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Article

Guidelines for future agricultural technology development to increase productivity in the Agricultural sector

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Abstract: Technology development in the agricultural sector is important in the development of Thailand's economy. The purpose of this research was to study the approach of guidelines for future agricultural technology development to increase productivity in the Agricultural sector in order to develop a structural equation model. The research applied mixed-methodology. Qualitative research by in depth interview from 9 experts and focus group with 11 successful businesspersons for approve this model. The quantitative data gather from firm, in the 500 of agricultural sector by using questionnaire, using statistical tests of descriptive analysis, inferential analysis, and multivariate analysis. The research found guidelines for future agricultural technology development to increase productivity in the Agricultural sector composed of 4 latent. The most important item of each latent were as following: 1) Agrobiology Technology ($\overline{X}$ = 4.41), in important item as choose seeds that for disease resistance and tolerate the environment to suit the cultivation area, 2) Environmental Assessment ($\overline{X}$ = 4.37),, in important item as survey of cultivated areas according to topography with geographic information system, 3) Agricultural Innovation ($\overline{X}$ = 4.30), in important item as technology reduces operational procedures, reduce the workforce and can reduce operating costs, and 4) Modern Management Systems ($\overline{X}$ = 4.13), in important item as grouping and manage as a cooperative to mega farms. In addition, the hypothesis test found that the difference in manufacturing firm sizes. Medium and Small size and large size revealed overall aspects that were significantly different at the level of 0.05. The analysis of the developed structural equation model found that there was in accordance and fit with the empirical data and passed the evaluation criteria. Its Chi-square probability level, relative Chi-square, the goodness of fit index, and root mean square error of approximation were 0.062, 1.165, 0.961, and 0.018, respectively.

Keywords: structural equation modeling; agricultural technology; environmental assessment; agrobiology technology; modern management systems; agricultural innovation

1. Background and importance of the problem

Thailand is an agricultural country and one of the important food production areas in the world, Thailand's strength is agriculture. Currently, there has been an important structural change, the application of modern machinery and technology tends to replace human labor. The growth pattern of the agricultural sector has changed from the previous emphasis on quantitative expansion, expanding the cultivation area increasing the use of production factors, etc., which comes as growth with greater quality or productivity. In the past, Thailand had the expansion of qualitative factors at the top level in the world. However, it has continually fallen to a low level until it has been overtaken by neighboring countries (Sommarat et al., 2019). From the national strategic plan 2018–2037, the national strategy for building competitiveness,

there are development goals that focus on raising the country's potential based on the concept of building on the past, adjusting the present, and creating new value in the future. National strategic issues regarding building competitiveness have been determined (Chaiwat et al., 2017). Value-creating agriculture is an important topic in the production and trade of agricultural products on the world stage. By creating added value focusing on high-quality agriculture and driving agriculture with technology and innovation that gives importance to increasing production productivity in both quantity and value (National Strategy 2018–2037, 2018, Office of the National Economic and Social Development Council, 2018). Thailand has a total population of 66,090,475 people (National Statistical Office, 2022). A survey found that in 2020, Thailand had an area of agricultural use of 149,251,940 rai. Thailand's weather depends on the 2 types of monsoon winds that blow through the seasons which are the northeast monsoon and the southwest monsoon It will affect the climate in Thailand differently according to the influence of the monsoon. In the agricultural sector, water availability is a critical factor for cultivation. When comparing annual rainfall data from 2015 to 2017, there was an increase until 2018 and 2019, followed by a decrease. Rainfall then consistently increased until 2022, reaching 1848 millimeters. Climate variations result in unpredictable rainfall, leading to water scarcity in drought-prone areas and severe rainstorms in the monsoon zone, potentially causing flooding (National Hydroinformatics Data Center, 2023). During the growing years 2017–2022, productivity per rai of important economic crops, including off-season rice, in-season rice, factory cassava, pineapple, animal feed corn, and soybeans, tended to decrease (Office of Agricultural Economics, 2022). This decline may exacerbate issues related to compensation for agricultural workers. From 2015 to 2021, agricultural workers received an average monthly wage of 6195 baht per person. When considering Labor Productivity as an indicator reflecting labor skills and income potential, it's evident that the agricultural sector consistently has the lowest values, with a recorded value of 0.55 hundred thousand baht per person per year in 2021 (National Statistical Office, 2022). As the source of food production, the agricultural sector plays a crucial role in maintaining global food security, especially with the projected population increase to 9.7 billion by 2050, as stated by the Food and Agriculture Organization of the United Nations (FAO). With an anticipated 60 percent increase in demand for food crops, technology must be introduced to enhance production efficiency and meet future food demands (Nation Science Technology and Innovation Policy Office, 2018). Challenges, such as changing environmental conditions leading to decreased crop yields, labor shortages, and rising wages, are evident. Despite these challenges, the value of agricultural exports and products with export potential has increased, highlighting the growing demand for agricultural products. To address these challenges and enhance competitiveness, the development of agricultural technology is crucial, impacting productivity, and value, and contributing to the strengthening of the country's economy.

2. Literature review

Through the study of concepts, theories, and a review of literature on guidelines for future agricultural technology development to increase productivity in the

agricultural sector, aiming to foster competitiveness and integrate scientific knowledge with local wisdom in managing the agricultural sector for improvement and change. This involves monitoring and evaluating environmental trends, as well as forecasting yields developing and enhancing the cultivation process (Saleem et al., 2023), harvesting, and processing crops with modern technology. The promotion of new ideas and methods in designing and creating products is emphasized, along with the establishment of an efficient system for collecting and managing information within the organization. All these efforts contribute to creating agricultural innovations that are beneficial for increasing productivity in the agricultural sector of Thailand (Suthasinee et al., 2020). From this research, the researcher concludes that guidelines for future agricultural technology development to increase productivity in the agricultural sector encompass four key elements, namely:

(1) Components of Environmental Assessment refer to the use of knowledge, scientific equipment, or tools and technology for monitoring the environment as a factor in the agricultural sector (Piyarat, 2019) in monitoring soil quality. Survey of water use by plants weather forecasting, disease detection, and forecasting the environment and production situation that may change and occur in the future (Gorlov et al., 2021). Related concepts and theories include: 1) PEST and PESTLE Analysis (Wattanakomola and Silpcharu, 2022); 2) concepts about agricultural geography; 3) concepts about the environment in farm business (Phawat, 2020).

(2) Components of Agrobiology Technology refer to the development and improvement of cultivation processes in the agricultural sector to save time, and budget, and get higher quality and quantity of products by selecting plant varieties, controlling the cultivation, maintenance, harvesting, and transportation processes throughout the life of agricultural products (Reumaux et al., 2023; Issarath, 2020). Related concepts and theories include 1) technology Acceptance Model (Devendra et al., 2020); 2) technology Management (Srivastava and Jain, 2023); 3) precision agriculture.

(3) Components of Modern Management Systems refer to the collection of information within the organization to make administration more efficient and maximize the resources within the organization. This involves systematic capital management, including the utilization of ready-made program systems for accounting, purchasing, marketing, and human resource management. Managing data both inside and outside the organization aims to achieve the development of innovative management in modern agribusiness organizations (Sudarat and Viroj, 2019; Ludwig-Ohma et al., 2023). Related concepts and theories include: 1) farm management (Nalan, 2020); 2) risk management (Suraphong, 2021); 3) management information system (MIS) concepts (Adeoye, 2023); 4) enterprise resource planning (ERP) concepts (Al-Amin et al., 2023).

(4) Components of Agricultural Innovation involve inventing, designing, improving, changing, and modifying products to obtain results from altering concepts, methods, knowledge, and operations within the organization. This leads to modern management in the agricultural sector, encompassing the development, monitoring, and prediction of factors related to cultivation, genetic development, planting and care processes, harvesting, and processing into agricultural products that are different from the original or new products. These can be distributed to meet the needs of consumers

for increased productivity, expanded marketing channels, and added value to the agricultural sector (Ren et al., 2023). Related concepts and theories include 1) the concept of innovation strategy (Khemmaree et al., 2020); 2) the concept of a new product development process (Suchada et al., 2017); 3) product development and strategic modern products (Nathathai and Pattarapun, 2022); 4) innovative human capital (Apiluck and Teerawat, 2017).

2.1. Research objectives

1) To study the structure and operating characteristics of business organizations in the agricultural sector with guidelines for future agricultural technology development to increase productivity in the agricultural sector.

2) To study the elements of guidelines for future agricultural technology development to increase productivity in the agricultural sector.

3) To develop a structural equation model to guidelines for future agricultural technology development to increase productivity in the agricultural sector.

2.2. Research hypothesis

In research on guidelines for future agricultural technology development to increase productivity in the agricultural sector, the following hypotheses were set:

H1: Components of Environmental Assessment have a direct influence on the components of Agrobiology Technology. Salahuddin et al. (2020) researched the impact of environmental quality on agricultural products and found that environmental quality and climate change are of great importance to agricultural products and the effects of climate change are slow but it affects agricultural products.

H2: Components of Environmental Assessment have a direct influence on the components of Modern Management Systems. Seijger and Hellegers (2023) conducted a research study and found that, concerns about the sustainability of the environment climate change and the properties between water and soil that change pressure is increasing for new approaches to agricultural economic development. Resource and environmental management reforming agricultural water management leads to sustainable production and consumption patterns.

H3: Components of Environmental Assessment have a direct influence on the components of Agricultural Innovation. (Liu et al., 2021), The environmental assessment of agricultural innovation focuses on modern agribusiness and assesses the impact of agricultural innovation on change, integration in production-processing-sales activities and the integration of various service activities was found to be supported by a positive environment.

H4: Components of Modern Management Systems have a direct influence on components of Agrobiology Technology. Yu et al. (2020) conducted a research study and found that, Agricultural Information Technology Management Systems play a role in promoting agricultural development. The information management system can reflect different agricultural choice factors and policy incentives which have an important influence on the development of the agricultural sector.

H5: Components of Agrobiology Technology have a direct influence on components of Agricultural Innovation. Solis-Navarrete et al. (2023), conducted a

research study and found that, key trends in agricultural and food biotechnology are fueling innovation. Technological development has a tendency to expand larger in the future, and Peng et al. (2020) found that, selecting the right innovation is critical to developing innovation in the manufacturing industry. The overall development trend of production and technology innovation capabilities is good, when raising the level of innovation and promoting technological capabilities.

H6: The level of importance of guidelines for future agricultural technology development to increase productivity in the agricultural sector differs when classified according to the size of the business. According to Pimarksorn et al. (2022), factors related to the characteristics of business entrepreneurs overall have different relationships with success in business operations between small and medium-sized businesses, and large businesses. Considering the trend of the Thai industrial sector, it is anticipated to face more severe challenges such as increased competition in world trade and technological changes. Consequently, all relevant sectors must adapt quickly and cooperate. The growth of Thai establishments reveals an increasing disparity between large and small establishments. This is manifested in the added value of large establishments that are growing well, while smaller establishments are experiencing slower growth or shrinkage.

3. Research methodology

This research is an Inductive Research using Mixed–Methodology.

1) In qualitative research using in-depth interview techniques, there are nine experts, consisting of experts in three groups: three people from entrepreneurs or executives in agricultural business organizations, three people from government and related agencies, and three from academic groups (Krit and Thanin, 2021), the researcher determined the interview guideline to have four components, including the Environmental Assessment component, Agrobiology Technology component, Modern Management Systems component, and Agricultural Innovation component.

2) For the quantitative research involved the creation of a draft questionnaire, which was then provided to five experts for evaluation to determine the tool's quality. The assessment focused on checking the Item Objective Congruence (IOC) between the questions and the research objectives. The values ranged from 0.60 to 1.00, all exceeding 0.50. Following this, the questionnaire underwent a Try-Out. The results of the analysis revealed discriminant power for each item, ranging between 0.32 and 2.83, surpassing the 0.30 threshold. Additionally, the questionnaire's reliability was assessed by determining Cronbach's Alpha Coefficient, which was calculated at 0.99, exceeding the 0.80 benchmark.

The research targeted a population of 1329 entrepreneurs in the agricultural business sector. The researcher selected a sample size of 500, categorized as 'very good.' This sampling method, according to Silpcharu (2024), employed a multi-stage sampling approach, specifically cluster sampling. The agricultural businesses were divided into two sizes: small and medium-sized, and large. Probability sampling using the lottery method was then applied to collect data from groups of 250 people each. The collected data underwent a thorough analysis, including the examination of descriptive statistics and reference statistics using the SPSS package. Additionally, an

equation model analysis was conducted using the advanced statistical data analysis software, AMOS. The criteria for evaluating the consistency of the structural equation model consisted of four values, as follows: (1) chi-square probability level value *CMIN-ρ* > 0.05; (2) chi-square value relative (CMIN/DF) < 2; (3) good fit index (GFI) > 0.90, and (4) root mean square error of approximation (RMSEA) < 0.08 (Arbuckle, 2016).

3) Qualitative research with group discussion techniques to certify the model, the population used in this research consisted of 11 experts.

4. Results

Presentation of summary of research results, the researcher would like to present an overview of guidelines for future agricultural technology development to increase productivity in the agricultural sector and conclusions from research results in order as follows:

1) Overall, research results indicate that large agricultural businesses place more importance on guidelines for future agricultural technology development to increase productivity in the agricultural sector than small and medium-sized agricultural businesses. Large agricultural businesses attribute higher importance, with an average of 4.38, while small and medium-sized agricultural businesses consider it important at a high level, with an average value of 4.22. For the research results in each aspect, it was found that in small and medium-sized businesses, all aspects are important at a high level as follows: (1) the agrobiology technology component has an average of 4.31; (2) the environmental assessment component has an average of 4.30; (3) the agricultural innovation component has an average of 4.29; (4) modern management systems components have an average of 4.00, respectively. Large agricultural businesses found that it is important at the highest level as follows: Agrobiology Technology has an average value of 4.50 and is considered important at a high level. Additionally: (1) environmental assessment has an average of 4.45; (2) agricultural innovation components have an average of 4.32, and (3) modern management systems components have an average of 4.26, respectively.

2) Results of research on statistics used to compare differences in the importance of guidelines for future agricultural technology development to increase productivity in the agricultural sector (**Table 1**) overall, when classified by type of large agricultural business and small and medium-sized agricultural business, there is a statistically significant difference at the 0.05 level (**Table 2**).

3) The results of the structural equation modeling analysis (**Figure 1**) on the guidelines for future agricultural technology development to increase productivity in the agricultural sector revealed that, initially, all four values did not meet the required criteria. Subsequently, the researcher proceeded to refine the structural equation model, considering the Modification Index value through the variable elimination method. The results after adjustment indicated that the chi-square probability level achieved a value of 0.062, surpassing the 0.05 threshold and meeting the criteria. The relative chi-square value stood at 1.165, which was below 2.00, indicating success against the criteria. The model's completeness value reached 0.961, exceeding the 0.90 threshold and fulfilling the criteria. Furthermore, the model's error value was 0.018, below

the .08 limit and meeting the criteria for statistical significance at 0.001, aligning with the literature and empirical data. The results also satisfied the consideration criteria outlined by Arbuckle (2016).

Table 1. The level of importance of the components of guidelines for future agricultural technology development to increase productivity in the agricultural sector as a whole, classified by the size of agricultural businesses.

Variable Latent	Small and Medium Size			Large Size			*t*-Value	*P*-Valve
	$\bar{X}$	*S.D.*	Level of importance	$\bar{X}$	*S.D.*	Level of importance		
Overall level.	4.22	0.48	High	4.38	0.44	High	−3.84	0.00*
Agrobiology Technology	4.31	0.52	High	4.50	0.50	Highest	−4.11	0.00*
Environmental Assessment	4.30	0.57	High	4.45	0.54	High	−2.96	0.00*
Agricultural Innovation	4.29	0.58	High	4.32	0.51	High	−0.67	0.50
Modern Management Systems	4.00	0.70	High	4.26	0.65	High	−4.49	0.00*

Table 2. Statistics to evaluate the consistency of the structural equation model, and compare before and after improving the model.

Statistics	Criteria used for consideration	Before improvement	After improvement
CMIN-p	>0.05	0.000	0.062
CMIN/DF	<2.00	4.517	1.165
GFI	>0.90	0.482	0.961
RMSEA	<0.08	0.084	0.018

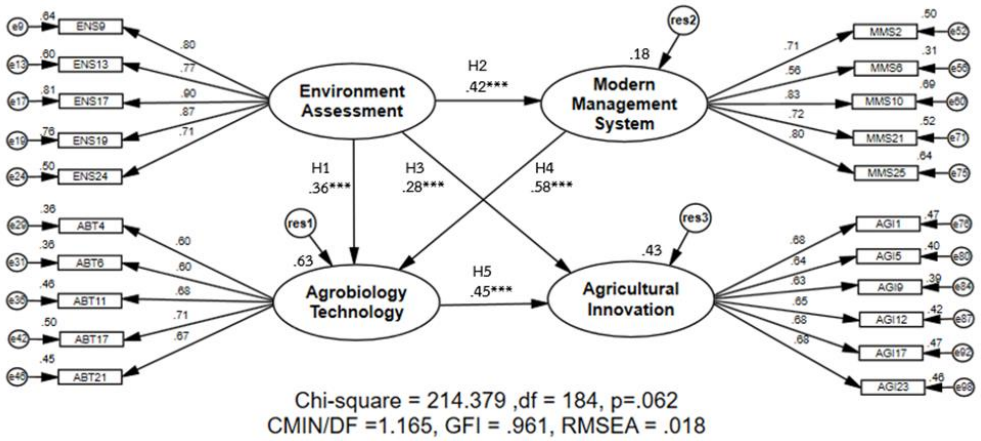

Figure 1. Structural equation model of Guidelines for future agricultural technology development to increase productivity in the agricultural sector.

4) Results of hypothesis testing to analyze causal influences between latent variables in the structural equation model for guidelines for future agricultural technology development to increase productivity in the agricultural sector, 5 hypotheses were found including:

H1: Components of Environmental Assessment directly influence the components of Agrobiology Technology with statistical significance at the 0.001 level, with a Standardized Regression Weight value of 0.36, by the set research hypothesis.

H2: Components of Environmental Assessment directly influence the components of Modern Management Systems with statistical significance at the 0.001

level, with a Standardized Regression Weight equal to 0.42, in line with the research hypothesis set.

H3: Components of Environmental Assessment have a direct influence on components of Agricultural Innovation with statistical significance at the 0.001 level, with a Standardized Regression Weight value of 0.28, in line with the research hypothesis set.

H4: Components of Modern Management Systems directly influence components of Agrobiology Technology with statistical significance at the 0.001 level, with a Standardized Regression Weight value of 0.58, in line with the research hypothesis set, and

H5: Components of Agrobiology Technology have a direct influence on the components of Agricultural Innovation with a statistical significance of 0.001, with a Standardized Regression Weight value of 0.45, by the set research hypothesis set.

5. Conclusion and discussion

Guidelines for future agricultural technology development to increase productivity in the agricultural sector consist of 4 latent variables, including Environmental Assessment components, components of Agrobiology Technology, components of Modern Management Systems, and components of Agricultural Innovation. From the hypothesis test results, it was found that the overall influence was highest, it is the Environmental Assessment component that has an overall influence on the components of Agrobiology Technology. There is a weight on the overall influence line (Standardized Regression Weight) at 0.60 showing the empirical data that under climate change the growing environment is important and must be controlled to match the type of plant, providing minerals, nutrients, and water according to the plants' needs during the growing period. It is accurate and reasonable according to the water use needs of plants, keeping the environment in balance while improving agricultural production (Garcia-Tejero and Duran-Zuazo, 2022), the highest direct influence is the component of Modern Management Systems, directly influencing the Agrobiology Technology component, which has the highest direct influence, has a Standardized Regression Weight at 0.58, shows the empirical data that management plays an crucial role in improving technological infrastructure. Essential investment management, product line planning strategy development to improve the business to have technological capabilities and apply innovation to the success of the organization. This indicates that organizations need to invest in technological resources. Rajan et al. (2021) factor that affect sustainable operations include production quality management quality, and the quality of life of members (Pannarai et al., 2020). Therefore, knowledge management, resource management, and the use of information technology for processing help predict yield and harvest time for easy control, follow-up, report results, and plan production, solving problems quickly to build confidence in the sustainable agricultural industry (Krit and Thanin, 2021).

6. Research suggestions

Guidelines for future agricultural technology development to increase productivity in the agricultural sector. Represent management principles which

consistent with those within industrial business organizations but are structured to align with the nature of agricultural operations. Emphasizing the importance of agricultural technology administration and management, these guidelines aim to transform organizations into models that facilitate the sharing of experiences, address various issues, and implement improvements in both structure and operations. The ultimate goal is to achieve success in agricultural business management, increase productivity, and create added value to compete commercially. Furthermore, these guidelines serve as a valuable reference for farmers at the upstream of the agricultural business, enabling them to enhance labor productivity and improve the quality of life in an agricultural society. In this research, the researcher has suggested principles and guidelines for future agricultural technology development to increase productivity in the agricultural sector the details are as follows:

6.1. Suggestions at the policy level

1) The Ministry of Agriculture and Cooperatives should promote and disseminate the use of the agricultural map system (Agri-Map) among farmers and personnel in agricultural businesses. This aims to help them recognize and understand the benefits of the Agri-Map system, encouraging them to update information regularly for it to remain up-to-date and usable.

2) Department of Agriculture Research and Development of Economic Crop, varieties that are appropriate to the climate should be researched and developed, resistant to disease and has a high yield, to lead entrepreneurs in the agricultural sector or farmers to create added value for the business sector and develop the overall economy of Thailand.

3) The Department of Agricultural Extension should provide knowledge and understanding, and see the benefits of forming a network of farmers or using large-scale agricultural practices. Including increasing activities that are the starting point for grouping and creating networks in the agricultural sector by providing real ideas and principles.

4) The National Science and Technology Development Agency (NSTDA) should accelerate the transfer of knowledge in science, technology, and innovation to commercialization in the private sector, by working together with the government and universities, expand the promotion of science, technology, and innovation capabilities for children, youth, and educational personnel, to increase labor skills in research and development of technology to meet the needs of the agricultural sector.

5) The Office of the National Higher Education Science Research and Innovation Policy Council (NXPO) should gather technological knowledge and local wisdom to create spatial agricultural innovation. Concretely transfer knowledge through higher education institutions in agricultural areas, to be able to further develop the career as an agricultural identity, create career options and improve the living standards of the agricultural society.

6.2. Suggestions at the operational level

1) Agricultural businesses should give importance to cultivation technology. It starts with selecting seeds that are resistant to diseases and environmental conditions,

easy to grow, easy to care for, have high yields, and are suitable for the planting area. Additionally, preparing to improve the soil with organic fertilizer to enhance the basic soil condition before using chemical fertilizers is essential to increase the amount of minerals appropriate for the respective plants, focus on managing water resources effectively, and choose the right chemical fertilizer that does not damage the environment in the long term.

2) Agricultural businesses should give importance to environmental assessment by surveying the farmland using the Geographic Information System (GIS), choosing technology and various measurement tools that are appropriate for actual use, and then analyzing the obtained data to plan and find solutions to prevent in the event of climate change, and should concentrating on measuring or collecting various environmental data such as rainfall, humidity, wind speed, amount of sunlight, etc., to analyze and plan the next round of planting.

3) Agricultural businesses should give importance to agricultural innovation, provide personnel with access to technology and be able to use technology to help reduce work procedures, reduce labor force, and reduce operating costs, packaging design and there is innovation to preserve products for even longer. Moreover, should concentrates on marketing methods that can continuously connect with customers or consumers including choosing environmentally friendly packaging.

4) Agricultural businesses should give importance to modern management systems, support grouping and management in the form of cooperatives or large-scale agriculture. Providing management knowledge application of technology to collect data to improve and develop better management practices. In addition, should focus on studying information from government agencies both database, databases and promotion centers, various learning centers for accessing knowledge sources and applying them to suit the organization's situation.

5) Agricultural businesses should promote business matching activities among entrepreneurs, expanded business, creates cooperation, builds a network, expands the market, and increases new opportunities for entrepreneurs.

6) Agricultural businesses should give importance to setting clear policies and management system directions. Emphasis is placed on the application and development of technology so that it is easy to understand, easy to perform, repeatable, scalable, and continuously evolving. Focus on the results of improving the old things and expanding on ideas to make changes to be better, to drive the organization to innovation.

7) Agricultural businesses should promote learning promotion centers, for being a source of information and access to agricultural academic knowledge sources to keep the information up to date there is staff to promote knowledge, help, analyze problems, solve problems, convenient to apply, and keep up with the situation.

8) Agricultural businesses should consider planning and preparing various financial information to support business expansion or predict future operations.

6.3. Suggestions for further research

1) Study guidelines to develop the ability to export Thai agricultural products to the world market.

2) Study guidelines to apply modern technology for maximum benefit to farmers.

3) Study guidelines to reduce cultivation costs with new agricultural theories.

4) Study the factors in the modern management system to become an agricultural innovation organization.

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