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SOIL AND MICROCLIMATE AMELIORATION OF SHORT ROTATION FORESTRY-BASED AGROFORESTRY IN CUENCA, BATANGAS, PHILIPPINES

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ABSTRACT

Marginal uplands are among the highly vulnerable areas exposed to extreme environmental harsh conditions. To ensure the ecological stability of the watershed, rehabilitation strategies of these marginal degraded uplands is of urgency. Among the promising rehabilitation species is *Jatropha curcas* L. Jatropha is receiving heightened attention for its ability to grow on marginal land characterized by infertile soil and with limited rainfall. Similarly, the widely distributed oil-bearing woody Jatropha receives a lot of attention from Clean Development Mechanism project developers all over the tropical world. The study assessed the influence of the Short Rotation Forestry (SRF)-based agroforestry production systems on the microclimate and soil properties at marginal upland condition of Cuenca, Batangas, Philippines from February 2008 to February 2010. *Jatropha curcas* L. was planted in different spacing of 2 x 2 m and 3 x 3 m in the monoculture plantation and 2 x 2 m as an intercrop in the SRF-based agroforestry system. The SRF species were *Acacia mangium, Pongamia pinnata* and *Eucalyptus deglupta.* Production systems have significant influence on the change in topsoil organic matter, total nitrogen and available phosphorus, and the subsoil pH. Microclimate amelioration was observed with air and soil temperature, and wind velocity as significantly influenced by the production systems but not relative humidity. Results of this study provided significant benchmark information on establishing the potential of Jatropha as a rehabilitation species in the upland marginal condition and a suitable species in an agroforestry-based production system vis-à-vis its amelioration in the soil and microclimate. The SRF species namely, *A. mangium* and *E. deglupta* proved to have beneficial influence on the site factors.

Key words: marginal upland, rehabilitation, site factors

INTRODUCTION

In the Philippines, uplands cover 17.6 M hectares, which is 59 percent of the total land area of the country (Fortenbacher and Alave, 2014). It is a home to 24 M Filipinos (Payonga and Gonzalez, 2009). However, population pressure, commercial logging and extraction activities alarmingly led to the land conversion, agricultural expansion and slash and burn farming in the fragile uplands. The potential suitability of Jatropha in the country is based on its inherent drought resistant characteristics having robust growth even on marginal areas. Moreover, it is not browsed by animals and has few pests and diseases (Gu¨ bitz *et al.*, 1999; Openshaw, 2000 and Augustus *et al*., 2002). Jatropha is a valuable multi-use crop that can alleviate soil degradation, desertification and deforestation. In addition to ameliorating the edaphic properties, atmospheric condition is likewise benefited through its contribution towards making the objectives of stabilizing Green House Gas (GHG) emission. Moreover, the seed production and by-products that could be developed from Jatropha have the potential to increase income of rural farming families (Tomomatsu and Bent 2007). Godilano (as cited by Villancio, 2006) studied the suitable planting areas in the Philippines for Jatropha which is estimated at 12,992.812 hectares. Ecologically, Jatropha has a niche in the Philippine uplands and in the coconut-based agroforestry system. A recent study showed that Jatropha grown on marginal soils improved soil aggregation thereby decreasing soil erosion. Jatropha has the potential to increase soil carbon sequestration and nutrient content. The use of Jatropha to reclaim marginal lands could help to improve future availability of food (Ogunwole *et al.* 2008).

Meanwhile, *Acacia mangium* Willd., a fast growing nitrogen-fixing species has also gained an increasing interest for reforestation and rehabilitation programmes in the humid tropics for its remarkable growth potential even on marginal land which are very acidic and infertile soils (Yamamoto *et al.* 2003). *Eucalyptus deglupta* has been used in reforestation and in enriching planting trials in logged-over forest (Orwa *et al.* 2009). Given the environmental impacts of inorganic fertilizer including its cost, combining nitrogen fixing species with other short rotation species is a silvicultural prescription that could facilitate rehabilitation efforts. There is increment in biomass production of eucalypt plantations when acacia is introduced as an understorey (Laclau *et al.* 2008). Hence, this study was conducted to assess the influence of the Short Rotation Forestry (SRF)-based agroforestry production systems intercropped with *Jatropha curcas* on the site factors. Specifically, the study determined the resulting influence of the SRF-based agroforestry system on the microclimate and soil properties of marginal upland conditions in Cuenca, Batangas, Philippines.

MATERIALS AND METHODS

Experimental Site

The experiment was established in Mt. Makulot, San Isidro, Cuenca, Batangas, Philippines. Mt. Makulot is located at the southern portion of Taal Volcano Caldera in the Municpality of Cuenca, Batangas, which is about 94 kilometers from Metro Manila. The climate in the area belongs to the Type I classification with pronounced dry season from November to April and wet season from May to October. The weather station in Ambulong, Batangas had recorded that from 1998-2007 the annual average rainfall, maximum and minimum air temperatures were 1679.4 mm, 31.69 and 23.78°C, respectively. The soils of the Municipality of Cuenca are mainly derived from volcanic materials which are either deposited by air or reworked by water. Soil texture ranged from silt loam to light clay which are friable and have very favorable tillage properties. Soil type at San Isidro belongs to the Ibaan series. The topsoil is light reddish brown, brown to dark brown, friable, blocky and coarse granular clay loam to loam with 20 to 35 cm depth. The soil origin is volcanic tuff. The experimental site is located from 650 to 700 masl with a slope ranging from 35-60%.

Experimental Design and Treatments

The experiment was arranged using Randomized Complete Block Design (RCBD) with 3 replications. T_1 and T_2 represented the pure plantation of *Jatropha curcas* at two different spacing. T_3 and T_4 were the SRF-based agroforestry system intercropped with nitrogen fixing species while T_5 was the SRF-based agroforestry system intercropped with non-nitrogen fixing species. Specifically, the experimental treatments were: T_1: control plots purely planted with *J. curcas* at 2 x 2 m in quincunx design; T_2: purely planted with *J. curcas* at 3 x 3 m spacing; T_3: *Acacia mangium* + *J. curcas*; T_4: *Pongamia. pinnata* + *J. curcas*; and T_5: *Eucalyptus deglupta* + *J. curcas*. The distance between each treatment plot was 3 m. The SRF are fast growing species planted at 4 x 2 m. The *J. curcas* planted as intercrop in the SRF agroforestry-based systems is also planted at 2 x 2 m. The experimental plots were established and maintained from February 2008 until February 2010.

Data Collection and analysis

Soil chemical properties. Benchmark information on the soil properties prior to the establishment of the study was determined on February 2008. The measured soil parameters were soil pH, organic matter content (%), total nitrogen (%), available phosphorus (ppm), exchangeable potassium (me/100g soil) and cation exchange capacity (cmo(+)/kg soil) which were analyzed using standard procedure of potentiometric method, Black and Wakley procedure, computation based on organic matter content; Bray No. 2 method and ammonium acetate, respectively. The laboratory analyses were conducted at the Analytical Services Laboratory, Agricultural Systems Cluster, College of Agriculture, University of the Philippines Los Baños. Final measurement of soil chemical properties was done on February 2010.

Microclimate parameters. The above canopy air temperature and relative humidity were measured using a thermo hygro digital meter from 1000-1030H. It was assessed that during period that more or less a balance among the microclimate parameters being measured exists, thereby avoiding extreme influence of air temperature on other parameters. Soil temperature at 5 cm depth and wind velocity above the vegetation canopy were measured using soil thermometer and wind anemometer, respectively. The microclimate parameters were determined monthly starting from November 2009, when the crops planted have already established growth and survival after outplanting, until February 2010.

The data were subjected to ANOVA using the SAS 9.1.3. (TS1M3) software for Microsoft Windows. Significant differences among treatment means were determined using LSD.

RESULTS AND DISCUSSION

Soil Chemical Properties

The extent and rate of soil quality improvement as influenced by tree-mediated processes have been proven (Chirwa *et al*. 2007; Sileshi *et al*. 2007). Specifically, these include increased nitrogen (N) input through biological N fixation, enhanced availability, greater uptake and utilization of nutrients, increased activity of soil biota and improved water dynamics. The succeeding discussion shows the influence of the different production systems on the edaphic chemical properties (Table 1) in the marginal lands of Mt. Makulot, San Isidro, Cuenca, Batangas.

Initial Topsoil and Subsoil Chemical Properties. Among the six chemical properties, only the available phosphorus had difference in its initial soil condition (Table 1). *A. mangium* + *J. curcas* plot had the highest available phosphorus, and yet, it decreased after the experiment period. In terms of the influence of the available phosphorus that decreased in *A. mangium* + *J. curcas* it could be due to the requirement of leguminous species for phosphorus uptake for nodule development, nitrogen fixation and root development (Bargaz *et al*. 2012). The organic matter content serves as reserve for the amount of nitrogen that could be released. Hence, the increase in the organic matter regardless of treatments resulted in increase in total nitrogen except for T_4.

Final Topsoil and Subsoil Chemical Properties. The total nitrogen is the only topsoil chemical property that was significantly influenced by the different agroforestry production systems (Table 1). The highest and lowest total nitrogen were observed in T_5 (0.22%) and T_1 (0.19%), respectively. T_5 had the highest topsoil total nitrogen content because the fast growing nature of *E. deglupta* could have absorbed soil nutrient from the lower soil horizon and returned it to the soil surface via the nutrient pumping phenomena (Lasco and Visco 2003). T_3 and T_4 which had nitrogen-fixing SRF species could have significantly contributed to the total topsoil nitrogen content. The SRF-based agroforestry production systems proved to have beneficial effect on the topsoil total nitrogen. T_2 had the lesser plant density of Jatropha which absorbs nitrogen from the topsoil. This is validated by Chaudhary *et al*. (2007) wherein the soil N availability increased significantly with increase in spacing vis-à-vis T_1 and T_2.

Table 1. Top and subsoil properties as influenced by the different production systems of Jatropha.

Soil Properties/ Treatment	**Measurement Period**					
	Topsoil			**Subsoil**		
	Initial	**Final**	**Difference**	**Initial**	**Final**	**Difference**
pH						
T_1	5.6 a	5.8 a	0.17 a	5.7 a	5.8 ab	0.17 ab
T_2	5.5 a	5.7 a	0.17 a	5.5 a	5.6 c	0.10 b
T_3	5.7 a	5.9 a	0.17 a	5.7 a	5.9 a	0.27 a
T_4	5.6 a	5.8 a	0.17 a	5.7 a	5.8 abc	0.07 b
T_5	5.7 a	5.7 a	0.00 a	5.6 a	5.7 c	0.13 ab
Organic Matter (%)						
T_1	4.13 a	5.20 a	1.07 ab	3.69 a	4.39 a	0.70 a
T_2	4.40 a	5.91 a	1.50 ab	3.77 a	5.28 a	1.15 a
T_3	3.69 a	5.36 a	1.67 a	3.44 a	4.80 a	1.37 a
T_4	5.07 a	5.40 a	0.33 b	3.68 a	4.66 a	0.98 a
T_5	4.38 a	5.54 a	1.16 ab	3.74 a	4.82 a	1.08 a
Total Nitrogen (%)						
T_1	0.18 a	0.19 b	0.001 ab	0.20 a	0.17 a	-0.030 a
T_2	0.02 a	0.21 ab	0.03 a	0.21 a	0.20 a	-0.01 a
T_3	0.02 a	0.20 ab	0.02 ab	0.17 ab	0.17 a	0.0003 a
T_4	0.23 a	0.20 a	-0.04 b	0.13 b	0.18 a	-5.56 a
T_5	0.20 a	0.22 a	0.02 ab	0.18 ab	0.18 a	-0.003a
Available Phosphorus (ppm)						
T_1	0.95 b	1.67 a	1.23 a	1.06 a	1.67 a	1.03 a
T_2	0.95 b	1.33 a	0.90 a	1.06 a	1.33 a	0.70 a
T_3	1.81 a	1.33 a	-1.57b	1.09 a	1.33 a	0.63 a
T_4	1.24 b	1.67 a	0.60 a	1.09 a	1.67 a	0.97 a
T_5	1.09 b	1.67 a	0.97 a	1.32 a	1.33 a	0.03 a
Exchangeable Potassium(me/100 g)						
T_1	3.35 a	3.92 a	0.58 a	3.12 a	3.43 ab	0.31 a
T_2	3.24 a	3.00 a	-0.24 a	3.08 a	2.92 ab	-0.16 a
T_3	3.63 a	3.77 a	0.14 a	3.18 a	3.49 a	0.31 a
T_4	3.47 a	2.92 a	-0.56 a	3.41 a	2.83 b	0.57 a
T_5	3.42 a	3.04 a	-0.39 a	3.05 a	3.11 ab	0.06 a
CEC (cmol(+)/kg soil)						
T_1	29.55 a	28.63 a	-0.02 a	28.37 a	28.30 a	0.00 a
T_2	30.00 a	29.97 a	0.00 a	25.73 a	29.17 a	2.70 a
T_3	27.10 a	30.70 a	3.60 a	29.97 a	29.70 a	0.43 a
T_4	29.90 a	29.57 a	-0.33 a	29.47 a	28.70 a	-0.08 a
T_5	28.29 a	30.20 a	1.91 a	27.43 a	29.73 a	2.30 a

Means followed by the same letters within a row are not significantly different at 5%.

MAO – Months after Outplanting,

T_1 – 2 x 2 m spacing, T_2 – 3 x 3 m spacing, T_3 – *A. mangium* + *J. curcas* L., T_4 – *P. pinnata* + *J. curcas* L., T_5 – *E. deglupta* + *J. curcas* L., T_1 and T_2 – represented the pure plantation, T_3 and T_4 – SRF-based agroforestry system with nitrogen fixing species and, T_5 – SRF-based agroforestry system with non-nitrogen fixing species

The treatment means of the topsoil chemical properties which were not significantly different were pH, organic matter content, available phosphorus, and cation exchange capacity (CEC) (Table 1). The observed topsoil pH and CEC for all the treatments are within the critical level range of 5.5-6.5 and 15-35 cmol (+)/kg soil, respectively. The topsoil organic matter and exchangeable potassium content for all the treatment plots was qualitatively high. The available phosphorus for all the production systems had low quantity which could be attributed to the soil pH which is slightly acidic. The subsoil pH and exchangeable potassium were significantly influenced by the different production systems (Table 1). The subsoil pH for all the production systems was within the critical level range. T_3 had the highest subsoil pH of 5.9 while the least was recorded in T_2 (5.6) and T_5 (5.7). The differences could be attributed to the different species in the production systems, which exerts varying nutrient uptake and safety net mechanisms to prevent leaching that would affect the protonation in the soil (Binkley as cited by Mead and Cornforth 1995).

Four subsoil chemical properties namely, organic matter content, total nitrogen, available phosphorus and CEC were not significantly influenced by the different production systems (Table 1). Highest subsoil organic matter (5.28%), total nitrogen (0.20%) and CEC (29.17 cmol (+)/kg soil) were noted in T_2 which has lesser plant density resulting in lesser potassium uptake.

Topsoil Properties Difference. All treatments had positive effect on P except T_3. The change in the topsoil pH, K and CEC before and after the experimentation were not significantly influenced by the different production systems (Table 1). The exchangeable potassium increase in T_1 could be accounted for by the significant Jatropha litter fall production of 1.63 t/ha monitored from this production system. T_2 to T_5 had similar litterfall production of 0.83, 1.13, 0.93 and 1.00 t/ha, respectively. The agroforestry production systems significantly influenced topsoil organic matter, total nitrogen and available phosphorus. The highest mean increase in organic matter was observed in *A. mangium* + *J. curcas* (1.67%) and the least was noted in *P. pinnata* + *J. curcas*. Nutrients are released from trees into the soil through prunings, litter and dying roots, or are leached from the crown by throughfall and stemflow (Schroth *et al*. 2001) which is in warmer temperatures (Leiros *et al*. 1999). The relatively higher organic matter content in T_1 could have been influenced by the relatively higher air temperature prevailing in the locality (Table 2), coupled with the highest litter fall production. On the other hand, the highest increase of organic matter content in T_3 could be attributed to the beneficial influence of *A. mangium* biomass (Galiana *et al*. 2002) leading to soil fertility improvements.

Subsoil Properties Difference. Only the subsoil pH had significant treatment mean difference (Table 1). The production systems elicited an increase in the subsoil pH. The highest subsoil pH increase of 0.27 was observed in T_3 indicating the SRF-based agroforestry production systems had amelioration effect on subsoil.

Microclimate

Microclimate refers to the atmospheric characteristics prevailing in the layer near the ground that is affected by the ground surface. It influences humidity (by evapotranspiration), temperature and wind (Wood and Burley 1991).

Air temperature. The air temperature was influenced significantly by the production systems from the 18th to the 22nd month of monitoring. Both the monocropping production systems vis-à-vis T_1 (33.83°C) and T_2 (33.73°C) recorded the highest air temperature. The vegetation cover from these monocropping production systems received direct and diffuse sunlight, thereby, increasing air temperature (Shanker *et al*. 2005). The study of Silva (as cited by de Souza *et al. 2010)* proved that the environment receiving direct radiation from the sun, heats and stores this transformed energy.

The SRF-based agroforestry systems (T_3, T_4 and T_5) had lower air temperatures from the 18th to the 21th months of monitoring compared to the monocropping of Jatropha. This could be attributed to the shading effect of the SRF intercrops. However, on the 22nd month, the monocropping of Jatropha in T_1 (27.36°C)) and T_2 (27.91°C) had significantly lower air temperature similar with T_5 (28.36°C). The greater air movement in T_2 due to the relative faster wind velocity (26.66 km hr^{-1}), lowered the prevailing air temperature in this production system. The significantly highest air temperature in T_3 could be due to the dense canopy of this SRF-based agroforestry system compared to the other two SRF-based agroforestry systems (T_4 and T_5) which prevents the latent heat flux dissipation (Hardwick *et al.* 2015). The significantly highest soil temperature, from 19th to 21st months of monitoring, was observed in T_1 and T_2 which coincided with the occurrence of the highest air temperatures. The pattern of the soil temperature is similar to that of the air temperature observed in each of the production systems which indicates the prevailing air temperature influenced the soil temperature (Egziabher 2006; Anderson *et al.* 2007). Moreover, in the study of Binkley (as cited by Mead and Conforth 1995) the presence of varying canopy cover in T_3 to T_5 as compared to the monoculture production systems probably had more influence on the light attenuation reaching the soil and long wave emissions from the soil.

Wind velocity. The production system had also significant influence on wind velocity during the last five months of monitoring. Consistently, T_5 had the highest wind velocity measurement among the production systems. The greater height difference of the intercrops in this SRF-based agroforestry system formed a rougher canopy surface which creates greater air turbulence (Pennypacker and Baldocchi 2015). Similarly, the prevailing high wind velocity in T_2 was comparable to that of T_5 from the 18th to the 21st month of monitoring. The observed wind velocity in T_2 could be attributed to the wider spacing in this treatment allowing greater space for air movement within and above the canopy. During the last monitoring month (22nd), all production systems had statistically similar wind velocity except for T_4 with 38.50 km hr^{-1}. During this period, *P. pinnata* created rougher canopy effect facilitating greater air movement. *P. pinnata* is a documented species adapted to wind exposed areas (Schmidth 2009).

The production systems elicited significant influence on relative humidity for the first two months, and on the 18th, 19th and 21st months of monitoring (Table 2). The young vegetation cover of the production systems on the 1st month elicited significant influence on relative humidity. The significantly highest relative humidity was observed in T_1 (60%) which could be attributed to the higher plant density and leaf area index which yields higher transpiration rate, and consequently more atmospheric water vapor. The comparable higher relative humidity in T_2 (57%) could be attributed to the exposed soil surface subjected to evaporation. The least relative humidity was measured in T_3 (49.6%). On the 2nd month, T_5 (69.5%) had the highest air temperature. This is comparable to the two SRF-based agroforestry systems, T_3 and T_4 with a relative humidity of 66.87% and 66.66%, respectively. The uneven canopy cover caused more air turbulence increasing the rate of transpiration in this production system. While the comparable relative humidity in T_1 (64.32%) could still be attributed to the higher plant density and leaf area. On the 18th and 19th months, the pattern of influence of the production systems on relative humidity is reflective also of the influence of air temperature on relative humidity. These results are consistent with the findings of Medeiros *et al.* (2006) about the inverse relationship between air temperature and relative humidity. On the 21st month, the observed relative humidity measurements were significantly different among the five production systems. The influence of the SRF-based agroforestry system intercropped with Jatropha shows that T_4 had significantly the highest prevailing relative humidity of 75%, followed by T_3 (73%) and T_5 (72%). The ordinal ranking observed for the relative humidity on the 21st month of monitoring could be attributed to the exposed canopy transpiring. The varying foliage and crown canopy of the SRF species elicited the observed relative humidity. The larger leaf size of *P. pinnata* and *A. mangium* compared to that of *E. deglupta* probably influenced rate of water vapor removal at the canopy surface. Moreover, the greater height difference of *E. deglupta* with Jatropha provided greater roughness to facilitate air mixing, thus, its lower relative humidity compared to that of the other two SRF-based agroforestry systems. The monoculture of Jatropha planted in 2 x 2 m spacing and 3 x m spacing have the lowest prevailing relative humidity. The lower number of planting density in T_2 resulted in the least relative humidity (70.3%) in its immediate surface compared to T_1 (71%) Jatropha trees were found to be conservative in their water use, and were unlikely to transpire more water (Gush 2008).

Table 2. Microclimate parameter means as influenced by the different agroforestry production systems.

MAO	T_1	T_2	T_3	T_4	T_5
			Air Temperature (°C)		
18	33.83 a	33.73 a	32.50 b	31.60 c	30.50 d
19	32.10 a	32.03 a	30.70 b	29.87 c	28.70 d
20	28.93 a	28.80 a	27.50 b	26.60 c	25.50 d
21	27.87 ab	28.27 a	26.93 bc	26.33 cd	25.67 d
22	27.36 c	27.91 c	31.99 a	29.31 b	28.36 bc
			Soil Temperature (°C)		
19	30.53 a	31.07 a	29.57 b	28.97 b	28.20 c
20	27.37 a	27.83 a	26.37 b	25.70 b	25.00 c
21	26.83 b	27.43 a	26.00 c	25.20 d	25.00 d
22	27.36 c	27.91 c	31.99 a	29.31 b	28.36 bc
			Relative Humidity (%)		
1	60.00 a	57.00 ab	49.67 c	53.67 bc	53.67 bc
2	64.32 ab	60.62 b	66.88 ab	66.66 ab	69.55 a
18	65.67 a	62.67 ab	55.33 c	59.00 bc	59.00 bc
19	63.00 d	62.33 e	65.00 b	67.00 a	64.00 c
21	71.00 d	70.33 e	73.00 b	75.00 a	72.00 c
			Wind Velocity (km hr^{-1})		
18	12.67 c	18.67 ab	16.00 bc	15.00 bc	23.33 a
19	15.00 c	21.67 ab	20.00 abc	18.33 bc	25.00 a
20	14.00 b	20.00 ab	20.00 abc	16.67 ab	25.00 a
21	18.00 b	24.00 ab	25.33 ab	21.67 b	31.00 a
22	22.00 b	26.67 b	22.67 b	38.50 a	22.67 b

Means followed by the same letters within a row are not significantly different at 5%

MAO – Months after Outplanting, T_1 – 2 x 2 m spacing, T_2 – 3 x 3 m spacing, T_3 – *A. mangium* + *J. curcas* L., T_4 – *P. pinnata* + *J. curcas* L., T_5 – *E. deglupta* + *J. curcas* L., T_1 and T_2 – represented the pure plantation, T_3 and T_4 – SRF-based agroforestry system with nitrogen fixing species and, T_5 – SRF-based agroforestry system with non-nitrogen fixing species

Final air temperature. Air temperature was significantly affected by the production systems (Fig. 1). The lowest air temperature (28.9°C) was noted with T_5 while significantly higher air temperatures were noted in T_1, T_2 and T_3 at 30.48°C, 30.63°C, 30.62°C, respectively. The canopy structures for the plantation treatments of 2 x 2 and 3 x 3 m spacing are of uniform height which had less air turbulence compared to those treatments with SRF species intercropped with Jatropha. Moreover, the wind velocity in T_1 had significantly the slowest speed (16.19 km hr^{-1}). The lower air temperature in T_5 could also be attributed to the significantly fastest wind speed (22.57 km hr^{-1}) that could have aided the air mixing. Moreover, evaporative cooling induced by transpiration reduces the maximum plant surface temperature by about 15 °C on a hot and dry day (Novák and Havrila 2006). This could also account for the lower temperatures observed in the SRF-based agroforestry systems in T_5 and T_4. The intercropping of two species yielded higher transpiration resulting in lower above canopy air temperature. This also indicates the effective air temperature amelioration of the SRF-based agroforestry particularly T_5.

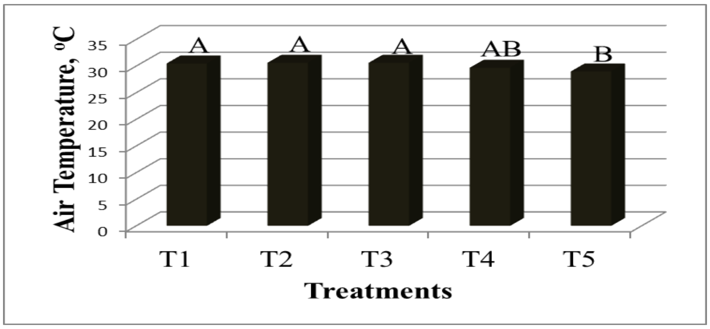

Fig. 1. Final air temperature above the canopy of the experimental site as influenced by the different agroforestry production systems.

Means followed by the same letters are not significantly different at 5% . T_1 – 2 x 2 m spacing, T_2 – 3 x 3 m spacing, T_3 – *A. mangium* + *J. curcas* L., T_4 – *P. pinnata* + *J. curcas* L., T_5 – *E. deglupta* + *J. curcas* L., T_1 and T_2 – represented the pure plantation, T_3 and T_4 – SRF-based agroforestry system with nitrogen fixing species and, T_5 – SRF-based agroforestry system with non-nitrogen fixing species

Final relative humidity. Relative humidity was not significantly influenced by either a plantation or agroforestry production systems (Fig. 2). Vegetation cover of the production systems may not reach the expanse of canopy to affect relative humidity (Brom *et al*. 2009). Air temperature also affects relative humidity. Thus, the statistically similar air temperature of T_1 to T_4 could have contributed to similar relative humidity in these production systems.

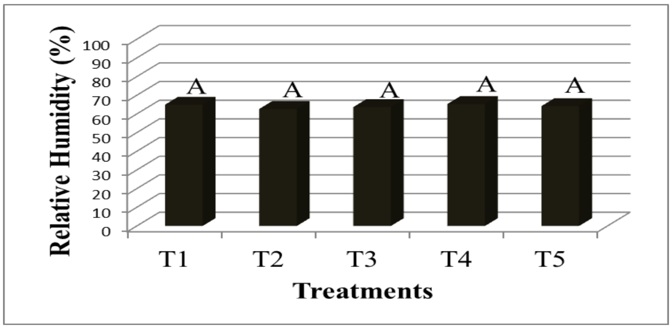

Fig. 2. Final relative humidity above the canopy of the experimental site as influenced by the different agroforestry production systems.

Means followed by the same letters are not significantly different at 5% . T_1 – 2 x 2 m spacing, T_2 – 3 x 3 m spacing, T_3 – *A. mangium* + *J. curcas* L., T_4 – *P. pinnata* + *J. curcas* L., T_5 – *E. deglupta* + *J. curcas* L., T_1 and T_2 – represented the pure plantation, T_3 and T_4 – SRF-based agroforestry system with nitrogen fixing species and, T_5 – SRF-based agroforestry system with non-nitrogen fixing species

Final soil temperature. It is suggested that moderate shading in an intercropping can result in a buffering effect on microclimate conditions (Clinch *et al*. 2009) thus less variation in soil temperature across a range of weather conditions were observed (Fig. 3). It was observed that T_5 had the significantly lowest soil temperature of 27.83°C, while T_2 and T_3 had the significantly highest soil temperature of 29.21°C and 29.07°C, respectively. The highest soil temperature in T_2 could be attributed to the lesser plant density providing soil cover (Genxu *et al*. 2008). The intercropping of *Pongamia pinnata* + Jatropha and *Eucalyptus deglupta* + Jatropha had comparable lower soil temperature and lower air temperature. These SRF-based agroforestry systems probably yielded higher transpiration rate which enhanced evaporative cooling effect resulting in lower soil temperatures. Plant transpiration has been demonstrated to modify climatic conditions at the land surface and in the soil during the vegetative season (Pokorný 2001).

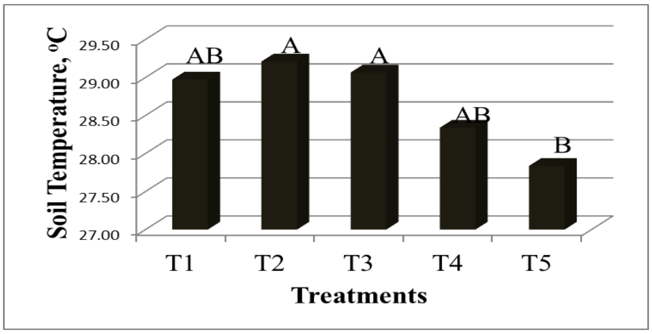

Fig. 3. Final soil temperature at 5 cm depth of the experimental site as influenced by the different agroforestry production systems. Means followed by the same letters are not significantly different at 5%. T_1 – 2 x 2 m spacing, T_2 – 3 x 3 m spacing, T_3 – *A. mangium* + *J. curcas* L., T_4 – *P. pinnata* + *J. curcas* L., T_5 – *E. deglupta* + *J. curcas* L., T_1 and T_2 – represented the pure plantation, T_3 and T_4 – SRF-based agroforestry system with nitrogen fixing species and, T_5 – SRF-based agroforestry system with non-nitrogen fixing species

Final wind velocity. The production systems significantly influenced the prevailing wind velocity (Fig. 4). Over 22 months, T_5 significantly had the highest wind velocity of 22.57 km hr^{-1}. The greater height difference of the intercrops in this SRF-based agroforestry system provided the greatest air turbulence resulting in higher wind velocity in T_5. T_2 (20.38 km hr^{-1}) and T_4 (20.17 km hr^{-1}*)* had comparable wind velocity with T_5 and T_3 (19.29 km hr^{-1}*)*. Meanwhile, T_1 had the slowest wind velocity (16.19 km hr^{-1}). This could be attributed to the more dense planting density in this production system thereby restricting air movement (Youssef *et al*. 2012). The more even vegetative cover in T_1 resulting from the monoculture of *J. curcas* planted in 2 x2 m spacing created reduced wind speed as less roughness produces only a boundary layer effect rather than a perturbed turbulent air layer (Salem 1991).

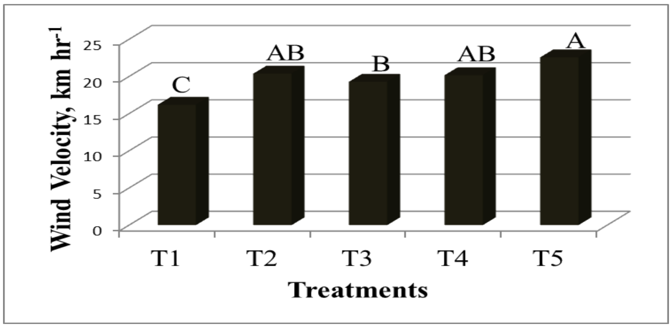

Fig. 4. Final wind velocity above the canopy of the experimental site as influenced by the different agroforestry production systems. Means followed by the same letters are not significantly different at 5%. T_1 – 2 x 2 m spacing, T_2 – 3 x 3 m spacing, T_3 – *A. mangium* + *J. curcas* L., T_4 – *P. pinnata* + *J. curcas* L., T_5 – *E. deglupta* + *J. curcas* L., T_1 and T_2 – represented the pure plantation, T_3 and T_4 – SRF-based agroforestry system with nitrogen fixing species and, T_5 – SRF-based agroforestry system with non-nitrogen fixing species

CONCLUSION

The production systems influenced significantly air and soil temperatures, and wind velocity but not relative humidity. The Short Rotation Forestry (SRF) –based agroforestry systems and the wider planting distance of monocrop Jatropha influenced positively soil chemical properties, specifically topsoil nitrogen, subsoil pH and exchangeable potassium. This study provided significant benchmark information on establishing the potential of Jatropha as a rehabilitation species in the upland marginal condition of Mt. Makulot, San Isidro Cuenca, Batangas and a suitable species in an agroforestry-based production system vis-à-vis its amelioration in the soil and microclimate. The SRF species namely, *A. mangium* and *E. deglupta* proved to have beneficial influence in the aforementioned site factors.

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