Evaluating the Current Ecological Adaptability and Future Trends of Agricultural Land Use Systems for Spatial Orientation of Land Use Planning in Quoc Oai District, Hanoi City

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Key words: land use systems, land use planning

SUMMARY

Land evaluation in general and the effectiveness of ecological adaptability in particular are important parts of the process of land use planning, especially in agricultural land use. However, in Viet Nam, most research only focus on building land unit maps for land evaluation, which have not fully considered the interdependence of components in the assessment process. Thus, the effectiveness of evaluating ecological adaptability in land use system will allow to identify the interdependence of factors in the system (A land use system consists of a specified land utilization type practised on a given land unit, together with its associated inputs and outputs, FAO, 1984). Furthermore, Quoc Oai district is oriented to develop ecological village and high-tech agriculture in the construction master plan of Hanoi city. Quoc Oai district has a large area of agricultural land with 9637.91hectares, accounted for 63.77% of total area of natural land of district. The study identified 46 agricultural land use systems (LUS) which are based on 34 land units (LU) and 7 major land use types (LUT) in the Quoc Oai district. The research results evaluate the effectiveness of ecological adaptability in present and future. This research identified land use systems in the district's agricultural production including: wet rice, rice-fish, vegetables, perennial fruit trees, tea, production forest, protection forest. Perennial trees and vegetables are land use systems which have wide ecological adaptability area and the best effectiveness. LUS evaluation process can be applied to other districts which have an agricultural area in Hanoi.

SUMMARY (optional summary in one other language in addition to English, e.g. your own language)

Đánh giá đất nói chung và đánh giá mức độ thích nghi sinh thái nói riêng có vai trò quan trọng trong công tác quy hoạch sử dụng đất, đặc biệt đối với đất nông nghiệp. Tuy nhiên, ở Việt Nam hầu hết các nghiên cứu mới chỉ dừng lại ở xây dựng bản đồ đơn vị đất đai, sau đó tiến hành đánh giá đất để phân hạng thích hợp mà chưa xem xét đầy đủ *mối quan hệ tương hỗ* giữa các hợp phần trong quá trình đánh giá. Do đó, nghiên cứu đánh giá đất đặc biệt là đánh giá mức độ thích nghi sinh thái theo tiếp cận hệ thống sử dụng đất sẽ toàn diện, đầy đủ hơn và cho phép xác định mối quan hệ tương hỗ giữa các hợp phần trong hệ thống. Mặt khác, huyện Quốc Oai được định hướng phát triển làng sinh thái và nông nghiệp công nghệ cao trong quy hoạch chung xây dựng của thủ đô Hà Nội. Diện tích đất nông nghiệp của huyện tương đối lớn 9637.91ha chiếm 63.77% tổng diện tích đất tự nhiên của huyện. Đề tài nghiên cứu đã xác định huyện Quốc Oai với 46 hệ thống sử dụng đất nông nghiệp dựa trên cơ sở phân tích 34 đơn vị đất đai và 6

loại hình sử dụng đất chính trên địa bàn. Kết quả đánh giá mức độ thích nghi của các hệ thống sử dụng đất hiện tại và tương lai cho phép xác định các hệ thống sử dụng đất trong sản xuất nông nghiệp của huyện bao gồm: chuyên lúa, lúa-cá, cây ăn quả lâu năm, chè, rau màu, rừng sản xuất và rừng phòng hộ. Trong đó, cây lâu năm và rau màu là hệ thống sử dụng đất có diện thích nghi rộng và hiệu quả cao nhất. Quy trình đánh giá mức độ thích nghi sinh thái hệ thống sử dụng đất nông nghiệp có thể áp dụng cho các huyện khác có quỹ đất nông nghiệp trên địa bàn thành phố Hà Nội.

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1. INTRODUCTION

Land assessment in general and assessment of ecological adaptation in particular play an important role in land use planning, especially for agricultural land. However, in Vietnam, most research only focus on building land unit maps for land evaluation, which have not fully considered the interdependence of components in the assessment process FAO, 1976 [9]; Dao Chau Thu, 1998 [2]; Ministry of Agriculture & Rural Development, 2008 [1]). Thus, the effectiveness of evaluating ecological adaptability in land use system will be more comprehensive, more complete and allow to identify the interdependence of factors in the system (Beek, 1978 [8]; Beek, 1981 [10]; Dent D và Younng A,1981 [15]; FAO, 1984 [10]). Thus, it is easy to identify the limiting factor of each land use system to choose the soil improvement measures to improve land suitability and extrapolate the evaluation results. Therefore, the results of assessing the level of ecological adaptation according to the approach of land use system for the spatial orientation of land use planning will be more complete and accurate than the land evaluation.

On the other hand, Quoc Oai is a suburban district in the west of Hanoi capital with a large agricultural area of 9637.91 ha, accounting for 63.77% of the district's total natural land area [4]. In general construction plan of Hanoi capital, Quoc Oai district is oriented to develop ecological villages and high-tech agriculture [5]. Thus, the district will be both a producer and a supplier of ecological agricultural products to Hanoi capital. Therefore, a study to assess the current ecological adaptation and future trends of agricultural land use systems in Quoc Oai district is essential.

2. THEORICAL BACKGROUND

2.1 Land evaluation

Land evaluation is one part of the process of land use planning (FAO, 1976 [9]). Its precise role varies in different circumstances. In the current context, land evaluation is the most important in the period of comparing and evaluating each type of land for the different uses.

Therefore, land evaluation is understood as the process of matching and comparing the inherent quality of land / land plots to be assessed with the land use requirements that land use types need to have (FAO, 1976 [9]). The evaluation process itself includes a description of a variety of promising land use type, then assessing and comparing of these categories for each land unit identified in the study area. This result in recommendations related to one or a number of priority land use types. These recommendations can then be used in making decisions regarding land use planning assistance. However, the reciprocal relationship between the components in the assessment process has not been fully considered, leading to a limited ability to identify measures to improve land suitability and extrapolate evaluation results for spatial orientation.

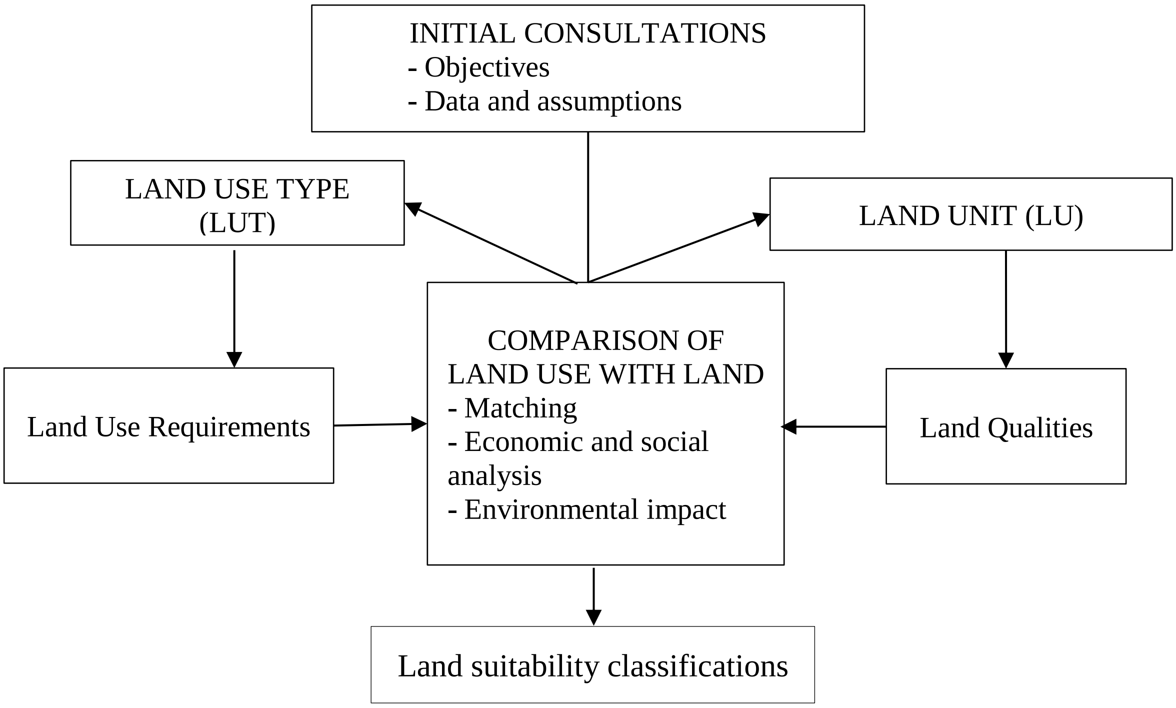

Fig.1. Process of land evaluation according to FAO, 1976

2.2 Evaluation of land use system

Land use system (LUS) is a combination of a land use type with a separate land condition that forms two closely interrelated components. These interactions will determine the characteristics of the level and type of investment costs; level and type of land reclamation; and productivity and yield of land use types (FAO, 1984 [10]; Driessen và Konijn (1992) [12], Hermand Huizing (1995) và ITC (1998) [7]; Ministry of Agriculture and Rural Development, 2008) [6]). In order to be more specific for the definition, Beek (1978) and Dent D. & Young A (1981) [15] have proposed the structure model of LUS (Figure 2). In this structure model, the interaction between land unit (LU) and land utilization type (LUT), inputs and outputs of the system have been shown. The close interaction between land unit and land use type in a system of LUS determines the quantity and quality of the output of the system.

In particular, H ... out the composition and structure of the L ... serts: "LUS is a system

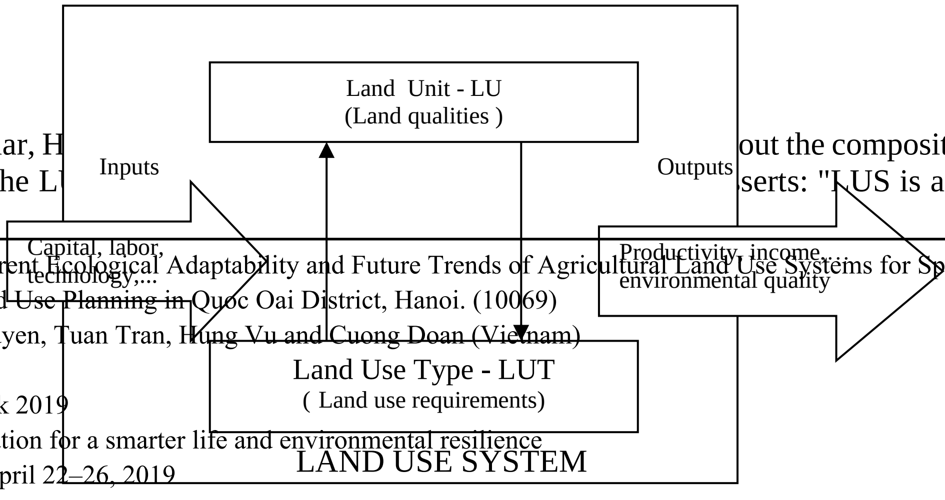

Fig.2. The structure of Land use system according to Dent D and Younng A (1981)

of a LU and a LUT, separately". Huizing has generalized the land use system with a shorter formula rather than the LUS = LU + LUT [11]. In Vietnam, many authors inherit and develop their research on LUS. Although there are not many studies, it also contributes to the building of theoretical basis and general research experience in many fields for future studies such as Dao Chau Thu (1998) [1]; Tran Van Tuan, Nguyen Cao Huan (2014);... In particular, Tran Van Tuan, Nguyen Cao Huan and others (2014) affirmed that "LUS is a natural - human system including a component of land and a component of land use that interact with each other by flow of matter and energy" [3]. With the advantage of structural simulations, the approach evaluated LUS will allow easy extrapolation of land evaluation results for spatial orientation and land use planning (Beek, 1978 [8]).

The evaluation of LUS serves two purposes. First, this is a convenient way to address the combination of LUT with LU. Second, it provides an analytical framework to evaluate the effectiveness of variations in the system. A change in any of the major components of the input data source such as its LUT and requirements, its LU and quality will have an impact on the output. In other words, it shows the interaction between components. Therefore, this concept provides a basis for analyzing the consequences of change: for land quality (by land reclamation), for land use type (by modifying technical characteristics), or input (Beek, 1981; FAO, 1984) [10]. Therefore, assessing LUS and simulating a compact structure of the combination of LUT and LU allow a full consideration of the mutual relationship between components in the LUS and between LUSs in particular by structural simulations in that system. Therefore, the evaluation study follows the approach of land use system from the point of view that the system will be comprehensive, more complete and allow for extrapolation in land assessment and land use planning.

3. MATERIALS AND METHODS

3.1 Study area

Quoc Oai district is a suburban district, located in the west of Hanoi city. It has geographical coordinates from: 20º 54' to 21º 04' north and 105º 30' to 105º 43' east longitude. It is located about 20km from Hanoi city center. Geographical position of Quoc Oai district is located in the transition area between the mountainous and midland regions in the North and the Northern Delta region, creating a diversified nature and many mineral resources and many advantages for trade development compared to other districts in Hanoi city, contributing to economic development of the district. The total natural land area of the district is 15112.8 ha, of which agricultural land area is 9637.91 ha [4].

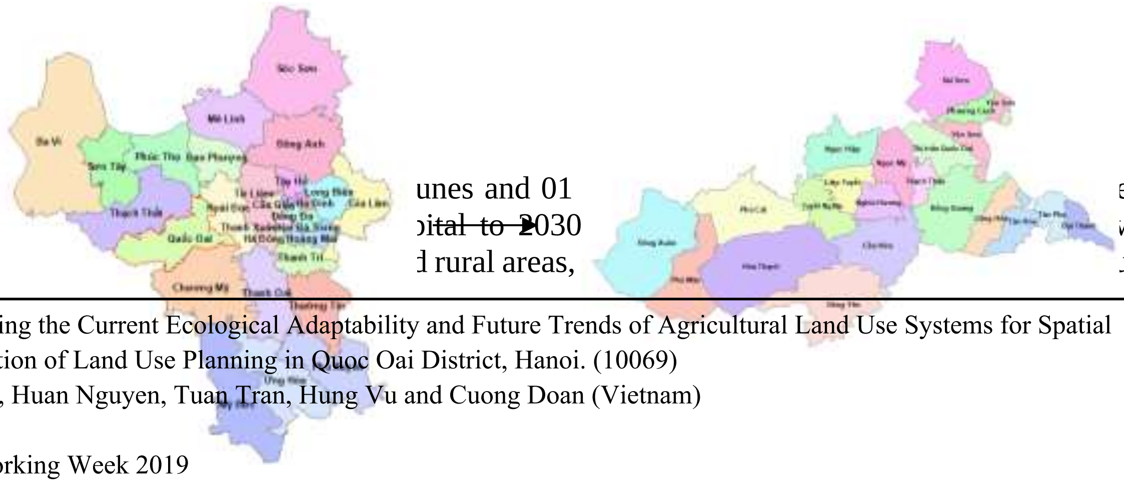

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Fig.3: Diagram of the study area

landscape and highly productive agricultural areas. Agriculture in the district aims to develop ecological villages and high-tech agriculture [5].

3.2 Methods

+ *Methods to synthesize and analyze data and documents*: to collect and process data sources, documents, map components such as geological maps, topographical maps, geomorphological maps, maps soil, hydrological and irrigation diagrams, etc. In addition, there are other maps, annual reports on socio-economic conditions, documents of economic development programs and projects - society and all other relevant data sources of departments of Quoc Oai district, Hanoi city.

+ *Method of field survey:* In order to explore and survey the current status of different types of land use in agricultural production in the district; check and compare documents on nature and socio-economic in the field.

+ *Expert method:* Consult the leading experts on agriculture to determine the evaluation criteria and the importance of the evaluation criteria in the LUS, thereby making the basis for comparison matrix for AHP weighting technique. The form of consultation is direct interview and interview by questionnaire.

+ *Analytic Hierarchy Process (AHP):* Each indicator selected to assess the level of ecological adaptation will affect the different levels to the appropriate capacity of the LUS. Therefore, it is necessary to determine the weight for each indicator in assessing ecological adaptation. In this study, AHP is used to calculate the weight of the evaluation criteria. This is a weight calculation method applied to multi-criteria decision making problems, so it is very suitable for the multi-criteria analysis problem in LUS evaluation. In addition, this method also helps convert qualitative judgments into numerical values.

Constructing norm comparison matrix: this comparison is done between the pair of indicators together and aggregated into a matrix of n lines and n columns (n is the number of indicators). The element aij represents the importance level of the item i compared to the target of column j.

$$A = \left(a_{ij}\right)_{n\times n} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix}$$

The relative importance of indicator i compared to j is calculated by the ratio k (k from 1 to 9). In particular, the point scale compares the following criteria [13], [14]:

Table 1. Table of relative scores.

Value of a_{ij}	Interpretation
1	i and j are equally important
3	i is slightly more important than j

5	i is more important than j
7	i is strongly more important than j
9	i is absolutely more important than j

To calculate the weights for indicators, AHP can use different methods, two of which are most widely used are Lambda Max (λ_{max}) and geomatric mean.

Consistency check: According to Saaty, it is possible to use a consistent data ratio (Consistency Ratio - CR). This ratio compares the consistency with the objectivity (randomness) of the data:

$$CR = \frac{CI}{RI}$$

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

CI: Consistency Index

RI: Random Index

n: Number of indicators

For each level n comparison matrix, Saaty tested the creation of random matrices and calculated the RI index (random index) corresponding to the matrix levels as shown in the table below:

Table 2. RI random index

N	1	2	3	4	5	6	7	8	9	10
R	0	0	0.52	0.90	1.12	1.24	1.32	1.41	1.45	1.49

If the value of a consistent CR ratio of 0.1 is acceptable, if it is larger, the decision maker will reduce the heterogeneity by changing the importance level between the pairs of indicators.

+ *Mapping and GIS methods:* in order to determine the homogeneity or territorial differentiation of the constituent elements of LUS as well as the expression of LUSs and the results of assessing the ecological adaptation of LUSs, the best way is using the map. In the current period, in addition to using the traditional map method, it is also supported by Geographic Information System (GIS), especially the spatial analysis and spatial modeling advantages to to establish integrated evaluation maps quickly.

4. RESULTS AND DISCUSSION

4.1 Characteristics of agricultural land use system in Quoc Oai district

4.1.1. Land Unit

Identifying criteria and decentralizing criteria for land unit maps construction play important roles, because it not only ensures the accuracy of land unit maps but also the evaluation criteria to reflect strictly meet the land use requirements of LUT with land qualities in the land use system. Based on the natural conditions of the district and the method of interviewing experts, the research selected 8 criteria for building land units for the study area, including: bedrocks, topography, slope, soil type, texture, soil depth, irrigation regime, drainage regime. In particular, the criteria are decentralized as follows:

(1). Bedrocks: Based on geological maps of the study area, decentralized source rocks include basic magma parent rocks (b); shale (s); silica limestone (v); quartz schist (t); sediment of rivers, streams and swamp lakes (a); sediment mixed with river - flood area (ap); swamp sediment (alb); river and marine sediments (am).

(2). Topography: Based on topographical and geomorphologic maps of the study area, the topography is classified into the following levels: mountain; high hill; low hills; land area in the dyke; alluvial ground.

(3). Slope: From the digital elevation model (DEM), the research built slope map with 6 levels including in the study area: I (0 - 3^O); II (3^O - 8^O); III (8^O - 15^O); IV (15^O - 20^O); V (20^O -25^O); VI (> 25^O).

(4). Soil type: From the soil map of the study area, the district consists of 9 types of soil with the following symbols: Fk, Fs, Fp, Fl, Pk, Pb, Pg, Pj, J.

(5). Soil depth: soil depth is divided into 3 levels: 1 (>100 cm); 2 (70-100cm); 3 (50-70 cm).

(6). Texture: consists of 3 levels as follows: light soil (c); medium soil (d); heavy soil (e).

(7). Irrigation regime: based on hydrological and irrigation diagrams and interviews with district officials, irrigation regime is decentralized as follows: active irrigation; semi-active irrigation; difficult irrigation; no irrigation.

(8). Drainage regime: This criteria is decentralized including: active drainage; semi-active drainage; difficult drainage; self-flowing drainage.

For each assessment criteria, a thematic map will be established. Then, applying GIS technology to overlap thematic maps by UNION tool. The results are based on this differentiation, building a map of Quoc Oai district land unit with 34 land units numbered sequentially to differentiate the LUs. In particular, the land map unit 22 has the largest area (2853 ha); unit of land map 1 has the smallest area (8.5 ha).

4.1.2. Land use type

Based on map of the land use status in 2018, the annual land use yearbook in the district and the field survey, the research identified the district with 9 major land use types as shown in Table 2. However, this study selected 7 types of agricultural land use mainly including: rice (LUC); rice - fish (LUK); vegetables (HNK); perennial fruit trees (LNQ); tea (LNC); production forest (RSX); and protection forest (RPH). Because these are land use types that occupy the main area and are oriented in the land use planning of the district. In particular, LUT specialized in rice and LUT specialized in fruit trees account for the largest area on the district's map of agricultural land use.

Table 3. Types of major agricultural land use in Quoc Oai district

No	Name of LUT	Symbol	Area (ha)	Ratio compared to the total area of agricultural land (%)
1	Rice	LUC	4959.31	51.46

2	Rice - fish	LUK	250.74	2.60
3	Vegetables	HNK	784.46	8.14
4	Perennial fruit trees	LNQ	1631.01	16.9
5	Tea tree	LNC	137.0	1.42
6	Production forest	RSX	755.86	7.84
7	Protection forest	RPH	356.54	3.70
8	Freshwater aquaculture	TSN	533.94	5.54
9	Other agriculture	NKH	229.05	2.4

4.1.3. Agricultural land use system

Based on a combination of 34 LU and 7 agricultural land use type, the research identified the agricultural land use systems of Quoc Oai district. On the basis of GIS application, the research has been overlaps two maps: land mapping units và map of land use type. As a result, there are 46 agricultural land use systems in Quoc Oai district which will be the input of the process of assessing ecological adaptation, assessing economic efficiency, social efficiency, environmental efficiency and assessing the integration of land use systems in the study area. In this paper, we used 46 agricultural land use systems as input to the process to assessing ecological adaptation.

In order to identify agricultural LUS units, LUS is denoted by n - X, which X is the land use type, n is the land unit. For example, LUS is 22 – LUC (type of land use LUC on land unit 22). In a land use system, under the influence of person, the value of **X** is selected which is suitable in terms of ecological adaptation to the land unit **n**, it can create "specialties" or "geographical indications" for the locality. In Quoc Oai district, it is reputation for Dai Thanh late-ripening logan (Dai Thanh commune), Long Phu tea (Long Phu village) and Quang Yen vegetables (Quang Yen village). Besides, 2 products have been registered for geographical indications to protect local brands such as Long Phu tea and Dai Thanh late late-ripening logan. Thus, assessing the level of ecological adaptation of agricultural land use systems plays an important role in determining the potential for agricultural development and the orientation of the land use planning of Quoc Oai district.

4.2 Evaluate the ecological adaptation of Quoc Oai district agricultural land use system

4.2.1. Ecological demand of agricultural land use system

Each type of land use has different ecological needs to adapt, which has a weighting effect of different factors. Based on the expert method, the research identify the ecological needs and weights of each LUT in the LUS as follows:

Table 4. Decentralize the degree of adaptation of LUS

LUS	**Criteria**		**The appropriate level**

		Weight	Highly Suitable (4 points)	Moderately Suitable (3 points)	Marginally Suitable (2 points)	Not Suitable (1 points)
Rice	Soil type	0.13	Pk,Pg	Pb	Pj, Fl	Fk,Fs,J, Fp
	Texture	0.06	e	d	c	
	Topography	0.13	In the dyke	Alluvial ground	Low hill	High hill, mountain
	Soil depth	0.06	1	2	3	
	Irrigation regime	0.23	Active irrigation	Semi-active irrigation	Difficult irrigation	No irrigation
	Drainage regime	0.12	Active drainage	Semi-active drainage	Difficult drainage	Self-draining
	Bedrocks	0.03	a,am	ap	alb	b,s,v,t
	Slope	0.24	I	II	III	IV, V,VI
Rice-fish	Soil type	0.13	Pj	Pk, Pg	Pb, Fl	Fk, Fs, J, Fp
	Texture	0.06	e	d	c	
	Topography	0.12	In the dyke	Alluvial ground	Low hill	High hill, mountain
	Soil depth	0.06	1	2	3	
	Irrigation regime	0.24	Active irrigation	Semi-active irrigation	Difficult irrigation	No irrigation
	Drainage regime	0.12	Active drainage	Semi-active drainage	Difficult drainage	Self-draining
	Bedrocks	0.03	a,am	ap	alb	b,s,v,t
	Slope	0.24	I	II	III	IV,V,VI
Vegetables	Soil type	0.10	Pk,Pb	Fl, Fp	Pg	Fk,Pj,J,Fs
	Texture	0.16	c	d	e	
	Topography	0.14	Alluvial ground	In the dyke	Low hill	High hill, mountain
	Soil depth	0.07	1	2	3	
	Irrigation regime	0.14	Active irrigation	Semi-active irrigation	Difficult irrigation	No irrigation
	Drainage regime	0.27	Active drainage	Semi-active drainage	Difficult drainage	Self-draining
	Bedrocks	0.04	a	ap, am	alb	b,s,v,t
	Slope	0.07	I,II	III	IV	V,VI
Perennial fruit trees	Soil type	0.18	Pk	Fk,Fs,Fp,Pb	Fl	Pg,Pj,J
	Texture	0.06	e	d	c	
	Topography	0.17	In the dyke	Alluvial ground	Low hill	High hill, mountain
	Slope	0.18	II	I	III	IV,V,VI
	Soil depth	0.19	1	2	3	
	Irrigation regime	0.08	Active irrigation	Semi-active irrigation	Difficult irrigation	No irrigation
	Drainage regime	0.10	Active drainage	Semi-active drainage	Difficult drainage	Self-draining

	Bedrocks	0.04	a,am	ap,s,b	alb	v,t
Tea tree	Soil type	019	Fs, Fk	Fp	Fl	J,Pb,Pk,Pj,Pg
	Texture	0.06	d	c	e	
	Topography	0.16	Low hill	High hill	In the dyke	Alluvial ground, mountain
	Slope	0.21	III	II	I	IV,V,VI
	Soil depth	0.16	1	2	3	
	Irrigation regime	0.09	Active irrigation	Semi-active irrigation	Difficult irrigation	No irrigation
	Drainage regime	0.10	Active drainage	Semi-active drainage	Difficult drainage	Self-draining
	Bedrocks	0.04	s,b	ap	am	alb,a, v, t
Forests (including production forests and protection forests)	Soil type	0.23	Pbe, Pe,Fs, Fp	Fl	Pg	J, Pj
	Texture	0.07	e	d	c	
	Slope	0.20	IV,V,VI	III	II	I
	Soil depth	0.22	1	2	3	-
	Irrigation regime	0.10	Active irrigation	Semi-active irrigation	Difficult irrigation	No irrigation
	Drainage regime	0.05	Active drainage	Semi-active drainage	Difficult drainage	Self-draining
	Bedrocks	0.05	b,s,t,a	ap,am	alb	v
	Topography	0.08	Mountain, high hill	Low hill	In the dyke	Alluvial ground

4.2.2. Evaluating the current ecological adaptability of agricultural land use systems

The adaptability of land use systems is assessed by the comparison of the requirements of land use type with soil characteristics, topography, irrigation conditions, and drainage,... in each land unit according to the evaluation criteria. Follow FAO guidelines and refer to previous research experiences, the suitability level (S) of the soil is divided into three classes: Highly Suitable (S1); Moderately Suitable (S2); Marginally Suitable (S3). No Suitable level (N) is divided into 2 classes as Currently Not Suitable (N1); Permanently Not Suitable (N2).

Table 5: The results evaluated the adaptability of the land use system

Result	**Highly Suitable**	**Moderately Suitable**	**Marginally Suitable**	**Not Suitable**
Rice				
LUS	22-LUC; 23-LUC; 24-LUC; 25-LUC; 26-LUC; 28-LUC; 29-LUC; 32-LUC; 34-LUC	19-LUC; 20-LUC; 30-LUC; 33-LUC	11-LUC; 16-LUC; 18-LUC	6-LUC; 7-LUC; 9-LUC
Area (ha)	3689.01	528.4	580.8	161.1
Percentage (%)	74.39	10.65	11.71	3.25
Rice-fish				
LUS	-	27 – LUK	17 – LUK	-
Area ha)	-	217.74	33	-

Percentage (%)	-	86.84	13.16	-
Vegetables				
LUS	32-HNK	22-HNK, 24-HNK	16-HNK	14-HNK
Area (ha)	556.36	94.6	113.6	19.9
Percentage (%)	70.92	12.06	14.48	2.54
Perennial fruit trees				
LUS	24-LNQ; 32-LNQ	15-LNQ; 22-LNQ, 14-LNQ; 16-LNQ	6-LNQ; 9-LNQ, 10-LNQ; 11-LNQ	5-LNQ
Area (ha)	528.1	551.51	530.7	20.7
Percentage(%)	32.38	33.81	32.54	1.27
Tea tree				
LUS	-	14-LNC	-	-
Area (ha)	-	137.0	-	-
Percentage(%)	-	100	-	-
Forests (including production forests and protection forests)				
LUS	-	-	2-RPH, 3-RPH, 3-RSX, 4-RSX, 5-RSX, 6-RSX; 12-RSX, 13-RSX	-
Area (ha)	-	-	1112.3	-
Percentage (%)	-	-	100	-

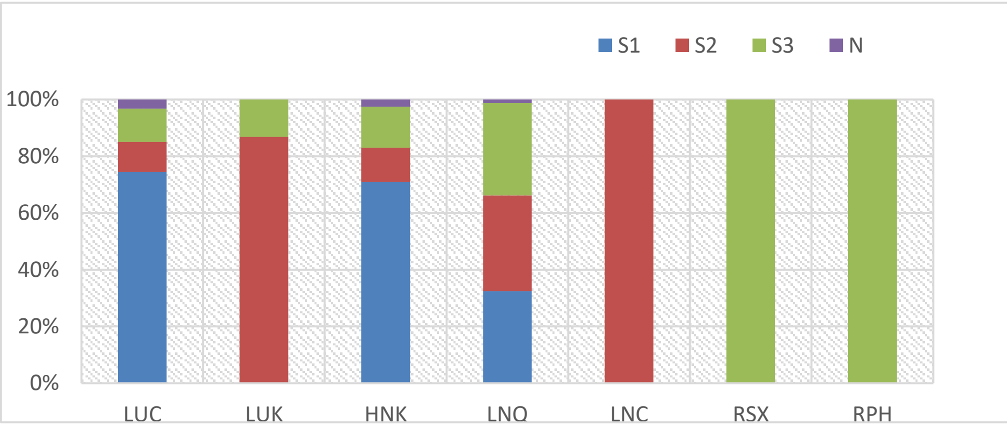

Fig 4. The chart compares the current level of adaptation of agricultural land use systems

4.2.3. Future trends of agricultural land use systems

The results of the current adaptation assessment for the LUSs in the study area reflect the natural productivity on each land use system and that is the basis for the orientation of the district's agricultural land use space. Thus, it is possible to maintain the existing LUS which are rated as highly suitable (S1) and moderately suitable (S2). For the marginally suitable (S3) and Not suitable (N) will conduct future adaptive assessments on the basis of considering and improving the limited elements in the land use system to orient the land use space of this group for more efficiency. With the system model, changing any of the inputs (e.g land reclamation,...) in the LUS also leads to the change of the output element of the LUS. At the same time, it is easy to identify which land use system is “Currently Not Suitable” or “Permanently Not

Suitable". For LUS which has "Permanently Not Suitable" will be recommended, so it is better to change the land use purpose.

Table 6. Summary results of future land adaptation area (%)

Land use system	Total area of investigation (ha)	Highly Suitable (S1)	Moderately Suitable (S2)	Marginally Suitable (S3)	Not Suitable (N)
Rice (LUC)	4959.31	74.39	13.9	11.71	-
Rice – fish (LUK)	250.74	217.74	33	-	-
Vegetables (HNK)	784.46	75.54	21.93	2.53	-
Perennial fruit trees (LNQ)	1631.01	42.38	23.81	33.81	-
Perennial industrial plants (tea) (LNC)	137.0	-	100	-	-
Production forests (RSX)	755.8	-	100	-	-
Protection forests (RPH)	356.5	-	100	-	-

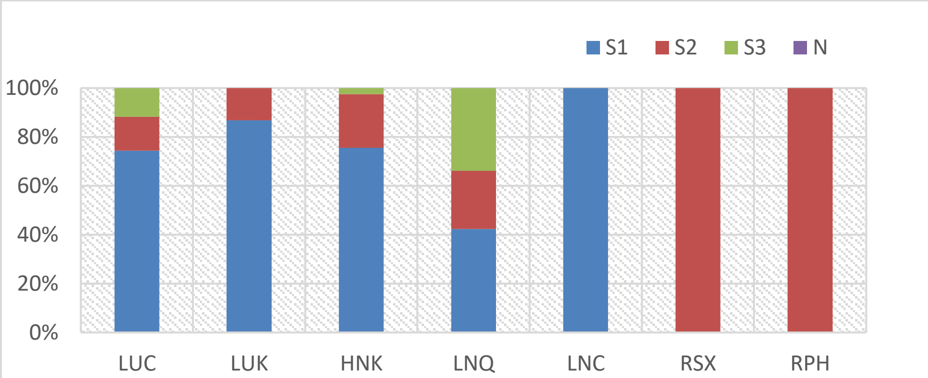

Fig 5. Chart comparing future adaptation levels of agricultural land use systems

In this district, land use system which is marginally suitable or non-suitable has the main limiting factor of irrigation and drainage regime. Improving and applying techniques in the marginally suitable or not suitable groups includes many different contents but most importantly is still irrigation. For Quoc Oai district area, the need for irrigation and drainage of agricultural LUS are considered necessarily. If this problem is solved, it will certainly increase the land adaptation capacity of each LUS. For example, from class "Currently Not Suitable" due to limiting factors are irrigation conditions, drainage conditions but in the future if the irrigation system is rehabilitated, it can be increased to Moderately Suitable (S2) or Marginally Suitable (S3). According to the chart, it is possible to compare the combined results between the current and future adaptation areas: in the future, if the research area has investment and improvement in irrigation system, it is certain LUS will greatly increase the level of adaptation. Most agricultural LUS are very adaptable and moderately adaptable. Non-adaptive ratio is not available. That means: in the future, to improve irrigation and drainage, the quality of land will be improved. Therefore, Quoc Oai district needs to focus on improving irrigation systems, so it is certain that agricultural land use systems will change in a better way and give higher productivity, especially LUS of rice.

Natural productivity (also known as the level of ecological adaptation) is a major factor that influences the cost of investment more or less of LUS. The higher the level of ecological adaptation, the less the investment cost of human will be. Therefore, based on the results of the assessment of ecological adaptation, the district has a high adaptive area for 7 agricultural LUS groups. This is the premise for the orientation of the land use planning towards the development of ecological villages and high-tech agriculture in the district. Thus, the annual LUS should be oriented in the eastern area of the district, where there is a flat terrain and suitable ecological conditions. LUS of perennial trees should be oriented in the mountainous areas in the west of the district.

5. CONCLUSION

Assessment of land use system is the research direction that creates an important scientific basis for the sustainable agricultural land use planning. The agricultural land use system in Quoc Oai district is quite diverse with 46 systems based on the analysis of 34 land units and 7 types of land use in the district. The results of the assessment of ecological adaptation of land use systems allow the identification of advantages and limitations in the development of agricultural land use systems in the area, including: LUS for rice, rice – fish, vegetables, perennial fruit trees, tea, production forests and protection forests. The land use system for perennial crops (tea, longan, pomelo) and LUS for vegetables have been prioritized for development in the land use planning until 2030 with a vision of 2050, due to a large area of adaptive and high economic efficiency. However, in order to serve the spatial orientation of more objective and accurate land use planning, it is necessary to further evaluate the economic, social and environmental efficiency of agricultural land use systems.

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