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Multicriteria Analysis for Land Suitability Assessment for "Gia Lun" Banana in Nam Dong District, Thua Thien Hue Province, Vietnam

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1. Introduction

"Gia lun" banana (*Musa sapientum* Linn.) is one of the major fruit crop in Nam Dong district, Thua Thien Hue province, Central Vietnam. Currently, the total land area of the home garden in the Nam Dong district is 584 hectares and the average household has 1.200 m^2 with the main crop is "Gia lun" banana (Viet, 2012). However, productivity of "Gia lun" banana was low to compare to those in other regions in Vietnam and other countries. The problem of selecting the suitable land not only for "Gia lun" banana but also for cultivation of a certain type of agriculture production in the district is mainly empirical issue. The considerable constraints facing "Gia lun" banana development in the district included physical conditions and socio-economic factors. This study aims to determine physical land suitability areas for the "Gia lun" banana production by using multi-criteria evaluation, and the GIS technique to achieve optimum utilisation of the available land resources for sustainable agricultural production following framework for land evaluation FAO (1976). In order to facilitate processing for sustainability assessment, geoprocessing models proposed by Long and Böhme (2011) were applied. The models were applied with change of input parameters and set of necessary values to obtain the suitable map for "Gia lun" banana. The results of this study will be brought forward by local land users and administrator who need to have scientific support in order to meet the increased demand for fruit production without enhancing environmental degradation for their decision on the future land use systems in the study area.

2. Research methods

Data Collection

Data set required includes maps of land use, soil types, digital elevation model (DEM) scale 1: 25,000 were collected from Nam Dong cadastral department, with the soil map was classified by the method of FAO/UNESCO. Monthly precipitation, temperature and sunshine were obtained from Nam Dong statistical department as followed the Nam Dong Weather Observation Station. The land use requirements for "Gia lun" banana were adopted Sys *et al*. (1991), (Table 1).

Field works were carried out and workshop was organized to define the score weight of each factor according to AHP (Saaty, 1980). Fifteen participants participated in workshop including agricultural extension,

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experiment farmers, young farmers (include men and women) who have good personal experience in agriculture to obtain data for the weighting factors calculation.

Table 1. Land use requirements for "Gia lun" banana

Land quality	Diagnostic land characteristic	Unit	S1	S2	S3	N
Temperature	Mean annual tem.	^{0}C	18	18-16	16-14	< 14
	Mean annual pre.	mm	> 1500	1500-1250	1250-1000	< 1000
Sufficiency of water	Soil depth	m	>75	75-50	50-25	< 25
	Soil drainage	class	moderate	imperf.	poor	not drainab.
	CEC	(cmol(+)/kg clay)	>16	< 16	-	-
Sufficiency of nutrients	pH		6.4-5.6	5.6-5.2	5.2-4.5	< 4.5
			6.4-7.5	7.5-8.0	8.0-8.2	> 8.2
	OM	%	>1.5	1.5-0.8	< 0.8	-
Topography	Slope	%	0-4	4-8	8-16	> 16

(adopted from Sys *et al*., 1991)

Data analysis

To achieve the objective of the study, multi-criteria evaluations and GIS technique were used to evaluate land suitability as structured in Figure 1. Multi-criteria decision making in GIS approach involves the evaluation of alternative choices based on the criteria for land suitability. Factors or criteria used in land evaluation were standardized with fuzzy method by selecting suitable membership function (MF). With this approach, the attribute values were converted to common membership grades (from 0 to 1.0), according to the class limits specified by crop requirements (Sys, *et al.*, 1991).

According to Baja, *et al.*, (2002), if $MF(x_i)$ represents individual membership value for i^{th} land property x, then, the basic model function take the following form in the computation process:

$$MF(x_i) = [1/(1 + \{(x_i - b)/d\}^2)] \quad (1)$$

where: d = width of transition zone (x at MF = 0.5 or at crossover point); x_i = value of i^{th} land property x; and b = value of land attribute x at the ideal point or standard index.

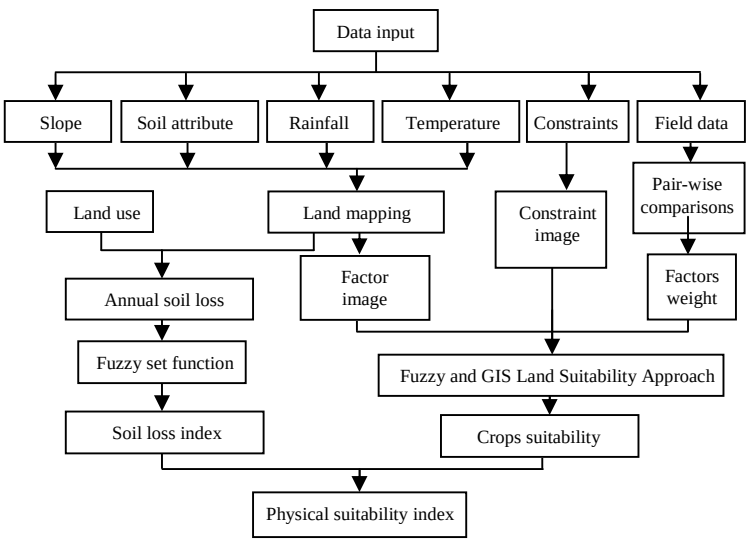

Figure 1: The framework for land suitability assessment implemented in GIS in this study

This approach consists of two basic functions: symmetric and asymmetric. The first function, also called an 'optimum range', distinguishes two variants: one that uses a single ideal point, while the other employs a range of ideal points. The second function, an asymmetric model, is used where only the lower and upper boundary of a class has practical importance. This function consists of two variants: asymmetric left and asymmetric right.

Factors are standardized using fuzzy method by selecting suitable membership function with MF values of individual land characteristics, then combined using a convex combination function to produce a joint membership function (JMF) of all attributes, as follows: (Baja, *et al.*, 2002).

$$JMF(Y) = \sum_{i=1}^{n} W_i MF(x_i) \quad (2)$$

where: W_i = weight factor for the i^{th} land property x; $MF(x_i)$ = membership grade for the i^{th} land property x.

Environment suitability is based on soil erosion index, the soil erosion index were generated by using fuzzy membership based on soil loss tolerance (T-value) was adopted Baja, *et al.,* (2002). The Revised Universal Soil Loss Equation (RUSLE) developed by Renard *et al*. (1997) was used to estimate the annual soil in the study area:

$$A = R \times K \times LS \times C \times P \quad (3)$$

where: A = annual soil loss (t/ha/y); R = rainfall erosivity factor; K = Soil erodibility factor; LS = slope factor (L= slope length, and S = slope steepness); C = land cover management factor; P = conservation practice factor.

The procedure for physical suitability assessment followed the multicriteria evaluation is represented in Figure 1. That model consists of two sub-models: which are crop suitability index model; and soil loss index model. Both were modeled based on fuzzy set methodology in a GIS, and incorporated farmers' perceptions as well as their preferences into the decision-making process by using AHP. And the annual soil loss was defined, and it was standardized. After that crop suitability index and soil loss index was used to determine physical suitability index by using joint membership function with the weight factors. In order to facilitate processing for sustainability assessment, geoprocessing models were used by applying the models that were built by Long and Böhme (2011). All input data were entered and all thresholds were assigned.

The results of physical suitability index based on the fuzzy set methodology in a GIS ranging from 0 (very poor or not suitable) to 1.0 (excellent or highly suitable). The continuous value of physical suitability was classified based on guideline for definitions of classes for each crop according to Dent and Young (1981) and FAO (1983).

3. Results

The weight factor was estimated by pair-wise comparison method (Saaty, 1980) based on a number of land characteristics. After structuring the problem as a hierarchy, workshop was organized and the matrix of pair-wise comparisons was established, checking consistency and ranking the weight of the factors were done. The criteria weights are showed in table 2 and table 3.

Table 2. The weight of criterion for crop suitability

Criterion	Temp.	Rainfall	Depth	Drainage	CEC	pH	OM	Slope
Weight	0.141	0.256	0.141	0.256	0.034	0.02	0.076	0.076

Table 3. The weight of criterion of crop suitability and environmental suitability

Criterion	Crop suitability	Environmental suitability
Weight	0.67	0.33

All geoprocessing models were used to execute the sequence of commands to generate physical suitability map for “Gia lun” banana. The physical suitability map for “Gia lun” banana (Figure 2) showed that 6.26% of total arable area was highly suitable for banana production (1,298.34 ha). 55.64% (11,543.40 ha) and 38.1% (7,903.98 ha) was moderately and marginally suitable, respectively.

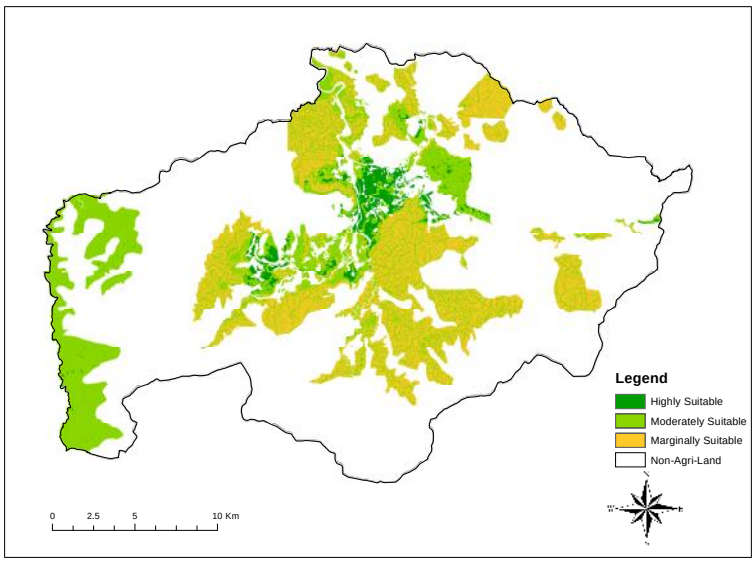

Figure 2. The physical suitability map of "Gia lun" banana in Nam Dong district, Thua Thien Hue province, Vietnam

4. Conclusion

- Geoprocessing models were successfully applied for "Gia lun" banana with highly reliable.
- The physical suitability map of "Gia lun" banana in Nam Dong district, Thua Thien Hue province was done that help local land users and administrator who need to have scientific support for their decision on the future land use systems.

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