MULTICRITERIA LAND SUITABILITY EVALUATION FOR CROPS USING GIS AT COMMUNITY LEVEL IN CENTRAL VIETNAM

With case study in Thuy Bang- Thua Thien Hue province

Huynh Van Chuong

Faculty of Land Resources and Agricultural Environment, Hue University of Agriculture and Forestry (HUAF)
102 Phung Hung Str, Hue, Vietnam, Email: **huynhvanchuong@huaf.edu.vn**
Tel: +84 54 516514, Fax +84 54 524923.

ABSTRACT

This study was to investigate the applicability of the GIS techniques in combination with a multi-criteria approach for analysing the land suitability for certain fruit crops in Thuy Bang commune. At first, the databases for GIS analyses had to be developed. The data were obtained through scientific literature review, expert opinions, interviews, and professional officers. The suitability assessment in the studied area has been done in two ways: physical suitability evaluation and social-economic, environmental suitability evaluation.

On the basis of the established GIS databases, in the Thuy Bang commune with a total investigated area of 2,298ha, 26 land units could be distinguished after overlaying the thematic maps. Firstly, the classification of physical land suitability for citrus trees and mangosteen revealed that there is no area of high-suitability level (S1), the area of medium-suitability level (S2) is 500.48ha for citrus fruits and 105.02ha for mangosteen, and the area of low-suitability level (S3) is 530.35ha for citrus fruits and 499.90ha for mangosteen. The area of non-suitability level (N) is 1,071.20ha for citrus fruits and 1,547.22 for mangosteen. The limitations of suitability included three dominant factors as soil type, soil slope, topsoil depth and two additional factors as soil texture and soil fertility. Next, the classification of social-economic and environmental suitability was conducted according the multi-criteria approach. There were three main criteria and 17 sub-criteria applied for this analyses. The final result shows that the area of level S2 is 918.56ha for citrus trees and 476.65ha for mangosteen and the area of level S3 is 116.23ha for citrus trees and 0.00ha for mangosteen.

Integration of GIS and multi-criteria approach for land suitability analysis could be a useful methodology for further research in Vietnam. This approach makes it possible to select suitable land use types and crops for each administrative unit at community level.

1. INTRODUCTION

Land suitability evaluation and agricultural land use planning is very necessary and is the basic information for right decision making afterward (FAO, 1993). This study looks to a new research approach that combines the “top-down” and “bottom-up” information (Fresco et al, 1992) for land suitability evaluation for agricultural crops at the community level in Vietnam. When considering this approach it is important that two groups of factors are considered including the physical land factors and socio-economic, environment factors and it is necessary to adopt a technique that allows an estimation of the importance of various evaluated criteria. Therefore, the main objective of this study is to produce the databases in Land Information

System (LIS) and assess land suitability for the selected fruit crops in a representative commune in central Vietnam by applying the multi-criteria analysis and GIS techniques.

2. STUDY AREA

This study has chosen Thuy Bang commune in Thua Thien Hue province, central Vietnam locating at 107°33'E-107°37'E and 16°20'N-16°26'N. Situated in the climate zone of hills and plain of Thua Thien Hue province, central Vietnam, it is influenced by common effects of tropical monsoon climatic belt with the two distinct seasons. The annual average temperate is over 24^0C-25^0C. The average annual rainfall volume is about 2,555mm but is irregularly distributed. The rainy season is from September to January and accounting for 70% of total.

Administratively, there are 13 villages with 1,603 households and 7,766 inhabitants; its density is 338people/km^2. People in labour age are 3,579, in which the man labour is about 48% and woman labour is 52%. As exceptional agricultural communes, home-craft industry and services have not developed yet. Of the natural area only small part can be used for agriculture because most of the land is sloping and has very low fertility.

3. DATA SOURCES AND METHODOLOGY

3.1 Data sources

Spatial data source

The main spatial data sources (maps) need for this study including:

(1) Sheets of soil map with scale 1:10,000 (Thua Thien Hue DST, 2003);
(2) Sheets of topography map with scale 1:10,000;
(3) Current land use maps in year 2005 with scale 1:10,000;
(4) Existing land use planning maps for period of 2000-2010;
(5) Infrastructural accessibility maps wich scale 1: 10,000.
(6) Other existing spatial databases;

Attribute data source

The main attribute data sources need for this study including the data accompanying with spatial data above and the non spatial data:

(1) The data of location, climate;
(2) The last census of physical, social-economic, infrastructures;
(3) The last census of agricultural production and fruit production sector;
(4) Ecological requirements of selected fruit crops.

3.2 Methodology

Methodologies for data collection: Selective inheritance of available information and database sources; inventory and gathering the needed attribute data; interviewing, discussion and seminar; field work and up-to-date the existing maps; overlaying the thematic maps by GIS.

Framework of land suitability evaluation for selected crops in study area: The criteria selection and development for suitability assessment in the study area have been divided into two ways: (1) physical land suitability evaluation (see Figure 1) and then (2) social-economic, environmental suitability evaluation (see Figure 2).

In the first phase (1), the five following main physical factors were used for considering and calculating to address the physical land suitability.

1. Soil unit type (according to FAO soil classification system)
2. Soil texture
3. Soil effective depth
4. Soil slope degree

5. Soil fertility

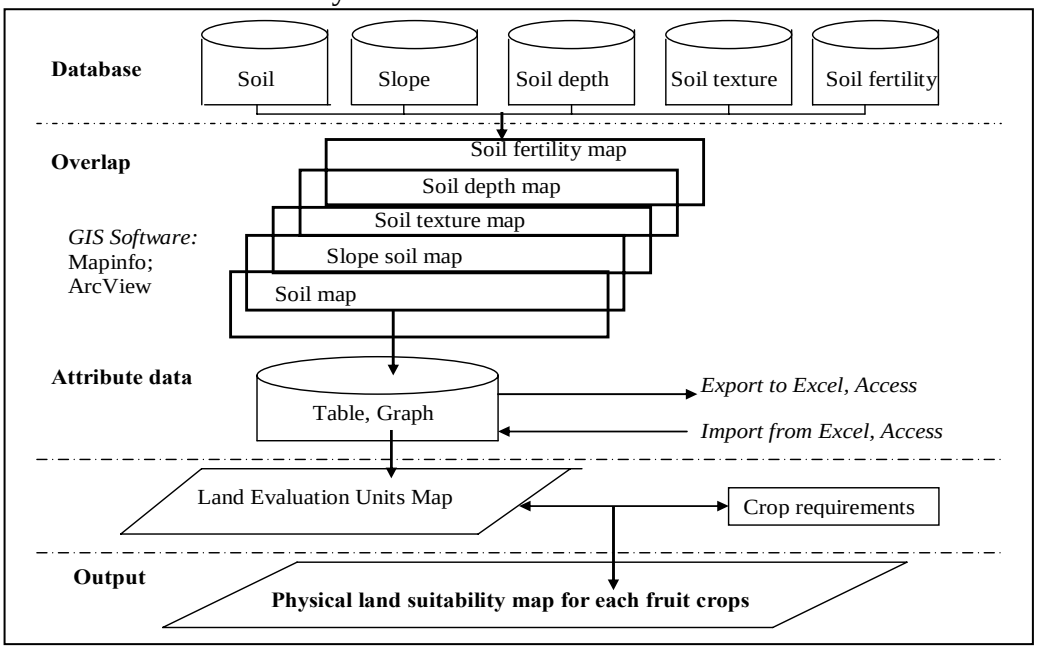

Figure 1. Chart of GIS applications to physical land suitability evaluation for crops

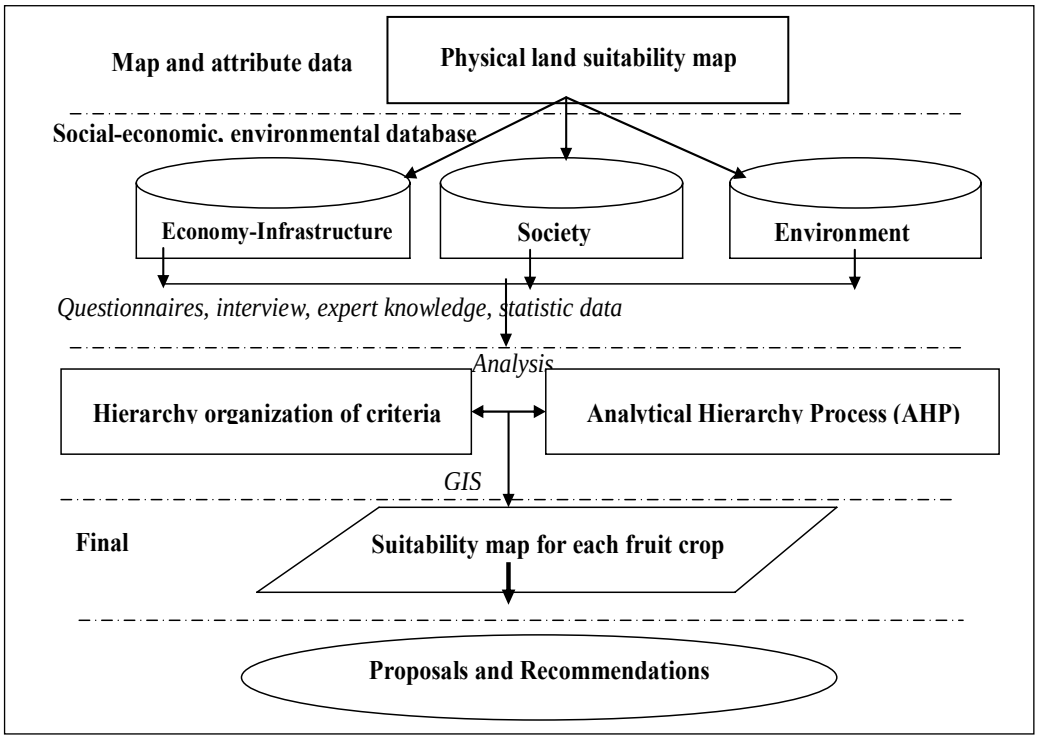

Figure 2. Schematic chart of social-economic and environmental suitability evaluation

In the second phase (2) the selection, development and hierarchical organization of criteria and sub-criteria for social-economic and environmental suitability evaluation is shown as Table 1.

In order to gain the importance of evaluated criteria and weightings for integrating into GIS context, the Analytical Hierarchy Process (AHP) technique of Saaty (1977) was used. There are three steps for this technique:

- The first step of AHP technique is to structure the overall goal (land suitability) into a number of criteria and sub-criteria in a hierarchy.

- The second step of AHP technique is the comparison of the alternatives, criteria and sub-criteria. They are compared in pairs with respect to each factor of the next higher level.
- The last step of AHP technique, we synthesize the comparisons to get the priorities of the alternatives with respect to each criterion and the weights of each criterion with respect to the goal.

Table 1. Weights of criteria for land suitability evaluation for selected fruit crops

Criteria		**Sub-criteria**		**Overall weights**
1. Economy-infrastructure	W1		Wi	**($w_i = w_1$ x w_2)**
	0.634	1.1 Rural road systems	0.132	0.084
		1.2 Irrigation and drainage systems	0.362	0.229
		1.3 Transportable vehicles and agri-implements	0.067	0.042
		1.4 Storage and processing facilities	0.036	0.023
		1.5 Market channels	0.057	0.036
		1.6 Benefit/Cost	0.346	0.228
2. Society	W2	2.1 Labour availability	0.059	0.008
	0.086	2.2 Capital resources accessibility	0.244	0.021
		2.3 Price and market information	0.105	0.009
		2.4 Farmer's technology skills	0.132	0.011
		2.5 Cultivation habits of farmers	0.038	0.003
		2.6 State policy for agriculture	0.027	0.002
		2.7 Cultivated land per capita	0.395	0.034
3. Environment	W3	3.1 Physical conditions	0.643	0.18
	0.280	3.2 Soil coverage level	0.092	0.026
		3.3 Water source protection	0.218	0.061
		3.4 Biodiversified level	0.047	0.013
Sum	1.00			1.00

Once the weight value (see Table 1) assigned for each class of each map, all of maps of factors for each land use type will be multiplied together. This study conducted calculations of the weight and fact value of each criteria and sub-criteria, produced the theme layers of each sub-criteria, overlaid all the theme layers for having the final suitability classification.

Standardization of the criteria maps: This process of setting the relative importance of the classes of criteria into GIS is called standardization. Some sub-criteria of them can be represented by the GIS layer and some are purely non spatial.

The formula for calculating the suitability index of each layer as follow:

$S_i = \sum X_i$ x W_i

Where

W_i is weighting of the each criterion, as presented in AHP techniques above.

X_i is fact value of each criterion, an example of X_i is showed in Table 5.7.

S_i: is suitability index.

Value or score (X_i) of each level of criterion is computed for each evaluated land unit. Scores for the social-economic, physical criteria were calculated basing on the expert and farmer opinions as well as local conditions use questionnaire, seminar and discussion.

4. RESULTS AND DISCUSSION

4.1 Thematic maps and the evaluated land units map in the study area

Basing on the above-mentioned objective and the facts of the study area, the research puts forward the criteria to set up thematic maps and for evaluated land unit map including: soil classification (see Figure 3a), soil sloping, soil layer depth, soil texture, soil fertility (level of nitrogen, phosphorus, potassium, pH_{KCL}, organic matter) and current land use structure.

In addition to these criteria, in order to establish a more detailed thematic map, the study also pays attention to other criteria, but in term of non-spatial data. These data are generalized and analyzed for the whole area without being separated for evaluated land units.

After overlaying thematic maps with supporting of the specialised GIS software, there are 26 land units found on the map of Thuy Bang commune with the scale of 1:10000. The detailed information on the properties of the 26 land units is presented in Figure 3b.

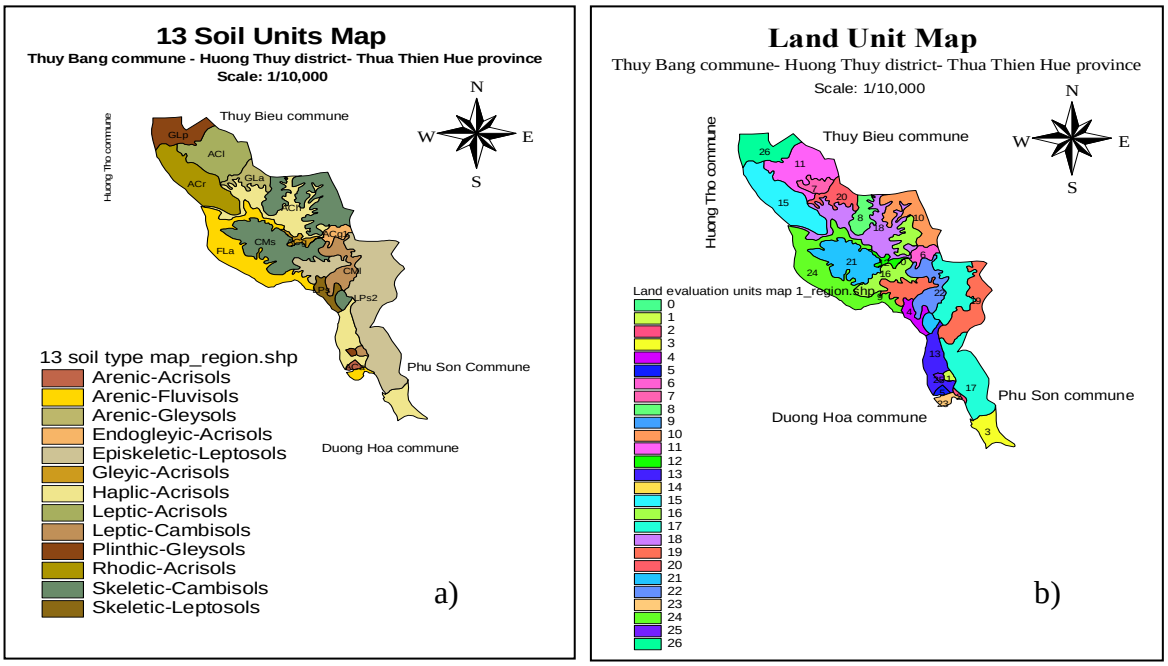

Figure 3. The map of soil units classification and evaluated land units of Thuy Bang

The data in Figure 4 reveal a fact that although the area of the commune is not too large, the number of land units found is rather much. The area of each land unit varies greatly, from 0.09ha to 281ha. Large number of land units also means that there is a big difference in the characteristics of soil criteria in a small area of land, and there is no homogeneity. This is a distinctive feature of the hilly land in Central Vietnam in comparison with other regions.

4.2 Presentation the physical land suitability evaluation for the selected fruit crops

Classifying the physical land suitability level for crops is comparing the ecological requirements of that crop with the characteristics of each evaluated land unit.

Thuy Bang commune with the total natural area of 2,298ha has 26 land units. The study carried out the classification of physical land suitability for citrus fruit and mangosteen. The

suitability classification results are shown in Figure 4a and 4b. In the table of land suitability classification always attach the limitation factors affecting the growth, development and productivity of fruit crops. For example, S3d.t.p in the second row of Figure 5a means that land unit of number one is low suitable (S3) for citrus fruits with the limited factors including soil depth (d), soil texture (t), and soil fertility (p).

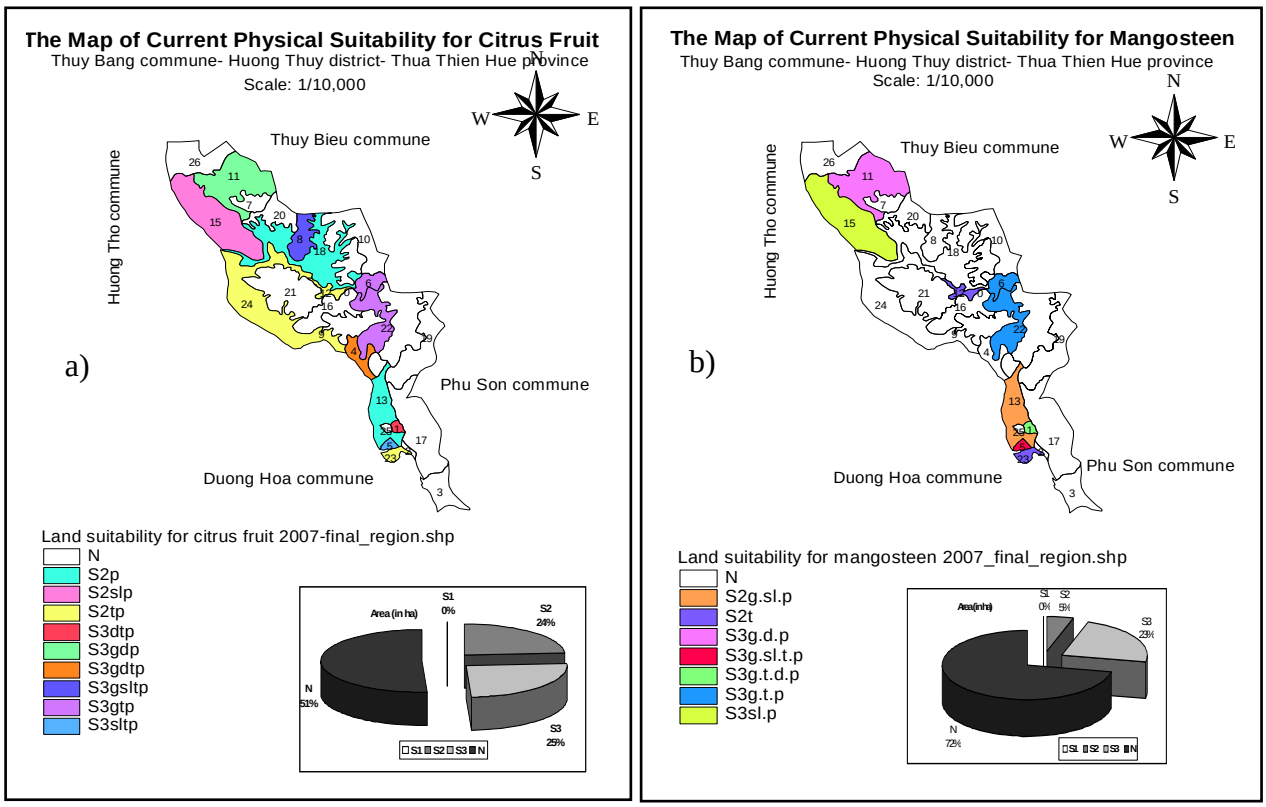

Figure 4. The map of current physical land suitability classification for fruit crops

4.3 Presentation the social-economic and environmental land suitability evaluation

The social-economic and environmental suitability assessment is only conducted on those land units with result of physical suitability level of S1, S3, and S3. The identification of 3 main criteria and 17 sub-criteria in this phase reveals that the final suitability assessment is rather complicated. As each criterion has a different role, the weight of each criterion was worked out to estimate the influence of each criterion to the final result.

From the results of physical land suitability evaluation and the results of the methodology-mentioned multi-criteria analysis, by overlaying the attributive information of sub-criteria, the final results of land suitability for citrus fruits and mangosteen crop in Thuy Bang commune are presented in Figure 5a and 5b.

By applying multi-criteria method to suitability assessment for crops in Thuy Bang commune, Thua Thien Hue province, the study has identified different levels of suitability of land units for selected fruit crops. According to data of Figure 5a, the limitations and difficulties relating to natural and socio-economic conditions have resulted in 0ha of level S1 for citrus fruits. Level S2 has 918.56ha (43.61%). Level S3 has 116.23ha (5.51%). According to Figure 5b, the limitations and difficulties relating to natural and socio-economic conditions have resulted in 0ha of level S1 for mangesteen. Level S2 has 476.65ha (22.66%). Level S3 has 0.00ha. The area of unsuitable land for mangosteen in Thuy Bang is 1629.62ha (77.34%).

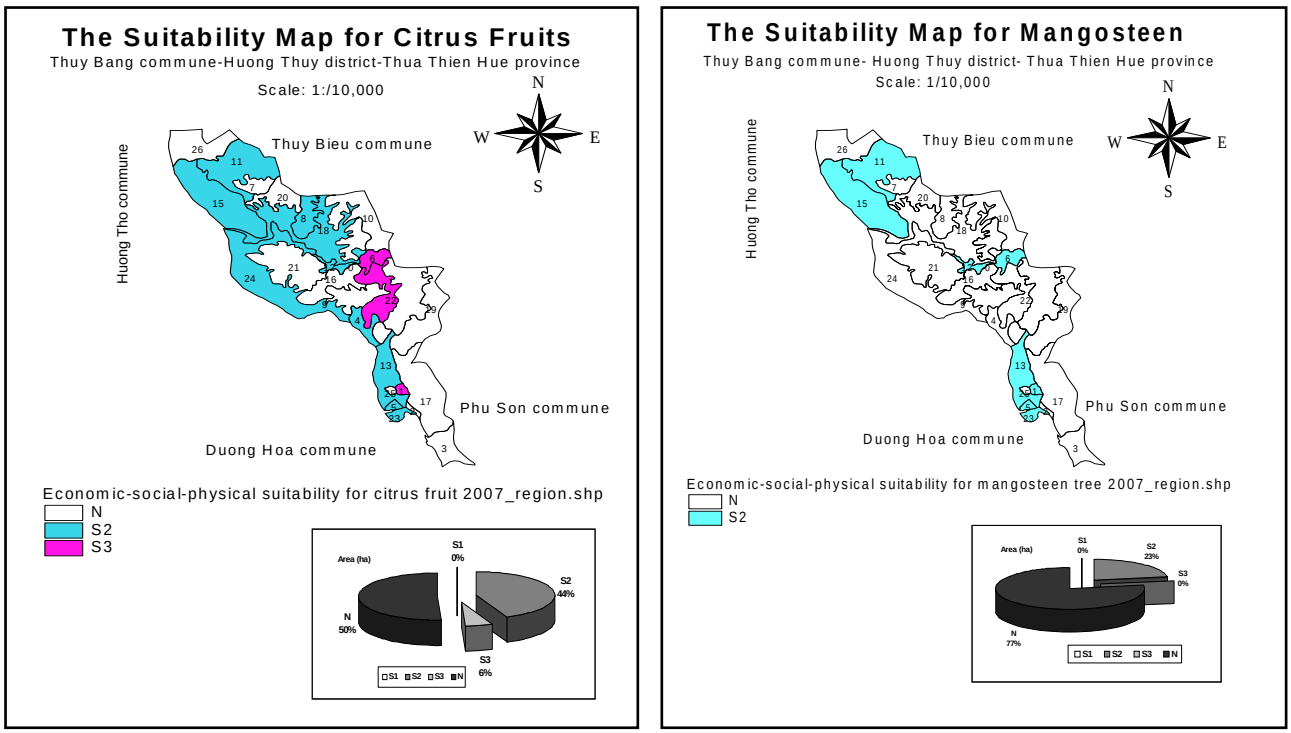

Figure 5. Suitability map for selected fruit crops in Thuy Bang commune

5. CONCLUSIONS

The multi-criteria suitability land evaluation method, together with the GIS technology for agricultural crops has high feasibility and is appropriate at community level. It could be further expanded to other communes with similar conditions in Central Vietnam.

The study has also indicated that GIS is a useful supporting tool in integrating social-economic and environmental data for community level. Database LIS can support as an efficient technical tool for spatial analysis and spatial modelling functions for crop production to obtain insights into community development problems and right decision making.

The most difficult problem for LIS building at community level is that the patterns of spatial and attributive databases are inconsistent; the data are collected at different points of time. Besides, each professional agency has its own way of managing information and data; and the software systems for managing map figures are also different.

6. REFERENCES

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