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Development of Criteria for High-Technology Rice and Corn Suitability Assessment – A Case Study in the An Giang province, Viet Nam

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ABSTRACT

This study identified the zones likely to apply high-tech rice and corn technology based on criteria from different expert groups. Based on the resulting limiting factor for ability suitable, structural and non-structural solutions have been proposed to improve the suitability of rice and corn with high-tech applications. It was the basic foundation to support strategic planners in agricultural development sustainability in the future. High technology application in agricultural production is an inevitable trend in today's society. In Vietnam, high-tech agricultural production has developed for a long time in high-tech industrial park production. However, in agricultural production, applying high technology with mass production has yet to have any specific regulations on criteria for implementation in production. On that basis, the research aimed at determining the requirements for developing high-tech agriculture with mass production. Therefore, the predefined criteria for primary and secondary data were developed, which were used for the data collected from farmers, managers, and scientists. Thereby, a production hierarchy of adaptations for rice and corn was built based on consultation results with the farmers and scientists and published studies. The results also made three land adaptation zones apply high technology in mass production for these two crops. The areas suitable for producing rice and corn with high technology applications were marginally suitable, and not suitable prevailed. No region in the An Giang province has a strong potential for cultivating high-tech rice and corn. This result also established adaptive upgrading solutions for applying high technology in the future, which helped improve agricultural production efficiency.

Keywords: An Giang province; corn production; high-tech; multi-criteria; rice production.

INTRODUCTION

Agriculture high-tech application uses advanced technologies and techniques in agricultural production to create products with high productivity, quality, competitiveness, and environmental friendliness (Government, 2015; Xo & Nhuong, 2006). The application of high technology in agricultural production is an urgent requirement between production practice and the essential solutions to industrialization and agricultural modernization in rural areas (Thomas, 2012; Hien, 2014). However, the implementation still has limitations, such as the small, fragmented agricultural production scale, the lack of planning, and the large-scale establishment of concentrated production areas (Chung, 2018; Dung & Ninh, 2015). Moreover, the application of scientific-technological advances to production is limited, not bold in selecting plant varieties and applying biotechnology, which results in low productivity, product quality, and competitiveness, and high investment capital for agricultural production using high technology (Khuong et al., 2014; Hien, P.V., 2014). Significantly, the criteria for constructing high-tech agricultural applications still need to be completed. Therefore, the research

was necessary to be raised in the current period. The study aimed to identify and evaluate the existing agricultural land use, apply high technology for rice and cash crop (corn) production, and propose solutions to improve the efficiency of the high-tech application.

MATERIALS AND METHODS

Systematizing theoretical bases of hi-tech application agriculture

Based on the legal documents and previous studies in Vietnam and around the world. The research established the requirements for hi-tech application agricultural production, as shown in Table 2.

Data collection

Secondary data collection

The study collected data on the current land use, reported agricultural production, socio-economic development, statistical yearbook, and reports on the implementation of resolution 09-NQ/TU of the provincial party committee. The study collected data on the province's agricultural land use and administration maps.

Primary data collection

Expert consultation to identify high-tech application agricultural production criteria

The study consulted experts on rice (24 farmers, 24 managers, and 15 scientists) and corn (19 farmers, 16 managers, and 16 scientists) to build the requirements for developing a high-tech application for mass production.

The classification of land suitability for high-tech application

The study consulted the farmers, managers, and scientists and synthesized previous studies to build the hierarchy requirement for mass production. The sample size was calculated based on Slovin (1960) with an allowable margin of error of 10%.

Creating land characteristics

The study inherits the soil characteristics data from the project, evaluating the potential and distributing soil fertility based on soil maps to assess the constraints to crop cultivation in the An Giang province (Du et al., 2019).

Data processing

The data were processed to analyze non-parametric data using Microsoft excel software. Then, the chart was drawn. Finally, the current state of agricultural land use, hi-tech applications in agriculture, and applications of rice and corn in current conditions were analyzed and evaluated.

Besides, the study identified the current agricultural land use status on paper maps through discussions with agricultural managers to determine the location and distribution of land use types.

Criteria for hi-tech agricultural development

The data from expert consultation was synthesized to determine the priority of requirements using the Microsoft Excel software and the multi-objective assessment method (Sharifi., 1990). From ranking the criteria of interest of the target groups for each condition for high-tech crop production, the data were standardized to the same value from 0 to 1 (Eq. 1) (Sharifi., 1990).

$$Xi = \frac{\sum Y(j)i}{\sum Zmax(j)} \quad (1)$$

where: Xi – the standardized point of the level of interest required i,
$\sum Y(j)i$ – the total score of the assessors for requirement i in requirement group j for high-tech application development,
$\sum Zmax(j)$ – the highest total score of requirement group j for high-tech application development assessed by the expert.

Delineation of the hi-tech agricultural production area

This method was based on the adaptive assessment method (FAO, 1976 and 2007) with 05 basic steps from Figure 1.

RESULTS

Factors affecting high-tech agricultural production in the study area

Current agricultural land uses

The rice and corn production areas dominate in the An Giang province (Table 1 and Figure 2). Table 1 shows the advantages of agricultural development, which are favorable conditions for

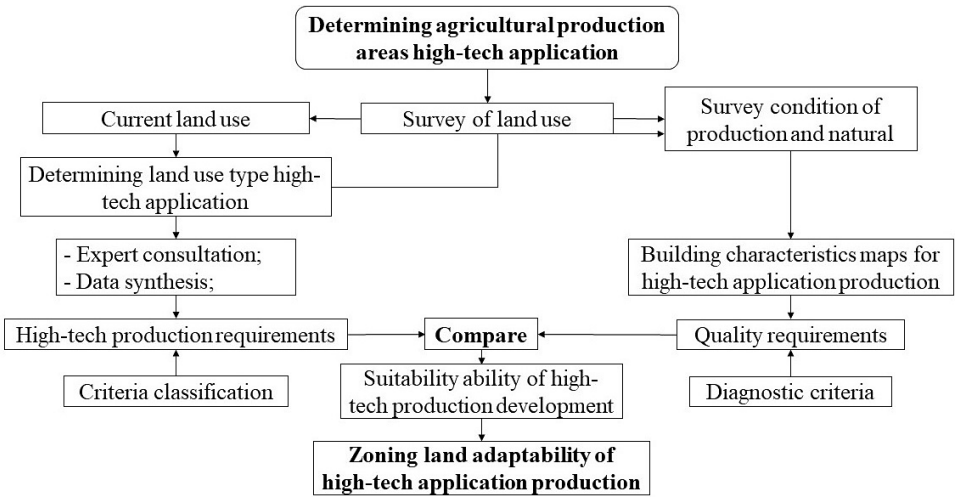

Figure 1. Process of ability zoning for high-tech application

Table 1. The area of agricultural land-use types in 2019

No	Land use types	Area (ha)	Ratio (%)
1	Triple rice	194,748.30	68.31
2	Double rice	60,890.25	21.36
3	Double rice - Cash crops	390.46	0.14
4	Rice - Cash crops	418.11	0.15
5	Rice - Shrimp	53.37	0.02
6	Cash crops	13,100.72	4.60
7	Fruits	9,945.44	3.49
8	Aquaculture	5,530.36	1.94
Total		285,077.01	100.00

Source: Agriculture and Rural Development Department of An Giang, 2019.

applying new science and technology to agricultural cultivation more conveniently and synchronously.

Application of high-tech for rice and corn production

Rice

In current cultivation had been applied new techniques (such as seed; 1 must consider 5 reductions, 3 reductions-3 gains, and integrated pest management) (Monica et al., 2020). At the same time, the province was also developing rice production systems according to VietGAP,

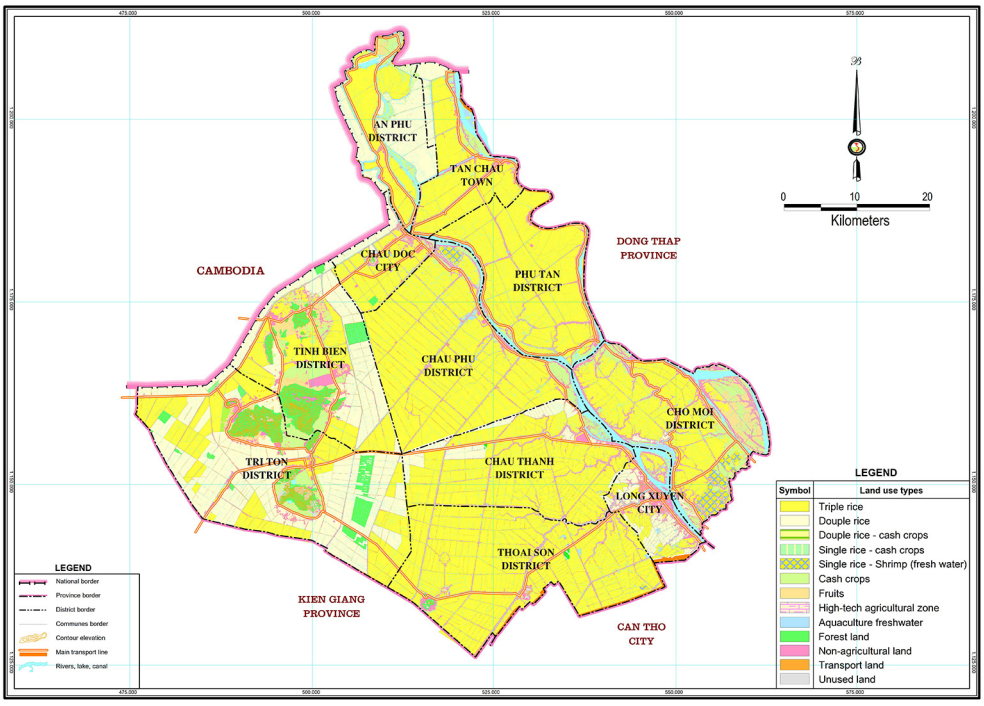

Figure 2. Current agricultural land use in 2019 in An Giang province

Table 2. Index of specific requirements for high-tech application in rice and corn production

General requirement	Code	Specific requirements	Source of requirements for hi-tech application	Index rice			Index corn		
				Farmer	Manager	Scientist	Farmer	Manager	Scientist
Physical	1	Soil	Indur M. Goklany, 2001; Karehka Ramey, 2012; FAO, 2001; WHO, 1990; Horlings & Marsden, 2011; Tilman D. et al., 2001; Xo and Nhuong, 2006; Law of high-tech, 2008; Decree 1895/2012/NĐ-TTg; Decision 66/2015/QĐ-TTg; Nguyen et al., 2017; Khuong et al., 2014; Chung, 2018; Sundkvist et al., 2005; Spencer et al., 2003; FAO, 1976; FAO, 2007;	0.889	1.000	0.929	1.000	0.923	1.000
	2	Water		0.778	1.000	1.000	0.923	1.000	1.000
	3	Weather		1.000	0.909	0.857	0.769	0.846	0.750
Average of the Physical requirement group (A)				0.889	0.970	0.929	0.897	0.923	0.916
Economy	4	Cost		0.909	1.000	1.000	1.000	0.750	0.857
	5	Profit		0.909	1.000	1.000	0.882	0.750	0.857
	6	Capital efficiency		0.727	0.833	0.929	0.647	0.313	1.000
	7	Consumer market		1.000	1.000	1.000	1.000	1.000	1.000
	8	Product price		0.636	0.500	0.643	0.882	0.500	0.857
	9	Investment capital		0.545	0.917	0.786	0.588	0.250	0.286
Average of the economic requirement group (B)				0.788	0.875	0.893	0.814	0.594	0.810
Society	10	Farmers' education		1.000	0.917	0.733	0.824	1.000	1.000
	11	Management ability		0.750	1.000	0.933	0.176	0.583	0.714
	12	Labor source		0.250	0.583	0.533	0.294	0.667	0.429
	13	Infrastructure		0.750	0.833	0.933	0.941	0.667	1.000
	14	Production organization		0.750	0.917	1.000	0.882	0.833	1.000
	15	Land use rights		0.333	0.417	0.600	0.000	0.250	0.000
	16	Policy support		0.583	0.750	0.933	0.412	1.000	0.429
	17	Techniques		0.667	0.833	1.000	1.000	0.750	0.857
Average of the social requirement group (C)				0.635	0.781	0.833	0.566	0.719	0.679
Environment	18	Salinity/alumification		1.000	0.909	1.000	0.833	0.857	1.000
	19	Soil degradation		1.000	1.000	1.000	0.889	1.000	1.000
	20	Water pollution		1.000	0.909	1.000	1.000	0.929	1.000
Average of the environment requirement group (D)				1.000	0.939	1.000	0.907	0.929	1.000
Index of general requirement (RI) = [(3*A+6*B+8*C+3*D)/20]				0.828	0.891	0.913	0.741	0.743	0.802

GlobalGAP, and organic standards (Thang et al., 2017); and application of machine tools to mechanize farming stages (Martin et al., 2013; Castelein et al., 2022). Moreover, the province has built large sample fields associated with production links (Gokul et al., 2020). These were favorable conditions for the development of high-tech applications.

Cash crops

The province applied high technology and implemented the replication in the area, such as seeding, applying agricultural mulch, and using cultivators' soil. However, several techniques still need to be replicated, such as building net and membrane houses, spraying water and drip irrigation, and building cooperative groups.

Limitations in high-tech application

The assessment results also showed that the current application of high technology in agricultural production still faced many limitations, such as a lack of investment capital, human resources, incomplete infrastructure, consumer markets, and farming techniques that still needed to be replicated. For example, there were still obstacles in corn production that have not promoted mechanization.

Determining the requirements for high-tech applications

Based on preliminary criteria defined by the systematization of high-tech agricultural production applications. The study engaged farmers,

managers, and scientists to assess the parameters required for mass manufacturing high-tech rice and corn applications. Figures 3a, 3b, and Table 2 depict the findings of expert evaluations for high-tech applications of rice and corn. The results showed that the requirements of land use rights,

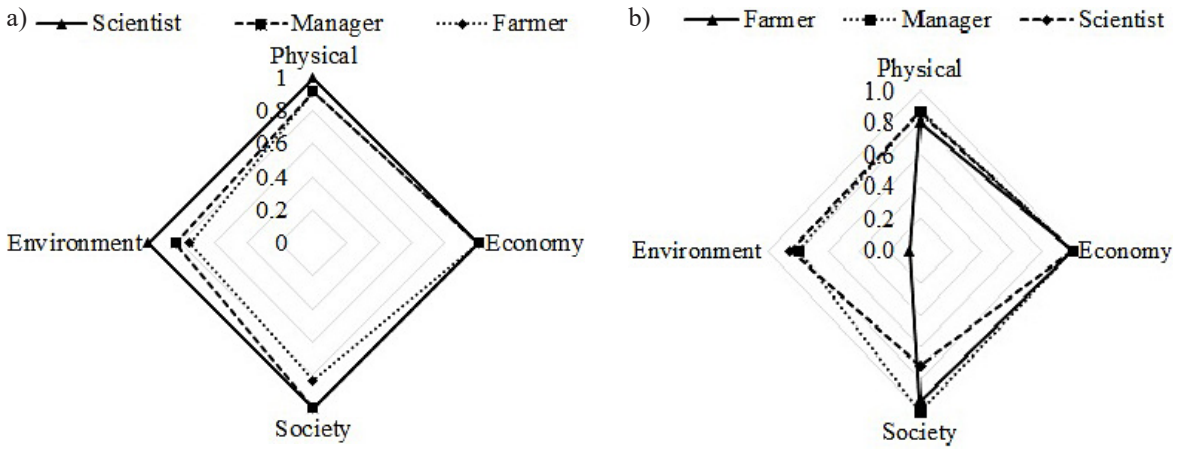

Figure 3. Index of general requirements for high-tech (a) rice application and (b) corn application

Table 3. Factors rating for high-tech application of rice and corn production

Quality requirements	Diagnostic criteria	Suitability rice				Suitability corn			
		S1	S2	S3	N	S1	S2	S3	N
Sulfuric hazard	Depth appears in sulfuric	No alum, >100	50-100	<50	-	No alum, >100	50-100	<50	-
	Depth appears in generating materials alum (cm)	No alum, >100	50-100	<50	-	No alum, >100	50-100	<50	-
Water holding ability	Soil structure	Silt loam	Clay, Silt	Sandy loam	Sand	Silt loam, Silt	Sandy loam	Clay, Sand	-
Flooding hazard	Flooding depth (cm)	<30	30-60	-	>60	-	-	-	-
	Flooding duration (month)	<3	3-6	-	> 6	<3	-	-	>3
Drought hazard	Additional irrigation duration (month)	<2	2-3	3-4	>4	<2	2-3	3-4	>4
Return of Capital	Profit	>80%	60-80%	40-60%	<40%	>80%	60-80%	40-60%	<40%
	Capital efficiency	>80%	60-80%	40-60%	<40%	>80%	60-80%	40-60%	<40%
Market ability	Stability of consumer market	Stable	-	-	Unstable	Stable	-	Not yet Stable	Unstable
	Stability of product price	Stable	Less volatility	-	Very Volatile	Stable	Less volatility	-	Very Volatile
	Product Quality	Good	Medium	-	Weak	Good	Normal	-	Bad
Model development ability	Farmers' qualifications and management	Good	Medium	Weak	Very weak	Good	Medium	-	Weak
	Infrastructure	Complete	-	Not yet complete	Incomplete	Complete	-	Not yet complete	Incomplete
	Production organization	Cooperative	Cooperative group	Individual	-	Cooperative	Cooperation Group	-	Not
Technique applying ability	Techniques apply	Modern	-	-	Traditional	Modern	-	-	Traditional
Environmentally friendly ability	Salinity/ acidification	Low	Medium	-	High	Low	Medium	-	High
	Soil degradation	Little	Medium	-	Much	Little	Medium	-	Much
	Water pollution	Little	Medium	-	Much	Little	Medium	-	Much

Table 4. Suitable classification for high-tech application rice production

Zone	Suitable classification	Limited factors	Area (ha)	Ratio (%)
1	Moderately suitable	• Additional irrigation duration; • Poor quality of labor; • Water pollution; • Poor management ability; • Product prices are less volatile; • Investment capital is not available;	105,972.28	34.47
2	Marginally suitable	• Infrastructure not yet; • Soil structure;	25,699.48	8.36
3	Not-Suitable	• Additional irrigation duration; • Poor quality of labor; • Product prices fluctuate widely; • Salinity/acidity • Soil degradation; • Water pollution; • Small-scale production;	175,725.81	57.17

Table 5. Suitable classification for high-tech application corn production

Zone	Suitable classification	Limited factors	Area (ha)	Ratio (%)
1	Moderately suitable	• Irrigation duration; • Poor quality of labor; • Water pollution; • Mechanization of some stages; • Poor management ability; • Product prices are less volatile; • Investment capital is not available;	121,028.94	39.37
2	Marginally suitable	• Infrastructure not yet;	28,645.20	9.32
3	Not-Suitable	• Irrigation duration; • Poor quality of labor; • Product prices fluctuate widely; • Salinity/acidity; • Soil degradation; • Water pollution; • Small-scale production;	157,723.43	51.31

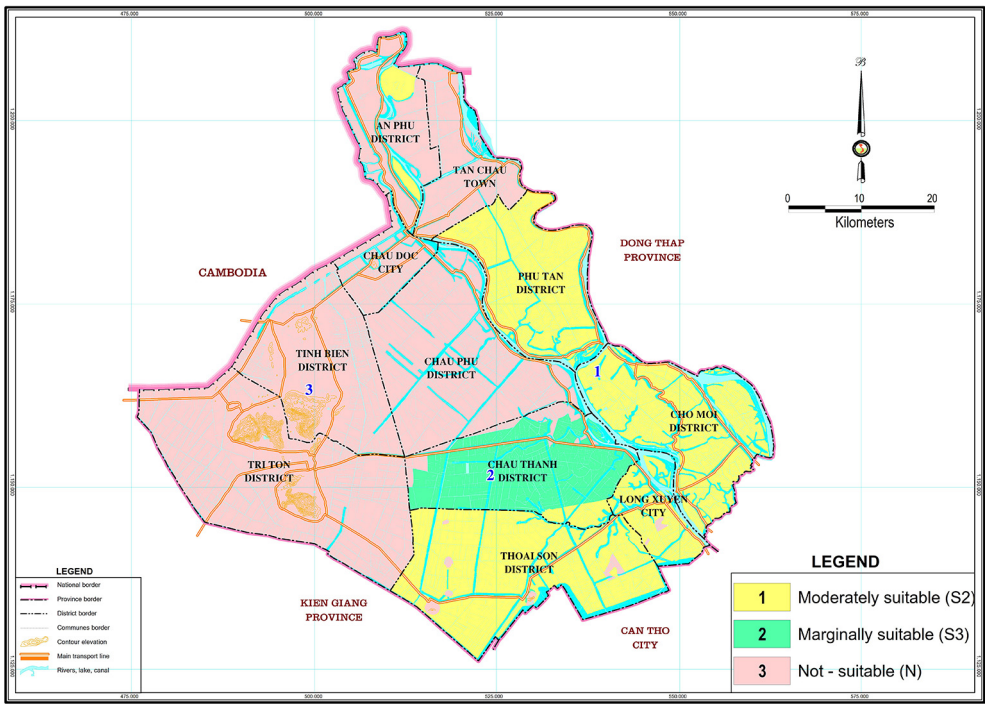

Figure 4. Zoning of land suitability for high-tech application rice production

managerial capacity, labor resources, capital investment, and support policies were little interest to expert groups.

Developing the requirements and diagnostic criteria for high-tech applications for rice and corn production

Based on the assessment of the amount of interest in specific requirements for rice and corn production by expert groups, it was combined the results of consultations gricultural managers and farmer interviews. Since then, nine quality requirements for the high-tech application of rice and corn production in the An Giang province have been established (Table 3).

Zoning the high-tech application

Zoning suitable land for rice and corn high technology application

The study built 192 land characteristic units based on land characteristics for high-tech applications. It compared the suitability hierarchy for high-tech applications and land unit characteristics. Three suitability zones of high-tech applications for rice production in An Giang province are shown in Table 4 and Figure 4, whereas for corn - Table 5 and Figure 5.

Solutions for enhancement of high-tech application

1) The local government should have the plan to implement and build agricultural infrastructure synchronously. It was necessary to regularly train technicians for the people in agricultural production in the direction of safety, organic, eco-technology, and product quality assurance to enhance the value of Vietnamese agricultural products. Science and technology applications should be implemented to deliver to farmers. People should be instructed on how to use chemical fertilizers and pesticides correctly and at the appropriate time.
2) The locality needs to build concentrated production areas, use seeds and apply synchronous production techniques to create a homogeneous product quality and high yields that can access the fastidious market during the integration period.
3) The government should develop policies to support businesses in investing in the agricultural sector because enterprises can identify and find output markets for products and build brands to increase the production value of farmers.
4) Each locality needs to have appropriate policies about land to develop high-tech applications.
5) Training human resources in the right industry and choosing suitable subjects is necessary. The next step is facilitating investment and capital support for businesses, individuals, and qualified people.

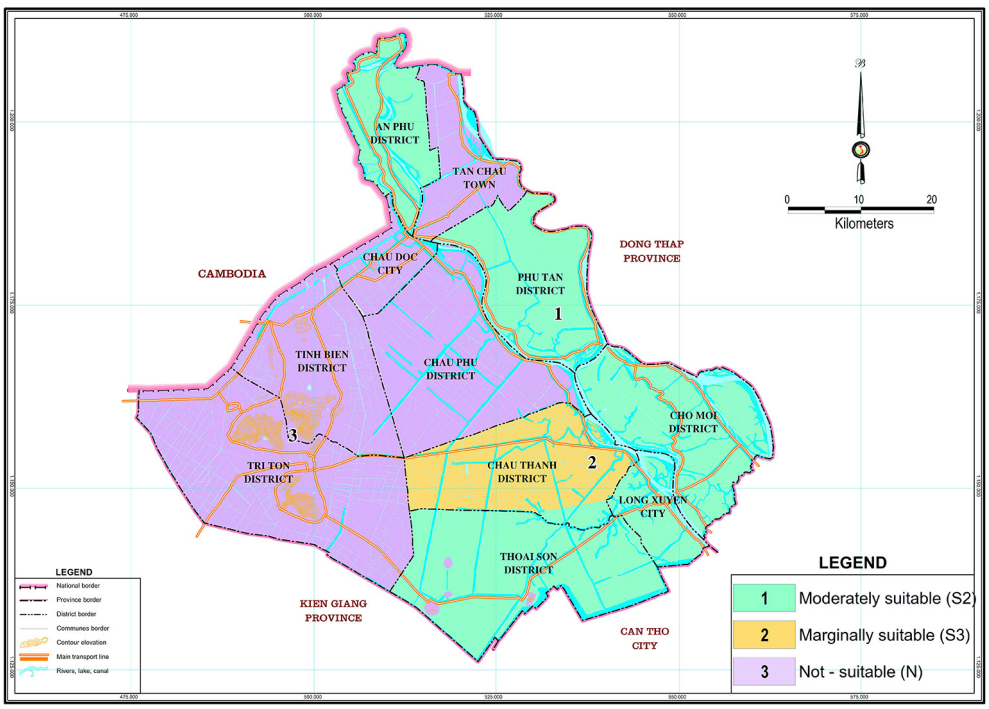

Figure 5. Zoning of land suitability for high-tech application corn production

DISCUSSION

Developing high-tech agriculture was one of the global trends to meet the demand for eatables, foods, and quality agricultural products (Giller et al., 2021; FAO, 2017). Thereby, the conditions of agricultural production in the world, in general, were still fragmented and small-scale (Meyer, 2010; Woodhill et al., 2020). Assessing the applicability of advanced technology requires that the physical, economic, social, and environmental conditions can be determined by opinions from different experts, including managers, scientists, and farmers (Nguyen et al., 2017). The requirements for high-tech agricultural production needed to pay much attention to the provisions of soil and water because these were essential inputs for agricultural cultivation. Moreover, the conditions on the capital capacity of farmers and the product consumption market were indispensable because when implementing high-tech agriculture, farmers must meet sufficient investment resources.

Furthermore, when creating products, it needs to have a stable place of consumption because high-tech agricultural production creates large outputs that are homogenous, and the role of linkage in production is enhanced (Johann & Kurt, 2002). In addition, to apply new scientific and technical measures to high-tech agricultural production, the farmers' knowledge was indispensable (Šūmane et al., 2017; Khondokar, 2015; Ajayi, 2008). Besides, the requirements on organizations supporting agricultural production were necessary to improve the role, efficiency, and linkage in the process of consuming farming products and supplying agricultural materials for high-tech agricultural production (Douxchamps et al., 2015; Ross et al., 2013; Johann & Kurt, 2002).

Moreover, the infrastructure conditions must be met to serve the transport of agricultural goods and meet the demand for electricity for irrigation and drainage by electric pumps (Bacior and Prus, 2018; Marie-Agnès, 2013; Murakami et al., 2007). Therefore, identifying the areas with the potential for development to apply high-tech rice and maize is necessary. In addition, there should be solutions to upgrade the areas that are not eligible to develop sustainable agriculture and adapt to climate change.

CONCLUSIONS

The results showed the current status of agricultural land use with the central area of rice land, followed by the cash-crops area (mainly corn). The results also identified the techniques applied in rice and corn products, such as seed technology, mechanization, farming techniques, and production association. The study initially built a hierarchy with 9 quality requirements, 21 criteria for rice, and 20 criteria for high-tech corn application. The results identified three zones of high-tech application for rice and corn production. The not-suitable area (N) occupied the most, and the highest suitable level was moderate (S2). The research had built the solutions to improve the efficiency of rice and corn production high-tech applications such as supporting policies, enhancing human resources, developing infrastructure, and linking production.

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