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APPLICATION OF GIS FOR ASSESSING ADAPTATION OF ECOLOGICAL SCENERY TO SERVE PRIORITY SPATIAL ORIENTATION FOR CASSAVA DEVELOPMENT AT KON TUM PROVINCE

Bui Thi Thuy Dao, Pham Thi Thuong Huyen, Quach Thi Chuc
Hanoi University of Natural Resources and Environment, Vietnam

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Abstract

Geographic Information System (GIS) has been becoming a useful application in the assessment and management of many fields. This paper studies on integrating the average multiplication method and application of GIS for assessing the ecological adaptation of cassava to scenery factors. The methodology of this study is divided into two steps that are defining the scenery features as well as building the criterions assessment, and establishing a thematic database for building zoning map of scenery, then the average multiplication is integrated to assess the ecological adaptation of cassava. The experiment of study is applied for Kon Tum province in Vietnam where there is a diverse area in terrain, land types and monsoon tropical climate. The results showed that the current land use at Kon Tum province is 38.206 ha that is 54,87% higher than its potential acreage. This study is a confidence result to the managers in managing and developing the appropriate field for growing cassava at Kon Tum province.

Keywords: GIS; Multiplication; Ecological adaptation; Scenery factors.

Corresponding author. Email: bttdao@hunre.edu.vn

1. Introduction

Recently, cassava has become the main crop in Tay Nguyen area in Vietnam, especially in Kon Tum province where cassava is providing high economic value. The cassava has some advantages compared to other crops, such as easy to grow, low investment costs, etc. Thus, the cassava is considered as a "plant to poverty reduction" for the ethnic minority in many areas, including Kon Tum. According to a statistical report, there are approximately 39000 hectares of cassava planting in Kon Tum province, and the local management evaluates that the cassava is one of the main products in Kon Tum [1, 2, 7]. However, planting cassava has also caused some negative impacts on the natural environment, such as cassava cultivation has a huge effect on land resources that can cause landslides due to the rainy season. Therefore, it is necessary to evaluate ecological adaptation to determine the priority space for cassava development. Then, the managers can define which areas are suitable for planting cassava getting high economic value, which areas do not allow to plant cassava for preventing landslides.

The aim of ecological adaptation assessment is to determine the favorable level of some factors for developing object planning, such as scenery units, ecological scenery units, etc. For instance, ecological adaptation assessment of scenery units is implemented by applying the average method or average multiplication, factor analysis, and land use assessment, etc [3, 9].

This paper studies on integrating the average multiplication method and GIS for assessing the ecological adaptation of cassava to scenery factors. The methodology of this study is divided into two steps that are defining the scenery features as well as building the criterions assessment; and establishing a thematic database for building a zoning map of scenery, then the average multiplication is integrated to assess the ecological adaptation of cassava. The experiment of study is applied for Kon Tum province in Vietnam where there is a diverse area in terrain, land types and monsoon tropical climate.

2. Material and method

2.1. Material

This study is limited to assess the ecological adaptation of cassava in Kon Tum province. The research data are collected including a scenery map at 1:100.000 scale and other thematic maps. To get high accuracy of assessment, the scenery map and thematic maps are integrated to extract information and assess some criterions such as slope, layer thickness, temperature, raining amount, etc, according to climate types.

2.2. Method

The Average Multiplication is used for evaluating with some specific criteria. The assessment results are given by evaluating the score of each scenery type to planting cassava in Kon Tum. The suitable level of each criterion is quantified as follows: very suitable: 3 points; suitable: 2 points; Less appropriate: 1 point and irrelevant (not to judge): 0 point. The score distance of each suitable level in the adapting scoring system is calculated by the below equation [3, 8]:

$$S = \frac{(S_{max} - S_{min})}{H} \quad (1)$$

Where: S_{max} is the largest adapting assessment value, S_{min} is the lowest adapting assessment value, H is the number of assessment levels.

Furthermore, Geographic information systems (GIS) are used to figure out the research area according to the constituent elements of scenery, then show the spatial results of ecological adaptation assessment on a map.

3. Results and discussion

3.1. Selection and classification of evaluation criteria

Ecological demand of the cassava

According to previous studies of the ecological demand of cassava [4, 5], the assessment criteria and function of scenery units in Kon Tum province are defined as below:

* Temperature: Cassava originates from tropical climates, so it grows as well under high temperature conditions. The most suitable temperature for cassava growth is 23 - 27^{o}C.

* Light mode: Cassava is a light-loving plant, so it responds positively to short daylight. It is suitable for 8 - 10 hours/day lighting cycle.

* Water mode: Cassava can live in high drought tolerance, but it only grows and develops as well in hot and humid climates. The annual average rainfall suitable for cassava growing is 1000 - 2000 mm. However, Cassava plants require different amounts of water in different growth periods, such as 70 - 80% moisture in the early growing period and an increase to 75 - 85% of soil saturation moisture in the middle of the life cycle.

* Land type: Cassava can be grown on many different types of soil, such as alluvial soil, sandy soil, feralit soil, peat soil, degraded soil, sandy soil, etc. In general, cassava can grow in different soil types even with acidic soil (pH = 4) or with alkaline soil (pH = 7.5).

Classify of evaluation criteria

According to the principles of selecting evaluation criteria, ecological demand of cassava and ecological features in Kon Tum, this study proposed 11 criteria for classification as follows:

- *Slope*: Problems with erosion, leaching, irrigation, use of cropping practices and distribution of crops. The slope in the target area is divided into 4 levels: <8^{o}, 8^{o} - 15^{o}, 15^{o} - 25^{o} and > 25^{o}

- *Type of soil*: There are 10 types of soil in the research area, adapted for different land uses.

- *The composition of soil mechanics*: Related to the degree of water retention and drainage, the porosity and the adsorption capacity of the soil. This indicator is divided into 4 categories: mixed sand, light meat, medium meat and heavy meat.

- *Thick layer*: Determines the amount of moisture retained in the soil, related to plant arrangement as well as farming techniques. The soil thick layer is divided into 4 levels: <30 cm, 30 cm - 70 cm, 7 cm - 100 cm and > 100 cm.

- *Soil fertility*: The fertility of the soil, also known as the productive capacity of the soil, is a combination of conditions and factors to ensure the growth and development of cassava. Soil fertility is divided into 3 categories: high fertility, medium fertility and low fertility.

- *Terrain type*: The type of terrain and slope are factors that are both decisive to production and exploitation conditions, and also a factor affecting the growth and development of plants. The topography of the area is divided into 5 categories with different priority levels: mountain valley, low plateau, highland, low mountain and medium mountain.

- *Vegetation cover*: This is an important environmental factor that regulates climate, water regime of rivers and streams, temperature, humidity, groundwater. The vegetation cover includes primary forests, watersheds, production forests, grassland, annual crops, perennial crops, etc.

- *Average annual temperature*: The temperature greatly affects the ecological characteristics of the plant, it means that cassava can be affected by both too high and too low temperature. Thus, depending on the heat demand of the plant groups, this criterion is divided into 3 different grades: <18ºC, 18ºC - 22ºC and > 22ºC

- *Average annual rainfall*: Provides moisture in the soil, air, rivers, lakes, groundwater, affecting the growth and development of plants. In case of the research area, rainfall is divided by space and divided into 3 levels as follows: <1500 mm, 1500 mm - 2000 mm and > 2000 mm.

- *Number of dry months*: This is an important indicator for plants. According to the bio-climate differentiation, the number of dry months is divided into 2 categories: 1 dry month and 2 dry months.

- *Number of cold months*: According to the biochemistry of climate, the number of cold months is divided into 3 levels: no cold month, 1 to 3 cold months and 4 or more cold months.

According to the important role of indicator factors for the development of cassava, each criterion is divided into 4 levels as shown in Tab. 1:

Table 1. Results of cassava-specific assessment in Kon Tum province

No	Criteria	Suitability rate			
		Very good (S1)	**Good (S2)**	**Poor (S3)**	**Very poor (N)**
1	Slope	< 8º	8º - 15º	15º - 25º	> 25º
2	Topographic condition		Low hills	Low mountains, medium-high mountains, highland, valley	
3	Soil type	Fk, Fs	Fa, Fp, Fq, X, Xa	Hs, Ha, Pc, D	
4	Vegetation		Savan, bushes	Annual plants; perennials plants	Woodlands
5	Average annual rainfall (mm)			1500 - 2000	<1500, >2000
6	Average annual temperature (ºC)		>22ºC	18ºC - 22ºC	<18ºC
7	Cool temperature months (month)		0	1 - 3	> = 4

8	Drought months (month)			1 to 2	
9	Soil thickness	>100cm	70 - 100 cm	30 - 70 cm	< 30 cm
10	Soil texture	Sandy loam	Sandy clay	Clay	
11	Soil fertility	High	Medium	Low	

[6 - TCVN 8409:2010]

3.2. Determine the weight of the evaluation criteria

According to analyzing the assessment criteria, a dataset of 134 scenery units is built in the target area. Then, the dataset is filtered considering the criteria that are not suitable for the cassava. The scenery units were filtered including forest cover with slope > 25°, soil thickness < 30cm, and scenery with average annual temperature below 18ºC, number of cold months is more than 4 months. Finally, there are only 35 scenery types that were evaluated for cassava development in Kon Tum province.

The results of the calculation of point distance and the classification of priority levels for evaluation purposes are as bellow:

+ Fair adaptive level (S1): with evaluation score 1,668 ÷ 1,969.

+ Average adaptive level (S2): with evaluation score 1,366 ÷ 1,668.

+ Less adaptive level (S3): with evaluation score 1,065 ÷ 1,366

3.3. Results

GIS was used to figure out the spatial results of ecological adaptation assessment on a map as shown in Figure 1. The evaluating results show that:

- There are 7 scenery types which are at medium-high adaptive level (scenery numbers are 79, 105, 106, 107, 112, 115, 118) with a total acreage of 24,669.19 ha, accounting for 2.55% of the natural area (natural land area). They are mainly distributed at low highland terrain with the altitude of 400 m - 600 m; with an average rainfall of 1500 - 2000 mm per year; located on soils of red and yellow soil; with a soil layer thickness of > 70 cm; have a medium level of mechanical composition and fertility.

- There are 17 scenery types which are at medium adaptive level (scenery number are 31, 32, 42, 47, 68, 80, 85, 86, 87, 90, 91, 101, 103, 113, 114, 116, 129), with total acreage of 71,306.99 ha, accounting for 7.38% of the natural land area. They are mainly distributed at some specific fields such as the midlands, low mountains, high plateaus with elevations from 600 to 1800 m, with a slope of 15 - 25º on host soils, and scattered in mid-mountain valleys with slopes 8 - 15º.

- There are 11 scenery types which are at low adaptive level 9, 10, 43, 48, 49, 57, 58, 94, 95, 133, 134) with an area of 59,843.3 ha, accounting for 6.19% of the natural land area. Their distribution is mainly limited by slope (15 - 25º), thin layer (30 cm - 70 cm), low fertility, and on major soils, Hs is less suitable for cassava.

- The unsuitable level (not assessed by scenery units) is the remaining scenery types including the current state of forest types or scenery with very steep slope >250, low temperature <18ºC and thin layer <30 cm.

Overall, the results showed that the area assessed to be fair adaptive level (S1) has a total acreage of 24,669.19 ha while the actual usable area is 38,206 ha. It can be seen that the actual current status of land use for cassava compared to the potential, is considered quite adaptable at 154.87%, exceeding 54.87% of the acreage. According to the field investigation, cassava is a plant with outstanding advantages compared to other crops, because cassava is a short-term crop, it can be cultivated on steep terrain, thin cultivation layer. Cassava is also a plant that does not require high cultivation techniques, low investment costs, and is suitable for the cultivation level of ethnic minority households. Consequently, the average adaptive level (S2) areas were also used for cassava planting, thus the acreage of cassava planting in reality is much higher. However, cassava is a very rapidly degrading crop, which discourages the development of cassava on basalt red soil,

even in areas that are considered suitable for cassava planting. Therefore, this study suggests that cassava should only be cultivated in areas that are considered to be very adaptable to minimize negative impacts on the environment and threats to the forest area of cassava.

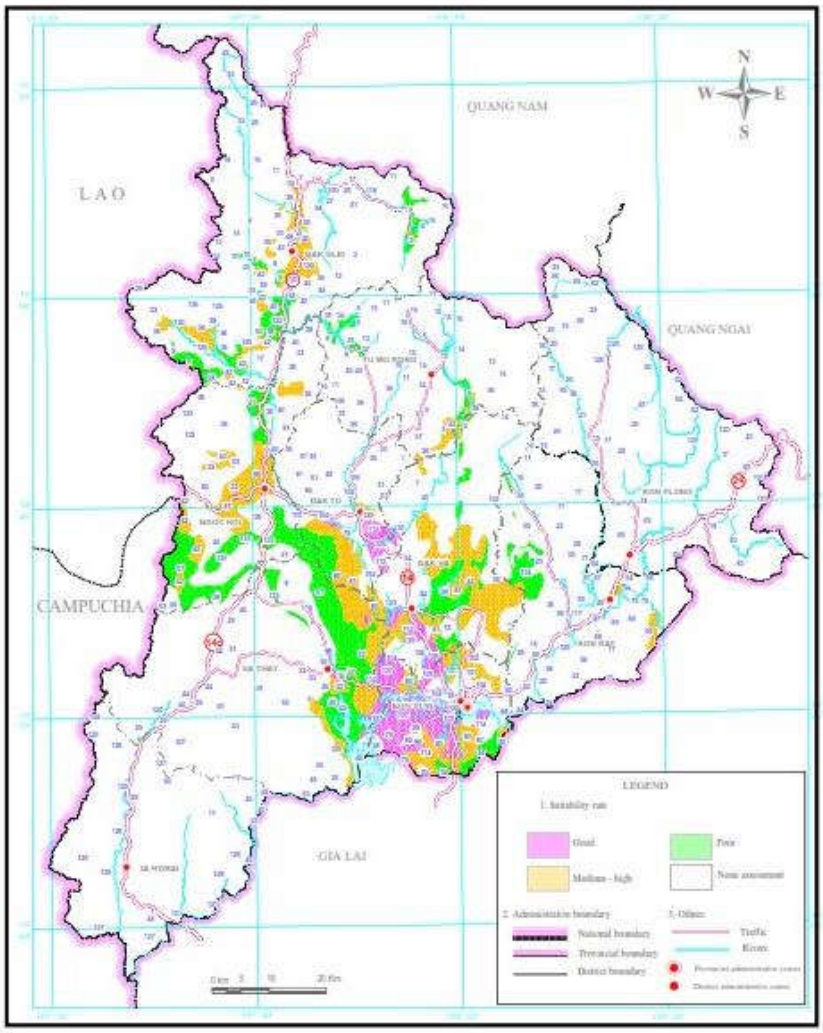

Figure 1: Map of ecological adaptation assessment for cassava in Kon Tum

4. Conclusion

This study integrated the Average Multiplication method and GIS for assessing the ecological adaptation of cassava to scenery factors in Kon Tum province. The research results show that the average multiplication method can be used to analyze the ecological adaptation levels of crops in specific sceneries and given quantitative acreage. Moreover, GIS technology can be applied for showing the spatial of ecological adaptive areas that help the managers to be able to visually manage and plan the crop planting.

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