Environmental Sustainability Assessment of Forage Sorghum (Sorghum Bicolor) and MULATO II Grass (Brachiaria hybrid, CIAT 36087) in Belle Vue, Saint Kitts

Paper by

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INTORUDCTION: THE PROBLEM

In Saint Kitts-Nevis, as in many Caribbean islands, poor nutrition is one of the major factors limiting productivity of small ruminants in the Region. During the dry season (December to May), inadequate quantity and quality of forage is a major constraint to ruminant productivity. Natural pastures cannot support the desired level of productivity of sheep and goats and this limits year round local supply of meat. As a consequence, cultivated pasture or forage banks are considered necessary to improve forage availability and quality in order to increase the overall productivity of small ruminants in the Caribbean region (Borucki *et al.,* 2013).

There are additional constraints on small ruminant production, including praedial larceny and dog predation. As a result, farmers tend to maintain their animals under semi-confinement and adopt a zero grazing, "cut and carry" system to meet the daily nutritional needs of animals. Under the "cut and carry" system, the quality and quantity of forage delivered to the animals are crucial determinants of small ruminant productivity.

The livestock research programme of the Caribbean Agricultural Research and Development Institute (CARDI) promotes the use of forage species, such as "Mulato" grass (*Brachiaria* sp.) for small ruminant production in CARICOM. This forage crop is easy to sow and establish, and is well adapted to the weather conditions of the region. Natural legumes, trees and shrubs such as *Leucaena leucocephala* and *Gliricidia sepium* can also form part of a forage supplementation program to improve forage availably in the dry season.

As part of the CARICOM Project, *Sorghum bicolor* and *Brachiaria* hybrid CIAT 36087 (Mulato II), drought-tolerant, high-yielding crops have been recently introduced for ruminant production in CARICOM. *Sorghum* is a cane like grass with bunched clusters of grains at the apex. Its leaves resemble those of maize and they occasionally curl. The inflorescence which consists of racemes of spikelets possess two types of flowers, one flower carriers both the male and female part and the other flower is stalked with only the male parts (Rampho, 2005). The other introduced grass in this study *Brachiaria,* is shorter than *Sorghum,* semi-erect and grows in bunches. The lanceolate, pubescent leaves have a distinct soft feel and the blades appear much greener than the *Sorghum's* blades. Its inflorescence is consisted of a panicle with 4-6 racemes with a double row of spikelets (Argel et.al, 2007).

Both grasses belong to the family Poaceae. They primarily reproduce by seeds but can be propagated by stems as well. They are pollinated mainly by the wind and are involved in self and cross pollination. Both grasses exhibit rapid establishment and are adapted to a wide range of ecological conditions.

Results have shown that when preserved as silage, these forage crops have the potential to increase the year-round forage supply and enhance small ruminant productivity in the CARICOM region (Borucki *et al* 2013).

Clearly, the rationale of the above mentioned intervention can be readily accepted when one considers the importance of food security in the Caribbean given the region's high annual food import bill of more than US$4 billion (Food and Agriculture Organization Sub-Regional Office, 2013). There are two principal concerns, namely: (1) that the extraordinarily high food import bill increases the pressure on Caribbean governments to provide increased foreign exchange, as well as social protection programme to alleviate the effects of higher food prices; and (ii) the health implications of increased consumption of imported processed foods.

The introduction of the technology to produce good quality forage for small ruminants in Saint Kitts and Nevis is therefore a commendable intervention to address longer term food security issues in the Caribbean. However, other considerations relate to sustainability of the components of an ecosystem; particularly those related to biodiversity and soils in the targeted locations.

Biodiversity is essential for the maintenance of the health of ecosystems and people, through the following: supporting services (seed dispersal); provisioning services (food and raw materials); and cultural services (scientific discovery and use of nature in books, paintings, etc.) (Millennium Ecosystem Report, 2005). The greater the variety of species, the healthier the ecosystem is to support life. Likewise, the more sustainable the ecosystem is the better it is as a source of medicine and, food. Basically, the term sustainability is used in to refer to the ability of an ecosystem to function (including the provision of services mentioned above) and maintain productivity over a prolonged period. Goal 7 of the Millennium Development Goals (MDGs) is articulated as "Ensure Sustainability". Additionally, Target 7.B is set to *reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss*. For example, Ahmad *et al*. (2007) recommend the addition of synthetic fertilizers to Sorghum to increase the yield of fodder. However, this may cause water and soil pollution and decrease soil fertility, as well as alter the availability of soil nutrients and the plant community composition in the area under cultivation. The ripple effects would include nutrient unavailability and changes in the structure and function of the ecosystem.

Further, unless managed appropriately, Mulato grass has the potential to become invasive because of reduced seed production and germination. Additionally, in monoculture cultivation, Mulato or Sorghum plants are more vulnerable to certain pests and diseases. A plausible response is the application of pesticides. Pesticides increase production costs and pose a risk to ecosystems, while monoculture practices result in a reduction in biodiversity and a change in the gene pool (Iwanaga *et al*., 2000). Alteration of natural processes and natural habitats may also result from the introduction of Sorghum and Mulato.

Soil quality is a reliable quantifiable indicator of sustainable agriculture, as soil plays a critical role in maintaining balance in an ecosystem and producing good agricultural products (Reytar, Hanson and Henninger, 2014). Any significant alteration of the soil will therefore have long terms consequences of agriculture and food security; hence the inclusion of soil quality in the study. As Toth, Stolbovoy and Montanarella (2007: 22) note *"the ability of soil to perform any of the identified functions (on given levels) depends on its physical, biological and chemical characteristics also referred to as "internal" characteristics. The realization of the performance is conditioned by natural (e.g. slope steepness) and/or anthropogenic (e.g. artificial drainage) factors referred to as 'external' factors".*

OBJECTIVES

General Objective

To determine whether the use of a "grass-Sorghum silage based" feeding system for small ruminant production is environmentally sustainable.

Specific Objectives

- To identify the impacts of a grass-Sorghum silage-based feeding system on the biological and physical components of an existing ecosystem.
- To evaluate the significance of these impacts in the context of environmental sustainability of the "intervening technology".
- To recommend practical solutions that would assure sustainability of the "grass sorghum silage based feeding system

Methodological Approach

Soil

Soil sampling and analysis were conducted during the dry season (March 27 & 28, 2013) and the wet season (December 14 & 15, 2015). A total of 9 soil samples were collected from both the control and Mulato plots. In the control plot, samples were taken at specific intervals along the centre of the plot in an alternating pattern (Figure 1). In the Mulato plot, samples were collected in an X pattern (Figure 2). During the dry season one additional sample was collected from the centre of the X. In both the Mulato and control plots, samples were collected to a depth of not more than 30 cm. At each sampling point, the samples were mixed thoroughly and a weight of at least 500 g of each sample was retained for analysis. Different sampling patterns were used in each of the plots to accommodate and account for the difference in plot shape. Due to the

discontinuation of the Sorghum crop, the soil assessment concentrated only on the Mulato and control areas

After collection, the samples were double sealed in zip lock bags in order to preserve the integrity of the sample during transport to the lab for analysis. The samples were analyzed for the following parameters: pH, total salts, calcium, magnesium, potassium, iron, boron, chloride, total nitrogen, phosphorous, sand (%),silt (%) , clay (%), organic matter content, and cation exchange capacity. The mean levels for these parameters were calculated for the control and Mulato fields for both seasons. This data was then analysed using the independent samples t – test statistical method to identify statistically significant differences among the data taken during the wet and dry seasons.

Figure 1 showing Control Plot

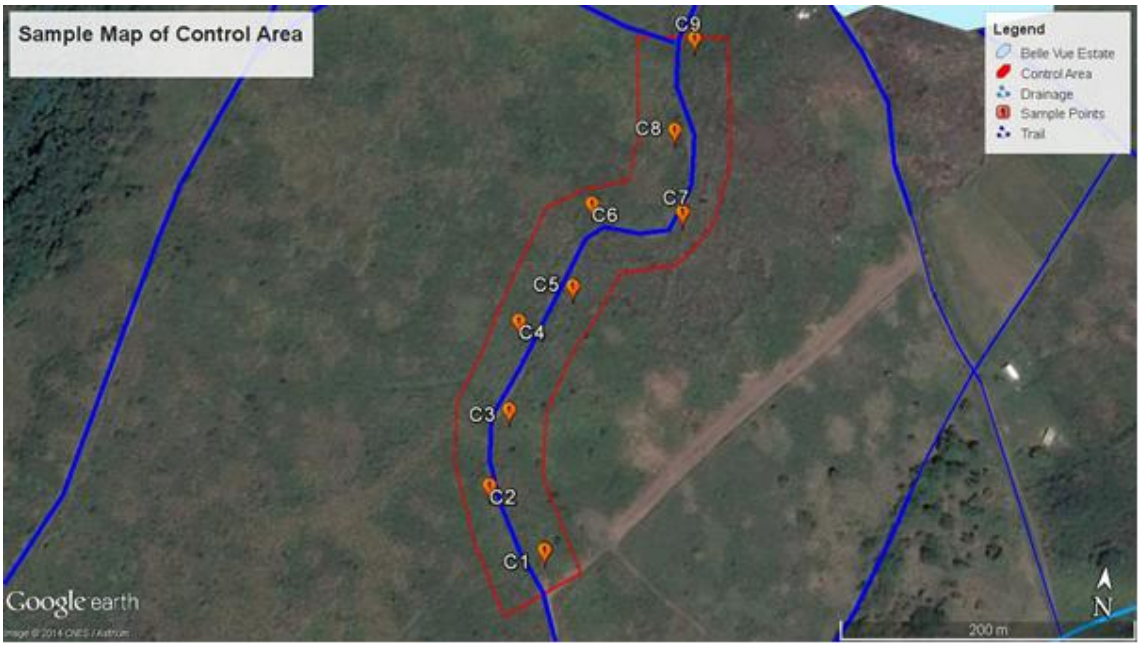


Figure 2 Mulato Plot

Biodiversity

Two insect biodiversity surveys were conducted in 2013, the first during the dry season and the second during the wet season. The dry and wet season surveys were conducted from March 24 - 29, and December 9 – 15, respectively. Insects were surveyed both during both during the day and night.

Active and passive sampling techniques were employed to ensure that a comprehensive inventory of the insect fauna was obtained. Passive techniques required the use of sampling devices that were left in *Sorghum*, Mulato II and control areas while active sampling involved direct collection of insects. Passive techniques employed for this research were coloured pan traps (blue, yellow, red and white); pitfall traps (clear plastic drinking cups) and flight intercept traps. Active methods used were sweep netting, light trapping, beat sampling, leaf litter searches and direct collection by hand. Light trapping commenced at 7:00 pm and lasted one hour per night. This study focused mainly on one keystone taxa, the pollinators. Methods used for this study were those described by Mc Gavin (1997). These are described below.

Sweep netting: During the dry season survey sweeping was conducted in all three sites using 45 cm diameter sweep nets. Sweeps were done in *Brachiaria* hybrid (Mulato II) and *Sorghum* over a three day period while in the control sweeping was conducted over a 2 day period. Sweeps lasted for a period of one hour daily and were conducted in the mornings by a single individual. Sweeping was conducted along standardized transects. Insects collected in nets were photographed and transferred to labeled collection jars containing rubbing alcohol. Butterflies caught were photographed, identified and stored in paper envelopes.

Pit fall traps: these were used to target insects that moved along the ground. Pitfall traps were baited with fruits (mainly banana skins and pineapples). Pitfall traps used measured 9cm in diameter and 12 cm in height and were sunk into the ground with the rim at ground level. These traps were placed randomly in the field. However, due to the soil structure (rocky in nature) and the resultant difficulties in installing traps, only a few were set up. A total of 20 pitfall traps were installed in *Sorghum* fields. No pitfall traps were installed in Mulato II or control plots. Locations of pitfall traps were marked with flagging tapes so that they could have been easily monitored and retrieved. Pitfall traps remained opened for two consecutive nights and were checked in the morning and afternoon. Traps were re-baited daily.

Malaise and Fly intercept Traps: Attempts were made to use malaise and fly intercept traps but these had to be abandoned because of heavy winds and lack of support structures for the installation of flight intercept traps.

Coloured pans: Twenty-five coloured pans (white, blue, red and yellow) measuring approximately 16 cm were placed randomly in the three sampling sites to target mainly flying insects such as flies and wasps. The pans which were secured to the ground and filled with saline water to which detergent was added to reduce the surface tension were left in the field for two consecutive days. Pans were checked in the morning and afternoon and insects caught were retrieved and transferred to the preservative. Bowls were photographed before insects were removed. Pans were refilled daily to replace water that would have evaporated due to the very hot and windy conditions during the time of the survey.

Plate 1 Insect collected in coloured pan

Plate 2 Coloured pan in Sorghum field

Beat Sampling and litter search: Beat sampling was also conducted in Sorghum and control fields. A bowl was placed under the branch of a tree which was beaten lightly with a piece of stick. Insects collected in the bowl were photographed and transferred to a container containing preservative.

Litter search involved the placement of litter on a white sheet after which the litter was thoroughly searched for insects. Insects were then collected from the sheet, photographed and placed in 70% alcohol.

The dry season survey was conducted over a three days period, while the wet season survey was conducted over a four days period. However, due the abandonment of the *Sorghum* field biodiversity assessment was only conducted in Mulato and control areas. The sampling effort with respect to days varied between the two seasons and was therefore not standardized.

ANALYTICAL FRAMEWORK

The biodiversity and soils in the plot that was under Mulato cultivation were used to provide an indication of the state of these two components with the introduction of the technology. The biodiversity of the Sorghum field was also determined. The environmental conditions (biodiversity and soils quality) in these plots were/are then compared to those in the control plots in order to give an indication of the direction of the change (whether positive or negative) and the significance of the change arising from the introduction of the crop. The indicators related to biological diversity were abundance and richness, while those related to soil were the twelve soil quality parameters mentioned in Section III.

The data was then analysed with the IBM SPSS Statistical Software (Version 21). The Independent Samples T – Test statistical method was then used to identify statistical differences among the data taken during the wet and dry seasons. Furthermore, the Shannon Diversity Index and the Simpson's Index of Diversity were calculated for both seasons.

A numerical measure of 1 or 2 was assigned to each indicator, with the value indicating the value of indicator in the Mulato field against that in the control. All indicators were given an equal weighting.

Table 1 in the Appendix details the Sustainability Assessment Framework.

Two levels of sustainability were identified based on the maximum and minimum values for the specific indicators that were analysed in the study with respect to environmental sustainability analysis as represented mathematically as follows:

$\sum Sus = \sum B_w + \sum B_D + \sum S_w + \sum S_D$,

where:

Sus = level of sustainability;

B_W = biodiversity wet season;

Bw = biodiversity wet season;

B_D = biodiversity dry season.

The two levels of sustainability are: Low = 49-64; and High = 32-48.

RESULTS

Soil Samples

The raw results of the soil analyses conducted for the control and Mulato fields in the dry season are indicated in the Table 2 and Table 3, respectively; while Tables 4 and 5 (provided in the Appendices) highlight the raw results of the soil analyses in the control and Mulato fields, respectively, in the wet season. The mean values for the parameters are indicated in the final column of each of the tables.

The mean levels of potassium and total nitrogen in the Mulato field (0.79 mg/kg and 4013.33 mg/kg) were higher than in the control (0.60 mg/kg and 4013.33 mg/kg) during the wet season, while higher mean levels of phosphorous were found in the control plot (715.56 mg/kg compared with 504.44 mg/kg). The mean calcium, magnesium and total salt concentrations were higher in the Mulato plot (594.89 mg/kg, 139.44 mg/kg and 170.22 mg/kg) as compared with the control (497.78 mg/kg, 88.17 mg/kg and 92.33 mg/kg) and the higher mean concentration of chlorides was found in the control plot (102.22 mg/kg compared with the Mulato field (95.56 mg/kg).

During the dry season, the mean levels of potassium and nitrogen were higher in the control (0.48 mg/kg and 4496.44 mg/kg) in comparison with the Mulato field (0.42 mg/kg and 3394.00 mg/kg). Additionally, the mean concentrations of chloride and magnesium were higher in the control (93.33 mg/kg and 119.78 mg/kg) than the Mulato field (83.10 mg/kg and 117.90 mg/kg), while the mean total salts concentration was higher in the Mulato plot (328.60 mg/kg versus 316.56 mg/kg). Mean concentrations of phosphorous and calcium were lower in the control (523.33 mg/kg and 591.11 mg/kg in comparison to 770.00 mg/kg and 591.11 mg/kg. respectively).

Biodiversity

Due to the unavailability of comprehensive taxonomic keys for insect identifications on the Caribbean, specimens collected were identified based on morphological characteristics. Morphospecies were identified mainly up to family or order. However, when possible, insects were classified up to the species level.

A total of 1619 insects were collected for the entire research period in the control, Mulato and Sorghum plots. The entire collection is represented by 9 orders. The most dominant orders were Hymenoptera with 588 individuals, Diptera with 313 individuals, Lepidoptera with 283 individuals, Hemiptera with 198 individuals and Orthoptera with 108 individuals (See Figure 3 below).

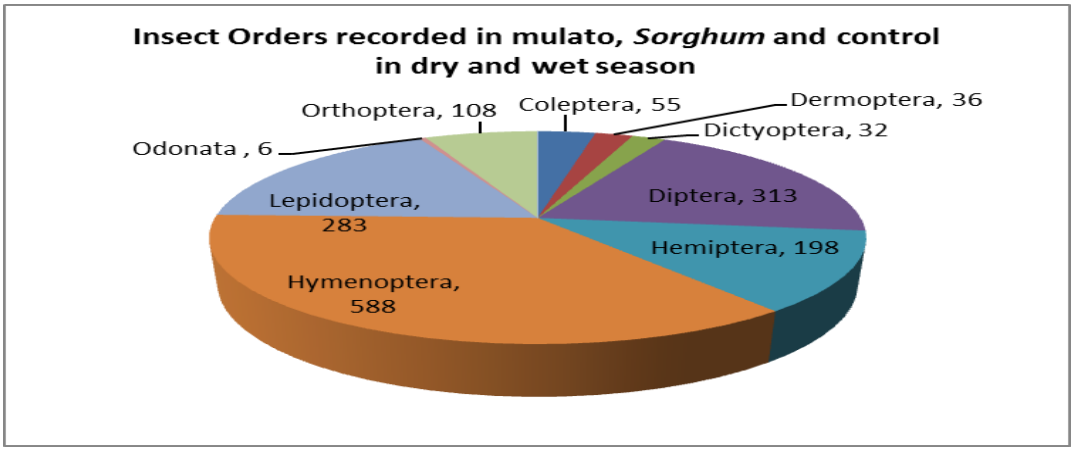
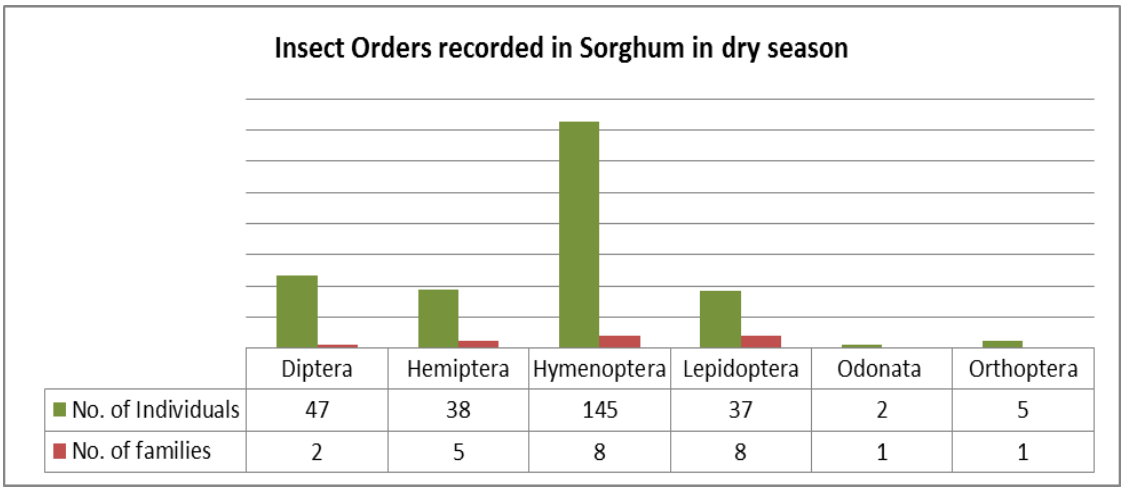


Figure 3: Insect orders and individuals recorded in three areas in dry and wet season

In Sorghum a total of 274 insects were collected. The collection represented six orders and 25 families. The most dominant orders were the Hymenoptera and Diptera, represented by 145 and 47 individuals respectively. The Hemiptera and Lepidoptera also represented a large proportion of the insect individuals within this study area, that is, 38 and 37 individuals respectively. Both Hymenoptera and Lepidoptera were represented by 8 families, while the Hemiptera was represented by 5 families, the Diptera by 2 families and both the Odonata and Orthoptera by 1 family each (See Fig 4).



	Diptera	Hemiptera	Hymenoptera	Lepidoptera	Odonata	Orthoptera
No. of Individuals	47	38	145	37	2	5
No. of families	2	5	8	8	1	1

Figure 4: Insect diversity in *Sorghum* in dry season

Regarding Mulato, a total of 592 insects were collected for both the wet and dry season. The collection represented 39 families within 9 orders. The dominant insect orders were Hymenoptera, Diptera Lepidoptera, and Orthoptera, represented by 152, 124, 112 and 79 individuals respectively. The other orders with less significant numbers of individuals were the Hemiptera and the Coleoptera (See Figure 5).

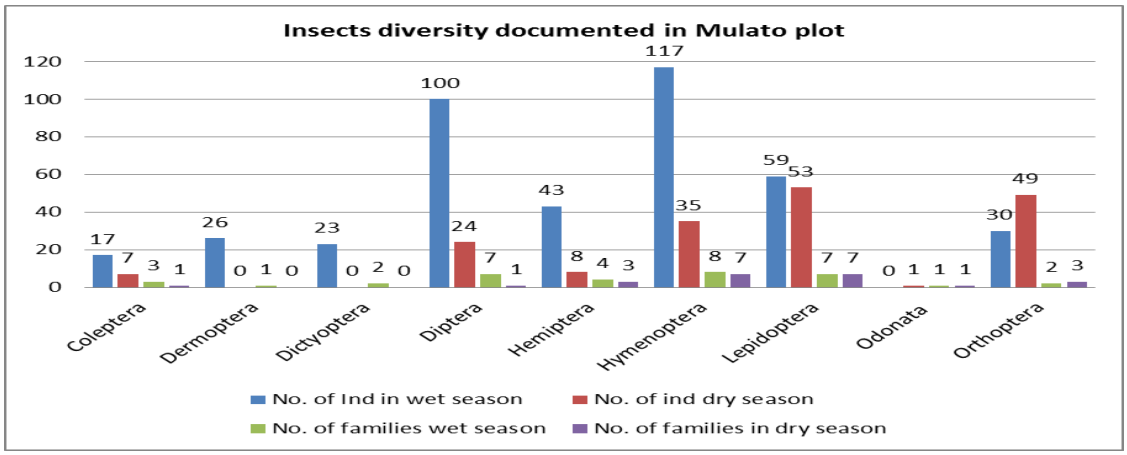


Figure 5: Seasonal diversity of insect in Mulato

In the control a total of 753 insects were collected for both the wet and dry season. The collection represented 67 families within 9 orders. The dominant insect orders were Hymenoptera with 291 individuals, Diptera with 142 individuals, Lepidoptera with 134 individuals, and Hemiptera with 109 individuals. Similar to the Mulato site a large number of Coleoptera were noted along with the order Orthoptera (See Figure 6).

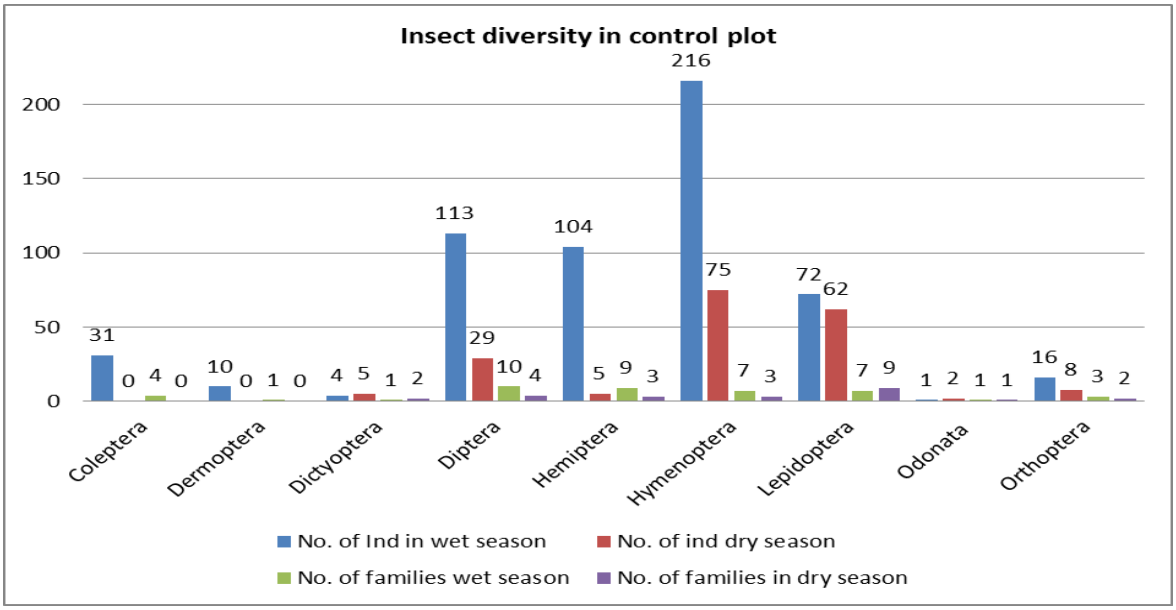


Figure 6: Seasonal diversity of insects in Control plot

During the dry season survey the number of individuals recorded for each order in the three study areas varied. The number of Dipterans, Hemipterans and Hymenopterans were highest in Sorghum followed by the control and Mulato. The number of individuals of Orthoptera and Coleoptera were highest in Mulato while Dicyoptera were only recorded in the control area. The number of Lepidoptera was highest in the control followed by the Mulato plot (See Figure 7).

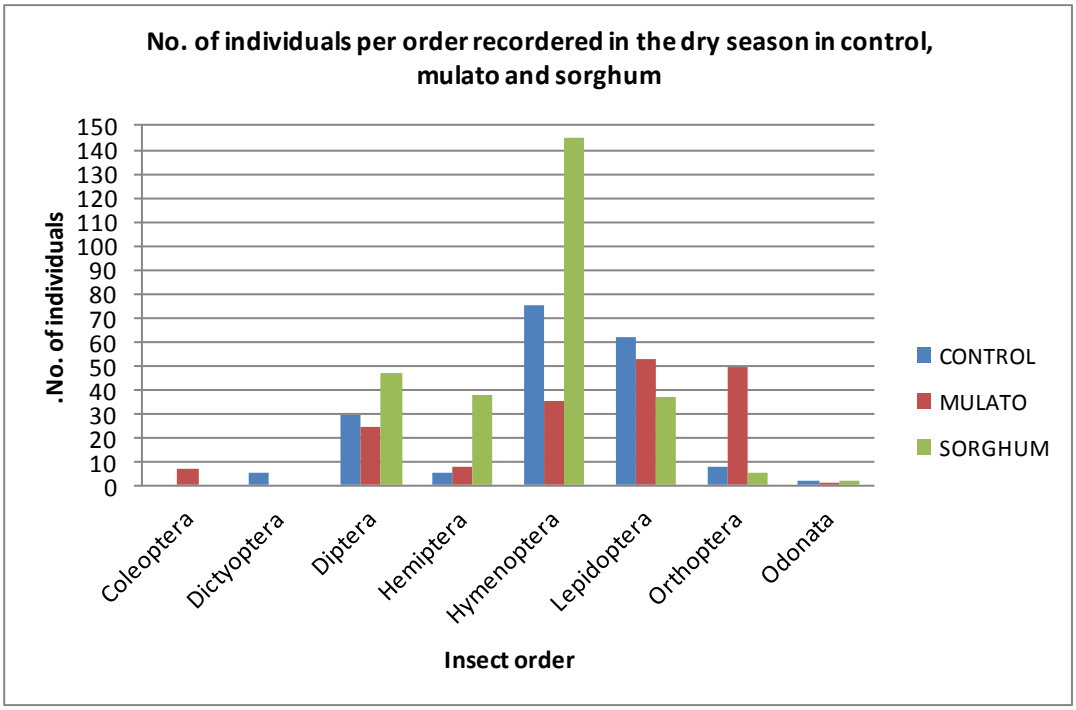


Figure7: Insect diversity recorded in three study plots in the dry season

With regards to families 24 were recorded in the control and *Sorghum* plots while 23 were recorded in the Mulato plot. Of the 24 families recorded in the control plot 9 and 4 belonged to the orders Lepidoptera and Diptera respectively, while in *Sorghum*, eight families each were recorded for the orders Lepidoptera and hymenoptera. In the Mulato plot more than half of the families represented the orders Lepidoptera and Hymenoptera (See Figure 8).

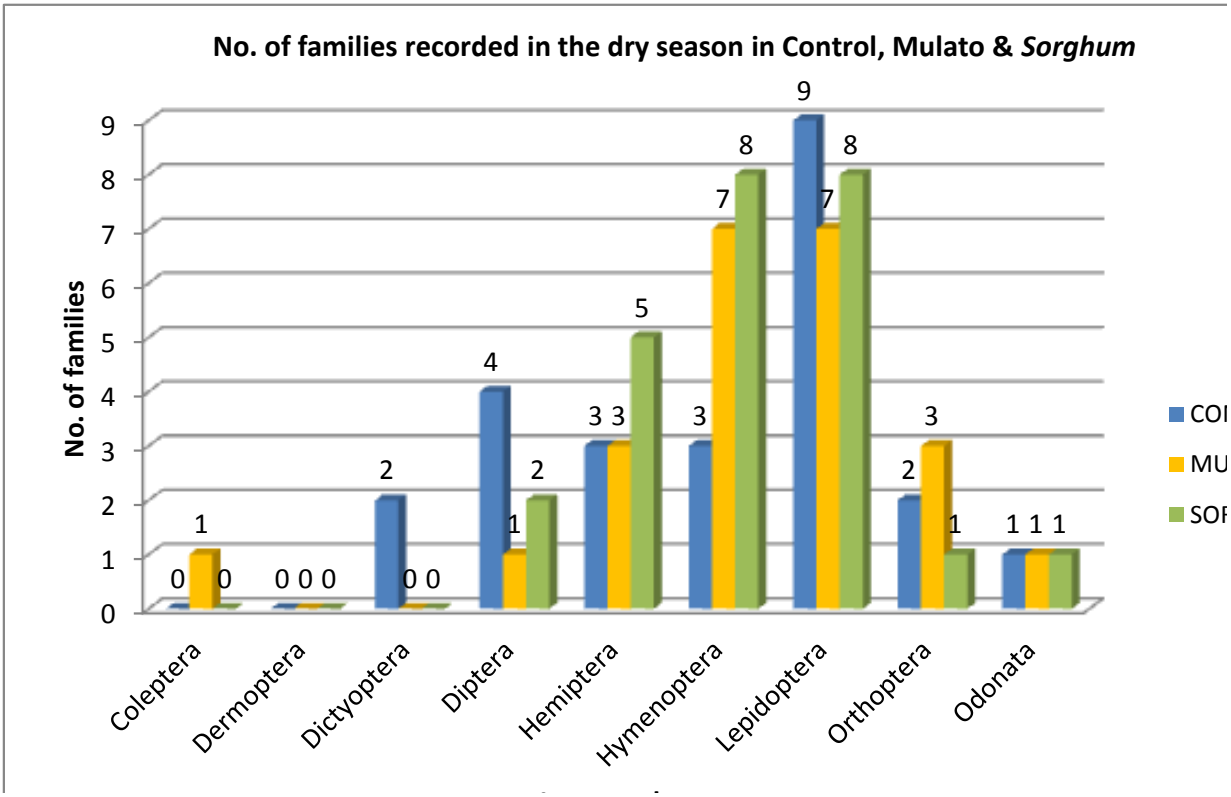


Figure 8: Insect families recorded in the three plots surveyed

During the wet season results were only obtained for Mulato and control because *Sorghum* was no longer being cultivated. Results of showed that in Mulato higher number of individuals were recorded. Further, these individuals represented the orders Hymehoptera, Lepidoptera, Hemiptera and Diptera. When considering families, 10 Dipteran, 9 hemipteran, 7 hymenopteran and 7 Lepidopteran were recorded in control plot while in the Mulato plot 8 Hymenoptera, 7 Lepidoptera and 7 Diptera families were recorded (See Figure 9).

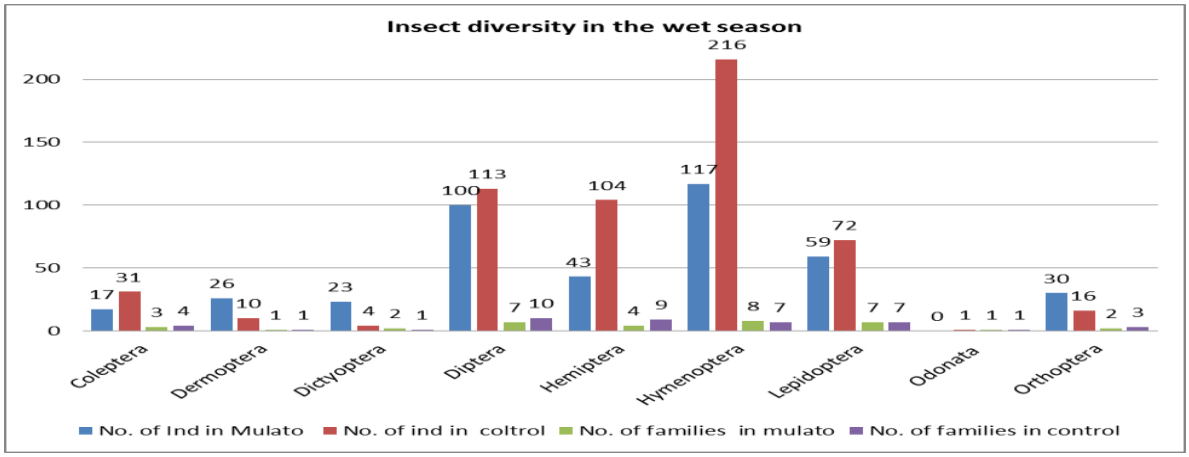


Figure 9: Insect diversity in wet season in the two plots

Based on the two levels[3] of sustainability and as indicated in Table 6, several statements can be made.

Components	Indicators	Criteria for Evaluation	Scores/ Values to be assigned		Actual Result from the Assessment	Value Assigned
			Low Magnitude (1)	High Magnitude (2)		
Biodiversity	Shannon Diversity Index (H') – Wet Season	0 – 4.6 (the greater the value, the larger the diversity - richness and dominance	>2.3	<2.3	Mulato = 3.31	1
	Simpson's Index of Diversity (1-D) – Wet Season	0 – 1 (0 – no diversity; 1 – infinite diversity) – evenness and dominance	>0.5	<0.5	Mulato = 0.955	1
	Shannon Diversity Index (H') – Dry Season	0 – 4.6 (the greater the value, the larger the diversity - richness and dominance	>2.3	<2.3	Mulato= 2.82	1
	Simpson's Index of Diversity (1-D) – Dry Season	0 – 1 (0 – no diversity; 1 – infinite diversity) – evenness and dominance	>0.5	<0.5	Mulato = 0.936	1
	ANOVA – Wet Season	p = 0.05; statistically significance difference in abundance	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.293	1
	ANOVA – Dry Season	p = 0.05; statistically significance difference in abundance	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.919	1
	t test – Wet Season	p = 0.05; statistically significance difference in abundance	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.153	1

[3] The higher the value assigned, the lower the level of sustainability

	t test – Dry Season	p = 0.05; statistically significance difference in abundance	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.984	1
Soil	pH– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.020	2
	Total salts– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.000	2
	Calcium– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.020	2
	Magnesium– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.000	2
	Potassium– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.010	2
	Iron– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.001	2
	Boron– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.281	1
	Chloride– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.639	1
	Total Nitrogen– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.055	1
	Phosphorous– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.418	1
	Organic matter– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.446	1
	Cation exchange capacity– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.001	2
	pH- Dry Season	t test – no	p>0.05 (no	p<0.05	0.469	1

		difference between means	significant difference)	(significant difference)		
	Total salts- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.773	1
	Calcium- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.002	2
	Magnesium- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.569	1
	Potassium- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.170	1
	Iron- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.071	1
	Boron- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.034	2
	Chloride- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.568	1
	Total Nitrogen- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.170	1
	Phosphorous- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.001	2
	Organic matter- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.720	1
	Cation exchange capacity- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)	0.006	2

Table 6 Sustainability Assessment Results

First, the introduction of Mulato II does not result in any significant change with respect to diversity or abundance as indicated by the value of 1 that has been assigned to each indicator (in both seasons). Second, there was no difference in seasonality. Third, for the soil in the wet season, 58.3% of the indicators had an assigned value of 2. These indicators are: pH, total salts, calcium, magnesium, potassium, iron and cation exchange capacity. Fourth, for the dry season, 33.3% of the indicators for soil had the assigned value of 2. These indicators are: calcium, boron, phosphorus and cation exchange capacity. Fifth, there were significant changes to the soil ecosystem as indicated by magnitude values (t-test) of 7 of 12 indicators in the combined seasons (both dry and wet). These indicators were pH, total salts, calcium, magnesium, potassium, iron and cation exchange capacity during the wet season and calcium, boron, phosphorus and cation exchange capacity during the dry season. The higher salinity levels in the Mulato plot as compared to the control in both the wet and dry season may have been a result of application of synthetic fertilisers (may have contained some potash) to the grass.

Further, during both the wet and dry seasons, the calcium and cation exchange capacity had an assigned value of 2. Importantly, the lower levels of Ca and Mg in the control plot as compared to the Mulato plot may have been due to the leguminous vegetation that are heavy feeders of Ca and Mg (Beegle n.d.). According to Rahetlah (2012), there are lower levels of phosphorus, potassium, carbon and nitrogen in ecosystems with mono-cropping. This study, which was a mono-crop of Mulato II, resonates with the findings of Rahetlah (2012) in respect of phosphorus and potassium. Despite this, the composite score assigned to the introduction of Mulato II to the ecosystem (soil and biodiversity) for both seasons is 43, which essentially indicates that the ecosystem has high sustainability based on the two parameters assessed-soil and biodiversity. The implication here is that the biodiversity would be able to function (including the provision of services) and the soil could maintain its productivity over a prolonged period.

CONCLUSIONS

The study aimed at establishing whether small ruminant production can be environmentally sustainable, using "grass-sorghum silage based feeding system. Specifically, the introduction of Mulato has caused no significant changes in the diversity of the insects within the studied ecosystem, as revealed by the ANOVA single factor and independent t-test. The control area and the Mulato field possess the same insect orders: namely, Coleoptera, Dermoptera, Dictyoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera and Orthoptera. Notably, insects collected under these orders are important to the ecosystem in several respects: they act as pollinators, scavengers, recyclers and parasitoids. Overall, slight seasonal variations in the abundance of some species were evident with slightly higher numbers recorded during the wet season. Additionally, mild seasonal variations in numbers of certain morphospecies were noted between the Mulato II and the control. For example the grasshopper *Schistocerca* and the moth *Utetheisa*

bella were more prevalent in the Mulato II field during the dry season. 75 % of the indicators used to measure the sustianability of the soil ecosystem showed signficant changes. However, this does not imply that there was any major disruption in the functioning or productivity of the ecosystem in totality. In fact, results obtained from the experiments (for both the wet and dry seasons) suggest that the sustainability of the ecosystem (with reference to the soil and insect biological diversity) has not been compromised by this type of technology. Therefore, it can be reasonably argued that fodder from *Brachiaria* hybrid CIAT 36087 (Mulato II) is useful as a supplementary diet for small ruminants in the 'drive' for food security.

REFERENCES

References

Alfaro, M A, S C Jarvis, and Gregory, P.J. (2004). Factors affecting potassium leaching in different soils. *Soil Use and Management*, 20, 182-189.

Ahmed, A.U.H., I. Qadir and Mahmood, N. (2007). Effect of integrated use of organic and inorganic fertilizers on fodder yield of sorghum (*Sorghum bicolar* L.). *Pak. J. Agri. Sci*., 44, 415-421.

Argel .J.A, Miles .J.W, Guiot .J.D, Cuadrado .H, and Lascano. C.E., (2007). Cultivar Mulato II (Brachiaria hybrid CIAT 36087) A high quality forage grass, resistant to spittlebugs and adapted to well drained, acid tropical soils. Retrieved February 20, 2014, from: http://ciat-library.ciat.cgiar.org/articulos_ciat/mulato_ii_ingles.pdf.

Beegle, D. (n.d.) *Soil Fertility Management for Forage Crops.* Vols. 31-A. Pennsylvania State University: Agronomy Facts.

Borucki. B, Hosein. S, Watts. A, Berry. I, J and Phillip, L. E. (2013). Tropical Forage Mulato II Grass (*Brachiaria* hybrid CIAT 36087) and Forage Sorghum *(Sorghum bicolor*) for Silage conservation and Sheep production in St. Kitts and Nevis. Retrieved February 20, 2014 from: https://www.mcgill.ca/globalfoodsecurity/sites/mcgill.ca.globalfoodsecurity/files/2013_tropicalforages_0.pdf.

Millennium Ecosystem Report (2005) *Ecosystems and Human Well-Being: Synthesis*. (2005). Washington, DC: Island Press. Retrieved February 20, 2014 from http://www.unep.org/maweb/documents/document.356.aspx.pdf.

Mc. Gavin, G.C. (1997). *Expedition Field Techniques: insects and other terrestrial arthropods*. London: Royal Geographical Society.

Rahetlah, V B, Randrianaivoarivony, J. M, Andrianarisoa, B., Razafimpamoa, L. H. and Ramalanjaona, V. L. (2012). Yield and quality of **Brachiaria Sp.**cv Mulato-forage perennial peanut (**Arachis pintoi**) mixture in the Highlands of Madagascar. **Livestock Research for Rural Development, 24, Article #171.** Retrieved May 6, 2015, from http://www.lrrd.org/lrrd24/10/rahe24171.htm.

Rampho E.T. (2005). *Sorghum bicolor* (L) Moench, Retrieved February 20, 2014, from http://www.plantzafrica.com/plantqrs/sorghum.htm.

Reytar, K., Hanson, C. and Henninger, N. (2014). *Indicators of Sustainable Agriculture: A Scoping Analysis. Working Paper June 2014*. Washington DC: World Resources Institute.

Tóth, G, Stolbovoy, V., and Montanarella, L. (2007). Soil Quality and sustainability evaluation: an integrated approach to support soil-related policies of the European Union – A JRC Position Paper. Italy: Institute for Environment and Sustainability

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APPENDIX

Table 1 Assessment Framework

Components	**Indicators**	**Criteria for Evaluation**	**Scores/Values (1-2, +/-)**	
			Low (1)	High (2)
Biodiversity	Shannon Diversity Index (H') – Wet Season	0 – 4.6 (the greater the value, the larger the diversity - richness and dominance	>2.3	<2.3
	Simpson's Index of Diversity (1-D) – Wet Season	0 – 1 (0 – no diversity; 1 – infinite diversity) – evenness and dominance	>0.5	<0.5
	Shannon Diversity Index (H') – Dry Season	0 – 4.6 (the greater the value, the larger the diversity - richness and dominance	>2.3	<2.3
	Simpson's Index of Diversity (1-D) – Dry Season	0 – 1 (0 –no diversity; 1 – infinite diversity) – evenness and dominance	>0.5	<0.5
	ANOVA – Wet Season	p = 0.05; statistically significance difference in abundance	p>0.05 (no significant difference)	p<0.05 (significant difference)
	ANOVA – Dry Season	p = 0.05; statistically significance difference in abundance	p>0.05 (no significant difference)	p<0.05 (significant difference)
	t test – Wet Season	p = 0.05; statistically significance difference in abundance	p>0.05 (no significant difference)	p<0.05 (significant difference)
	t test – Dry Season	p = 0.05; statistically significance difference in abundance	p>0.05 (no significant difference)	p<0.05 (significant difference)
Soil	pH– Wet Season	t test – no statistically difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Total salts-– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Calcium– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Magnesium– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Potassium– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Iron– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Boron– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Chloride– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)

Components	Indicators	Criteria for Evaluation	Scores/Values (1-2, +/-)	
	Total Nitrogen– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Phosphorous– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Organic matter– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Cation exchange capacity– Wet Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	pH- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Total salts- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Calcium- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Magnesium Dry Season -	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Potassium- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Iron- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Boron- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Chloride- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Total Nitrogen- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Phosphorous- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Organic matter- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)
	Cation exchange capacity- Dry Season	t test – no difference between means	p>0.05 (no significant difference)	p<0.05 (significant difference)

Table 2: Results of the analysis of soil in the control field in the dry season

Sample #/Parameter	1	2	3	4	5	6	7	8	9	Mean Level
pH	5.19	5.83	5.61	5.69	5.50	5.66	5.41	5.48	6.06	5.60
Total Salts (mg/kg)	474	279	261	298	360	266	414	304	193	316.56
Calcium (mg/kg)	509	592	606	581	638	572	542	649	631	591.11
Magnesium (mg/kg)	115	125	127	122	123	110	112	120	124	119.78
Potassium (mg/kg)	0.36	0.49	0.47	0.49	0.63	0.62	0.52	0.35	0.40	0.48
Iron (mg/kg)	10.1	4.89	6.78	7.24	6.84	9.48	9.45	6.53	5.49	7.42
Boron (mg/kg)	0.40	0.41	1.04	0.37	0.93	1.44	1.21	1.29	0.49	0.84
Chloride (mg/kg	10	110	110	140	70	110	110	110	70	93.33
Total Nitrogen (mg/kg)	5380	2560	5500	6888	4520	1700	2540	4940	6440	4496.44
Bray Phosphorous (mg/kg)	460	490	440	440	510	430	790	640	510	523.33
Sand (%)	67.21	64.15	60.71	59.12	63.51	62.95	56.58	66.23	60.35	62.31
Silt (%)	16.50	16.85	20.25	19.10	19.60	19.30	26.50	17.15	21.55	19.64
Clay (%)	11.05	13.35	15.35	15.25	12.80	9.40	11.85	8.95	11.25	12.14
Organic Matter (%)	7.26	5.03	7.26	7.83	7.26	10.6	8.93	9.5	9.5	8.13
Cation Exchange Capacity (meg/100 g)	4.65	5.14	5.23	5.06	5.35	4.92	4.79	5.38	5.33	5.09

Table 3: Results of analysis of the soil in the Mulato field in the dry season

Sample #/Parameter	1	2	3	4	5	6	7	8	9	10	Mean Level
pH	5.66	5.52	5.83	5.50	5.36	5.56	5.56	5.39	5.47	5.48	5.53
Total Salts (mg/kg)	303	244	328	317	421	232	232	269	469	471	328.60
Calcium (mg/kg)	661	734	635	745	758	639	589	639	668	680	674.80
Magnesium (mg/kg)	121	101	122	127	125	121	113	118	109	122	117.90

Potassium (mg/kg)	0.50	0.26	0.30	0.31	0.41	0.54	0.50	0.38	0.51	0.44	0.42
Iron (mg/kg)	7.77	12.40	14.20	9.66	9.74	9.93	8.00	8.28	6.63	6.67	9.33
Boron (mg/kg)	0.22	0.34	0.69	0.46	0.48	0.35	0.61	0.43	0.45	0.69	0.47
Chloride (mg/kg	70	40	1	90	120	110	70	110	110	110	83.10
Total Nitrogen (mg/kg)	4300	4820	2040	3880	6160	1500	3880	2340	2820	2200	3394.00
Bray Phosphorous (mg/kg)	640	890	780	680	730	970	520	890	830	770	770.00
Sand (%)	53.07	53.89	51.79	52.16	51.07	61.75	60.60	57.65	58.52	62.83	56.33
Silt (%)	23.20	29.20	25.05	23.25	30.10	18.35	22.25	22.90	24.05	19.60	23.80
Clay (%)	20.00	13.75	16.35	16.15	15.40	12.60	11.70	13.25	13.00	12.00	14.42
Organic Matter (%)	6.14	6.14	6.14	11.20	2.23	12.30	8.93	10.10	8.93	5.07	7.72
Cation Exchange Capacity (meg/100 g)	5.45	5.64	5.33	5.91	5.96	5.34	5.03	5.32	5.39	5.55	5.49

Table 4: Results of analysis of the soil in the control field in the wet season

Sample #/Parameter	1	2	3	4	5	6	7	8	9	Mean Level
pH	5.25	5.01	5.00	5.98	6.32	5.68	5.88	4.93	4.98	5.45
Total Salts (mg/kg)	99	92	74	89	61	119	107	96	94	92.33
Calcium (mg/kg)	530	556	610	532	443	316	457	524	512	497.78
Magnesium (mg/kg)	73.2	84.8	75.8	98.8	84.9	80.5	109.0	93.1	93.4	88.17
Potassium (mg/kg)	0.55	0.55	0.44	0.32	0.76	0.82	0.69	0.62	0.64	0.60
Iron (mg/kg)	12.1	13.9	15.5	13.0	20.7	13.5	4.23	11.8	11.9	12.96
Boron (mg/kg)	0.31	0.11	0.71	0.34	0.39	0.84	0.33	0.23	0.61	0.43

Chloride (mg/kg	70	140	70	140	110	110	70	70	140	102.22
Total Nitrogen (mg/kg)	1900	2760	1360	4080	2580	3460	2520	2400	2220	2586.67
Bray Phosphorous (mg/kg)	490	460	440	480	410	590	310	2730	530	715.56
Sand (%)	59.05	57.05	55.14	65.44	66.91	69.52	71.54	62.43	52.84	62.21
Silt (%)	25.55	27.00	19.85	20.10	24.95	23.05	13.85	22.60	32.55	23.28
Clay (%)	9.70	9.25	7.50	9.85	6.00	5.30	4.30	10.90	7.25	7.78
Organic Matter (%)	10.60	12.30	22.30	7.26	3.90	6.71	7.26	9.50	7.26	9.68
Cation Exchange Capacity (meg/100 g)	4.41	4.64	4.83	4.63	4.08	3.42	4.35	4.55	4.49	4.38

Table 5: Results of analysis of the soil in the Mulato field in the wet season

Sample #/Parameter	1	2	3	4	5	6	7	8	9	Mean Level
pH	5.47	5.78	5.83	6.10	5.98	6.02	6.16	6.09	6.01	5.94
Total Salts (mg/kg)	123	139	142	231	237	145	178	164	173	170.22
Calcium (mg/kg)	504	627	638	698	535	583	700	564	505	594.89
Magnesium (mg/kg)	136	128	125	200	131	130	129	127	149	139.44
Potassium (mg/kg)	0.58	0.75	0.80	1.02	0.76	0.83	0.78	0.74	0.82	0.79
Iron (mg/kg)	7.43	8.46	9.73	5.32	5.23	5.19	5.24	5.89	5.09	6.40
Boron (mg/kg)	0.56	0.37	0.41	0.68	0.66	0.84	0.52	0.30	0.51	0.54
Chloride (mg/kg	110	70	70	140	70	70	110	110	110	95.56
Total Nitrogen (mg/kg)	1640	4020	2820	3520	6900	2520	5560	2560	6580	4013.33
Bray Phosphorous (mg/kg)	420	490	440	560	560	510	570	430	560	504.44
Sand (%)	59.35	41.64	51.42	43.33	61.74	60.44	59.53	60.24	60.30	55.33
Silt (%)	24.00	37.85	30.55	41.2	21.6	21.7	20.3	15.45	20.35	25.89
Clay (%)	11.00	13.95	14.80	9.50	12.20	9.70	12.45	10.10	13.05	11.86

Organic Matter (%)	8.38	10.62	8.93	11.17	8.83	7.26	7.26	8.93	1.67	8.12
Cation Exchange Capacity (meg/100 g)	4.80	5.34	5.37	6.28	4.91	5.14	5.71	5.02	4.91	5.28