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LAND SUITABILITY ASSESSMENT OF RICE CULTIVATION USING GIS IN VO NHAI, THAI NGUYEN, VIETNAM.

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Abstract:

Vo Nhai is a moutainous district in Thai Nguyen, has complicated topography with population is almost of minority ethnics. The famers cultivate rice in the small plots, traditional practices and lack of consideration about the suitable factors leading to get low yield and rice quality. It is very important to choose suitable land for rice production in order to improve yield, quality and ensure food security. In this study, we used GIS associate with multi-criteria assessment to construct the suitable map for rice production for Vo Nhai District. Acording to FAO 1976 [4], we chosen 4 factors (temperature, rainfall, slope, soil type) that's are deeply affected rice cultivation. The result of this study, there were 4,215 (ha) highly suitable area (S1) for rice production (5% total area Vo Nhai), 43,777(ha) moderately suitable area (S2) for rice production (52.1% total area Vo Nhai) and 36,068(ha) marginally suitable area (S3) for rice production (42.9 % total area Vo Nhai).

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ỨNG DỤNG GIS TRONG ĐÁNH GIÁ THÍCH NGHI ĐẤT TRỒNG LÚA TẠI VÕ NHAI, THÁI NGUYÊN, VIỆT NAM.

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Thông tin bài viết

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Từ khóa:

Canh tác lúa, geographic information system (GIS), đánh giá đa tiêu chí, Võ Nhai, phân tích thứ bậc

Tóm tắt

Võ Nhai là một huyện miền núi của tỉnh Thái Nguyên với địa hình phức tạp và đa số người dân là dân tộc thiểu số. Người nông dân ở đây canh tác lúa trên những thửa ruộng nhỏ với kỹ thuật canh tác truyền thống mà không có sự nghiên cứu về các nhân tố ảnh hưởng đến sinh trưởng cây lúa cho nên năng suất lúa ở đây thấp và chất lượng gạo chưa cao. Vấn đề đặt ra là cần lựa chọn các vùng đất thích hợp với canh tác lúa để cải thiện năng suất, chất lượng. Trong nghiên cứu này, chúng tôi sử dụng GIS kết hợp với đánh giá đa tiêu chí để xây dựng bản đồ thích hợp trồng lúa tại Huyện Võ Nhai, Thái Nguyên dựa trên 4 tiêu chí đánh giá nhiệt độ, lượng mưa, độ dốc và loại đất. Kết quả cho thấy có 4215 ha thích nghi cao (S1), 43777 ha thích nghi khá (S2), 36068 (ha) thích nghi trung bình, không có diện tích đất không thích nghi (N).

1. INTRODUCTION

Rice (*Oryza sativa L.*) is a globally important cereal plant and necessary source food for more than 3 billions people in the world [Krishnan et al, 2011] [8]. The majority of rice in today's world market is grown in South and Southeast Asia (India, China, Indonesia, Bangladesh, Thailand, Vietnam, Myanmar, Philippines) and many large rice producing nations import rice at times to meet demand [FAO,2016] [4]. Despite the large global cultivated rice areas and growing rice in many countries, the total demands often exceed the production. In the recent decades, two major issues like population growth (in particular, in the major rice producing/consuming countries) [GeoHive, 2014] [6] and climate change put enormous pressure on the global food demand and its production. In addition, the global rice consumption is projected to be ~873 million tonnes in 2030 [Purevdorj and Kubo, 2005] [10]. Since problems with food security persist in many areas of the World, improving rice production and quality is necessary.

Vo Nhai is a moutainous district in Thai Nguyen Province, Viet Nam has complicated topography with population is almost of minority ethnics. The famers cultivate rice in the small plots with variety of care and fertilizers due to the lack of comprehensibility in rice production leading to low yield, low quality, low economic profit. So the farmer has the trend to tranfer rice area to different land use goal like: plan different crops, build the house….due to reducing the rice area while the demand of rice is increasing with rising population. Therefore, It is necessary to build a plan of rice suitable land in order to improving yield, quality and economic profit. In order to ensure the optimum production of rice crops, we has to grow the crops, where they suit best and for which first and the foremost requirement is to carry out land suitability analysis [Ahamed et al., 2000] [1]. Suitability is a function of crop requirements and land characteristics

[Mustafa et al., 2011][9]. Matching the land characteristics with the crop requirements gives the suitability. So, Suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land use [FAO, 1976] [4]. Land suitability analysis has to be carried out in such a way that local needs and conditions are reflected well in the final decisions [Prakash, 2003][11]. Hence, this study aimed to reseach the suitability of the study areas for rice cultivation with a view to determining suitable factors (climate, topography, soil characteristics) using GIS and a multi-criteria decision base on Analytical Hierarchical Process (AHP).

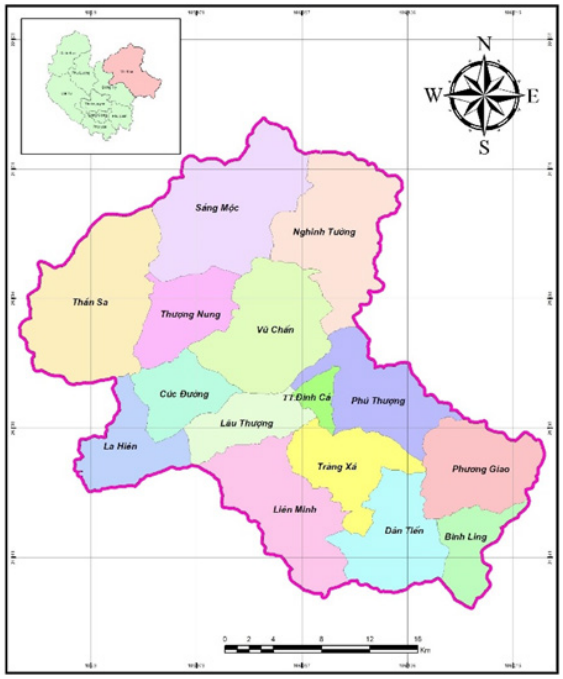
2. METHODOLOGY

Study area

Geographically, Vo Nhai District is located at 21^0 60' – 21^0 96' North and 105^0 84'- 106^0 22' East and has a natural area of 83839 ha (The yearly report in Thai Nguyen 2020). The district is bordered by Dong Hy District, Lang Son Procince and Bac Kan Province.

Data Collection

The hardcopy Maps from Department of Natural Resource and Environment in Thai Nguyen and the data of soil types, slope from the Department of Natural Resource and Environment in Thai Nguyen, the data of temperature and rainfall from the Department of Meteorology in Thai Nguyen.



Picture 1: The area Map of Vo Nhai

Table 1: The Data used in the research

No	Name of Map	Description	Source
1	Soil type Map	Soil classification Scale 1:25000	Department of Natural Resource and Environment in Thai Nguyen.
2	Slope Map	Slope classification Scale 1:25000	Department of Natural Resource and Environment in Thai Nguyen.
3	Temperature	Temperature classification Scale 1:25000	Department of Natural Resource and Environment in Thai Nguyen.
4	Rainfall	Rainfall classification Scale 1:25000	Department of Natural Resource and Environment in Thai Nguyen.
5	Administrative map	Administrative boundaries of wards in Vo Nhai Scale 1:25000	Department of Natural Resource and Environment in Thai Nguyen.

Parameters for suitability analysis

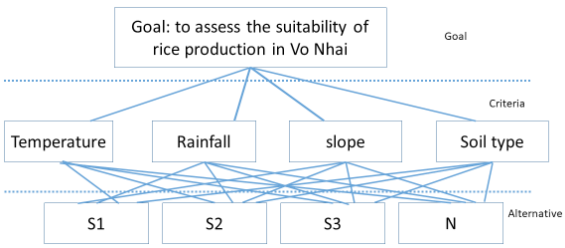
The factors identified were related to climate (temperature, rainfall), topography (slope), soil charcteristics (soil type). Each criterium of source map was reclassified into four classifications. The classification used the following suitability classes: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N) (table 2) (FAO, 1976)[4].

Table 2. The level suitability of criteria for rice production

	S1	S2	S3	N
Soil type	Pc, Pg, Pf, Py	Pbc, D	Fl, B, Rk	other
Average temperature(^{0}C)	25-32^{0}C	19-24^{0}C	11- 18^{0}C	<11^{0}C or >36^{0}C
Rainfall (mm)	1800-2000 mm	1500-1800 mm	1000-1500 mm	<1000 mm
Slope (degree)	0 - 8^0	8 - 20^0	20 - 25^0	>25^0

Multi-criteria weight by AHP

Weights were used to determine the priorities of criteria (rainfall levels, temperature, slope, soil types) and to identify the suitability of different land uses for rice production. The resultant AHP weights were used to determine the priority of each criterion for weighted overlay applications using GIS.



Figures1: The AHP Framwork to select suitable area for rice production

In the first stage of the analysis, we organized elements of the decision model into a hierarchy that included first level (goal), second level (criteria), and third level (alternative) elements. The first level involved selecting the goal. The second level of the hierarchy considered rules or criteria associated with the goal. The lowest level considered alternative decisions (Figures1).

The second phase involved scoring the criteria via pairwise comparisons and scoring scales of relative importance (Table 3). Questionnaires were used to gather expert opinions on the relative importance of the considered criteria and factors. Comparative results (for each factor pair) were described as integer values of 1 (equal value) to 9 (extremely different), where a higher number denotes that the chosen factor was considered to be more important than other factors to which it was compared.

Table 3: Preference scale for AHP pairwise comparison (Saaty 1989)

Scale	Degree of preference	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgments slightly favor one activity over another
5	Strong or essential importance	Experience and judgments strongly favor one activity over another
7	Very strong importance	An activity is favored very strongly over another
9	Extreme importance	The evidence favoring one activity over another is the highest possible order of affirmation
2,4,6,8	Intermediate values between two adjacent judgments	When compromise is needed

Third, the pairwise matrix (3) was calculated acorrding to the Render& Stair (2000) [12], Moore and Weatherford (2001) [7] in order to determine weights of priority criteria and normalized Eigen values (λmax value).

$$\begin{bmatrix} C_{11} & C_{12} & \dots C_{1n} \\ C_{21} & C_{22} & \dots C_{2n} \\ . & . & . \\ . & . & . \\ C_{n1} & C_{n2} & . C_{nn} \end{bmatrix}.$$

The principle value suggests that four criteria were consistent. The judgments were also checked to determine the consistency index (CI), which was calculated as:

$$CI=\frac{\lambda_{max}-n}{n-1}$$

Here: n is the total number of criteria.

Saaty (1989) [13] also introduced the consistency ratio (CR) and compared it to the consistency index and the random index (RI) value (table 4), which is the calculated value for matrices of different sizes.

The consistency ratio was calculated as:

$$CR = \frac{CI}{RI}$$

Table 4: Random index (RI)

n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

If the consistency ratio CR 0.10, decision-maker's pair-wise comparisons are relatively consistent.

If the consistency ratio CR > 0.10, the decision-maker seriously consider re-evaluating pair-wise comparision- the sources of inconsistency must be identified and resolvedand the analysis re-done.

GIS analysis

Suitability assessment criteria were used as the raster data layers for soil types, rainfall, slope, temperature. Suitable weight were used to determine the priority for each criteria. Each criteria source map was classified into four classifications: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N). For each of the suitability levels, we chose a suitability score. The suitability score is a way of computing values across the source layers so that there is a common standard. All source layer values are placed on the same scale with the same units. The same scale is used for all individual suitability layers and for the final overall suitability layer. In this study, we used a score of 9 for highly suitable areas, a score of 7 for moderately suitable areas, a score of 5 for marginally suitable areas, and a score of 3 a restricted value for unsuitable areas**.**

Weighted overlays are raster calculator tools used to identify the best or most preferable locations for rice production. The weight of suitable in each area were reclassified as follow: 8-9 : highly suitable (S1), 6-7: moderate suitable (S2), 5-6: marginal suitable (S3), <5: Not suitable (N). Using the reclassification and weighted overlay method, a spatial analysis was conducted, and a suitability map for Rice production was created (Eckert and Sujata 2011; Gatrell et al. 2011) [2], [5].

3. RESULTS AND DISCUSSION

Determine the weight of each criteria using AHP analysis and muticriteria analysis

The weight of factors involved in the planning problem is the influential degree of that factor, weight has an important influence on the final outcome of the problem to be solved. On the basis of consultation experts, theoretical basis has been research, It conducted weight calculation for each influencing factor by direction method of hierarchical analysis 9 levels.

To start the computation we proceed to compare each pair of factors with the consultative experts. This method also uses the law of "the minority obey the majority"; For example: when comparing soil type with temperature, if 04 experts say that soil type is preferred over temperature factor (value is 3 - according to preference scale for AHP pairwise comparison (Saaty 1989))[13], while there are 03 experts saying that soil type is preferred rather than the temperature factor (the value is 5 - according to Preference scale for AHP pairwise comparison (Saaty 1989))[13], a value of 3 will be chosen in the pair comparison matrix. Based on that, the results of the pair comparison matrix are shown in the table 5:

The results of table 5 show that the soil type is the most effective factor to effect on rice cultivation area so the weight is 0.56, the next is weight of temperature (0.26), following that is weight of rainfall (0.12) and final is weight of slope (0.06).

Table 5: The results of the pair comparision matrix calculation

	Soil Type	Temperature	Rainfall	Slope	Priority vecto (Weight)
Soil Type	1	3	5	7	0.56
Temperature	1/3	1	3	5	0.26
Rainfall	1/5	1/3	1	3	0.12
Slope	1/7	1/5	1/3	1	0.06
Sum	2	5	9	16	1.00
Sum* PV	0.95	1.19	1.10	0.88	
Lamda max	4.12				
CI	0.040				
CR	0.044				

According to AHP, check the reliability of the weights is very important. The first, it is necessary to calculate the values parameters of the composite comparison matrix and then determine the CR (consistency ratio) for evaluation the accuracy of the expert opinion panel, the results of the parameters are shown in the table 5. The value of CR (0.044 < 0.1) is satified the requirement so the weight of each

criterium can be used to calculate the suitable index in building the rice map.

Coding, hierarchical adaptive index

After calculating the weight for each indicator, then determine the preferred index Y for each land unit for rice cultivation through the total equation plus scores of 4 criteria: soil type, temperature, rainfall, slope corresponding to X_1, X_2, X_3, X_4 in each level suitability (table 6).

The suitable index for each criterion are calculated in table 7. Finally, the suitable index for land unit are point out. according the formular:

$$S= 0.56* X_1 + 0.26* X_2 + 0.12 * X_3 + 0.06* X_4$$

Table 6: Coding adaptive index with value

Criteria Xi	Coding Mi			
	S1(9)	S2(7)	S3 (5)	N (3)
Soil type	Pc, Pg, Pf, Py	Pbc, D	Fl, B, Rk	other
Temperature (^{0}C)	25-32^{0}C	19-24^{0}C	11- 18^{0}C	<11^{0}C or >36^{0}C
Rainfall (mm)	1800-2000	1500-1800	1000- 1500	<1000
Slope (degree)	0 - 8^0	8 - 20^0	20 - 25^0	>25^0

Table 7: Results of suitable index for each criteria

Criteria (Xi)	9	7	5	3
Soil type	5.04	3.92	2.80	1.68
Average temperature (^{0}C)	2.34	1.82	1.30	0.78
Rainfall (mm)	1.08	0.84	0.60	0.36
Slope (degree)	0.54	0.42	0.36	0.18

Suitable map for rice cultivation in Vo Nhai, Thai Nguyen, Viet Nam.

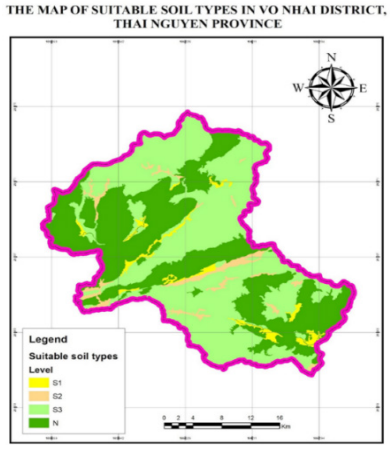
The results of soil suitable classification for each criterion are:

About suitable soil type areas for rice cultivation, there are 2,475 ha highly suitable areas (S1), 3,006 ha moderately suitable areas (S2), 44,120 ha marginally suitable areas (S3) and 34,459 ha not suitable areas.

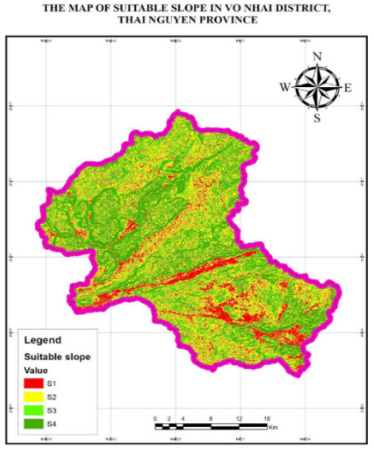
About suitable slope areas for rice cultivation, there are 22,623 ha highly suitable areas (S1), 24,519 ha moderately suitable areas (S2), 13,720 ha marginally suitable areas (S3) and 23,198 ha not suitable areas.

About suitable temperature areas for rice cultivation, there are 31,059 ha moderately suitable areas (S2), 53,001 ha marginally suitable areas (S3), no areas of highly suitable (S1) and not suitable (N).

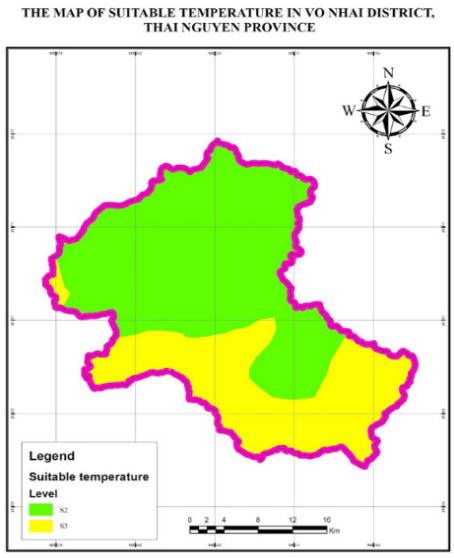
About suitable temperature areas for rice cultivation, there are 41,663 ha highly suitable areas (S1), 42,397 ha moderately suitable areas (S2), no areas of marginally suitable (S3) and not suitable (N).



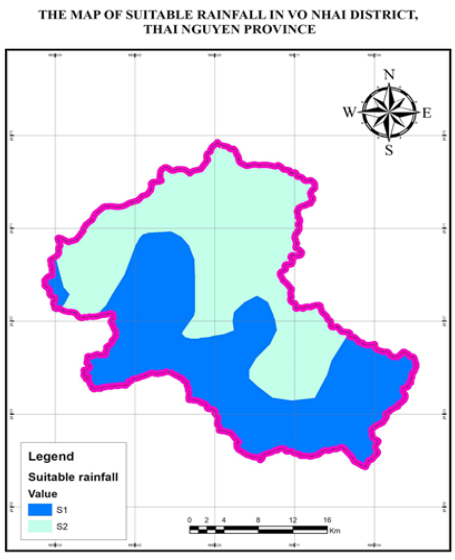
a) Soil type



b) slope



c) Temperature



d) Rainfall

Figure 2: The suitable map of each criterion: a) soil type, b) slope, c)Temperature, d) rainfall

To get the final suitable map for rice cultivation in Vo Nhai, Thai Nguyen, Viet Nam, we used raster calculator function in Arc GIS 10.2 sorfware to stack maplayer and then reclassify the raster data. The result showed that there is 4,215 (ha) high suitable area (S1) for rice cultivation (5% total area Vo Nhai) which has soil types of Pc, Pg, Pf, Py, 0-8 % of slope, 25- 32^{0}C of temperature and 1800-2000mm/year of rainfall. For moderately suitable areas (S2), It has 43,777 ha acoungting to 52.1% total area Vo Nhai. And It has 36,068 (ha) marginal suitable area (S3) for rice cultivation, accounting to 42.9 % total area Vo Nhai. So, based on 4 criteria, we determined suitable rice growing areas in Vo Nhai, Thai Nguyen is 47,992 ha which are highly suitable (S1) and moderately suitable (S2) areas in suitable land assessment.

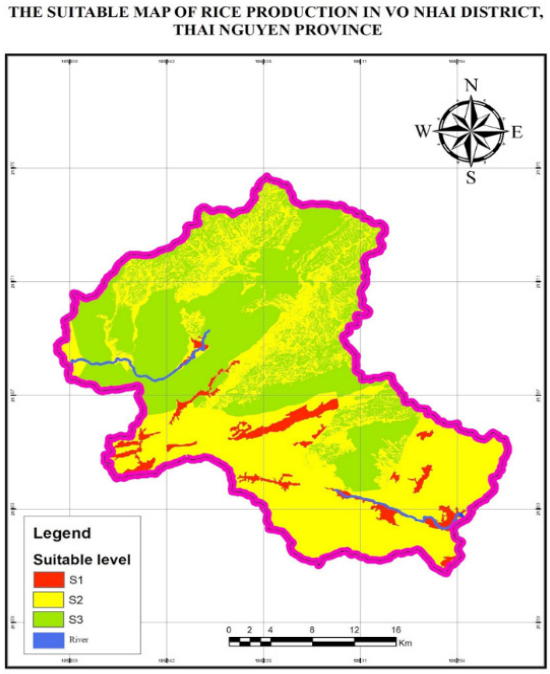


Figure 3: The suitable map for rice cultivation in Vo Nhai, Thai Nguyen, Viet Nam

CONCLUSION

Vo Nhai is a hilly district where the North areas are mainly hills and mountain, the South areas are flatter. In term of application GIS with the data of factors (soil type, slope, temperature and rainfall) that effect to grow and develop rice, the map of rice cultivation for Vo Nhai District, Thai Nguyen is issued. It is help the managements, businessman….to release their plan to develop economy, society and protect the environment. Beside this, it is help to develop the sustainable agriculture.

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