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PROMOTING NEW AGRICULTURAL TECHNOLOGY ADAPTATION: A REVIEW OF THEORETICAL AND PRACTICAL ISSUES, AND SOLUTIONS FOR VEGETABLE FARMERS IN SVAY RIENG PROVINCE, CAMBODIA

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Abstract. An idea for sustainable agricultural development, new agricultural technology adaptation (NATA) in agricultural production helps overcome problems in agricultural production by utilizing the best aspects of technology application. In order to identify the obstacles and suggest some solutions for improving the NATA in agricultural production in Cambodia in the future, this research reviewed theoretical and practical difficulties on boosting NATA in Svay Rieng province. The study demonstrated that the NATA application in agricultural production is an unavoidable route for the agriculture sector development in Svay Rieng under the context of global integration and impacts of the industry revolution 4.0. This was based on secondary information and data from published papers and documents. Thus, the Cambodian government has recently given close attention to NATA promotion in agricultural output. Despite the impressive accomplishments, there are currently few businesses and farm households using NATA in agricultural output, and NATA growth in Svay Rieng still confronts many obstacles. Improving the current policy structure is essential for raising the NATA in agricultural output in Svay Rieng. Additionally, in the near future in Svay Rieng province, NATA application implementation, NATA development and planning, human resource training, credit assistance, and propaganda on the NATA's effectiveness in agricultural production should all be strengthened.

Keywords: new agricultural technology adaptation, agricultural production, vegetable production, agricultural development

Abstrak. Sebagai sebuah gagasan untuk pembangunan pertanian berkelanjutan, adaptasi teknologi pertanian baru (NATA) dalam produksi pertanian membantu mengatasi masalah-masalah dalam produksi pertanian dengan memanfaatkan aspek-aspek terbaik dari penerapan teknologi. Untuk mengidentifikasi hambatan dan menyarankan beberapa solusi untuk meningkatkan NATA dalam produksi pertanian di Kamboja di masa depan, penelitian ini mengulas kesulitan teoritis dan praktis dalam meningkatkan NATA di provinsi Svay Rieng. Penelitian ini menunjukkan bahwa aplikasi NATA dalam produksi pertanian merupakan jalan yang tidak dapat dihindari untuk pengembangan sektor pertanian di Svay Rieng dalam konteks integrasi global dan dampak revolusi industri 4.0. Hal ini didasarkan pada informasi dan data sekunder dari makalah dan dokumen yang telah dipublikasikan. Oleh karena itu, pemerintah Kamboja baru-baru ini memberikan perhatian yang besar terhadap promosi NATA dalam hasil pertanian. Terlepas dari pencapaian yang mengesankan, saat ini hanya ada beberapa bisnis dan rumah tangga pertanian yang menggunakan NATA dalam hasil pertanian, dan pertumbuhan NATA di Svay Rieng masih menghadapi banyak kendala. Memperbaiki struktur kebijakan saat ini sangat penting untuk meningkatkan NATA dalam hasil pertanian di Svay Rieng. Selain itu, dalam waktu dekat di provinsi Svay Rieng, implementasi aplikasi NATA, pengembangan dan perencanaan NATA, pelatihan sumber daya manusia,

bantuan kredit, dan propaganda tentang efektivitas NATA dalam produksi pertanian harus diperkuat.

Kata Kunci: adaptasi teknologi pertanian baru, produksi pertanian, produksi sayuran, pembangunan pertanian

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INTRODUCTION

New agricultural technology adaptation (NATA) in agricultural production is a concept for sustainable agricultural development that aids in resolving issues in agricultural development through the superior features of technology, such as cultivation technology, automation technology, and sensor technology, thereby aiding in cost savings, productivity gains, lower expenditures and improved agricultural product quality, environmental protection, and all of these benefits simultaneously (Zhang et al., 2010). As the 4.0 industrial revolution has a significant impact on the agricultural industry in Cambodia, agricultural development employing NATA is emerging as a mainstream trend, the secret to success for nations with sophisticated agriculture (Tran, 2019).

Cambodia has a population of around 17 million people, however due to industrialization and modernity, its average agricultural land area per person is among the lowest in the world and is also declining. Promoting the use of NATA in agricultural production is both a pressing issue from a practical standpoint and necessary to satisfy the increased demand for ready-made goods in both quantity and quality (due to rising incomes and changing consumption trends). The industrialization and modernization of agricultural and rural areas is a crucial solution as well. As a result, the Royal Government of Cambodia and the Ministry of Agriculture, Fisheries, and Forestry (MAFF) have recently released a number of guidelines and policies to encourage the development of high-tech agriculture, including the Agricultural Development Strategic Plan 2019–2023 and the National Policy on Agricultural Development 2022–2030. One strategy and program to support the growth of the agricultural sector and raise the standard of living for rural residents is the NATA application. Although some first results have been obtained, developing NATA in agricultural production in Cambodia still faces numerous problems and difficulties for a variety of reasons (MAFF, 2019).

The Provincial Department of Agriculture, Forestry, and Fisheries' annual report for 2021 states that Svay Rieng province continues to have numerous issues with agricultural

production, particularly with the production of rice and vegetables. The cultivation methods are still based on tradition, and NATA application knowledge and awareness are also inaccessible. Their agricultural yields, production outputs, and market prices are still poor as a result of these difficulties (PDAFF, 2021).

The theories and methods of NATA implementation in agricultural productivity in many nations have been the subject of numerous papers in recent years. However, the majority of the publications highlight the function of NATA application in agricultural production or examine specific NATA use in agricultural production models. No studies exist to be evaluated, analyzed, or synthesized in any way.

This study aims to bring together a variety of theoretical and practical concerns regarding encouraging the use of NATA in agricultural production in the Svay Rieng province, Cambodia. It then proposes some solutions to encourage the use of NATA in agricultural production, especially vegetable farmers in Cambodia in the near future.

METHODS

The information and data used in this study were primarily gathered from the MAFF and Royal Government of Cambodia's policy documents, as well as from related articles on the development of NATA and its use in agricultural productivity. The primary methods used in the research process are desk study, synthesis, and inheritance methods. Besides the secondary data, the interview with policy makers in the Department of Agricultural Engineering, MAFF, has been done and transcribed. These methods are used to analyze and synthesize research results in order to provide assessments, comments, and quickly propose some solutions to support NATA application in agricultural production in the future

RESULTS AND DISCUSSION

Some concepts of promoting new agricultural technology adaptation (NATA)

Technology: The term "technology" used to refer to the systematic study of technology or the engineering sciences. Tekhne, which means skill or method, and logos, which denotes science or investigation, are the roots of this word in Greek. Since the 1960s, activity in all sectors have been referred to as technology, first in the US and then in Western Europe. In order to increase the effectiveness of human activities, these activities employ knowledge derived from scientific research as well as self-developed applications of science (Crabhar, 1998). Technology, as defined by the MISTI of 2021, is the practical application of science to the production of goods and services. Technology can also be thought of as a collection of

techniques, procedures, skills, instruments, and equipment used to convert raw materials into finished goods (MISTI, 2021).

Agricultural technology: According to Brown (2013), agriculture technology is a branch of technology with a high concentration of scientific research and technological development integrated from scientific and technological accomplishments, modern technology, and the ability to produce goods of exceptional quality, features, high added value, and environmental friendliness. It also plays a significant role in the development of new or contemporary production and service industries (Brown, 2013). Farmers and communities working in the agricultural development sector will require a number of technologies, including NATA application in agricultural output. In the world, there are many concepts related to agricultural technology, NATA and NATA application in agricultural production. According to the idea of developed nations, NATA application is the nearly 60-year-old, advanced and modernized industries that employ environmental, ecological, and biotechnological advances to promote sustainable and secure development while ensuring the production of enough agricultural goods. without affecting the environment, and ship quality to satisfy society's rising consumer needs (Zhang et al., 2010). Thus, NATA can be considered the application of advanced technology in the agricultural production process. According to the National Bank for Agriculture and Rural Development of India (NABARD, 2020), high-tech agriculture mainly refers to agricultural activities involving the latest technologies. This is a capital-intensive agriculture because it requires large capital to buy specialized equipment, protect assets, and train labor. High-tech agriculture mainly involves commercial farming systems that serve the needs of both domestic as well as export markets. It uses farming technology to increase yields, ensure high quality (usually pesticide-free), and increase market value. According to Le Linh (2020), high-tech agriculture is an agriculture that properly applies new and advanced technologies to production to improve efficiency and create breakthroughs in productivity and quality of agricultural products. satisfy the increasing needs of society and ensure sustainable agricultural development (Le Linh, 2020). According to the Ministry of Agriculture and Rural Development, high-tech agriculture is agriculture that uses information technology, biotechnology, new material technology, automation technology, post-harvest technology and management technology to Increase productivity, quality, efficiency and competitiveness of agricultural products, ensuring sustainable development. Besides the high-sounding concept of agriculture, many concepts such as 10-year agriculture, smart agriculture, and mainstream agriculture have appeared recently. According to Do Kim Chung (2017), agriculture 1.0 can also be called smart agriculture or digital agriculture. The original characteristic of agriculture

4.0 is the digitalization of production and business activities from farms to processing, marketing and consumption through an internet of things connection system, combining centralized operating and operating system (Do Kim Chung, 2017). Automation and intelligence between physical technology, biotechnology and operating technology ensure that the production and business process is continuous, effective and sustainable. Also according to Do Kim Chung (2017), in terms of technology, high-tech agriculture is based on the foundation of the 4th generation of technology with a borderless intersection between physical technology and technology. biological technology and operational technology (Do Kim Chung, 2017). Also according to Article 3 of Vietnam's High Technology Law No. 21/2008/QH12, agricultural enterprises that apply high technology are enterprises that apply high technology. High productivity in producing agricultural products with high quality, productivity, and added value. Thus, it can be seen that advanced agriculture is the application of science and technology to solve challenges in agricultural development with the superiority of new, modern technologies (such as biotechnology, greenhouse, drip technology, sensor technology, automation, internet of things...) help agricultural production save costs, increase productivity, lower costs and improve the quality of agricultural products, protecting the environment. , the trend helps farmers be proactive in production, overcome seasonality, reduce dependence on weather and climate, and meet market demand for agricultural product quality.

Promoting the application of NATA in agricultural production: According to the Vietnam Encyclopedia (2005), promotion is to stimulate, create conditions, and motivate activities and develop stronger in a certain direction, usually good direction. Therefore, promoting the application of high technology in agricultural production is understood as activities, methods or solutions to stimulate, create favorable conditions and create motivation for farmers, farmers or businesses to increase their productivity (Vietnam Cultural Publishing House, 2005). Application of advanced technology in agricultural production to improve productivity, quality and efficiency of the export process. Promoting the application of high technology in agricultural production helps increase productivity, quality, added value, increase competitiveness of agricultural products, promote business links, and create money to form cooperative groups. , cooperatives or other forms of association, forming rural enterprises, attracting high-quality human resources into agricultural production, reducing the bleeding of invaders in rural areas (Nguyen Thi Ngoc Anh, 2020; Nguyen Xuan Cuong, 2019).

Overview of promoting the application of high technology in agricultural production in Cambodia

- *Regarding policies to promote the application of NATA in agricultural production*

In agricultural development, state management plays a significant and indispensable role, demonstrated through strategic orientation for agricultural development aligned with each stage of the country's socio-economic development. This includes managing internal relations within the agricultural and rural sector in relation to the broader economy, supporting the development of household economies, farm economies, agribusinesses, and other forms of production organizations in agriculture and rural areas. These functions are carried out through national and local government institutions that promulgate guidelines and policies for agricultural and rural development. The goals of agricultural policy often focus on increasing agricultural production through improved productivity, quality, and competitiveness; developing infrastructure to enhance rural living standards; strengthening international integration; and using and protecting natural resources and the environment in a sustainable and effective manner (OECD, 2015).

In Cambodia, in recent years, the State and various provincial authorities have introduced specific guidelines and policies aimed at promoting the application of modern technologies in agricultural production. Following the adoption of the Agricultural Sector Strategic Development Plan (ASSDP) 2014–2018, which emphasized technological upgrading and innovation as key drivers of agricultural growth, the Royal Government of Cambodia launched several initiatives to support high-tech agriculture. In 2017, the Ministry of Agriculture, Forestry and Fisheries (MAFF) issued Sub-Decree No. 39 ANK/BK on the Establishment of Agricultural Technology Parks, aiming to create centers for research, training, and demonstration of advanced agricultural practices. Additionally, under the Rectangular Strategy Phase IV (2018–2023), the government prioritized investment in agricultural modernization, including digital agriculture and climate-smart farming techniques. The Ministry also implemented Decision No. 6211/MAFF-AGR on Promoting Investment in High-Tech Agriculture in 2019, which identified priority technologies and products encouraged for development. Furthermore, in 2020, MAFF collaborated with the National Bank of Cambodia (NBC) to introduce the Agricultural Finance Policy Framework, which included provisions for preferential loans targeting farmers and businesses adopting modern and high-tech agricultural practices.

However, the implementation of these policies faces numerous challenges. Some policies exist but lack detailed implementing guidelines, leading to delays in execution (Sovannarith et al., 2021). Accessing financial support and credit for high-tech agricultural development remains difficult, especially for smallholder farmers and micro-enterprises (Chhoun & Neou, 2020). There is also a limited number of targeted policies designed to encourage individual

households and private enterprises to invest in technology-based agricultural production (Heng & Sotheara, 2022).

- *Regarding planning and implementation of agricultural production development planning using high-tech applications*

Planning is the systematic arrangement and spatial distribution of socio-economic, defense, and security activities in relation to infrastructure development, resource use, and environmental protection within a defined and manageable territory. It aims to effectively utilize the country's resources to achieve regional development goals over a specified period (Planning Law 2017). The planning of regions and zones for developing agricultural production using high-tech applications is an issue that has been implemented by many countries around the world, such as the United States, China, India, and Thailand, to focus resources on promoting the application of advanced technologies in agricultural production.

In Cambodia, the government has increasingly recognized the importance of strategic planning in agriculture, especially through the establishment of specialized zones aimed at promoting modern and high-tech farming practices. Under the Agricultural Sector Strategic Development Plan (ASSDP) 2014–2023, the Royal Government of Cambodia emphasized the need for targeted spatial planning to improve productivity, enhance market access, and promote sustainable land use. The Rectangular Strategy for Nation Building and Development Phase IV (2018–2023) also identified the development of agro-industrial zones and technology parks as key priorities for transforming the agricultural sector.

The Ministry of Agriculture, Forestry and Fisheries (MAFF) launched several initiatives to support the creation of High-Tech Agricultural Zones (HTAZs) across the country. In 2019, MAFF issued Decision No. 6211/MAFF-AGR, which outlined criteria and procedures for identifying priority areas suitable for investment in high-tech agriculture. The goal was to establish at least five HTAZs by 2025, focusing on integrated value chains for key export crops such as rice, cassava, and rubber. Additionally, under the National Policy Framework for Agricultural Finance (2020), financial mechanisms were introduced to support investment in these zones. For example, in Takeo Province, local authorities have initiated plans to develop an agricultural technology zone focused on smart irrigation systems, greenhouse cultivation, and post-harvest processing. Similarly, in Kampong Cham, pilot projects have been launched to integrate digital technologies into rice and vegetable farming, aiming to increase yield and reduce post-harvest losses (Heng & Sotheara, 2022).

However, the implementation of planning for high-tech agricultural zones in Cambodia has encountered numerous challenges. As of 2022, only two HTAZs had been officially

approved and partially operationalized (Sovannarith et al., 2022). One of the major obstacles is the lack of a coherent legal framework specifically tailored to the establishment and management of HTAZs, resulting in inconsistent implementation across provinces (Chhoun & Neou, 2020). Many planned zones face delays due to lengthy administrative procedures, difficulties in land acquisition, and insufficient infrastructure development. According to recent studies (Kim & Sok, 2021; Chhim & Mony, 2022), the challenge of consolidating fragmented landholdings remains a significant barrier to establishing large-scale, technologically advanced agricultural zones. Unlike industrial zones where land is often state-owned or easier to acquire, agricultural land in Cambodia is mostly held under individual land titles or communal tenure arrangements, making it difficult to assemble contiguous plots suitable for modern farming operations.

Therefore, strengthening the implementation of planning for high-tech agricultural zones and regions—by addressing land consolidation issues, improving infrastructure development, and building more efficient land leasing and investment mechanisms—is an issue that needs urgent attention from both researchers and policymakers in Cambodia in the near future.

- *Regarding improving human resource level for NATA application in agricultural production*

Human resources in NATA are individuals who possess the qualifications and skills necessary to meet the demands of NATA-related activities, including research, development, application, services, operations management, equipment handling, and production line management (Minh Trang, 2020). The application of NATA in agricultural production requires a well-trained and technically capable workforce to facilitate the adoption and effective use of modern processes and technologies. However, the majority of agricultural workers in Cambodia lack the technical expertise required for successful NATA implementation. Therefore, training and capacity-building programs aimed at improving the technical skills of agricultural workers—so that they can understand, operate, and manage advanced technologies effectively—are essential for promoting the adoption of high-tech agriculture. This issue is central to advancing modern agricultural practices in Cambodia and remains a key challenge for policymakers and practitioners alike.

In reality, Cambodian agriculture has long relied on traditional knowledge and experience-based practices, while highly skilled human resources in the agricultural sector remain limited. According to data from the National Institute of Statistics (NIS), in 2021, out of approximately 3.4 million people employed in the agricultural sector, over 70% had not received any formal vocational training (NIS, 2021). Vocational training programs have made some progress, but

overall, they tend to focus on generic curricula offered by training institutions rather than being tailored to the specific needs of farmers and agribusinesses (Sovannarith et al., 2021).

Studies show that there is a significant gap between the demand for skilled labor in modern agriculture and the current supply. It was estimated that by 2025, the agricultural sector in Cambodia would face a shortage of approximately 200,000 trained workers, particularly in areas such as precision farming, digital agriculture, and agro-processing (Kim & Sok, 2022). Thus, it can be concluded that Cambodia is encountering major challenges related to the lack of qualified labor and technical expertise needed to support the development of NATA and smart agriculture.

Some limitations in applying NATA in agricultural production include:

(i) the lack of systematic and comprehensive theoretical and practical studies on human resource development for NATA; and

(ii) the absence of clear regulations or guidelines specifically supporting the development of human resources for high-tech agriculture.

For instance, while the Agricultural Sector Strategic Development Plan (ASSDP) 2014–2023 includes general goals for improving human capital in agriculture, it does not provide detailed strategies for training personnel in high-tech applications. Similarly, Sub-Decree No. 39 ANK/BK (2017) on Agricultural Technology Parks emphasizes infrastructure and investment but lacks provisions for workforce development aligned with technological advancement.

Moreover, the effectiveness and outcomes of training programs depend on various factors, including the quality of training providers, relevance of content, training methods, duration, trainee motivation, availability of post-training support, and access to financial resources (Chhim & Mony, 2022). For example, many rural farmers find it difficult to attend training due to time constraints, lack of transportation, and insufficient incentives.

Hence, assessing the demand for human resource training and refining policy mechanisms to support capacity building for NATA adoption in agriculture—by both national and local authorities—is an urgent and strategic priority for Cambodia's agricultural transformation.

- Regarding credit support for NATA application in agricultural production

The application of New Agricultural Technology Adaptation (NATA) requires a relatively large amount of investment capital. Given that agricultural enterprises, cooperatives, and farming households often face limited access to internal financial resources, access to credit support plays a critical role in promoting the adoption of NATA in agricultural production.

According to Mohamed & Temu (2008), access to credit can stimulate the adoption of new technologies by reducing asset constraints and increasing farmers' capacity to take on risk.

In Cambodia, implementing NATA-based agricultural models—such as setting up smart greenhouses or precision irrigation systems—requires significantly more capital compared to traditional farming methods. For example, establishing a modern greenhouse equipped with automated climate control and drip irrigation technology can cost between $50,000 and $100,000 per hectare, depending on the level of automation and imported components (Heng & Sotheara, 2022). This high initial investment poses a major barrier for smallholder farmers and local agribusinesses, many of whom lack sufficient collateral or formal financial records required by banks. To address this challenge, the Royal Government of Cambodia, through the Ministry of Agriculture, Forestry and Fisheries (MAFF) and the National Bank of Cambodia (NBC), has introduced several credit support mechanisms aimed at promoting agricultural modernization. One notable initiative is the Agricultural Finance Policy Framework (2020), which encourages commercial banks and microfinance institutions (MFIs) to provide loans for investments in high-tech agriculture, including irrigation systems, post-harvest processing, and digital farming tools.

Additionally, under the Rectangular Strategy Phase IV (2018–2023), the government emphasized the need to improve access to finance for rural producers, particularly those adopting innovative technologies. The Sub-Decree No. 39 ANK/BK (2017) on Agricultural Technology Parks also includes provisions for facilitating credit access to investors operating within designated zones. As of 2022, the total outstanding agricultural loans provided by MFIs and banks reached approximately $1.2 billion, with a growing portion allocated to modern farming practices (NBC, 2022). However, despite these efforts, access to credit remains a major constraint for farmers and businesses aiming to adopt NATA.

Several challenges persist:

- Lack of clear criteria for identifying eligible beneficiaries of NATA-related loans. The current system lacks quantifiable standards to determine whether a project qualifies as high-tech, making it difficult for lenders and borrowers to align expectations.
- Absence of property ownership certificates on agricultural land: Unlike industrial or residential land, agricultural land in Cambodia cannot be used as collateral due to restrictions on land titling for agricultural purposes. As a result, many farmers are unable to meet the requirements for secured lending.

- High perceived risk of agricultural lending: Due to vulnerability to climate change, pests, and natural disasters, banks remain hesitant to extend long-term credit to agricultural projects, even those using advanced technologies (Chhoun & Neou, 2020).

According to Sovannarith et al., 2022, only about 12% of Cambodian farmers have access to formal credit, and among them, very few receive funding specifically for technology adoption. Many rely on informal lenders who charge exorbitant interest rates, further limiting their ability to invest in modern equipment or infrastructure. Therefore, strengthening the regulatory framework to enable the issuance of land-use rights documentation for NATA projects, clarifying eligibility criteria for credit programs, and simplifying loan procedures are essential steps to facilitate broader access to financing. Additionally, introducing risk-sharing mechanisms, such as agricultural insurance and partial credit guarantees from the government, could help reduce the reluctance of financial institutions to lend to the sector.

In conclusion, improving access to credit tailored to NATA applications in agriculture is a crucial policy priority for Cambodia's future agricultural development. It will require coordinated action across ministries, financial institutions, and development partners to create an enabling environment for sustainable and inclusive growth in the sector.

- Regarding promoting linkages in the production and consumption of agricultural products by application of NATA

Establishing strong linkages between production and consumption of agricultural products developed using New Agricultural Technology Adaptation (NATA) is essential, especially for smallholder farmers. These households often operate on a small scale, have limited financial capacity, and possess low levels of technical knowledge, making it difficult for them to adopt modern technologies independently. As such, collaboration and support from relevant stakeholders—such as cooperatives, agribusinesses, research institutions, and government agencies—are crucial. According to Hau (2012), through coordinated production linkages, small-scale producers can overcome limitations related to inconsistent supply volumes and quality standards required by domestic and international markets. Tran Thuy Phuong (2013) highlights the example of Israeli agriculture, which thrives despite harsh environmental conditions due to robust cooperation among researchers, farmers, processors, and service providers throughout the value chain.

In Cambodia, the majority of agricultural production remains fragmented and small-scale, limiting the ability of farmers to produce consistent, high-quality outputs that meet market demands. The connection between farmers, cooperatives, traders, and agro-processing

enterprises is still weak and underdeveloped. Most existing linkages are informal, lack contractual agreements, and do not include clear mechanisms for sharing risks or benefits (Sovannarith et al., 2021). This situation is even more pronounced in the case of NATA-based agricultural products, where technological investment and market alignment must go hand-in-hand to ensure sustainability and profitability. While some efforts have been made to promote value chain integration—particularly under the Agricultural Sector Strategic Development Plan (ASSDP) 2014–2023 —the implementation of structured and formalized linkages remains limited.

The Royal Government of Cambodia has introduced several policy frameworks aimed at improving coordination across the agricultural sector. For instance, the Rectangular Strategy Phase IV (2018–2023) emphasizes strengthening backward and forward linkages in key commodity chains such as rice, cassava, and rubber. Additionally, Sub-Decree No. 39 ANK/BK (2017) on Agricultural Technology Parks encourages public-private partnerships to foster innovation and improve market access for high-tech agricultural products. Despite these initiatives, formalized production-consumption linkages for NATA-based agriculture remain underdeveloped. One major reason is the absence of specific provisions and incentives within existing policies to promote trade and marketing of high-tech agricultural goods (Heng & Sotheara, 2022). Unlike general agricultural linkages, there is no dedicated legal framework or targeted financial support for connecting NATA producers with processing and marketing entities. According to experts from the Cambodia Development Resource Institute (CDRI), the lack of organized value chains results in high transaction costs, poor product traceability, and limited access to premium markets (Chhoun & Neou, 2020). This further discourages private sector investment in high-tech farming models. Moreover, the absence of contract farming arrangements and agricultural insurance schemes leaves many farmers exposed to price volatility and production risks. As noted by Sovannarith et al., 2022, only a small percentage of Cambodian farmers currently engage in contract farming, particularly those producing non-traditional, high-value crops. Therefore, developing formal and inclusive linkages between NATA producers and downstream actors —such as processors, exporters, and retailers—is critical to ensuring stable and profitable markets for modern agricultural products. Key interventions should include:

- Encouraging contract farming models tailored to high-tech agriculture.
- Strengthening cooperatives and farmer associations to enhance collective bargaining power.

- Providing technical and financial support for post-harvest infrastructure and branding.
- Establishing market information systems to improve transparency and responsiveness.
- Introducing incentive mechanisms for businesses investing in NATA-related value chains.

To conclude, building effective production-consumption linkages for NATA-based agricultural products is vital for Cambodia's agricultural transformation. It requires coordinated action among policymakers, development partners, private investors, and local communities to create an enabling environment for sustainable and inclusive growth on the effectiveness of NATA agricultural applications.

Ultimately, farmers' decisions to use NATA in agricultural production or not depend on the results and effectiveness of network technology for them. According to Foster & Rosenzweig (2010), the key factor determining the adoption and application of new technology is the income and profits brought to farmers from the application of technology. According to Le Dang Lang et al. (2014), the effectiveness of NATA application in agricultural production is shown through increased productivity, quality, quantity of products consumed and or reduced production costs when applying new technology. Normally, economic efficiency is calculated by the profit earned on invested capital. For small-scale farmer associations using family labor, the main effect can be reflected through the income gained from NATA application. In addition to economic efficiency, social efficiency, environmental efficiency are also aspects that need to be considered when evaluating the effectiveness of NATA application in agricultural production.

Implementation of NATA in Cambodia and neighboring countries

In recent years, the adoption and adaptation of new agricultural technologies has played a crucial role in enhancing food security, improving farmer livelihoods, and increasing climate resilience across Southeast Asia. In countries such as Cambodia, Vietnam, and Laos, smallholder farmers have increasingly embraced climate-smart agricultural practices —a key component of what can be referred to as New Agricultural Technology Adaptation (NATA). These interventions aim to modernize traditional farming systems while addressing environmental sustainability and productivity challenges (CCAFS, 2021).

The Climate-Smart Village (CSV) initiative, led by the International Center for Tropical Agriculture (CIAT) and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), has been instrumental in promoting NATA in the Mekong region.

From 2016 to 2021, this program supported the introduction of innovative technologies such as Alternate Wetting and Drying (AWD) irrigation, System of Rice Intensification (SRI), drought-tolerant crop varieties, Integrated Pest Management (IPM), and solar-powered irrigation pumps. These technologies were piloted in rural communities where agriculture remains the primary source of income and employment (CIAT, 2020).

The implementation of these technologies demonstrated significant benefits. For instance, AWD irrigation helped reduce water usage by up to 30% and lowered methane emissions from rice paddies, contributing to both economic and environmental gains. Similarly, SRI techniques improved rice yields while requiring fewer seeds and inputs, making them especially beneficial for resource-poor farmers (World Bank, 2020). In Cambodia, approximately 45% of pilot villages adopted these technologies, resulting in an average yield increase of 20% and income improvements of 15–20%. Comparable results were observed in Vietnam's Mekong Delta and parts of Laos, although terrain and infrastructure limitations affected the scale of impact in the latter (FAO, 2019).

Despite these successes, several challenges hindered broader adoption. Limited access to financing, lack of technical knowledge, cultural resistance to change, and poor rural infrastructure slowed down the spread of NATA practices. To address these barriers, the CSV program included capacity-building activities such as farmer training workshops, peer-to-peer learning, and demonstration farms to encourage trust and familiarity with new methods (CCAFS, 2021).

Overall, the NATA initiatives in Cambodia and neighboring countries serve as a model for integrating sustainable technologies into smallholder farming systems. They highlight the importance of a holistic approach that combines technological innovation with education, financial support, and community engagement to ensure long-term success and scalability.

Solutions for the effectiveness of NATA agricultural applications

Ultimately, farmers' decisions to adopt New Agricultural Technology Adaptation (NATA) in agricultural production depend largely on the perceived and actual effectiveness of the technology in improving their livelihoods. According to Foster & Rosenzweig (2010), the key factor influencing the adoption of new agricultural technologies is the increase in income and profitability that these technologies bring to farming households.

As noted by Le Dang Lang et al. (2014), the effectiveness of NATA application in agriculture can be demonstrated through several indicators: increased productivity, improved product quality, higher yields, greater marketability, or reduced production costs. For smallholder farmers who often rely on family labor and limited capital, the economic efficiency

—measured by the net income generated per unit of input—is a primary determinant of whether a technology is deemed successful or not.

However, economic efficiency alone is not sufficient to fully assess the impact of NATA. It is also essential to consider social and environmental outcomes when evaluating the overall effectiveness of technology adoption. Social efficiency may include improvements in employment opportunities, rural development, and household welfare. Environmental efficiency refers to sustainable resource use, reduced chemical inputs, and lower carbon footprints—key concerns in Cambodia's increasingly climate-sensitive agricultural sector.

Despite growing interest in high-tech agriculture, there remains a lack of comprehensive studies analyzing the specific factors that influence economic, social, and environmental performance in NATA-based farming systems in Cambodia. In particular, few studies have quantified the level of impact of various determinants such as access to credit, land tenure security, training programs, market linkages, and government support policies (Sovannarith et al., 2021; Chhoun & Neou, 2020).

Therefore, further research is necessary to:

- Confirm the overall effectiveness of NATA applications in Cambodian agriculture,
- Identify the key influencing factors, and
- Measure the degree of influence of each factor using modern analytical methods such as econometric modeling, cost-benefit analysis, and participatory assessments.

Such evidence-based findings would serve as a foundation for awareness-raising campaigns and targeted policy interventions aimed at enhancing the effectiveness of NATA adoption among different types of agricultural producers—ranging from smallholder farmers to agro-enterprises and cooperatives.

To sum up, understanding and improving the multi-dimensional effectiveness of NATA —including its economic, social, and environmental impacts—is crucial for promoting sustainable agricultural development in Cambodia. This requires coordinated efforts between researchers, policymakers, extension services, and private sector stakeholders to ensure that technological innovations truly benefit all actors along the agricultural value chain.

CONCLUSION AND RECOMMENDATION

Given that Cambodia's average agricultural land area per capita is among the lowest in the region and continues to shrink due to rapid industrialization, urban expansion, and land-use changes, the development of New Agricultural Technology Adaptation (NATA) has become

an urgent necessity. In the context of the global 4.0 industrial revolution, transitioning toward high-tech agriculture offers a strategic pathway for Cambodia to enhance agricultural productivity, improve product quality, and meet growing domestic and international demand.

In recent years, the Royal Government of Cambodia has introduced various policy frameworks aimed at promoting the adoption of modern technologies in the agricultural sector. These include the Agricultural Sector Strategic Development Plan (ASSDP) 2014–2023, the Rectangular Strategy Phase IV (2018–2023), and the Sub-Decree No. 39 ANK/BK on the Establishment of Agricultural Technology Parks (2017). While these initiatives have laid a solid foundation and yielded some initial progress, the number of successful NATA implementation cases remains limited.

The development of high-tech agriculture in Cambodia still faces numerous challenges, including:

- Limited access to finance and credit for smallholder farmers and agribusinesses,
- Inadequate infrastructure and technical support systems,
- Fragmented land holdings and unclear land use rights,
- Insufficient human resources trained in modern agricultural practices,
- Weak market linkages and lack of post-harvest value addition.

However, beyond these structural and economic constraints, there are also deeply rooted political, cultural, and logistical barriers that must be addressed to ensure effective implementation of NATA-related policies and programs.

- Political Barriers

One major obstacle lies in the fragmented governance structure and limited coordination between ministries and local authorities. While national-level policies may promote technological advancement, inconsistent enforcement and overlapping mandates at sub-national levels can delay or distort implementation. Additionally, land tenure insecurity —often linked to politically sensitive land concessions and redistribution issues—discourages long-term investment in new technologies by both farmers and private investors.

- Cultural Barriers

Many Cambodian farmers remain skeptical of new technologies due to cultural attachment to traditional farming methods, which have been passed down through generations. This skepticism is further reinforced by low levels of formal education and digital literacy, particularly in rural areas. There is also a tendency to resist change when immediate benefits are not apparent, especially among older generations who perceive technology as complex or unnecessary.

- Logistical Barriers

Even where interest in NATA exists, poor rural infrastructure —such as inadequate roads, unreliable electricity, and limited internet connectivity—hinders the deployment and maintenance of advanced agricultural technologies. Moreover, the lack of cold storage, transport systems, and processing facilities undermines the ability of farmers to benefit from value-added opportunities and market integration.

To effectively promote the application of NATA in agricultural production in the coming years, it is essential to undertake the following priority actions:

1. Comprehensive Policy Review and Evaluation: Conduct a thorough assessment of existing policies related to high-tech agriculture to identify gaps, overlaps, and inefficiencies. Based on this evaluation, propose reforms to create a more coherent and targeted policy framework that aligns with national development goals and private sector interests.
2. Strategic Planning and Implementation Monitoring: Review and update plans for high-tech agricultural zones to ensure they are realistic, location-specific, and integrated with broader rural development strategies. Strengthen monitoring and evaluation mechanisms to ensure transparency and accountability in implementation.
3. Human Resource Development: Expand vocational training programs tailored to NATA applications, focusing on both technical skills and business management for farmers, cooperatives, and agro-enterprises. Encourage collaboration between educational institutions, research centers, and the private sector to deliver demand-driven training.
4. Enhanced Access to Credit and Investment Support: Improve access to affordable financing by expanding agricultural credit programs, introducing risk-sharing mechanisms (e.g., partial guarantees or insurance), and facilitating partnerships between banks, microfinance institutions, and technology providers.
5. Strengthening Market Linkages and Value Chains: Promote contract farming, farmer cooperatives, and public-private partnerships to improve coordination between producers, processors, and buyers. Develop infrastructure for storage, processing, and logistics to reduce post-harvest losses and increase product value.
6. Awareness Raising and Knowledge Dissemination: Implement targeted communication campaigns to raise awareness about the benefits and practical applications of NATA in agriculture. Highlight success stories and best practices to encourage wider adoption among farming communities.

In conclusion, the transition to high-tech agriculture through NATA is not only necessary but also strategically aligned with Cambodia’s long-term socio-economic development goals.

However, the success of this transition depends on addressing not only technical and financial constraints but also the political, cultural, and logistical barriers that currently impede progress. By fostering inclusive, transparent, and adaptive policy frameworks—and building capacity at both institutional and community levels—Cambodia can unlock significant potential for sustainable agricultural growth, food security, and rural prosperity.

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