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Original article

Decision Support System for Eucalypt Plantation Investment in Chachoengsao Province

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ABSTRACT

The present study was aimed to develop an integrated decision support system (DSS) for eucalypt plantation investment in Chachoengsao province that could be able to determine site suitability, plantation yield, appropriate plantation management, and economical profits.

To meet all objectives of the present study, the DSS development can be separated into 4 main parts including database design and analysis, DSS procedure, user interface design and system output. Firstly, a system database was designed and developed to provide critical requirements for decision making based on the DSS objectives. Secondly, decision hierarchy was constructed to clarify the choice situation of user-defined areas accordingly. Based on economic production of the 3-year rotation, site suitability was classified into 4 classes, i.e. very good, good, moderate and unsuitable sites. Yield estimation of eucalypt plantation was analyzed to provide information for financial analysis procedure. Thirdly, the user interface management system was designed according to the user-friendly interactive concept for simplicity and high information content. The welcome homepage, input data page, interactive pages and output page were then designed to communicate with users step by step. Lastly, summary report output page was designed to briefly provide all information needed for decision making of eucalypt plantation investment.

Furthermore, the DSS developed in the present study was designed to be flexible and could be updated some system database for future uses and development. Development of a growth model that integrated site potential, climatic data and physiological characteristics as well as management practices is, therefore, essential to improve the accuracy of the growth/yield prediction in decision making.

Keywords: Decision support system, Eucalypt plantation, Site suitability, Chachoengsao

INTRODUCTION

A rapid expansion of wood-based industries has led to the acute demand for eucalypt wood in Thailand. Consequently, commercial plantations of eucalypts, playing an outstanding role in woodchip and short-fiber wood pulp industries, have been expanded extensively in both government and private sectors. The current production capacity based on the total plantation area of about 500,000 ha seems sufficient to meet the domestic demand. Nevertheless, Thailand has been facing eucalypt timber shortage since the major sources of raw material seem rather too far to be profitably transported to woodchip factories (Thaitusa *et al*., 2004). Plantation entrepreneurs have also realized the extremely high variations in their growth and yield as the results of planting genetic materials, site conditions and environments, and silviculture and management practices (Luangviriyasaeng, 2003; Thaitusa *et al*., 2004), regardless of their fast and easy growing and low mortality rates. Moreover, costs of plantation establishment and management must be taken into consideration prior to the investment of commercial plantations. These factors lead to complicated decision making for plantation management to fulfill the demand for eucalypt wood and to maximize profits.

Decision support system (DSS) is an interactive computer-based information system, which helps to utilize data and models in order to solve non-structured management problems for improved decision making (Turban and Aronson, 2000). It basically utilizes data, provides an easy-to-use interface, and allows for the decision maker's own insights. Application of DSS for forest management is considered valuable since the requirements defined are extremely high due to the complexity, the uncertainty and the enormous amount of data. Many support tools are also available in practices for commercial plantation management, e.g. potential of planting site, soil mapping, growth model, benefit-cost analysis, but these have not yet been brought together into an integrated system. The present study was, therefore, aimed to develop an integrated DSS for eucalypt plantation investment in Chachoengsao province, where major woodchip and pulp industries have been located, to be able to determine the site suitability, provide plantation yield information, recommend appropriate plantation management, and analyze the economical profits.

MATERIALS AND METHODS

Study Site

The present study focused solely on eucalypt plantations in Chachoengsao province, well-known as an industrial complex for woodchip and pulp industries. Specifically, privately-owned plantations available in the province were selected to obtain growth data in a wide range of soil series.

Data Preparation

As summarized in the conceptual framework (Figure 1.), data prepared for the DSS development included spatial data, soil series map and description and published allometric equations for eucalypt yield estimation. The spatial data set was prepared for system database including administrative boundary derived from the Department of Provincial Administration in 2004, land-use classification from the National Parks, Wildlife and Plant Conservation Department in 2000, rainfall and temperature distribution from the Thai Meteorological Department in 2008, and topographic map from the Department of Water Resources. The digital map cooperated with soil series in Chachoengsao province derived from Land Development Department (LDD) was also employed.

Data Collection

The soil suitability map for eucalypt planting defined by the LDD (Soil Survey and Classification Division, 2000) was used to locate sampling plots in privately-owned plantations of all soil series, where eucalypt plantations were mainly established. Such soil series were classified mainly as suitable and partly as fairly unsuitable for eucalypt planting. Number of sampling plots for each soil series depended on land area, variation in soil properties, and existing plantation areas. The sampling plots of different ages, 2-5 years old, were scattered throughout each soil series. Practically, the sampling plots were undertaken on the plantations, which were established with different genetically improved clones well adapted to the site and with intensive management. Totally, there were 327 sampling plots located in 24 soil series. For each sampling plot, the location was undertaken using global poisoning system (GPS) and mean diameters at breast height (DBH) and heights were obtained from stands.

In addition to plantation growth, details and costs of plantation establishment, management, harvesting and transportation were obtained by interviews with targeted plantation entrepreneurs and farmers in the study area.

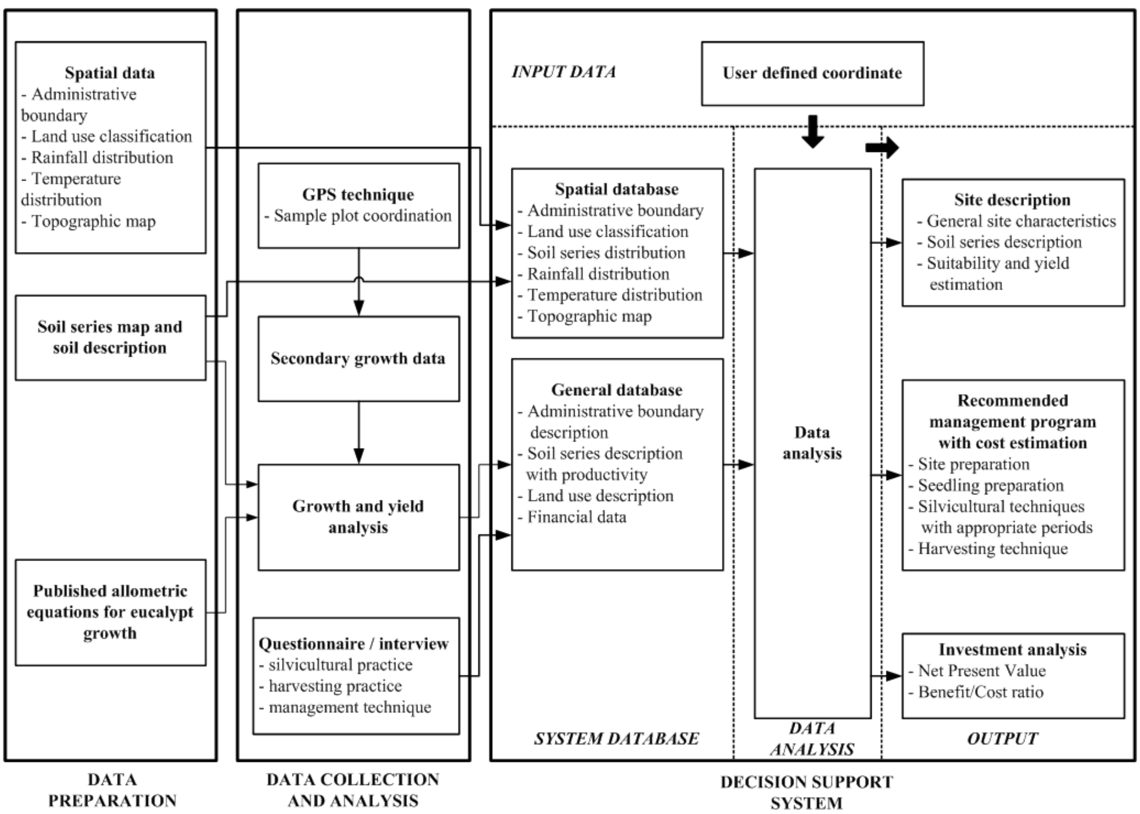


Figure 1. A conceptual framework of the DSS for eucalypts plantation investment in Chachoengsao province.

Data Analysis

Eucalypt plantation yield, above-ground biomass (dry weight) and economic production (stem fresh weight), of each sampling plot were analyzed by allometric equations (Wachrinrat, 2003) and the differences among soil series were also compared. Site quality index of eucalypts planted on the soil series, where plantation growth was undertaken, were established according to anamorphosis method (Prasomsin, 1991) on the 3-year basis. The defined site quality for each soil series was then prepared to produce site suitability map for the DSS database. Net Present Value (NPV) and benefit-cost ratio (B/C ratio) were also employed as economic parameters to financially evaluate whether the investment of eucalypt plantation is economically worthwhile.

DSS Design

DSS for eucalypt plantation investment in Chachoengsao province was developed in the web-based interactive system using the PHP script. The UMN Internet Mapserver was applied in the process of spatial data display and user defined location input, while the MySQL was used for database design. Due to user-friendly concept, the Thai system language was applied to simply communicate with Thai entrepreneurs and farmers. The DSS design can be separated into 4 main parts, i.e. system database development, database analysis system, user-interface management system, and system output.

Development of system database generally involved spatial database (e.g. administrative boundary, land use classification, soil series) and generally database (e.g. description of related spatial database, financial database). Data analysis system was mainly related to the eucalypt production models, based on site suitability classification of each soil series, and financial analysis. The user interface management system was also designed to communicate with users step by step. Lastly, the system output was designed to provide information for investment of eucalypt plantation, e.g. site characteristics, site suitability, plantation yield, economical profits, and recommendation for plantation management.

DSS Evaluation

To evaluate DSS that provides sufficient information for users, interviews were periodically made during the process of DSS development in order to include all essential data or information needed by users in the proposed design. Furthermore, growth data of other 34 sampling plots of 2-to-5-year old eucalypt plantations in 7 soil series, where growth data were not obtained for the site suitability classification, were collected and the plantation yield was analyzed to compare with that predicted by the DSS in respective soil series.

RESULTS AND DISCUSSION

Database Design

The system database as depicted in the DSS conceptual framework (Figure 1.) was designed and developed to meet all objectives of DSS for eucalypt plantation investment in the present study. The system database consists of 11 entities of spatial and general databases. The spatial database designed comprises of the following 6 entities: (1) *Subdistrict* entity, attributes related to administrative boundaries; (2) *CCS_SoilSeries* entity, attributes of soil series classification; (3) *LandUse* entity, attributes related to land use classification; (4) *TopoMap* entity, the topographic map used as a background map; (5) *Rainfall* entity, attributes of rainfall distribution; and (6) *Temperature* entity, attributes of temperature distribution.

Of the 5 entities of general database, the 4 entities, i.e. *Subdistrict*, *SoilDesc*, *Soilsuit* and *LandUseClass*, are integrated by the first 3 respective entities of spatial database. In addition, the Financial entity, attributes containing costs per unit land area throughout the management program, is based upon the manual for eucalypt planting provided by targeted entrepreneurs in the study area. Timber price was also provided for estimating financial returns. Moreover, loan and deposit interest rates and discount factor were given to analyze data in monetary terms.

DSS usually evolves a somewhat simple and straightforward management approach based on a multiple-use concept to a complex multi-faceted process. Computer based modeling, particularly linear programming, has been widely applied to address the complex problems involved in the DSS for forest management. Moreover, a spatial DSS has been developed to assist analysts and decision makers to link between spatial DSS and GIS for forest management planning (Church *et al*., 2000). In this study, simple growth model was applied to predict eucalypt plantation yield according to site suitability integrated by related GIS database, e.g. topographic map, land use classification, soil series, climatic data. Site description and plantation yield as well as alternative management according to soil conditions and site qualities were given to decision making of the investment.

Database Analysis

Soil Classification

Based on the digital map in Chachoengsao province cooperated with soil series classification by LDD (1983), there are 30 soil series and other 23 soil mapping units, which can not be distinguished solely in either group. Such soil mapping units includes soil variant, soil association, unidentified soil group, soil complex, and soil phase. The occurrence of the total 53 soil series/soil mapping units can be categorized into 4 groups based on soil geology and parent materials, i.e. tidal flat, former tidal flat, alluvial terrace and fan complex, and erosion surface and local washes. In addition to the 4 soil categories, there are also the slope complex and other land uses, e.g. residential areas, ponds, canals, reservoirs, occupying 4.04 and 0.10% of the total land area, respectively.

Based on the LDD criteria (Soil Survey and Classification Division, 2000), the total 53 soil series/mapping units in Chachoengsao province were classified into 3 soil suitability classes for eucalypt planting, i.e. suitable, fairly unsuitable and unsuitable, based on general soil characteristics of the soil series group. The 28 soil series/mapping units, occupying about 46% of the total area of, was classified to be suitable for eucalypt cultivation, while 15 and 10 soil series/mapping units were categorized to be fairly unsuitable and unsuitable, occupying about 18 and 35% of the total area respectively. Apparently, suitable soils for eucalypt planting mainly occur on the alluvial terrace and fan complex and erosion surface and local wash categories, both of which the soils are moderately well to well drained, and mostly found in the eastern uplands of the province.

Site Suitability Classification

According to an anamorphosis method (Prasomsin, 1991) on the 3-year basis, the site quality of eucalypt plantations in Chachoengsao province was classified into 3 classes, i.e., very good, good and moderate. The productivity of eucalypt plantations on the very good, good and moderate sites ranged from 17.72 - 20.67, 14.79 - 17.72 and 11.86 - 14.79 tons/rai (area 1 ha=6.25 rai), respectively (Table 1.).

Table 1. Summary of site suitability classification for eucalypt planting based on 3-year rotation in Chachoengsao province

Site suitability class	No. of soil series[1]	Economic production (tons/rai)[2]	Area (rai)[3]	Coverage percentage
Very good	21	17.72 - 20.67	1,109,071.75	34.61
Good	15	14.79 - 17.72	671,757.24	20.96
Moderate	1	11.86 - 14.79	42,525.19	1.33
Unsuitable[4]	16	-	1,381,433.07	43.10
Total	53	-	3,204,787.25	100.00

Remarks: 1.No. of soil series including other soil mapping units, e.g. soil variant, soil association, soil phase etc.;
2. Economic production referring to stem fresh weight;
3. Area 1 ha = 6.25 rai; and
4. Area of unsuitable site including the area of slope complex and other land uses e.g. residential areas, rivers, ponds, canals.

Most of soil series/mapping units, categorized in the present study as a very good site quality, were classified by LDD criteria as suitable soils for eucalypt planting (Soil Survey and Classification Division, 2000). They were observed preferentially on the eastern uplands, erosion surface and local wash and alluvial terrace and fan complex, sandy loam to sand, and moderately to very well drained (Figure 2.). Likewise, the good site quality was observed in soil series/mapping units classified by LDD criteria as suitable and fairly unsuitable soils. The only one soil series was classified as a moderate site quality, Chon Buri series (Cb). The unsuitable sites were mainly soil series categorized by LDD criteria mainly as unsuitable soils and partly as fairly unsuitable soils, where existing eucalypt plantations were not observed. They were found mainly on the western lowlands, tidal flat, former tidal flat and alluvial terrace and fan complex. In conclusion, site suitability in the present study was classified into 4 classes, i.e. very good, good, moderate, and unsuitable sites, occupying 34.61, 20.96, 1.33 and 43.10% of the total area, respectively (Table 1., Figure 2.).

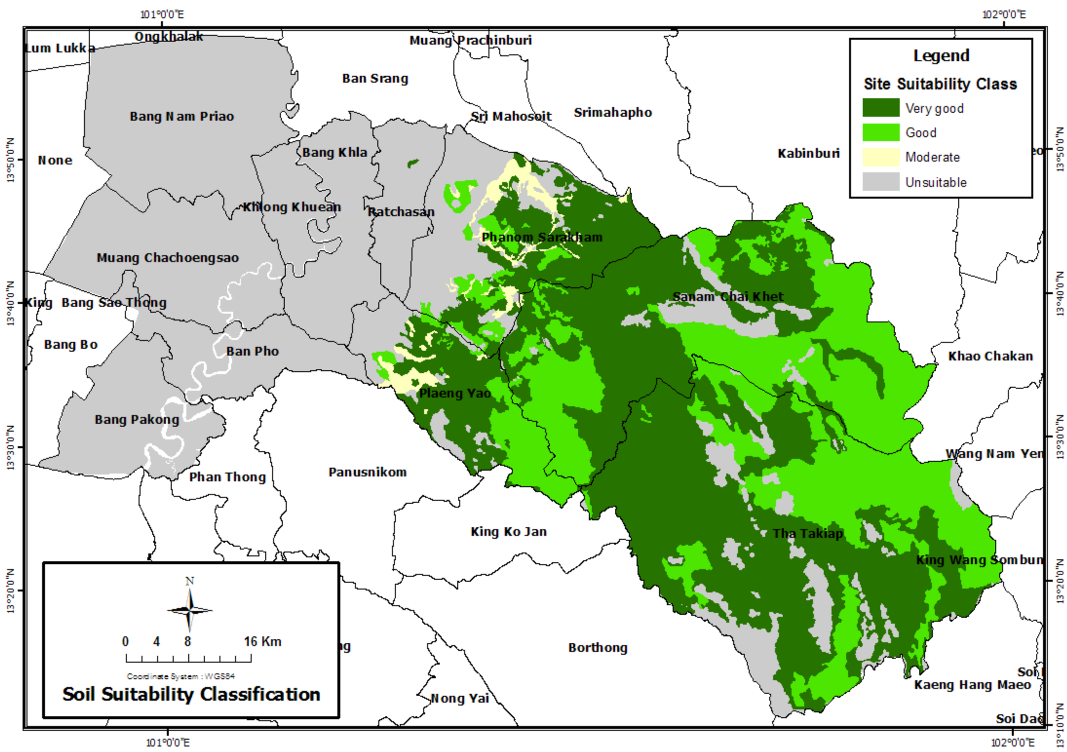


Figure 2. Classification of site suitability for eucalypt planting in Chachoengsao province based on an anamorphosis method on the 3-year basis.

The site potential may not be a complete indicator for growth and yield of eucalypt plantations since the sampling plots were taken from privately-owned plantations with different clones and management regimes. Practically, such plantations were well established with genetically-improved materials well adapted to the site and with intensive plantation management suitable to the site. Nevertheless, estimation of growth of eucalypt plantation based on the site quality index could be used to represent the growth range as data input for DSS for eucalypt plantation investment in the study area.

Financial Analysis

Cost benefit analysis in terms of B/C

ratio and NPV was carried out to recommend users whether the investment of eucalypt plantation is economically worthwhile. The average price of stem fresh weight was taken to be 1,250 baht per ton (US$ 1= about 33 baht), based on the timber price in 2008 given by targeted entrepreneurs in the study area. The price is understood to be for timber larger than 2.5 inches in diameter, including bark, sold at the spot market. Costs for harvesting and transport were, therefore, necessary to be included to the total cost (Table 2.). The investment cost includes all costs of eucalypt planting occurring from site preparation through transportation to a spot market, based on 400 trees per rai and up to 5-year rotation. The costs were mainly establishment costs, while transportation and harvesting costs accounted for 13.6 and 10.4% of timber price, respectively.

The financial analysis revealed that the benefits from eucalypt plantations varied remarkably with site qualities and rotation (Table 2.). The finding suggested that the investments of eucalypt plantation were economically profitable after 3 years for all site qualities. The investments were even more economically worthwhile for longer rotations as the tending costs decreased after a few years of establishment. Xu (2003) set up cost scenarios for eucalypt plantation on plantation establishment and management regimes in Southern China and suggested that the investment tended to gain more profits after the first rotation, despite of lower productivity of the second one. This was mainly because, in the second rotation, establishment costs were deduced and tending costs were minimal.

Table 1. Cost-benefit analysis of eucalypt plantation investment on different site suitability classes in Chachoengsao province

Site suitability class	Rotation (years)	Yield (tons/rai)	Benefit (baht)	Cost (baht)	B/C ratio	NPV (baht)
Very good	3	19.20	23,998.14	10,519.55	2.11	8,994.77
	4	23.79	29,733.81	12,596.11	2.11	9,929.28
	5	31.84	39,798.77	15,431.70	2.24	12,492.72
Good	3	16.26	20,323.13	9,637.55	1.94	7,006.76
	4	20.14	25,180.46	11,503.31	1.93	7,730.04
	5	26.96	33,704.11	13,968.99	2.07	9,864.43
Moderate	3	13.33	16,658.65	8,758.07	1.74	5,024.45
	4	16.51	20,640.15	10,413.64	1.73	5,537.10
	5	22.10	27,626.91	12,510.46	1.86	7,243.67

Remarks: Based on 7% of loan interest rate and 12% of deflation rate.

DSS Procedure

The DSS for eucalypt plantation investment in Chachoengsao province can be separated into 4 main parts, namely input data, system database, data analysis, and system output (Figure 1.). In order to clarify the choice situation of the user-defined location, decision hierarchy was constructed as depicted in Figure 3. The top of the hierarchy involves input data of a user-defined location. The system specifies whether the location is in the Chachoengsao boundary. Subsequently, the location within water boundaries or protected areas is basically excluded from the DSS procedure as not within possible areas for commercial planting. Alternatively, the location, which does not meet such criteria, is then classified whether it is within suitable soil series. The suitable area is proceeded further for site suitability classification, i.e. very good, good, moderate (Figure 2.). The yield estimation and financial analysis of the respective site quality are then determined.

A hierarchical approach to DSS is very conceptually appealing and has been widely used for forest planning, for example, forest planning for forest ecosystem management (Church *et al*., 2000) and landscape ecological forest planning (Kangas *et al*., 2000). In this study, the decision hierarchy was simplified to clarify choice situation in the form of true (T) or False (F) and detailed information was provided accordingly.

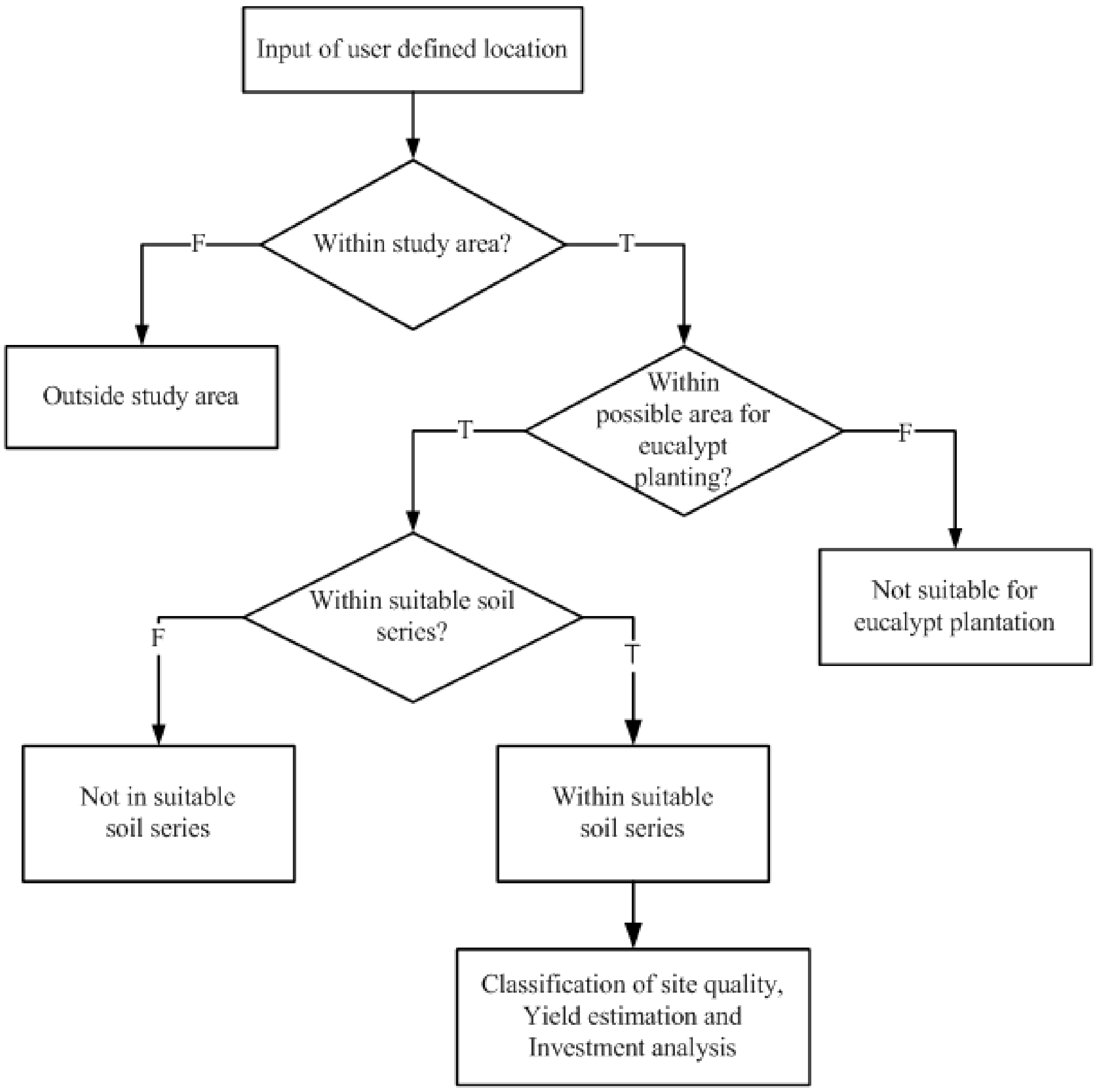
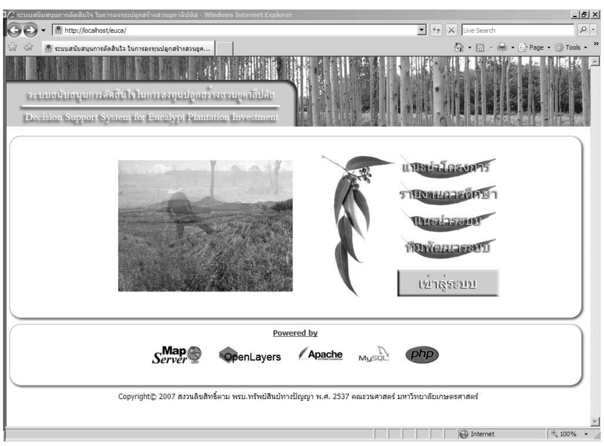


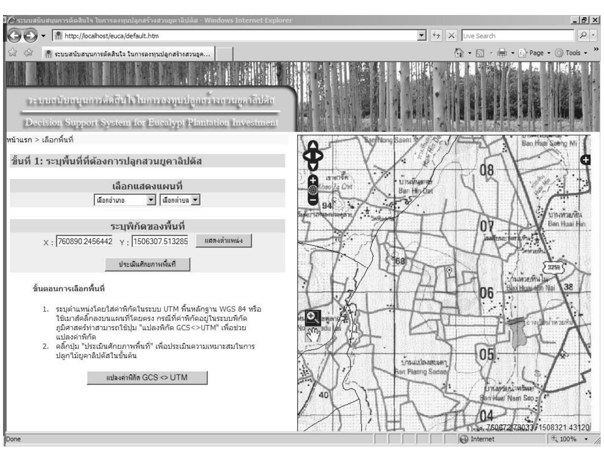
Figure 3. Decision hierarchies of the DSS for eucalypt plantation investment in Chachoengsao province.

DSS User Interface Design

The user interface management system was designed according to the user-friendly interactive concept. Due to such a concept, the Thai system language was applied to simply communicate with Thai entrepreneurs and farmers. The user interface design, which is used to communicate with users step by step, includes welcome homepage, input data page, interactive pages and output pages, as shown in Figure 4. The welcome homepage provides general information on the DSS, e.g. introduction, instruction (Figure 4a), while the input data page requires users to define location of the area (Figure 4b.). Once the user-defined location has been entered, decision hierarchy is proceeded to clarify whether the location meets criteria of possibility for eucalypt planting. Interactive pages or notifications are made by dialogue boxes to users step by step (Figure 4c). If the user-defined location is within the possible areas, classification of soil series, soil description, climatic data and classification of site suitability for eucalypt planting are provided. Users could also obtain detailed information on soil characteristics of the defined soil series as preferred. For a suitable site, yield estimation and analysis economical profits are proceeded accordingly. The pre-defined financial data set is provided and allowed to modify by users to suit the current financial situations. The output pages are also displayed to provide information on wood production, benefits, and aggregate costs of plantation investment as well as choices for the investment (Figure 4d.).



a) welcome homepage



b) input data page

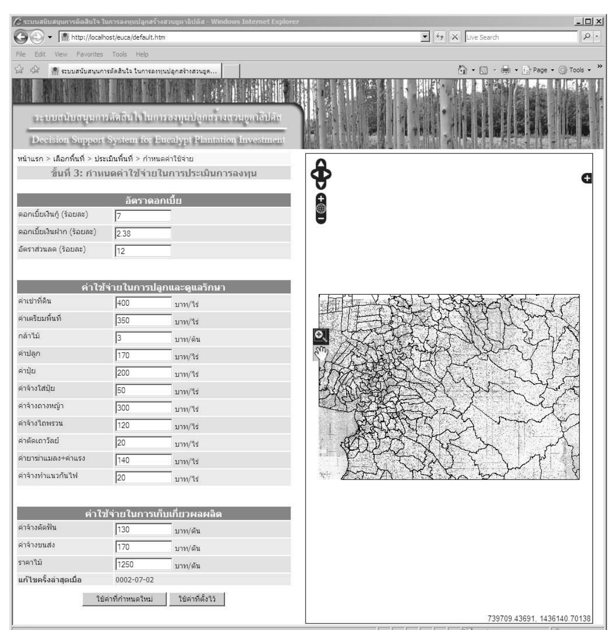
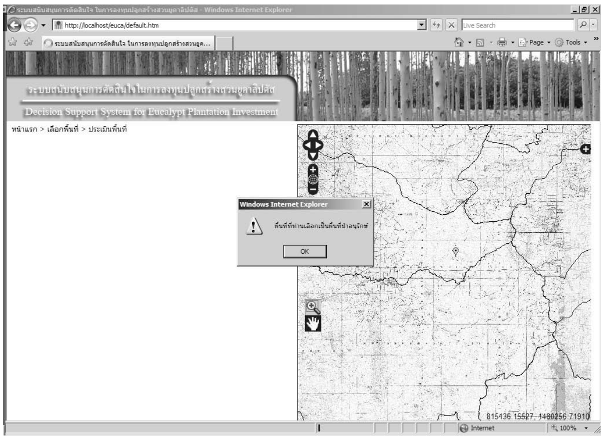
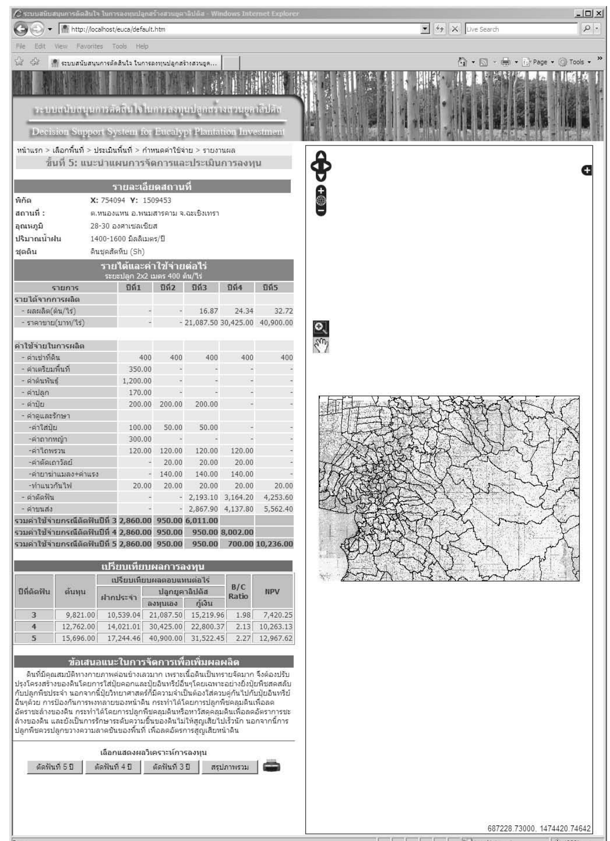


Figure 4. User interface design of the DSS for eucalypt plantation investment in Chachoengsao province.



c) interactive page



d) output page

Figure 4. (continued).

DSS Output

In order to meet all specific objectives of the DSS for eucalypt plantation investment developed in the present study, summary report output page was designed to briefly provide all information needed for decision making as follows: (1) general information of the defined area; (2) wood production and benefits; (3) aggregate costs throughout the plantation management program; and (4) financial analysis (Figure 4d.).

Moreover, preliminary report output pages providing information on site suitability classification, e.g. coordinate, administrative boundary, temperature data, rainfall data, are given in separate output page as preferred. Similarly, financial report output pages are also presented to provide detailed information for benefits from wood production and aggregate costs throughout the 5-year rotation as well as the financial analysis of different choices of harvesting during 3 to 5 years. Additionally, the DSS also demonstrates choices of economic returns depending on sources of investment. Current deposit and loan interest rates are applied in case of users investing their own money or loaning from financial organizations, respectively.

DSS Evaluation

Economical production of other 34 sampling plots in 7 soil series was analyzed to compare with that obtained from the DSS in the respective soil series. The scatter diagram in Figure 5. indicated the close relationship between observed and estimated values of economic production in younger stands, 2-3 years. Overestimation of the plantation yield by the DSS became more pronounced in older stands due to great variation in observed yields in each soil series. The finding suggested that, for the choice of longer rotation, particularly 5-year rotation, overestimation of the financial benefits should be taken into consideration prior to decision making of the investment. (Figure 5.)

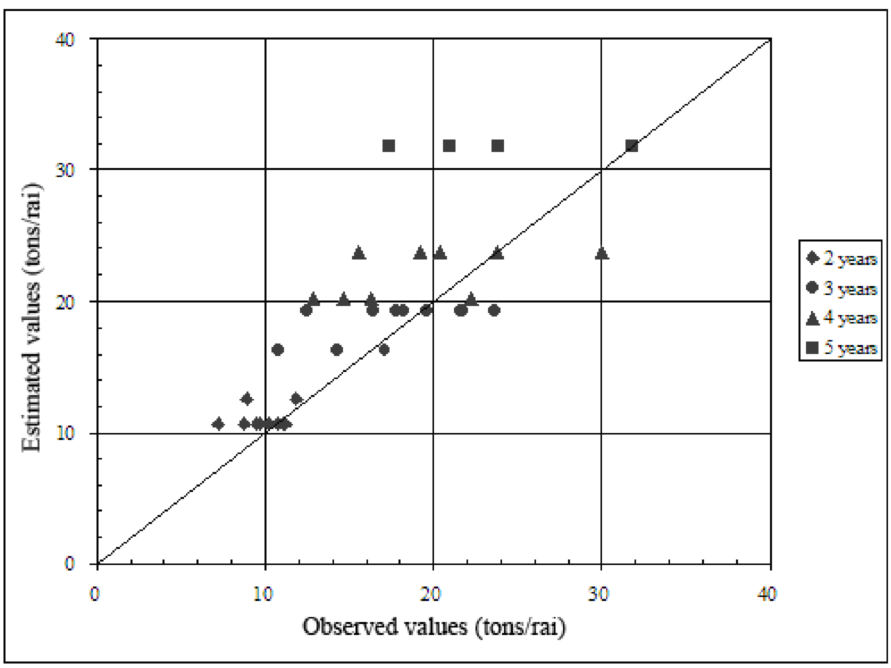


Figure 5. Scatter diagram of the relationship between observed and estimated values of plantation yield of eucalypt plantation on different site qualities in Chachoengsao province.

The present study intends to provide preliminary information prior to the investment based on site potential developed from simple growth model. Growth and yield of eucalypt plantation generally depends not only on site potential but also on suitable planting materials and plantation management. Productivity of eucalypt plantations could be increased by matching suitable clones to the site (Aramsri, 1999) and by appropriate site managements (Bouillet *et al*., 2000; Gonçalves *et al*., 2000). Successful decision making to maximize economic profits of the plantation investment generally requires reliable, versatile and efficient methods for predicting the harvesting yield of wood products in relation to site conditions and stand management. Simple process-based models have attracted increasing interest as an integrated tool or as a component of a sophisticated management information system. Prediction of eucalypt plantation yield in the present study was, therefore, based primarily on simple growth model in relation to site quality index. The 3-PG model, from which climatic factors, site conditions and physiological characteristics of the species are modeled, has been widely implemented for both softwood and hardwood plantations in many countries (Landsberg *et al*., 2003). Recently, Morris and Bakker (2003) had developed a process-based model to estimate eucalypt productivity in southern China based on the 3-PG model. However, the DSS developed in the present study was designed to be flexible and could be updated some system database for future uses and development. Development of such a growth model that integrated site potential, climatic data and physiological characteristics as well as management practices is, therefore, essential to improve the accuracy of the growth/ yield prediction in decision making of eucalypt plantation investment in Chachoengsao province for future uses. Furthermore, the DSS developed in the present study could be implemented to other planting areas by modifying the related system database.

CONCLUSION AND RECOMMENDATION

The DSS development for eucalypt plantation investment in the present study can be separated into 4 main parts including database design and analysis, DSS procedure, user interface design and system output. A system database was designed and developed to provide critical requirements for decision making to meet the DSS objectives, while decision hierarchy was constructed to clarify the choice situation of the user-defined areas accordingly. The user interface management system was also designed based on the user-friendly interactive concept for simplicity and high information content. The welcome homepage, input data page, interactive pages and output page were then designed to communicate with users step by step. Finally, summary report output page was designed to briefly provide all information needed for decision making, i.e. general information of the area, wood production and benefits, aggregate costs throughout the plantation management program, financial analysis.

The DSS developed in the present study was designed to be flexible and could be updated some system database for future uses and development and for implementation to other planting areas. Development of a growth model that integrated site potential, climatic data and physiological characteristics as well as management practices is, therefore, essential to improve the accuracy of the growth/yield prediction in decision making of eucalypt plantation investment.

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