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The Development of an Expert System for Decision Making in Forest Resources Managemant

Nur Ilyana Mohd Zukki, Latifah Abd Manaf and Mohd Armi Abu Samah

Department of Environmental Sciences, Faculty of Environmental Studies, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

Abstract

Tropical forests are a repository of biodiversity which provides habitats for more than 50% of the earth's plant and animal species, an important sink for carbon stores which provides many goods and ecosystem services and a critical contributor to livelihoods, mainly of the indigenous groups which are totally dependent on forests. Yet, forests are under pressure. Tropical forests are among the earth's most threatened ecosystems, particularly threatened by human activities and climate change. Consequently, tropical forests are loosing capacity to provide basic goods and services that are essentials to human livelihood. Hence, every decision involving forest utilization should consider various criteria that are important for sustainable forest management. However, making decision about forest resources management often involves balancing conflicting, inadequate and incompatible values of many users and usage of a resource. One of the most fundamental and difficult task is the effective integration of environmental, economic and social values to achieve and maintain ecologically sustainable development. Therefore, an integrated technology such as an Analytical Hierarchy Process and expert systems is essential to be performed in making decision process for forest resources management because an AHP method is capable to capture both tangible and intangible criteria. This study places emphasis on the development of expert system for forest resources management to assist decision makers to select the best forest resources use based on Malaysian Criteria and Indicators [(MC&I)2002].

Keywords: expert systems; multi-criteria decision making; analytical hierarchy process; forest resources management

1. Introduction

Forest resources are defined as all that is provided by the forests in their various functional aspects. Thus, it would include timber forest resources, non-timber forest resources, the forestûs potential for recreation as well as its potential for providing important scientific information, drinking water and other services (Gan and Weinland, 1996).

Since early times the Malaysian forest played a significant role in man's relationship with his environment. Forests are important as a physical, economic resource, social, cultural and spiritual resource for livelihoods plus the basis of beliefs, identity and survival, by indigenous and forest-dependent peoples as well as environmentalists. Thus, proper forest management is vital to ensure that the next generation has the opportunity to benefit from forest resources. Over the years, forest management in Malaysia has slowly been moving from the traditional single use, single-resource management of sustained yield towards a more holistic scope of multiple-value, multi-resource management. The current trend is not only looking towards sustaining the yield of the forest resource but also including environmentally appropriate and socially acceptable management of the forests (Ginny, 2000).

Forest resource planning is a very complex problem mainly due to the multiplicity of wide-ranging criteria involved in the underlying decision-making process. Thus, every decision made affects criteria of different nature like economic issues (e.g., timber, forage, livestock, hunting, etc.); environmental issues (e.g., soil erosion, carbon sequestration, biodiversity conservation, etc.); and social issues (e.g., recreational activities, level of employment, population settlement, etc.) (Luis and Carlos, 2008).

With regards to the above considerations, apparently the concept and measurement of the sustainability of a forest system is a very complex problem, and there is no consensus about how to address it. In this respect, one of the most widely used orientations to measure the sustainability of a system is the so-called "indicators approach". Within this perspective, the main subject is to aggregate the different indicators used into a single index that measures the sustainability of the forest system as a whole. Analytically, the stated problem of aggregation fits in very well with a MCDM approach (Luis and Carlos, 2008).

However, the major problem is the scarcity of real experts thus making consultation very expensive in the decision making process. Experts are bound by limitations and it is quite difficult for an expert to consider all the essential factors while making decision. Something always escapes and remains unattended (Prasad and Sinha, 2005). Some tools or assistance is needed, even for experts to update his knowledge and get help in decision making process.

The main objective of the study is to develop an expert system prototype with Analytical Hierarchy Process as the knowledge base. The prototype is capable of performing important tasks such as evaluation and selection of the best forest resources use with regard to SFM and selecting the Forest Functional Class for selected areas of forest in Malaysia. The users will get recommendations and suggestions from the developed prototype. It will act as a decision support tool during the decision making process that involves evaluation and selection of the best forest resources use.

2. Methodology

This research involves 2 main methods namely (1) development of hierarchy structuring using the AHP; (2) the development of prototype expert system.

2.1. Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) is designed to help with multiple-criteria decisions (Saaty, 1980). An AHP model typically consists of an overall goal, a set of criteria, and finally, at the lowest level of the hierarchy, the decision alternatives to be evaluated. Beyond the decomposition principle, the AHP is based on pairwise comparisons of elements in a decision hierarchy with respect to the parent element at the next higher hierarchical level (i.e., among criteria and lower level elements). Pairwise comparisons are made on a scale of relative importance where the decision maker has the option to express the preferences between two elements on a ratio scale from equally important (i.e., equivalent to a numeric value of one) to absolute preference (i.e., equivalent to a numeric value of nine) of one element over another (Saaty, 2001).

AHP allows the consistent comparison of both qualitative and quantitative criteria or alternatives, since different scales of input information are transformed to uni-dimensional priorities. Ratings of decision makers are arranged as numerical numbers in a comparison matrix. Based on this, relative weights for all elements of the hierarchy are calculated with the eigenvalue method. Saaty (2001) indicated the priority level for each element in the hierarchy. Accordingly, priorities for the alternatives are gained by judgments with respect to each above-level element of the hierarchy. Their performance are weighted with the relative weights of criteria and sub-criteria (i.e., indicators), and added to an overall priority for each alternative (i.e., how they contribute to the goal), which allows a cardinal ranking of the alternatives. Moreover, the eigenvalue approach of the AHP provides a measure for the consistency of the judgments (consistency ratio), aiming to improve the coherence among redundant judgments.

2.2. Expert System Technology

Expert systems typically have three basic components: a knowledge base, a user interface and an inference engine. The knowledge base contains knowledge necessary for understanding, formulating and solving problems. It includes two basic elements: (1) facts, such as the problem in its various states and (2) rules that direct the use of knowledge to solve specific problems in a particular domain. Modification of knowledge base is important in most engineering domains, since knowledge is continually changing and expanding. The user interface is the part of the program that controls the conversation between user and computer. User interfaces can be defined as the point where users interact with a computer system (Mockler and Dologite, 1992). The user interface determines whether the conversation consists of selecting items from menus, responding yes or no to question or filling in forms. The user interface is also responsible for the degree to which the system can explain its solution or otherwise assist users. The inference engine is the heart of the expert system since this is the part of the program that builds the bridge between information and solutions. Two different approaches to problem solving are usually distinguished and inference engines are accordingly characterized in two different ways, as either backward chaining or forward chaining. A backward chaining inference process justifies a proposed conclusion by determining if it will result when rules are applied to the facts. On the other hand, a forward chaining inference strategy reaches a conclusion by applying rules to facts (Liao *et al*., 2004).

3. Results and Discussion

This study integrates two parts of knowledge domain, namely (i) Analytical Hierarchy Process and (ii) an expert system technology. There are two modules being developed for the expert system prototype, namely (i) module for selecting the best forest function and (ii) module for selecting Forest Functional Class (FFC). Note that the purpose of evaluation is to select the best forest resources use with regards to SFM and to select the Forest Functional Class for selected areas of forest.

The development of the expert system prototype is referred from the common method introduced by Dym (1987) and Stefik. (1995), which involve five inter-related steps as shown by the flow chart in Fig. 1. The five stages involved are explained as the following:

Stage 1: Task Analysis

The first stage of developing the expert system involved analysis of the tasks. During the analysis phase, the main objective was for the knowledge engineers to identify and understand the problem to be solved. The outcome of the analysis is important to identify the strategies, methods and techniques in the development of the prototype (Ahmadbasri *et al*., 2008). An Analytical Hierarchy Process as a Multi Criteria Decision Making tool would be applied as a knowledge domain since it has the capabilities to deal with the presence of multiple objectives. It also capable to evaluate both tangible and intangible criteria that would be prioritized in a decision making process.

The tool for expert system development is web based programming language, with AHP as a knowledge base. The expert system is developed by using an expert system shell and the language used for programming is Hyper Text Markup Language (HTML). HTML Browser such as Internet Explorer or Netscape Navigator will translate HTML codes. Yet, Hypertext Preprocessor (PHP) is required to be incorporated together. The user interface will be dynamic and interactive by using PHP and HTML, whilst the display is updated automatically depending on the current input data.

Stage 2: Knowledge Acquisition

Knowledge acquisition is the knowledge engineering job of acquiring and organizing the knowledge needed to develop an expert system which involves organizing and representing knowledge in a way that ensures an accurate replication of the knowledge and the decision situation under study in a form useful for transferring the knowledge to a computer system. The goal of knowledge acquisition and representation is the transfer and transformation of problem-solving and decision-making expertise from some knowledge source into a form useful for developing an expert system. In this study, the knowledge acquisition process can be divided into three phases.

Phase I: The knowledge acquired from various textual sources on the subject of forestry and decision making, as the foundation of the prototype knowledge base.

Phase II: Interview sessions with the experts and site observations to obtain further detailed information on forest resources management.

Phase III: Analysis of recent development and research publications.

Stage 3: Prototype Development

In this stage, knowledge expertise will be transform into computer programmed where rapid prototyping is applied. At other times, prototypes will be developed of different segments or modules of a system, as the overall system is developed in increments. In developing prototypes, an effort is made to select only the most critical factors and show only their most basic relationship, in order to test the underlying structure and concept of the system. There are two modules being developed for the expert system prototype, namely

(i) Module of Selecting the Best Forest Function

This module improvise system in selecting the best forest function which consists of Protection, Production and Social/Needs functions which using Analytical Hierarchy Process to evaluate Pairwise Comparison Matrix (PCM) for criteria and alternatives, It include two sub-modules as following:

- Sub-module of evaluating PCM for criteria over goal: module evaluating criteria over goal using Saaty's (1/9, 9) ratio scale.
- Sub-module of evaluating PCM for alternatives over criteria: module evaluating alternatives over criteria using Saatyûs (1/9, 9) ratio scale.

(ii) Module of Selecting Forest Functional Class (FFC)

This module improvises system in selecting forest functional class using IF-THEN rules for selected areas of forest. The examples of IF-THEN rules are shown as below:

- IF Altitude of forest > 1, 000 above sea level, and Slope gradient > 40°
  THEN Logging is prohibited within this area

- IF Altitude of forest > 1, 000 above sea level, and Slope gradient < 40° and Good transportation
  THEN Logging is allowed; Suggested FFC is "timber production forest under sustained yield".

Stage 4: Expansion and Refinement

This stage required the expert to add more knowledge expertise from interviews, field observation and research publication such as proceeding and journals. The prototype reviewed repeatedly and rapidly until a sufficiently satisfactory prototype is achieved. The performance and utility of the prototype program will be evaluated and revised as necessary. It also involves checking for mistakes in knowledge acquisition and to establish the system performs with an acceptable level of accuracy, user-friendliness, and overall usefulness.

Stage 5: Verification and Validation

An important step of an expert system development process is the evaluation of the performance of the systems, which involves both testing and validation. It is very important that expert systems are tested and validated before their effective employment in the intended user environment. Verification involves program debugging, error analysis, input acceptance, output generation, etc, while validation concerns with the diagnosis of how closely the expert system solutions match those of human experts. This is done by meeting with the experts to discuss if he/she agreed with the solution given by the prototype (Ahmadbasri *et al*., 2008).

5. Conclusion

This paper presents a developing process for an expert system prototype for forest resources management. Based on this process this expert system development project can be considered as a merging of AHP application and an expert system technology. The prototype may be used to serve as supporting tool for the decision makers when selecting the best forest resources use with regard to Sustainable Forest Management as well as Forest Functional Class for selected forest areas. It is crucial for the system to be user friendly to the expected end users such as the decision makers from federal and state forest department to assist in the decision making process for forest resources allocation in particular areas. When the whole system is tested, calibrated and validated on a real situation it is believed that it will improve significantly the efficiency of the forest management.

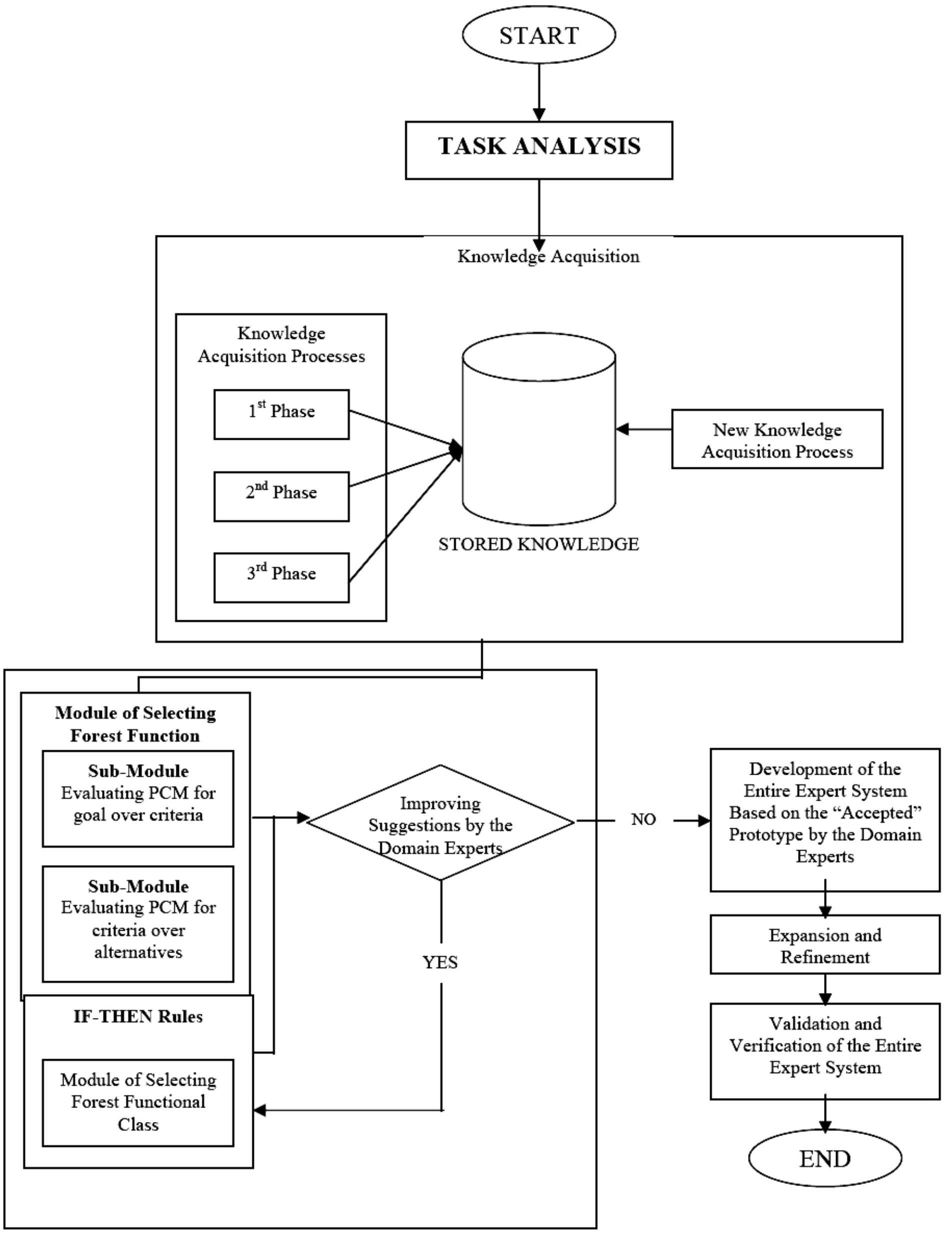

Figure 1. The flow chart of expert system development for forest resources management

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Correspondence to
Dr. Latifah Abd Manaf
Department of Environmental Sciences,
Faculty of Environmental Studies,
Universiti Putra Malaysia,
43400 UPM Serdang,Selangor,
Malaysia
Tel: (603)8946 6747
Fax: (603)8946 7463
E-mail: latifah@env.upm.edu.my