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Evaluation of Sugarcane-Based Land Utilization Types in Negros Occidental, Philippines

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ABSTRACT

Five major soil series (Guimbalaon, Isabela, Luisiana, San Manuel, and Silay) in Negros Occidental were studied to identify the different sugarcane-based land utilization types (LUTs) in the province; determine the physical and chemical characteristics of different land utilization types cultivated to sugarcane; evaluate the existing management practices of different sugarcane-based land utilization types; and draw soil management recommendations for sugarcane production based on soil constraints of major soil series.

LUT 5 received the highest pH value and was also rated very high in exchangeable Ca and available P. Organic carbon content was rated very low in all LUTs and low in percent total N. Exchangeable Mg was rated medium in LUTs 1, 3, 5, and 6 while LUTs 5 and 6 were also rated medium in cation exchange capacity. Exchangeable K, on the other hand, was rated high in LUT 4 and low in LUTs 1, 2, 3, and 5 while exchangeable Na was rated low (LUT 1) to very low (LUTs 2–6). Soil management recommendations for constraints on topography in Guimbalaon and Luisiana series (LUTs 1, 2, and 4), were the implementation of a good soil conservation cropping and tillage practices such as contour terracing or farming while problems on wetness in Isabela, San Manuel, and Silay series (LUTs 1–6) could be managed by raising the height of the soil surface and elevate the site by adding 25-30cm of well-drained topsoil, compost or other organic matter to raise the planting zone and build drainage canals to direct water away from plants or other spots that collect water.

Keywords: sugarcane-based, land utilization types, soil management recommendations

INTRODUCTION

Sugarcane is one of the major crops in the Philippines. It is cultivated in 19 provinces across the country. From 2002 to 2006, sugarcane production

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contributed an average of P24.91 billion/per year to national agricultural production. Based on the latest statistical data, about 392,300 hectares are for sugarcane production which accounts for 7.43% of agricultural lands for major crops (www.philexport.ph). The growth rate of sugar production has been achieved mainly through the expansion of cultivated areas. Sugar cane was planted in 382,956 hectares for crop year 2007 which was higher than the 372,339 hectares for crop year 1995-1996. However, this pattern of growth can no longer continue due to the ongoing land conversion, competition from other crops, and the declining land frontier. Therefore, a strategy for developing the Philippine sugarcane industry should focus on increasing farm productivity. The country's national average yield of 60 tons cane per hectare is still one of the lowest among sugar producing countries in Southeast Asia. At the farm level, productivity varies enormously (Padilla-Fernandez & Nuthall 2009).

The sugar industry is the lifeblood of the economy of Negros Occidental. The province is known as the "Sugarbowl of the Philippines" (www.philippine-islands.ph). As the major sugar producer, it contributes to more than half of the country's total sugar production (www.negros-occ.gov.ph). Some 54% of its agricultural land is sugarcane-based, and raw sugar is its leading traditional export product. More than half of the available agricultural land in the lowlands is devoted to sugarcane cultivation. The social and ecological problems associated with monoculture sugarcane production pervade the island. Negros became infamous in the 1980's when the collapse of the sugar industry led to the starvation of thousands of sugar workers and their families. Today, much of the landscape of Negros remains in monoculture sugarcane production under the control of wealthy plantation owners known as *hacienderos*. Many landless laborers continue to toil in the cane fields for US$1.50-2/day and are locked into a cycle of poverty, indebtedness, and physically gruelling work (Mulkins 2000).

Land evaluation provides a rational basis for taking land-use decisions based on the analysis of relations between land use and land, giving estimates of required inputs and projected outputs. The principal objective of land evaluation is to select the optimum land use for each defined land unit, taking into account both physical and socio-economic considerations and the conservation of environmental resources for future use. Consequently, proper management strategies can be employed to improve the suitability of a land for a particular farming enterprise (Sys et al 1991). Land evaluation defines the optimum use of land for sustainable production. It determines soil-based production constraints, sets corrective measures to improve yield, and suggests ideas for possible alternative land uses (Cañete et al 2016). The activities in land evaluation that are specifically concerned with the choice and evaluation of cropping, irrigation and management systems (i.e. with land use) start with decisions about the alternative type of land utilization that will be separately evaluated. Land utilization studies are important procedures in land evaluation and these play a balancing role in soils, land mapping, and resource survey. LUT consists of a set of technical specifications within a socio-economic setting (FAO 1984). Relatively, proper land quality evaluation generates a more specific land utilization type to which spatial and climatic variability are recognized. It also provides sound management recommendations to bridge the gap between land quality and land quality requirements. On the other hand, inappropriate land use leads to inefficient exploitation of natural resources, destruction of the land resource, poverty, and other social problems (Shalaby et al 1996).

Thus, this study aimed to identify the sugarcane-based land utilization types in Negros Occidental; determine the physical and chemical characteristics of different land utilization types devoted to sugarcane; evaluate the existing management practices of different sugarcane-based land utilization types; and draw soil management recommendations for sugarcane production based on soil constraints of major soil series.

MATERIALS AND METHODS

Survey, Assessment, and Selection of the Study Sites

A comprehensive assessment looking on sugarcane areas was conducted. Topographic, geologic, and soil maps as well as other publications were used as basis in identifying the sampling sites. Major soil series of the province that were mostly grown to sugarcane were identified and utilized in this study. Out of the nine soil series that were mostly planted to sugarcane in Negros Occidental, five (Guimbalaon, Luisiana, Isabela, San Manuel, Silay) were comprehensively assessed and utilized in this study since these are the most widespread soil series found in the province (Figure 1).

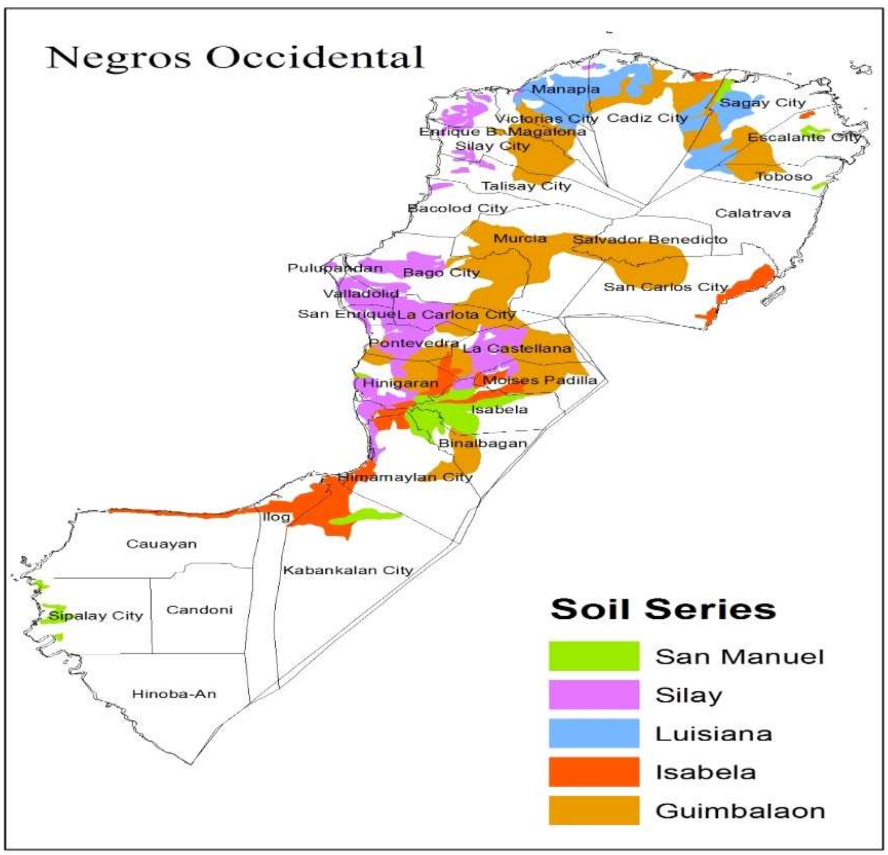

Figure1. Distribution of the five major soil series grown to sugarcane in Negros Occidental

Identification of Land Utilization Types (LUTs)

Existing Land Utilization Types (LUTs) in the study areas were identified through farm survey and verified through field inspection. An interview of five sugarcane farmers in each soil series was done in order to know the history of the land being cultivated especially on the number of years the land was planted with sugarcane and the management practices being used. Results collected from the interview were used in grouping the extensively and less-extensively managed sugarcane areas as well as irrigated and non-irrigated management scheme for each soil series. Each LUT was identified with its corresponding management attributes using the FAO framework. These include cropping system or pattern, farm size, land tenure, crop variety, cultural management practices (eg, fertilizer input and use, crop protection), irrigation system, labor intensity, power, mechanization, farm inputs, crop yield, capital intensity, livestock, farm sales, technical knowledge, and market orientation.

Soil Collection and Laboratory Analysis

Twenty soil samples were collected from representative sites at depths of 0-30 and 30–60cm and were processed and analyzed in the laboratory for soil pH, total N, available P, exchangeable bases, percent organic carbon, extractable Fe, exchangeable Al, particle size distribution, and cation exchange capacity following standard procedures.

RESULTS AND DISCUSSION

Description of Land Utilization Types (LUTs) identified in Negros Occidental

According to FAO (1976) and Sys et al (1991), an LUT is a specific subdivision of a major kind of land-use, serving as the subject of land evaluation and defined as precisely as possible in terms of produce and management. The land utilization type should not only define the crop or crop rotation (produce), but in addition, it has to be precise on how to farm these crops (management). This implies that the concept of LUT includes the kind of crop and the succession of crops in a rotation or farming system with precision of the management type.

In the study area, six LUTs were identified based on the soil series and sugarcane cultivation and management practices. The extent and distribution of these LUTs were mapped and shown in Figure 2.

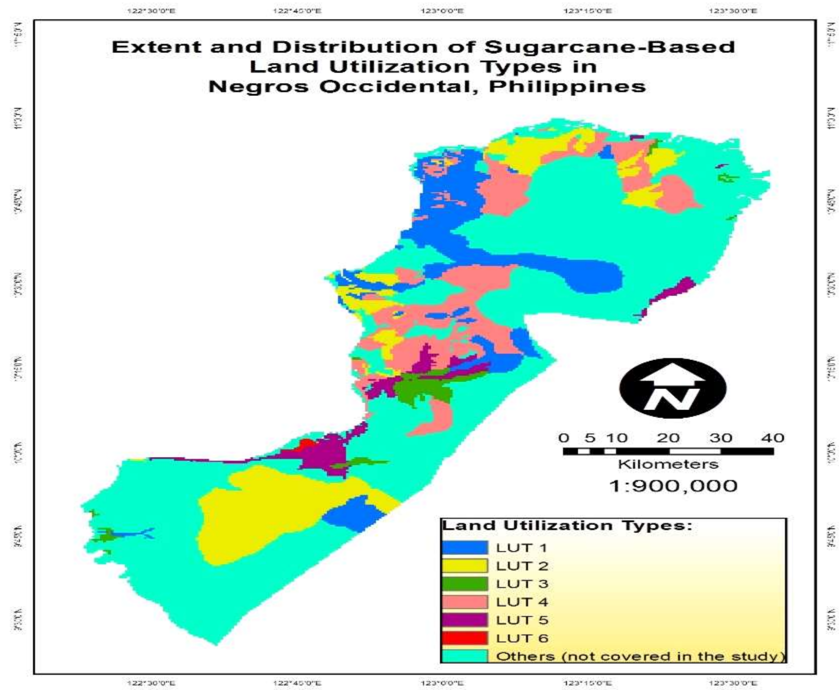

Figure 2. Extent and distribution of sugarcane-based Land Utilization Types in Negros Occidental , Philippines

- LUT 1 – with intermediate level of farm technology producing sugarcane in a monocropping cropping pattern with farm sizes ranging from 1.16 – 7.0 hectares. Farm practices were based on power-driven implements particularly on land preparation including plowing, harrowing and furrowing by using tractors during at plant cane and animal-driven using carabao at 1st and 2nd ratoon while the rest of the farm operations such as planting, fertilization, weeding, pesticide application, and harvesting were done manually thus requiring high labor intensity. Irrigation system was carried out by fuel-driven machine to irrigate the crops. Capital intensity is higher which is brought about by high cost of farm production inputs. Soils that belong to this LUT were Guimbalaon, Luisiana, San Manuel, and Silay soil series.

- LUT 2 – with intermediate level of farm technology producing sugarcane that are mainly rain-fed in a monocropping cropping pattern with farm sizes ranging from 0.70 – 3.60 hectares. Farm practices were based on power-driven implements particularly on land preparation including plowing, harrowing and furrowing by using tractors during at plant cane and animal-driven using carabao at 1st and 2nd ratoon while the rest of the farm operations such as planting, fertilization, weeding, pesticide application, and harvesting were done manually thus requiring high labor intensity. Capital intensity brought about by the cost of farm production inputs is moderate. Soils that composed this LUT were Isabela, Luisiana, and Silay soil series.

- LUT 3 – with intermediate level of farm technology producing sugarcane that are mainly rain-fed in a crop rotation cropping pattern with farm sizes ranging from 1.0 – 1.10 hectares. Farm practices were based on power-driven implements particularly on land preparation including plowing, harrowing and furrowing by using tractors during at plant cane and animal-driven using carabao at 1st and 2nd ratoon while the rest of the farm operations such as planting, fertilization, weeding, pesticide application, and harvesting were done manually thus requiring high labor intensity. Capital intensity brought about by the cost of farm production inputs is moderate. Soils found in this LUT were San Manuel and Silay soil series.

- LUT 4 – with intermediate level of farm technology producing sugarcane that are mainly rain-fed using a monocropping cropping pattern with farm sizes ranging from 0.3 – 0.5 hectares. Farm practices were based on carabao-drawn implements particularly on land preparation including plowing, harrowing and furrowing during at plant cane and 1st and 2nd ratoon while the rest of the farm operations such as planting, fertilization, weeding, and harvesting were done manually requiring low labor intensity due to smaller sizes of the farm. In addition, lower amounts of fertilizers were applied hence requires lower capital intensity for the cost of production inputs. Guimbalaon and Silay series belong to this LUT.

- LUT 5 – with intermediate level of farm technology producing sugarcane using a crop rotation cropping pattern with a farm size of 0.5 hectares. Farm practices were based on carabao-drawn implements particularly on land preparation including plowing, harrowing and furrowing during at plant cane and 1st and 2nd ratoon while the rest of the farm operations such as planting, fertilization, weeding, and harvesting were done manually requiring low labor intensity due to smaller size of the farm. Irrigation system was carried out by fuel-driven machine to irrigate the crops. Capital intensity is high which is brought about by high cost of farm production inputs. Soils under this LUT belong to Isabela series.

- LUT 6 – with intermediate level of farm technology producing sugarcane using a monocropping cropping pattern with a farm size of 2.0 hectares. Farm practices were based on carabao-drawn implements particularly on land preparation including plowing, harrowing and furrowing during at plant cane and 1st and 2nd ratoon while the rest of the farm operations such as planting, fertilization, weeding, and harvesting were done manually requiring high labor intensity. Irrigation system was carried out by fuel-driven machine to irrigate the crops. Capital intensity is high which is brought about by high cost of farm production inputs. Isabela series belongs to this LUT.

Table1. Summary of Land Utilization Types (LUTs) identified in Negros Occidental

Soil Series	LUT	Management								
		Produce and Use or Disposal	Size of the Farm (ha)	Labor Intensity	Capital Intensity	Source of Farm Power	Technical Know-How of Farmers	Cropping Pattern	Irrigation System	Farm Input Utilization
Guimbalaon, Luisiana, San Manuel, Silay	1	Sugarcane sold to sugar milling factories or sugar traders	1.16 – 7.0	High	High	Power-driven implements used at land preparation during plant cane while animal-drawn at 1st and 2nd ratoon. Other farm operations were done manually.	Intermediate level of farm technology intervention	Mono-cropping	Fuel-driven machine	High
Isabela, Luisiana, Silay	2	Sugarcane sold to sugar milling factories or sugar traders	0.70 – 3.60	High	Moderate	Power-driven implements used at land preparation during plant cane while animal-drawn at 1st and 2nd ratoon. Other farm operations were done manually.	Intermediate level of farm technology intervention	Mono-cropping	Rainfed	High
San Manuel, Silay	3	Sugarcane sold to sugar milling factories or sugar traders	1.0 – 1.10	High	Moderate	Power-driven implements used at land preparation during plant cane while animal-drawn at 1st and 2nd ratoon. Other farm operations were done manually.	Intermediate level of farm technology intervention	Crop Rotation	Rainfed	High

Table1 Continuation

Soil Series	LUT	Produce and Use or Disposal	Size of the Farm (ha)	Management						
				Labor Intensity	Capital Intensity	Source of Farm Power	Technical Know-How of Farmers	Cropping Pattern	Irrigation System	Farm Input Utilization
Guimbalaon, Silay	4	Sugarcane sold to sugar milling factories or sugar traders	0.3 – 0.5	Low	Low	Animal-drawn implements used at land preparation during plant cane and 1^{st} and 2^{nd} ratoon. Other farm operations were done manually	Intermediate level of farm technology intervention	Mono-cropping	Rainfed	Low
Isabela	5	Sugarcane sold to sugar milling factories or sugar traders	0-5	Low	High	Animal-drawn implements used at land preparation during plant cane and 1^{st} and 2^{nd} ratoon. Other farm operations were done manually.	Intermediate level of farm technology intervention	Crop Rotation	Fuel-driven machine	High
Isabela	6	Sugarcane sold to sugar milling factories or sugar traders	2.0	High	High	Animal-drawn implements used at land preparation during plant cane and 1^{st} and 2^{nd} ratoon. Other farm operations were done manually.	Intermediate level of farm technology intervention	Mono-cropping	Fuel-driven machine	High

Soil Physico-Chemical Properties of LUTs in Negros Occidental

Table 2 presents the soil chemical properties of the different LUTs identified in the study area. The mean soil chemical analyses results obtained from different land units belonging to each LUT was computed. Interpretation of the results on these soil chemical properties obtained in different LUTs was described using the standard interpretation guide of PCAARRD (2013) on quantitative soil analysis with ratings from very low to very high.

Table 2. Soil physico-chemical properties of different Land Utilization Types in Negros Occidental

Soil Chemical Properties	Land Utilization Types (LUTs)					
	1	2	3	4	5	6
pH (H2O)	5.81	5.46	5.67	5.58	6.85	6.41
pH (CaCl2)	5.06	4.72	5.05	4.84	6.32	6.03
Total N (%)	0.11	0.11	0.10	0.11	0.15	0.14
Organic C (%)	1.12	1.03	0.67	0.93	1.37	1.35
CEC (me/100g)	12.61	9.66	12.14	8.23	111.28	77.75
Available P (mg/kg)	39.64	37.40	33.92	6.58	107.24	122.45
Exch. K (me/100g)	0.25	0.22	0.14	1.17	0.27	0.31
Exch. Na (me/100g)	0.12	0.04	0.08	0.09	0.07	0.06
Exch. Ca (me/100g)	16.14	7.16	17.35	6.16	43.40	7.13
Exch. Mg (me/100g)	1.48	0.92	1.55	0.75	1.82	1.92
Exch. Al (me/100g)	0.03	0.18	0.01	0.03	0.01	0.01
Extr. Fe (mg/kg)	103.51	75.22	99.96	84.54	50.71	70.52
clay (%)	35.91	27.29	27.00	30.67	46.00	42.00
silt (%)	19.82	12.71	19.00	23.67	14.00	24.00
sand (%)	44.27	60.00	54.00	45.67	40.00	34.00

Table 3 revealed that soil pH of the six LUTs ranged from strongly acid (LUTs 2 and 4) which is considered low to moderately acid (LUTs 1 and 3), slightly acid (LUT 6) to near neutral (LUT 5) which is high. Organic Carbon content of all LUTs were very low with values ranging from 0.67–1.37% (Table 4) while Total Nitrogen was rated as low with values that ranged from 0.10–0.15% (Table 5). Available Phosphorus obtained in the different LUTs was rated as high (LUTs 1, 2, and 3) to very high (LUTs 5 and 6) except for LUT 4 that has very low amount of P (Table 6). Furthermore, Cation Exchange Capacity of LUTs 2 and 4 were rated as very low with values of 9.66 and 8.23, respectively. LUTs 1 and 3 received a rating of low while medium for LUTs 5 and 6 (Table 7). Table 8, on the other hand, shows the general interpretation of exchangeable bases values of the six LUTs. For exchangeable K, LUTs 1, 2, and 5 were rated as low while medium to very high on exchangeable Ca. Low (LUT 1) to very low (LUTs 2, 3, 4, 5, and 6) ratings were described on all LUTs for exchangeable Na and low (LUTs 2 and 4) to medium (LUTs 1, 3, 5, and 6) for exchangeable Mg.

Table 3. General interpretation of soil pH obtained from sugarcane-based LUTs in Negros Occidental

Soil Series	Land Utilization Types	pH Value	Rating	Interpretation
Guimbalaon, Luisiana, San Manuel, Silay	LUT 1	5.81	Medium	Moderately Acid
Isabela, Luisiana	LUT 2	5.46	Low	Strongly Acid
San Manuel, Silay	LUT 3	5.67	Medium	Moderately Acid
Guimbalaon, Silay	LUT 4	5.58	Low	Strongly Acid
Isabela	LUT 5	6.85	High	Near Neutral
Isabela	LUT 6	6.41	Medium	Slightly Acid

Table 4. General interpretation of organic carbon obtained from sugarcane-based LUTs in Negros Occidental

Soil Series	Land Utilization Types	Organic C (%)	Rating
Guimbalaon, Luisiana, San Manuel, Silay	LUT 1	1.12	Very Low
Isabela, Luisiana	LUT 2	1.13	Very Low
San Manuel, Silay	LUT 3	0.67	Very Low
Guimbalaon, Silay	LUT 4	0.93	Very Low
Isabela	LUT 5	1.37	Very Low
Isabela	LUT 6	1.35	Very Low

Table 5. General interpretation of total nitrogen obtained from sugarcane-based LUTs in Negros Occidental

Soil Series	Land Utilization Types	Total N (%)	Rating
Guimbalaon, Luisiana, San Manuel, Silay	LUT 1	0.11	Low
Isabela, Luisiana	LUT 2	0.11	Low
San Manuel, Silay	LUT 3	0.10	Low
Guimbalaon, Silay	LUT 4	0.11	Low
Isabela	LUT 5	0.15	Low
Isabela	LUT 6	0.14	Low

Table 6. General interpretation of available phosphorus obtained from sugarcane-based LUTs in Negros Occidental

Soil Series	Land Utilization Types	Available P (mg/kg)	Rating
Guimbalaon, Luisiana, San Manuel, Silay	LUT 1	39.64	High
Isabela, Luisiana	LUT 2	37.40	High
San Manuel, Silay	LUT 3	33.92	High
Guimbalaon, Silay	LUT 4	6.58	Very Low
Isabela	LUT 5	107.24	Very High
Isabela	LUT 6	122.45	Very High

Table 7. General interpretation of cation exchange capacity obtained from sugarcane-based LUTs in Negros Occidental

Soil Series	Land Utilization Types	CEC (me/100g)	Rating
Guimbalaon, Luisiana, San Manuel, Silay	LUT 1	12.61	Low
Isabela, Luisiana	LUT 2	9.66	Very Low
San Manuel, Silay	LUT 3	12.14	Low
Guimbalaon, Silay	LUT 4	8.23	Very Low
Isabela	LUT 5	22.48	Medium
Isabela	LUT 6	22.67	Medium

Management Practices of Different Sugarcane-Based LUTs

Careful attention to crop management is the key to high crop yields. The study assessed the existing management practices of sugarcane farmers with respect to their land utilization types. Monocropping and crop rotation were practiced with fuel-driven and rainfed-based irrigation systems under a conventional farming operation using either semi-mechanized or purely animal-drawn land preparation. Chemical fertilizers were continuously applied in larger amounts. Pesticides application and burning of trashes were some of the farming activities done in the field. The summary of the management practices of different sugarcane-based land utilization types is shown in Table 9.

Soil Management Recommendations for Different LUTs

Soil management aims to protect the soil and enhance its performance to increase farm profitability and preserve environmental quality. It is also the combination of soil factors to maximize crop production at the lowest possible cost while maintaining the soil's productive state. Thus, it involves maintaining the soil in good physical condition and fertility status, and influencing the biological aspect of the soil to attain maximum benefits (Harpstead et al 1997, PhilRice 2014).

Appropriate soil management practices were recommended to address the problems or constraints of each soil series that may limit sugarcane production. Constraints on topography as identified in Guimbalaon and Luisiana soil series under LUTs 1, 2, and 4 respectively, could be alleviated by implementing good soil conservation cropping and tillage practices such as contour terracing. Problems on wetness due to flooding and poor drainage observed in Isabela, San Manuel, and Silay soil series could be alleviated by raising the height of the soil and elevating the site by adding 25-30cm of well-drained topsoil, compost or other organic matter to raise the planting zone, build drainage canals to direct water away from plants or other spots that collect water, construct broad beds, ridges or furrows, and addition of an organic substance into the soil to improve the water-holding capacity of the soil. Furthermore, limitations on physical soil characteristics such as presence of outcrops, shallow rooting depth found in Guimbalaon soil series was recommended to be alleviated by subsoil tillage or deep tillage to improve the structure and characteristics of topsoil and shift to crop rotations instead of monocropping so that it can help utilize plant nutrients that have moved below the rooting depth of shallow-rooted crops more effectively. Isabela soil series which has a moderately constraint in having sandy loam texture cannot be changed but can be managed properly by controlling tillage, proper fertilization, addition of organic materials or leaving crop residues into the soil surface by reducing the burning of trashes. Soil fertility constraints observed in Luisiana and Silay series were identified as low in base saturation, pH, and organic carbon content thus, is recommended to have an adequate fertilization, incorporation of organic materials into the soil, increase application of calcium, potassium, magnesium, and/or sodium- containing amendment to improve the base status of the soils, additions of lime to raise the desired pH of the soil, and to minimize or reduce burning of trashes. On the other hand, climatic constraint specifically on high relative humidity of the area can be addressed in all LUTs through scheduling of farm activities. The summary of the soil management recommendations for the five soil series under study observed in six LUTs identified in the province were presented in the following tables below (Tables 10-14).

CONCLUSIONS

Six LUTs were identified based on the soil series and sugarcane cultivation and management practices in Negros Occidental. LUT 5 showed the highest pH value and was rated very high in exchangeable Ca and available P. Organic carbon and total N contents were very low in all LUTs. Exchangeable Mg was rated medium in LUTs 1, 3, 5, and 6 while LUTs 5 and 6 were also rated medium in cation exchange capacity. Exchangeable K, on the other hand, was high in LUT 4 and low in LUTs 1, 2, 3, and 5 while exchangeable Na was rated low (LUT 1) to very low (LUTs 2 – 6).

Existing management practices in the different LUTs were observed to be monocropping and crop rotation with fuel-driven and rainfed-based irrigation systems under a conventional farming operation using either semi-mechanized or purely animal-drawn land preparation. Chemical fertilizers were continuously applied in larger amounts. Pesticides application and burning of cup residues were some of the farming practices done in the field.

Soil management recommendations to alleviate constraints on topography in Guimbalaon and Luisiana series (LUTs 1, 2, and 4) include the implementation of good soil conservation cropping and tillage practices such as contour terracing or farming while the problems on soil wetness in Isabela, San Manuel, and Silay series (LUTs 1 – 6) could be alleviated by raising the height of the soil surface and elevating the site by adding 25-30cm of well-drained topsoil, compost or other organic materials raise the planting zone. Construction of drainage canals to direct water away from plants or other spots that collect water could be another strategy to alleviate the wetness problem.

Table 8. General interpretation of exchangeable bases obtained from sugarcane based LUTs in Negros Occidental

Soil Series	LUTs	Exchangeable Bases (me/100g)							
		K		Na		Ca		Mg	
		Value	Rating	Value	Rating	Value	Rating	Value	Rating
Guimbalaon, Luisiana, San Manuel, Silay	LUT 1	0.25	Low	0.12	Low	16.14	High	1.43	Medium
Isabela, Luisiana	LUT 2	0.22	Low	0.04	Very Low	7.16	Medium	0.92	Low
San Manuel, Silay	LUT 3	0.14	Low	0.08	Very Low	17.35	High	1.55	Medium
Guimbalaon, Silay	LUT 4	1.17	High	0.09	Very Low	6.16	Medium	0.75	Low
Isabela	LUT 5	0.27	Low	0.07	Very Low	43.40	Very High	1.82	Medium
Isabela	LUT 6	0.31	Medium	0.06	Very Low	7.13	Medium	1.92	Medium

Table 9. Management practices of different sugarcane-based Land Utilization Types

Soil Series	LUT	Cropping Pattern	Water Management	Physical Land Operation	Fertility Enhancement	Climatic Adjustments	Other Farm Practices
Guimbalaon	1	Monocropping	Fuel-driven irrigation	Conventional (semi-mechanized)	Application of chemical fertilizers	Scheduling of farm activities	Pesticide application; Burning of trash; Trash filing (practiced by few)
	4	Monocropping	Rainfed-based irrigation	Conventional (purely animal-drawn)	Application of chemical fertilizers	Scheduling of farm activities	Pesticide application (practiced by few); Burning of trash

Table 9 continued

Soil Series	LUT	Cropping Pattern	Water Management	Physical Land Operation	Fertility Enhancement	Climatic Adjustments	Other Farm Practices
Isabela	2	Monocropping	Rainfed-based irrigation	Conventional (semi-mechanized)	Application of chemical fertilizers; Application of soil conditioners, chicken dung, and rock phosphate (practiced by few)	Scheduling of farm activities	Pesticide application; Burning of trash; Trash filing and addition of lime before burning (practiced by few)
	5	Crop rotation	Fuel-driven irrigation	Conventional (purely animal-drawn)	Application of chemical fertilizers	Scheduling of farm activities	Pesticide application; Burning of trash
	6	Monocropping	Fuel-driven irrigation	Conventional (purely animal-drawn)	Application of chemical fertilizers	Scheduling of farm activities	Pesticide application; Burning of trash
Luisiana	1	Monocropping	Fuel-driven irrigation	Convenrional (semi-mechanized)	Application of chemical fertilizers	Scheduling of farm activities	Pesticide application; Burning of trash; Trash filing (practiced by few)
	2	Monocropping	Rainfed-based irrigation	Conventional (semi-mechanized)	Application of chemical fertilizers; Application of soil conditioners, chicken dung, and rock phosphate (practiced by few)	Scheduling of farm activities	Pesticide application; Burning of trash; Trash filing and addition of lime before burning (practiced by few)

Table 9 continued

Soil Series	LUT	Cropping Pattern	Water Management	Physical Land Operation	Fertility Enhancement	Climatic Adjustments	Other Farm Practices
San Manuel	1	Monocropping	Fuel-driven irrigation	Conventional (semi-mechanized)	Application of chemical fertilizers	Scheduling of farm activities	Pesticide application; Burning of trash; Trash filing (practiced by few)
	3	Crop rotation	Rainfed-based irrigation	Conventional (semi-mechanized)	Application of chemical fertilizers	Scheduling of farm activities	Burning of Trash
Silay	1	Monocropping	Fuel-driven irrigation	Conventional (semi-mechanized)	Application of chemical fertilizers	Scheduling of farm activities	Pesticide application; Burning of trash; Trash filing (practiced by few)
	2	Monocropping	Rainfed-based irrigation	Conventional (semi-mechanized)	Application of chemical fertilizers; Application of soil conditioners, chicken dung, and rock phosphate (practiced by few)	Scheduling of farm activities	Pesticide application; Burning of trash; Trash filing and addition of lime before burning (practiced by few)
	3	Crop rotation	Rainfed-based irrigation	Conventional (semi-mechanized)	Application of chemical fertilizers	Scheduling of farm activities	Burning of trash
	4	Monocropping	Rainfed-based irrigation	Conventional (purely animal-drawn)	Application of chemical fertilizers	Scheduling of farm activities	Pesticide application (practiced by few); Burning of trash

Table 10. Soil management recommendations for Land Utilization Types belonging to Guimbalaon soil series

Soil Series	Soil Constraints	LUT	Soil Management Recommendations				
			Topography	Wetness	Physical Soil Characteristics	Soil Fertility Characteristics	Climate
Guimbalaon	topography; presence of outcrops and pebbles; shallow rooting depth; high RH	1 4	Implement a good soil conservation cropping and tillage practices wherever possible that will minimize runoff of water and sediment to surface water through: • Contour terracing / farming where crop rows are tilled up the contour; • use and filing of outcrops to install erosion control structures such as diversions • establishing a permanent 3 m (10 ft) vegetated buffer strips alongside surface water; • adopt strip cropping where applicable • reduce the number of tillage passes • rotate crops with a variety of crop species including forages and cereals • plant cover crops	-	• Implement subsoil tillage or deep tillage to improve the structure and characteristics of topsoil as well as improving the ecological environment for root development and root activities that will enhance the anti-stress capacity of plants; • Crop rotations can help utilize plant nutrients that have moved below the rooting depth of shallow-rooted crops more effectively.	-	Climate concerns were addressed by scheduling of farm activities Climate concerns were addressed by scheduling of farm activities

Table 11. Soil management recommendations for Land Utilization Types belonging to Isabela soil series

Soil Series	Soil Management Recommendations						
	Soil Constraints	LUT	Topography	Wetness	Physical Soil Characteristics	Soil Fertility Characteristics	Climate
Isabela	seasonal flooding occurrence; poor to moderate drainage; sandy loam texture; high RH	2 5 6	-	• Raise the height of the soil and elevate the site by adding 10-12 inches of well-drained topsoil, compost or other organic matter to raise the planting zone. Till or work the amendment in the soil until a homogenous mixture is developed; • Build drainage canals to direct water away from plants or other spots that collect water; • Construct broad beds, ridges or furrows; • Addition of an organic substance into the soil before planting and distributing large amounts of compost or organic material throughout the soil medium can greatly improve the water-holding capacity of the soil; • Addition of gypsum (calcium sulfate) helps pull clay particles together which allows better drainage to develop as more micro pores form; • Cultivate only optimum moisture content; • Practice cover cropping	• Control tillage; • Topsoil addition accompanied by proper fertilization or addition of organic amendments; • Leave crop residues on the soil surface and minimize or reduce burning of trashes.	-	Climate concerns were addressed by scheduling of farm activities Climate concerns were addressed by scheduling of farm activities Climate concerns were addressed by scheduling of farm activities

Table 12. Soil management recommendations for Land Utilization Types belonging to Luisiana soil series

Soil Series	Soil Constraints	LUT	Soil Management Recommendations				
			Topography	Wetness	Physical Soil Characteristics	Soil Fertility Characteristics	Climate
Luisiana	topography; low base saturation and pH	1	Implement a good soil conservation cropping and tillage practices wherever possible that will minimize runoff of water and sediment to surface water through:	-	-	• Adequate fertilization; • Incorporation of organic materials into the soil; • Increase application of calcium, potassium, magnesium, and/or sodium- containing amendment to improve the base status of the soils; • Additions of lime to raise the desired pH of the soil	Climate concerns were addressed by scheduling of farm activities
		2	• Contour terracing / farming where crop rows are tilled up the contour; • use and filing of outcrops to install erosion control structures such as diversions • establishing a permanent 3 m (10 ft) vegetated buffer strips alongside surface water; • adopt strip cropping where applicable • reduce the number of tillage passes • rotate crops with a variety of crop species including forages and cereals • plant cover crops	-	-		Climate concerns were addressed by scheduling of farm activities

Table 13. Soil management recommendations for Land Utilization Types belonging to San Manuel soil series

Soil Series	Soil Constraints	LUT	Soil Management Recommendations				
			Topography	Wetness	Physical Soil Characteristics	Soil Fertility Characteristics	Climate
San Manuel	seasonal flooding	1	-	• Raise the height of the soil and elevate the site by adding 10-12 inches of well-drained topsoil, compost or other organic matter to raise the planting zone. Till or work the amendment in the soil until a homogenous mixture is developed; • Build drainage canals to direct water away from plants or other spots that collect water; • Construct broad beds, ridges or furrows; • Cultivate only optimum moisture content; • Practice cover cropping	-	-	Climate concerns were addressed by scheduling of farm activities
		3	-		-	-	Climate concerns were addressed by scheduling of farm activities

Table 14. Soil management recommendations for Land Utilization Types belonging to Silay soil series

			Soil Management Recommendations				
Soil Series	Soil Constraints	LUT	Topography	Wetness	Physical Soil Characteristics	Soil Fertility Characteristics	Climate
Silay	seasonal flooding occurrence; poor to moderate drainage; low organic carbon content; high RH	1	-	• Raise the height of the soil and elevate the site by adding 10-12 inches of well-drained topsoil, compost or other organic matter to raise the planting zone. Till or work the amendment in the soil until a homogenous mixture is developed; • Build drainage canals to direct water away from plants or other spots that collect water; • Construct broad beds, ridges or furrows; • Addition of an organic substance into the soil before planting and distributing large amounts of compost or organic material throughout the soil medium can greatly improve the water-holding capacity of the soil; • Addition of gypsum (calcium sulfate) helps pull clay particles together which allows better drainage to develop as more micro pores form; • Cultivate only optimum moisture content; • Practice cover cropping	-	• Incorporation of organic materials into the soil to increase organic carbon content such as plowing under of crop residues and green manuring; • Minimize or reduce burning of trashes	Climate concerns were addressed by scheduling of farm activities
		2	-		-		Climate concerns were addressed by scheduling of farm activities
		3	-		-		Climate concerns were addressed by scheduling of farm activities
		4	-		-		Climate concerns were addressed by scheduling of farm activities

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