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APPLICATION OF ANALYTICAL HIERARCHY PROCESS (AHP) IN GENERATING LAND SUITABILITY INDEX (LSI) FOR SUGARCANE IN CENTRAL MINDANAO, PHILIPPINES

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ABSTRACT

Sugarcane is one of the most promising industry in the Philippines and planted in any land in the country, particularly in Central Mindanao without prior assessment of the land to the crop. Application of an enormous amount of inputs to ensure better production is among common practice even in unsuitable areas. Generation of Land Suitability Index (LSI) in Central Mindanao as a major sugar cane district of Bukidnon province was made to identify the major factor that affects to sugarcane production, using Analytical Hierarchy Process (AHP) and GIS. The study was conducted last September 2015 to February 2016 on the 3rd district of Bukidnon. Weights of six performance factors in determining LSI to sugarcane production were established using AHP. Soil depth was the most important among the factors. Utilizing the LSI, land sugarcane suitability maps were generated for the Central Mindanao. The results matched the validation by comparing the results with the actual yields from sugarcane growers, correlation analysis and other relevant data from the Regional Sugar Regulatory Authority. Soil water holding capacity has a significant positive effect on the sugarcane yield while elevation and slope have significant negative effects. Don Carlos, Maramag and Quezon that are extensive sugarcane growing municipalities are highly suitable in the study and actual conditions.

Key words: land evaluation, GIS, Bukidnon, *Saccharum officinarum*, land assessment,

INTRODUCTION

Sugarcane, *Saccharum officinarum L.*, is a strongly growing grass and one of the most promising industry in the Philippines that generates 765 billion annually for the government in the form of tax (National Wages and Productivity Commission, 2014) and helping to not less than 62,000 farmers on their livelihood. The sugarcane production in all uses increased by 14.4 percent last quarter of year 2015 from its production level of 6.29 million metric tons during the same period last year to its current level of 7.19 million metric tons (PSA, 2017b). Sugarcane covers around 422,384 ha of the country's land area (SRA 2014) and about 17% is in Bukidnon (70, 863 ha) that mostly planted in Central part of the province and as one of the fast-growing area in Mindanao of the crop. In Bukidnon province, almost 200,000 ha of its land area is utilized for agricultural crops and 31 % is planted with sugarcane (PSA, 2017a). Central Mindanao has favorable environmental condition for growth in terms of temperature, radiation and precipitation or rainfed condition that match the sugarcane physiological requirements. It is classified as Type IV climate, characterized as no dry season (PAG-ASA/DOST, 2015). This high dependence on rainfed production highlights the importance of the weather on sugarcane production. Land productivity in areas suitable for rainfed sugarcane production is typically much higher than for cultivated land in cooler climates or arid sub-tropical and tropical agriculture (Fischer et al. 2007).

Principal climatic components that control sugar cane growth, yield and quality are temperature, light and moisture availability (Tu Khao, 2007). The study of Deressa et al., (2005) reveals that ripening stage requires low temperature levels to allow for sucrose accumulation. Sugar recovery is highest when the weather is dry with low humidity; bright sun shine hours, cooler nights with wide diurnal variations and very little rainfall during ripening period (Tu Khao, 2007). However, there is a diversity of cultural management practices without proper assessment of the land. Most of the sugarcane planters established and even expanded their farms regardless of the characteristics of the soil and land. Hence, some of the areas may not be suitable and farmers are compelled in applying high inputs to ensure good production. This will have implications on the competitiveness of the country's sugar. Moreover, farmers do not have desirable land indicators in sugarcane productions.

Generation of Land Suitability Index (LSI) of sugarcane locally and crop diversification is a way to address this problem. However, crop diversification is not usually practiced by the sugarcane farmers because they still consider sugarcane as the most profitable crop. Thus, local LSI is necessary to guide the most influential factors to obtain the optimum productivity. Considering the potential and suitability of these areas are necessary to avoid problems such as land misuse, environmental problems and increase indebtedness (Paiboonsak and Mongkolsawat, 2007). According to Perveen and Nagasawa (2006), land suitability evaluation provides general alternatives for local farmers in the area of agricultural land management of a particular crop. In most of the land suitability studies, the different factors are weighted of equal importance, but, some factors may be more important than the others. It is imperative that farmers could identify vital factors that affect the sugarcane production of their farms. This study attempts to determine the relative importance of the different factors of land suitability to sugarcane using the Analytical Hierarchy Process (AHP) and determine the influence of different factors to the yield of sugarcane growing areas.

MATERIALS AND METHODS

Study Area. The study was conducted in the 3rd District of Bukidnon Province, Philippines the most extensive sugarcane growing district of the province, covering an area of approximately 204,000 ha. The third district has a topography of flat, rolling and steep areas. It covers 8 municipalities: Damulog, Dangcagan, Don Carlos, Kadingilan, Kibawe, Kitaotao, Maramag and Quezon (Fig.1A) of which, 54 sampling locations (Fig.1B) were determined based on the soil series across the study site. The eastern part of the district is mostly very steep areas, particularly portions of the municipalities of Quezon and Kitaotao. The highest elevation is 1,660 m above sea level (masl) and the lowest point is 38 masl. The District has Type IV climate, characterized as having no dry season (PAG-ASA/DOST, 2015). The annual average monthly rainfall distribution from 2006-2011 was 241.68 mm. The rainy season lasts from March to October with rainfall generally more than 200 mm. The dry season has a mean monthly rainfall of generally 7.1 to 150.0 mm (www.buk.gov.ph, 2016).

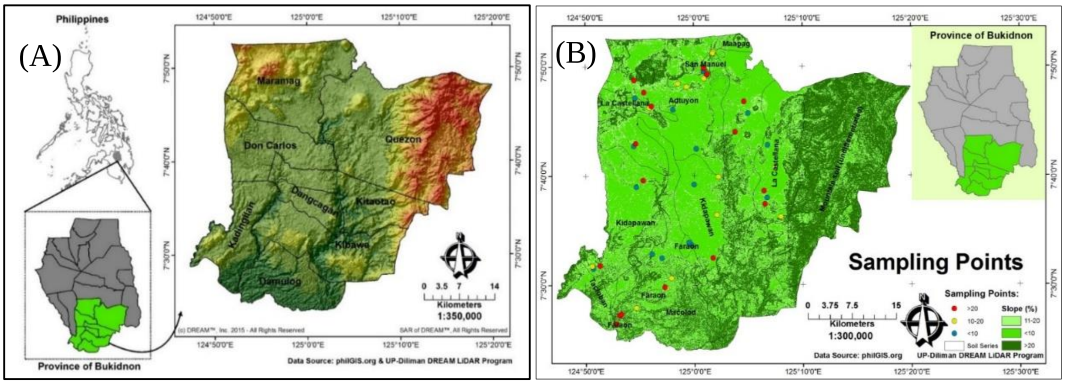

Fig. 1. (A) Administrative map and (B) sampling location of the study.

Implementation of analytical hierarchy process (AHP) in land suitability assessment. The AHP method enables users to determine the weights of the parameters in the solution of a multi-criteria problem (Akinci et al., 2013) and used as to determine consistent sets of estimates of relative weights and criteria from an expert (Saaty, 1980). AHP allows the participation of different groups or persons (considered as experts) but available literature does not recommend a specific number of respondents for AHP applications (Chavez et al, 2012). The foremost reason for using AHP was the collection of ideas from different stakeholders of sugarcane production in identifying the weights of different factors of production. Two groups of sugarcane suitability evaluators were organized, consisting of five experts from the sugarcane industry and academe and ten experienced sugarcane farmers. Each expert makes a judgement of relative weights (w_i) of all pairs of the n factors and these judgements are included in as a number (a_{ij}) in a square matrix A (*i.e.* the comparison matrix):

$$A = (a_{ij}), (i,j = 1,2, \ldots \qquad \text{(eq. 1)}$$

To ensure that the evaluators fully understand the factors considered, each factor was discussed with the participants prior to the assessment. As structured in Fig 2, the goal of the study was to generate Land Suitability of Sugarcane in six criteria. The criteria were the performance factors of sugarcane production with sub-criteria in each performance factor and the alternatives were the summation of criteria based on the value obtained from the sub-criteria. There were six criteria: soil depth (m), water holding capacity (WHC) (%), slope orientation, soil texture, slope (%) and elevation (m). These criteria were the factors that affect the main goal of the study and used as weights of different factors for sugarcane production.

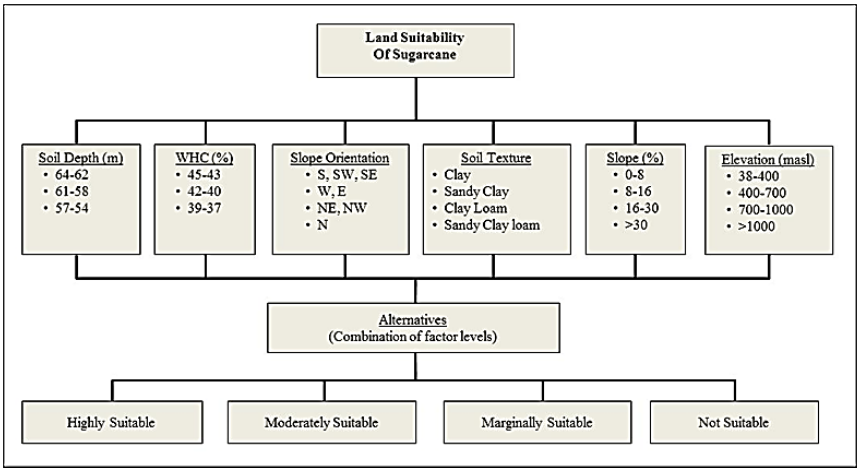

Fig. 2. Structure of elements, criteria, sub-criteria and alternatives in the application of AHP in determining land suitability to sugarcane.

Pairwise comparison of elements in each group was made, weighting and consistency ratios were calculated. To perform the pairwise comparisons, a scale of numbers was needed. Evaluators were asked to rate the different criteria affecting suitable land for sugarcane production. This scale indicates the dominance of one element among element with respect to the criteria on which they are compared (Saaty, 2008). The Saaty's scale, which was a scale from 1 (equally important) to 9 (extremely more important) was used for comparisons (Saaty, 2008). First level comparison has an associated eigenvector with the maximum eigenvalue. The normalized eigenvector gives the priority ordering and the maximum eigenvalue was a measure of the consistency of the judgment. The eigenvector was calculated using the following condition:

$$AW = \lambda_{max} w \qquad (2)$$

where A was the comparison matrix, W was the eigenvector and λ_{max} was the maximum eigenvalue, which was used to estimate the consistency of the result. A positive reciprocal matrix like matrix A was fully consistent when λ_{max} was equal to n (Saaty, 1980). The closer λ_{max} was to n, the more consistent was the judgement. The deviation from consistency was called the consistency index (CI) and is represented by:

$$CI = \frac{\lambda \max - n}{n-1} \quad (3)$$

The estimated consistency was compared with the consistency value from a randomly generated reciprocal matrix, which was called the random index (RI). The Consistency Ratio (CR) relates the CI to the average RI for the same order matrix (fixed value):

$$CR = CI / RI \quad (4)$$

Alternatives were evaluated according to the weighting and ranking of the factors was made. After the analysis, the consolidated weight values were used for weighing the factors for sugarcane suitability. Consistency of giving weight values was guided by Consistency Ratio (CR), which measures the consistency of the judgements made. If the $CR \leq 0.10$ then the consistency was acceptable (Saaty, 1980). When a $CR > 0.10$ was detected, the respondent was asked to reconsider changing her/his more problematic judgments. The evaluators' responses were entered and calculated into an existing excel program developed by Goepel (2013). The results of the evaluation were grouped into three to determine which rating group was better. The three rating groups were: (1) the Experts, coming from the academic and research institutions involved in sugarcane; (2) the Farmers, who were experienced sugarcane farmers; and (3) the Combined Groups, which was the combination of the Experts and Farmer groups. The study opted to modify the inputs of decision maker, although the study of Franek & Kresta (2014) suggested that the inconsistency of the matrix inputs can be amended by checking relationships among the criteria and to find out the pairwise comparison that was not consistent with others in terms of chain of preferences. Revisions of several inputs was not practicable (Goepel, 2013). Moreover, according to the study of Goepel (2013), the distribution of CR values for all (80) participants in his projects, the median value is CR = 0.16, 80^{th} percentile is at CR = 0.36. The ten-percent rule was obviously too strict for the practical applications and would have resulted in rejection and revision of most questionnaires.

Measurement of the Factors Affecting the Sugarcane Production

Soil depth determination. Determination of soil depth was done using post-hole soil auger (Fig. 3) for three weeks, the method was considered fast and easy. The soil depths were measured on identified sampling site. Sampling site was identified using slope map, sugarcane profile report of SRA and satellite image of google earth. The auger was marked every 15 cm from the end of the auger with a maximum of 100cm. For every 15 cm depth, soil samples were collected and driven further until the auger cannot penetrate anymore. The collected samples were laid continuously in a white broad sheet according to the depths that they were taken. For a more accurate measurement, a meter stick was used to measure the entire profile through the sampling hole. Soil samples were categorized in three (3) slope percentage (0- 10%, 11-20% and >20%) and replicated three (3) times. Though there were nine (9) soil series identified in the study site, only six (6) soil series planted with significant area of sugarcane. Fifty-four (54) soil samples were collected across the six (6) soil series. Among the soil series considered for sampling were Adtuyon, La Castellana, Macolod, Kidapawan, Faraon and San Manuel.

Water holding capacity and soil texture determination. Soil sampling was performed for the analysis of WHC and soil texture determination. Top soil samples were collected from the sampling sites, then air dried for one (1) week. Dried soil samples were pulverized using wooden mallet and sieved with 2mm sieve. Samples were then sent to Soil and Plant Analysis Laboratory (SPAL) in Central Mindanao University, Musuan, Bukidnon for the determination of soil texture and water holding capacity.

Fig. 3. Soil sampling for depth determination.

Geographic characterization. Geographic characteristics for optimum sugarcane production such as elevation, slope and slope orientation were extracted and determined using the Synthetic Aperture Radar-Digital Elevation Model (SAR-DEM) (UP-DREAM Project, 2015) with a pixel resolution of $10m^2$. Geographic characteristics were categorically classified based on sugarcane suitability level for certain geographic property.

Application of N, P_2O_5 and K_2O containing fertilizers. Essential nutrients such as N, P_2O_5 and K_2O containing fertilizers applied by farmers in synthetic form. Famers were interviewed regarding the amount of applied fertilizers, recorded and analyzed.

Land suitability evaluation. A database of the six factors in land suitability was created. These were: topography (slope), slope orientation, elevation, soil texture, water-holding capacity of soil and soil depth. The weights of each criteria were obtained using AHP and with the help of Multi Criteria Evaluation (MCE) procedure and with the weighted sum overlay within ArcGIS 10.2.2 to produce the land suitability map for sugarcane with spatial resolution of $10m^2$. The cultural practices of the farmers such as fertilizer application, weed management, land preparation and others were not considered since these factors largely vary between sugarcane farms and will make the suitability analysis complicated. Farmers' farm operations are not synchronized within the entire District. Since the area belongs to the same climate (Corona Classification), the study did not include the climate that could affect the sugarcane production. Each factor in the land suitability were standardized based on the results of AHP analysis and will form six thematic layers according to the groups of evaluators (Table 1). Each member of the group has weighted factors to the average of every criteria for land suitability. Hence, there were three groups that generates different map of land suitability.

Geographical characteristics categorically classified based on sugarcane suitability levels while mapping of the soil physical factors were interpolated based on the result of analysis. Interpolation is the process of obtaining a value for a variable of interest at a location where data has not been observed, using data from locations where data has been collected (Krivoruchko 2012). Interpolation of the data was made using Kriging model in ArcGIS 10.2.2. Kriging predictors have standard errors that quantify the uncertainty associated with the predicted values. Kriging uses a semi variogram – a function of the distance and direction separating two locations - to quantify the spatial dependence in the data (Krivoruchko 2012).

The author classified the factors for suitability of sugarcane production according to their characteristics as not easily alterable such as the identified six physical factors. The degree of suitability of each factor for each land unit studied was classified as Highly suitable (S1), Moderately suitable (S2), Marginally suitable (S3), and Not suitable (N) based on the classification of Sys et al (1993). Three suitability maps were generated based on different groups of suitability evaluators. The suitability maps were validated by comparing with the actual sugarcane yields, results of the correlation analysis and other relevant data. The suitability map that was consistent with the actual yields and correlation analysis was considered the most suitable.

Table 1. Classification of sub-factors based on their particular factors.

Factors	Sub-factors	Classification
Soil Depth, m	64-62	Highly Suitable
	61-58	Moderately Suitable
	57-54	Marginally Suitable
WHC	45-53	Highly Suitable
	42-40	Moderately Suitable
	39-37	Marginally Suitable
Slope Orientation	S, SW, E	Highly Suitable
	W, E	Moderately Suitable
	NE, NW	Marginally Suitable
	N	Not Suitable
Soil Texture	Clay	Highly Suitable
	Sandy Clay	Moderately Suitable
	Clay Loam	Marginally Suitable
	Sandy clay Loam	Not Suitable
Topography/slope, %	0-8	Highly Suitable
	8-16	Moderately Suitable
	16-30	Marginally Suitable
	>30	Not Suitable
Elevation	38-400	Highly Suitable
	400-700	Moderately Suitable
	700-1000	Marginally Suitable
	>1000	Not Suitable

Socio-economic survey of sugarcane farmers. A socioeconomic survey was conducted among sugarcane farmers to characterized and validate the degree of suitability of sugarcane growing areas by comparing with farmers' sugarcane yields. A stratified sampling of the farmers was made based on the extent of sugarcane growing area. From the eight (8) sugarcane growing municipalities of the third District, three (3) municipalities having extensive sugarcane area were selected, namely: Maramag, Don Carlos and Quezon. From the three municipalities, the barangays with large sugarcane areas were randomly selected from where the survey respondents were randomly selected. Sample size of the survey was determined using the Sloven's formula below. From the total population, 191 farmer respondents were selected, which is only 50% of the total sample size.

$$Sample\ Size = \frac{\frac{z^2 x\, p(1-p)}{e^2}}{1 + (\frac{z^2 x\, p(1-p)}{e^2 N})}$$

Where:

Z = sample size

p = the percentage picking a choice, expressed as decimal

c = confidence interval, expressed as decimal

The respondents were asked on their cultural practices and the yield performance of sugarcane. Farmer's farm geographic coordinates were also collected using the global positioning system (GPS) receiver device.

RESULTS AND DISCUSSIONS

Weighing of LSI performance factors using AHP. Among the 3 suitability evaluator groups, the Combined Groups has the least inconsistent value (1.6%) followed by the Farmers (2.5%) and the Experts (5.2%). Generally, the CR value decreases as the number of participant increases. Nevertheless, the CR values of three groups were still within the Saaty's rule of thumb on acceptable consistency ratio of <0.10 (Goepel, 2013). The ranking of the importance of the factors varied with the evaluator groups. However, soil depth (Rank 1) was consistently considered as the most important factor by all suitability evaluator groups. This may be related to sugarcane root penetration and ease in land preparation with the use of farm machineries in which approximately 75% of farmers used machineries. Generally, soil depth is one of the factors that most affected in heavy practice of machineries in sugarcane production (Foth, 1951) and reduced the soil permeability (Soane and Van Ouwerkerk, 2013). Meanwhile, the least important factor varied between the Expert and the Farmer but if Combined Groups to be considered, the least important factor was elevation. The least important factor in determining suitability of sugarcane production for Experts was elevation and slope orientation for farmers. According to farmers, using compass during planting was never their considerations. Nevertheless, the study of Bennie et al. (2008) showed the influence of slope orientation to the amount of solar radiation intercepted by the surface and vegetated surface while the study of Akinci et al. (2013) showed the importance of elevation as factor that influences due to the differences in temperature. The sun's energy is more concentrated on the Northern Hemisphere where its rays hit the Earth more directly and are thus more intense (Mclamb, 2011). Table 2 shows the percentage and ranking of factors of three groups.

Table 2. Percentage rank of LSI factors under different set of groups who evaluated the suitability to planting of sugarcane.

LSI FACTORS	Experts		Farmers		Combined Groups	
	%	Rank	%	Rank	%	Rank
Soil Depth	28.6	1	25.6	1	26.7	1
Water Holding Capacity	20.7	2	17.9	3	19.4	2
Slope Orientation	16.4	3	9.4	6	11.7	5
Soil Texture	16.0	4	12.6	5	14.1	4
Slope	10.2	5	20.6	2	16.5	3
Elevation	8.1	6	13.9	4	11.6	6

The system was based primarily on an integration of land qualities as related to crop requirements. The method was usually implemented using the pairwise comparison technique that simplifies preference ratings among decision criteria (Tienwong et al. 2009). After the land suitability map was generated, the best suited key factor for the suitability was used and become the basis for further discussions. Farmer's suitability assessment was the best among the three evaluators as this group were able to identify clearly the land classification of the studied areas.

Land suitability to sugarcane. Using the LSI evaluation results, three sugarcane suitability maps were generated from the Experts, Farmers and Combined Groups (Fig. 4) that generates three classification on the suitability. Relatively, result shown that none of the area in the district was not suitable for sugarcane production. The Experts' suitability map has the largest highly suitable areas with the least marginally suitable areas and the second highest moderately suitable areas. The farmers' suitability map has the second highest highly suitable areas with the least moderately suitable areas. The Combined Groups suitability map has the highest moderately suitable areas. In all the suitability maps generated, most of the highly suitable areas were in the western portion of the district covering almost all of Don Carlos, Dangcagan, northern portions of Kibawe and Kadingilan, southern portion of Maramag, and western portion of Kitaotao. Other highly suitable areas were dispersed in Quezon, Kitaotao, and Damulog. Most of the marginally suitable areas were in the eastern part of the district covering certain portions of Quezon and Kitaotao, of which were the areas with very steep slopes and are obviously not suitable for sugarcane production. Other marginally suitable areas can also be seen in Maramag, Kadingilan and Damulog.

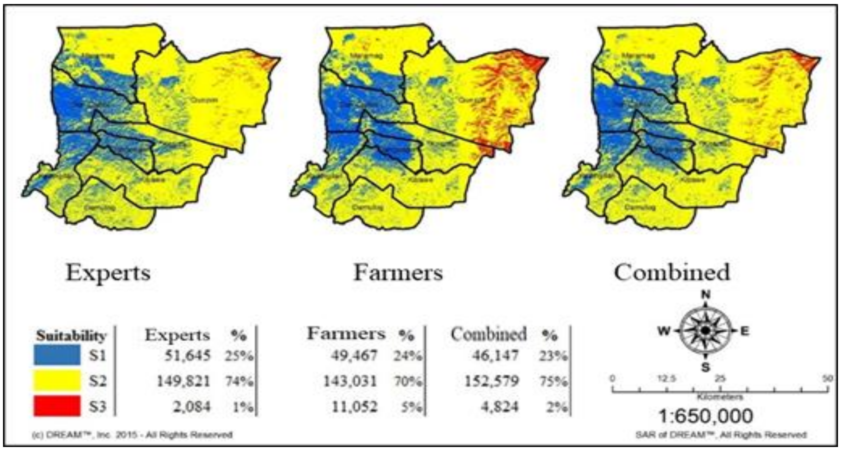

Fig. 4. Land suitability to sugarcane maps generated from AHP for the 3 different evaluator groups.

Quantitatively, the map generated from the Experts has the largest area (25%) identified as highly suitable followed by the Farmers and the Combined Groups with 24% and 23%, respectively. In contrast, the Combined Groups has the largest area (75%) identified under moderately suitable areas over the Experts and Farmers with 75% and 70%, respectively. On the other hand, the map for the Farmers has the largest (5%) area of marginally suitable for sugarcane production while the map with the least (1%) identified marginally suitable areas was from the Experts.

Validation of the land suitability assessments. The three suitability assessments were validated by comparing the results with the actual sugarcane yields obtained from the socio-economic survey and the correlation analysis. Sugarcane yields obtained from farm samples were grouped according to their suitability classes for the 3 suitability evaluator groups. Comparison of yield levels between suitability classes showed consistent yield trends corresponding to the suitability classes for all evaluator groups (Table 3). Highest yields came from the highly suitable areas, followed by moderately suitable and marginally suitable having the lowest yield. Meanwhile, classification for not suitable area (N) was not included in this analysis as there is no areas covered that falls under N classification. Further, this indicates the applicability of AHP in sugarcane suitability assessment. The results of the correlation analysis shown that most of the important factors identified from AHP application, *i.e.* elevation, slope, and water holding capacity have significant influence on sugarcane yield. While soil depth, which was identified as an important factor in the AHP application, has no significant influence on yield in the correlation analysis (Table 4). Although the 3 evaluators have identified soil depth as a very important factor since sugarcane is deep rooted crop and necessary for its cultivation using heavy machinery, soil depth data obtained from the sample farms have similar values, hence, may not be considered a variable in the locality and need not be included in the evaluation.

Table 3. Mean sugarcane yields (t/ha^{-1}) under different sugarcane suitability classes for the different evaluator groups. 3rd District, Bukidnon.

Evaluator Groups	Suitability Classes		
	Highly	**Moderately**	**Marginal**
Experts	59.60	54.02	-
Farmers	59.48	54.30	50.87
Combined Groups	59.10	54.57	-

Table 4. Descriptive statistics of significant factors affecting yield of sugarcane.

Variable	Correlation Coefficient	Mean^n	SD
N kg ha^{-1}	0.39*	137.96	54.00
P_2O_5 kg ha^{-1}	0.29*	38.69	31.57
K_2O kg ha^{-1}	0.39*	26.74	32.30
Elevation	-0.14*	398.12	128.77
Slope	-0.15*	8.87	7.78
WHC	0.17*	41.74	1.63
Slope Orientation	-0.01^{ns}	175.90	96.81
Soil Depth	-0.13^{ns}	59.65	1.56
Soil Texture	-0.11^{ns}	1.27	0.84

n = 191, * = significant, ns = not significant

Improving sugarcane production under high suitable areas. Some highly suitable areas identified in the suitability assessment have lower yields compared with those in the moderately suitable areas. This could be attributed to the exclusion of other factors, which are important in sugarcane production. One of these was fertilizer application. Survey results showed high variability in fertilizer application among the farmer respondents. None of them followed the recommended fertilizer rate with many applying more N than the recommended rate and less P and K levels. Following the recommended rate might be essential in achieving optimum yield. Fertilizer application, which was not included in the AHP application was significantly correlated with sugarcane yield particularly N and K application, having correlation coefficient values of 0.39 and 0.39, respectively. Farmers' average fertilizer application of 138-39-27 kg NPK ha^{-1} was low compared to the recommended rate of 128-92-120 kg NPK ha^{-1} specially for P and K. Literature would show that among the macro elements, N and K is the most needed by sugarcane followed by P (Tu Khao 2007).

Elevation, which was one of the important factors identified in AHP varies with the different areas. Some areas in the central and eastern portion of Quezon have high elevation with lower temperature that is unfavorable elevation for sugarcane. This could be attributed to the fact that at higher altitudes, temperature is cooler and makes sugarcane production period longer before maturity (Deressa *et al*, 2005). Sugarcane grows well where the temperature ranges between 20 and 35 °C. The use of varieties adaptable to high elevation would be essential in improving the yield in these areas. WHC significantly influence the yield of sugarcane but the sugarcane areas in the municipalities of Kadingilan, Kitaotao, Kibawe and Damulog have relatively low WHC than the other municipalities. Zero tillage or minimum tillage of 2:1 or 3:1 row-furrow ratio and retaining trash on the field could help increase WHC in the areas. The steep slope areas in the municipalities of Maramag, Quezon, Kadingilan and Kitaotao, could be susceptible to soil erosion. The practice of zero tillage or contour farming on the sloping areas could help in minimizing soil erosion and improve sugarcane yield.

Applicability of AHP on land suitability. The land suitability maps generated from the 3 evaluator groups showed relatively similar maps on the degree of highly and moderately suitable areas. However, the better suitability assessment was from the farmers' assessment since it clearly identifies obviously the marginally suitable areas. Comparing the generated suitability map with the SRA report, it was found out that the marginally suitable areas are considered not suitable areas and are not planted with sugarcane. While, some areas classified either as moderately or highly suitable areas were not planted with sugarcane as reported by SRA. Thus, this could be attributed to other reasons, one of which is the accessibility. Further, none of the area being studied was classified as not suitable for sugarcane production regardless of other factors. AHP was shown to be applicable in land suitability assessment especially in hilly regions (Pramanik 2016). The suitability map generated from AHP would show the areas' potential performance of sugarcane and can be applied in land use planning (Memarbashi et al 2017) but should be accompanied with good management practices like fertilizer application.

CONCLUSION

The results of the study shown the applicability of AHP in generating LSI to sugarcane production and effectively use for land suitability but with some limitations such as their cultural practices. As indicated in the validation of the results, suitability classes were consistent with the actual yield levels, *i.e.* highly suitable areas have higher actual yields and marginally suitable areas have the lowest actual yields. However, among the LSI performance parameters included, water holding capacity was consistently ranked high in AHP and correlation analysis. Soil depth was ranked high in AHP but not significantly correlated to sugarcane yield. Slope and elevation were correlated with sugarcane yield but was ranked second and fourth in AHP, respectively.

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