CHAPTER II

LITERATURE REVIEW

2.1 Preliminary Definitions

These definitions are synthesized from Food and Agriculture Organization of The United Nations (FAO) 1976, 1983, 1984, 1985.

Land: An area of the earth's surface, the characteristics of which embrace all reasonably stable, or predictably cyclic, attributes of the biosphere vertically above and below this area, including those of the atmosphere, the soil and underlying geology, the hydrology, the plant and animal populations, and the results of past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of the land by humans. Rossiter (1996) suggested include time-series of land attributes, thereby weakening the requirement that these be stable or predictably cyclic.

Land Evaluation: The process of predicting the use potential of land on the basis of its attributes. It does not include optimal land allocation. However, land evaluation supplies the technical coefficients necessary for optimal land allocation.

Land Mapping Unit (LMU): A specific area of land that can be delineated on a map and whose land characteristics can be determined. It is the evaluation unit about which statements will be made regarding its land suitability. The LMU can be a grid cell, a single map delineation (polygon), or a set of map delineations with common Land Characteristics, i.e. a legend category of a thematic map. Land that has not been, or can not be mapped may be evaluated at specific locations.

Land Characteristic (LC): A simple attribute of the land that can be directly measured or estimated in routine survey, including remote sensing and census as well as natural resource inventory. The same LC can be measured at different times, resulting in a time-series of values. The LC can be measured at different points or areas within the LMU, but for land evaluation purposes, these individual observations are usually aggregated or summarized to a single value or a parameterized distribution. Bouma *et al.* (1996) provide a useful classification of LCs along three axes: (1) sample size ("point" or minimum representative volume versus area), (2) time-series or repeated measurements versus a single point in time, and (3) method of obtaining the value: measurement, estimate, pedotransfer function or simulation model.

Land Utilization Type (LUT): A specific land-use system with specified management methods in a defined technical and socio-economic setting, and with a specific duration or planning horizon. The description of a LUT may include a time-series of activities and outputs. The definition of a LUT is not a complete description of the farming or other land-use system: it includes only those attributes that serve to differentiate the suitability of land areas, for example, those that can be expressed as Land use requirements with critical values in the study area. The definition of a LUT also includes attributes that limit the land use options by discarding those that are a priori unfeasible over the entire evaluation area.

Land Use Requirement (LUR): A condition of the land necessary for successful and sustained implementation of a specific Land Utilization Type. A LUT may be defined by a set of LURs. A LUR expresses the "demand" side of the land use-land area matching procedure.

Land Quality (LQ): A complex attribute of land which acts in a manner distinct from the actions of other land qualities in its influence on the suitability of land for a specified kind of use; the ability of the land to fulfill specific requirements for a LUT. It can not usually be measured or estimated in routine survey, and so must be inferred from a set of "diagnostic" land characteristics. The LQ expresses the "supply" side of the land use versus land area matching procedure. If the LUT is defined as a set of LURs, Land Suitability is based on the set of severity levels of the LQs corresponding to the LURs. The value of a LQ may vary over time, resulting in a time-series of severity levels.

Land Suitability: The fitness of a given LMU for a LUT, or the degree to which it satisfies the land user. In a more operational sense, suitability expresses how well the LMU matches the requirements of the LUT. It may be expressed on a continuous scale of "goodness" or, more commonly, as a set of discrete classes, which are conventionally numbered from class 1 meaning "completely suited" upwards to some maximum meaning "completely unsuited".

2.2 FAO Land Evaluation Method

Land evaluation is normally carried out by matching land quality and land use requirement. Overall physical suitability of each land mapping unit for each land use type is the result of combining the factor ratings for each land quality in some ways to obtain overall measure of suitability. Rossiter (1994) described the ways in which the evaluation can be performed by this combination according to the maximum limited method, algebraic combination of land quality rating, and multi-criteria decision making approach.

Land suitability evaluation for sustained crop production involves the interpretation of data relating to soils, vegetation, topography, climate, etc., during an effort to match the land characteristics with crop requirements. Based on the suitability of land characteristics to different crops The Food and Agricultural Organization (FAO, 1976) proposed land evaluation in terms of two broad classes, "suitable". (S) and " not suitable " (N).

Class S1: Highly suitable: land having no significant limitations for sustained applications to a given use, or only minor limitations that will not significantly reduce the productivity.

Class S2: Moderately suitable: land having limitations that in the aggregate are moderately severe for sustained application to a given use and may reduce the productivity marginally. These lands have slight limitations and/or no more than three moderate limitations.

Class S3: Marginally suitable: land with limitations that in the aggregate are severe for sustained application to a given use and as such reduce productivity significantly but is still marginally economical. These lands have more than three moderate limitations and/or more than one severe limitation that, however, does not preclude their use for the specified purposes.

Class N1: Currently not suitable: land that has qualities that appear to preclude sustained use of the kind under consideration.

Class N2: Permanently not suitable.

According to Rosstiter (1996), the logic that makes land evaluation possible and useful can be summarized as follows:

1. Land varies in its physical, social, economic, and geographic properties ("land is not created equal");
2. This variation affects land uses: for each use, there are areas more or less suited to it in physical and/or economic terms;
3. The variation is at least in part systematic, with definite and knowable causes, so that...;

4. The variation (physical, political, economic and social) can be mapped by surveys, i.e. the total area can be divided into regions with less variability than the entire area;

5. The behavior of the land when subjected to a given use can be predicted with some degree of certainty, depending on the quality of data on the land resource and the depth of knowledge of the relation of land to land use, therefore...;

6. Land suitability for the various actual and proposed land uses can be systematically described and mapped, so that...;

7. Decision makers such as land users, land-use planners, and agricultural support services can use these predictions to inform their decisions.

Modern land evaluation practice grew out of agricultural land capability classification as reviewed by McRae and Burnham (1981) and Olson (1974), beginning with the work of Stewart (1968), through the doctoral dissertation of Beek (1978) and working groups of mostly European soil scientists in the 1970s. The Food and Agriculture Organization of the United Nations (FAO)'s leading to publication of the "Framework for Land Evaluation" in 1976 (FAO, 1976). Subsequently, the FAO organized workshops leading to publication of guidelines for land evaluation in rainfed agriculture (FAO, 1983), forestry (FAO, 1984), irrigated agriculture (FAO, 1985), extensive grazing (FAO, 1991), steeplands (Siderius, 1986), and guidelines for land use planning (FAO, 1993) provides standards, definitions and a description of land qualities that can be formed from land characteristics. It also sets the guidelines for physical and economical land evaluation that seems to be a worldwide application. However, FAO allows local variations and many different implementation methods. The FAO manual is world-wide application, it based on concept and procedures of land evaluation (Figure 2.1).

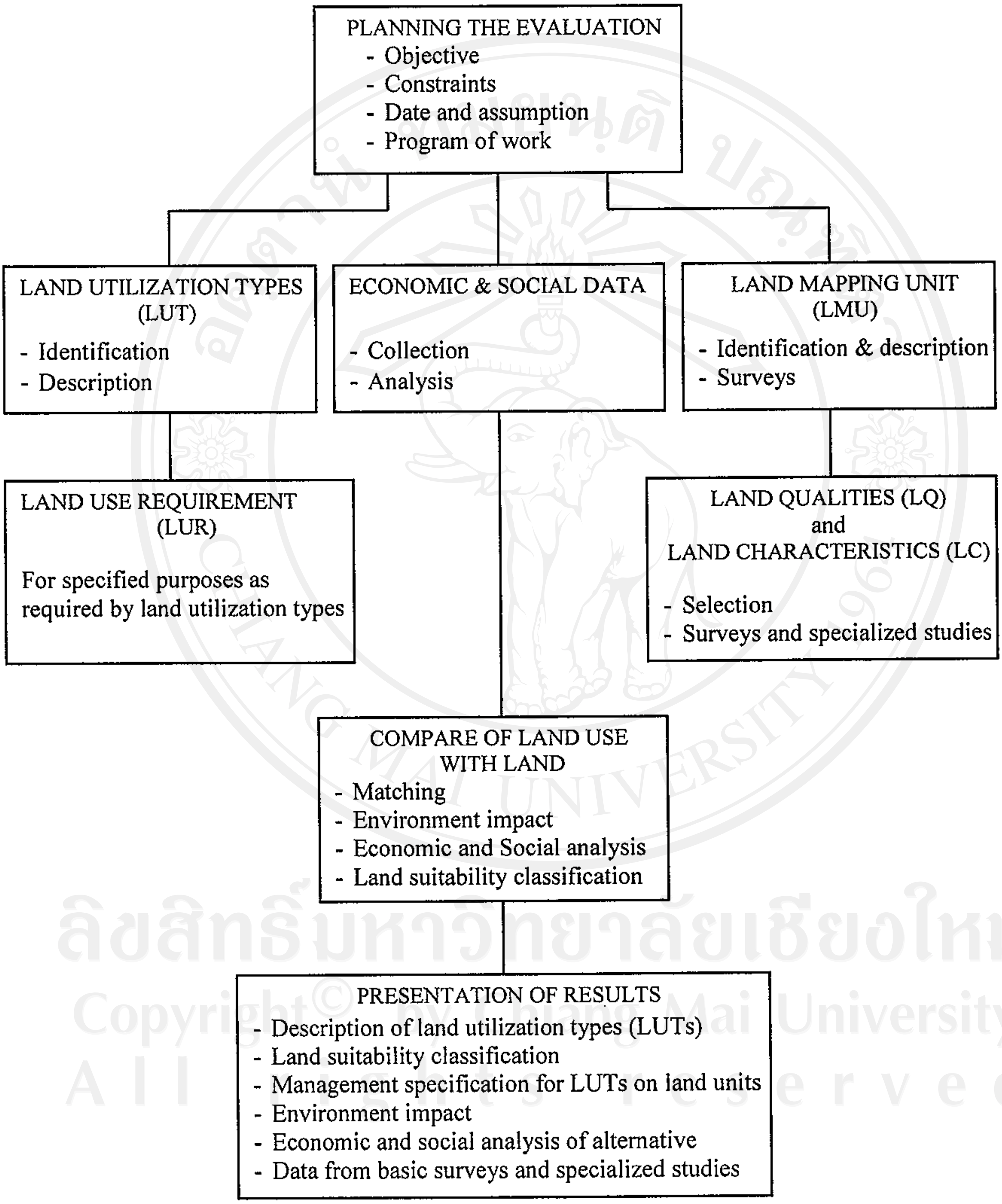


Figure 2.1 Procedures in land evaluation (FAO, 1984; Dent and Young, 1981).

2.3 Automated Land Evaluation Method

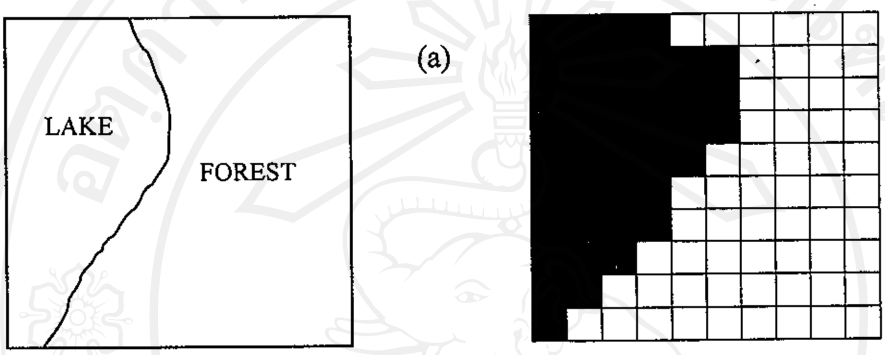
Automated land evaluation method is a computerized realization of the FAO's framework that allows land evaluator to build their own knowledge base system with which they can compute the physical and economic suitability of LMU. Evaluators built decision trees to express inferences from land characteristics to land qualities, from land qualities to predicted yields and from land qualities to overall physical suitability (Rossiter, 1994).

Automated land evaluation method can be easily facilitated by using computer in storage and retrieval of data manipulation and graphic presentation. Along with convenience in handling large amounts of data, computerized method allows evaluator to edit or change data, parameters and decision trees to obtain the set of results quickly.

Many attempts have been made to automate land evaluation process. The mathematical or quasi-mathematical models are used to describe the relationship between land characteristics, water and climate and the desired land qualities. There are many kinds of models available ranging from very simple to highly complex. The kinds of models used in land evaluation are empirical models, deterministic process models and stochastic process models (Burrough, 1989).

2.4 Fuzzy Land Evaluation

Fuzzy set theory was introduced by Zadeh (1965) and the definitions of fuzzy set and fuzzy membership (Kauffman and Gupta, 1985; Zimmermann, 1955). Fuzzy set theory is a powerful tool to model imprecise and vague situations where exact analysis is either difficult or impossible. Central to the theory is the concept of fuzzy set, which is a class of elements or objects without well-defined boundaries between those objects that belong to class and those that do not. It allows the objects to belong partly to multiple sets (Figure 2.2). Fuzzy logic is useful for describing the vagueness of entities in the real world, where belonging to a set is really a matter of degree. It is basically a multivalued logic that allows intermediate values to be defined between conventional evaluations such as, yes/no, true/false, and black/white (Malczewski, 1999). Fuzzy set theory provides useful concepts and tools for representing geographical information more complex (Wang *et al.*, 1990).



(a)

(b)

0	0	0	0	.1	.5	.9	1	1	1
0	0	0	0	0	.2	.5	.8	1	1
0	0	0	0	0	.2	.6	1	1	1
0	0	0	0	.2	.3	.7	1	1	1
0	0	0	.1	.2	.6	.9	1	1	1
0	0	.1	.3	.6	.7	.9	1	1	1
0	.1	.2	.2	.7	.8	1	1	1	1
0	.1	.2	.6	1	1	1	1	1	1
.1	.1	.6	1	1	1	1	1	1	1
.1	.6	1	1	1	1	1	1	1	1

Fuzzy region: FOREST

1	1	1	1	.9	.5	.1	0	0	0
1	1	1	1	1	.8	.5	.2	0	0
1	1	1	1	1	.8	.4	.1	0	0
1	1	1	1	.8	.7	.3	0	0	0
1	1	1	.9	.8	.4	.1	0	0	0
1	1	.9	.7	.4	.3	.1	0	0	0
1	1	.8	.8	.3	.2	0	0	0	0
1	.8	.4	.1	0	0	0	0	0	0
.9	.9	.4	.1	0	0	0	0	0	0
.9	.4	.1	0	0	0	0	0	0	0

Fuzzy region: LAKE

Figure 2.2 Crisp versus fuzzy (a) crisp presentations (b) fuzzy presentations (Malczewski, 1999).

2.3 Land Evaluation in Vietnam

Vietnam soil scientists also evaluate land using FAO methods. From 1990 to 1993 many land evaluation has been done in many programs for nine ecological regions of Vietnam with map scale of 1:250,000 (Institute of Planning and Designing Agriculture of Vietnam, 1994). This research specially focused on there following: (i) soil pollution and classification, (ii) physical, chemical and biological characteristics of soil, (iii) building soil map in different scales, and the lastly land information on quality and quantity to make scientific premise for land use and management.

The program for the Eastern region of the south of Vietnam created soil map with scale 1/250,000 was done by Sub-Institution for Agricultural Planning and Projection in South Vietnam based on the previous research from 1978 to 1988. Total 8 soil groups and 44 soil units were generated followed new soil classification is base on the soil properties and identification of elementary soil process. The delineation, rectifying and amending boundaries of spatial distribution based on comparison of the correlation between existing soil maps and geological maps of the region. The field verification was conducted in establishing soil classification and in correcting contours of mapping unit (Phan, 1992).

In Dong Nai province, land was evaluated in 1996 for its potential of agricultural land productivity. The maximum limitation method was applied. It was suggested that industrial perennial crops, fruit trees, soybean, corn, and cotton will become the strength of the province (Vu *et al.,* 1996).

Land evaluation of mountainous Doan Hung district, Phu Tho province at a scale of 1:25,000 used GIS technique was completed in 1999 (Duc, 1999).

A program for land evaluation in Bac Lieu province in Mekong delta, applied GIS software and FAO land evaluation method. The project aimed to create thematic maps such as, land mapping unit, and land suitability maps for crops. This study played an important role in land use planning in Bac Lieu province (Nguyen, 2000).

2.4 Geographic Information Systems (GIS) and Land Evaluation

There have been a number of attempts to define a GIS. On careful scrutiny, most definitions of GIS focus on two aspects of the system: technology and problem solving. GIS is conventionally seen as a set of tools for the input, storage and retrieval, manipulation and analysis, and output of spatial data. Accordingly, the technological perspective on GIS identifies four components of the system: data input, data storage and management, and data manipulation and analysis, and data output. Data input refers to the process of identifying and gathering the data required for a specific application. The process involves acquisition, reformatting, georeferencing, compiling and documenting the data. The data input component converts data from their raw or existing form into one that can be used by a GIS. The systems typically provide alternative methods of data input including: keyboard entry for non-spatial attributes and occasionally locational data, manual locating devices, automated devices, or the importation of existing data files. The data storage and management component of a GIS includes those functions needed to store and retrieve data from the database. The methods used to implement these functions affect how efficiently the system performs operations with the data.

Most GIS systems are database oriented. The database can be defined as a collection of non-redundant data in a computer organized so that it can be expanded, updated, retrieved and shared by various uses (Malczewski, 2004). The distinguishing feature of a GIS is its capability of performing an integrated analysis of spatial and attribute data. The data are manipulated and analyzed to obtain information useful for a particular application. There is an enormously wide range of analytical operations available to the GIS users and a number of classifications of those operations have been suggested.

The data output component of a GIS provides a way to see the data, information in the form of maps, tables, diagrams, etc. The output displays the results of GIS data processing and analysis to the users. The results may be generated in the hardcopy or electronic format. Maps are the most standard output format, but frequently are accompanied by tabular display. A variety of output devices are used, including display monitors, pen plotters, electrostatic plotters, laser printers, line printers, dot matrix printers (Malczewski, 2004). Results, particularly in the map forms, are often modified or enhanced interactively through cartographic map composition functions to add elements such as legends, titles, north arrows, scale bars, color modification, and symbology adjustments. Output functions are determined by the user's needs, and so user involvement is important in specifying the output requirements. In addition, two forms of data output from GIS can be distinguished: display and transfer. The former presents the information to the GIS user in some form (maps and tables). The latter transmits the information into another computer-based system for further processing and analysis. Digital data can be output directly to disk, tapes, or a network and than input into another computer-based system (Malczewski, 2004).

The evolution of GIS-based land suitability modeling has been a function of the development of information technology in general and geographic information technology, in particular. It is also a function of the evolving perspectives of planning and GIS. The modern era in GIS can be divided into three time periods: (i) the GIS research frontier period in the 1950–1970s which can be referred to as the innovation stage, (ii) the development of general-purpose GIS systems in the 1980s or the integration stage, and (iii) the proliferation stage which is characterized by the development of the user-oriented GIS technology in the last decade. The progression in the GIS development corresponds to the likewise evolving perspectives of planning. The primary focus has been shifted over time from the scientific, system approaches, through political perspectives to the public participatory and collective design approaches (Brail and Klosterman, 2001). The GIS development and the changing perspective of planning have been influencing the methods and approaches used in the land suitability analysis (Collins *et al.*, 2001)

The GIS-based approaches to land suitability analysis have their roots in the applications of hand-drawn overlay techniques used by American landscape architects in the late nineteenth and early 20th century (Collins *et al.*, 2001). McHarg (1969) advanced the overlay techniques by proposing a procedure that involved mapping data on the natural and human-made attributes of the environment of a study area, and then presenting this information on individual, transparent maps using light to dark shading (high suitability to low suitability) and superimposing the individual transparent maps over each other to construct the overall suitability maps for each land use. The overlay procedures play a central role in many GIS applications (O'Sullivan and Unwin, 2003) including techniques that are in the forefront of the advances in the land-use suitability analysis such as: multicriteria decision analysis (MCDA) (Malczewski, 1999). Over the last forty years or so GIS-based land-use suitability techniques have increasingly become integral components of urban, regional and environmental planning activities (Brail and Klosterman, 2001).

One of the most useful applications of GIS for planning and management is the landuse suitability mapping and analysis (Brail and Klosterman, 2001). Broadly defined, land suitability analysis aims at identifying the most appropriate spatial pattern for future land uses according to specify requirements, preferences, or predictors of some activity (Collins et al., 2001). The GIS-based land suitability analysis has been applied in a wide variety of situations including ecological approaches for defining land suitability, habitant for animal and plant species (Store and Kangas, 2001), geological favorability (Bonham, 1994), suitability of land for agricultural activities (Kalogirou, 2002), landscape evaluation and planning (Miller et al., 1998), environmental impact assessment (Moreno and Seigel, 1988), selecting the best site for the public and private sector facilities (Church, 2002), and regional planning (Janssen and Rietveld, 1990). This monograph focuses on land suitability analysis as applied to urban, regional, environmental planning and management rather than agricultural, ecological, geological applications.

Most GIS have been developed with theories of spatial representation and of computing in mind, and with strong assumptions about the instrumental rationality underlying planning procedures. Instrumental rationality is based on a positivist ideal, which puts spatial reasoning and scientific analysis at the core of planning. It assumes a direct relationship between the information available and quality of planning and decision making based on this information. On the other hand, communicative rationality postulates an open and inclusive planning process, public participation, dialogue, consensus building, and conflict resolution (Innes, 1995). Klosterman (2001) has characterized the 1990s as the period of 'collective design' in information technology where processes are designed to facilitate social interaction and discourse in the pursuit of collective goals. In this context, GIS is seen as a tool for plan-making with the public, rather than for the public. While the instrumental and communicative perspectives are often viewed as competing theoretical perspectives, the role of information is relevant to both of them. It is rather the type of data and the way in which the data are processed to obtain information that makes the two perspectives different.

Land suitability analysis is more than a GIS-based procedure even if it involves participatory approaches. While databases and spatial information systems are important components of planning activities, planners deal with constituencies, power relationships, and complex urban and regional problems. This calls for socio-political perspectives on the use of GIS as a tool for planning. Harvey and Chrisman (1998) argue that like other technologies, GIS is socially constructed via negotiations between various social groups such as developers, practitioners, planners, decision-makers, special interest groups, citizens, and others who may have interest in the planning and policy making process.

2.5. Geoprocessing Model

Geoprocessing forms a vital part of the work many companies do with a GIS. Countless geoprocessing tasks may be performed on a daily basis. Some common geoprocessing tasks include:

- Converting data such as converting a shapefile to a geodatabase feature class.
- Overlaying data by unioning or intersecting datasets.
- Extracting data by clipping a subset of data, or selecting data with certain characteristics.
- Finding what's nearby by buffering data or finding points near other features.

- Managing data by joining fields, copying datasets or creating new datasets.

- Finding suitable locations or paths by running spatial analyst tools such as weighted overlay and cost path.

Geoprocessing is the processing of geographic information, one of the basic functions of a GIS. It provides a way to create new information by applying an operation to existing data. Any alteration or information extraction want to perform on data involves a geoprocessing task. It can be a simple task, such as converting geographic data to a different format, or it can involve multiple tasks performed in sequence, such as those that clip, select, then intersect datasets (Chang, 2002). A typical geoprocessing operation takes an input dataset, performs an operation on that dataset, and returns the result of the operation as an output dataset. Geoprocessing allows for definition, management, and analysis of information used to form decisions.

The geoprocessing tools in ArcGIS make it easy to process spatial data to model aspects of the real world. However, when there are many steps involved in geoprocessing work flow, it can be difficult to keep track of the assumptions, tools, datasets, and other parameter values used (Zeiler, 1999).

GIS tools are the building blocks for assembling multi-step operations. A tool applies an operation to existing data to derive new data. The geoprocessing framework in a GIS is used to string together a series of these operations, enabling users to automate work flows, program analytical models, and build recurring procedures. Stringing a sequence of operations together forms a process model that is used to automate and record numerous geoprocessing tasks in the GIS (McCoy, 2004).

One of the easiest ways to author and automate your work flow and keep track of the geoprocessing tasks is to create a model. A model consists of one process or more commonly, multiple processes strung together. A process consists of a tool, a system tool or a custom tool and its parameter values. Examples of parameter values include input and output data, a cluster tolerance, and a reclassification table (Zeiler, 1999).

A model allows to perform a work flow, modify, and repeat it over and over with a single click. ModelBuilder is a productive mechanism to share methods and procedures with others within, as well as outside, an organization.

The ModelBuilder interface provides a graphical modeling framework for designing and implementing geoprocessing models that can include tools, scripts, and data. Models are data flow diagrams that string together a series of tools and data to create advanced procedures and work flows.

Models can be used to export to scripts to allow the automation of repetitive processes or complex flow of control. Scripts have traditionally been the staple working environment of long term ArcGIS users. Scripts can include calls to geoprocessing tools, models, and other scripts. Scripts are easy to author in the scripting environment of choice. After a script is authored, it can be exposed to users as a standard tool and embedded in other models or scripts like any other tool (McCoy, 2004).