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Technology adoption and its impact on environmental and socioeconomic outcomes for vegetable producers in Svay Rieng Province, Cambodia

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Abstract

Agricultural extension workers have been instrumental in encouraging farmers to adopt new technologies to improve productivity, income, social status, and climate resilience but there are challenges. This study assessed technology adoption and its impact on vegetable production, economic and social enhancement, and climate resilience in Svay Rieng province, Cambodia. Data from 302 agricultural cooperative members were analyzed using Pearson's correlation to examine relationships and linear regression to predict factors influencing farmers' achievements. Results show that internal challenges (labor, capital, technical know-how) significantly influenced success in vegetable production. Investments in hard technologies (e.g., net houses, drip irrigation) strongly correlated with achievements, while soft technologies (technical knowledge) had a lesser impact. Regression analysis identified internal challenges and adoption of hard technologies as key predictors, explaining 25% of overall performance, including 36%, 29%, and 25% of economic, social, and climate resilience improvements, respectively. For production, only internal challenges and hard technologies were determinants, predicting 30%. Addressing internal challenges and enhancing technology applications are critical to improving vegetable producers' success.

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Introduction

The adoption of agricultural technology has increasingly become a pivotal factor in enhancing the productivity and resilience of smallholder farmers, particularly in developing countries. In Cambodia, the agricultural sector remains a significant driver of the economy, with vegetable production contributing substantially to rural livelihoods and national food security. Despite this importance, farmers in provinces like Svay Rieng face numerous challenges in adopting modern technologies, which often limit their capacity to increase productivity and improve socio-economic conditions (Thort, 2019). Moreover, the low rate of technology adoption in vegetable farming highlights the need for targeted interventions to address barriers such as limited access to capital, technical knowledge, and market opportunities (Keo and Roth, 2023). Addressing these challenges is essential to support farmers in achieving sustainable agricultural practices and adapting to climate change. The effectiveness of these services can be constrained by both internal challenges, such as limited labor and financial resources, and external challenges, such as infrastructure gaps and market uncertainties (Ke and Babu, 2018). Understanding these constraints and their interplay with technology adoption is key to designing strategies that can maximize the socioeconomic and environmental benefits for smallholder vegetable producers. In addition, there is limited research examining how these challenges interact to influence key outcomes such as economic improvement, social enhancement, and climate resilience. Moreover, the environmental implications of adopting these technologies in resource-scarce settings like Svay Rieng province remain poorly understood. This gap in knowledge limits the ability of policymakers and stakeholders to design targeted interventions that effectively address these barriers and promote sustainable agricultural practices.

This study examined the challenges in technology adoption and its impacts on vegetable production performance that contributes to economic and social enhancement, and climate resilience of vegetable producers in Cambodia's Svay Rieng province.

Materials and methods

Survey site and sampling

Svay Rieng province is situated in the southeast part of Cambodia. According to the Provincial Department of Agriculture, Forestry and Fisheries (PDAFFF) (2020), 87% of the province's population (667,260 individuals) live in rural areas and 68.5% of them are involved in agricultural production. In 2018, the province reported total land area for vegetable production of 1,760 hectares, generating 18,480 tons of produce per year equivalent to 33% of the total demand in the province (SAAMBAT Project, 2020). The province is home to 86 agricultural cooperatives (ACs) in which 9 ACs are involved in vegetable production with a total number of 933 households. These ACs are actively producing vegetables, supplying them to provincial and national markets, in a more collective way. Since the study focuses on vegetable producers, members of the 9 ACs were selected for the study. To determine the sample of vegetable producers as survey respondents, Cochran's formula was used to calculate the sample size with a margin of error of 5%, confidence level of 95%, response rate of 50%, resulting in a sampling size of 273 farmers. During the survey a total sample of 302 was interviewed in which 92% of them are male and majority of them are above 45 years old, with more than half with only primary school education.

Construction of survey questionnaire

The construction of the questionnaire considered items that addressed the objectives of the study, including farmers' awareness of and access to technologies as well as benefits and challenges of technology adoption. Likert Scale was used for each item or question. After completion of the questionnaire, validity and reliability checking was conducted. Firstly, the questionnaire was sent to three agricultural extension and rural development experts to confirm the validity of the tool and the necessary revisions. The revision was conducted until the questionnaire reached the level of satisfaction from the experts that they are valid as per the study objectives and context of vegetable farmers in the province. Then, questionnaire testing was conducted with 36 households to determine the reliability of the questionnaire. The result of the reliability calculation using Cronbach's Alpha is 0.795 which is acceptable for use in actual data collection.

Data analysis

The survey results were collated and subjected to descriptive statistics such as frequency, percentage, means, mode, and standard deviation to measure tendency and variability of the observations in the data set. Pearson Product Moment Correlation and multiple correlations were used to determine the correlation between variables, finding out the relationship between the determinants of influencing factors and technological adoption behavior of farmers. Stepwise Multiple Regression Analysis was conducted to predict factors influencing farmers' behavior and achievements.

Results and discussion

Access to technology

Awareness of technology among farmers was high, including use of net houses (96%) and plastic houses (93%), and seed selection (95%), indicating widespread familiarity with these practices. Technologies with high adoption rates among farmers included plastic houses (92%), net houses (88%), soil erosion management (85%), and smart irrigation through drip irrigation (82%), reflecting a strong focus on infrastructure and environmental management. Technologies with moderate adoption rate included integrated pest management (IPM) (77%), fertility management (75%), and good agricultural practices (GAP) (62%), indicating progress in sustainable farming but with room for improvement. Low adoption rates for key practices like seed selection (30%), crop rotation (32%), and organic agriculture (31%) suggest barriers to technology adoption. Additionally, only around half of the farmers have adopted critical business practices like financial management (53%), marketing (51%), and production planning (49%), while proper postharvest and packaging practices were adopted by just 44% of the farmers, revealing missed opportunities for value addition.

Challenges in production and technology adoption

Vegetable producers in Svay Rieng province have faced various challenges in their production ventures. Environmental challenges emerged as the most critical, followed by technical and input-related issues, emphasizing the need for targeted interventions in these areas to improve productivity and resilience among vegetable producers. At the same time, major barriers to adoption of technologies were the high investment cost, affecting 83% of respondents, indicating financial constraints as the primary challenge. Too complicated technologies (20%), lack of technical support (19%), and lack of labor force (16%) are the moderate barriers, suggesting that complexity, insufficient guidance, and workforce shortages also hinder adoption.

Benefits of adopting technologies

Vegetable producers have benefited from adopting technologies in a number of ways, including improved production, economic and social status, and resilience to environmental condition. The production benefits highlighted significant improvements in production efficiency and product quality. Farmers rated the highest the increased production times (67%), reflecting improvements in operational efficiency. Savings in time and labor (66%), cost reductions (66%), and improved quality and values (64%) further emphasize the effectiveness of the interventions in streamlining processes and delivering higher-quality outputs. These ratings highlight the perceived value of production improvements in achieving sustainable productivity gains.

The economic benefits received high ratings, with increased yields (65%) and income (64%) standing out as important indicators of financial growth. Increased production size (63%) and the ability to meet market demand (63%) demonstrate the alignment of agricultural outputs with market needs. Ratings for solving capital shortage issues (64%) and increased profits (64%) suggest enhanced financial capacity, ensuring better economic security and sustainability for stakeholders.

The social impacts are well-rated, reflecting tangible improvements in community-level benefits. Increased child education opportunities (65%) and better social recognition (64%) demonstrate the positive effects of agricultural development on family and community well-being. Knowledge sharing (62%), collaboration among producers (63%), and increased participation in agricultural events (62%) highlight farmers' empowerment through networking and capacity-building initiatives. Opportunities for leadership (60%) also indicate progress toward greater social inclusion and influence.

Lastly, environmental outcomes received positive ratings, indicating the effectiveness of sustainable practices. Resilience to pests (64%) and reduced environmental pollution (64%) reflect advancements in ecological health and resource management. Improved production resilience (63%) and adaptability to water shortages (62%) and water excess (61%) underscore the significance of climate-resilient farming techniques. These ratings emphasize the growing emphasis on balancing agricultural productivity with environmental sustainability.

Overall, the ratings across production, economic, social, and environmental aspects reflect a cohesive system of agricultural improvement. Enhanced efficiency and quality in production contribute to economic growth by increasing yields, profits, and market responsiveness. Economic stability enables investments in social initiatives, such as education, collaboration, and leadership, while sustainable environmental practices ensure the longevity of these benefits. Together, these aspects form an interconnected framework that drives agricultural development, social progress, and environmental resilience, fostering sustainable and inclusive growth.

Correlation analysis

To understand the relationship between the technological adoptions and its benefits, correlation analysis was conducted, shown in Table 1. Hard technologies refer to physical infrastructure such as net house, plastic house and irrigation system while soft technologies refer to technological awareness of farmers. In addition, management refers to knowledge regarding marketing, planning, and postharvest handling which farmers were aware of.

Table 1. Correlation between technology adoption and benefits (n=302)

Factors	HT	ST	MGT	IC	EC	PB	EB	SB	EnvB	OB
HT	1									
ST	0.420**	1								
MGT	0.308**	0.482**	1							
IC	-0.152**	0.109	0.253**	1						
EC	-0.296**	-0.108	-0.025	0.401**	1					
PB	0.318**	0.040	-0.044	-0.495**	-0.268**	1				
EB	0.324**	0.018	-0.095	-0.547**	-0.274**	0.876**	1			
SB	0.185**	-0.099	-0.173**	-0.529**	-0.210**	0.766**	0.849**	1		
EnvB	0.210**	-0.122*	-0.136*	-0.464**	-0.223**	0.702**	0.739**	0.764**	1	
OB	0.283**	-0.044	-0.120*	-0.551**	-0.263**	0.912**	0.945**	0.924**	0.877**	1

HT = Hard Technology, ST = Soft Technologies, MGT = Management, IC = Internal Challenges, EC = External Challenges, PB = Production Benefits, EB = Economic Benefits, SB = Social Benefits, EnvB = Environmental Benefit, OB = Overall Benefits

The relationship test shows that hard technologies have been perceived in a more positive way by vegetable producers, indicating less value being given to soft technologies. Hard technologies are significantly associated with all aspects including internal and external challenges (negative association) whereas benefits in production and economics are the highest followed by environmental and social benefits as least beneficial. This indicates that hard technologies can convince respondents to value its benefits. On the contrary, soft technologies are not statistically associated with any challenges and benefits, except the management. The association tests have two implications – (1) that farmers have inadequate knowledge and perceived soft technologies of limited value or (2) farmers have the soft knowledge but lack capital to invest in improving hard technologies. However, the first implication seemed to be more valid as the internal challenges were found to be very significantly and inversely correlated with all the benefits. The external challenges were found to have the same direction to a lesser extent. Apart from this, management knowledge has a slight relationship with the overall benefits of production.

Regression analysis

To determine the effects of technology adoption on the overall production, economic, social, and environmental benefits, linear multiple regression analysis was conducted. Eighteen technologies were included. The result showed that the 18-technology adoption rate was able to estimate by 41% the benefits from technology adoption, as the regression coefficient value was 0.668 (Table 2). This indicates a significant prediction level for the factors determining farmers' benefits.

Table 2. One-way ANOVA of the multiple regression analysis of the 13 variables predicting the level of beneficial performance

Source of variation	df	SS	MS	F
Regression	18	37.570	2.087	12.391*
Residual	277	46.661	0.168	
Total	295	84.231		

*Significant at α = 0.05

Since the 18 technologies contain variables with limited influence on the level of benefits from the production, further analysis using stepwise multiple regression was conducted to determine the most influential technologies that can generate a significant estimate of the overall production benefits (Table 3).

Table 3. One-way ANOVA of the multiple regression stepwise analysis of the 18 technologies predicting the level of benefits from the adoption

Source of variation	df	SS	MS	F
Regression	9	36.815	4.091	24.673*
Residual	286	47.416	0.166	
Total	295	84.231		

*Significant at α = 0.05

The above result indicates that 9 technologies can generate significant impacts on vegetable producers. The equation can also estimate the benefits of production at 41% as the regression coefficient value was 0.661.

Repeating the linear multiple regression analysis for each type of the four benefit groups; production, economic, social and environment; the result indicated that the adoption of technology can highly predict the result of each type at 38%, 36%, 40%, and 30% respectively. The result indicates the significant contribution of technologies to production at different aspects which are very crucial for the livelihood development of vegetable producers.

Conclusion

Various technologies in vegetable production have been promoted in Svay Rieng province. The most influential technologies included net house, fertilizer application, GAP, organic farming, soil erosion management, financial management, IPM, crop rotation and greenhouse. The results confirmed that the benefits accruing to vegetable producers in terms of production, economic, social and environmental aspects are highly attributable to the adoption of technologies including hard and soft technologies and management. Vegetable farmers perceived hard technologies as the most influential contributors to their achievement while limited acknowledgement was given to soft technologies. The management aspect was more associated with social and environmental benefits than production and economic benefits. It is recommended that the promotion of technologies should be sustained, with a focus on soft technologies since there is limited recognition. In addition, a higher promotion of physical infrastructure is very important to cope with various challenges, especially external ones.

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