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Light Regime Under *Eucalyptus deglupta* as Hedgerows and its Effect on Intercropped *Zea mays*

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Abstract: The study uses randomized complete block design in determining the light regime under 7 year old *Eucalyptus deglupta* as hedgerows with *Zea mays* underneath. The result shows that the mean Photosynthetic Active Radiation (PAR) was highest at 1200 hr. and lowest at 1500 hr. across treatments (Eucalyptus hedgerows) and cropping season. The solar radiation in the 1x3m and 1x9m hedgerow spacing were lowered by 56% and 46%, respectively compared to the sole maize plot across growing period and cropping season. The total mean height and diameter increment of *Eucalyptus* at the end of the study (two cropping season) were not significantly different. The canopy diameter of Eucalyptus in the wider hedgerow spacing is more spacious than that of the narrow spacing. The grain yield of maize was found higher in sole maize plot than that of the hedgerow treatment. However, the yield is not statistically difference. In agroforestry, light management powers the long-term sustainability and enhances socio-economic profitability of the system. These can be done through appropriate and systematic designs of hedgerows trees that consider the temporal and sequential compatibility of the hedges with the alley crops.

Keywords: Photosynthetic Active Radiation, Hedgerow, Canopy Development, Maize, Grain Yield, Philippines

1. Introduction

In tropical and semi-temperate highland regions, agroforestry is recognized as an appropriate land-use that safeguards sloping landscape and the best alternative for slash and burn agriculture. The recognition of agroforestry systems as alternative land management options in upland areas is premised on its potential ecological, economic and social benefits (Macandog et al. 2004).

The benefits or services that can be obtained from effective agroforestry systems are increased crop productivity, minimization of soil erosion and run-off, improvement of soil properties, moisture conservation, minimization of risks of complete crop failure from pest, disease and calamities, increased space utilization, and improved environmental conservation. These benefits can be an effective tool for rehabilitating and managing degraded uplands and promoting rural development (Vergara and Briones, 1987). However, in spite of its enormous potentials widespread adoption has not been fully realized. In addition to biophysical conditions, there are a variety of socioeconomic, design and management factors that should be considered to enable farmers to attain optimal productivity on a sustained basis.

According to Nair (1993), the success of agroforestry relies heavily on the exploitation of component interactions (i.e., the influence of component of a system on the performance of the other component as well as the system as a whole). Tree-crop interaction in agroforestry can be spatial, temporal or both (Noordwijk and Purnomosihi 1995 as cited by Ong and Leakey 1999). Their net results can be positive (beneficial or production enhancing) and negative (harmful or production-decreasing). These interaction exist because trees and crops differ greatly in size, penology, capacity to capture and efficiently use available resources (Garcia-

Barrios and Ong, 2004). Wojtkowski (1998) said that the productive basis for all agroforestry system is how essential resources (e.g., light; water and nutrients) are allocated to the different plant components. Therefore, a comprehensive understanding of tree and crop interactions in agroforestry system is very much necessary to fully achieve the long-term benefits of agroforestry. This study was conducted to evaluate the light quality below canopy of 7-year old bagras (*Eucalyptus deglupta* Blume) planted with maize (*Zea mays* L.). Specifically, the study aimed to: a.) determine the amount of light under different bagras hedgerow spacing arrangements; b.) observe canopy development of the hedgerows; and determine the growth and yield performance of maize as affected by the different bagras hedgerow spacing arrangements.

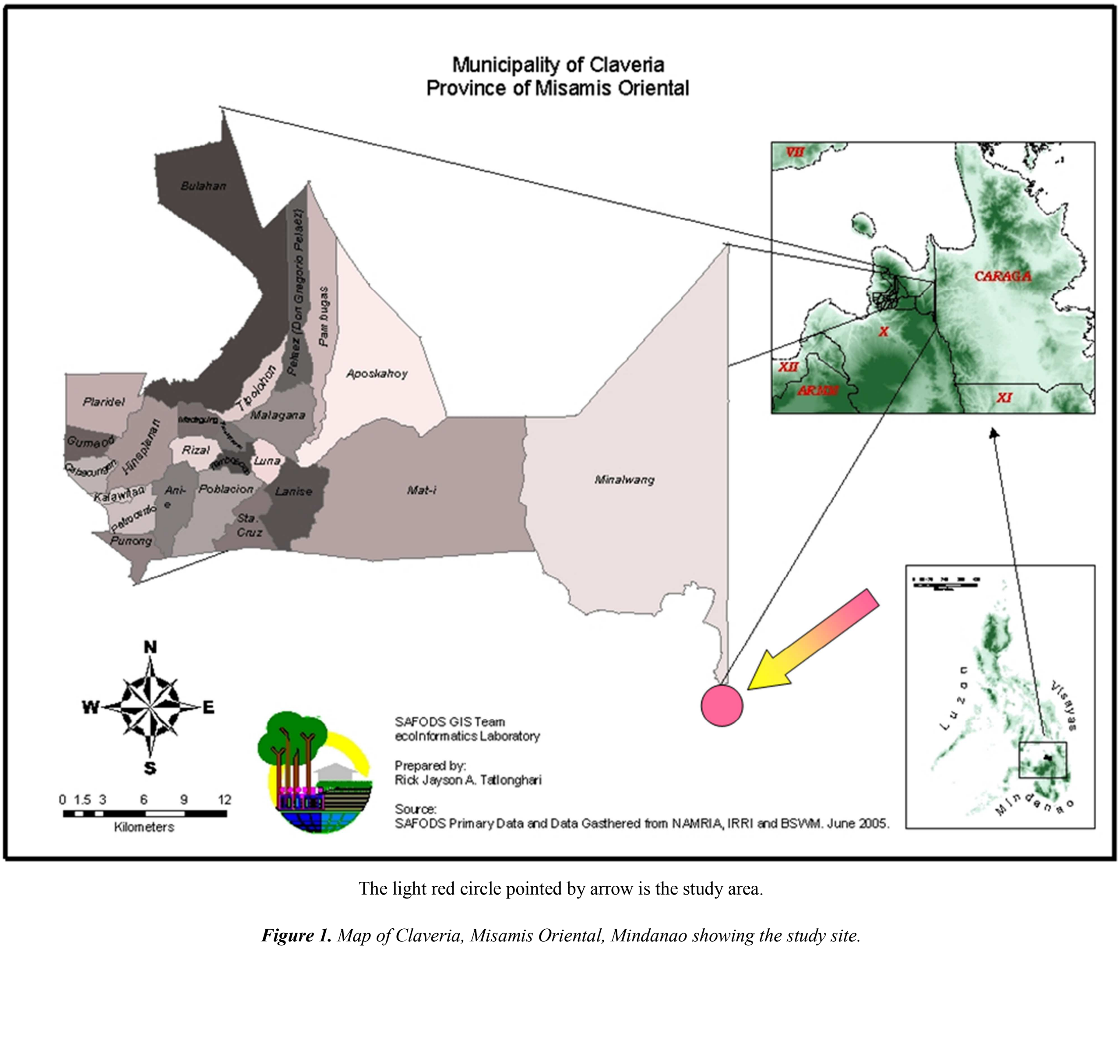
2. Methodology

2.1. The Site

The study was conducted at the former trial study area of Mr. Manuel Bertomeu. The experimental plots were established in 1997-1998 at Sitio Tunggol, Barangay Patrocenio, Claveria, Misamis Oriental (Figure 1). The present study was conducted from February to September 2004.

Claveria is a land-locked agricultural municipality in the province of Misamis Oriental, Northern Mindanao. It is geographically located at 12°45'E longitude and 8°34' to 8°35' latitude (Rañola et.al. 2003). The municipality is about 40.26 kilometers northeast of Cagayan de Oro City, the provincial capital.

Claveria is the biggest municipality in the province of Misamis Oriental with a total land area of 82,500 hectares and is composed of 24 barangays. The municipality sits on a volcanic plateau abruptly ascending from west with 350m asl to 1,200m asl in the East. (Macandog, 2003). It has eight (8) major watersheds namely: Cabulig the biggest watershed in the municipality that covers 13 villages and approximately 19,460 has; Odiogan (11,782 has); Tagonino-Sagpulon (8,468 has); Balatocan (8,180 has); Ojot (7,750 has); Ticala-Pugaan (4,116 has); *Malitbog* (4,099 has); and Siloo, the smallest village with an area of 3,865 hectares (CFLUP, 1998).



The light red circle pointed by arrow is the study area.

Figure 1. *Map of Claveria, Misamis Oriental, Mindanao showing the study site.*

The topography of Claveria is generally rugged, characterized by gently rolling hills and mountains with cliffs and escarpments. The municipality is a volcanic plateau ascending abruptly from the west with elevation ranging from 350 meters above sea level (m asl) to 1,200 m asl in the east. The area is divided into two topographic regimes: Upper Claveria with elevation range of 650-915 m asl and Lower Claveria with elevation range of 390-650 m asl (Macandog 2003). More than 68% of its total land area has slopes greater than 18% (Table 1).

Table 1. *Slope categories and are of coverage in Claveria.*

DESCRIPTION	SLOPE RANGE	AREA (Has.)	PERCENT TOTAL AREA
Level to gently sloping	0-3%	2,721.69	3.30
Gently sloping to rolling	3.1-18%	23,357.01	28.32
Rolling to hilly	18.1-30%	15,266.18	18.51
Hilly to steep hilly	30.1-50%	14,177.51	17.19
Steep hilly to very steep	>50%	26,952.93	32.68

Source: Claveria CLUP, 1999.

Claveria soil is classified as Jasaan Clay, with a deep soil profile (>1meter) and rapid drainage. The soil class is fine, mixed, isohyperthermic Ultic Haplorthox with textural class ranging from clay to silty clay loam derived from volcanic parent materials (Bureau of Soils 1985). Soils pH is generally acidic with values ranging from 3.9 to 5.2 It has also low cation exchange capacity (CEC) and low to moderate organic matter (OM) content (1.8%) (Magbanua and Garrity, 1990). The soil has high aluminum saturation and low levels of available phosphorus (P) and exchangeable potassium (K).

Visayan is the dominant culture in the study site. For them land is classified according to topographic qualities such as terrain, land use, and texture. Visayan called land as Yuta, Lupa for Magindanawn (Abas, 1997) and Tausug (Kaing, 1995). The Visayan traditional culture land domain analyses is presented in Figure 2. The terrain is classified for them as Bukid (Mountainous) and Patag (level land). Bukid is classified as pangpang (cliff), bakilid (sloping), patag na bukid (level upland), and patag sa baba (level low land). Soil texture (lugas sa lupa) is classified as fine soil (pino nga lugas), and coarse soil (dagko nga lugas). Land-uses is classified into six (6) groups:upland rice field (kahumayan), cornfield (kamaisan), sugarcane field (katubuhan), grassland (kasagbutan), forestland (kakahuyan), and lowland rice field (basakan).

2.2. Experimental Design and Treatment

The study was laid out in a randomized complete block design (RCBD) with two replications. There were three treatments as follows:

T_0 = Pure maize

T_1 = 1x3m hedgerow spacing + maize

T_2 = 1x9m hedgerow spaqcing + maize

The hedgerow species used in the study was bagras (*Eucalyptus deglupta*). At the time of the study, the hedgerows were already seven year old.

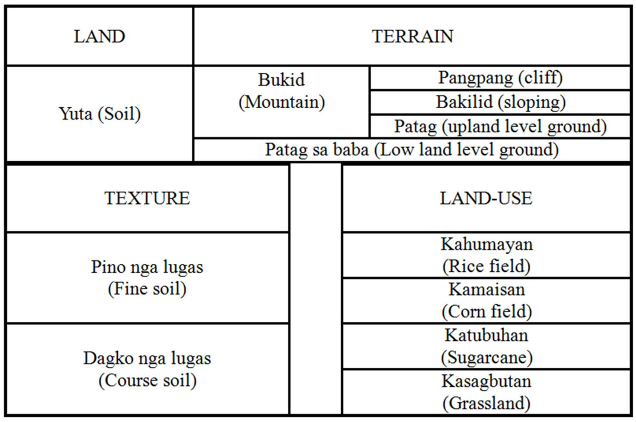


Figure 2. *Land domain matrix in Sitio, Tunggol, Patrocinio, Claveria, Misamis, Oriental Mindanao.*

The field layout of the experiment is shown in Figure 3. In T0 maize was planted as sole crop (without hedgerow). In Treatment 1, the hedgerow were spaced at 1 meter within rows and 3 meters in between rows (Figures 4). On the other hand, within row and between row spacing for Treatment 2 was 1 meter and 9 meters, respectively (Figure 5). There were seven (7) hedgerow established in Treatment 1 and three hedgerows for Treatment 2. Each experimental plot measured 16 meters along the contour and 18 meters along the slope. A buffer zone of six meters between experimental plot was maintained (Figures 6-7).

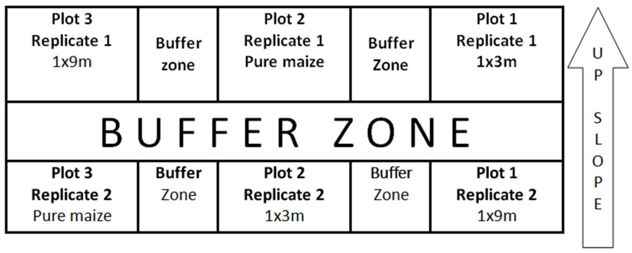


Figure 3. *Experimental layout of the study.*

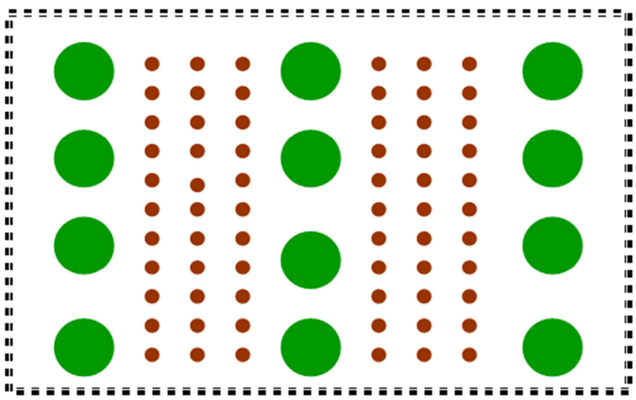


Figure 4. *Hedgerow and crop layout under T1 (1x3m spacing). (Note: Dark green circle denotes bagras and small brown circle represent maize).*

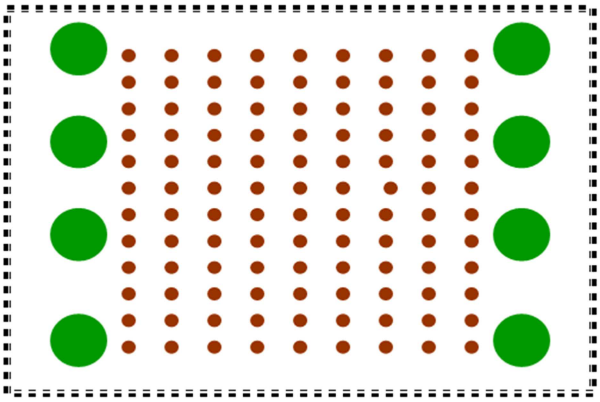


Figure 5. *Hedgerow and crop layout under T2 (1x9m spacing). (Note:Dark green circle denote bagras and small brown circle represent maize).*

Figure 6. *A view of the experimental plot with 1x3m hedgerow spacing, (Photo taken from the northwest side of the plot).*

Figure 7. *A view of the experimental plot under 1x9m hedgerow spacing (Photo taken from the northwest side of the plot).*

2.3. Maize Planting, Maintenance, and Harvesting

The experimental site was cleaned thoroughly before maize was planted. Each plot was plowed and harrowed with the use of animal drawn single blade moldboard. Harrowing was done after heavy rain to ensure that the soil was completely pulverized.

The maize cultivar Pioneer Hybrid 3014 was planted for two cropping season. The planting distance was 75cm between furrows and 25cm between plants within furrows. There were three rows of maize planted per alley in 1x3m and nine maize rows per alley in 1x9m. Weeding of the alleys and inter- row cultivation of maize were done 30 days after planting. Hilling up of maize plants was done two weeks after planting.

Nitrogen fertilizer (Urea, 46-0-0) and phosphorus fertilizer (Solophos, 0-18-0) were applied at the rate of 195.65 kg/ha^{-1} and 166.67 kg/ha^{-1}, respectively. The fertilizer applied was covered with enough soil to avoid contact with seeds before sowing. Nitrogen fertilizer was applied as side dressing thirty (30) days after planting (DAP). Inter-cultivation was done to cover the fertilizer with soil.

Maize harvesting was done once the ears reached maturity. Destructive sampling of 16 sample plants per plot was done to determine maize biomass. Maize leaf, stalk, root and cob were segregated and the fresh weight was taken. One hundred fifty grams fresh sample from each maize component part was taken for oven drying at 70°C for 48 hours. Dry weight of each maize component was determined.

3. Data Collection

3.1. Agroforestry Practices

The information on community farming practices in the study were extracted from the work of Macandog et al. (2004). They used the participatory rapid appraisal (PRA) approach in obtaining the benchmark information from the farmers. PRA tools and approaches include: (a) timeline to capture the history of tree domestication in the area; (b) transect mapping to identify various types of agroforestry practices; and (c) mind mapping to understand the motivation of farmers to adopt tree growing or agroforestry.

Spot interview with the oldest farmers in the study site was conducted to get information on Visayan culture land domain analysis.

3.2. Soil Physical and Chemical Properties

A composite sample was taken in each plot for the analysis of soil physical and chemical properties. Soil samples were collected from the top layer of the soil (0-15cm depth). Soil sampling was conducted before land preparation, after the harvest of the first maize crop, and after the harvest of the second crop maize. The collected soil samples were mixed properly and sub-sample of 1kg were taken and brought for soil analysis at Department of Agriculture-Soils Laboratory, Cagayan de Oro City. Soil chemical properties analyzed were pH, total N, available P, exchangeable K, and OM while the physical properties include texture, bulk density, and particle density.

3.3. Eucalyptus Growth Performance

The initial measurement of bagras height and DBH were done a week before the planting of maize. Succeeding measurements were done after every maize harvest. Tree height was measured with the use of Zunto clinometer's (Optical height meter PM-5/1520) while DBH was measured using a diameter tape. Canopy width was measured from the bole of the tree to the margin of the canopy. Four measurements were done for each tree following the four cardinal directions to determine the average canopy width.

Relative canopy density (RCD) is a measure of the extent of tree canopy shading between hedgerows. It is a simple indicator of tree shading and can be calculated based on a ratio of tree canopy diameter to tree row spacing (alley). This means that when the ratio is >1, meaning the canopy diameter is wider than the spacing between tree rows or the tree hedgerows overlap with the adjoining rows.

3.4. Photosynthetically Active Radiation

A **q**antum meter (model BQM Sun 1444) was used in measuring PAR under the different treatments. The measurements were carried out at two weeks interval until the termination of the study. Light readings were taken at 900 hr, 1200 hr, and 1500 hr of the day. The positions of measurements were at 0-cm from the hedgerow trunk, middle of the plot and outside of the hedgerow in following the four cardinal directions. In the case of control or pure maize, the measurement was taken only at the center of the plot directly above the maize canopy.

The quantum meter sensor indicates direct PAR reading in µmol m^{-2} s^{-1}. The solar radiant (light) reading was directly indicated by the quantum meter sensor and recorded in data sheet.

3.5. Maize Agronomic Performance

Height. The height of maize was determined from selected 16-sample plants marked inside each experimental plot. Measurements were carried out at 15, 45, 75 and 105 days after planting (DAP). Maize height was determined from the ground level to the tip of the longest leaf of each plant.

Number of leaves. The leaves of the sample plants were counted starting from the first measurements of the other maize parameters.

LA and LAI. The length and width of the largest and smallest maize leaves were measured manually with the used of a foot ruler. Sixteen plants per experimental plot were sampled for this purpose.

In estimating the area of each individual leaf blade, the equation used by Elings (2000) was followed.

$$A_L = (L \text{ x } Mw)\ 0.75$$

Where: A_L = individual leaf blade (cm^2) = LA
L= leaf length
Mw = maximum leaf width

LAI was computed following the equation used by Paudel (2005):

$$\text{LAI} = \frac{\text{Total leaf area (sq. cm.)}}{\text{Ground area occupied by plant sample (cm2) based on maize spacing}}$$

Dry biomass and grain yield. The dry biomass and grain yield of sixteen randomly selected maize plants per plot was determined first by segregating the different parts into grain and biomass (leaves, stalk, root, ears and cobs). Maize fresh biomass was oven dried at 105°C for three days to determine dry weight production. The grain weight was determined after air-drying for three days.

The percent dry matter of maize was computed using the following formula.

$$\%\ DMY = 100 - MC$$

Where: $\%\ MC = \frac{\text{Fresh weight} - \text{Oven dry weight}}{\text{Fresh weight}} \times 100$

The dry matter yield in kg/ha was computed as follows:

Dry Matter weight (kg/ha) = Fresh weight (kg/ha) x % Dry Matter.

Total dry matter and grain yield of the alley crop was computed based on full alley as used by Visco (1997).

$$ACY_{FA} = Y_{AC} / A_{OCA} \text{ x } (10{,}000m^2)$$

Where:

ACY_{FA} = Alley crop yield (based on area occupied by crops only)

Y_{AC} = Actual yield in the alley

A_{OAC} = Area occupied by alley crops

To evaluate the aboveground interaction of the alley crop and the hedgerow (solar energy resources sharing) four (4) sample plants were randomly selected from the first, center, and last rows of the alley crop. The same agronomic characters previously mentioned were also determined from the selected maize plants.

3.6. Hemispherical Photographs

Hemispherical photograps were taken at a defined point of each plot. The points were laid out as follows: First, the points were established in tree at the center of the plot with 50cm distance in all directions. Second, succeeding points were established at a regular distance of 1 meter from each other. The number of hemispherical photographs taken in each plot was dependent on the hedgerow spacing (Figures 8 and 9). Photographs were taken only during overcast sky and after dusk to avoid the shadow effect.

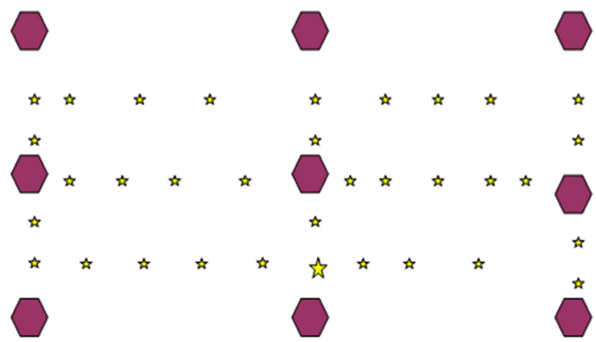


Figure 8. *Camera position in the 1x9m hedgerow spacing (Note: Brown color hexagons denote trees while yellow stars are camera positions).*

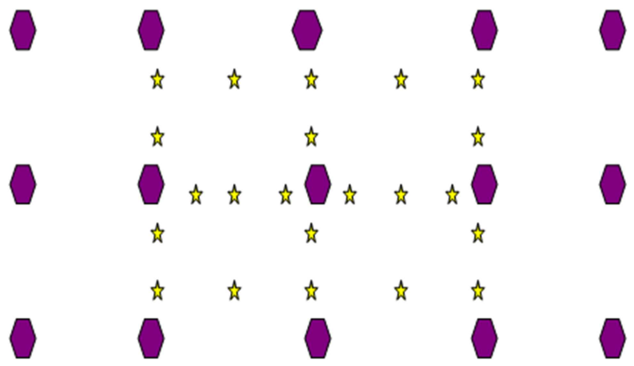


Figure 9. *Camera position in the 1x3m hedgerow spacing (Note: Violet color hexagons denote trees while yellow stars are camera positions).*

4. Data Analysis

The Analysis of Variance (ANOVA) method in Randomized Complete Block Design (RCBD) was used to test for significant differences among the treatments. The STATISTICA software was used to process the data. The Duncan Multiple Range Test was used to test the treatments probability of significance.

5. Results and Discussions

5.1. Agroforestry Practices

Tree-based system is the most common type of agroforestry practice in the municipality of Claveria. These can be found in any barangay and elevation classes. The widely adopted practices are parkland (30%), hedgerow intercropping natural vegetative strip (18%), block/taungya (16%), and border planting (8%) (Macandog et al. (2004). The trees planted under these practices include coffee (*Coffee robusta*, *C. excelsa*, *C. arabica*), yemane (*Gmelina arborea*), falcata (*Paraserianthes falcataria*), mangium (*Acacia mangium*), mahogany (*Swietenia macrophylla*), and bagras. The main reasons identified by farmers for participating in tree planting activity were for additional income, raw furniture materials, soil and water conservation, shade and cooler air, soil fertility restoration, wildlife habitat, and sources of food and medicine.

5.2. Rainfall Characteristics

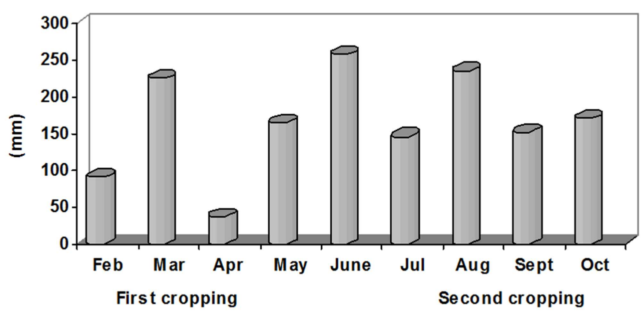


Figure 10. *Monthly rainfall distribution throughout the duration of the study.*

The monthly rainfall recorded during the conduct of the study is shown in Figure 10. The highest amount of rainfall was obtained in June (256.54 mm) while the lowest were in February and March (89.92 mm). A total of 1474.72mm rainfall was recorded during the duration of the study.

5.3. Soil Physical and Chemical Characteristics

The soil physical characteristics of the experimental area were examined based on sample collected after the harvest of the second cropping season. However, the data were not subjected to statistical analysis.

The textural characteristics of the soils obtained in the experimental area are shown in Table 2. Texture was classified as light clay from a dept of 0-28cm, and heavy clay throughout the depth measured. Percent clay increased with soil depth while silt and sand declined. The percent soil moisture content also increased with soil depth. According to Buckman and Brady (1969) heavy clay soil has a high moisture holding capacity.

Table 2. *Textural characteristics of the experimental area.*

DEPTH (CM)	TEXTURE	% CLAY	% SILT	% SAND	% MC
0-28	Light clay	31.5	22.3	42.5	5.36
28-42	Heavy clay	49.8	17.8	32.4	6.75
42-57	Heavy clay	67.8	14.3	17.9	7.05
57-85	Heavy clay	78.9	10.8	10.3	7.61
85-127	Heavy clay	82.8	10.8	6.4	7.96
>127	Heavy clay	82.8	10.8	6.4	8.03

The bulk density obtained in the study area is shown in Table 3. The average soil bulk density in the treatment plots was 1.29 g/cm. The lower bulk density in the hedgerow cropping treatments was due mainly to continuous integration and decay of organic matter coming from the hedgerows. Pritchet (1979) pointed out that the addition of more organic matter in the soil would decrease soil bulk density.

The soil chemical properties, obtained from the study site are presented in Table 4. The mean pH, exchangeable K and OM levels increased in both the hedgerow treatments after the conduct of study. However, total N and available P was lower after the final maize cropping. This decline may be attributed to crop usage of the available soil nutrients during the growing season. The increase in pH may have been brought by the addition of exchangeable bases like potassium from the hedgerows and maize organic residues. According to Asaduzzaman (2000), organic matter contributes much to soil

CEC resulting to higher pH. Young (1987) and Thomson (1957) concluded that organic matter has greater beneficial effects on chemical and physical properties of soil.

Table 3. *Bulk density in the experimental study as influenced by 7-year-old bagras hedgerows.*

TREATMENT	SOILS SAMPLE COLLECTION		MEAN
	Before 1st cropping	After 2nd cropping	
Sole maize	1.32	1.29	1.31
1x3m spacing	1.30	1.23	1.30
1x9m spacing	1.30	1.24	1.27
Total			1.29

Table 4. *Soil chemical characteristics of the experimental area.*

TREATMENT	SOIL SAMPLE COLLECTIONS (0-15cm depth)				
	pH	N (%)	P (ppm)	K (ppm)	OM (%)
Initial					
1x3m spacing	5.30	0.63	6.0	50	2.40
1x9m spacing	5.50	0.63	6.0	50	2.40
Mean	5.40	0.63	6.0	50	2.40
Final					
1x3m spacing	5.98	0.175	1.58	99.00	3.50
1x9m spacing	5.70	0.160	2.45	83.85	3.20
Mean	5.84	0.17	2.02	91.43	3.35

5.4. Eucalyptus Height and DBH

The height and diameter growth of the 7-year old *Eucalyptus* hedgerow are shown in Figure 11. Height increase was not significantly affected by hedgerow spacing (Appendix Table 1). The mean height growth in the 1x3m and 1x9m hedgerow spacing were 2.7 m and 2.2 m, respectively. Total mean height of bagras at the end of the study, however, was lower in the 1x3 m hedgerow spacing (15.03m) than in the 1x9m (16.8 m).

Similarly, no significant difference was found in the diameter increment of the hedgerows (Appendix Table 2). At the end of the study, the diameter of the hedgerows increased by 3.70 cm in 1x3m and 3.95 cm in 1x9m. The mean diameter of the bagras hedgerow in 1x3m and 1x9m were 15.00 cm and 18.06 cm, respectively.

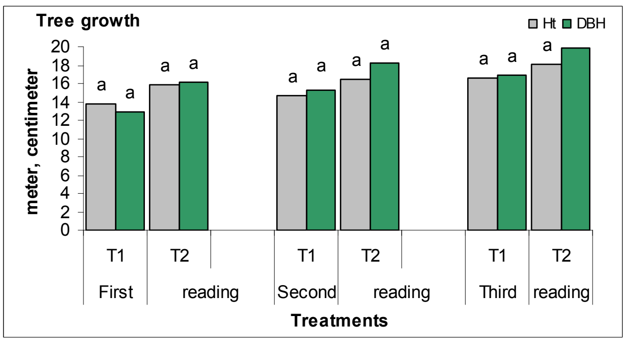


Figure 11. *Height (m) and DBH (cm) growth of 7-year old bagras hedgerows under different spacing arrangements. (Note: T1 = 1x3m spacing and T2 = 1x9m spacing).*

The relatively better height and diameter of wide-spaced hedgerow (1x9m spacing) could be attributed to the lower tree density resulting in lesser tree competition. The lack of significant difference in growth increments between the treatments could be due to the short duration of the observation period. Bagras is also a fast growing species and may have already reach the age where growth rate has already tapered. Tewari et al, (2001) reported similar observation during an eight-year rotation period of the species and grown in an area with favorable soil fertility and rainfall environment.

5.5. Canopy Development

The vertical profile and extent of canopy development of the hedgerow are shown in Figures 13 to 18 and Table 5. The results show that canopy diameter was significantly affected by hedgerow spacing (Appendix Table 3). Mean canopy diameter of trees in 1x9m hedgerow spacing (7.72 m) was wider than that of 1x3 m spacing (5.28 m). The larger canopy diameter obtained by trees in the 1x9 m treatment could be attributed to more growing space between hedgerows which allowed greater canopy expansion. In the 1x3m spacing, the available growing space between adjoining hedgerows is narrower which could have suppressed the growth and further expansion of the canopy. This condition can be considered as negative interaction between single species as consequences of high plant density in the system. Hedgerow trees also compete with one

another for available light, nutrients and water in alley cropping system (Singh et al. 1989).

In order to find a simple indicator of tree shading, RCD of the hedgerow trees was calculated. This was based on the ratio of tree canopy diameter to hedgerow spacing. An RCD value of greater that one indicates that adjoining tree crowns overlap with each other. The results show that RCD was significantly affected by spacing (Appendix Table 3). The RCD of 7-year old bagras in the 1x3m spacing was 1.76 which means that the canopy diameter were wider than the distance between hedgerows. This indicates the presence of canopy overlap between trees of adjoining rows. The immediate effect of this condition is the decline in light levels for the use by understory crops. The RCD in the 1x9m hedgerow spacing was only 0.86, which suggests that there is still no inter-crown contact between adjoining hedgerows.

The canopy openness computed by GLA software shows that there was no significant difference between the hedgerow spacing treatments (Table 5 and Appendix Table 4). It is evident that canopy overlap occurs in the former due to closer hedgerow spacing, gap openings in the canopy was similar to the wider spaced hedgerow. Mean percentage canopy openness across cropping season was 40% in 1x3m hedgerow spacing and 38% in 1x9 m. The canopy extension of trees in the 1x9m spacing despite the wider alley and absence of overlap as computed by RCD still produced canopy opening comparable to the 3 m spacing. However, this depends on canopy geometry and structure. According to Canham (1995), there are various predictable relationships between the geometry of gap and the transmission of diffuse and direct PAR to any particular point in a canopy gap opening.

Table 5. *Mean canopy diameter, RCD and canopy openness of 7-year old bagras under different hedgerow spacing treatments.*

TREATMENT	CD†(m)	RCD†	CANOPY OPENNESS (%)†	
			First Cropping	Second Cropping
1x3m spacing	5.28[a]	1.76[b]	39.55a	41.41a
1x9m spacing	7.72[b]	0.86[a]	39.01a	37.20a

† Means in column followed the same letters are not statistically different (P<0.01) by DMRT.

5.6. Light Dynamics in the Eucalyptus Cropping System

5.6.1. PAR at Different Times of the Day

Solar radiations under the different cropping treatments measured at three different times of the day are presented in Table 6. Overall, solar radiation increased as solar angle increased during the day. The mean PAR was highest at 1200 hr and lowest at 1500 hr (across treatments and cropping season).

The amount of PAR differed significantly in the hedgerow spacing treatments compared to the sole maize system (Appendix Tables 5-10). Light measured at 0900 hr and 1200 hr was significantly lower in both hedgerow treatments (1x3m and 1x9m). Light reductions at 1500 hr were also observed although the difference with sole maize was not significant. The difference in light received by the 1x3m and 1x9m treatment was not statistically significant (across time of day and growing season).

Table 6. *Mean PAR under the different treatments during the first and second cropping season measured at different times of the day.*

TREATMENT	PAR (µmol m^{-2} s^{-1}) †		
	0900 hr	1200 hr	1500 hr
	First Cropping		
Sole maize	1244.41b	1385.65b	507.78ab
1x3m spacing	549.08a	805.38a	622.92b
1x9m spacing	493.28a	937.35a	375.22a
Mean††	762.26b	1042.79c	501.97a
	Second Cropping		
Sole maize	1108.72b	1569.22b	584.75b
1x3m spacing	572.02a	771.94a	385.74a
1x9m spacing	571.63a	789.90a	318.51a
Mean††	750.79b	1043.68c	429.67a

† Means followed by the same letters in a column are not statistically different (P<0.05).
††Means followed by the same letters in a row are not statistically different (P<0.01).

The quantity of light received by a plant depends on shading, geographic location, time of day, season, and cloud cover (Power and McSorley 2000), and canopy architecture, height, leaf area angle (Kozlowski and Pallardy 1997).

5.6.2. PAR Received During the Growing Season

The mean amount of PAR received by the treatment plots during the growing two growing seasons are shown in Table 7. The results show that mean solar radiation in the alley was significantly affected by the presence of bagras hedgerows (Appendix Tables 11). Mean solar radiation in the 1x3m and 1x9m hedgerow spacing treatments were lower by 56% and 46%, respectively compared to the sole maize plot (across growing period and cropping season). The observed decline in solar radiation is consistent with the percentage canopy openness recorded in the hedgerow spacing treatments. There was no significant difference for PAR received by the 1x3m and 1x9m hedgerow spacing. Gonzal (1994) found poor growth and performance of upland rice and corn in unpruned hedgerows due to shade PAR problem brought by the dense canopy of the hedgerow (*Gmelina arborea*).

In the first cropping season, solar radiation was not significantly different in the terms of growing period or time of measurement (across treatment). However, mean PAR received in the treatment plots during the second cropping season was comparatively lower at 45 DAP than 75 DAP and 105 DAP.

The lower intensity of solar radiation in the hedgerow spacing treatments compared to the sole maize system clearly demonstrate the extent of shading effect created by the hedgerows. Power and McSorley (2000) emphasized that the quantity or intensity of light received is dependent on shading, geographic location, time of day, season, cloud cover and many others. The present study shows that reduction in the quantity of solar radiation is a direct consequence of the shade effect of the bagras hedgerows. According to Ong and Huxley (1996), the shading effect of tall trees alters not only the quantity but also the spectral composition of solar radiation. The implication is that in tree-based intercropping systems, the radiation that reaches the understory crops may be severely depleted in PAR and not maximally available as in monocropping systems.

Table 7. *Mean PAR during the first and second cropping season at different times of the growing period. (DAP-Day After Planting of maize).*

TREATMENT	PAR (µmol m^{-2} s^{-1})†			
	45 DAP	75 DAP	105 DAP	Mean
	First cropping			
Sole maize	1079.26	912.86	1021.3	1004.47b
1x3m spacing	707.83	747.94	620.38	695.05a
1x9m spacing	619.09	608.33	578.44	601.95a
Mean††	802.06a	756.38a	740.04a	
	Second Cropping			
Sole maize	784.47	1386.13	1251.44	1140.68b
1x3m spacing	253.19	638.29	445.38	445.62a
1x9m spacing	223.88	884.64	531.03	546.52a
Mean††	420.513a	969.687c	742.617b	

† Means followed by the same letters in a column are not statistically different (P<0.05).
††Means followed by the same letters in a row are not statistically different (P<0.01).

5.6.3. PAR Spatial Variability in the Alley

Light intensity in the hedgerow treatments measured at different position in the alley are presented in Table 8. The analysis of variance showed that PAR was significantly affected by spatial position in the alley (Appendix Table 12). In both hedgerow spacing treatments, PAR was significantly lower at the lower row (LR) and upper row (UR) near the hedge compared to the center row (CR) indicating greater light attenuation towards the hedgerow. Solar radiation decline relative to PAR received at the center of the alley was 63% for LR and 30% for UR. The decline was higher during the second cropping season with 72% and 35% in the LR and UR, respectively.

Hedgerow spacing effects on PAR at different positions in the alley was not significant. However, similar trend in PAR attenuation near the LR and UR hedgerow was also observed in both cropping seasons.

This light condition in the alley would greatly affect intercrop performance. Ong et. al. (1996) observed that millet rows adjacent to the hedges intercepted 100-150 MJ $m^{-2}s^{-1}$ radiation than the three central rows. Kang et al. (1985) found that maize row adjacent to *leucaena* received 51-69% of the available light compared with 75-81% by mid alley rows. Their study in Nigeria demonstrated competition for light in a maize *leucaena* alley cropping system.

Table 8. *Mean PAR at different position in the alley as affected by bagras hedgerow spacing treatments.*

TREATMENT	PAR (µmol m^{-2} s^{-1})†		
	LR	CR	UR
Dry Cropping Season			
1x3m spacing	462.40	1094.80	786.14
1x9m spacing	362.41	1144.93	787.12
Mean	412.41a	1119.87c	786.63b
Wet Cropping Season			
1x3m spacing	342.20	1069.76	537.79
1x9m spacing	249.26	1072.15	675.47
Mean	295.73a	1070.96c	606.63b

† Means followed by the same letters in a row are not statistically different (P<0.01) by DMRT.

5.7. Maize Agronomic Characteristics

Maize Height – The mean height growth trend in all treatment showing a linear pattern from 15 until 75 DAP Figure 12. Overall, the height of alley crop maize through its growing period was significantly affected by the presence of 7-year-old Bagras hedgerows. Sole maize was markedly taller than those planted as intercrop in the two hedgerow spacing treatments. This situation could be attributed to low light availability under the hedgerow system compared to sole maize crops. The negative interaction cr4eated by hedgerows on maize height was evident as early as 15 DAP and continued until 105 DAP matured stage.

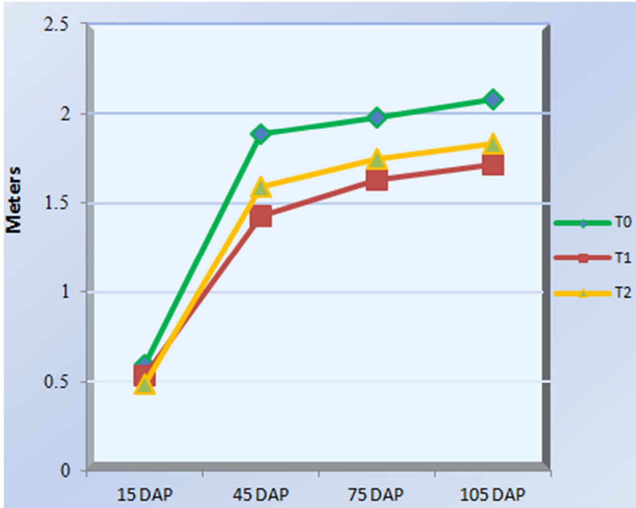


Figure 12. *Maize height growth.*

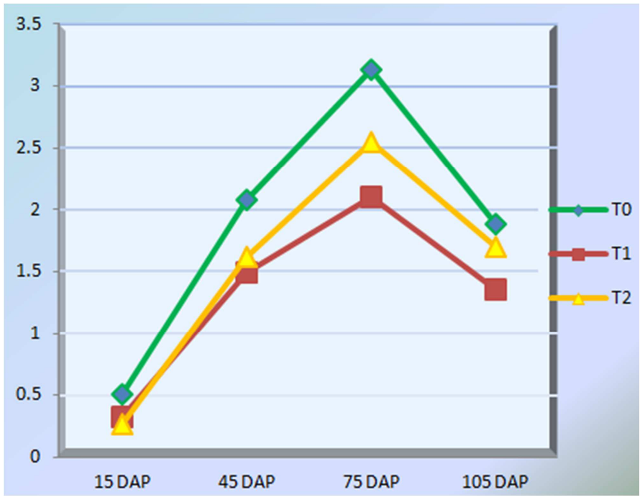


Figure 13. *Maize LAI.*

Leaf Area Index – The LAI growth pattern is shown in Figure 13. The LAI in the sole maize system differed significantly from the LAI under hedges treatments. The highest LAI was obtained in sole cropping followed by wider hedges and the least was in narrow spacing. The difference between in LAI between the two hedgerow spacing treatments was statistically insignificant. The LAI was generally increasing up to 75 DAP and decline thereafter regardless of treatments. The decline trend across treatments may be attributed to senescence of leaves as maize matures particularly, those under the canopy layer.

Grain Yield - The grain yield of maize was found higher in sole maize (1.36 tons ha^{-1}), followed by 1x3m (0.75 tons ha^{-1}), and in spacing 1x9m was lower (0.59 tons ha^{-1}) Figure 14. However, the yield difference was statistically insignificant. The lower yield of maize under the hedgerow treatments compared to sole maize cropping could be attributed to shading effect of the hedgerow resulting to lower light availability for understory crops. In alley cropping system, aboveground competition for light could be more pronounced especially in high rainfall areas (Abunyewa et al., 2004). The results also agrees with the observation of Duguma et al., (1988) and Lawson and Kang (1990) who reported that higher hedgerow height reduced the yield of associated crop as a result of reduction in light transmission. Solera (1993) observed that the yield of upland rice significantly increased because of the reduction of shading by pruning the hedgerow.

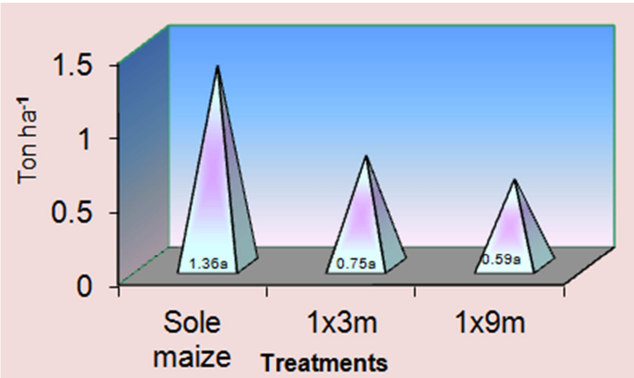


Figure 14. *Maize Grain Yield.*

6. Conclusion

In agroforestry, light management powers the long-term sustainability and enhances socio-economic profitability of the system. These can be done through appropriate and systematic designs of hedgerows trees that consider the temporal and sequential compatibility of the hedges with the alley crops. Based on the finding of the study the following conclusions were drawn:

- Bagras and maize were compatible species in an agroforestry farming system.
- Bagras transmits light that still suit to alley crops maize growth necessity.
- Bagras canopy geometry has a manageable negative interaction in the system.
- Light under 7-year-old Bagras hedgerow could be manage through appropriate design of the hedgerow system

Recommendation

Based on the experiences that had been encountered in this research work the following recommendations were formulated:

- Long-term study should be conducted to capture in the future the appropriate philosophy of an agroforestry system.
- This study should be replicated in other province and Island, to verify the findings veracity.
- Future research should gear on the design of agroforestry technology, to obtained valuable technical knowledge that improves the compatibility of different species in agroforestry system.

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