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Socio-Economic Assessment of Sugarcane-Based Cropping System in Negros Occidental, Philippines

CLEA ANNE V. CORSIGA
http://orcid.org/0000-0002-3546-2630
cleaannecorsiga@gmail.com
Visayas State University-Villaba, Villaba, Leyte, Philippines

RODRIGO B. BADAYOS
http://orcid.org/0000-0001-8705-0
rodbadayos@gmail.com
Philippine Sugar Research Institute Makati City, Philippines

PEARL B. SANCHEZ
http://orcid.org/0000-0001-6253-5
pbsanchez@uplb.edu.ph
University of the Philippines - Los Baños, College, Laguna, Philippines

ERLINDA S. PATERNO
espaterno@yahoo.com
University of the Philippines - Los Baños, College, Laguna, Philippines

POMPE C. STA. CRUZ
http://orcid.org/0000-0003-4058-8
pompestacruz@yahoo.com
University of the Philippines - Los Baños, College, Laguna, Philippines

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ABSTRACT

The sugar industry is the life-giving force of the economy of Negros Occidental which contributes to more than half of the country's total sugar production. The study aims to know the socio-economic status of sugarcane farmers in the province; evaluate their management practices on sugarcane production profitability based on the suitability and constraints exhibited by the major soil series grown to sugarcane, and to determine the effect of these farmers' practices on the properties of the soils. A survey on twenty-five (25) farmers was conducted. FAO soil constraints and suitability analysis tool were used to identify the constraints and suitability of Guimbalaon, Isabela, Luisiana, San Manuel, and Silay soil series. Existing management practices of farmers like monocropping, burning of trashes, and intensive and inappropriate use of inputs such as fertilizers and pesticides may either affect soil physical, chemical, and biological properties. Topography and wetness were the severe constraints in all soil series. Sugarcane farmers with farms belonging to Silay series have the highest profitability based on net income, return on investment, and benefit-cost ratio while those belonging to Isabela series have the lowest profitability which could be attributed to varying constraints for sugarcane production thus, appropriate soil management interventions are necessary for this series.

***Keywords* —** Soil science; socio-economic assessment; survey; Philippines

INTRODUCTION

Sugarcane production is a principal economic activity in over 100 countries, particularly in developing countries with a high proportion of poor and unemployed groups. As a provider of income and employment, sugarcane-based agriculture has an important role to play in the economic growth of developing economies, especially in the upliftment of financial condition of under-skilled rural people. The world of sugarcane industry has expanded enormously over the past two decades with perhaps the most fundamental change being the expansion of ethanol production. Sugarcane production is becoming more concentrated within countries, with the top ten sugarcane-producing countries increasing their share from 56% in 1980 to around 70% in 2010. The increase in world sugar consumption resulting from rising incomes and changes in food consumption patterns, particularly in Asia and Africa was the chief driver for the expansion of sugarcane production (Meyer, Rein, Turner & Mathias, 2013).

Sugarcane is one of the major crops of the Philippines. Sugarcane was cultivated in 19 provinces across the country. Based on the latest statistical data, about 392,300 hectares are for sugarcane production which accounts for 7.43 percent of agricultural lands for principal crops (Philippine Exporters Confederation, Inc., n.d.). The growth rate of sugar production has been achieved mainly through the expansion of cultivated areas. 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, an effective strategy for developing the Philippine sugarcane industry should focus on increasing farm productivity. The country produced a national average yield of 60 ton-cane per hectare and is still considered as one of the lowest among sugar-producing countries in Southeast Asia. At the farm level, productivity varies enormously (Padilla-Fernandez and Nuthall, 2009).

Negros Occidental, known as the "Sugarbowl of the Philippines", were the lifeblood of the economy is on sugar industry (Discover World Ventures, Inc., 2018) and as the major sugar producer, contributes to more than half of the country's total sugar production. Some 54 percent of its agricultural land is sugarcane-based, and raw sugar is its leading traditional export product. More than half of the agricultural arable land in the lowlands is devoted to sugarcane cultivation. Supporting the sugar industry are the 13,039 planters owning 12,851 farms with a total area of 164,157 hectares. The social and ecological problems associated with monoculture sugarcane production pervade the island. Negros Occidental 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 Occidental remains in monoculture sugarcane production under the control of wealthy plantation owners known as "*haciendero*s". Many landless laborers continue to toil in the cane fields for 1.50-2 US$/day and the cycle of poverty, indebtedness and physically gruelling works remain in the system (Mulkins, 2000).

The efficient and sustainable use of land involves matching site conditions with the specific requirements and potential impacts of different land uses. Lands that are not physically capable of supporting might incurred significant costs to the environment and society. Suitability analysis is of great help in assessing and determining the appropriateness of a given area for a particular use. The fundamental premise of suitability analysis is that each aspect of the landscape has intrinsic characteristics that are in some degree either suitable or unsuitable for the activities being planned. It is used extensively to find and maintain better cropland as well as ensure proper crop rotation. Hence, in the process, it helps to ensure that land resources are used in the most productive and sustainable ways because different crops require different land types and growing conditions. Consequently, the productive potential of soil is limited by its inherent constraints. Identifying and managing these constraints is fundamental to sustainable production systems.

OBJECTIVES OF THE STUDY

The study aimed to: 1.) Determine the socio-economic status of sugarcane-based cropping system in Negros Occidental; 2.) Assess the suitability of major soil series grown to sugarcane in the province, and 3.) Identify possible constraints of the soils for sugarcane production.

Specifically, the study intended to: 1.) Evaluate the farmers' management practices on sugarcane production profitability based on the suitability and constraints exhibited by the major soil series grown to sugarcane and 2.) Determine the effect of these farmers' practices on the properties of the soils.

MATERIALS AND METHODS

Survey, Assessment, and Selection of the Study Sites and Potential Sugarcane Farmers

A comprehensive assessment was conducted on sugarcane areas in the province. Topographic, geologic, and soil maps as well as other publications, were used as materials in identifying the sampling sites. Major soil series grown to sugarcane were identified and utilized in this study. Out of the nine (9) soil series planted to sugarcane in Negros Occidental, five (5) soil series (Guimbalaon, Luisiana, Isabela, San Manuel, Silay), were comprehensively assessed and utilized in this study since these are the most abundant soil series found in the province.

A courtesy call made to the provincial and municipal offices were made before the conduct of the study. Ten municipalities in the province that covered the five major soil series were delineated in the map. Sugarcane farmers belonging to each municipality corresponding to the above mentioned soil series used in this study were randomly selected and interviewed. A survey questionnaire form particularly on the social and economic background of the farmers were formulated and used during the interview to know the history of the land being cultivated particularly on the number of years it was planted with sugarcane and the management practices used as well as the economic status of their land.

Soil Data and Climatic Characteristics Collection

Data on soil and climatic characteristics of the soil series being studied were collected from available references. Simplified Keys to Soil Series of Negros Occidental (PhilRice, 2014) and Soil Survey Reports of Negros Occidental (Alicante, Rosell, Barrera, Jaug & Engle, 1951) were used as references for most of the soil characteristics. Climatic characteristics of each soil series were obtained from www.en.climate-data.org.

Suitability Evaluation and Constraint Analyses

Soil and climatic characteristics of the five soil series (Guimbalaon, Isabela, Luisiana, San Manuel, Silay) were matched with the criteria set by Sys, Ranst, Debaveye and Beernaert (1993) for sugarcane requirements to determine their suitability class. The matching utilized the FAO land evaluation system using the following interpretations for suitability classes:

- S1 – soils without limitations or with 2 or 3 slight limitations.
- S2 – soils with 2 or 3 slight limitations and no more than two moderate limitations.
- S3 – soils with more than two moderate limitations and/or no more than one severe limitation that however does not exclude the use of the land.
- N1 – soils with one severe limitation that excludes the use of the land or more than one severe limitation that can be corrected.
- N2 – soils with severe or very severe limitations excluding the use of the land and that cannot be corrected.

Accordingly, land suitability indicates whether the land unit is suitable (S) or not suitable (N) for a specified use. Classes spell the degree of suitability. Subclass reflects the kinds of limitation due to topography, soil wetness (flooding and drainage), soil physical properties (texture, coarse fragments, and soil depth), soil fertility (apparent CEC, base saturation, and soil pH) and climate (annual precipitation and mean monthly temperature). Letter suffixes were assigned to each subclass: "t" for topography, "w" for wetness, "s" for physical properties, "f" for fertility, and "c" for the climate. Soil parameters that were identified to limit production after determining the suitability of the soils were considered constraints. Suitability and Constraints Maps were made after that.

RESULTS AND DISCUSSION

Suitability Evaluation of Major Soil Series Grown to Sugarcane

The evaluation applies the information on topography (t), wetness (w), physical soil characteristics (s), soil fertility characteristics (f), and climate (c) of the different major soil series under study which was matched to the standard crop requirement of sugarcane-based on Land Evaluation of Sys et al (1993) involving climate, landscape, and soil conditions. Each parameter acquired by the different soil series were rated as highly suitable (S1), moderately suitable (S2), marginally suitable (S3), currently not suitable (N1), and permanently not suitable (N2). A land suitability classes were made after that as shown in table 1. Based on the results, each soil series have different suitability concerning the different parameters mentioned. Suitability map as shown in Figure 1 revealed that all soil series, namely, Guimbalaon, Isabela, Luisiana, San Manuel, and Silay were classified as marginally suitable (S3) however, a limitation for sugarcane production varies in each soil series. Soils that were not studied and found on the map were indicated as others.

Crop Constraints Analysis of Major Soil Series Grown to Sugarcane

The use of land limitations is a way of expressing the land characteristics or land qualities in a relative evaluation scale. Limitations are deviations from the optimal conditions of a land characteristics/land quality which adversely affect a kind of land-use (Sys et al., 1991). The suitability ratings were utilized in the determination of the limitations or constraints of the crop from the different soil series under study. Based on the results, topography and wetness became the severe constraints for most of the soils. The influence of landscape on agricultural land use is multiple. Topography or relief is the expression of the interaction of the several different phenomena and processes within the earth's crust and on its surface. Its form and dimensions are primarily related to geological formations and to the climate, both past, and present, which have either directly or indirectly acted upon these formations. On the other hand, wetness situation of a land unit is defined by drainage and flooding. Drainage is considered in almost every system of land capability classification. For instance, the suitability for upland crops decreases when drainage conditions become impeded. Likewise, flooding is also considered an earnest limitation (Sys et al., 1991).

Nevertheless, climate specifically relative humidity (RH) was observed to be the common factor for all soil series which moderately limit production of sugarcane since it exceeded the maximum requirement of humidity needed by the crop. At specific crop development stages, a too high relative humidity may affect susceptibility to diseases. A too low relative humidity at seed formation may cause shrinkage of seeds and lower yields (Sys et al., 1991).

Other factors noted were physical soil characteristics and fertility, however, a limitation is moderate and manageable. Table 2 presents the summary of constraints of the soil series for sugarcane production. Isabela, San Manuel, and Silay series have problems with wetness due to its seasonal flooding occurrences. On the other hand, Guimbalaon and Luisiana series have a constraint on topography because of its rolling to hilly to a mountainous topographic position (Figure 2). It was noted that sugarcane does not require any specific type of soil as it can be successfully raised on diverse soil types ranging from sandy soils to clay loams and heavy clays. However, a well-drained, deep, loamy soil with a bulk density of 1.1 to 1.2 g/cm^3, optimum soil pH is about 6.5, and an available water holding capacity of 15% or more (15 cm per meter depth of soil) is considered ideal for sugarcane cultivation (Khao, 2007). Khao (2007) also reported that a shallow-depth and sandy soils, with too rolling to hilly topography or relief, and incomplete/excessive/deficient drainage is considered an unfit soil for sugarcane production.

Soil Management Recommendations for Major Soil Series Grown to Sugarcane

Soil management aims to protect the soil and enhance its performance to increase farm profitability and preserve environmental quality. Soil management 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 (Hampstead et al., 1997 as cited by PhilRice, 2014).

Based on the crop constraints analysis (table 2) previously discussed, an appropriate soil management practices were recommended to address the problems or constraints mentioned in each soil series that may limit sugarcane production. Constraints on topography as identified in Guimbalaon and Luisiana soil series were recommended to implement a proper soil conservation cropping and tillage practices such as contour terracing or farming (Tables 3 and 5). Problems with wetness which include flooding and drainage observed in Isabela, San Manuel, and Silay soil series were suggested to 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; 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 (Tables 4, 6, and 7). Furthermore, limitations on physical soil characteristics such as presence of outcrops and shallow rooting depth found in Guimbalaon soil series were recommended to implement 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 (Table 3). Isabela soil series which has a moderate constraint on sandy loam texture cannot be changed but can be managed correctly by controlling tillage, proper fertilization, an addition of organic materials or leaving crop residues into the soil surface by reducing the burning of trashes (Table 4). Soil fertility constraints observed in Luisiana and Silay series were identified as low in base saturation, pH, and organic carbon content thus, 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 (Table 5 and 7). On the other hand, climatic constraint specifically on the high relative humidity of the area was addressed by all sugarcane farmers cultivating on the different soil series through scheduling of farm activities.

In addition, it was earlier discussed that all the soil series that were evaluated in this study were found to be marginally suitable for sugarcane production which means that 25-50% potential yield of crop can be attained. However, to increase the potential yield, an appropriate soil management was recommended depending on the constraints or limitations observed in each soil series. PhilRice (2014) reported that soil factors such as slope, texture, and climate cannot be changed and was observed in Guimbalaon and Luisiana soil series. However, control tillage, crop rotations, soil amendments, and other management choices can be done. Through these choices, the structure, biological activity, and chemical content of the soil can be altered and later on influence erosion rates, pest population, and nutrient availability and crop production.

Table 1. Suitability Evaluation of Major Soil Series Grown to Sugarcane in Negros Occidental

Land Qualities / Land Characteristics	GUIMBALAON		ISABELA		LUISIANA		SAN MAN-UEL		SILAY	
	Qualities	Rating	Qualities	Rating	Qualities	Rating	Qualities	Rating	Qualities	Rating
Topography (t) Slope (%)	18 - 25	S3	0 – 2	S1	18 – 40	S3	0 - 5	S1	0 - 2	S1
Class		**S3**		**S1**		**S3**		**S1**		**S1**
Wetness (w)										
Flooding	None	S1	Seasonal flooding	S3	None	S1	Seasonal flooding	S3	Seasonal flooding	S3
Drainage	Moderate to Good	S1	Poor to moder-ate	S2	Good	S1	Good	S1	Poor to moder-ate	S2
Class		**S1**		**S3**		**S1**		**S3**		**S3**
Physical Soil Charac-teristics (s)										
Texture	C/FSL/GL	S1	C/SL	S2	C	S1	L /FSL	S1	FSL/L/C	S1
Coarse Fragment	Outcrops and pebbles	S2	None	S1	None	S1	None	S1	None	S1
Effective Rooting Depth (cm)	Shallow (0.5m)	S2	Deep (>1.0 m)	S1	Very Deep (>2.0 m)	S1	Deep (>1.0 m)	S1	Moderate (0.8 m)	S1
Class		**S2**		**S2**		**S1**		**S1**		**S1**

C – clay; FSL – fine sandy loam; GL - gravelly loam; SL – sandy loam; L – loam

Soil Fertility Character-istics (f)										
Apparent CEC (cmol(+)/kg clay)	45.96	S1	195.94	S1	16.20	S1	49.00	S1	32.85	S1
Base saturation (%)	130.38	S1	134.59	S1	34.51	S3	157.50	S1	118.31	S1
pH H_2O	6.07	S1	6.45	S1	4.86	S3	5.76	S1	5.54	S1
Organic Carbon (%)	1.03	S1	1.20	S1	1.13	S1	1.08	S1	0.83	S2
Class		**S1**		**S1**		**S3**		**S1**		**S2**

Climate (c)										
Temperature (°C)	26.9	S1	27.3	S1	27.4	S1	27.2	S1	27.1	S1
Rainfall (mm)	2, 513	S1	2, 243	S1	2, 156	S1	2, 374	S1	2, 722	S1
Relative Humidity (%)	82	S2	82	S2	82	S2	82	S2	82	S2
Class		**S2**		**S2**		**S2**		**S2**		**S2**
OVER-ALL CLASS	**S3tsc**		**S3wsc**		**S3tfc**		**S3wc**		**S3wfc**	

Table 2. Soil Constraints of Major Soil Series for Sugarcane Production in Negros Occidental

	Constraints to Crop Production				
Soil Series	**Topography**	**Wetness**	**Physical Soil Characteristics**	**Soil Fertility Characteristics**	**Climate**
Guimbalaon	The topography is rolling to hilly with 18 – 25 % slope.	-	There is the presence of outcrops and pebbles; and the effective rooting depth is shallow (0.5 m).	-	Relative humidity is more than the crop requirement.
Isabela	-	Seasonal flooding occurs with poor to moderate drainage.	The sandy loam soil texture is just moderately suitable for the crop.	-	Relative humidity is more than the crop requirement.
Luisiana	The topography is rolling to mountainous with 18 – 40 % slope.		-	Low base saturation and soil pH.	Relative humidity is more than the crop requirement.
San Manuel	-	Seasonal flooding occurs.		-	Relative humidity is more than the crop requirement.
Silay	-	Seasonal flooding occurs with poor to moderate drainage.	-	Low organic carbon content.	Relative humidity is more than the crop requirement.

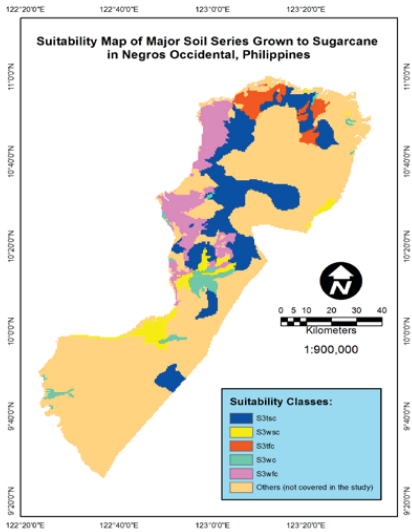

Figure 1. Suitability Map of Major Soil Series Grown to Sugarcane in Negros

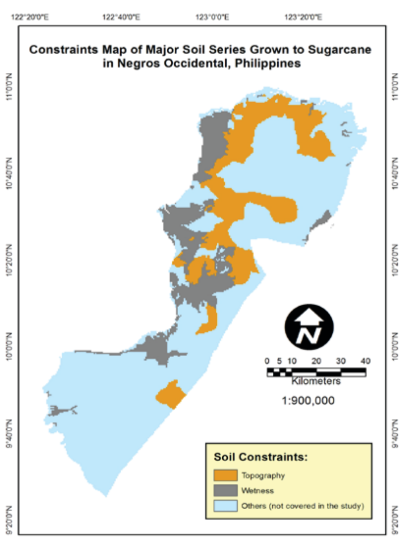

Figure 2. Constraints Map of Major Soil Series Grown to Sugarcane in Negros Occidental

Table 3. Soil Management Recommendations for Sugarcane Grown in Guimbalaon Soil Series

Soil Series	Soil Constraints	Soil Management Recommendations				
		Topography	Wetness	Physical Soil Characteristics	Soil Fertility	Climate
Guimbalaon	topography; presence of outcrops and pebbles; shallow rooting depth; high RH	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.

Table 4. Soil Management Recommendations for Sugarcane Grown in Isabela Soil Series

Soil Series	Soil Constraints	Soil Management Recommendations				
		Topography	Wetness	Physical Soil Characteristics	Soil Fertility Characteristics	Climate
Isabela	seasonal flooding occurrence; poor to moderate drainage; sandy loam texture; high RH	-	• Raise and elevate the height of the soil in the site by adding 10-12 inches of well-drained topsoil, compost, or other organic matter to raise the planting zone. Till and/or incorporate 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 micropores 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 the burning of trashes.	-	Climate concerns were addressed by scheduling of farm activities.

Table 5. Soil Management Recommendations for Sugarcane Grown in Luisiana Soil Series

		Soil Management Recommendations				
Soil Series	Soil Constraints	Topography	Wetness	Physical Soil Characteristics	Soil Fertility Characteristics	Climate
Luisiana	topography; low base saturation and pH	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	-	-	• 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.

Table 6. Soil Management Recommendations for Sugarcane Grown in San Manuel Soil Series

Soil Series	Soil Constraints	Soil Management Recommendations				
		Topography	Wetness	Physical Soil Characteristics	Soil Fertility Characteristics	Climate
San Manuel	seasonal flooding	-	• Raise and elevate the height of the soil by adding 10-12 inches of well-drained topsoil, compost, or other organic matter to raise the planting zone. Till and/or incorporate 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.

Table 7. Soil Management Recommendations for Sugarcane Grown in Silay Soil Series

Soil Series	Soil Constraints	Soil Management Recommendations				
		Topography	Wetness	Physical Soil Characteristics	Soil Fertility Characteristics	Climate
Silay	seasonal flooding occurrence; poor to moderate drainage; low organic carbon content; high RH	-	• Raise and elevate the height of the soil by adding 10-12 inches of well-drained topsoil, compost, or other organic matter to raise the planting zone. Till and/or incorporate 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 micropores 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 the burning of trashes	Climate concerns were addressed by scheduling of farm activities.

Socio-Demographic Profile of Sugarcane Farmers

Sugarcane is mostly grown and cultivated in different areas in Negros Occidental by the elderly male farmer with the mean ages of 45, 65, and 75 years old respectively. Most of the sugarcane farmers were married having 3 – 4 children and acting as the head of the family. At the same time, the parents were mostly involved in the growing and cultivation of sugarcane. Most of them were high school graduates and did farming while very few of them were employed by either government or private agencies or companies. Most of them stayed in the community for an average of 55 years while others at 35 hence, their lives were mostly devoted to sugarcane farming where they get their source of income to support their own families especially on food and health allocation. Most sugarcane farmers had a farm size between 1.6 – 2.0 hectares and preferred to cultivate 524 - sugarcane variety.

Management/Cultural Practices of the Sugarcane Farmers

Thirty-six percent (36%) of the respondents owned the land they cultivate for sugarcane production while the other sixty-four percent (64%) were tenants, lessee, and/or an association that do profit sharing. Most of the sugarcane farmers that own their land cultivate their fields for not more than five (5) years, however, few of them cultivated it for a longer time already between 21 – 25 years. Monocropping and crop rotation were the cropping system practiced by sugarcane farmers where the former was mostly practiced by many using sugarcane plant, and the latter was practiced by few using alternate sugarcane and rice crops hence, rice was the only crop planted in the field aside from sugarcane. There are sugarcane farmers who previously applied pesticides particularly herbicides and/or weedicides which was mostly applied and others use rodenticides, insecticides, or a combination of those pesticides to minimize and eliminate pest in their fields. However, there were also few farmers who did not apply. Moreover, a lime application was also previously applied in their fields by few sugarcane farmers while seventy-six percent (76%) of the respondents were not adding lime to their soil. Burning of trashes was mostly done by farmers, however; very few of them practiced the filing of those trashes in the fields while few also claimed of using both practices to manage their crop residues.

Mechanization has had a major impact on the demand and supply for farm labor; the profitability of farming; and the change in the rural landscape, including rural communities, however, in some parts of the world, agriculture is still highly labor intensive (Schmitz and Moss, 2016). Sugarcane production is said to be labor intensive. Results of this study reveal that sugarcane production in Negros Occidental is least mechanized and that human or manual labor is highly practiced. Labor intensity measured in man-days/ha for land preparation involving plowing, harrowing, and furrowing requires 1 – 2 persons; 7 – 9 for planting; 3 – 4 for fertilizer application who mostly applied urea, potash, and diammonium phosphate; 5 – 6 for weeding;1 – 2 for pesticide application; and 9 – 10 for harvesting. However, for irrigation, most sugarcane farmers relied on rain-fed irrigation while for those who have machine operated irrigation needs 3 – 4 persons to do the work. Notwithstanding, respondents also claimed that no diseases were observed during the growing period of the crop hence, no labor was needed for disease control. This is related to the previously discussed constraint on relative humidity wherein too high of RH may cause diseases, however; farmers have addressed the said limitations through scheduling of farm activities.

Sugarcane Yield Production of Farmers

Sugarcane yield obtained by most farmers' ranges from 51–100 ton-canes per hectares at plant cane and received almost the same amount of yield during first and second ratoon and gained mostly aLkg per ton canes of 101 – 150. Also, most of the farmers have a picul sugar per ton-cane of about 1.6 – 2.0.

Sugarcane Production Profitability: Net Income, Return on Investment, Benefit Cost Ratio

Obtaining high yield production will always be the target and aim of all farmers. However, some barriers exist in achieving this objective. These barriers include diminishing areas of arable land, declining soil fertility, high fertilizer costs, lack of capital for purchasing fertilizer inputs and lack of grower expertise in soil management and crop agronomy. Hence, production is linked with soil management. Knowledge of soil classification and understanding the behavior and characteristics of the soil is a great tool for a proper and appropriate management of the soils in attaining a high yield crop production.

It has been previously discussed the constraints or limitations of major soil series for sugarcane production (table 2) which were not addressed by farmers in their management. Thus, recommendations were made to address those limitations (tables 3-7).

Tables 8-12 present the production cost and income of sugarcane farmers using their existing management and compare it to the production cost and income to be gained using the recommended management and/or strategy by addressing the constraints or limitations of each soil series. Results revealed that a higher income would be obtained if possible all the limitations/constraints will be addressed and recommendations will be practiced consequently obtaining a higher return on investment (ROI) and benefit-cost ratio. Each soil series (Guimbalaon, Isabela, Luisiana, San Manuel, and Silay) have different net income, ROI, and benefit-cost ratio wherein Silay series showed the highest value and Isabela series has the lowest value. Higher ROI and benefit-cost ratio means that the production is profitable. Likely, it was emphasized that for every cost of a peso, there is a corresponding equivalent value of a benefit-cost ratio to be gained. The variation in net income, ROI, and benefit-cost ratio that were observed across soil series is due to the different soil characteristics possessed by each soil that was located at different topography or slopes hence have varied constraints or limitations for sugarcane production. Thus, proper and appropriate soil management should be determined, applied, and practiced.

Table 8. Production and Net Income of Sugarcane Grown to Guimbalaon Soil Series

Particulars	Farmer's Existing Management (Php)	Soil Management Recommendations (based on constraints) (Php)
Total Production Costs	98,936.10	103,976.20
Gross Income	123,252.58	135,597.63
Net Income	24,316.48	31,621.43
Return on Investment (ROI)	24.58	30.41
Benefit-Cost Ratio	1.25	1.30

Table 9. Production and Net Income of Sugarcane Grown to Isabela Soil Series

Particulars	Farmer's Existing Management (Php)	Soil Management Recommendations (based on constraints) (Php)
Total Production Costs	79,853.30	89,933.20
Gross Income	89,214.05	148,901.25
Net Income	9,360.75	58,968.05
Return on Investment (ROI)	11.72	65.57
Benefit-Cost Ratio	1.12	1.66

Table10. Production and Net Income of Sugarcane Grown to Luisiana Soil Series

Particulars	Farmer's Existing Management (Php)	Soil Management Recommendations (based on constraints) (Php)
Total Production Costs	69,098.88	93,977.78
Gross Income	91,794.36	128,525.30
Net Income	22,695.48	34,547.52
Return on Investment (ROI)	32.84	36.76
Benefit-Cost Ratio	1.33	1.37

Table11. Production and Net Income of Sugarcane Grown to San Manuel Soil Series

Particulars	Farmer's Existing Management (Php)	Soil Management Recommendations (based on constraints) (Php)
Total Production Costs	90,847.88	95,102.08
Gross Income	136,630.57	150,274.83
Net Income	45,782.69	55,172.75
Return on Investment (ROI)	50.39	58.01
Benefit-Cost Ratio	1.50	1.58

Table12. Production and Net Income of Sugarcane Grown to Silay Soil Series

Particulars	Farmer's Existing Management (Php)	Soil Management Recommendations (based on constraints) (Php)
Total Production Costs	83,346.70	93,963.95
Gross Income	154,570.66	193,213.33
Net Income	71,223.96	99,249.38
Return on Investment (ROI)	85.46	105.62
Benefit-Cost Ratio	1.85	2.06

CONCLUSIONS

Guimbalaon, Isabela, Luisiana, San Manuel, and Silay soil series were classified as marginally suitable (S3) for sugarcane production although, soil constraints varied across soil series. Topography and wetness became the severe constraints for most of the soils, however, the limitation for fertility and physical soil characteristics were considered moderate and manageable. Hence, soil management recommendations for these constraints were suggested. Guimbalaon and Luisiana soil series having constraint on topography were suggested to implement an appropriate soil conservation cropping and tillage practices such as contour terracing or farming while problems on wetness in Isabela, San Manuel, and Silay series were recommended to raise and elevate the height of the soil by adding 10-12 inches 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 may collect water.

Socio-economic data on sugarcane production in Negros Occidental reveals that the cultivation was done mostly by elderly married male farmers who were high school graduates. The irrigation patterns were in a rainfed system and monocropping pattern with high labor and capital intensity. A sugarcane yield of 51 – 100 ton canes per hectares was obtained by most farmers. Human labor was used for most of the farming operations. Existing management practices of farmers like monocropping, burning of trashes, and intensive and inappropriate use of inputs such as fertilizers and pesticides may either affect soil physical, chemical, and biological properties. Thus, appropriate and adaptable management practices should be carried out to increase sugarcane production. Furthermore, Guimbalaon, Isabela, Luisiana, San Manuel, and Silay have different net income, ROI, and benefit-cost ratio wherein Silay series showed the highest value of production while Isabela series was the least profitable. This may be due to the different characteristics across soil series which cause to have varied soil constraints, or limitations for sugarcane production hence, appropriate soil management should be done.

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