# DEVELOPING GIS DECISION SUPPORT TO STAKEHOLDERS ON AGRICULTURAL LAND USE PLANNING IN HA TINH PROVINCE, VIETNAM

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**ABSTRACT:** Land use planning in Vietnam has been conducted but still insufficient for many years. In rural areas, it has been predominantly relying on assessing the suitability of soil for agricultural production. Besides, the planning has extensively incorporated statistics. The current rapid economic growth of Vietnam during its economic transition has increased the pressure on land and water resources which leads to a necessity to adjust the approach to land use planning in order to support the economic growth of the country and provide a framework to manage the development in a sustainable manner. There is a need to have a closer alignment between socio-economic development plans, the overall environmental strategy and the land use plans. Therefore, the role of land use planning must be broaden through taking into account environmental, socio-economic parameters as well as involving different stakeholders who are affected by changes in land use. It is necessary to have a tool to support policy makers and planners in developing, appraising, and selecting planning scenarios which collaborate different social, economic, and environmental development dimensions in order to gain sustainable development goals. Information that have been collected including land use and management by applying Geographical Information Systems (GIS) to stakeholders activities in relationship with land use planning. Informatics and mathematical modeling techniques have been used in data processing, optimal solution determining and information providing for making decision support. The Decision Support System (DSS) providing tools for planners, policy makers and other stakeholders to improve policies on land use planning and implementation of other rural development and land resource management programs with adaptation to climate change.

## 1. INTRODUCTION

### 1.1 Problem issue

In Vietnam, the planning system basically follows the same system as before when the government interfered arbitrarily in the production and distribution process (Quang, 2003; Rock, 2004). All "planning" is viewed as a top-down process of implementing the planned investment of state resources, rather than a means of guiding and controlling private development or investment for the public interest (Lawrie, 2000) .

The current rapid economic growth of Vietnam during its economic transition has increased the pressure on land and water resources which leads to a necessity to adjust the approach to land use planning (LUP) in order to support the economic growth of the country, align its approach with globalization trends, and provide a framework to manage the development in a sustainable manner. This situation necessitates a change of land use planning from a static and descriptive approach to a dynamic, analytical and strategic one. There is also a need to have a closer alignment between socio-economic development plans, the overall environmental strategy and the land use plans.

Besides taking environmental, socio-economic parameters into consideration, land use planning must involve different stakeholders who are affected by changes in land use. In fact, human resource in LUP and management in local areas has been weak in many aspects such as the number of personnel staffs and human capacity. Therefore, it is necessary to have a tool to support policy makers and planners in developing, appraising, and selecting planning scenarios, which collaborates different social, economic, and environmental development dimensions in order to gain sustainable development goals. To address this problem, a Decision Support System (DSS) has been developed that interface with LUP tools. The research evaluates the options for representing the LUP problem within a DSS framework and explores the potential of applying DSS to multi-objective LUP.

### 1.2 Objectives of the Research

The overall objective is to develop a DSS for LUP and management and agricultural production in Viet Nam. This system can integrate GIS data on Land Use Type (LUT) and the data on the cultivation, cost, profit with calculation

modules experts' opinion and mapping to reach a rational decision of land use planning for agricultural production, adapt to the goal of sustainable agricultural development in climate change context. The specific objectives are: (i) To analyze and evaluate land suitability of land use types in agricultural production and propose suitable land use types towards sustainable development. (ii) To assess the existing framework of land use planning and land information system of the region (with a pilot study from Duc Tho district, Ha Tinh province, Vietnam) and (iii) To develop a method using experts' knowledge as a component of the DSS in regions with lack of data information in land use planning and management.

### 1.3 Methodology

Informatics and mathematical modeling techniques were used in processing data, determining the optimal solutions and providing information to develop a DSS. This research used land classification and land utilization types guided by the FAO framework for land evaluation to determine land suitability in studied areas. Based on the results of land suitability, an approach to improve land use can be proposed for land use planning with a focus on sustainable development and environmental protection.

The research then applied GIS techniques with a multi-criteria approach for analyzing land suitability for main crops in Duc Tho district, Ha Tinh Province. The data were also obtained through secondary data sources, results from interviews with farmers and personnel staffs. In doing so, it can be said that the suitability assessment in the studied area has been done on the ground of socio-economic and environmental suitability evaluation.

The above mentioned databases continued to be processed with DSS software to formulate alternative solutions which shall be consulted with experts' opinions to select the most rational one, adapted from Nguyen (2006). Based on the result, an approach to improve land use planning can be proposed with a focus on sustainable development and environmental protection.

## 2. GIS AND DSS IN LAND USE PLANNING

### 2.1 GIS and Decision-making in Planning

GIS is widely used in local and regional planning for managing, integrating, and visualizing spatial data sets. However, beyond basic levels of decision support, GIS remains largely external artifacts to the decision-making process. This suggests that despite increased analytic sophistication, most GIS software is more suited to providing limited outputs than as a tool for decision support. To improve the usefulness of GIS as a decision support tool, two needs should apparently be met. First, decision makers require methods that allow them easily to select alternatives most closely aligned with their priorities across a number of relevant criteria. Second, it is necessary to recognize explicitly that most decision-making processes involve multiple participants.

Since problem solving is often characterized by multiple and conflicting objectives, methods that contribute toward consensus building are required. Feick and Hall (1999) described a Spatial Decision Support System (SDSS) that satisfies these needs through a tight-coupling of GIS functionality and Multiple Criteria Analysis (MCA) techniques. The potential benefits of adopting this approach and future extensions to the prototype are discussed in light of a land use-planning example.

Much of the use of GIS in planning assumes use of a rational mode of decision-making which entails a linear process initiated with the identification of a problem, followed by a comprehensive search for alternatives and concluded with the selection of the optimal alternative as indicated by the gathered information (Batty, 1993). This process is typically characterized by recursive feedback loops in the decision process where evaluation and selection criteria are refined and steps repeated as a result of refinements. However, these loops are generally non-systematic and informal. Under bounded rationality, uncertainties and resource constraints in the decision environment cause decision makers to adopt a satisfying mode of behavior such that the search for solutions concludes once an option which meets or exceeds their context-specific aspiration levels (Malczewski and Ogryczak, 1996).

LUP is the systematic assessment of land and water potential, alternatives for land use and economic and social conditions in order to select and adopt the best land-use options. Its purpose is to select and put into practice those land uses that will best meet the needs of the people while safeguarding resources for the future. The driving force in planning is the need for change, the need for improved management or the need for a quite different pattern of land use dictated by changing circumstances.

### 2.2 Integrating GIS with the DSS

Most of the agricultural data have geographic attributes while GIS is an important tool for agricultural analysis, so it is very important to include GIS into the DSS for regional agricultural management. Nevertheless, it does not mean that the system should be developed on professional GIS.

The pure second-time development capacity of professional GIS makes it difficult to develop attractive interfaces for users. Besides, the difficulty of operating attribute data with professional GIS is not helpful in meeting the various demands of users. Considering the demand of the management and the improvement of the function of various GIS components, GIS components will be a good choice (Yongzheng, 2002). The geographic information system provides all the biophysical information for the DSS; this includes climate, soils and topographic data and information on the farm infrastructure.

### 2.3 Developing the Decision Support System

**Designing the System´s Interface:** In the research, Microsoft Visual Studio together with MapInfo MapXtreme software are used to develop the DSS. Microsoft Visual Studio is an Integrated Development Environment (IDE) from Microsoft which can be used to develop console and graphical user interface applications along with Windows Forms. Map Xtreme is a major release of MapInfo's industry leading location-based development environment which enables the creation of custom mapping applications or map enablement of applications and solutions in Microsoft Windows desktop and web environments.

**Main Menu:** The system's interface is designed in a user-friendly manner. The system shares certain rights to users.

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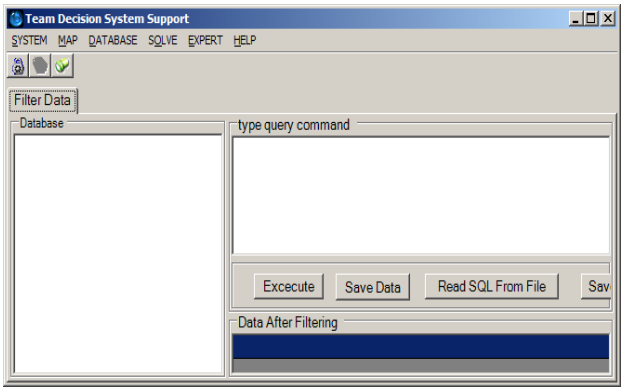


*Figure 1 Main Menu in DSS Program*

**Designing Database:** Data are stored in database SQL Server. The Database name is configured in file *App.Config* which includes parameters as follows: *Server name*, *Database*, *User*, *Password*. Data for the MOLP problem in LUP map data have been built by MapInfo software together with other collected data in the district to build the decision-making problems.

The MapInfo data and data collected are dynamic, which means they do not follow a standard data field, since designing a standard database is a difficult task. As a result, a dynamic database is designed in this study.
Administrator users can create other necessary database tables within their application. Only the administrator is able to create tables and data query command to support the MOLP problem. Other users involved only in solving problems to select an appropriate decision. The main data tables are described as follows; other data tables can be created to support data processing and decision making.

## 3. DECISION MAKING SUPPORT AND LUP

### 3.1 Decision Making Process in LUP

In order to make decisions in LUP, it is necessary to collect data from various sources. Map data are required, so the work of digitizing maps and importing data for the map is very important. Also, there is a need to have data on the land use, the appropriate level of crops and productiveness of crops. In terms of LUP in agriculture, a database of land resources based on the criteria of land suitability classification needs to be established to identify the characteristics of land. Setting up a database of suitable cultivation formulas should be based on both traditional farming and biotechnological advances. Factors including economic efficiency and social, ecological, and environmental effects must be taken into consideration. Regarding the evaluation on ecological and environmental effects, it is necessary to continue to study and propose more precise quantitative assessment methods.

The information of the database collecting from research area in Duc Tho district, Ha Tinh province is processed through mathematical models including the optimal mathematical model to determine optimal crop rotations, the model of land use classification and evaluation, and the forecast statistical and simulation models to find out measures for improving the efficiency of comprehensive land use and ensuring sustainable development in agriculture.

With collected necessary data, the program has using modules to create linear programming problem. Another module helps solve the planning optimization. Besides, a module with maps provides decision makers with an overview of LMU to identify suitable crops. Decision support systems can produce various options on each LMU. Finally, an integrated module with experts' evaluation helps decide the optimal solution. Decision-making process in LUP includes the following steps: (i) Retrieve data stored on GIS software (MapInfo). (ii) Transfer data to SQL Server database. (iii) Create local data collection tables. (iv)Activate modules to generate solutions automatically. When the problem is created, the program can run the tests to find the optimal output suitable with the proposed requirements. A MapInfo module displays essential information on LMU such as the total area in each region.

### 3.2 Advantages of Decision Making Support System in LUP

Derived from the urgent practical needs, we designed and built a system to support decision making in LUP with the following advantages. First, the system can create a model with specific applications, combining many different components (optimize calculations, integrate experts' opinions, apply GIS technology). Second, this system serves as the foundation for building a complete system to meet actual needs. The system is designed with the database storing the dynamic data tables. Administrators can use the profiles to match necessary queries based on these data to obtain the desired data. Third, the system helps draw maps to have a visual overview on the issue of planning. Another module reads MapInfo data which are shown in the Data Grid to help users store necessary data in the database for their problems. Fourth, the system enables creating queries automatically. When users update data in the database, the problems will be automatically updated. Data are stored in the data table; a module to solve single and multi-objective optimization linear planning problems will retrieve the data from this table to find the answer to the query of the optimal solution. Finally, the system has integrated the linear planning module with a three-phase method (design the encoding module, decode and store optimal solutions) and used the module based on experts' opinions to support decision making to select the proper solution for LUP.

## 4. RESULTS OF THE RESEARCH

The research has provided the foundation to design and build decision-making support systems in LUP for agricultural production in the area within district level. The research covers the important topics including the components of the decision-making support system, database design of land use on the basis of integrated spatial data and GIS data attributes such as horticultural formula, cost, and profit, and modules of computer program integrated into decision support system for LUP and agricultural production.

Strengths of the system are the ability to use database tables with dynamic data to retrieve the desired data, the ability to create problems to which objectives and required conditions are automatically added or removed, and the ability to support selection of LUP through experts' evaluation and to integrate GIS technology to create reports and maps. There are three of the selected results feasible alternative of Duc Tho LUP map on the Program are shown. The program results are tested with high accuracy. Data in Duc Tho district are processed with more than 30 variables and three target functions (more target functions can be possible). In addition, a number of supplementary constraint functions can be used when solving multi-objective optimization problems with cut methods.

### 4.1 Conclusions

Based on the results of the research, the following conclusions can be drawn. First, to evaluate the effectiveness of comprehensive land use and determine the optimal crop rotation, we need to integrate economic efficiency, social and environmental effects. Second, utilizing the information on land resource and LMU for LUP of agricultural land in area like Duc Tho district should be based on criteria such as types of soil, soil name, topographic feature, slope, irrigational conditions, flooding hazard, effective soil depth, soil depth, and soil texture. Third, determining the formulas of crop rotation should be based on economic, environmental, and ecological efficiency to ensure the diversification of cultivated production and to improve the coefficient of land use. Finally, applying multiple objective optimization models as a main quantitative tool to determine appropriate crop rotation enables users to select an accurate, logical and science-based formula of crop rotation which ensures a balance among economic efficiency, ecological and environmental sustainability, and land use efficiency.

### 4.2 Further Study and Development

Currently, we have done the first two parts including encoding and decoding. For further study in the near future, it is important to complete the calculating procedures to address linear planning problem by the three-phase method. We need to study methods and procedures for computing solution for the multi-objective optimization model, which can enable us to find out the structure of the optimal set of planning. This will also allow more effective decision making based on more complete information. Besides, we can continue to improve the system with the view to making it more user-friendly. We need to keep on examining and testing it on real problems as well. More relevant database and programs can be designed. The research topic can be further developed in various aspects including researches on the procedures of solving Multiple Goal Linear Programming to find the structure of the set of optimal solutions, the models of LUP with the upgraded modules of mapping to solve the problem of LUP with more variables, developing the decision support system for LUP on client servers via the Internet, and integrating with other expert systems to improve and develop models of LUP in general and agricultural land in particular.

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