 ^oC and spacing at 2 m, the MAI at site index = 19 m was 0.0302 m^3 ha^{-1} y^{-1} or equivalent to 6.042 m^3 ha^{-1} y^{-1}, provided that bagras is planted at 2 m (200 trees) along the boundary of a 1 ha lot. Planting bagras on poor site (site index = 13 m) will yield lower volume at 2.6 m^3 ha^{-1} y^{-1} (134.4 % higher than site index = 19 m) (**Figure 2**).

The predicted average yield of bagras planted along the boundary on a 10 year rotation of 6.93 m^3 ha^{-1} y^{-1} (2 m; site index = 19 m) was considerably below the FAO (2001) reported average yield of 25–30 m^3 ha^{-1} y^{-1} and the predicted volume of woodlot from this study (31 m^3 ha^{-1} y^{-1}).

This big difference in yield per hectare was expected because those cited were industrial plantations. Also, the number of trees used as multiplier to come up with a stand comparison (i.e. 200 trees for boundary; 667 trees for woodlot) was not equal. Generally, it is difficult to compare side by side these agroforestry systems, more so with industrial plantations. First, they vary in site conditions

Table 4. Validation data for yield prediction equation for bagras in boundary system.

Plot No.	SI (m)	A (y)	Temp (^oC)	S (m^2)	Predicted (m^3)	Observed (m^3)
5	13.12271	8	27.09	4	0.1303	0.3496
32	12.92949	12	26.98	4	0.1268	0.1689
43	10.81745	10	27.15	3	0.1090	0.2421
54	11.01007	13	27.02	3	0.0977	0.1465
56	12.872	11	27.01	3	0.1184	0.2069

Legend: SI = site index; A = age; S = spacing; Temp = mean annual temperature

Table 5. Paired comparison T – Test between predicted value derived from yield prediction equation for woodlot with the observed value.

Mean	STD.ERR	T Value	P > [t]
0.0782	0.0210	3.72	0.0338

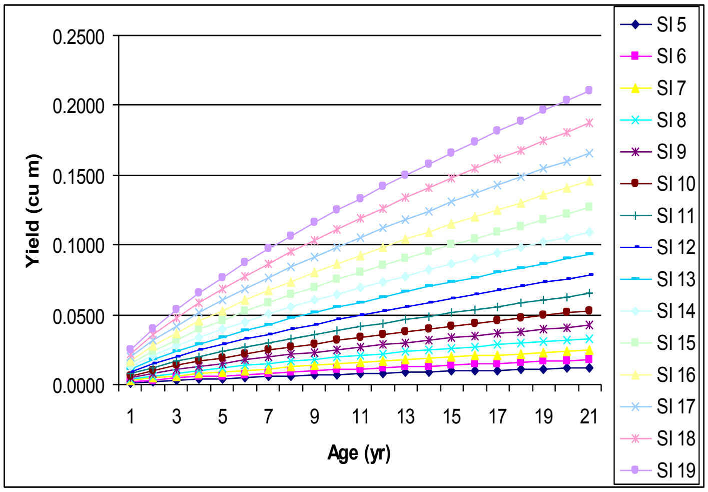

Figure 2. Yield curves of bagras planted along the boundary (spacing = 4 m and mean annual temperature = 26.7 °C).

and the environmental factors thought to influence their growth (i.e. aspect for boundary, elevation for alley and slope and elevation for woodlot). Second, there is a scarcity of published result for use on growth and yield of boundary planting where assessment could be made. In this study, data from plantation was used for comparison.

Carbon Density of Bagras in Agroforestry Systems

The biomass inventoried volume (BV) and constant are highly significant at 0.01 level based on the individual P value of the regression coefficients (**Table 6**). The equation from two parameter exponential growth curve was:

$$BEF = b1*b2^{bv} \quad (5)$$

The final BEF regression equation is:

$$BEF = 4.979136*0.2989477^{BV} \quad (6)$$

Where:
BEF = biomass equation factor in ton per hectare
BV = biomass inventoried volume in ton per hectare

The P >|t| value of the coefficients were highly significant at 0.01 level which indicates that BV in the regression equation have significant effects in the BEF variation. Change in values in the BV in the model cause changes in the BEF values exponentially.

The coefficient of determination showed that about 99.99 % of the variance in the BEF can be explained by BV. This implies that less than 1% was left unexplained by the BEF equation. The coefficient of determination is high enough and the BEF equation can be used to predict BEF for bagras in Misamis Oriental and Bukidnon.

Pearson et al. (*2007*) found out that BEF is significantly related to the growing-stock volume for most forest type, generally starting high at low volumes and then declining at an exponential rate to a constant low value at high volumes. This relationship also applies to bagras regardless of the type of agroforestry systems relative to the BEF model developed in this study. Similar conclusion was attained by the study of *Soares and Tome* (*2004*) that there was strong relationship of BEF with age and stand volume with higher BEF values for very young stands. The BEF value was within the range for tropical broadleaf at 2.0 to 9.0 reported by *Makipaa* (*In Press*).

Wood density in this study was defined as the oven-dry mass per unit of green volume (in Mg m^3). In general, the average value of wood density (0.420) used in this study was taken from *Alipon and Floresca* (*1990*). Wood density was necessary to calculate above ground biomass density (*Brown and Lugo 1992*). The biomass density of bagras plantation was calculated from biomass of inventoried volume (BV) per hectare and then expanding this value to take into account the biomass of other above ground components (*Brown and Lugo 1992*).

Besides its potential for wood production for local and national wood-based industries, bagras planted in the boundary also has role in providing environmental services such as carbon sequestration given the high growth rate of the species. Given the opportunity to sell the carbon sequestered during A/R for climate change mitigation, information on the capacity of corn-based boundary planting agroforestry systems in sequestered carbon in various environmental conditions is needed. The information on carbon sequestration can also be used by government agencies and local government units in developing policies and guidelines

Table 6. Regression coefficients of biomass inventoried volume and constant.

Model	Coefficients	P > [t]	R^2	Adjusted R^2	RMSE
BEF			0.9999	0.9999	0.0386
BV	4.979136	0.000			
Constant	.2989477	0.000			

pertaining to environmental services in their respective local, provincial and regional jurisdictions.

The estimated aboveground biomass density was determined. At ages 1, 10 and 20 years were 0.4700, 1.4052 and 1.5129 Mg per tree (site index = 19 m; spacing = 8 m (52 trees per ha); mean annual temperature = 27.5 ^{o}C). On a stand basis, with the same conditions, the predicted biomass accumulation at 52 trees per hectare was 24.44, 73.07 and 78.67 Mg ha^{-1}. The mean annual aboveground biomass accumulation was 24.44, 7.31 and 3.93 Mg ha^{-1} yr^{-1}. Biomass production can be highly variable – depending on environmental and soil characteristics and tree spacing.

The rate of CO_2 sequestration from bagras was 26.75 Mg ha^{-1} y^{-1}.

Assessing Future Climate Change Impact

In this study, future climate change impact was based on future changes in rainfall and temperature over the Province of Bukidnon. The selection of seasonal rainfall and temperature to represent future climate change was grounded on its inclusion in the yield prediction models constructed for bagras. The projected change in seasonal rainfall and temperature for Bukidnon was used because it is one of the study sites and it is the nearest province to Misamis Oriental compared to other provinces in Mindanao involved in the PAGASA project.

The projected change in seasonal mean rainfall and temperature from Bukidnon was factored in the yield models. The observations generated by PAGASA using PRECIS for the province of Bukidnon in 2020 and 2050 are found in **Table 7**.

On the other hand, seasonal mean temperature entered into the yield prediction equation. The equation developed had shown the predicted positive response of bagras to future changes in seasonal mean temperature. The response of bagras was presented in **Figure 3**. For instance, establishing bagras at a distance = 2 m, site index = 19 m, age set = 10 y was predicted to yield 0.1974 m^3 per tree in 2020. At 2050, yield was predicted to balloon to approximately 3.1182 m^3 per tree. In a related study, *Weigh and Karlsson* (*2000*) found out that on the growth response of Mountain Birch to

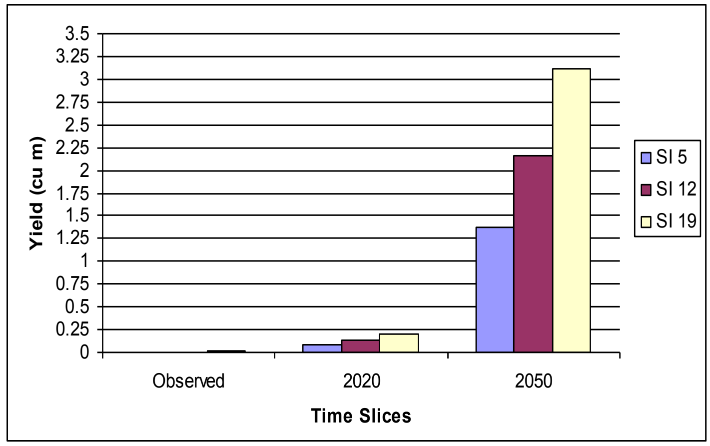

Figure 3. Response of bagras in boundary to future climate change scenario (temperature = 26.88 ^{o}C at 2020, 27.9 ^{0}C at 2050, 25.78 ^{0}C as observed; age = 10 y; spacing = 2 x 2 m)

air and soil temperature summarized that changes in air and soil temperature affected aboveground growth more than the belowground growth and that air and soil temperature had interactive effects on growth rate, N productivity and leaf-N content.

CONCLUSIONS AND RECOMMENDATIONS

The carbon sequestration potential of bagras-corn boundary planting agroforestry system can be determined using non-destructive method. In this study, the aboveground biomass density of bagras was determined using volume over bark, wood density and biomass expansion factor (BEF). The use of BEF is a non-destructive alternative method of determining carbon density aside from the common allometric equation. The BEF for bagras support the general view that there is a strong relationship of BEF with age and stand volume with higher BEF values forvery young stands. The aboveground biomass density per tree in bagras-corn boundary planting was in the order woodlot > boundary > alley.

The yield in this study is sensitive to seasonal mean temperature. In fact, bagras planted as boundary planting in the two provinces was predicted to have positive response to future changes in seasonal mean temperature. That is when yield increases at any given site, with increasing mean temperature.

Table 7. Projected change in seasonal rainfall and temperature for the Province of Bukidnon under scenario A1B.

Time Slices	DJF		MAM		JJA		SON		Total	
	RF (%)	T(^{o}C)	RF (%)	T(^{o}C)	RF (%)	T(^{o}C)	RF (%)	T(^{o}C)	RF (%)	T(^{o}C)
2020	2.90	1.0	-10.30	1.2	-4.40	1.2	-0.30	1.0	-12.10	4.4
2050	-5.10	1.9	-13.00	2.3	-9.70	2.4	-5.80	2.1	-33.60	8.7

DJF = December January February; MAM = March April May; JJA = June July August; SON = September October November

The equation offers an essential aid in the selection of suitable establishment of bagras-corn boundary planting agroforestry systems in Misamis Oriental and Bukidnon and for the future management of this land-use system.

A more detailed study using a greater number of sites over a broader range of environmental conditions may permit greater discrimination using these variables and incorporate measure of nutrient availability in an improved model.

There is limited consensus on which smallholder tree-based agroforestry systems are more efficient in sequestering and stocking carbon dioxide. This study could shed vital information that would explain the variability in superiority of agroforestry system. Likewise, the result of the study could be an essential aid in the preparation of feasibility studies pertaining to bagras-corn boundary planting establishment and management in agroforestry systems.

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