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Geospatial Information Technology for Conservation of Coastal Forest and Mangroves Environment in Malaysia

Kamaruzaman Jusoff

Forest Geospatial Information & Survey Laboratory

Department of Forest Production, Lebuh Silikon, Faculty of Forestry

Universiti Putra Malaysia

43400 UPM, Serdang, Selangor, Malaysia

Tel: 60-3-8946-7176 E-mail: kamaruz@putra.upm.edu.my

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Abstract

Mangrove forests are one of the most productive and bio-diverse wetlands environments on earth. Yet, these unique coastal tropical forests environment are among the most threatened habitats in the world. Growing in the intertidal areas and estuary mouths between land and sea, mangroves provide critical habitat for a diverse marine and terrestrial flora and fauna. The important need of living being is opportunity to continue their life in sustainable environment and suitable conditions. Potential stand is the place that obtains the possibility of germination and establishment of a plant species according to their physical, chemical, biological demands. In many cases are seen that because of unsuitable selection of site and species, afforestation and reforestation projects after spending time, cost and labor are forced to failure. Therefore, it is an obligation by the relevant authorities, especially Forestry Department to ensure that the rate of seedlings survival in the afforestation and reforestation activities is successfully monitored, mapped and quantified. One of the most efficient techniques available is the use of Geospatial Information Technology consisting of Geographical Information Systems (GIS), Global Positioning System (GPS) and remote sensing (RS). Using this technology and integrating the different thematically maps that shows environmental conditions of specific region, suitable and potential positioning of different species for plantation and rehabilitation programs could be well determined and monitored. For mapping and detection of individual mangrove species for reforestation and afforestation purposes, mathematical functions such as Boolean logic, fuzzy logic, and neural network can be easily applied. It is expected that suitable species-site matching for reforestation and afforestation of mangroves could be implemented with such geospatial tools.

Keywords: GIS, RS, Fuzzy, Boolean, Mangrove, Reforestation, Afforestation

1. Introduction

Mangrove forest is one of the most valuable coastal resources, important for its multiple economic, ecological, and scientific and culture resources for present and future generations. It is an important component of Malaysia's coastal zone ecosystem. In addition, mangrove forests are utilized as a source of fuel, wood and pole production. In recent decades, the coastal zone has been subjected to the effects of a growing population and economic pressure. In order to use coastal resources on a sustainable basis, a proper management planning process is necessary. Mangrove forest assessment and monitoring has been conducted continuously in Malaysia.

The integration of remote sensing and GIS for mangrove forest management is considered as an important tool for the development of effective plans by natural resource managers and planners. Successful application of GIS tools and concepts to the coastal zone is one of the great challenges still facing developers and users of the technology (Hussin et. al., 2007) GIS and remote sensing methods have been used as successful planning and management tools to reforestation of mangroves that have been destroyed in some parts of the world (Ratnasermpong , 2004). After is earned the different data layer according to demand of species, these layers were divided according of suitable or unsuitable for species growth. At the end were determined the region that is suitable for growth and establishment of species considered to relative factors with integrate of data layer, and so were earned the map of suitable site for forestation with foresaid species. In land classification, the final map is one of the main outputs but the information about utilization types and management specifications is also important. After the land suitability evaluation has been done, the decision about the use to be selected depends on physical and economical factors; in this way, perhaps the most suitable use will not be chosen due to its viability.

The main objective of this study is to demonstrate an effective approach for sustainable site selection with mangrove reforestation by using remote sensing and GIS technology. Preparing data layer in GIS is flexible and depends on used layers. In some layers such as topography map, basin boundary, ways network, slow changes are expected using them, but in some layers the change is fast such as cloud cover, snow cover, soil moisture condition, therefore we can use satellite images which are up to date and result in higher accuracy and exactitude in projects. Another advantage is that the GIS users have found that they can get the most of the input data with RS. Also digital satellite data are directly transmittable to GIS. Use of both GIS and RS techniques not only progress the geographical information but also give the ability to users to get economical data. Use of these two technologies are an emergency instruments in natural resources and agriculture that give clear and controlled points versus unclear points and out of control to programmers and managers. But how does the fuzzy logic works in a GIS? The processing is the same as classification of satellite image, but its module and boundary are normally determined by the fuzzy classification user (Juan Francisco, 2007).

2. Methods and Materials

2.1 Determining of Potential Site Selection using Boolean Method

The traditional concept of modelling employs a Boolean approach: the value is true or false. This approach tends to represent reality in a discrete way. But what can be found in the nature is that few elements are discrete, they are rather continuous. In the real world, some objects are quite differentiated from others and their boundaries are quire evident: a river crossing through a valley is quite distinguishable from its surroundings when in full discharge, an area covered by a lake is distinct from the land areas surrounding it; but soil and vegetation and other patterns in nature change transitionally: the limit between two types of soil or vegetation is, in most of the cases, not so clearly defined. Fuzzy modelling appears as an alternative to deal with these continuous or uncertain environments. While in Boolean logic a value is true of false, with fuzzy logic the value could be partially false of partially true which allows for a representation more according to the reality.In this method only were used numbers 0, 1. The pixels which are suitable for growing of species according ecological condition are assigned code1 and the pixels that are not suitable for are assigned code 0. Then all made layers that are consist of 0, 1 will algebra multiply together to district out put points in process of multiply layer. That is enough one of the corresponding pixels would has code 0, so related point that have assigned code 0 in output part will omit from stand. But if all corresponding points that have code 1, are defined with code 1 and be belonging to talented growing for specific species. In Boolean logic, the finality is considered not both sides.

2.2 Determine Potential Site Selection in Fuzzy Method

When done limitations for a topic be great on the earth, whereas we can not get suitable boundary by Boolean logic, should forgo some ideal condition and adjust, in this condition we can use Fuzzy logic, whereas also are classified between two numbers, i.e 0 and 1 and will determine Fuzzy degree membership. In this study, some ecological factors were defined, border domain that observed in before tables separately. In this method also, layers have been identified and classified based on the ecological demands of species and determined domain in Fuzzy logic. Then did action of integration with operator ADN and selection of minimum numeric quantity in each pixels, in integration layers, some layers are naturally Boolean and can not classified them with Fuzzy method, therefore some layers with Boolean classification in integration with Fuzzy layers were used.

2.3 Fuzzy Modelling and its Applications for Coastal Environment Suitability

Fuzzy logic was initially developed by Lotfi Zadeh (Iranian scientist) in 1965 as a generalization of classic logic. He defined a fuzzy set as “a class of objects with a continuum of grades of memberships”; being the membership a function that assigns to each object a grade ranging between zero and one, the higher the grade of membership the closest the class value to one. Traditionally thematic maps are represented with discrete attributes based on Boolean memberships, such as polygons, lines and points. These types of entities have a value or do not have it; an intermediate option is not possible. With fuzzy theory, the spatial entities are associated with membership grades that indicate to which extent the entities belong to a class. Figure 1 presents a representation of traditional Boolean sets and fuzzy sets: while with Boolean logic the boundary between sets is clearly defined (A and B), with fuzzy logic there is a transition zone where each set has less membership grade in relation to the other. In fuzzy theory, the map for A shows membership values closer to 1 when the set falls within A category, while the values are close to 0 when they are far from the category; the same applies for category B.

<Figure 1. Representation of crisp and fuzzy sets>

Fuzzy logic is also a generalization of Boolean logic that instead of using the binary TRUE and FALSE values applies “soft” variables such as deep, moderately deep, steep, etc. These variables are defined in an interval ranging between 0 and 1 allowing a continuous range of values.

Qualitative parameters obtained through interviews to stakeholders and quantitative parameters obtained through field measurements and recorded by FAO in the ECOCROP database (http://ecocrop.fao.org/) were considered to evaluate

the suitability. The quantitative parameters include soil fertility, drainage, texture, depth and pH. The purpose of their study was to asses the performance of Boolean classification methods such as FAO framework for land evaluation versus a fuzzy classification methodology. In their study it was found that the assignment of suitability orders with the Boolean theory (that is, S1 for suitable, S2 for less suitable, N for non-suitable and so on) restricts the results for available land for a potential use: large areas of the study areas were classified with the same rating while for the fuzzy classification a higher variation of suitability were found. These results are a consequence of the matching between suitability-class requirements and land characteristics, where the land is a member of the suitability class or is not and no intermediate values are possible. In this study it is concluded that fuzzy processing allows obtaining information about the degree of land suitability class, which is relevant for land use planers to know how highly or moderately suitable is the land for a crop (Rodrigo and Emmanuel, 2005).

Fuzzy Sets are sets (or classes) without sharp boundaries; that is, the transition between membership and non membership of a location in the set is gradual. A Fuzzy Set is characterized by a fuzzy membership grade (also called a possibility) that ranges from 0.0 to 1.0, indicating a continuous increase from non membership to complete membership. Four fuzzy set membership functions are provided in IDRISI for Windows: Sigmoidal, J-Shaped, Linear and User-defined.

Sigmoidal: The Sigmoidal ("s-shaped") Membership function is perhaps the most commonly used function in Fuzzy Set theory. It is produced using a cosine function. In use, FUZZY requires the positions (along the X axis) of 4 points governing the shape of the curve. These are indicated in the figure below as points a, b, c and d and represent the inflection points of the curve as follows:

a = membership rises above 0

b = membership becomes 1

c = membership falls below 1

d = membership becomes 0

In the fuzzy methodology the same parameters have been considered for fertility, but without taking into account pH, which may have strong fluctuations within the same soil unit. The calculation of the fuzzy memberships for the different factors influencing fertility was evaluated using a linear function as given in Figure 2.

<Figure 2. Linear or asymmetrical triangular membership function. Where x is the input data and, *a* and *c* are the limit values according to related Tables>

For depth an asymmetrical second grade function has been employed:

This function was tested successfully for soil depth. In the equation, *a* is a parameter that controls the shape of the function and the position of the cross-over points; the expression (x-c)2 controls the dispersion

<Figure 3. Membership function for asymmetrical second grade function (adapted from Burrough, 1989)>

A combination of symmetrical Gaussian functions was employed to assess the membership functions for depth. In this way the overlapping nature of soil depth can be assessed.

<Figure 4. Gaussian membership functions for fuzzy subsets of soil depth.>

For slope, an S membership function was employed. The limits a and g corresponded to the limit conditions of steep slopes and flat terrain respectively. This function gives better results when compared to other membership functions, and for this reason has been used four fuzzy sets with the linguistic labels{P, L, M, H}, which stand for *poor*, *low*, *moderate*, and *high*, respectively Fuzzy membership classes.

<Figure 5. S membership function >

3. Results and Discussion

Boolean logic is appropriate to potential site selection and can justice with high convenience. Fuzzy logic also is appropriate to potential site selection because district the points between 0 and 1. Closer number to 1 is more successful. This research could be used as a model for site selection in agriculture, natural resources and biological environment.

As a main advantage of the Boolean theory, it is possible to control and trace easily which factors are affecting the suitability of a plot, while with the fuzzy model it is necessary to review the interaction between membership functions and weights, which is not a straightforward process. Fuzzy theory allows intermediate possibilities of suitability beyond the traditional classes given by the Boolean methods, but on the other hand it can over estimate the potential of a land (Yanar and Akyure, 2007). Oppositely, the Boolean theory can underestimate the real potential of a plot. In this sense, perhaps the land evaluator has to try with both theories and check with information on the field which one agrees better with the reality. Traditional methodologies which rely on Boolean logic require high accuracy and data detail that is

difficult –if not impossible- to find in reality. Fuzzy logic can cope with low detail levels and allows for more flexibility in the suitability classification.

For selecting the region that is suitable for forestation of Mangrove species, Boolean model consider environment and parameters 0 and 1 (black and white) while Fuzzy logic has ability to consider gray, we should pay attention that the most of the environmental parameters are accordance with fuzzy logic. For species forestation the costs also is significant, in Boolean the risks and failure of project is less than the region that the Fuzzy has determined, because in fuzzy has determined the more extensive region that exist the possibility of the forestation than the Boolean one. The figure 6 is example which has compared the suitable region for forestation with Boolean logic and Fuzzy logic methods. The major results are the compilation of relevant thematic databases, assessment of forest land use and forest distribution in 1973, 1987, 1993 and 1998, as well as change in land use and land cover between 1987-1993 and 1993-1998 and development of a proposed forest land use plan. Remote sensing appears to be a significant tool for assessment and monitoring of coastal zone resources, especially mangrove forest.

<Figure 6. Sample of Boolean and fuzzy logic comparison; Boolean method have done in left one and Fuzzy logic in right one>

In addition, planning and management of forest land use is easily and effectively conducted using GIS. However, the integration of remote sensing and GIS for the development of mangrove forest management plans by natural resource managers and planners is necessary. The result of factor maps overlay is multiplied by the result of limitation maps overlay could result to selection of suitable locations for mangroves. The mapping of land use/land cover is essential for natural resource survey. In this context we can say that GIS is a special purpose digital database in which a common spatial coordinate system is the primary means of reference. Comprehensive GIS requires a means of (a) data input, from maps, aerial photograph, satellites, surveys and other sources, (b) data storage, retrieval and query, (b) data transformation, analysis and modelling, including spatial statistics, and (d) data reporting such as maps, reports and plans. GIS is a very powerful integration tool between the various data source.

It is found that the spatial distribution of the problems and their effects are very typical. This shows the role of spatial analysis and the importance of the GIS functionality. A GIS can provide better information to support this type of complex decision-making. With the rapid advancements taking place in computer hardware and GIS software, more complex models are being developed. These models help researchers and planners to simplify complex systems and to develop theory to understand the process at work better. Present analytical functions and conventional cartographic modelling techniques in GIS are based on Boolean logic, which implicitly assumes that objects in a spatial database and their attributes, can be uniquely defined. In the land evaluation process, with Boolean classification, all land units with values that exceed the given threshold may be defined as the class or set of acceptable land units which are to be rejected. These uncertain boundary definitions create some problems with loss of information. The deficiencies of the traditional Boolean logic for the design of spatial databases have been recognized in recent years. As an alternative to Boolean logic, Zadeh's fuzzy set theory has been proposed as a new logical foundation for GIS design.

The mangroves are considered to be highly biologically productive estuarine system and serve as nursery, feeding and breeding ground for many kinds live being. They also help to restrict cyclone damage as a biological shield against the cyclones and prevent soil erosion as well. Innumerable species of fish use them as nesting and feeding grounds. As the land runoff carrying coastal pollutants end up in the seas, the mangroves serve as sink or trap for the coastal pollutants. The mangroves are food source for many Phytoplankton's feed on the allochthonous detritus produced by the mangroves Understanding the status of mangroves including degradation areas and its causes is important decision making and also for creating public awareness to conserve these important coastal resources.

4. Conclusion and Recommendation

Map of land use planning is more accurate and totally conformable with applicative criteria future planning. Different factors in the field such as climate, soil, physiographic are highly interactive with each others and should be incorporated in future studies.

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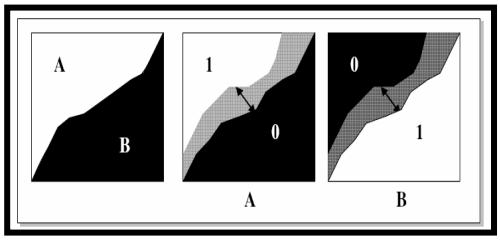

Figure 1. Representation of crisp and fuzzy sets

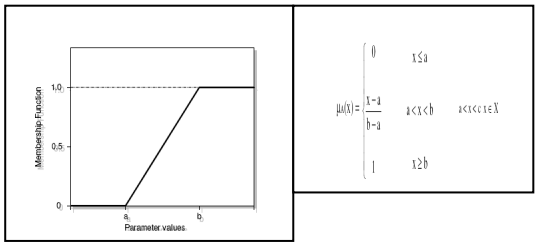

Figure 2. Linear or asymmetrical triangular membership function.

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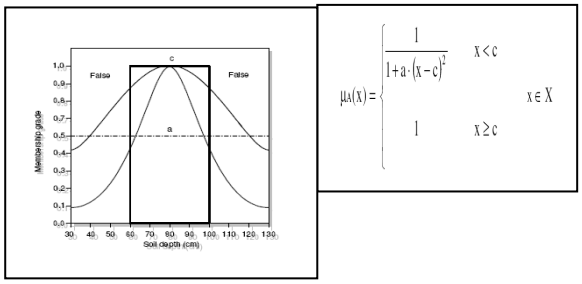


Figure 3. Membership function for asymmetrical second grade function.

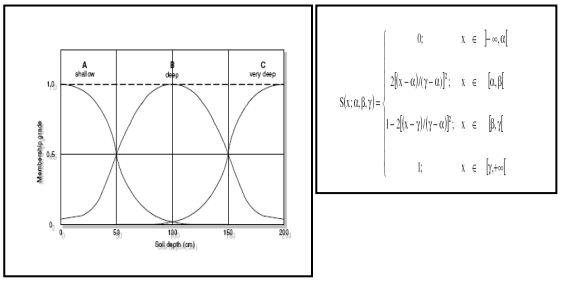


Figure 4. Gaussian membership functions for fuzzy subsets of soil depth.

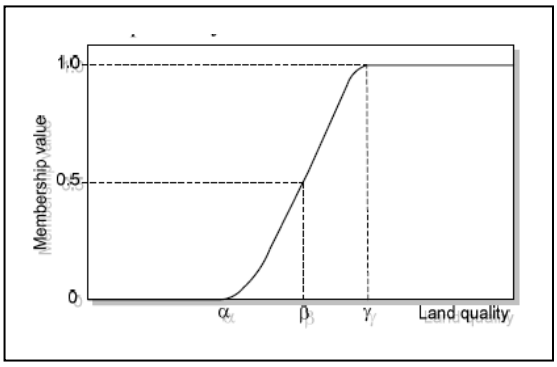
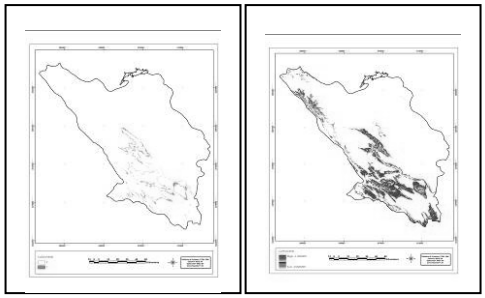


Figure 5. S membership function



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