45. MANAGEMENT AND DECISION SUPPORT SYSTEM FOR SMALLHOLDER TREE PLANTATION DEVELOPERS

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This paper reports experiences and inferences in the development of a decision support system (DSS) for smallholder tree plantation development in Regions 2, 10, and 13 in the Philippines. It was found out that farmers in these regions are not practicing intensive plantation management. Silvicultural practices and cultural management including weeding, fertilization, pruning and thinning, if practiced, are done arbitrarily. Choice of species is mainly based on seed availability, and time for harvest is selected based on gut feeling and more often dictated by the need to convert crops to liquid assets. Although the farmers claimed they are realizing positive returns from investment, analysis showed that the production from plantations can be increased. A DSS is being developed to show these realities to the farmers and to allow them to evaluate options to increase production.

The main component of the system is a database on silvicultural regimes and management requirements of mahogany, mangium and yemane in plantations. Data were gathered from reported results of previous studies. The DSS also has a database of the various policies affecting the decisions that farmers take. The other component of the system is a dynamic growth model that simulates plantation performance. With the databases and the dynamic models put together in a DSS, a decision-support tool is developed that allows the developers to conduct a trial and error or ‘what if’ analysis on a proposed or existing plantation, prior to implementation of an activity or treatment. The DSS is being developed to assist smallholder tree plantation developers in making technical and business decisions, from choice of species to conduct of cultural management activities to final harvest to transport of raw materials.

INTRODUCTION

This study is part of a research and development program to improve the furniture and handicraft industry in the Philippines. One major concern of the handicraft and furniture industry is the assurance of the sustainable supply of raw materials. Current sources of raw materials are the natural forests and the plantations. Because of the pressures to conserve biodiversity and to ensure stability of the environment, the natural forests cannot be relied upon as a major source of raw materials in the long run. Therefore, planted forests will supply much of the raw material requirements for the industry.

At present, many of the plantations are established and maintained by smallholder plantation developers on both private and public land. Previous surveys of these plantations showed that plantation management is not optimal. In other words, the production in these areas can be further improved if the developers are properly guided and assisted in making decisions about their plantations (Villanueva and Folledo 2000)

The improved DSS includes a database of policies that directly affect the planting, harvesting and transport of raw materials. One of the major problems of many raw material producers is the lack of up-to-date information on new policies, rules and regulations of the government regarding planting, harvesting and transport of timber crops. With this DSS a database of policies – the main feature of which is its ease of update on policies that often change – raw material producers will be better informed on business and technical decisions that are both affected by the physical characteristics of the resource and by government policies.

The general objective of the project has been to develop a management and decision support system (DSS) which can be used to assist smallholder tree plantation developers in making technical and business decisions, from choice of species to transport of raw materials to the furniture and handicraft manufacturers. The specific research objectives have been: (a)to review and evaluate existing data on silvicultural regimes and management of existing plantations in three regions of the Philippines; (b) to gather and store in a database the different policies that affect the decisions of growers from planting to harvesting of timber crops; and (c) to develop a DSS that:

- will simulate the plantation environment to allow plantation developers to conduct a trial-and-error or *what if* analysis on proposed or existing plantations prior to implementation of an activity or treatment;
- will enable plantation developers to formulate a comprehensive yet flexible plan of silvicultural activities;
- will assist the farmers in business decision-making; and
- will assist the farmers in technical and managerial decision-making.

FACTORS AFFECTING PLANTATION DEVELOPMENT

Site conditions that include edaphic, climatic and physiographic factors are non-controllable variables that affect plantation development. These are the same factors that determine the site's productivity and capability to grow tree crops. Information on these variables can assist in determining the silvicultural prescription to apply in a site in order to achieve optimal yield and productivity (see Figure 1). In extreme cases where these variables are severely limiting, it may not be feasible to establish a plantation (Folledo 2001).

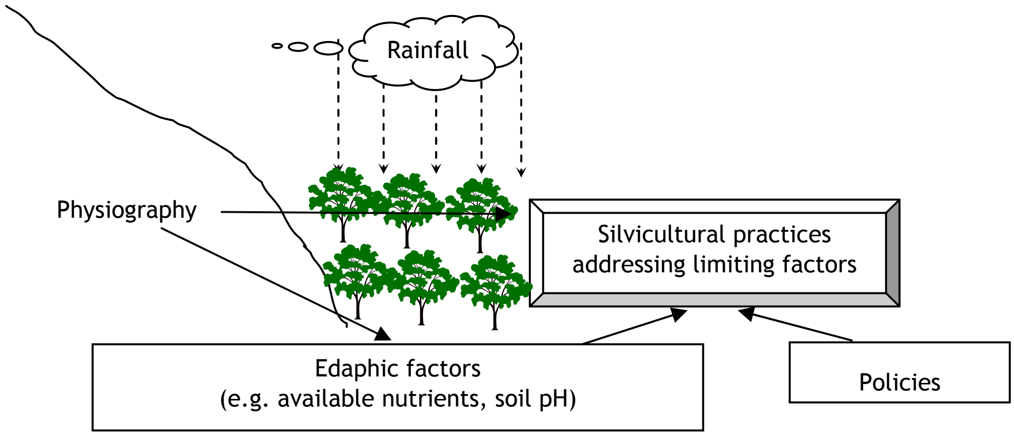

Figure 1. Factors affecting plantation development

There is a set of silvicultural treatments that leads to the most productive tree plantation. Allowing the plantation developers to choose their own silvicultural treatments and experiment on the effectiveness of their decision can help in deriving the optimal silvicultral regime. The final decision on what the plantation developer will apply can then be based on the results of a series of simulation experiments on alternative management regimes. As shown in Figure 1, plantation development is also affected by policies.

MODELS AND DECISION SUPPORT SYSTEMS: BASIC CONCEPTS

A model is a schematic representation of the conception of a system or an act of mimicry or a set of equations, which represents the behaviour of a system (Murthy 2005) or simply a representation of a process. Models approximate the world in a simpler process. Modelling is based on the assumption that any given process can be expressed in a formal mathematical statement or set of statements (Lembo 2001).

Modelling plant or tree growth uses mathematical formulae to simulate the growth and yield of plantations. Such models are composed of dependent and independent variables. Dependent variable is the variable of interest (e.g. volume, height) which is directly influenced by the independent variables (i.e. environment, management practices). The influence of the independent variables on the dependent variable is expressed either as coefficients or as rates.

Decision Support Systems are computerized information systems that aid in decision making. These classes of applications are developed to help people working alone or in a group to gather intelligence, generate alternatives and make choices. They also offer support in the estimations, evaluation and comparison of choices.

The term decision support system is a very broad term given the wide range of domains in which decisions are made and the varied approaches to making decisions. It provides information to augment the existing information and the judgment of the decision-maker.

There are five types of decision support systems. They may be communication-driven, data-driven, document-driven knowledge-driven or model-driven. The decision support system for this study will be based on tree growth models.

DSS in Forestry and Plantation Management

A Decision Support System (DSS) is an interactive information technology (IT) based system that helps decision-makers utilize data and models in making decisions. Its purpose is to assist and not replace decision-makers in making and implementing decisions. It can respond quickly to specific and changing requirements and circumstances of a decision-maker. It also facilitates but does not automate the decision-making process (Carter *et. al.*1992).

Decision support systems (DSS) are not widely developed in the Philippines, although they are highly popular in many developed countries. Some Computer Science undergraduate students of UP Los Baños implemented sample systems, but most of them are only prototypes and for the purpose of acquiring marks in a course (Madamba 1988, Wagan 1990, Hilario 1990, Tined 1993).

In forestry, a DSS for smallholder gmelina plantation developers in Bukidnon had been developed (Villanueva and Folledo 2000). This system showed strong potential in assisting smallholder gmelina farmers in increasing the yield and returns from their plantations. No other work had been done for other species and for other localities.

In developing a DSS, there is high reliance upon what technologies have been developed as far as growing the trees is concerned. For example, the work of Villanueva and Folledo (2000) in developing a DSS for gmelina depended on what researchers have discovered and developed for silvicultural systems of gmelina. The technologies which were included in the system were those developed by local researchers including Glori (1977), Castillo (1978), Machacon (1980), Maun (1983), Dichoso (1983), Guzman (1988), Haque 1995), Zabala (1996) and Baggayan (1996).

RESEARCH METHOD

Site Selection and Characterization

The plantations studied were planted with yemane, mahogany or mangium, in Regions 2, 10 and 13 in the Philippines. The number of sites representing the various silvicultural treatments applied by farmers for each species was determined based on the listings of registered tree farms in the selected regions which are kept by local Department of Environment and Natural Resources (DENR) offices.

Interviews of Farmers

Farmers were interviewed on what silvicultural treatments they had conducted since plantation establishment. A semi-structured questionnaire was prepared. Data were gathered regarding the area of the plantation, year of planting, prior crop and intercrop species, source of seeds, type of planting material (whether potted, bare root, or directly seeded), spacing, site preparation and plantation establishment operations, and frequency of tending operations. Data on timing and costs of site preparation and plantation establishment operations were also collected; these operations included weeding or ploughing, staking, ring weeding, holing and fertilization. Data were also collected on tending operations, including weeding, fertilization, thinning and pruning.

Yield Estimation

To estimate the current yield of the plantation, 20 m x 20 m sample plots were established. Considering that the volume of trees inside a farm generally was highly uniform, one plot was found sufficient to be used for estimation of current yield of the farm.

Individual tree measurements included diameter, merchantable height and total height. Measuring instruments used include metre tape, diameter tape and Haga altimeter. Measurements were then used to compute volume per tree using appropriate tree volume equations which can be found in the guidebook on the development and management of forest plantations (DENR 1998). These were then converted to volume per hectare and in total. The average volume per tree in each plantation was also computed.

Secondary data on the results of studies on the various plantation species were also gathered. These data included growth and yield observations, growth performance in various sites, and responses of seedlings to cultural treatments, pests and diseases.

Assessing the Soil Condition and Physiography

To assess the soil condition of the plantation, soil samples were taken and analyzed. In each plantation, 10–15 soil composites taken from 15-cm deep holes, evenly distributed throughout the area, with about 2 kg of soil taken from each site. The soils were then finely pulverized and mixed. Half a kilogram of the soil was then transferred into a resealable plastic bag. The soil samples were analyzed at the Soil Test Laboratory of University of the Philippines Los Baños (UPLB). Soil pH, organic matter content, available phosphorous and exchangeable potassium were estimated for the samples.

Average slope, used to estimate the ruggedness of the terrain, was measured using an Abney Hand Level. The altitude (metres above sea level) and geographical location (longitude and latitude) of each plantation were obtained using a hand-held Garmin Global Positioning System. Unique characteristics of each plantation that may provide an explanation on the plantation's current condition and productivity were recorded. These observations include exposed sedimentary rocks, plantation located on intermittent creek or valley bottom, predominance of weeds, fire occurrence, or adjacent land-use.

Changing Government Policies on Plantations

Rules and regulations related to plantation development and management, harvesting and utilization by government and private sectors were compiled and analyzed. Forestry regulations by commodity, land use and agreements were analyzed to determine overlaps, inconsistencies, conflicts and gaps. Policies reviewed and analyzed covered national, regional and local levels.

Model Formulation

Empirical models of tree growth have been used for many years to predict timber yield and other properties of trees (Constable and Friend 2000). However, such models rely on the measured relationship between tree growth and historical environmental conditions for given locations and time. Few tree growth models exists which incorporate the influence of human interference, such as different silvicultural practices or reliability of such empirical models.

In order to incorporate the effect of anthropogenic influences including silvicultural practices in predicting tree growth and yield, functional relationships between silvicultural practices and yield are taken into account. This is done by using different model coefficients for different time periods. Data from field surveys and published literature were used in order to establish the relationships between tree yield (volume) and silvicultural management practice (i.e. tree spacing, fertilization, weeding, pruning, and thinning), where the relationships are assumed to be linear in form.

Matrices of yield versus management input variables (Figure 2) where constructed for each silvicultural treatment for various ages of tree plantation. These matrices serve as look-up tables for the model in predicting tree yield for a given stand age and combination silvicultural practices. It should be noted that these functional relations are species-specific and location-specific.

Effect of Spacing

Age	S_1	.	.	S_j
1	Y_1	.	.	Y_j
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
M	Y_M	.	.	Y_{Mj}

Effect of Thinning

Age	T_1	.	.	T_j
1	Y_1	.	.	Y_j
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
M	Y_M	.	.	Y_{Mj}

Effect of Fertilization

Age	F_1	.	.	F_j
1	Y_1	.	.	Y_j
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
M	Y_M	.	.	Y_{Mj}

Effect of Weeding

Age	W_1	.	.	W_j
1	Y_1	.	.	Y_j
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
M	Y_M	.	.	Y_{Mj}

Effect of Pruning

Age	W_1	.	.	W_j
1	Y_1	.	.	Y_j
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
M	Y_M	.	.	Y_{Mj}

Figure 2. Yield matrices used for computing tree yield as affected by combination of silvicultural practices

The schematic relational diagram of the model with the various components, inputs and outputs is shown below.

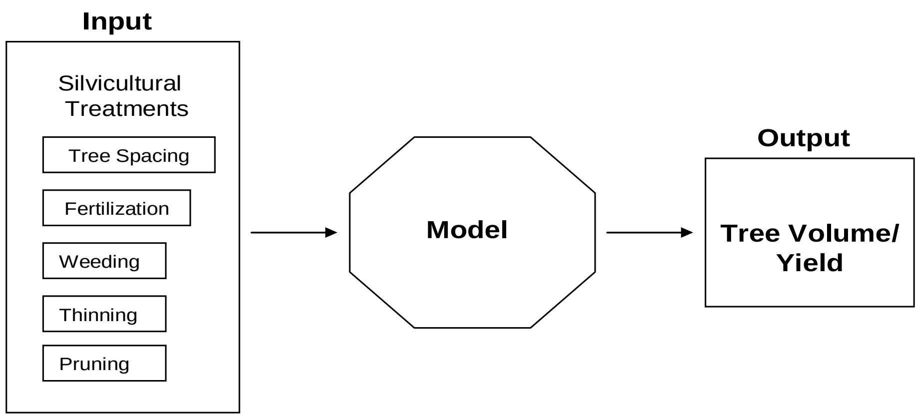

Figure 3. Schematic relational diagram of the model's input and output data

As mentioned, the models predict tree yield as affected by the silvicultural practices employed by the plantation owner. These data include: (a) size or total area of the plantation; (b) tree spacing; (c) timing of fertilization; (d) timing of thinning; and (e) timing of pruning. These data are entered by the plantation owner or field technicians on the forms provided by the decision support system. Using these data the model computes tree yield as influenced by the particular combination of silvicultural practices.

As an example, the yield matrices simulating the effect of tree spacing for three regions showed yield differences between locations for a specific tree spacing. This accounts the spatial differences between locations which may be attributed to site-dependent factors including climate and other environmental parameters.

The primary and sole output of the model is the tree yield based on the combination of silvicultral treatments implemented by the plantation owner. The management strategy implemented by the plantation farmer may involve from zero to five silvicultural treatments.

Development of the DSS

A computer-based DSS is being developed using appropriate computer software and programming language. The DSS utilizes the developed tree growth models for each of the three species in each site. As the models were formulated, they will be plugged-in into the system.

The DSS is being created as a web-based application. The motivations to adopt it include:

- No installation is required for the users. They will need to use a web browser which is ubiquitous in any popular computer operating system. As long as there is an Internet connection, they can access the website where the application will be hosted.
- Easy maintenance of software. Since the software is installed at one location, it would be easy for the developers to update code or the model used by the software. The intention is to keep the software centralized while there will be probable refinements to its core models and then the developers can opt to convert the application to a stand-alone computer application and distribute it in CD/DVD format once the model is proven to be sufficiently versatile and reliable.
- Relatively low-cost and fast software development and distribution.

The model-driven and web-based tree farm DSS is created with open-source or free software. PHP (a hypertext preprocessor) was used to develop the web application. The application utilizes a MySQL database for storage of lookup tables and data utilized by the various growth models. PHP is a free and popular programming language for developing dynamic web pages and web applications. PHP, along with the Linux operating system, Apache Web Server and MySQL Database server, form a free and easy to configure web application solution stack known to web developers as LAMP.

Users of the application are asked about their personal information, general tree farm specifications and intended or current silvicultural treatments that they have applied or will apply. They may specify various farm settings including fertilizer application, weeding and thinning schedules.

The DSS simulates the growth of the trees on the farm and also outputs various kinds of data in table and graphical form. These data include volume per tree (VPT) per year, operating costs and revenue based on projected price of logs from the plantation

Preliminary Assessment of Practices

Most farmers interviewed did not place importance on obtaining seeds from superior mother trees. Many of them obtained seedlings from DENR field offices from which the source of seeds was unknown.

Many plantations established are in degraded and steep areas, while others were in agricultural areas. The smallholder tree plantation developers planted cash crops before plantation establishment and during the first two to three years of the plantation. They inter-planted corn, rice, cassava, bananas, cotton or a combination of these crops. Some also intercropped semi-perennial and perennial crops including abaca, coffee and rubber.

Close spacing, either 2 x 2 or 2 x 3 metres was preferred. Few practiced thinning although that should have eliminated the suppressed and badly formed timber to give more growing space for the final crops. A few who thinned their plantations did so not to improve stand composition but to have early returns. With this in mind, they cut the best trees by the sixth or seventh year of the stand, expecting that suppressed and inferior trees left behind will perform like the dominant ones.

Cleaning and weeding were rarely practiced. A few developers used burning as a weeding method, which of course resulted in death or damage to trees. Fertilizer applications usually were intended for the cash crops but the forest seedlings also benefited from these. Some applied organic fertilizer in each seedling during plantation establishment.

Characteristics of the dynamic models developed

The models developed predicted tree yield as affected by silvicutural practices. The primary and sole output of the model is the tree yield based on the combination of silvicultural treatments implemented by the plantation owner. Because in practice the management strategy implemented by the plantation farmer involves up to five silvicultural treatments, the models developed mimicked all these possible strategies.

The model component of the decision support system predicts the yield of a particular plantation based on the input data provided by plantation owner or the field technician. The predicted yield is then used to compute the economic returns that the plantation owner will gain, based on the inputs and silvicultural management practices implemented on the plantation. Thus, the model will enable the plantation owner or the field technician to explore on the different combinations of silvicultural management options to be employed on the plantation in order to maximize the returns from the plantation.

The model needs to be verified or calibrated. This will be done by comparing actual yield from surveyed tree farms to the result of the simulation.

Description of Components of DSS being Developed

As of the time of writing, the web-based DSS utilizes the yield projection model of Folledo (2001) for gmelina. The DSS will be reprogrammed with the models that are specific to the tree species which are still being tested.

Usage of the DSS is straight-forward. Information required by the DSS is gathered through the use of a series of web-based forms. Users may input only information that they want or need. Once all desired information has been entered by the user, the system loads the appropriate model for the site and species and then simulates the development of one rotation of the tree farm. Lookup values are loaded from the system's database and utilized in the model's equations. The DSS simulates the growth of the tree farm over one rotation given the input silvicultural treatments. Once the simulation is complete, the system outputs reports, most especially the Volume per Tree of the tree farm, cost of operation and value of the plantation. The system can output printable reports if desired by the user. Below are screen shots of the prototype web-based application.

The website interface uses two languages namely English and Tagalog, to enable both researchers and farmers to use the system with ease (see Figure 4). Users may opt to select the language to use in the interface labels.

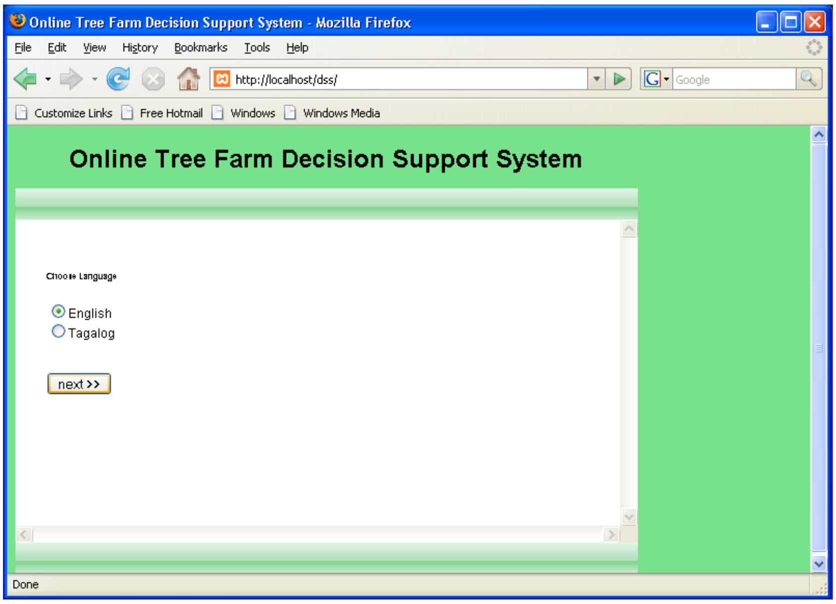

Figure 4. Language Selection Screen where users may select between English or Tagalog as user interface language

The user will then input basic information about their tree farm. The information being asked includes name of plantation owner, size of plantation, location and altitude of the plantation, tree species planted or to be planted, spacing, seed source, labour cost per worker and discount rate. Some of this information is collected for reference purposes as well as in the simulation. The two input screens are shown in Figures 5 and 6.

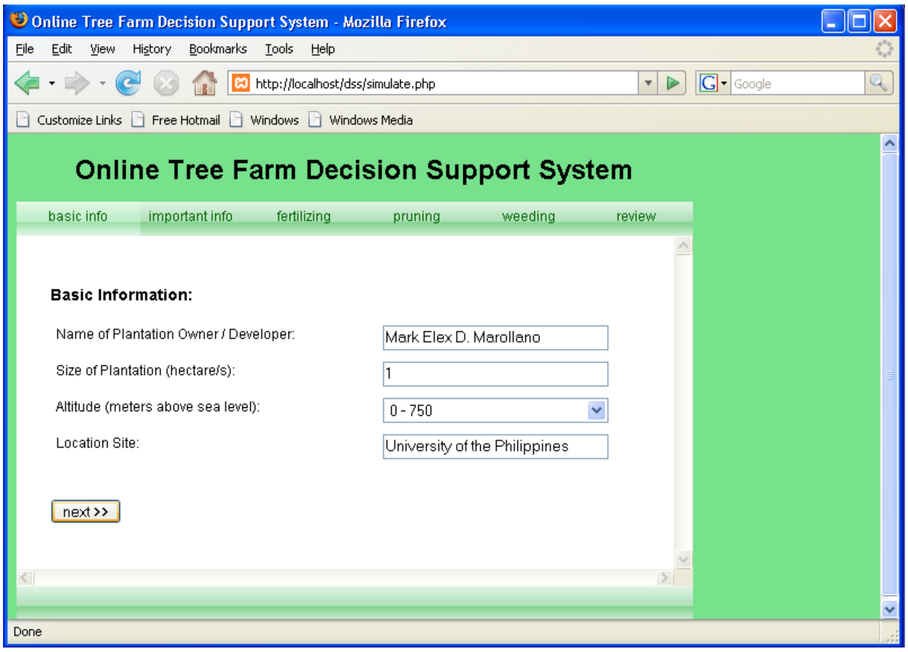

Figure 5. Basic information about the tree farm are inputted in this section of the DSS

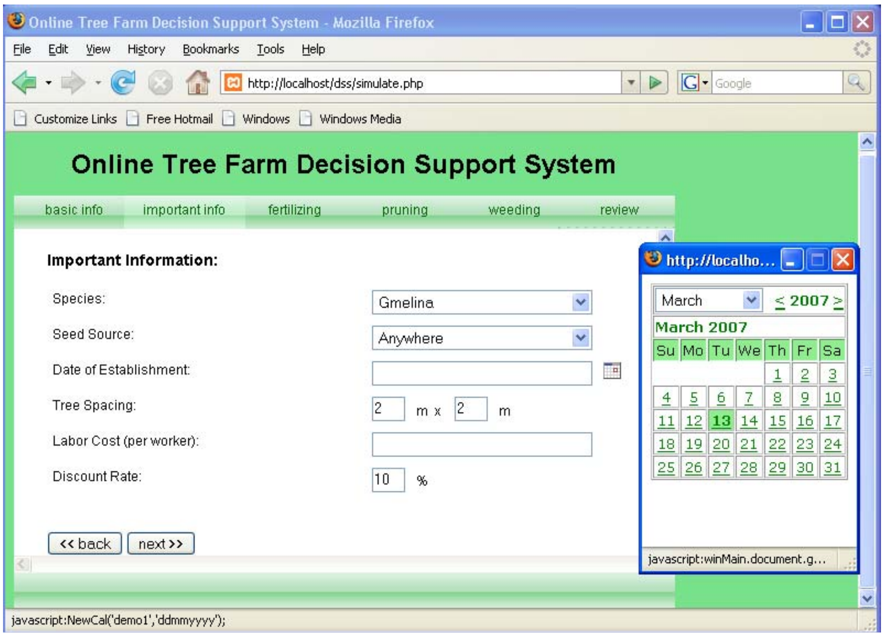

Figure 6. Important farm specifications

The user may also indicate fertilization details (Figure 7), pruning schedule (Figure 8) and weeding schedule (Figure 9). These input screens are optional and are only to be accessed if there are specific treatments applied to the plantation.

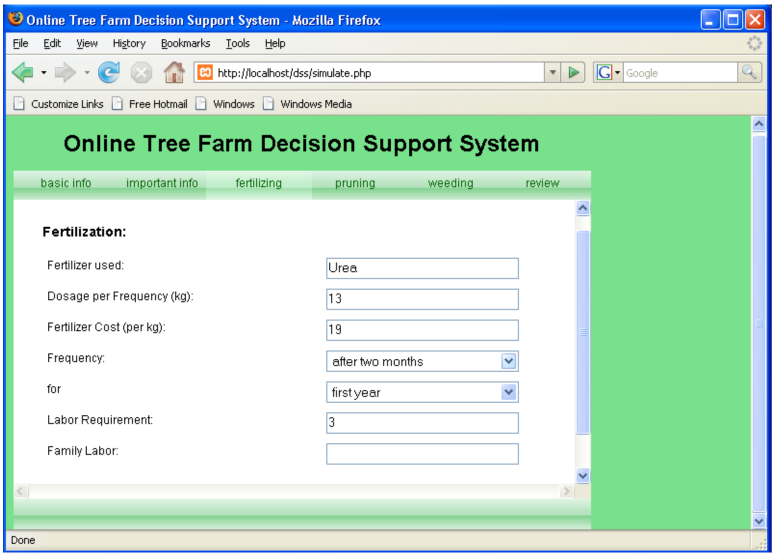

Figure 7. Fertilizer Application Screen, optional where desired fertilization application can be specified

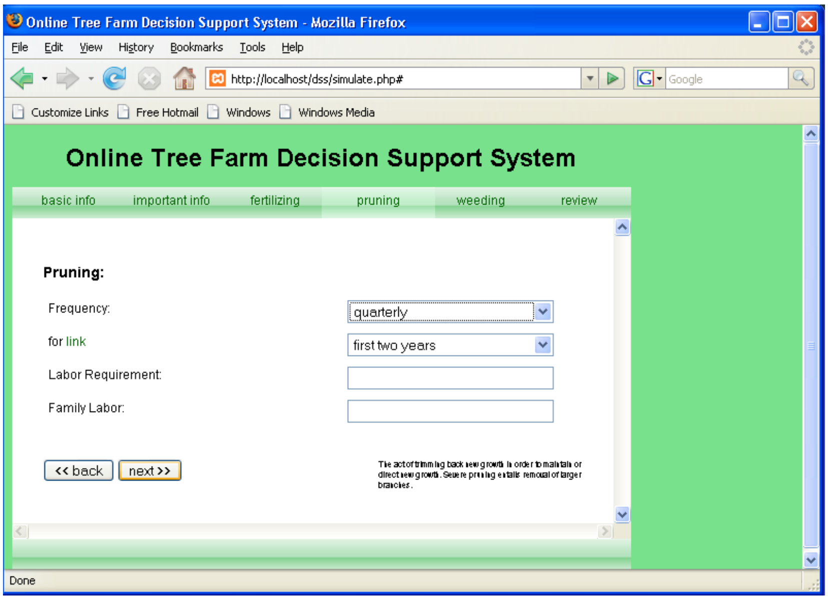

Figure 8. Pruning Schedule, this optional can also be specified in one of the menus

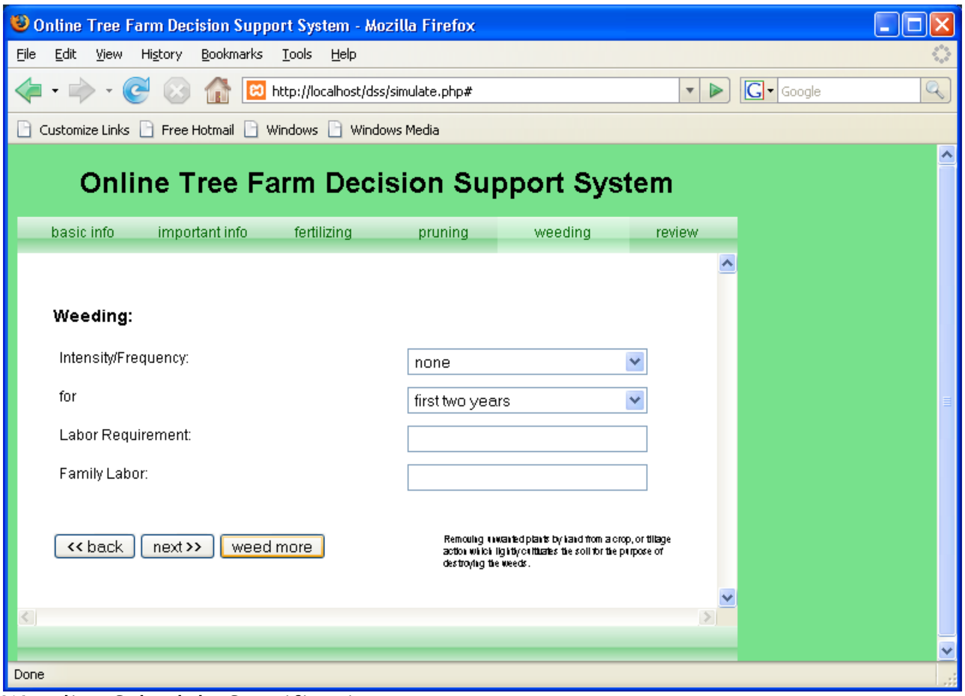

Figure 9. Weeding Schedule Specifications menu

After all plantation details are entered, the user will be directed to a *review* screen to review the input data to be submitted for simulation. The user may change the information specified in this screen (Figure 10).

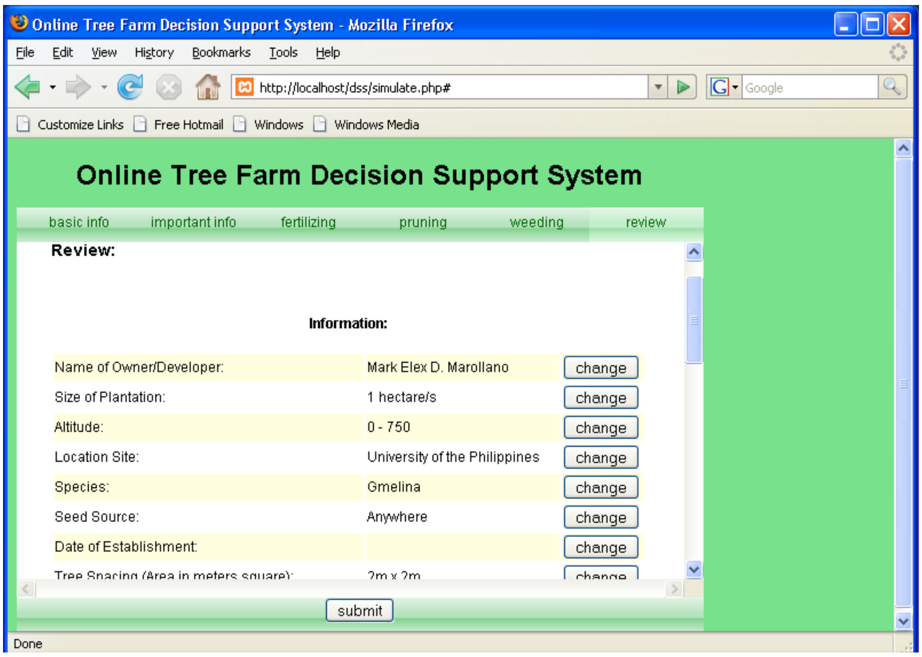

Figure 10. Review Screen, pre-simulation phase. Users may change values of the different silvicultural treatments specified in the previous screens

Once the data are submitted, the DSS will run a simulation of the plantation using the growth model of the tree specie specified. The online DSS can display simulation results in tabular form and also in graph form for visualization. Figure 12 shows the sample Projection Yield Table which is the output of the simulation.

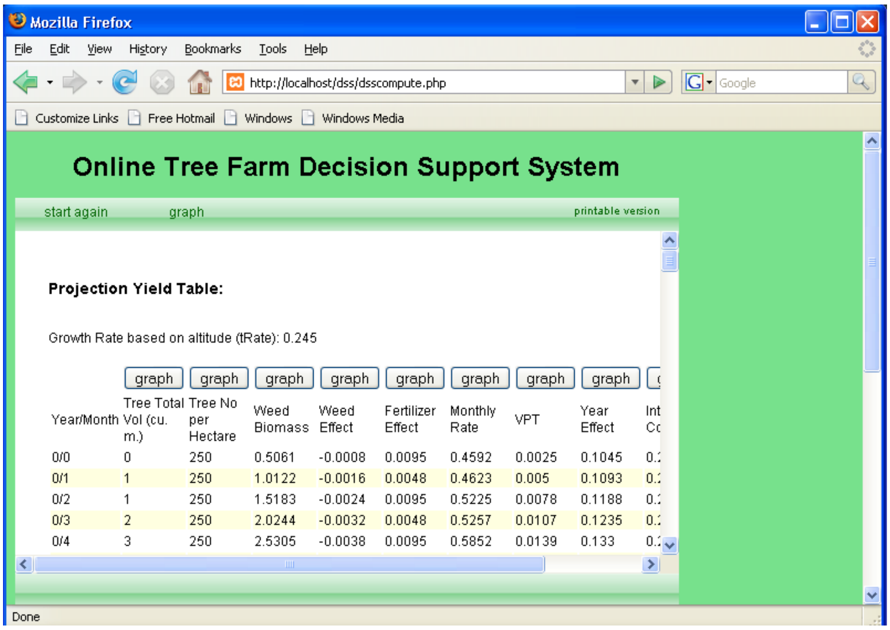

Figure 11. Simulation Report Part 1, production yield table and different monthly information that can be transformed into graph

The DSS can also generate a revenue report (Figure 12). The revenue report contains the yearly Net Present Value of the farm and also suggests what year is the best year to harvest.

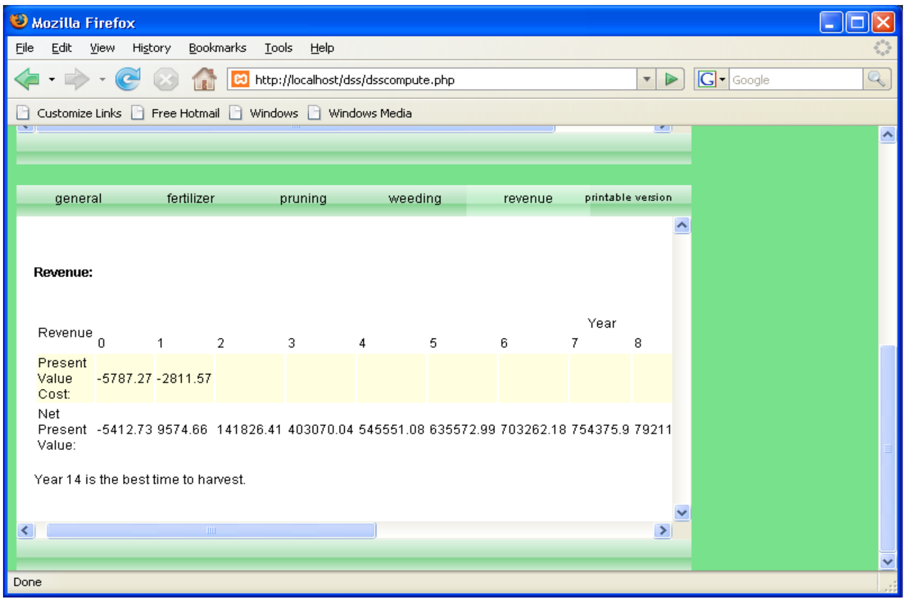

Figure 12. Revenue report

CONCLUSIONS AND POLICY IMPLICATIONS

The effectiveness of smallholder tree plantations as alternative sources of timber raw materials depends upon the plantation developer's capability to grow the species as affected by silvicultural treatments and site factors. The long-term nature of tree farms entails the necessity of a sound management plan because the impacts of poor decisions could be irreversible. Planning the development of plantations involves a lot of decision-making that can only be improved if based on information. In many cases, plantation developers rely only upon experience, intuition, gut feeling or common sense, or consult another person in making decisions.

The system being developed allows the user to simulate the development of the plantation and test its sensitivity to alternative silvicultural regimes, predicting yield and financial cash flows. Therefore the advantage of the DSS is its capability to answer 'what if' questions. Consider the following scenario. Most plantations studied used 2 x 2 metre spacing. This management option initially results in rapid total volume increment. But when the canopy closes and the trees begin to exhibit excessive competition, the growth increment is reduced. If the plantation developer does not conduct thinning, plantation yield will be very low. The system will show the result of such a regime if the user simulates a thinned plantation and compares its performance with that of an unthinned one.

Another advantage of the system is its ability to consolidate data from a variety of sources, including policies, regulations and requirements that developers have to comply with when undertaking specific action in their plantations. This is a proven time-saver for the plantation developers and extension workers.

The DSS takes advantage of the recent developments in interactive information technology and applies this to tree plantation management. Even small-scale plantation developers who may not necessarily have knowledge of financial and feasibility analyses can use it. The user can experiment on the simulated computer environment on various plantation management scenarios while the system generates feedback based on the data entered. The user can do this repeatedly in evaluating management alternatives until the optimal set of operations is attained, given the constraints of soil nutrients and other resources

A model-driven web-based decision support system can be developed as long as the underlying model does not require significant time for computation; otherwise, other means of providing the results back to the user may be needed (for example, the forms could be submitted and the simulation run, say overnight, the results of which may be viewed later by the user or sent via email). Because the application is web-based, there is no need for clients to install anything in their own computers. They only need to gain access to a computer with an Internet connection. Using a web-based system makes it easier for model developers to modify data or update or calibrate the model since the application is installed at one location only. The developers expect changes to the data and model utilized by the DSS during its initial usage and also expect frequent updates to the software itself. Web-based access also is more cost-effective than distributing the software in CD/DVD format. Once the model is found to really approximate reality, which can be verified through feedback from the users of the DSS, the developers may opt to translate the web-based application to a stand-alone application that can be installed from CD/DVD with an auto-updater so it can update itself on changes in data or model.

Since the software is developed from open source or free components and applications, the cost of developing the software is greatly decreased, added to the fact that the software is distributed via the web.

Current practices and work in yield projection modelling, in general, require improvement because the current models, if any, are not able to predict the effect of varying silvicultural treatments and sites to growth.

It should be noted that the reliability of a process-based model summarized in terms of the functional relationships depends largely on the reliability of the data collected from the field. In other words, the principle of 'garbage in, garbage out' strongly applies in the development of the model and the DSS. While the model is scientifically sound, its reliability is determined by the input data used to estimate yield.

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