INTEGRATION OF GIS AND AHP TECHNIQUES FOR LAND USE SUITABILITY ANALYSIS IN DI LINH DISTRICT – LAM DONG PROVINCE

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ABSTRACT

The integration of Geographic Information Systems (GIS) and Analytical Hierarchy Process (AHP) will help decision maker in landuse planning specially in landuse suitability. The research presents how the integrated GIS-AHP has effectively handled a land use suitability analysis for Di Linh District, Lam Dong Province of Viet Nam which considered simultaneously 5 different criteria.

The formula is as follows:

$$Y = \sum_{i=1}^{n} M_i . w_i$$

Y: Suitability index
w_i: weight of criterion i
M_i: score of criterion i

The results shown that the higher Y value is the higher suitability of land-use for specified landuse type. This process is done in Arcview GIS through the composite map of land mapping units. Arcview GIS function is used to perform the calculation based on the above equation as well as scores and weights of criteria. Integrating both spatial component and suitability index produces a continuous map of suitability.

1. INTRODUCTION

Deforestation in Vietnam is still occurring even though the government has tried in every means to address this problem. The problem causes are closely interacted whether the population pressure, limited of agriculture land, and poor economic status which seem to form the endless of cyclic poverty. The Government have 5 million hectares reforestation program between 1998 and 2010 to restore forest cover of the country back again to 43%, the same percentage that was under forest in 1943. The stated objectives of this effort are to reverse environmental degradation. At the same time the project means to boost the productivity of the national forestry sector.

Developments in mathematical techniques and operations research have considerably helped to promote multi-objectives decision making. Various desired target from either communities and management policies need to be prioritized ranking by Analytical Hierarchy

Process (AHP) before passing through the mathematical programming so called "Goal Programming, GP" to evaluate each objective achievement level under the criteria of limited resources.

Hence, this study attempts to solve the selected Dinh Linh district, Lam Dong province, as representative degraded headwater problems of the upper upstream Dong Nai watershed in the context of land use planning and watershed management through the GIS & AHP approach.

1.1 Objectives

The analysis of land use suitability requires consideration of variety of criteria including not only natural capacity of a land unit but also socio-economic and environmental impact implications.
The objectives of the study are:

1. To apply AHP technique to deternmine an indicator to forest species (*Pinus Kesya, Pinus merkusii, Acacia auriculiformis)*;
2. To apply GIS & AHP techniques to relocate land use sustainability in Din Linh district, Lam Dong province, upstream Dong Nai watershed, Vietnam.

2. METHODOLOGY

2.1. Location of the study area

Di Linh district locates in Lam Dong Province. The district is about 350 km from Ho Chi Minh City and about 45 km from Da Lat town, the center of Lam Dong province. The location of the study site is shown in the map bellows.
Di Linh is an highland district with elevation varies from 500 to 1,700 m. The study area is characterized by a range of hills with gentle to relatively high slopes and small valleys. Most of the land area of the district are sloping land. About 70% of the area in the district are land with medium to high slopes. In many locations, there is high risk of soil erosion, particularly on land located on hill sides with high slopes. In some hamlets of the village, transportation from fields to farmers' house is difficult, particularly during rainy season, due to a hilly topography and poor road condition. Flat land and land with low slopes occupy 20% and 10% of the total land area of the district, respectively.

The climate in the area is characterized by Highlands climatic zone 4, a tropical climate with monsoon. Average annual temperature is about 20.6^0 C with highest temperature about 28.5^0 C and lowest temperature about 13.4^0 C. The annual rainfall in the study area is about 2,600 mm.The total land area of the village is 161,000 hectare. The district is upstream Dong Nai watershed.

2.2. Method

Land-use suitability is the ability of a given type of land to support a defined use. The process of land suitability analysis involved evaluation and grouping of specific areas of land in terms of their suitability for a defined use. The principles of sustainable development make land-

use suitability analysis become increasingly complex due to consideration of different requirements/criteria. It includes consideration not only inherent capacity of a land unit to support a specific land use for a long period of time without deterioration, but also the socio-economic and environmental costs.

The process for land-use suitability analysis is shown in Figure 1.

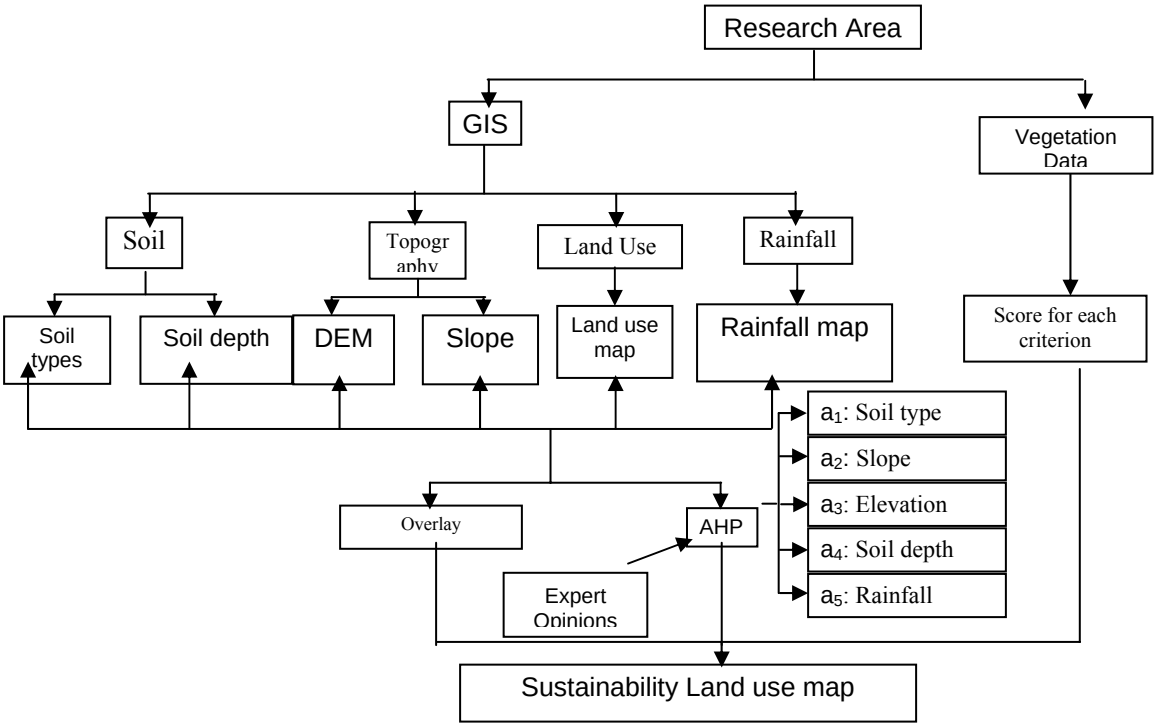


Figure 1. Land-use suitability analysis process in Di Linh District – Upstream Dong Nai watershed

2.3 AHP Technique

Saaty first developed the AHP (Analytical Hierarchy Process) in the mid 1970s and since that time, has been applied to many types of decision problems. The AHP is based on set of axioms that can be simplified them in order to understand their meaning. Harker (1989) further explains this aspect of AHP as follows :

Axiom 1. Given any two alternatives i and j out of the set of alternatives A, the decision maker is able to provide a pairwise comparison a_{ij} of these alternatives under any criterion c the subset of criterion C on a ratio scale which is reciprocal ; i. e.,

$$\mathbf{a_{ij} = 1/a_{ji}} \quad \text{for all } i, j \in A.$$

Axiom 2. When comparing any two alternatives i, $j \in A$, the decision maker never judges one to be infinitely better than another under any criterion $c \in C_{ij}$ i. e.,

$$\mathbf{a_{ij} \neq \infty} \quad \text{for all } i, j \in A$$

Axiom 3. One can formulate the decision problem as a hierarchy.

Axiom 4. All criteria and alternatives which impact the given decision problem are represented in the hierarchy.

Saaty (1980) indicated that since the AHP is the specified decision – aiding tool, the group must first construct an appropriate decision hierarchy that reflects the problem under study. Most groups are willing to accept the basic hierarchy structure of the AHP as a rational way of modelling their problem. It allows a group with widely varying perspective to decompose a complex problem into its most basic and important components.

Consistency: The eigenvector method for estimating weights (priorities) in the AHP yields a way of measuring the consistency of a decision maker's entries in a pairwise comparison matrix. Saaty (1980) defined the consistency index (C.I.) as :

$$C.I. = (\lambda_{max} - n) / (n-1)$$

where :

n = The dimension of the square matrix comparison

λ_{max} = The largest eigen value of an n × n pairwise comparison matrix

If it is perfectly consistent, then

$\lambda_{max} = N$ and

C.I. = 0

If the decision maker is inconsistent, then

$$\lambda_{max} > N$$

Saaty (1990) indicated that consistency ratio (C.R.) less than or equal to 10% is the acceptable level. On the other hand, it can be said that there is a 10% chance which the decision maker answered the questions in a purely random manner. To measure the degree of inconsistency by the equation :

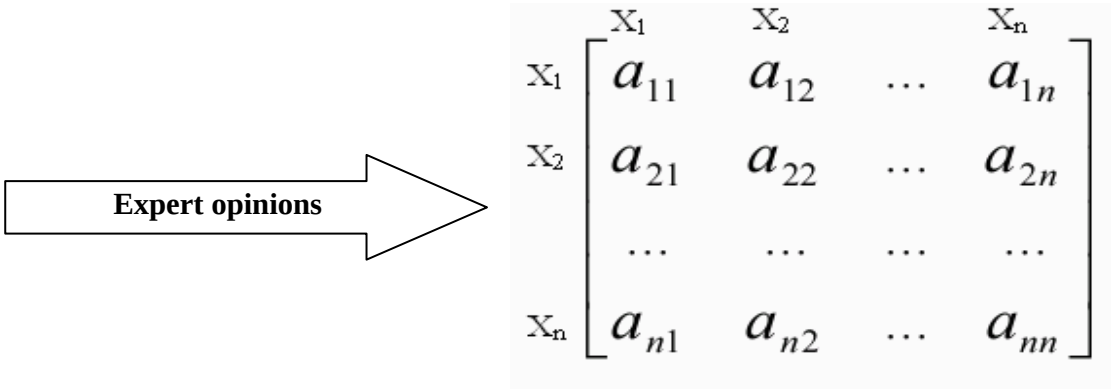
$$C.R. = C.I. / R.I.$$

where :

R.I. = Random Index

2.4 Determination of criteria weight base on Analytical Hierarchy Process (AHP)

X_1: Soil type; X_2: Slope; X_3: Elevation; X_4: Soil depth; X_5: Rainfall.



$a_{ij} > 0$, $a_{ij} = 1/a_{ji}$, $a_{ii} = 1$.

2.5 Determination of suitability index through score of each criterion

$$Y = M_1 * w_{11} + M_2 * w_{22} + M_3 * w_{33} + M_4 * w_{44} + M_5 * w_{55} = \sum_{i=1}^{n} M_i * w_i$$

Y: Suitability Index
Mi: Score of criterion i
w_i: Weight of criteria i

3. RESULTS

3.1. Weights of criteria in landuse suitability analysis

Based on FAO (Food and Agriculture Organization of the United Nations) Framework for Land Evaluation, the 5 natural characteristics are used in the calculation, including: soil type, slope, elevation, soil depth, and rainfall. The weight of criteria in landuse suitability is shown in Table 1, 2.

Table 1. Weights of criteria

Criteria	W_i
Soil type	0.300
Slope	0.250
Elevation	0.164
Soil depth	0.143
Rainfall	0.143

Table 2: AHP parameters

Parameter	Value
λ_{max}	5.004
n	5
Consistency Index (CI)	0.001
Ramdom Index (RI)	1.12
Consistency Ratio (CR)	0.001

In our model, CR=0.001< 0.1 is the acceptable level. The general equation is:

$$Y = 0.3M_1 + 0.25M_2 + 0.164M_3 + 0.143M_4 + 0.143M_5$$

3.2. The land use suitability map for *Pinus kesya, Pinus merkusii, Acacia auriculiformis* in Di Linh district, Lam Dong province

The landuse suitability map of Di Linh district is shown in Figure 2, 3, 4 for landuse type *Pinus Kesya, Pinus merkusii, Acacia auriculiformis*.

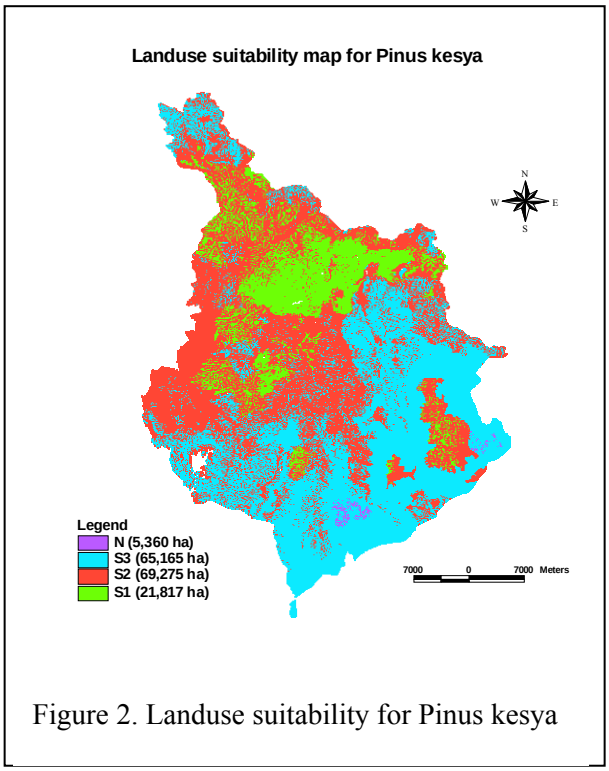


Figure 2. Landuse suitability for Pinus kesya

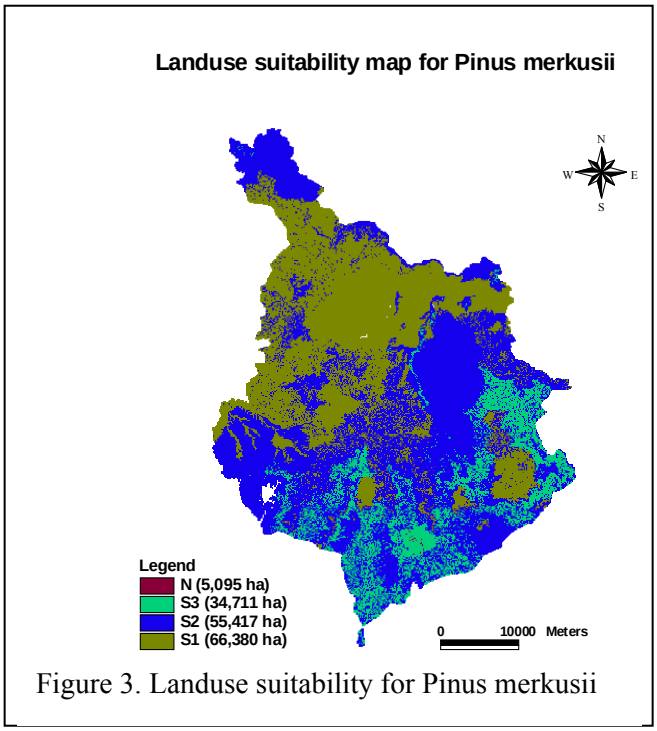


Figure 3. Landuse suitability for Pinus merkusii

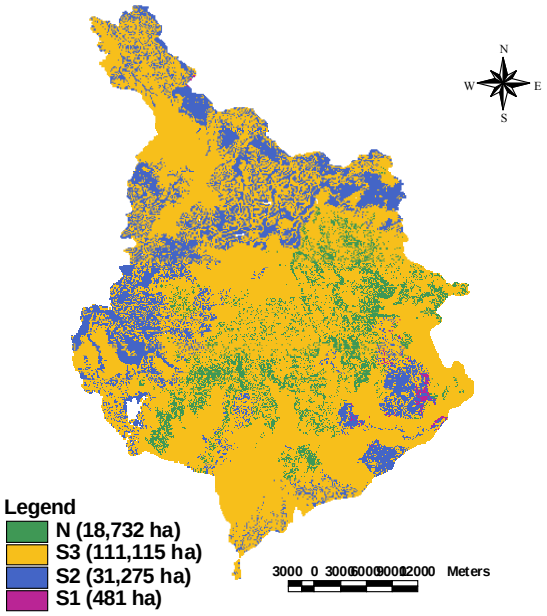


Figure 4. Landuse suitability for Acacia auriculiformis

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