# Qualitative land suitability evaluation for rice, maize, and potato crops in Quang Xuong distric, Thanh Hoa province

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**Abstract**

Quang Xuong is considered as one of the most developed districts in Thanh Hoa Province in terms of agricultural. The major purpose of this research is to find Good suitable area to suggest for crop production of rice, maize and potato in the case study. Therefore, the assessment of land suitability is essential for making strategies of sustainable agricultural development as this will help land-users and land managers to discover the potential and limitations of the current existing land conditions to make appropriate policies and plans for future land use. Regarding land suitability evaluation, the simple limitation, and parametric (Square root) methods were used to evaluate the suitability levels for the selected annual crops. The obtained results indicated that each applied method provides different results of land suitability level for a specific crop in certain land units, and OM, soil pH, soil texture, shortage of irrigated condition, shallow soil depth or some soil textures not suitable for agricultural crops, and relative topography are found out as the main limitation factors which affected land suitability level. The findings from this study also suggested that the simple limitation and the parametric methods can be applied and repeated in different areas for other agricultural crops.

***Keywords:*** *Land suitability evaluation, simple limitation method, rice, maize, potato, Quang Xuong District.*

## 1. Introduction

The dramatic growth of the world population has been leading to the increasing demand for food, and in order to meet the demand the farming communities have to improve productivity. On the other hand, land is so scarce that it is necessary to find areas which best suit for crop growing (Selassie et al., 2014; Maddahi et al., 2014 ). Therefore, it is essential to assess the potential and requirements of a certain land parcel for agricultural activities based on a scientific procedure of land evaluation (Rossiter, 1996).

Land evaluation was known as soil survey, it was traditionally based primarily on soil resource inventories (Nabarath, 2008). Land evaluation is to examine land performance and potential for a specific production purpose. It is important as it helps achieve optimum utilization of available land resources for sustainable agricultural production (FAO, 1976). According to Vargahan and Hajrasouli (2011), land suitability evaluation is the investigation of a particular area of land in order to satisfy an appropriate type of land use. Many factors are involved in this process and they may directly or indirectly control the ability of a certain part of land to host the land use. The result of land suitability assessment and generating suitable maps for different kinds of land use will facilitate to reach sustainable agriculture. Land suitability evaluation is not only the process of estimation and combination of specific patterns of land in terms of their suitability for defined uses, but also carried out separately for each category of land use (Gong et al., 2012). In general, land suitability evaluation can help decision-makers and land use-planners figure out the questions "the best site of land use" to apply under certain conditions (Rabia and Terribile, 2013).

The art of land evaluation is to classify the proposed strategies of land use as a wise or unwise utilization of land which may depend on the predication of the most essential changes, to decide whether these are desirable or acceptable (FAO, 1980). Generally, final evaluation of the suitability of using an area for a particular purpose is based on independent land qualities, which may each limit the land-use potential (Rossiter and Van Wambeke, 1997). To figure out proper plans and strategies for land development, it is pivotal to thoughtfully examine how suitable the land is for various uses (Marsh and Macaulay, 2002). Establishing appropriate suitability indices is the key factor in analysis of suitability. Evaluation of how suitable the land is for a particular use generally provides information for planning of land use (Fresco et al., 1989).

In the recent years, many researchers have been applied FAO guidelines on the land evaluation system (FAO, 1976, 1983, 1985) for the land suitability assessment for different crops such as *Pyrethrum* flower production, in Kenya (Wandahwa and Van Ranst, 1996); crop-land suitability analysis (Ahamed et al., 2000; Kamau et al., 2015); land suitability evaluation for sugar care in Thailand (Paiboonsak et al., 2004); *Robusta* coffee in the Dak Gan, Vietnam (D'haeze et al., 2005); qualitative land suitability evaluation for the growth of onion, potato, maize, and alfalfa, wheat, barley, safflower (Jafarzadeh and Abbasi, 2006, Jafarzadeh et al., 2008); for principal crops in the West Shoush Plain, Iran (Albaji et al., 2009); cropping system in a watershed, India (Martin and Saha, 2009); for Rabi and Kharif crops (Mustafa et al., 2011); for tobaco in Talesh, Iran (Amirhendeh et al., 2013); for cereal crops in Yigossa Watershed, Northwestern Ethiopia (Selassie et al., 2014), and for agricultural land in Fakkeh region, Iran (Albaji and Alboshokeh, 2017).

At present, the agricultural land in Quang Xuong District is dealing with encroachment for expanding residential area, basic construction and other non-agricultural land purposes. Studies on land evaluation for different types of land use and for agricultural crops in the past years have not been a big concern. Therefore, evaluation of land is an urgent and essential issue. This study aims to use the simple limitation and parametric methods to classify the qualitative physical suitability level for rice, maize, and potato crops with the use of integrated information for land use planning to increase the benefits for agricultural activities in the study site.

## 2. **Study area**

Quang Xuong is one of a coastal district of Thanh Hoa Province and is located in the tropical and temperate zone. It's geographical location is at 19$^0$34' - 19$^0$47'N latitude and 105$^0$46' - 105$^0$53'E longitude (Figure 1). The topography of Quang Xuong District is relative flat, which runs from the North to the South. The average height above sea level is from 3 to 5 meters. Similar to the climate of the entire province, this district is characterizes by strong monsoon influence, a considerable amount of sunny days, and with a high rate of rainfall and humidity. It is hot and humid weather by influence of the south-westerly dry wind in the summer, dry and little rain, occasional appearance of frost in the winter. The annual average precipitation ranges from 1600mm to 2000mm and is irregularly distributed. The rainy season is from July to October, the rainfall in this season is very high, from 190mm to 350mm, accounting for 80% of the annual average rainfall. The average account of the huminity is over 80% in most of the months and is rarely under 60%. The average annual evaporation level is about 82.25mm. The highest water evaporation in June, July and November is over 100mm, and reaches the peak of 126.12mm in June (Table 1).

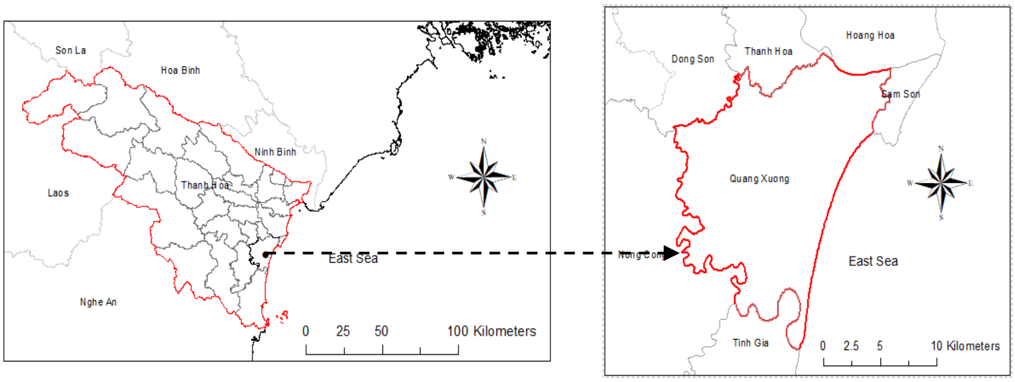



**Figure 1. Location of the study area**

**Table 1. Climate data in the study area recorded from 1996 to 2015**

| **Month** | **Temperature ($^0$C)** | | | **Evaporation (mm)** | **Precipitation (mm)** | **Relative humility (mm)** |
|---|---|---|---|---|---|---|
| | Minimum | Maximum | Everage | | | |
| Jan | 14 | 18.6 | 16.3 | 64.54 | 18.38 | 84.4 |
| Feb | 13.5 | 21.3 | 17.4 | 45.365 | 15.45 | 88.2 |
| Mar | 16.8 | 21.8 | 19.3 | 46.51 | 44.15 | 89.4 |
| Apr | 22.4 | 25.4 | 23.9 | 51.2 | 66.52 | 85.7 |
| May | 25.7 | 28.4 | 27.05 | 89.755 | 170.4 | 85.5 |
| Jun | 28.1 | 30.6 | 29.35 | 126.115 | 166.32 | 80 |
| Jul | 28.4 | 30.3 | 29.35 | 113.67 | 196.15 | 81.9 |
| Aug | 27.4 | 28.6 | 28 | 79.515 | 295 | 86.8 |
| Sep | 25.3 | 27.9 | 26.6 | 80.15 | 349.77 | 86.2 |
| Oct | 23.8 | 26.1 | 24.95 | 98.335 | 224.18 | 83.1 |
| Nov | 21 | 24.6 | 22.8 | 102.3 | 80.85 | 78.6 |
| Dec | 16.2 | 20.6 | 18.4 | 89.54 | 31.81 | 60.5 |
| Aver.Sum | 21.88 | 25.35 | 23.615 | 82.25 | 138.25 | 82.52 |

*Source: Climate station of Thanh Hoa City*

## 3. **Materia and methodology**

### 3.1 Data resources used for this study

In this study, FAO instructions of land evaluation (FAO, 1976, 1983, 1985) and examining cultivation structure has been modified for Vietnamese conditions and applied in order to arrange the institution for collecting, calculating and evaluating data. In addition, the spatial data of topography, administrative, current land use of 2015, and other existing spatial databases were collected and inherited from Department of Natural Resources and Environment Management of Thanh Hoa Province, and from Quang Xuong District offices. A part of soil map data was inherited from a project of building soil classification map for Thanh Hoa Province in 2012 according to FAO-UNESCO soil classification guideline implemented by Natural Resources and environmental Management faculty of Vietnam National University of Agriculture. All of thematic maps were created, overlaid, and presented on ArcGIS software (ArcGIS version 10.2), afterward converted into raster data and reclassified for land evaluation. All maps were displayed at scale of 1:25,000 with UTM projection, Zone 48 North, and datum of WGS 84. Furthemore, the attribute data associating with the spatial data were also gathered and collected from Department of Natural Resources and Environment Management, Division Statistic, Department of Agriculture and Rural Development of the province and the district, and other related offices. After collecting, these non-spatial data was calculated, reclassified, and combined by using Excel software. The climate condition were also taken into consideration. Nevertheless, these factors were consistent in the whole area of the research, they were not shown in the land mapping unit. Still, they were generally examined for the selection of annual agricultural crops in the study site.

### 3.2 Simple limitation method

Land limitation is an approach to indicate the land qualities in a relative assessment scale. Limitations are deflection from optimal conditions of a land characteristic which contrarily affects a kind of land-use. If a land characteristic is optimal for growing crops, it means there is no limitation. However, when the same quality is unfavorable for plant growth, it has severe limitation (Sys et al., 1991). Depending on the level of limitations, the land characteristics are assigned numbers ranging from 0 to 4 of degree of limitation as presented in Table 2.

**Table 2. A schematic relation between the limitation and class level**

| Limitation levels | Class levels | Description |
|---|---|---|
| **0: no limitation**<br>**1: slight limitation** | $S_1$ | Very suitable |
| **2: moderate limitation** | $S_2$ | Moderately suitable |
| **3: severe limitation** | $S_3$ | Marginally suitable |
| **4: Strongly severe limitation** | $N_1$ and $N_2$ | Unsuitable and non-susceptible to correction |

*Source: (FAO, 1976; Sys et al., 1991)*

Regarding the simple limitation method (FAO, 1976), the crop requirement tables have to be generated for each land utilization type first, and then land suitability classes are defined basing on the lowest class level of only or more characteristic. the flowchart of this method is shown in figure 2.

### 3.3. Parametric method

In this study, the square root method (Khiddir, 1986) is used for the evaluation of land qualities. It shows a numeral rating of the different limitation levels of the land characteristics in numerical scale from a maximum to a minimum value. If the land quality has no limitation for considered land utilization type the maximum rating of 100 is assigned. Conversely, if the same land characteristics have strongly limitation for plant growth then a minimal rating is applied (Sys et al., 1991). The square root method can be subsumed under the rubric of the parametric methods. The equation of this method respectively shows:

$$\boldsymbol{I = R_{min} * \sqrt{\frac{A}{100} * \frac{B}{100} * \frac{C}{100} \ldots}}$$

Where: I is index of square root method, $R_{min}$ is the minimum rated criterion (%), and A, B, C, etc. are remaining ratings (%).

Suitability classes are arbitrarily defined by determining specific land index and using the guideline suggested by Sys et al., (1991) (Table 3), the qualitative land suitability classes and the limiting elements of the given plant growth in different soil series for each crop are figured out. The flowchart of square root method is shown in Figure 3.

**Table 3. Determine classes of land suitability for different land indices**

| Symbol | Description | Land index |
|---|---|---|
| $S_1$ | Highly suitable | 75 – 100 |
| $S_2$ | Moderately suitable | 50 – 75 |
| $S_3$ | Marginally suitable | 25 – 50 |
| $N_1$ | Currently not suitable | 12.5 – 25 |
| $N_2$ | Permanently not suitable | 0 – 12.5 |

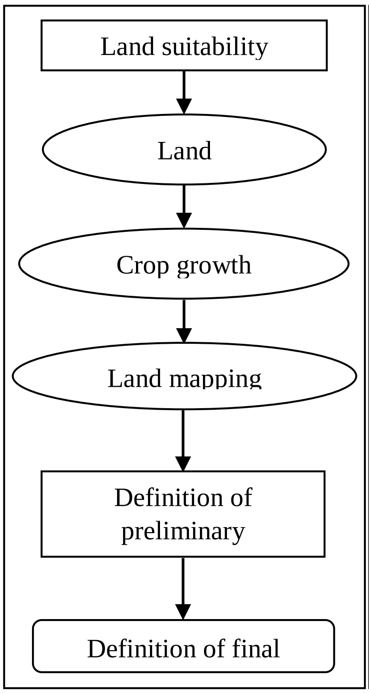



**Figure 2. Simple limitation method**

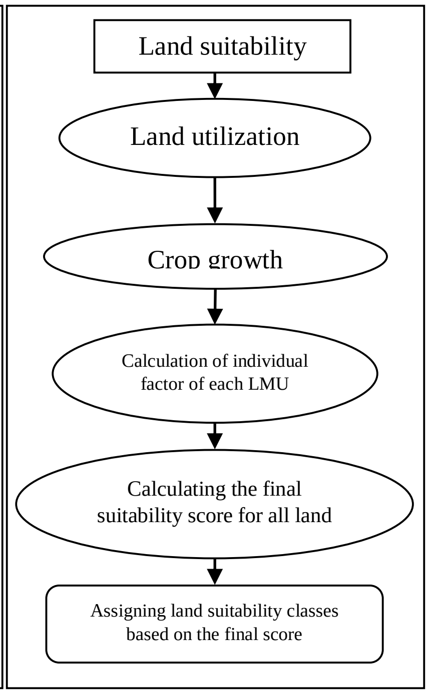



**Figure 3. Squre rootmethod**

## 4. **Results and discussion**

### 4.1. Selection of criterion for building land mapping unit (LMU)

LMUs are created through overlaying different kinds of thematic maps. Thus, identifying a set of appropriate land characteristics for generating the land mapping unit influences the ability of land use effectively, so that the achievements of land evaluation are more reliable and meet the requirements of practical production. The land unit data presented on land unit map is the main information source to connect to the land requirement of each agricultural crop. Choosing and decentralizing thematic criteria for building a map of land units have depended on the process of land evaluation by FAO (1976), which was modified to be suitable for the condition of Vietnam and was ratified by Ministry of Agriculture and Rural Development (1998). In this study, nine criteria have been chosen for building LMU, namely: organic matter (OM), cation exchange capacity (CEC), pH, base saturation (BS), soil texture, irrigation condition, soil depth, drainage capacity, and relative topography. The chosen criterion and its the decentralized levels for building land mapping unit are shown in Table 3.

**Table 3. Decentralized level and its symbol of land characteristic for building mapping unit**

| 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 | > 75cm | D1 | | 5.5 - 6.0 | pH3 |
| | 50cm- 75cm | D2 | | < 6.0 | pH4 |
| | 30cm -50cm | D3 | CEC | > 15.0 | CEC1 |
| | < 30cm | D4 | | 10.0 - 15.0 | CEC2 |
| Relative topography | Flat | R1 | | < 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 | Actively irrigated | I1 | | Clay loam | TX2 |
| | somewhat irrigated | I2 | | Loam | TX3 |
| | Poorly irrigated | I3 | | Loamy sand | TX4 |
| | None_irrigated | I4 | | Sandy loam | TX5 |
| OM | > 2.0 | OM1 | | Coarse sand | TX6 |
| | 1.0 - 2.0 | OM2 | | Silty clay loam | TX7 |
| | < 1.0 | OM3 | | Silty clay | TX8 |

After overlaying all thematic maps together with the help of ArcGIS software, 42 land units were found on the map of Quang Xuong district. The land mapping units associated with attribute data of the study area are shown in Table 4 and Figure 4.

## 4.2. Land requirement and determination classes for selected crops

Land requirement is the ecological requirement of different crops regarding edaphic and environmental conditions. It suggests that each land utilization type mentioned in the land assessment can grow and sustainably develop. In this research we compared the physical land characteristics with the crop requirements introduced by MARD (2009) and Sys et al., (1993). The land characteristics for land suitability classification of rice, maize and potato crops are displayed in Table 5.

**Table 4. Characteristics of land units in the study area**

| LMU | Characteristic of Land Mapping Unit (LMU) | | | | | | | | | Area (ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| | I | R | TX | OM | CEC | pH | BS | D | DR | |
| 1 | 4 | 5 | 6 | 3 | 3 | 4 | 2 | 3 | 1 | 400.41 |
| 2 | 3 | 3 | 4 | 3 | 3 | 3 | 1 | 2 | 1 | 160.11 |
| 3 | 3 | 3 | 4 | 3 | 1 | 3 | 1 | 2 | 1 | 781.38 |
| 4 | 3 | 3 | 3 | 3 | 3 | 4 | 1 | 2 | 2 | 483.66 |
| 5 | 3 | 3 | 5 | 2 | 3 | 4 | 1 | 2 | 1 | 494.1 |
| 6 | 3 | 3 | 4 | 3 | 3 | 4 | 2 | 1 | 1 | 58.14 |
| 7 | 2 | 1 | 5 | 3 | 3 | 2 | 1 | 2 | 1 | 502.56 |
| 8 | 1 | 2 | 3 | 3 | 3 | 3 | 1 | 1 | 2 | 247.5 |
| 9 | 1 | 2 | 3 | 1 | 1 | 3 | 1 | 2 | 2 | 164.34 |
| 10 | 2 | 3 | 4 | 3 | 3 | 4 | 2 | 3 | 1 | 70.47 |
| 11 | 2 | 2 | 3 | 1 | 1 | 3 | 1 | 2 | 2 | 30.42 |
| 12 | 2 | 3 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 155.79 |
| 13 | 2 | 3 | 7 | 1 | 2 | 2 | 1 | 2 | 2 | 301.41 |
| 14 | 2 | 3 | 3 | 1 | 2 | 2 | 1 | 1 | 2 | 63.36 |
| 15 | 1 | 1 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 275.4 |
| 16 | 2 | 3 | 1 | 3 | 3 | 3 | 1 | 3 | 2 | 529.47 |
| 17 | 2 | 3 | 3 | 2 | 3 | 2 | 1 | 2 | 2 | 469.89 |
| 18 | 2 | 1 | 1 | 3 | 2 | 4 | 2 | 2 | 2 | 133.92 |
| 19 | 2 | 3 | 3 | 1 | 3 | 4 | 2 | 2 | 2 | 440.91 |
| 20 | 2 | 3 | 2 | 2 | 2 | 3 | 1 | 1 | 2 | 122.76 |
| 21 | 2 | 3 | 1 | 2 | 1 | 4 | 2 | 2 | 2 | 336.78 |
| 22 | 2 | 1 | 1 | 2 | 1 | 4 | 2 | 2 | 2 | 139.41 |
| 23 | 2 | 3 | 2 | 2 | 2 | 4 | 3 | 2 | 2 | 517.95 |
| 24 | 2 | 3 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | 243.45 |
| 25 | 1 | 2 | 2 | 2 | 2 | 4 | 2 | 2 | 2 | 376.74 |
| 26 | 1 | 1 | 7 | 1 | 2 | 1 | 1 | 1 | 2 | 300.06 |
| 27 | 1 | 2 | 3 | 1 | 2 | 1 | 1 | 3 | 2 | 101.88 |
| 28 | 1 | 4 | 2 | 2 | 2 | 4 | 2 | 2 | 2 | 356.22 |
| 29 | 1 | 4 | 1 | 2 | 2 | 4 | 1 | 1 | 2 | 930.15 |
| 30 | 1 | 2 | 1 | 1 | 1 | 3 | 1 | 2 | 2 | 95.85 |
| 31 | 1 | 2 | 7 | 1 | 1 | 2 | 1 | 2 | 2 | 157.59 |
| 32 | 1 | 1 | 1 | 1 | 2 | 4 | 1 | 2 | 2 | 433.71 |
| 33 | 1 | 4 | 8 | 1 | 1 | 4 | 1 | 2 | 2 | 453.6 |
| 34 | 3 | 3 | 3 | 3 | 3 | 4 | 1 | 2 | 2 | 455.58 |
| 35 | 1 | 4 | 1 | 3 | 3 | 3 | 1 | 3 | 2 | 61.92 |
| 36 | 4 | 6 | 5 | 3 | 3 | 4 | 2 | 4 | 1 | 219.33 |
| 37 | 1 | 2 | 1 | 1 | 2 | 4 | 2 | 2 | 2 | 258.39 |
| 38 | 1 | 4 | 3 | 1 | 2 | 4 | 2 | 2 | 2 | 406.17 |
| 39 | 1 | 4 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 629.82 |
| 40 | 2 | 3 | 1 | 1 | 2 | 2 | 1 | 2 | 2 | 458.64 |
| 41 | 2 | 3 | 3 | 1 | 2 | 3 | 2 | 2 | 2 | 405.54 |
| 42 | 1 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | 717.03 |
| | | | | | **Sum** | | | | | **13,941.81** |

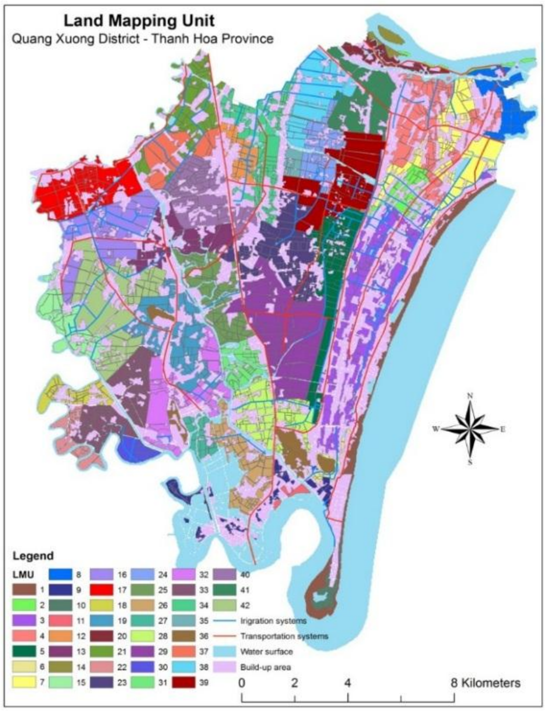



**Figure 4. Land Mapping Unit of Quang xuong**

**Table 5. Land characteristics for determination of suitable classes for rice, maize and potato crops**

| Land quality | Level of suitability | | | | | |
|---|---|---|---|---|---|---|
| | S1 | | S2 | S3 | N1 | N2 |
| | 100 95 | 85 | 60 | 40 | 25 | 0 |
| | 4 | | 3 | 2 | 1 | |
| **Rice** | | | | | | |
| *Soil texture | - | SiC; SiCL; CL | SiL; L | SL; LS | - | cS |
| Topography | Low flat | Flat | Upper flat | Depression | High | |
| Soil depth | > 90 | 90 - 75 | 75 – 50 | 50 - 20 | < 20 | |
| Irrigation | Active | | Somewhat | Poor | None | - |
| Drainage | - | Moderate | Good | Very poor | - | - |
| BS | > 80 | 80 - 50 | 50 – 35 | 35 - 20 | < 20 | |
| pH | 6.5 - 6.0; 6.5 - 7.0 | 6.0 - 5.5 | 5.5 - 5.0 | 5.0 - 4.5 | - | < 4.5 |
| OM | > 2.0 | 2.0 - 1.5 | 1.5 - 0.8 | < 0.8 | - | - |
| CEC | > 15.0 | 15.0 - 10.0 | < 10 | - | - | - |
| **Maize** | | | | | | |
| Soil texture | SiC; SiCL; SiL; CL | L | SL; LS | - | - | cS |
| Topography | Flat | Upper flat | High | Low flat | Depression | |
| Soil depth | > 100 | 100 - 75 | 75 – 50 | 50 - 20 | - | < 20 |
| Irrigation | Active | | Somewhat | Poor | None | - |
| Drainage | Good | Moderate | Imperfect | Poor and imperfect | Poor but drainable | Poor - not drainable |
| BS | > 80 | 80 - 50 | 50 – 35 | 35 - 20 | < 20 | - |
| pH | 6.6 - 6.2; 6.6 - 7.0 | 6.2 - 5.8 | 5.8 - 5.5 | 5.5 - 5.2 | < 5.2 | - |
| OM | > 2.0 | 2.0 - 1.2 | 1.2 - 0.8 | < 0.8 | - | - |
| CEC | > 15.0 | 15.0 - 10.0 | < 10.0 | - | - | - |
| **Potato** | | | | | | |
| Soil texture | L | SiL; SiCL; CL; SL | LS | SiC | - | cS |
| Topography | Flat | Upper flat | High | Low flat | Depression | |
| Soil depth | > 90 | 90 - 60 | 60 – 40 | 40 -20 | - | < 20 |
| Irrigation | Active | | Somewhat | Poor | None | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| Drainage | Good | Moderate | Imperfect | Poor and imperfect | Poor but drainable | Poor - not drainable |
| BS | 65 - 50; 65 – 80 | 50 - 35; 80 - 100 | < 35 | - | - | - |
| pH | 6.3 - 6.0; 6.3 - 6.5 | 6.0 - 5.6; 6.5 - 7.0 | 5.6 - 5.2 | 5.2 - 4.8 | < 4.8 | - |
| OM | > 1.5 | 1.5 - 1.2 | 1.2 - 0.8 | < 0.8 | - | - |
| CEC | > 15.0 | 15.0 - 10.0 | < 10.0 | - | - | - |

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

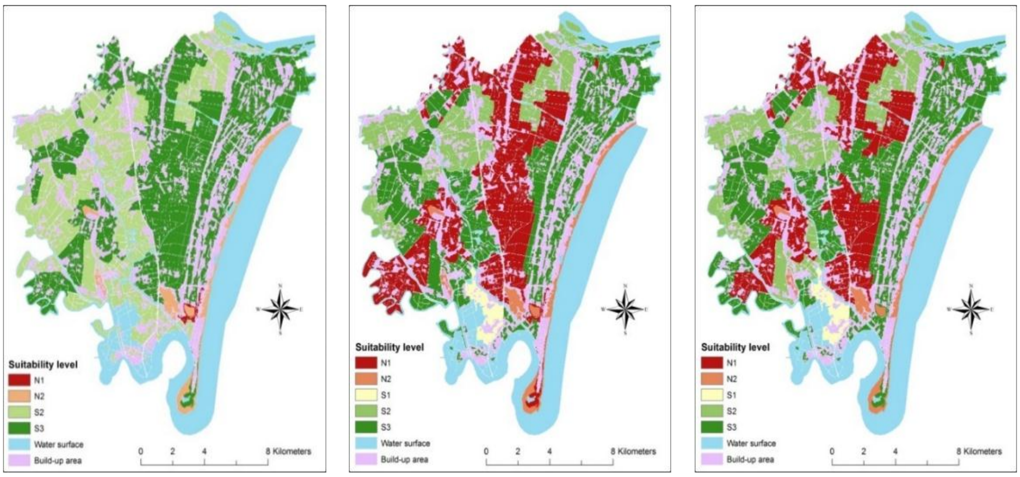
### 4.3. Land suitability evaluation

The ultimate evaluation of the qualitative physical land suitability for rice, maize, and potato cultivation using the simple limitation method is given in Table 6 and land area suitability for these crops in Figure 5.

**Table 6. Suitability level area for growing the selected crops using the simple limitation method**

| Rice | | | Maize | | | Potato | | |
|---|---|---|---|---|---|---|---|---|
| Suitability class | Area (ha) | Percent (%) | Suitability class | Area (ha) | Percent (%) | Suitability class | Area (ha) | Percent (%) |
| - | - | - | S1 | 300.06 | 2.15 | S1 | 300.06 | 2.15 |
| S2 | 5266.17 | 37.77 | S2 | 2496.24 | 17.90 | S2 | 2929.95 | 21.02 |
| S3 | 7997.76 | 57.37 | S3 | 5534.73 | 39.70 | S3 | 6020.91 | 43.19 |
| N1 | 58.14 | 0.42 | N1 | 4991.04 | 35.80 | N1 | 4071.15 | 29.20 |
| N2 | 619.74 | 4.45 | N2 | 619.74 | 4.45 | N2 | 619.74 | 4.45 |
| **Sum** | **13941.81** | **100** | **Sum** | **13941.81** | **100** | **Sum** | **13941.81** | **100** |

The results show that the land with a high level of suitability for rice crop was not found out in the study area. The largest evaluated area was fell into the marginally suitable level for growing rice with 7997.76ha, accounting for 57.37%. The next largest evaluated area belonged to the moderately suitable class with 5366.17ha or 37.77% of the investigated area. Only 58.14ha, equivalent to 0.42% and 619.74ha, accounting for 4.45% of the agricultural land were classified under the current unsuitable class and the permanent suitable class for rice production, respectively. Regarding this method, 300.06ha, accounting for 2.15% and 619.14ha, equivalent to 4.45% of the investigated area were defined as the highly suitable and the permanent unsuitable class for both of maize and potato production, respectively. The assessed results from Table 5 also reveal that 2496.24ha, equivalent to 17.90%, 5534.73ha, amounting to 39.70%, and 4991.04ha were classified as moderately, marginally, and currently unsuitable for maize cultivations while these levels for potato crop were 2929.95ha, equivalent to 21.02%, 6020.91ha, accounting for 43.19%, and 4071.15ha, making up 29.20% of the study area, respectively.




***(a). Rice*** ***(b). Maize*** ***(c). Potato***

**Figure 5. Suitability map for rice, maize and potato using the simple limitation method**

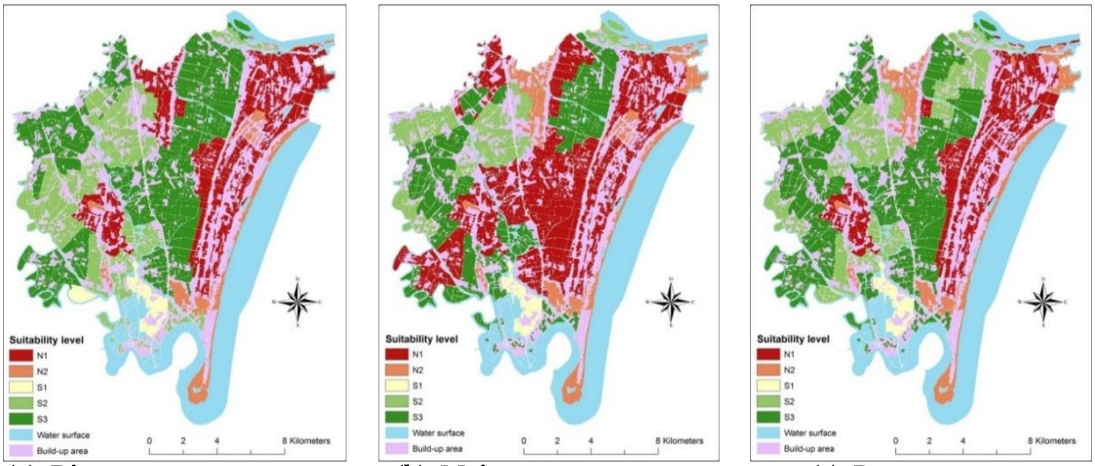
The results of the qualitative physical land suitability for rice, maize, and potato by applying the parametric method are presented in Table 7 and Figure 6.

**Table 7. Suitability level area for growing the selected crops using the parametric method**

| Rice | | | Maize | | | Potato | | |
|---|---|---|---|---|---|---|---|---|
| Suitability class | Area (ha) | Percent (%) | Suitability class | Area (ha) | Percent (%) | Suitability class | Area (ha) | Percent (%) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| S1 | 395.91 | 2.84 | S1 | 300.06 | 2.15 | S1 | 300.06 | 2.15 |
| S2 | 3177.36 | 22.79 | S2 | 1847.25 | 13.25 | S2 | 3120.03 | 22.38 |
| S3 | 5992.47 | 42.98 | S3 | 3906.90 | 28.02 | S3 | 6144.84 | 44.07 |
| N1 | 3467.61 | 24.87 | N1 | 6276.06 | 45.02 | N1 | 2925.45 | 20.98 |
| N2 | 908.46 | 6.52 | N2 | 1611.54 | 11.56 | N2 | 1451.43 | 10.41 |
| **Sum** | **13941.81** | **100** | **Sum** | **13941.81** | **100** | **Sum** | **13941.81** | **100** |

The assessment results of land suitability from by applying the parametric method from Table 7 and classified maps in Figure 6 reveal that 395.91ha, equivalent to 2.84% of the evaluated area was found as highly suitable land for rice crop while the highly suitable level for both of maize, and potato is about 300.06ha, making up 2.15% of the investigated area. The dominant suitability classes were as follows: marginally suitable level for rice with 5992.47ha, currently unsuitable class for maize with 6276.06ha, and marginally suitable level for potato with 6144.84ha. These classes make up 42.98%, 45.02%, and 44.07% of the cultivated area, respectively. The moderately suitable class for rice, maize, and potato was 3177.36ha or 22.79%, 1847.25ha or 13.25%, and 3120.03ha, or 22.38%, respectively. The assessed results of the parametric also shown that the currently and permanently unsuitable levels for rice growing were 3467.61ha or 24.87%, and 908.46ha or 6.52% while the currently and permanently unsuitable levels for potato production were 2925.45ha, equivalent to 20.98%, and 1451.ha, accounting for 10.41%, respectively. According to this method, 3906.90ha, making up 28.02%, and 1611.54ha or 11.56% of the study area were classified as marginally suitable level, and permanently not suitable for maize cultivation, respectively.




**(a). Rice** **(b). Maize** **(c). Potato**

**Figure 6. Suitability map for rice, maize and potato using the parametric method**

The consequences of qualitative physical land suitability evaluation by using the simple limitation and parametric methods revealed the range changes amongst class levels from permanently unsuitable to highly suitable levels for rice, maize, and potato crops in this research. The different results of land suitability evaluation for those crops can explain that the suitability level depended on matching of the collected data for each land unit with the crop requirements for developing as mentioned in Table 5. This means that, different suitability classes were determined for different land characteristics. Based on the simple limitation method, the final suitable class of land units for a specific crop was considered to be as the lowest level among suitable classes. However, In parametric method, differences in results could be explained by the consequences of multiplication of the land suitability ratings in calculating of the land suitability index. Due to multiplication of different land suitability ratings of each parameter, so the final suitability level of Each land mapping unit for a specific crop might have been lower, equal or higher in comparing with the simple limitation method. Manna et al., (2009) stated that it is difficult to figure out the most feasible method for land evaluation as there have been a limited number of studies on this topic. He also suggested that more complicated methods have better predictive ability than more simplified approaches. Therefore, in order to determine which method is more reliable, the observed yield is recommended to estimate for a certain kind of crops associated with each land unit.

## 5. CONCLUSIONS

In this study, the simple limitation and parametric methods were implemented for the land evaluation process. These methods were adopted by Vietnam after the FAO framework with modifications to suit the local environment. The consequences of land suitability for rice, maize and potato crops lead to a conclusion that all the land units are maintaining certain degree of limitation which may affect the land quality. The findings found out that the most serious limitations for cultivating and developing of mentioned crops were relative topography, soil chemical and physical properties such as low percentage of organic matter content, high acid in soil, shortage of irrigated condition, shallow soil depth or some soil textures not suitable for agricultural crops. Its also suggested that the simple limitation and the parametric methods can be expanded and repeated in different areas of the province as well as applied to determine land evaluation for other agricultural crops. The main factors used for land suitability evaluation can be changed to be suitable for a particular area.

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