

Research on the Potential Environmental Zonation of Red Flesh Dragon Fruit in Vinh Phuc Province

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Abstract Red flesh dragon fruit (*Hylocereus polyrhizus*) or pitaya is well-known as an excellent source of antioxidants and high content of nutrients. The Red flesh dragon fruit is a hybrid of the white flesh dragon fruit *Hylocereus undatus* and a native *Hylocereus costaricensis* from Middle and North America. It brings high economic efficiency and currently being developed in the province of Vinh Phuc. The main objective of the study is to create a model, which help to determine the suitability in developing dragon fruit cultivation in Vinh Phuc province in order to support local agricultural and land use planning. The model is built based on the application of Geographic Information System (GIS), Kriging interpolation method, Multi-Criteria Decision Analysis (MCDA) method, Fuzzy Set Theory and Analytic Hierarchy Process (AHP) to evaluate and map the area suitable zonation for farming.

Keywords *Hylocereus polyrhizus* · GIS · MCDA · AHP

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1 Introduction

Vinh Phuc is located in Red River Delta. It is one of the seven provinces of the Northern key economic zone. Vinh Phuc province is bordered to the North by Thai Nguyen and Tuyen Quang, to the west by Phu Tho, to the south by Hanoi, to the east by 2 districts: Soc Son and Dong Anh of Hanoi city. The province has 9 administrative units: Vinh Yen City, Phuc Yen town and the districts: Binh Xuyen, Lap Thach, Song Lo, Tam Duong, Tam Dao, Vinh Tuong, Yen Lac (Fig. 1).

Vinh Phuc is one of the provinces that have the highest level of GDP growth rate of the entire country. In order to ensure the sustainable development, the province has identified the direction of developing the service industry to re-invest in agriculture, mobilizing investment capital for production development and construction of agricultural infrastructure (Vinh Phuc Provincial People's Committee 2011). In planning the agricultural development of the province, the red flesh dragon fruit was added to the list of crops with high economic value. However, until now, this crop has not been studied for the zonation developed in accordance with the environmental conditions of the province.

Red flesh dragon fruit is hybrid between white flesh dragon fruit *Hylocereus undatus* and *Hylocereus costaricensis*, a native breed originated in Central and North America. Red flesh dragon fruit is one of the fruit plants which bring high economic efficiency in both developed North and South Vietnam, most concentrated in Binh Thuan. Dragon fruit can grow and develop in different soil types such



Fig. 1 Vinh Phuc administrative map

as sandy soil, gray soil, alkaline soil to alluvial soil, red soil bazan, soil. The temperature suitable for the red dragon fruit growth and development ranges from 15 to 35 °C (Van Ke 1998), in which the most appropriate temperature ranges from 21 to 26 °C (Liaotrakoon 2013). The weather conditions of light frost, even for a short time will also affect red dragon fruit growth. The demand of precipitation for crops ranges from 800 to 2000 mm/year (Van Ke 1998). A good drainage system can reduce the influence of precipitation on the flowering, fruiting of trees. The red dragon fruit is photophilic plants, suitable for cultivation in areas where there are lots of light. In addition, it can be planted in the low slope area in (Truong Thi Dep 2000).

2 Methodology

The research applied a series of criteria in order to find potential development of the red dragon fruit tree planting. The criteria include temperature, precipitation, distance to the irrigation source, distance to roads, slope.

2.1 *Impact Factors for the Suitability of Growing Dragon Fruit*

Temperature

Temperature is a factor that greatly affects plant growth. Plants can grow in a wide temperature range, but different types of plants have different minimum and maximum temperature points. The minimum temperature and the maximum temperature for the growth of the plant are the temperature points at which the plant stops growing. Limits of temperatures growth change with the adaptation of plants in different ecological zones. To evaluate the regions having potential for the growth and development of dragon fruit, research based on the field examinations, using the Linear Regression with 2 variables: elevation and temperature to find the relationship between temperature and elevation, thereby construct the map of temperature for the target area. With 10 data points observed in fieldtrip, the research obtained.

Equation of variability of temperature depending upon elevation in the winter:

$$y = -0.006x + 18,769$$

Equation of variability of temperature depending upon elevation in the summer:

$$y = -0.0054x + 32.517$$

where: y is temperature (°C); x is elevation (m).

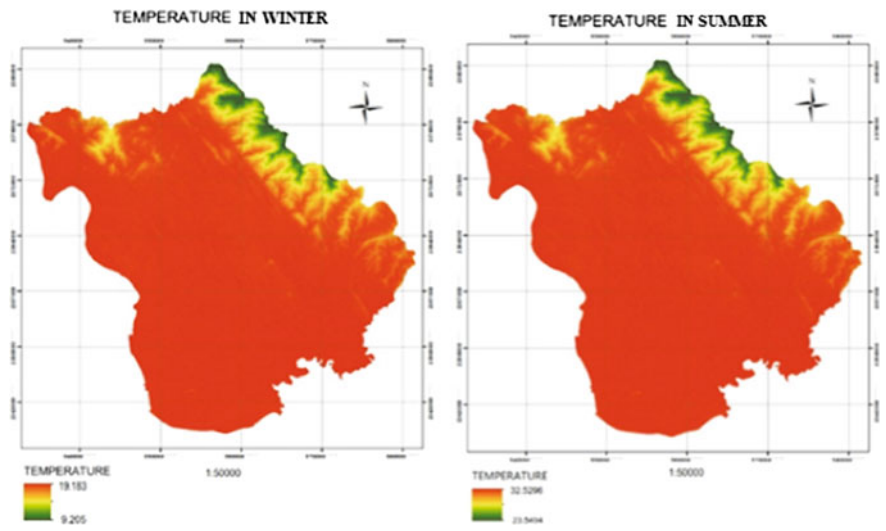


Fig. 2 Map of temperature in summer and winter

By the result of study about relationship between temperature and elevation, using DEM for Vinh phuc province, the research created temperature map for this area in the winter and summer (Fig. 2).

Precipitation

The research used the data of rain capacity monitored from monitor stations on the locality of Vinh Phuc province, as well as international monitoring data shared by Globalweather (NCEP). The precipitation map of the study area was interpolated by

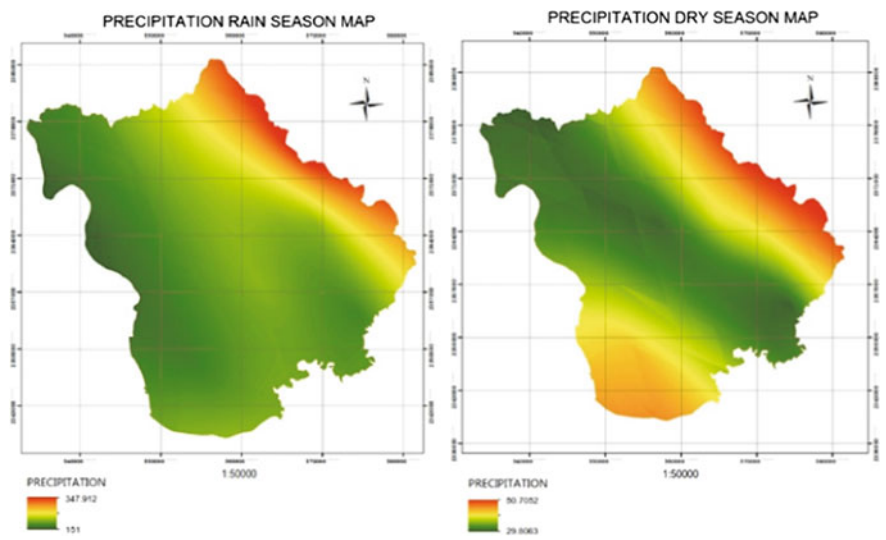


Fig. 3 Map of precipitation in rain and dry season

Ordinary Kriging from the average monitoring data of two seasons: rainy season (from April to September) and dry season (from October to March) (Fig. 3).

Slope

Slope is also an important factor in assessing suitability for selection of crop. Sloping land is often subjected to erosion, which leads to land degradation, soil degradation, poor nutrient, structural failure, pH reduction, increase of levels of soil toxicants and it can make the soil die biologically. Most of sloping lands are degraded and sour, many areas were deserted due to loss of agricultural and forestry production ability. For dragon fruit, the lower the slope, the more suitable for cultivation. In this study, the slope map was created based on the DEM of Vinh Phuc (Fig. 4).

Distance to Irritation Source, Distance to the Road

The distance to the irritation source is also taken into account in determining the suitability of cultivation. Based on the map of Red river in Vinh Phuc province, the study used the IDRISI tool to calculate the raster map showing the distance to

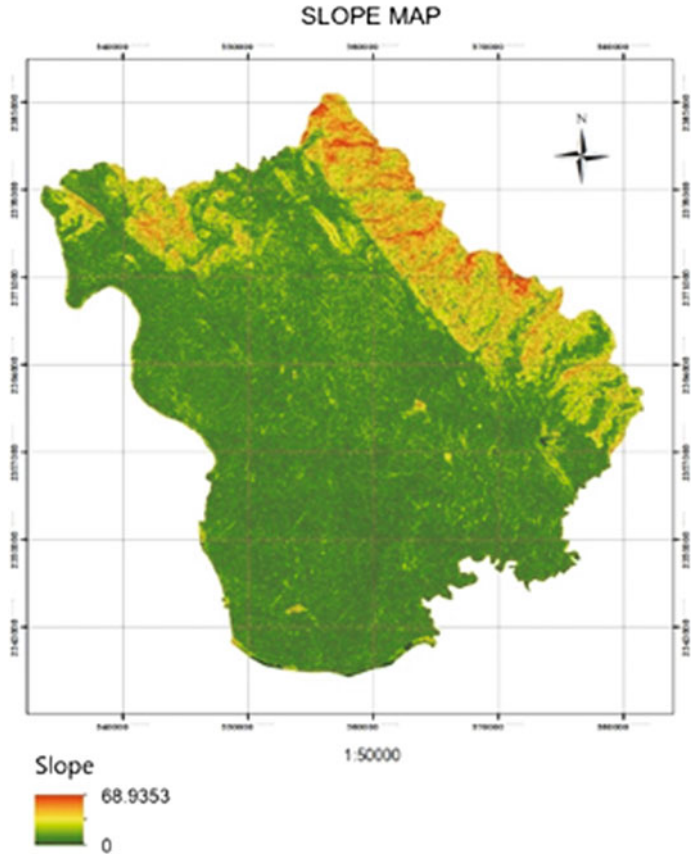


Fig. 4 Map of slope

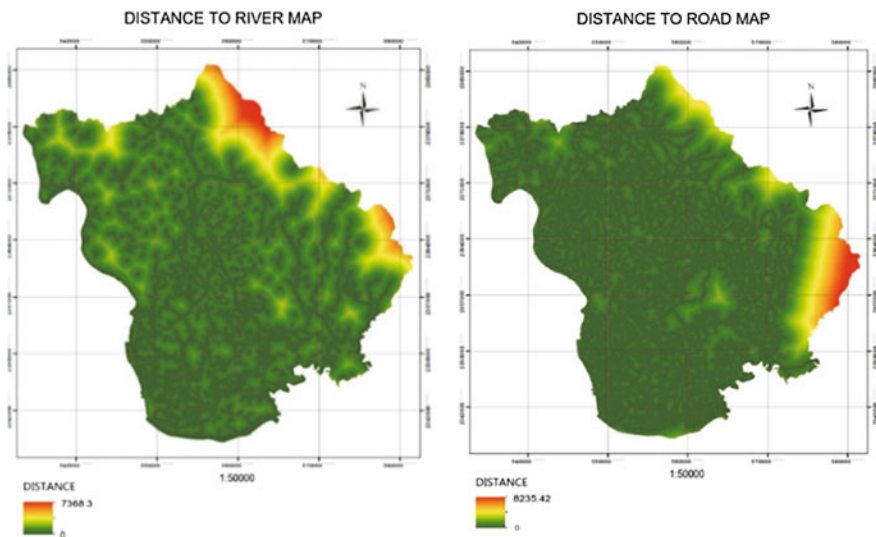


Fig. 5 Distance to the road and distance to irritation source

the irrigation source for each location. The distance to the irritation source for growing the dragon fruit should range from 20 m to 100 m. If the distance is less than 10 m, the location is not suitable for growing dragon fruit because it can be influenced by flooding and landslide. A distance of more than 100 m is also considered inappropriate due to the difficulty of water supply for irrigation.

For the purpose of harvesting, transporting products, the distance to roads is also included as an indicator to assess the suitability of dragon fruit cultivation. Research used optimal distance to the road from 20 to 100 m, over 5000 m is considered inappropriate (Fig. 5).

2.2 Evaluate, Synthesize and Analyze Data

Multiple-criteria decision analysis (MCDA)

Multiple-criteria decision analysis (MCDA) is a sub-discipline of operative research that explicitly evaluates multiple conflicting criteria in decision making. MCDA methods can be divided into 2 types: (i) multi-objective decision making (MODM) and (ii) multi-attribute utility theory (MAUT). This stage includes standardization, expert work, weighting calculation, and summary analysis of all criteria considered in the decision-making process

Standardize the evaluation factors

Since the datas collected are measured on different scales, the first step of MCDA is to standardize all data sets and comparable units. There are a large number of approaches that can be used to create attribute classes of comparable criteria. Based on the researches and experiences of the experts, in this study, the fuzzy set theory

was used to standardize the criteria of the data. The input data is converted to the same scale from 0 to 255. The values of the standard data are determined by J-shaped and Linear functions (Table 1).

Analytic Hierarchy Process (AHP)

AHP is a decision-making support technique that provides an overview of the order of the design choices and help to find out the most appropriate final decision. The AHP helps decision-makers find what is best for them and helps them to understand their problems. Based on mathematics and psychology, AHP was developed by Saaty in 1970 and has been expanded and added to date. AHP provides a precise framework for structuring of a problem to be solved. AHP is tightly combined with decision standards and decision makers use pairwise comparison to determine reciprocally between goals. The AHP method is to construct the weight of the selected criteria for assessing adaptation of the red dragon fruit. From that, put the weights into the AHP to calculate and establish the appropriate partition map (Table 2).

Therefore, the consistency ratio $CR = 0.06$ satisfied the criterias, the average weight is confirmed and put into the index calculations incorporate the adaptive building zonation map (Table 3).

Table 1 Fuzzy standardize the evaluation elements

Factors	Function used	Control points
Rainfall in rainy season	J-Shape increasing	a = 50 mm, b = 150 m, c = 176 m, d = 270 m
Precipitation in dry season	J-Shape symmetric	a = 29 mm, b = 51 mm
Temperature in hot season	J-Shape increasing	a = 15 °C, b = 21 °C, c = 26 °C, d = 35 °C
Temperature in cold season	J-Shape symmetric	a = 15 °C, b = 19 °C
Slope	Linear decreasing	a = 0%, d = 17%
Distance to roads	Linear symmetric	a = 5 m, b = 20 m, c = 100 m, d = 8000 m
Distance to rivers, lakes, ...	Linear symmetric	a = 5 m, b = 20 m, c = 100 m, d = 4000 m

Table 2 Weight of factors

Factors	Weight
Rainfall in rainy season	0.178
Precipitation in dry season	0.1116
Temperature in summer	0.0958
Temperature in winter	0.4689
Distance to rivers, lakes, ...	0.0859
Slope	0.0371
Distance to roads	0.0228

Table 3 Parameters of AHP

Factors	Value
Eigenvalues of Matrix (λ_{\max})	7.475
Factors (n)	7
Consistency index (CI)	0.079
Random (RI)	1.32
Consistency Ratio (CR)	0.06

3 Results

Results of the research are illustrated in the map of factors affecting dragon fruit in Vinh Phuc province, together with additional research methods to provide a suitable zonation map of each sites for dragon fruit planting (Fig. 6).

According to research results, it can be seen that most of Vinh Phuc province’s areas have suitable conditions for red dragon fruit, as follows: highly suitable area covers an area of 30,628.17 ha, located in Song Lo, Lap Thach, Vinh Tuong, Phuc Yen districts; the area which is lower suitable for growing dragon fruit is of 1586.08 ha, located in the Song Lo, Lap Thach, Tam Dao, Phuc Yen districts. There are 62148.28 ha, which is completely not suitable for dragon fruit growth (Fig. 7).

The research explored the potential development of red dragon fruit in the management of resources in Vinh Phuc province. The results have contributed to improvements in methodology, time and cost for planning and resources

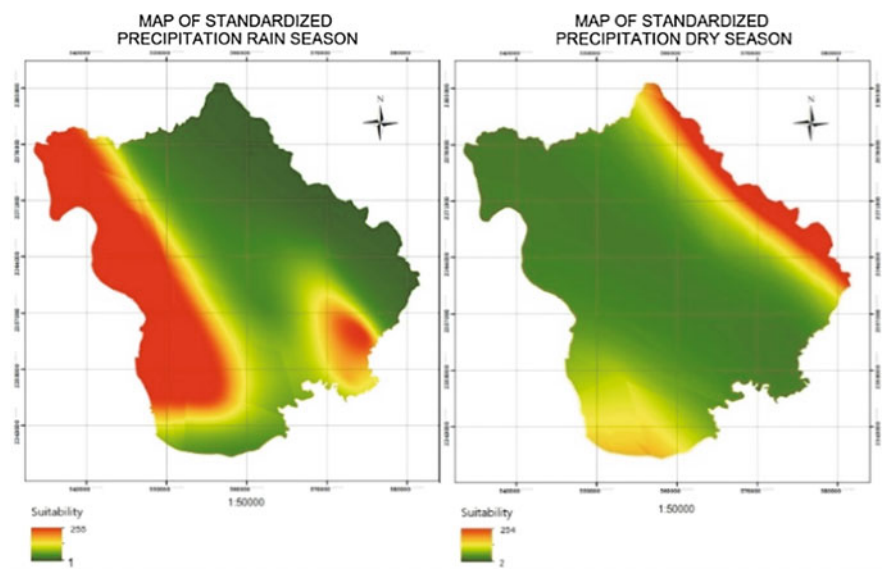


Fig. 6 Standardization map for precipitation

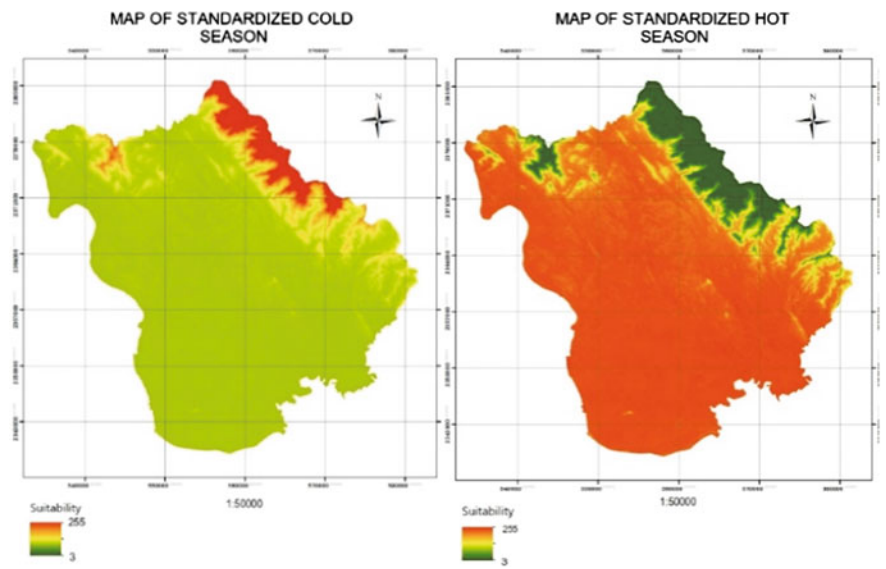


Fig. 7 Standardization map for temperature

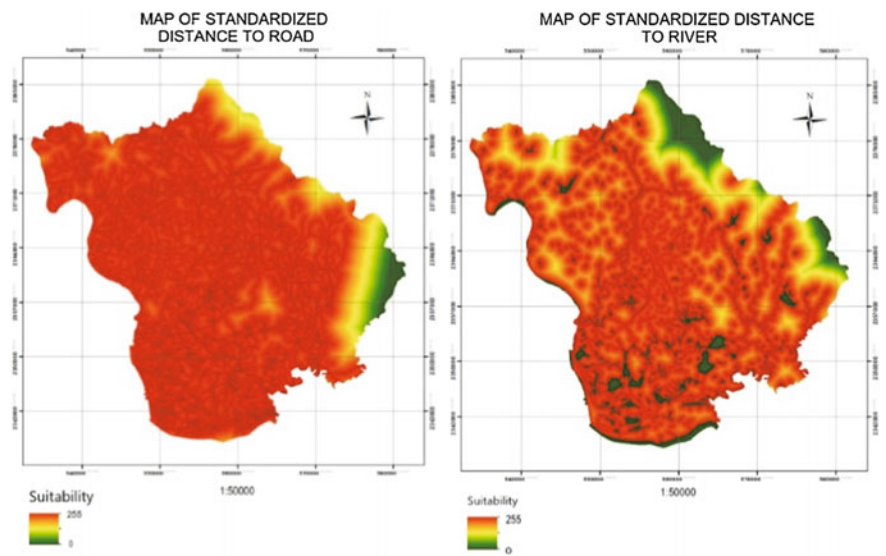


Fig. 8 Standardization map of distance to the road and to irritation source

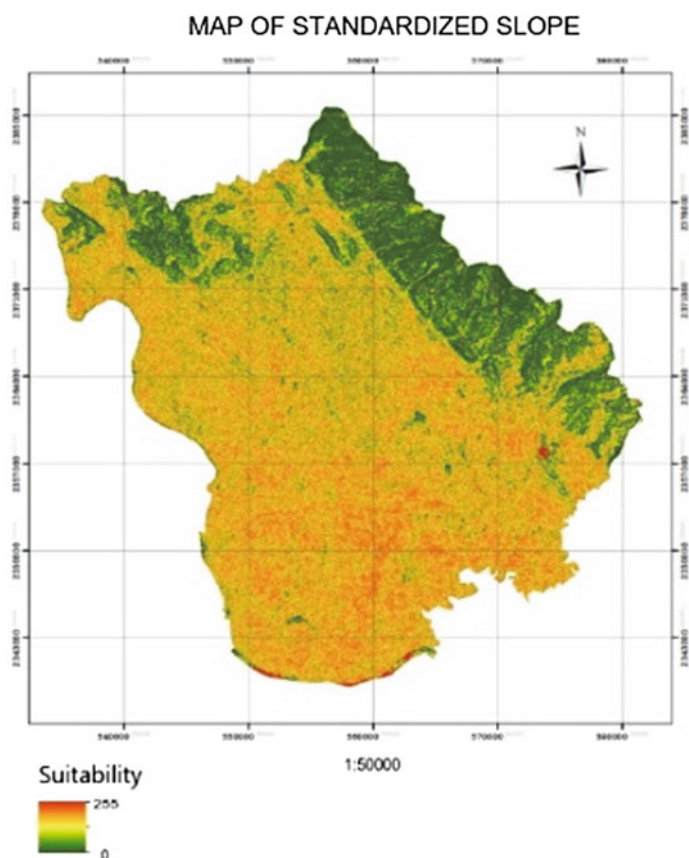


Fig. 9 Standardization map for slope

management. However, due to the difficulties of data collecting as well as the limitations of time and funding, the research only focused on a number of natural and social factors that affect growth of dragon fruit (Fig. 8).

4 Conclusion and Recommendation

To conclude, by using GIS and others analysis methods, the research showed that most of Vinh Phuc province's area are suitable for red dragon fruit growth (Fig. 9).

Based on the research results and the plan for agriculture, forestry and fishery development in Vinh Phuc province up to 2020 with a vision to 2030, the red dragon fruit is encouraged to develop for transforming forest land into economic

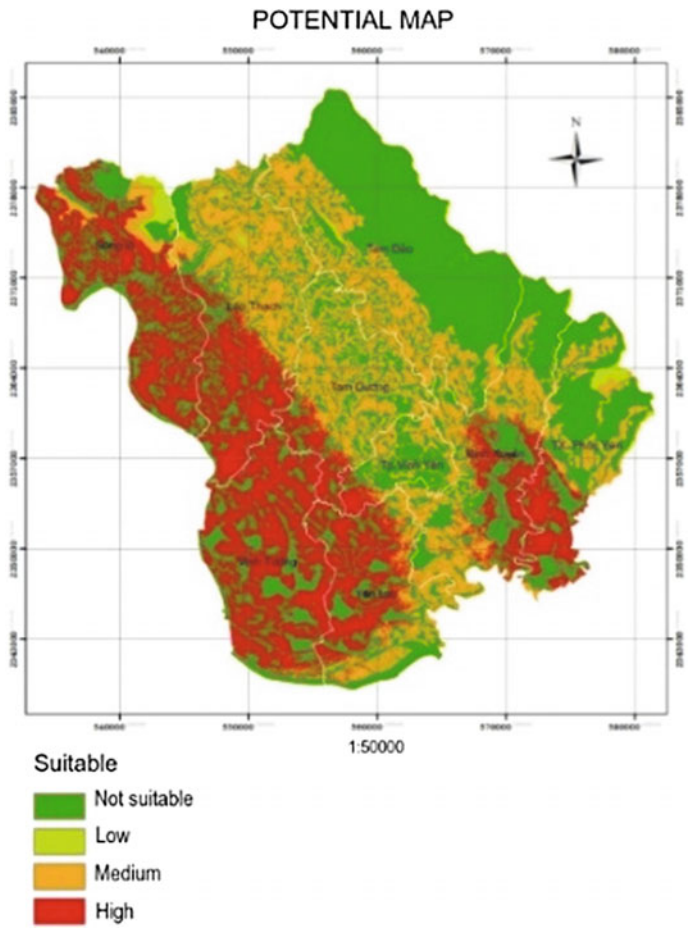


Fig. 10 Map of potential development of red dragon fruit in Vinh Phuc province

models. Song Lo, Lap Thach, Phuc Yen district should be focused on growing this fruit plant (Fig. 10).

The methodology of the research not only use for assessment and zonation of plant development, but also can be applied in many different fields such as: warning of natural disasters, nature conservation and evaluation, planning and rational use of land resources.

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