2. LITERATURE REVIEW

2.1 LAND EVALUATION

Land suitability evaluation is a process of assessing the suitability of land for specified kinds of use (Dent & Young, 1981). Purnell (1986) proposed that land evaluation is one way of improving managerial capabilities. It is an essential element in land-use planning that goes a step further, examines the options and systematically aids in the selection of the best alternative to meet the objectives of the land users. These induce productive use such as arable farming, together with uses that provide services or other benefit, such as tourism and wildlife conservation (Dent & Young, 1981).

Bennema (1973) suggested that land use planning is not included in land evaluation but the physical and part of the economic data for land use planning, an assessment of alternatives, should be provided by land evaluation. The basic of land evaluation is the comparison of the requirements of land use with resources offered by the land. The result of land evaluation is not complete without an economic and social study and an environmental impact analysis. The social study is necessary to ensure that any recommendations need and have the approval of the local community, without which they are doomed to failure. The environmental impact study is partly to ensure that on-site degradation has been thoroughly covered, but more particularly to investigate the off-site or downstream effects (Purnell, 1986).

There are several approaches to land evaluation, lead to alternative systems based on different principles (Abdulkadir, 1987). The world-wide uses are Land Capability Classification of USDA (Rossiter, 1990) and FAO Framework for Land Evaluation (FAO, 1976).

2.2 LAND SUITABILITY CLASSIFICATION

2.2.1 USDA System

To response to anyone other than soil scientists who wants to use not only the soil map but also the interpretations of the pedological of the soil map, the first approach to make natural resources inventories more accessible and useful to land use planning was made in the 50s and 60s (Higgins, 1978). The system of land capability classification has been found by experience to meet the needs of users. A world wide application, published in 1961, was the Land Capability Classification, the comprehensive handbook, formalized by Klingebiel and Montgomery (Dent & Young, 1981; Abele 1988; DeRoller, 1989). The technique was developed by the Soil Conservation Service of the United States Department of Agriculture (USDA) (Davidson, 1980).

The primary aim of the USDA method is to assess the degree of limitation to land use or potential imposed by land characteristics on the basic of permanent properties (Davidson, 1980). Those comments need to be made about the nature of permanent properties or limitation that base on a broader range of characteristics (i.e., slope angle, climate, and erosion hazard) than just pure soil properties (Davidson, 1980; Dent & Young 1981). There are three levels in its classification structure which consist of capability class, capability subclass, and capability unit. The capability class is divided into eight classes or types of land in which class I to class IV are cultivable whist the remaining classes are not. The ranges of land use options decrease when the degree of limitations and hazards increase.

The idea of capability class is the potential of the land for use in particular class and for all classes below it. They neither imply the best use for land nor express any profitable but only recommend the range of uses to each area (Dent & Young, 1981). For its simple in principlicity and easiness to present as the capability map, the USDA system had been applied to use in other counties, e.g., Canadian Land Capability Classification, Land Use Capability Classification: The British Method, LUS system in Zambia, Soil Interpretation Handbook for Thailand (Beek, 1978; Davidson, 1980; Mumba & Heilmann, 1980; Jangprai, 1990).

The criticism made against the USDA Land Capability System was not only for its generously specific in its correlation between land features and land capability class. The socio-economic analysis cannot rely altogether on the information produced from the capability map because it was not concerned with or specific land use type but only generalized types of land use (Beek, 1978). Dent & Young (1981) observed that it assumed arable use to be the most desirable; it strongly biased towards considerations of soil conservation; and it biased on negative land features. Purnell (1986) commented on its less successful in classifying land for other purposes.

2.2.2 USBR System

Land Suitability Classification according to the USBR system is the system developed by the United States Bureau of Reclamation for their irrigation development schemes. It is the economic system that defines land classes according to the relative degree of payment capacity, the amount of money left to a farmer after he paid all cost (excluding water charges) and allowance is made for family living (Devidson, 1980; EUROCONSULT, 1989).

There are two categories, classes and subclasses, given by quantitative economic significant through the farm budget studies (FAO, 1985). Six classes are assigned based on economic of production. Class I to class IV are used to identify the arable land for their suitability to the irrigation use. Class V is the alternate non arable land because of same specific deficiency (e.g., excessive salinity, undulating land, flooding hazard) that may be improved but need for further studies. Class VI is non arable land for that project economic condition. Land subclasses are categories within land class (only class II-VI) identifying a deficiency or deficiencies (EUROCONSULT, 1989; Jangprai, 1990) for example s -- soil deficiency, f -- flooding problem.

The mapping symbols by USBR system are similar to those by USDA system. The difference between these two systems is the method used to evaluate land. USBR system does not include weather data in evaluation process because it produces for irrigation system and it needs more additional informative appraisal than the USDA system such as soil productivity, land development cost, water requirement, land drainability and present land use (Jangprai, 1990).

2.2.3 FAO Land Evaluation Method

By 1970, many countries have developed their own systems of land evaluation. FAO's activities in this regard began with practical experience in field project and developed a framework for land evaluation by which land can be assessed (Beek, 1978). FAO has prepared a manual, entitled "*Framework for Land Evaluation*" (FAO, 1976). Land evaluation has been defined by FAO as:

> *The process of assessment of land performance when used for specified purposes, involving the execution and interpretation of surveys and studies of land forms, soils, vegetation, climate and other aspects of land to identify and make a comparison of promising kinds of land use in terms of applicability to the objectives of the evaluation.*

The FAO manual, intended to have world-wide application, is based on the concepts and procedures of land evaluation that have evolved during FAO assisted development projects. Figure 1 illustrates this procedure.

The critical step in the FAO method is to define objective since it relates to the levels of planning the study can be served. This is in turn limit

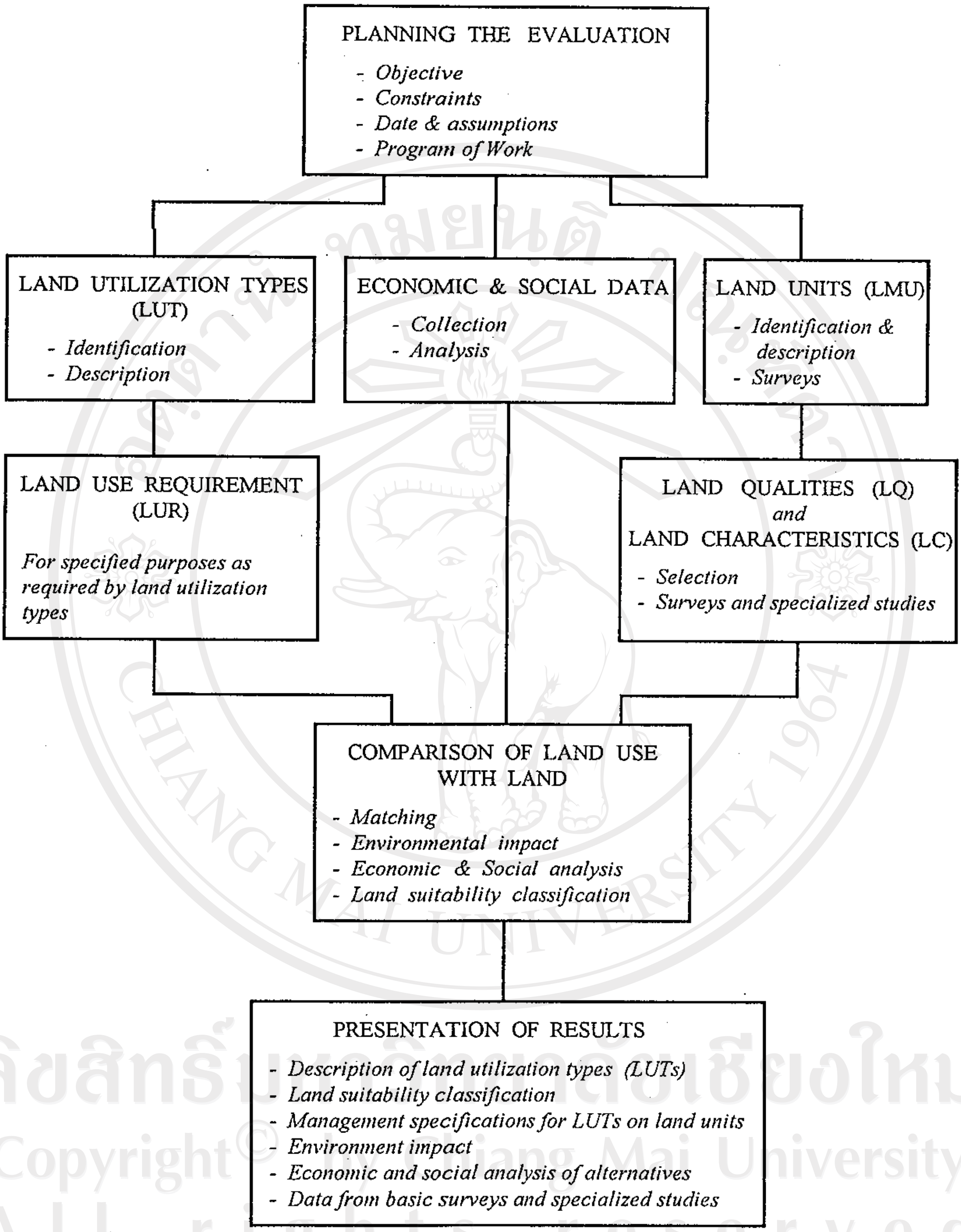

Figure 1. Procedures in land evaluation (FAO, 1984; Dent and Young, 1981).

the range of limitation needed and the types of surveys necessary. The objective of land evaluation must include the comparison between existing suitability of a particular use with other feasible uses of the same land. Environmental conservation is also taken into account for the objective of land evaluation (FAO, 1976).

The FAO framework recognizes four main kinds of suitability classification as they are quantitative classification, qualitative classification, classification of current suitability, and classification of potential suitability. There are four categories in the suitability classification.

i. Land Suitability Orders:	reflecting kinds of suitability.
ii. Land Suitability Classes:	reflecting degrees of suitability within orders.
iii. Land Suitability Subclasses:	reflecting kinds of limitation or kind of improvement required within classes.
iv. Land Suitability Units: required management within	reflecting minor difference in subclasses.

The symbols used are summarized in the Table 1.

Table 1. The symbols used in the FAO land evaluation method.

ORDER	CLASS	SUBCLASS	UNIT
S	S1		
	S2	S2n	S2n-1
	S3	S2f	S2n-2
		S2nf	
N	N1	N1w	
	N2	N1s	

The FAO evaluation process requires multidisciplinary approach from the field of natural science, technology of land use, economics and sociology. The suitability evaluation is made in term of relevance to the physical, economic and social context of the area considered. The comparison between different areas will be difficult to do for their different assumption. The assumption should be definitely expressed to avoid misunderstanding and to assist in comparisons between different areas.

The suitability classes are determined by the relationship between benefit and inputs. It should be expected that the class criteria can be reviewed on correction with time according to possible change in economic or social conditions and technology development (FAO, 1976; EUROCONSULT, 1989). Other main tasks of evaluators are describing land use requirements of individual land use types based on specified assumptions (Davidson, 1986).

The benefits of using land and the proper use for certain area result from FAO method are very useful for further step in land use planning. This information cannot be obtained from the USDA system nor the US Bureau of Reclamation (USBR) system (Jangprai, 1990).

The USBR land classification for irrigation, devised many years earlier, closely follows the procedures of specific-purpose economic suitability classification. USBR class I-III corresponds to suitability class S1 to S2 while class IV should be regarded as conditionally suitable, Class V as N1 and class VI as N2 (Dent & Young, 1981).

2.3 Land Evaluation in Thailand

The formal land evaluation system was initiated in Thailand using the USBR system that was adapted for the Feasibility Study of the Pamong Irrigation Development Project, Phase I in 1963 by the Department of Royal Irrigation, Ministry of Agriculture and Cooperative (Jangprai 1990). This system was modified later to be used as Irrigation Development Project Appraisal. It sets aside to the project purpose more precise than the USDA system because of its economic analysis and the aim of irrigation project evaluation.

The USDA land capability classification was implemented by the Department of Land Development (DLD) in 1964 (Jangprai, 1990). In 1973, DLD in collaboration with USAID and FAO adapted this system for agricultural appraisal in Thailand. They published the "*Soil Interpretation Handbook for Thailand*" that served as the land assessment for paddy rice, field crop and rubber tree. The Soil Survey Division, Department of Land Development improved this handbook for more application use and produced the manual called "*Land Suitability Classification of Economic Crops of Thailand*" in 1980 (Manajuti, 1987). This manual uses the physical environment of soil to build the table for suitability classification of particular crop. From these tables, the suitability classification of particular crop for each soil unit is ranked. DLD did not evaluate the economic suitability realizing that the economic conditions change quickly and large scale computation cannot be easily achieved with the manual method. Another weakness of this system is that land is evaluated for the single crop in rainy season not for multiple cropping.

The National Economic and Social Development Board also implemented FAO land suitability classification for the project appraisal on land development assessment in the western part of Thailand in 1980. Afterwards, FAO method has been used to evaluate the suitability of many important crops grown in Thailand by DLD since 1984. DLD also applied this method for land use planning at the provincial level.

2.4 AUTOMATED METHOD IN LAND EVALUATION

The evaluation method requires voluminous data and is tedious if many possibilities are to be compared. Manual procedures, both for construction of matching tables or transfer function and for calculation of suitability, are time-consuming and error proned (FAO, 1984; Rossiter, 1990). However, these can be easily facilitated by using a computer in storage and retrieval of data, in data manipulation and in the graphic presentation. Along with convenience in handling large amounts of data, computerized methods will rapidly revise the set of results when the initial data are changed (FAO, 1984).

Until now, many computer programs for land evaluation assessment are already available and the power of the micro-computer is highly increasing. This will make it possible to carry out basic land evaluation queries even in the provincial offices.

2.5 AUTOMATED LAND EVALUATION SYSTEM (ALES)

The ALES is a computerized realization of the FAO's framework that allows land evaluators to build their own knowledge base system with which they can compute the physical and economic suitability of land map unit. Evaluators build decision trees to express inferences from land characteristics to land qualities, from land qualities to predicted yields and from land qualities to overall physical suitability (Rossiter, 1990).

Land evaluation models predict the performance of areas when used in certain ways. ALES allows the evaluator to edit all data, parameters, and decision trees that entered into the current step of the computation until the evaluator is satisfied with the validity of the preliminary model. Figure 2 shows the flow in building a model.

Three main modules are provided by ALES:

i. ALES knowledge base;
ii. ALES decision tree;
iii. Physical and economic suitability evaluation.

The knowledge base represents the fact and the inferences needed to arrive at decision that consist of a set of proposed land use, a set of output and a set of land characteristics. The inferential knowledge is expressed in form of decision trees. Decision trees are user-constructed hierarchical multiway keys in which the leaves are results, the branches are the selected choice and the nodes of the trees are decision criteria. The results are usually presented as classified values.

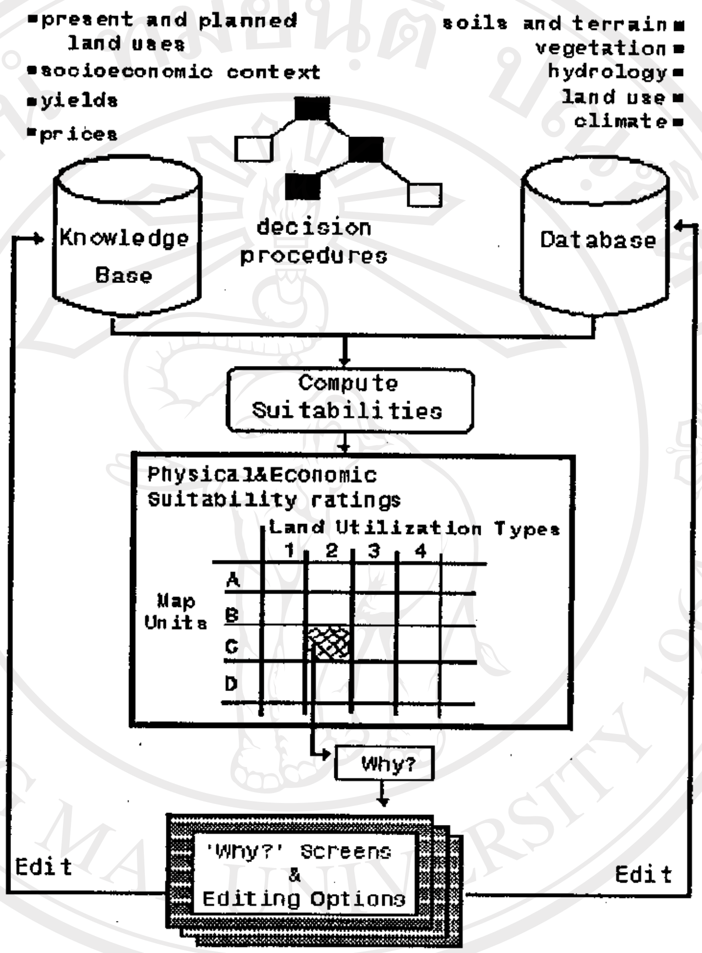

Figure 2. ALES program flow (Rossiter, 1990).

Physical suitability classification is achieved from matching of land use with land unit throughout the decision trees. The economic suitability can be estimated by using gross margin analysis for the land that can be used which determined by the physical suitability. As if the physical suitability is worst then the economic suitability is useless (Rossiter, 1990).

Data and information from ALES can be exchanged with other systems in form of ALES database, ALES knowledge base and the rational tables of land evaluation database. These are useful in any purpose such as to use the ALES knowledge base for field manual or as the public report. The rating table of land evaluation can be exported to the geographic information system and rebuilt as a layer for future spatial analyses.

2.6 Crop Yield Assessment for Land Evaluation

Input and output, such as nutrient and water requirements and expected crop yields of current and potential land utilization types have to be quantified in later stage of land evaluation (Van Lanen et al., 1992a). That information can be taken either from farmers' experience, expert judgment or experimental data (DeRoller, 1989; Van Lanen et al., 1992c). Yield values can also be obtained from productivity indices and empirical or mechanistic crop growth models (Dumanski & Onofrei, 1989).

Observed data, derived from farmers' estimate or by summarizing the expert opinions, can be converted to comparative indices and then can be used in the identification and comparison of potential land use alternative.

The study in Guatemala by DeRoller (1989) is an example of this performance.

Crop growth modeling is another procedure for estimating yield in the assessment of land evaluation (Johnson & Cramb, 1991). Many crop simulation models that predict crop yields have been developed (Burrough, 1989). The most extensive use of simulation modeling for land evaluation is being done by the International Benchmark Site Network for Agrotechnology Transfer (IBSNAT). Their goal is to predict crop performance, using validated models, for areas where the crop has not been grown (DeRoller, 1989). They have developed the Decision Support System for Agrotechnology Transfer (DSSAT), a computer software system, to be decision making tools that simulate outcomes of crop management strategies over time (IBSNAT Project, 1989). It consists of three components, database management system (DBMS), the crop models and the application programs. The DBMS is used to organize and to store the minimum data set (DMS) required by crop models. Three groups of crop models are available comprising of the simulation models for cereals, grain legumes and root crops. The application programs consist of the Strategy Evaluation program and the Weather Estimator program.

Other examples are the EPIC (Erosion Productivity Impact Calculator) and the PIXMOD (Productivity Index Model) with good potential for land evaluation. The EPIC model was developed to determine the relationship between soil erosion and soil productivity (William et al., 1990). It is composed of physically based components for simulating erosion, plant growth, and related processes and economic components for assessing the cost of erosion, determining optimal management strategies, etc. EPIC provides yield estimate for maize, soybean, winter and spring cereals, sunflower, soybean, alfalfa, cotton, peanut and grass. The PIXMOD estimates rainfed spring wheat yields from weather data during a given growing season, and for given soil and management conditions (Dumanski & Onofrei, 1989).

The WOFOST is also a good example of crop growth model that simulates the growth and yields of a crop and the soil water balance on a daily time steps under prevailing weather and site condition (Van Lanen et al., 1992(a); Van Lanen et al., 1992 (b)).

2.7 Evaluation of Results

The land evaluation results can be represented in many forms. The results from the ALES program were displayed in the evaluation matrix of physical suitability subclass, economic suitability class, gross margin, cost, return, land quality values and yields. The suitability class, both physical and economic, can also be represented by maps through the IDRISI, a grid-based geographic analysis system, program (Eastman, 1993). The evaluation results from the ALES database can be converted to show in raster images of IDRISI program by the ALIDRIS module of the ALES program (Rossiter, 1992).

To compare the evaluation results with the existing land use in the area, a technique in performing the accuracy assessment is required. The map similarity comparison has been investigated for more than 25 years. The most common way to represent the accuracy assessment is in the form of error matrix. The error matrix is a square array of numbers set out in rows and columns that express the number of sample units (i.e., pixels, cluster of pixels) assigned to a particular category relative to the actual category as verified on the ground (Congalton, 1991).

The error matrix can be used as a series of descriptive and analytical statistical techniques. In the descriptive technique, the total number of correct pixels in a category is divided by the total number of pixels of that category. The analytical statistical technique is in the form of the discrete multivariate method. One is called KAPPA analysis which results in the KHAT statistic computed as,

$$KHAT = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}$$

where: r = the number of rows in the matrix

x_{ii} = the number of observations in row i and column i

x_{i+} = the marginal totals of row i

x_{+i} = the marginal totals of column i

N = total number of observations

The result of the KHAT statistics lies between -1 to +1 which indicating either complete disagreement or complete agreement.