LAND SUITABILITY EVALUATION FOR GREEN PEPPER CROP IN QUANG NGOC COMMUNE, THANH HOA PROVINCE

Nguyen Huu Hao[1], Nguyen Thi Loan[1], Pham Huu Hung[1], Pham Thi Thanh Binh[1]

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Abstract: *The aim of this research is to identify suitable areas for green pepper crop production in Quang Ngoc commune, Thanh Hoa Province. Land suitability evaluation is crucial for local farmers to assess the capacity and constraints of current land conditions in order to support the development of appropriate land-use plans in the future. In this study, the limitation method regarding number and intensity of limitations was used to evaluate the suitability levels for green pepper crop. The results indicate that the most significant limiting factors consist of organic matter (OM), soil pH, soil texture, shallow soil depth, and relative topography, occurring either independently or in combination. Furthermore, the findings suggest that the proposed methodology for assessing the number and intensity of limitations is applicable and replicable across diverse regions and for various agricultural crops.*

Keywords: *Suitability evaluation, limitation method, green pepper, Quang Ngoc commune.*

1. Introduction

The convergence of population expansion, intensified food security requirements, and urban sprawl has led to significant competition for agricultural land. Consequently, the implementation of robust and reliable land assessment methodologies is imperative for sustainable management. As noted by Maddahi et al. (2014), these evaluations provide the analytical foundation for predicting land suitability, thereby ensuring the efficient utilization of scarce terrestrial resources [8]. The fundamental objective of land evaluation lies in forecasting land capability and identifying inherent constraints concerning shifting land-use patterns. This analytical process often encompasses the introduction of reclaimed land or the implementation of novel management practices [1]. According to Rossiter (1996) [11], the modern paradigm of land evaluation was established with the publication of the 'Framework for Land Evaluation' [2] and was further refined through subsequent guidelines addressing diverse land-use categories [3,4,5,6]. In this context, land evaluation functions as a systematic assessment of land performance, integrating multifaceted data including geomorphology, pedology, climatology, and vegetative cover to determine the viability of future production objectives [2].

[1]*Faculty of Agriculture, Forestry and Fisheries, Hong Duc University, Vietnam; Email: nguyenhuuhao@hdu.edu.vn*

Land evaluation serves as a fundamental mechanism for quantifying terrestrial potential, offering comprehensive insights into land characteristics, carrying capacity, and inherent biophysical constraints. Specifically, land suitability assessment functions as a systematic methodology to determine the degree of compatibility between a given land unit and the physiological requirements of specific cultivars [12]. Vargahan and Hajrasouli (2011) characterized land suitability evaluation as a multidimensional investigation aimed at aligning specific land units with optimal utilization types [15]. This analytical process integrates a complex array of biophysical and socioeconomic drivers that, either directly or indirectly, govern the capacity of a landscape to sustain particular land-use requirements. Ultimately, the synthesis of suitability assessments into geospatial mapping frameworks serves as a critical prerequisite for fostering sustainable agricultural development and informed resource management.

Crop yield is strongly influenced by ecological characteristics, including soil properties, prevailing climatic conditions, topography, and management practices. Therefore, the assessment of soil quality is essential for the development of agricultural crops and for alternative land-use planning aimed at sustainable resource utilization [7]. Green pepper is a widely cultivated crop in Thanh Hoa Province in general and in Quang Ngoc commune in particular. This crop exhibits high economic value compared to other short-duration vegetable crops and has seen widespread cultivation among local farmers in recent years. However, limited attention has been given to land suitability evaluation for green pepper cultivation in the study area. The present study applies the limitation method, considering both the number and severity of constraints, to classify qualitative physical land suitability classes for green pepper cultivation. By integrating multiple sources of information, this research seeks to support sustainable land resource management and enhance socio-economic benefits for local communities.

2. Materials and methods

2.1. Study area

Quang Ngoc is a coastal commune in Thanh Hoa province, covering a total natural land area of 34.39 km². This commune is characterized by the typical features of a delta region, with relatively flat terrain and minimal elevation differences. Geographically, the study area is situated at 19°40’02” N latitude and 105°45’10” E longitude (Figure 1). Quang Ngoc commune is characterized by a monsoon-influenced climate, featuring high solar radiation alongside substantial annual precipitation and humidity. The mean annual temperature is approximately 24°C, with annual rainfall typically ranging between 1,000 mm and 1,500 mm. The region maintains an average humidity above 80% for most months, rarely dropping below 60%. These conditions provide a conducive environment for agricultural production.

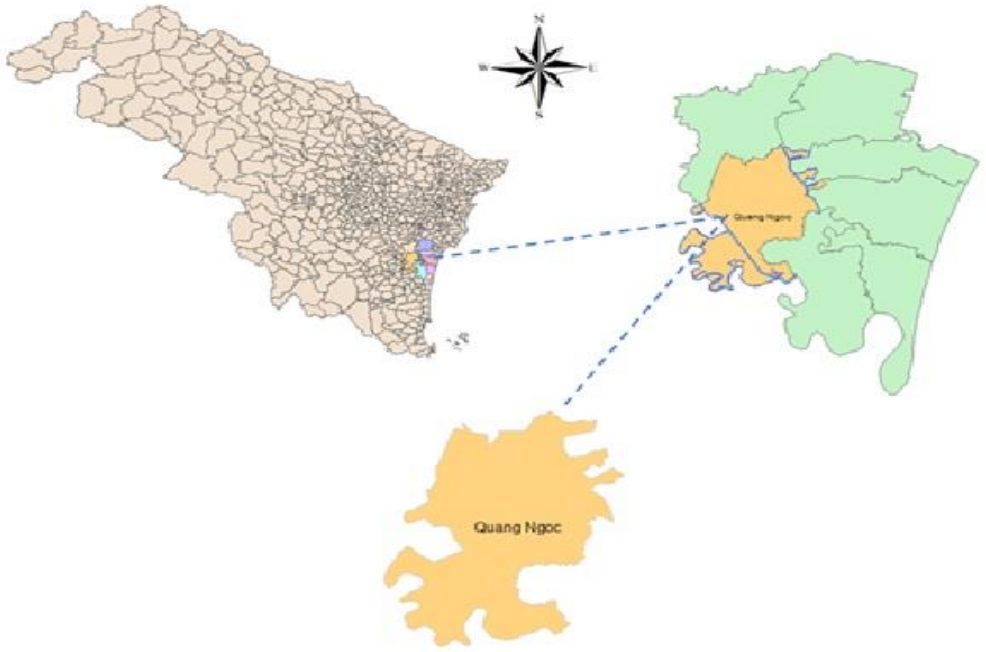

Figure 1. *Location of the study area*

2.2. Data sources used in this study

This study adapted the FAO land evaluation framework [2, 3, 5] and cultivation structure assessments to suit Vietnamese conditions, establishing a systematic protocol for data collection, calculation, and analysis. Spatial datasets comprising topography, administrative boundaries, and 2025 land-use status were obtained from Department of Agriculture and Environment of Thanh Hoa Province, and from Quang Ngoc commune offices. Furthermore, certain soil spatial datasets were derived from the existing soil classification project of Thanh Hoa Province in 2022.

2.3. GIS technology

All thematic layers were processed, overlaid, and visualized using ArcGIS software (version 10.8) at a scale of 1:10,000, referenced to the VN-2000 coordinate system (Zone 48 North) and datum of VN-2000.

2.4. Limitation method regarding number and intensity of limitations

The proposed methodology categorizes land units according to the frequency and severity of specific environmental constraints. The implementation of this approach necessitates the development of comprehensive requirement tables, where limitation levels are predefined for each distinct land characteristic [13]. Based on the aggregate severity of these constraints, land characteristics are systematically assigned to standardized classes ranging from S_1 (highly suitable) to N_2 (permanently not suitable) as presented in Table 1.

Table 1. *Schematic representation of the interplay between limitation intensity and land suitability classification levels*

Limitation levels	Description
S_1: Very suitable	Land units with no or no limitations or with no more than four slight limitations
S_2: Moderately suitable	Land units are categorized into this class if they exhibit either more than four slight limitations or a maximum of three moderate limitations
S_3: Marginally suitable	Land units with more than 3 moderate limitations or no more than 2 severe limitations
N_1: Actually unsuitable but potentially suitable	Unsuitable and non-susceptible to correction
N_2: Unsuitable	Land units with very severe limitations which cannot be corrected

(Source: [2, 13])

In accordance with the methodology assessing the frequency and severity of limitations, the evaluation is conducted by matching observed land characteristics against the predefined limitation thresholds in the crop requirement table.

3. Results and discussion

3.1. Selection of diagnostic criteria for land mapping units (LMUs) construction

The selection and categorization of thematic criteria for the delineation of land mapping units are grounded in the standardized land evaluation framework established by the FAO [2]. This methodology was subsequently adapted to the specific conditions of Vietnam and officially ratified by the Ministry of Agriculture and Rural Development in 1998 [10]. The specific classification thresholds and the decentralized hierarchical levels adopted for each criterion are systematized in Table 2.

Table 2. *Hierarchical classification and symbology of land characteristics*

Criteria	Decentralized level	Symbol	Criteria	Decentralized level	Symbol
Drainage capacity	Good	DR1	pH	> 6.5 - ≤ 7.0	pH1
	Moderate	DR2		6.0 - 6.5	pH2
Soil depth (cm)	> 75	D1		5.5 - 6.0	pH3
	50 - 75	D2		< 5.5	pH4
	30 - 50	D3	CEC	> 15.0	CEC1
	< 30	D4		10.0 - 15.0	CEC2

Relative topography	Flat	R1	(cmolc kg^{-1} soil)	< 10.0	CEC3
	Low flat	R2	Base saturation (%)	> 50	BS1
	Upper flat	R3		35 - 50	BS2
	High	R4		< 35	BS3
	Depressed	R5	Soil texture	Silty loam	TX1
Irrigation condition	Fully irrigated	I1		Clay loam	TX2
	Partially irrigated	I2		Loam	TX3
	Poorly irrigated	I3		Sandy loam	TX4
	Non-irrigated	I4		Silty clay loam	TX5
OM (%)	> 2.0	OM1		Silty clay	TX6
	1.0 - 2.0	OM2			
	< 1.0	OM3			

The spatial integration of thematic layers was performed using ArcGIS software, resulting in the delineation of 12 discrete LMUs within the administrative boundaries of Quang Ngoc commune. These units, which synthesize the spatial distribution and associated physicochemical attribute data of the study area, are systematically documented in Table 3 and visualized in Figure 2.

Table 3. *Biophysical characterization of LMUs in the study region*

Land unit	Characteristics of LMUs									Area (ha)
	I	R	TX	OM	CEC	pH	BS	D	DR	
1	2	3	5	1	2	2	1	2	2	31.52
2	1	1	1	2	2	3	2	2	2	108.98
3	2	3	1	3	3	3	1	3	2	0.013
4	2	1	1	3	2	4	2	2	2	132.65
5	2	3	3	1	3	4	2	2	2	414.86
6	2	1	1	2	1	4	2	2	2	137.55
7	1	2	2	2	2	4	2	2	2	85.89
8	1	2	1	1	1	3	1	2	2	96.69
9	1	1	1	1	2	4	1	2	2	169.46
10	1	4	6	1	1	4	1	2	2	445.62
11	4	4	4	3	3	4	2	4	1	32.69
12	1	2	1	2	2	2	1	2	2	602.07

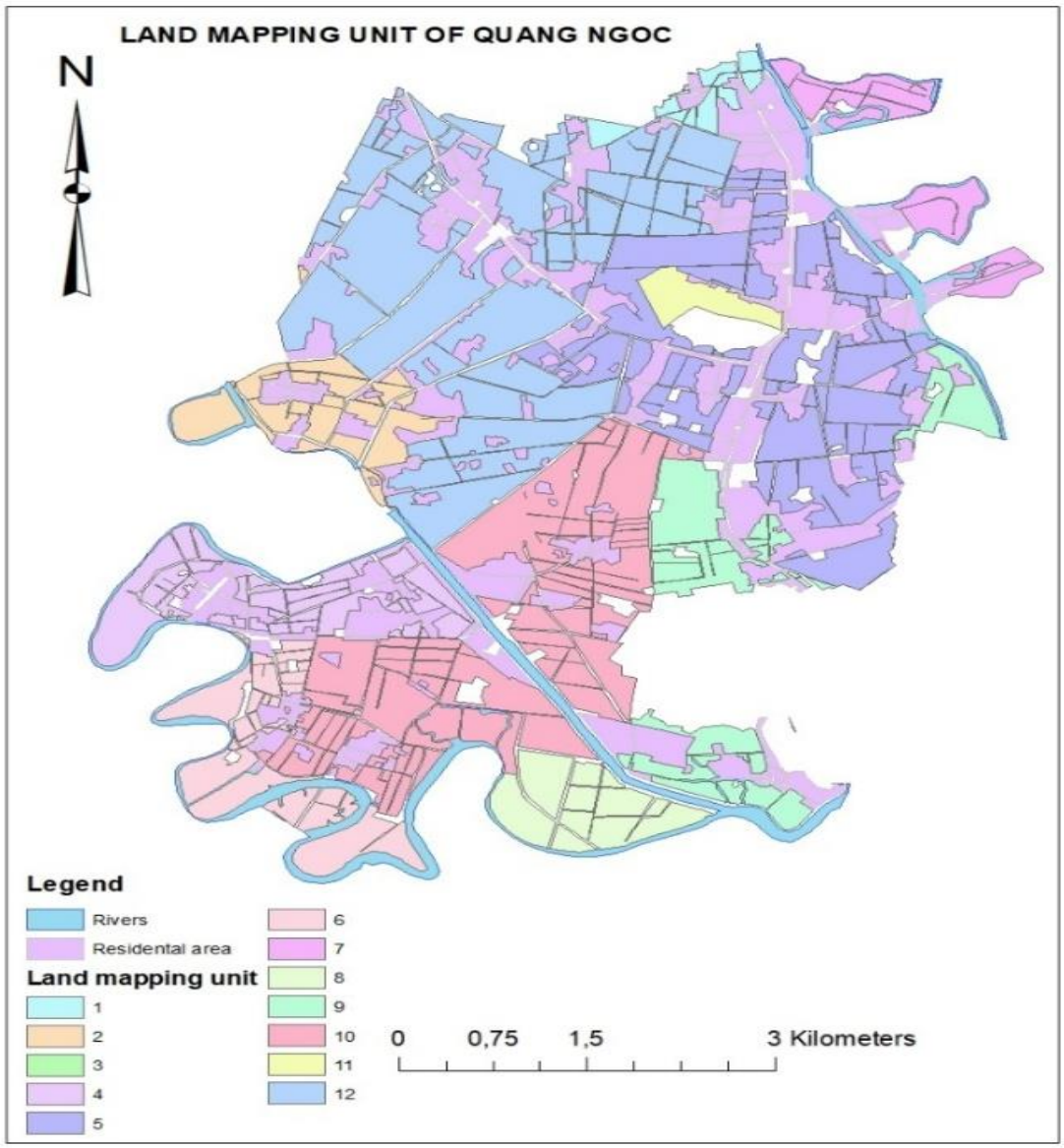

Figure 2. *Land mapping units of Quang Ngoc commune*

3.2. Ecological requirements and suitability class determination for green pepper

Land requirements encompass the specific edaphic and environmental conditions essential for the optimal growth of various crops. These requirements ensure that each land utilization type identified in the assessment can achieve sustainable development and long-term productivity within its designated environment. The assessment involved a comparative analysis between observed land qualities and the standardized requirements defined by MARD (2009) and Sys et al. (1993). The specific environmental and edaphic variables used to determine green pepper suitability are presented in Table 4.

Table 4. *Diagnostic land characteristics for the suitability classification of green pepper*

Land quality	Level of suitability				
	S1	**S2**	**S3**	**N1**	**N2**
*Soil texture	L; SL; SiCL; SiL; SiC	LS; CL	-	-	cS
Topography	Flat; Upper flat	High	Low flat	Depressed	-
Soil depth (cm)	> 100; 100 - 75	75 - 50	50 - 30	< 30	
Irrigation	Fully irrigated	Partially irrigated	Poorly irrigated	Non-irrigated	-
Drainage	Good; Moderate	Poor and imperfect	Poor but drainable	Poor but not drainable	-
BS	> 80; 80 - 50	50 - 35	< 35	-	-
pH	5.8 - 6.0	5.8 - 5.5	5.5 – 5.2	< 5.2	< 4.5
OM (%)	> 2.0; 2.0 - 1.2	1.2 - 0.8	< 0.8	-	-
CEC (cmolc kg^{-1} soil)	> 15.0; 15.0 - 10.0	< 10	-	-	-

(Source: [10, 13])

[*] *LS: loamy sand, SL: sandy loam, L: loam, SiL: silty loam, SiC: silty clay, SiCL: silty clay loam, CL: clay loam, cS: coarse sand*

3.3. Land suitability evaluation

The qualitative land suitability results for green pepper cultivation, obtained using the limitation method, are presented in Table 5 and Figure 3.

Table 5. *Spatial distribution and extent of land suitability classes for green pepper cultivation*

Level	Limitation method regarding number and intensity of limitations		
	Symbol	Area (ha)	Percent (%)
Moderately suitable	S_2	140.51	6.22
Marginally suitable	S_3	954.13	42.26
Currently unsuitable	N_1	1130.67	50.07
Permanently unsuitable	N_2	32.69	1.45
Total evaluated area		2258.00	100

The land suitability assessment results (Table 5 and Figure 3) reveal an absence of highly suitable (S1) areas for green pepper cultivation when applying the limitation method. As detailed in Table 5, the optimal suitability identified was at the moderately suitable (S2) level, covering 140.51 ha, which represents 6.22% of the total agricultural

land. The majority of the viable land falls under the marginally suitable (S3) category, encompassing 954.13 ha (42.26%). Notably, over half of the study area (1,163.36 ha, or 51.52%) is classified as unsuitable (N). This unsuitable portion is further divided into currently unsuitable land (N1), comprising 1,130.67 ha (50.07%), and permanently unsuitable area (N2), which accounts for 32.69 ha (1.45%) of the agricultural landscape.

The variation in land suitability classes was mainly determined by the degree to which the characteristics of each land unit matched the crop requirements presented in Table 4. The findings also revealed that the most significant limitations for green pepper cultivation were relative topography, soil properties in terms of low percentage of organic matter content, high soil acidity, shortage of irrigated condition, shallow soil depth or soil textures unsuitable for green pepper cultivation. Most of the limiting factors can be improved by applying appropriate agronomic practices, soil amendments, irrigation improvement, and fertilization.

When comparing various land evaluation methods based on the FAO framework, Manna et al. (2009) argued that increased methodological complexity correlates with higher levels of reliability and accuracy. Therefore, future studies should compare suitability classes with observed crop yields for each land unit to validate the reliability of the method.

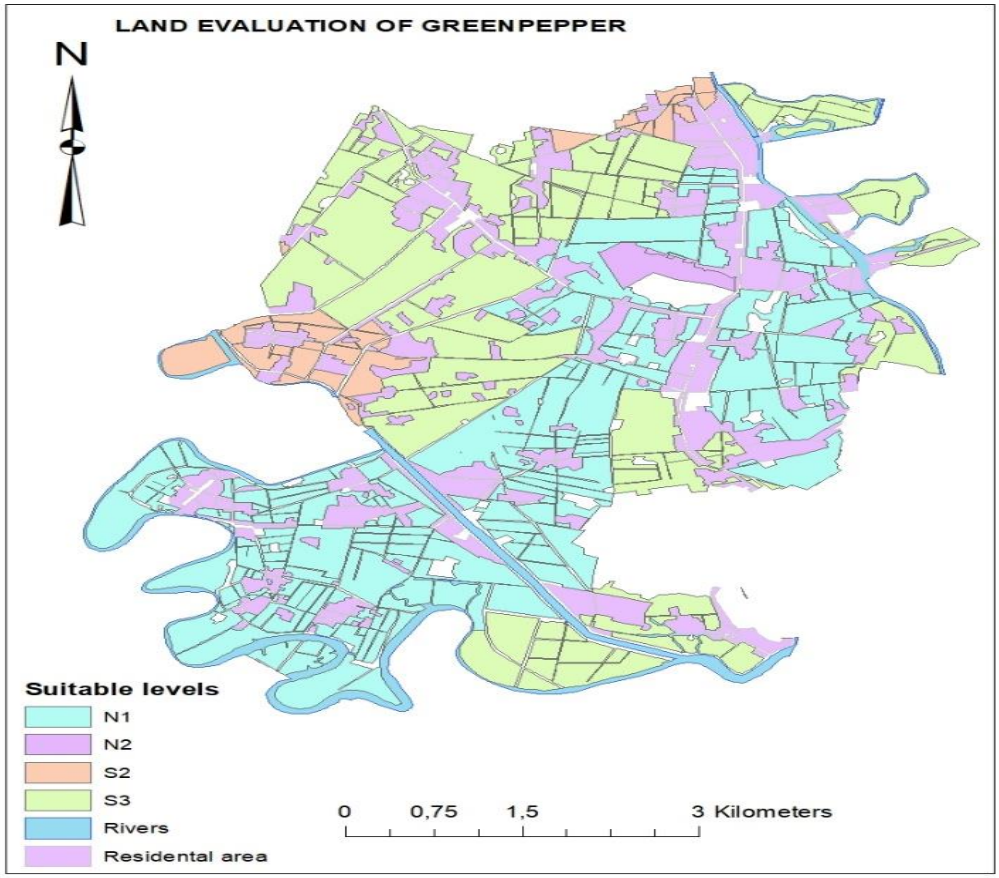

Figure 3. *Land suitability map for green pepper based on the limitation method*

4. Conclusions

In this study, the limitation method regarding number and intensity of limitations was applied for the land evaluation process. This method was adapted from the FAO framework and modified to suit local conditions in Vietnam. The results of land suitability evaluation for green pepper production led to a conclusion that all land units had certain limitations that may affect land quality. The results showed that the The results showed that the and suitability classes for green pepper cultivation mostly depended on soil qualities, and there were four suitability levels for green pepper production from N_2 to S_2, and more than a half of the investigated area was classified from N_2 to N_1, and 1,094.64 ha of the total area was evaluated from S_2 to S_3. The spatial information from this study could be used to assist effective land use based directly on its potential. This approach may help minimize environmental problems and improve farmers' income through appropriate land use. It is also suggested that the limitation method regarding number and intensity of limitations could be applied to land suitability evaluation for other agricultural crops in Thanh Hoa Province, provided that the evaluation criteria are adjusted according to crop-specific requirements and local conditions.

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