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Building land unit database for supporting land use planning in Thai Binh Province by integrating ALES and GIS

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Abstract. In order to ensure the effectiveness of land use planning, the information about land quality and land characteristics plays an important role. The application of information technology is one of the best solutions in the area of land use planning in which land unit database is considered firstly and seriously. The land unit database consists of spatial data and attribute data, both of which should follow the standard. The paper presents a procedure to build the land unit database, and illustrates an application of the database to land suitability classification for paddy field and crop in Thai Binh Province by comparing land unit with the requirement of each land use type according to ecology characteristic.

Keywords: ALES and GIS; Land suitability; Land unit database.

1. Introduction

Thai Binh Province is located in the Red River Delta. The province is close to the northern focus economic triangle Hanoi - Hai Phong - Quang Ninh and it is also a commercial exchange gate between Hai Phong, Quang Ninh and coastal provinces across the country.

Covering an area of about 1,535 km^2, Thai Binh makes up 0.5% of total area of Vietnam. The province borders on the Gulf of Tonkin in the east, Nam Dinh and Ha Nam provinces in the west and southwest, and Hai Duong, Hung Yen and Hai Phong City in the north.

The terrain is flat with slope less than 1% stiffing from north to south. Elevation varies from 1 to 2 m above mean sea level. Average annual temperature of the area is 23.3^{0}C. Total annual radiation is quite high. The average annual rainfall ranges from 1600 to 2000 mm. Rainy season lasts from April to October and dry season from November to March. In rainy season, large amount of rainfall is concentrated, accounting for 80 to 90% of the total annual rainfall.

The sediment includes mud and clay and is red-brown colored. pH of stabilized soil, loam or heavy loam is from 7.2 to 7.6. The soil is soft mud, rich in nutrient suitable for paddy and crops. The soil in Thai Binh is also good for plantation of foodstuff and industrial plants of short life, tropical fruit trees, flowers, etc.

Thai Binh has a population of 1.8 million people, of which 94.2% are rural and 5.8% are urban. Labor force is of 1.73 million people in which 74.3% are working in agriculture and forestry; 17% - in industry and construction; and 8.7% - in trade service.

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Total natural land area across the province is 153,596 ha, of which 94,187 ha is under cultivation. Thai Binh possesses fertile land and large labor force working in agriculture having experiences in cultivating 3-4 crops annually in one year. The convenient irrigational system has partly helped build up paddy fields yielding up to 14-15 tons/ha.

The purpose of this research is to build the database for land suitability classification by using integration ALES and GIS.

2. Materials and methods

The FAO method is based on matching land quality (supply side, the land) versus land use requirements (demand side, product). The key of this method is to divide the landscape of the studied area into specific types of land units called land systems. The land system concept, as explained by most scholars, is based on ecological principles and presumes closely interdependent links between parameters such as agro climate regime, rock types, landforms, soils, hydrological conditions and living organisms etc.

The first FAO publication setting out the principles of land evaluation as well as the broad methodological approach for identifying a range of relevant agricultural land-use options for a given area appeared in 1976, "A framework for land evaluation" (referred to hereafter as the '1976 Framework') (FAO, 1976). Subsequent FAO guidelines on land evaluation concerned detailed application of the 1976 Framework to several specific major land uses, namely, rain-fed agriculture, irrigated agriculture, livestock and forestry production (FAO, 1983; 1984; 1985; 1991 respectively). An example of the application at the national scale of automated approaches to land evaluation that are based on the original 1976 Framework principles was published in 1993 (FAO/UNEP, 1993) [1, 3].

More recently, the dynamic process of land use planning, the high demand for information on the suitability of land for various uses, and the advances in IT opened the possibilities for more automated systems where data storage, processing (rule-based), retrieval and iteration are facilitated. This is when software packages such as ALES (Automated Land Evaluation System) and some the others were introduced.

The ALES (the Automated Land Evaluation System) is developed at Cornell University follows the principles of FAO's 1976 Framework. In ALES, expert users can describe proposed land uses, as well as the geographical areas to be evaluated, using their own set of criteria based on their local knowledge, and subsequently allow the program to automatically do the matching [5].

Regarding the land evaluation methodology, each observation was singularly evaluated and attributed to one of the four suitability classes (0: not suitable, S1: very suitable, S2: moderately suitable, S3: marginally suitable).

3. Database building

The land units of the Thai Binh Province were digitized using ArcGIS software and presented with the attribute data as index map codification system. The database will be later built at scale of 1:50.000 based on the chosen parameters and characteristics of land units. After finishing, the existing land unit database contains only spatial data which is based on the georeference of topographic map. The thematic attribute data which describe the properties of land unit system, were not yet stored in digital format. Therefore, land unit database were not ready to be integrated with other thematic data. The further step is to organize the land unit database so that the spatial data are appropriately described by the attribute data for spatial land use planning [4, 5].

3.1. Spatial data georeferencing

The current trend of GIS users in applying integrated data for various purposes is to develop spatial data standards. The standardization of the spatial data for GIS applications certainly needs georeference standards.

Georeference standards of land system adopt the ellipsoid of the World Geodetic System 1984 (WGS 84). The grid system uses UTM grids with a 6x6 degree zone.

The method to do georeference standardization for the spatial data of the land system is as following. Firstly, the base layers (hydrography, transportation, administration boundary, and its toponymy) are tied onto the geographic and UTM coordinates using the georeferencing tools available in the ArcGIS software. The land unit boundaries are also registered into the geographic and UTM coordinates. Secondly, all based layers and land unit boundaries layer can be then superimposed in order to zone land suitability for each type of use.

Table 1. Criteria selection for paddy field

No.	Criteria	Symbol	Codification
1	***Soil characteristics***		
1.1	*Soil type or soil group*	G	
1	Sandy dunes and sand at river bank or coastal zone	Cc	1
2	Marine sandy soil	C	2
3	Heavy saline soil	Mn	5
4	Slight to moderate saline soil	M	6
5	Potential acid sulphate soil at depth, moderate saline	SP2M	10
6	Potential acid sulphate soil at shallow, severe saline	SP1Mn	11
7	Potential acid sulphate soil at shallow	SP1	12
8	Potential acid sulphate soil at depth	SP2	13
9	Alluvia, slight acid	Pbe	14
10	Alluvia, acid	Pc	15
11	Marine soil with alluvia on top	P/C	16
12	Alluvia, neutral, slight acid	Pt, Pt/c	17
13	Gley alluvia	Ph/g	18
	Gley loam clay soil	Phc, Ph/gs, Pt/g	
14	Alluvial soil reddish yellow stratified	Pf	19
1.2	*Mechanic composition on top soil*	TE	
1	Silt	g	
2	Heavy silt	e	
3	Moderate silt	d	
4	Slight silt	c	
5	Mixed sand	b	
6	Disjointed sand	a	
1.3	*Thickness*		
1.4	*Gley*		
2	***Terrain characteristic***		
	Relative altitude	DHDR	
3	***Hydrology and irrigation***		
3.1	*Drainage Potential*	DRA	
3.2	*Irrigation potential*	I	

3.2. Feature codification

Attribute database adopts a standardized codification for its feature data types. A feature codification is developed to describe land unit system. Each land unit is given an unique identifier. This key identifier includes information on natural characteristic of land unit and artificial characteristic of land unit. Natural characteristic consists of soil type, mechanic composition, and relative altitude. Artificial characteristic consists of irrigation conditions and drainage conditions.

3.3. Database design

Land in Thai Binh is divided into several units based on 5 parameters, namely: soil type, mechanic composition, relative terrain altitude, irrigation and drainage conditions.

For example, the soil type of the land unit No 25 is sand dunes and sand at river banks or coastal zone. Mechanic composition of the top soil is disjointed sand. Terrain form is depression, there is no active irrigation and drainage potential.

Table 2. Land units in Thai Binh Province

NN	Land characteristics					
	Soil type	Mechanic composition	Relative topography	Irrigation	Drainage	Districts
1	Cc	3	3	1	1	Thai Thuy
2	C	4	1	1	1	Thai Thuy
3	C	4	1	3	1	Thai Thuy
...	...	...	...	...	...	...
25	Cc	6	5	3	1	Hung Ha
26	Mn	3	3	1	1	Thai Thuy
27	Mn	3	3	3	1	Tien Hai
28	Mn	3	4	1	1	Tien Hai
29	Mn	3	5	1	1	Tien Hai
...	...	...	...	...	...	...

4. Application of land unit database for land suitability evaluation in Thai Binh Province

The main purpose of land use planning is to achieve sustainable development. For that purpose, the land system data base can be used for evaluating land suitability which is useful for rational allocation of agricultural zones.

The comparison between land quality and ecological requirements should be made before doing land suitability classification.

4.1. Standardized classification for land suitability

In order to classify land suitability for paddy field and crop, the standardized classification should be set up (Table 3).

Table 3. Standardized classification for land suitability according to ecological requirements of paddy, crop and aquaculture

Land use types	Selection of parameters	Suitability levels		
		S1	S2	S3
Paddy specialization	Soil type	Ph,P,Phg,Pg,Phf,Pf	M,S	Mn,Sn,Phb
	Mechanic composition	ed	bcg	a
	Relative altitude	Hill	Low hill	High, high hill, depression
	Irrigation	Active	Semi-active	Constrainted
	Drainage	Active	Semi-active	Constrainted
Paddy and crop	Soil type	Ph,P,Phf,Pf	Phg,Pg,M,S	Mn,Sn,Phb
	Mechanic composition	cd	be	ag
	Relative altitude	Hill	High hill	High, low, depression
	Irrigation	Active	Semi active	Constrainted
	Drainage	Active	Semi active	Constrainted
Aquaculture	Soil type	M	MnS	Ph,P,Pg,Phf,Pf,Sn,Cc
	Mechanic composition	dg	e	b
	Relative altitude	Low, depression	Hill	High, high hill
	Irrigation	Active	Semi active	Constrainted
	Drainage	Active	Semi active	Constrainted

4.2. Land suitability for paddy field

Table 4 illustrates the component evaluation for paddy. Each land unit has been compared according to standardized classification table that was set up above.

Table 4. Component evaluation for paddy

Land unit / Criteria	1	2	3	...	n
Soil type	S1	N	S2	...	S3
Mechanic composition	S1	S2	S3	...	N
Relative altitude	S2	S3	N	...	S1
...	...	...	...	...	...

In Table 4, the land unit with code 106 shows that soil type is potential acid sulphate soil at depth, moderate saline, slight mechanic composition under conditions of low hill and active condition of irrigation and drainage. This land unit is marginally suitable for paddy field due to some limitations, such as soil type. It is impossible to improve up to the levels S1 and S2 in order to extent the area suitable for paddy. Limitation factor of soil type is hardly to reclaim so the utilization in this case should be considered to change.

Table 5. Land suitability classification and limitation factors of land units for each land use type in Thai Binh

Land units	Land suitability classification		Limitation factors				
	Paddy	Suitable for paddy	Soil type	Mechanic composition	Relative altitude	Irrigations	Drainage
108	3G/I	S3	Ph/b	4	4	3	1
162	3I	S3	Ph/g	4	3	3	1
153	3I	S3	Ph/g	3	3	3	1
106	3G	S3	Ph/b	4	4	1	1
151	1	S1	Ph/g	3	3	1	1
163		S2	Ph/b	4	4	1	1
120		S1	Pt	3	3	1	1
97		S3	Ph/b	3	3	3	1
131		S2	Pt	4	3	1	1
...	...	...					...

Table 6. Limitation factors for S2,S3 and their affected area for paddy and crop in Thai Binh

Land use type	Suitability level	Limitation factors				
		Soil type	Mechanic composition	Relative altitude	Irrigation	Drainage
Paddy	S2	102.260,10	74.073,60	58.563,50	0	0
	S3	433.945,40	21.626,90	441.423,80	108.593,60	182.134,20
Crop	S2	80.183,84	27.218,40	36.461,60	0	0
	S3	433.945,80	21.627,10	638.145,53	108.593,60	182.134,30

The area of 441.423,80 ha in Thai Binh Province is marginal suitable for paddy. One and haft time of this amount is in the same situation for crop. Limitation factors, such as relative altitude and soil type, seem to be difficult to reclaim. The best solution for that area is to shift to other utilization.

Fig. 1 and Table 7 generalize the results of land suitability evaluation of Thai Binh.

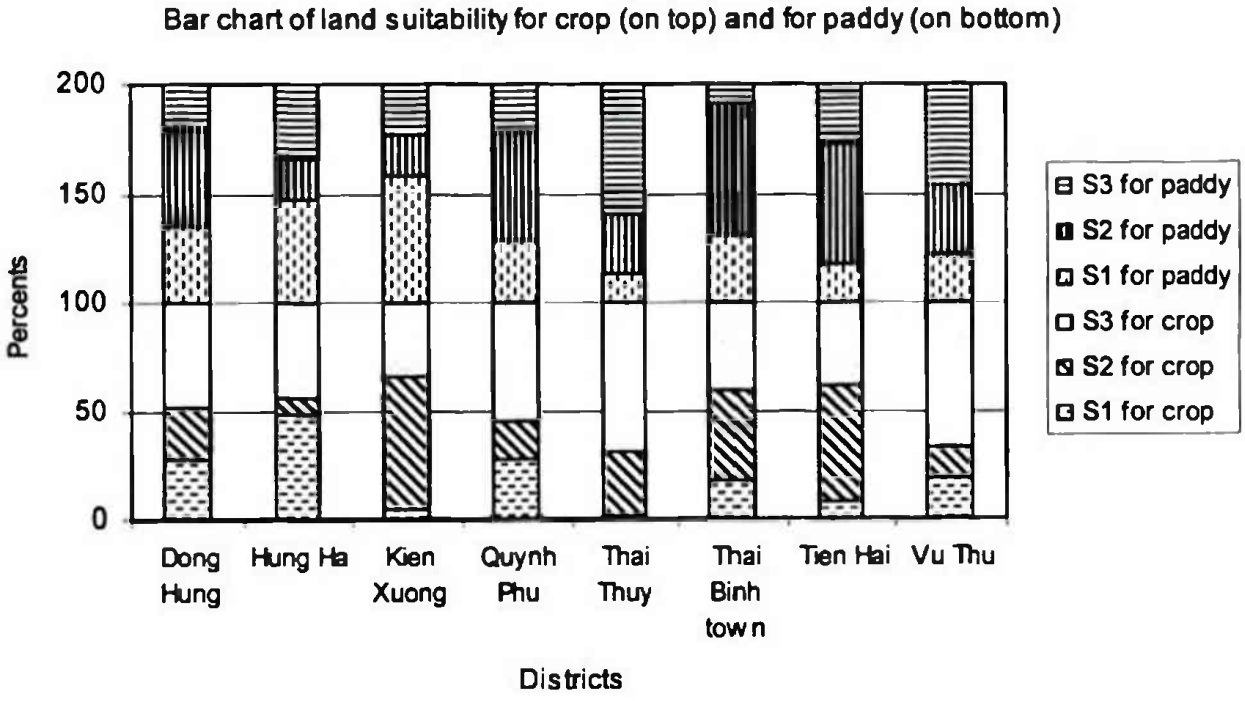

Fig. 1. Summary statistics of land suitability for paddy field and for crop in Thai Binh by district.

Table 7. Summary statistics of land suitability area for paddy field and crop in Thai Binh (unit: ha)

Land use type	Suitability level	District							
		Dong Hung	Hung Ha	Kien Xuong	Quynh Phu	Thai Thuy	Thai Binh town	Tien Hai	Vu Thu
Paddy	S1	602614	840273	970790	469411	246442	71881	267044	283897
	S2	760503	329505	308059	845928	532097	140671	820316	400608
	S3	351449	599450	377293	359771	1128153	21882	421843	590863
Crop	S1	478551	859876	68318	465295	19077	41288	121078	239090
	S2	402692	135186	1016922	287627	557835	97189	805948	182324
	S3	833364	774167	570910	922188	1329780	95956	585147	853953

5. Conclusions and recommendations

The test of ALES's use in the case of Thai Binh shows that the models and procedures proposed by ALES are applicable for the context of a deltaic province of Vietnam. The constraint is that ALES always requires quantitative attribute data for modeling. In Vietnamese context, the lack of quantitative data may become a big problem influencing on the quality of results.

There are 173 land units in Thai Binh Province which have been classified into three suitability levels: S1, S2 and S3. The chosen criteria such as soil type, mechanic composition, relative altitude, irrigation and drainage conditions. The summary statistics show that the Kien Xuong District's land has a high potential for paddy field; the Hung Ha District's land has the same potential for both paddy field and crop; the Thai Thuy District has a large part of area with S3 level of suitability for crop and paddy field which would be taken into account for reclamation in order to end up higher level as S2 or S1, or consideration of which type of land utilization should be applied.

The results of land suitability evaluation will be very useful for the planners or decision makers and can be considered as a decision support tool in land use planning.

As several attributes describing the human activities, such as irrigation and/or drainage planning, may change through the time, this part of the database must be updated timely.

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