Assessing the Performance of Climate Smart Rice Production Systems in the Upper Part of the Vietnamese Mekong River Delta

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ABSTRACT

Climate smart agriculture (CSA) has gained considerable attention in Vietnam due to its potential to increase food security and farming system resilience while decreasing greenhouse gas emissions. In recent years, several CSA practices have been introduced in rice production, the most important sub-sector of Vietnam's agriculture. However, few studies have been done in Vietnam to produce comprehensive assessments of CSA performance in the rice sector. This research proposes a comprehensive approach to assess CSA practices through a new set of evaluation indicators. A case study in An Giang province of the Vietnamese Mekong River Delta was implemented to evaluate the performance of five CSA models versus that of the triple rice crop system (i.e., benchmarking model). Results show that rice-shrimp and rice-lotus rotations are most profitable, low-risk, and applicable at a larger scale. Given that the current study analyzed and calculated only a small number of indicators and types of CSA practices, further research is necessary to test all indicators and diversified types of CSA models.

Keywords: rice production systems, climate smart agriculture, CSA, assessment indicators, Vietnamese Mekong River Delta

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INTRODUCTION

High-level policymakers have exerted substantial efforts to promote the implementation of the "triple win" climate smart agriculture in Vietnam to solve the food security-climate change pressure. In 2012, the Food and Agriculture Organization (FAO) initiated the idea of climate smart agriculture (CSA) in Vietnam and since then, several government policies (GOV 2008; 2010; 2011) have been issued to encourage the development and replication of green production models and organic agriculture projects. The Ministry of Agriculture and Rural Development approved a program on the reduction of greenhouse gas (GHG) emission in agricultural and rural areas,[1] which targets the reduction of GHG emission in agriculture by 20 percent in 2020. To improve productivity, reduce GHG emission, and adapt to climate change, the Agricultural Restructuring Plan[2] highlights the need to foster innovations in science and technology in the agriculture sector.

In recent years, several CSA practices have been introduced in rice production, Vietnam's most important sub-sector in agriculture. Nevertheless, very few authors in Vietnam provided comprehensive assessments of CSA performance in the rice sector. Majority of CSA assessment studies have been based on cost benefit analysis. However, social and environmental perspectives have been neglected (Ho and Shimada 2019; Branca et al. 2018) as well as farmer's behavior assessment (Dung 2020; Tran et al. 2019). As a result, central and local governments, international organizations, and the media often reported positive results about these innovative practices without science-based evidence.

To fill this gap, our paper aims to provide the first quantitative assessment of CSA practices in Vietnam using a comprehensive set of indicators to evaluate the strengths and weaknesses of rice systems in the Vietnam Mekong River Delta (VMD). The paper first explores the available CSA-related indicators developed by different organizations and researchers in the world. Based on such review, the paper then proposes a set of evaluation indicators applicable for Vietnam, which is the main contribution of the paper to the current discussion on CSA. A case study in An Giang province in the VMD is presented to evaluate the performance of five CSA models versus that of the triple rice crop system (i.e., benchmarking model) using this novel set of assessment indicators. Finally, discussion and conclusion are provided.

METHODOLOGY

Overview of Climate Smart Agriculture Concept

The first articulation of the CSA concept was presented in the 2009 FAO report titled *Food Security and Agricultural Mitigation in Developing Countries: Options for Capturing Synergies*, launched at the Barcelona Climate Change workshop in November that year. Since then, the CSA concept and methods were developed by international technical agencies, including the FAO, World Bank, and the Climate Change and Food Security Programme of CGIAR (Lipper and Zilberman 2018). In general, CSA is an integrated approach to manage landscapes—cropland, livestock, forests, and fisheries—addressing the interlinked challenges of food security and accelerating climate change. CSA aims to simultaneously achieve three outcomes (World Bank 2021):

1. ***Increased productivity.*** Produce more and better food to improve nutrition security and boost incomes especially of 75 percent of the world's poor who live in rural areas and mainly rely on agriculture for their livelihoods.
2. ***Enhanced resilience.*** Reduce vulnerability to drought, pests, diseases, and other climate-related risks and shocks and improve capacity to adapt and grow

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[1] Programme of Greenhouse Gas (GHG) Emissions Reduction in the Agriculture and Rural Development Sector up to 2020 (MARD 2011)

[2] Agricultural Restructuring toward Raising Added Values and Sustainable Development (GOV 2013)

in the face of longer-term stresses like shortened seasons and erratic weather patterns.

3. ***Reduced emissions.*** Pursue lower emissions for each calorie or kilo of food produced, avoid deforestation from agriculture, and identify ways to absorb carbon out of the atmosphere.

Development of CSA Evaluation Indicators

One key CSA document, the CCAFS-CIAT[3] CSA Prioritization Framework (CSA-PF) (CIAT 2014), aims to help decision makers identify best-bet CSA investment portfolios that achieve gains in food security, farmers' resilience to climate change, and low-emission development of the agriculture sector. The framework is divided into four phases: (1) initial assessment of CSA options, (2) identification of top CSA options via a workshop (3) calculation of cost and benefits of top CSA options, and (4) portfolio development and evaluation of barriers via a workshop. According to CCAFS (n.d.), key CSA indicators are used in phase 2. To assist farmers and policymakers in prioritizing strategic CSA interventions in phase 2, CCAFS (2016) introduced two methods—the CSA prioritization (CSAP) toolkit, and the participatory identification of CSA priorities (CSA-PI). The CSAP toolkit is based on a spatially explicit land use planning framework of agricultural production accounting for (1) spatial crop yields, inputs/outputs, and production costs; (2) land, water, and labor availability; and (3) GHG emission from agriculture (CCAFS n.d.). The CSA-PI constructs a simple list of qualitative CSA indicators based on three pillars: food security/livelihood, adaptation, and mitigation. All these indicators are ranked or scored by farmers (Duong, Simelton, and Hai 2016; Manda et al. 2019).

During the last five years, significant progress has been achieved in developing CSA assessment indicators. In 2016, World Bank published its complete set of CSA indicators (World Bank 2016). Most recently, FAO (2019a; 2019b) issued its set of indicators to integrate CSA with the global sustainable development goals. The most comprehensive set is introduced by Quinney, Bonilla-Findji, and Jarvis (2016), which is supported by a database of over 378 indicators. For this, CSA-related indicators were gathered from several international development agencies/institutions (FAO, DFID,[4] GIZ, IFAD,[5] World Bank, USAID, and CCAFS[6]). Quinney, Bonilla-Findji, and Jarvis (2016) developed a tool to assess not only productivity outcome, adaptation, and mitigation impacts but also access three other pillars: (1) indicator type (readiness/enabling environment) (Wollenberg, Zurek, and Pinto 2015), process/output, and outcome/impacts; (2) CSA type of intervention (technologies and practices, services, tools, incentive mechanisms/financial, empowerment, capacity building, and planning); and (3) scale at which the changes are intended to be measured.

In Vietnam, the study of Pham et al. (2017) is among a few that tries to use indicators in evaluating a CSA model against a benchmark. Pham developed a rapid assessment methodology to select CSA practical solutions in Vietnam in four steps: (1) create a list of potential CSA models, (2) select existing CSA models, (3) identify suitable CSA models to local characteristics, and (4) identify expandable CSA models suitable to specific local characteristics. In the third step, the author developed a list of specific indicators to rank the CSA models following three aspects of CSA: productivity, adaptation, and mitigation.

The research team developed a set of indicators that covered three main pillars of the CSA concept (FAO 2013): increased productivity, enhanced resilience, and reduced emissions. Moreover, this assesses the applicability of CSA models and follows the approach developed by Pham et al. (2017) for evaluation of CSA models given its suitability to the context of Vietnam.

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[3] Research Program on Climate Change, Agriculture and Food Security - International Center for Tropical Agriculture

[4] Department for International Development

[5] International Fund for Agricultural Development

[6] CGIAR Research Program on Climate Change, Agriculture and Food Security

Specifically, the three conceptual CSA pillars taken into account include: (1) productivity and food security (e.g., improvement in rice yield, net income, and benefit cost ratio); (2) adaptation and resilience to climate change; and (3) potential mitigation reflected by the potential to reduce GHG emissions (e.g., improvement in nutrient use efficiency, pesticide use efficiency, water use efficiency, and energy use efficiency). Moreover, the applicability of CSA models to natural and socioeconomic conditions is also assessed using a set of indicators including accessibility to labors, techniques, inputs, finance, market, and risks at the early stage of application. Figure 1 illustrates the structure of four groups of CSA assessment indicators proposed by our research team.

From broad CSA indicators, following FAO (2013), we developed detailed indicators (Table 1) based on the SMART rule (i.e., simple, measurable, attributable, reliable, and time bound). Specifically, these indicators must answer the following questions:

1. ***Validity.*** Does the indicator measure a change in climate risk or vulnerability?
2. ***Precise and specific meaning.*** Do stakeholders agree on exactly what the indicator measures in this context?
3. ***Practical, affordable, and simple.*** Are climate- and adaptation-relevant data available at reasonable cost and effort? Will it be realistic to collect and analyze information?
4. ***Reliability***. Can the indicator be consistently measured against the adaptation baseline over the short, medium, and long term? Regarding mitigation, are the indicators robust enough for formal auditing under measurement, reporting, and verification?
5. ***Sensitivity***. When the respective climatic effects or adaptive behaviors change, is the indicator susceptible to those changes?
6. ***Clear direction***. Is it certain that an increase in value is good or bad and for which particular aspect of adaptation? Is it ultimately attributable to intervention?

Figure 1. Broad CSA assessment indicators

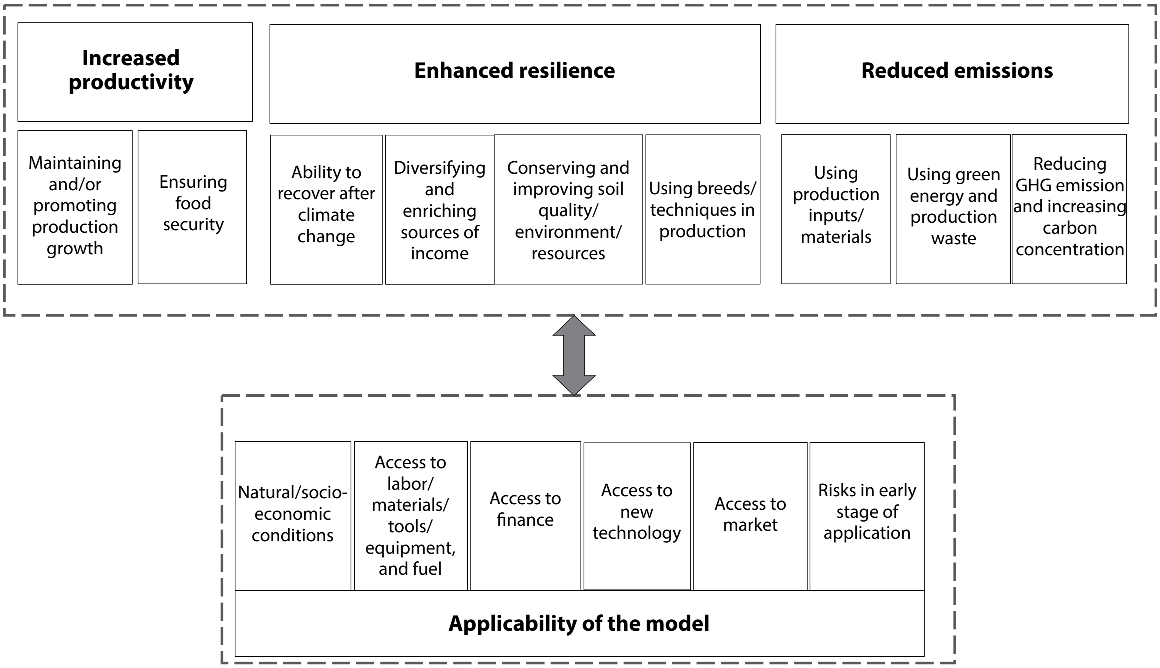

Table 1. Detailed proposed set of CSA assessment indicators

CSA Pillars	Broad Indicators	Detailed Indicators
Increased Productivity	Maintaining and/ or promoting production growth	Proportion of land area following the model to total area of the region
		Yield of main crops per unit area
		Yields of livestock per unit area
		• Cost of fertilizer per unit area • Cost of animal feed (model with minor livestock) per production unit • Cost of pesticides and chemicals per production unit • Cost of labor per production unit • Energy costs per production unit • Income from main crops per production unit
	Ensuring food security	Contributions from the model to total income of households
Enhanced Resilience	Ability to recover after climate change	Duration of "suffering" of crops/livestock from climate change impacts
		Frequency of expressing symptom of "suffering" from climate change in crops/ livestock
		• Yield losses of crops/livestock • Losses in income from the model • Time required to restore production after impact
	Diversifying, enriching income	Number of household income sources (from kinds of crops and livestock)
	Improving soil quality/ environment/ resources	Proportion of land area proactive in amount of irrigation after application of the model
		• Proportion of production area using organic materials instead of chemicals on land applying the model • Effective use of water (the amount of water required for one unit of product) • Analysis results of soil properties in the model
	Use breeds/ technique in production	Proportion of area in the model using new breeds resistant to unfavorable conditions
		Proportion of area in the model applying reasonable fertilizing and pesticide measures (e.g., IPM, GAP), reasonable crop rotation, and soil management
Reduced Emissions	Use materials in production	Amount of inorganic fertilizer per unit product/area
		• Nitrogen (converted to N) per unit product/area • Amount of organic fertilizer per unit product/area • Amount of pesticides (converted to active ingredient) per production unit • Amount of other chemicals (converted active ingredient) per production unit • Number of breeds (of minor livestock) for one production unit
		• Amount of water required per unit of product/area
	Use green energy and production waste	• Amount of fossil fuels used for one production unit • Use of renewable energy and non-fossil energy for one production unit
		Use of waste products (such as land cover materials, fertilizer, or animal feed)
	Reduce GHG emission and increase carbon concentration	Amount of emission (equivalent to total of CO_2) from the model per unit product/ area; burn plants (area or number of households)
		• Changes in total biomass of plants in the model per unit product/area • Concentration degree of carbon in soil when applying the model per production unit

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Table 1 continued

CSA Pillars	Broad Indicators	Detailed Indicators
Applicability	Natural/ socioeconomic conditions	Relevance of the model to scale of household farming area
		• Relevance of the model to infrastructure conditions of fields • Infrastructure conditions of local irrigation systems • Relevance of the model to policies and orientations of the locality • Requirement for new policies to promote the application of the model
	Access to labor/ materials/tools/ equipment, and fuel	• Ability to meet the requirement of local labor • Popularity of organic fertilizers used in the locality in the model • Popularity of new pesticides used in the locality in the model • Popularity of new probiotics and chemicals used in the locality in the model • Popularity of kinds of equipment used in the locality in the model • Popularity of fuel consumed in the locality in the model • Popularity of some breeds needed in the model
	Access to finance	• The amount of financial investment required to set basic infrastructure in the model per unit area • Total costs in one year (harvest) per unit product/area of the model • Proportion of the capital support that the model receives from the government to the total supportive capital in the agriculture sector
	Access to new technology	• Relevance of techniques to culture and customs of the locality • Demand of famers for services/knowledge training about biodiversity • Proportion of funding on technical training activities for the model
	Access to market	Ability to sell products from applying the model to local and in external markets
	Risks in application	Latency or time length (years) for the model on harvesting since the beginning

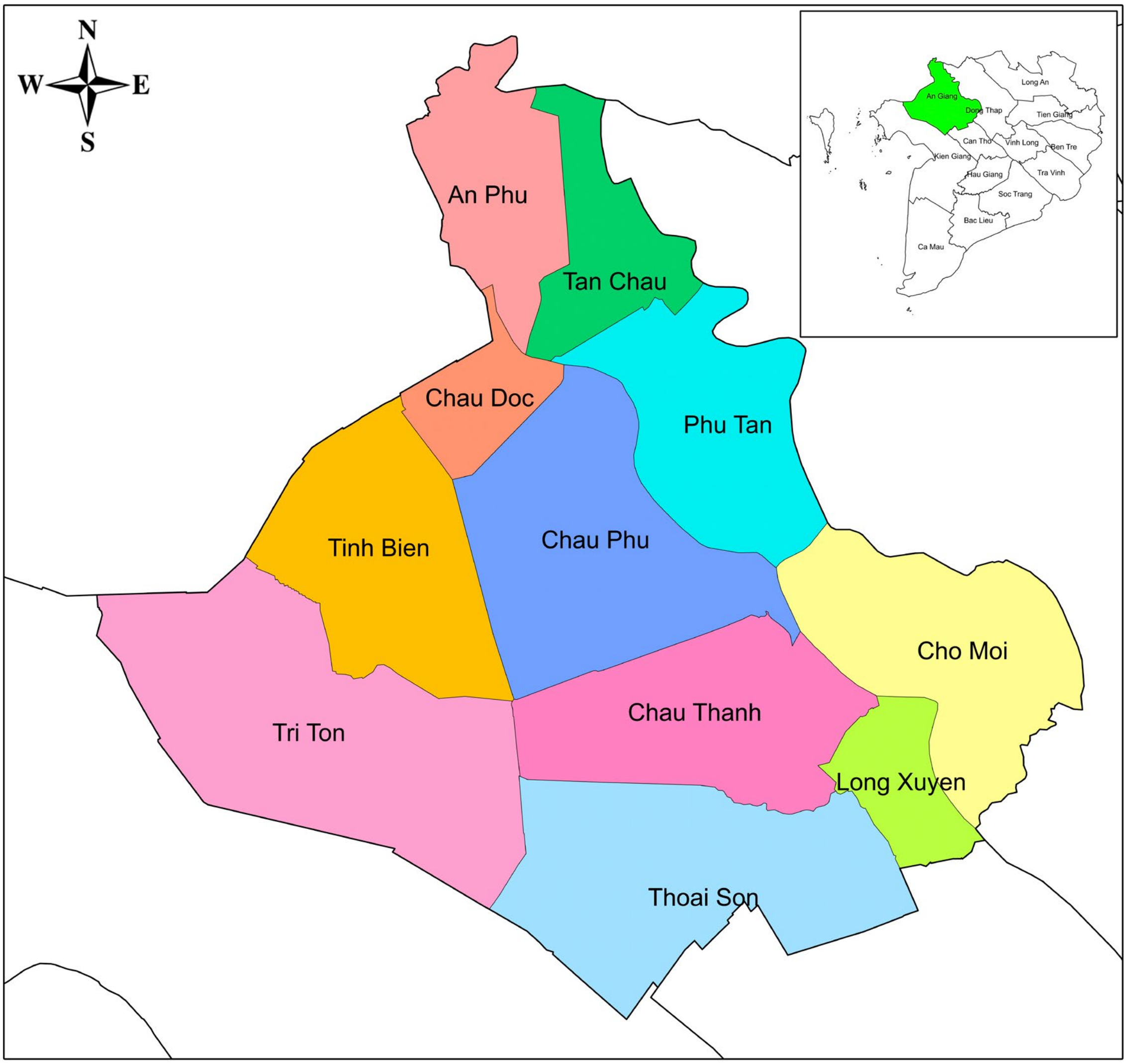
7. ***Utility***. Will the information collected be useful and relevant for adaptive management, results accountability, and learning? Does it measure achievable results?
8. ***Owned***. Do stakeholders agree that this indicator makes sense for testing the adaptation hypothesis?

The evaluation result is measured in terms of percentage of improvement in the mentioned four perspectives with comparison between adopters and non-adopters. The utilization of such a metric, suggested by Pham et al. (2017), would ease comparison and limit confusion in units of indicators, although some indicators remain too general and are difficult to measure.

Research Site and CSA Models

To test our proposed set of CSA assessment indicators, we compared the intensive triple rice cropping system (i.e., control group), the most popular farming system in the VMD, with some popular CSA models. The study site of An Giang province (Figure 2) ranks third in total rice cultivated area in the VMD. Its 257,000 ha rice production area accounts for 13.5 percent of the total rice growing areas of the delta, contributing four million tons of rice annually (Nguyen, Thoi, and Dung 2015). Moreover, this province has large-scale rice-based CSA systems that can provide sustainable alternative livelihoods in the flood season in the VMD. Five rice-based models were selected, namely, (1) Three Reduction Three Gains (3R3G); (2) One Must Five Reduction (1M5R); (3) rice-shrimp rotation; (4) rice-vegetables rotation; and (5) rice-lotus rotation (Table 2). According to local authorities and experts, these rice-based CSA practices have the greatest potential in An Giang province. However, there is lack of data and information on the effectiveness of these models in terms of food security, adaptation, mitigation, and applicability. Thus, the evaluation

Figure 2. Research location



of these practices would provide the central and local governments with scientific basis for CSA strategy and policy formulation and implementation in the future under the context of increasing impacts of climate change.

Survey

A household survey of 300 households was conducted from June to July 2017 to collect primary data on the performance, applicability, and barriers to the adoption of the five rice-based agriculture practices. The basis for the selection of the CSA models was their popularity and development potential in the study site. This is according to the data provided by the Department of Agriculture and Rural Development of An Giang province and the experts from An Giang University and Can Tho University.

Within the same village, farmer households were randomly chosen and grouped in two: (1) a targeted group that includes households who had been adopting CSA techniques, and (2) a control group that includes the conventional households who planted triple rice and did

Table 2. Summary of the benchmark model and selected CSA models

Model	Start Year	Description	Application Scale in the VMD
Triple Rice	Early 1990s	In this system, farmers use short-term, high yield, and low-medium quality rice varieties in good irrigation condition (i.e., inside dike system). On average, triple rice fields are exploited for about 11 months per year. The total time gap between crops is just about one month. Heightened dikes enable the cultivation of the third crop during the flood season but cut off the land from floodwater that brings sediments and attached nutrients. The annual returns of the three-crop rice model are small at VND[1] 44–51 million per hectare.	About 900,000 ha
3R3G	2004	The model originated from the Integrated Pest Management (popularly known as IPM) model. "Three reductions" refers to reducing three input factors (i.e., seeds, inorganic fertilizers, and pesticides). "Three gains" means three higher output results (i.e., yield, quality, and profit).	Not applicable
1M5R	2004	The model originated from the 3R3G model. "One must" refers to the use of certified seeds with quality that meets the Vietnamese quality standard (TCVN) 1776:2004. "Five reductions" refers to reduction in water use; reduction of the amount of seed used (80–100 kg/ha with drum seeder); reduction of postharvest loss; reduction of fertilizers (chemical fertilizer is applied using the leaf color chart); and reduction of pesticide use (pesticide is used only when necessary and with the guidance of technical people)	Not applicable
Rice-Shrimp	1960s and rapid development since 2000s	Tiger shrimp or sea crab in brackish areas and giant freshwater shrimp are intercropped with rice. The rice varieties of ST, Mot Bui Do, Nang Keo, OM5451, OM2017, OM6377, and OM6677 are used popularly in the system. Shrimp is raised during the dry season from February to August, while rice is cultivated during the wet season from September to January of the following year.	152,977 ha (28% of the total area of brackish water shrimp farming in the VMD)
Rice-Vegetables	1980s	This model can be (1) one rice crop intercropped with two crops of vegetables, or (2) two crops of rice intercropped with one crop of vegetables, or (3) triple rice and two crops of vegetables.	40,000 ha
Rice-Lotus	2007	This model can be (1) one crop of rice and one crop of lotus, (2) two crops of rice and one crop of lotus, or (3) one crop of rice and one crop of lotus combined with fish farming. For the one crop of rice and one crop of lotus model, rice is planted during winter-spring because it is the most profitable season. After 10 days of harvesting rice, the straw is buried in the soil to provide fertilizers for lotus seeds. Lotus plants are easily cultivated with lower costs for varieties, fertilizers, and caring compared to other crops. Lotus plants are grown only once per year. After three months of growing, the farmers can continuously harvest for three months.	About 1,000 ha

Note: [1] Vietnam Dong; USD 1.00 = VND 23,048.00 (2021) (bloomberg.com/quote/USDVND:CUR) not apply the innovation method of CSA. The distinct groupings of interviewees were purposely designed to collect baseline data that will help analyze differences between the CSA and the regular agriculture practices.

Data were collected using questionnaires administered through face to face interviews. The questionnaires included information about household characteristics, land and land plot characteristics, rice variety production, disaster frequency and its impacts, households' CSA measures, households' rice production income and expenditures, and their knowledge of climate change. The data on agricultural production, disaster impacts, farmer adaptation, and rice production were all collected at the plot level, while other data were collected at the household level.

Survey results show that majority of respondents are middle-aged (54.5 years old), male (71%) and with little education (5.7 years of school on average). Most of them (92%) had knowledge of at least one climate change related slow-onset event (rising temperature) or rapid-onset event (unpredictable/ off-season rain, drought, and flood). On average, each household had a few laborers (two) and a small plot of rice land (1 ha).

Evaluation Method

Step 1. Selection of evaluation indicators

Based on the broad set of indicators illustrated in Table 1, the research team selected eight indicators to assess the performance of five CSA rice models in An Giang province. These are rice yield, net profit, benefit cost ratio, seed use efficiency, nutrient use efficiency, water use efficiency, GHG emission, and applicability (Table 3).

Table 3. Brief description of CSA evaluation indicators used in this study

Indicators	Description/Purposes
Rice yield	This indicator measures productivity, which is defined as rice yield per hectare per crop cycle. An increase in rice yield would be considered positive. The sustainable rice platform (SRP) guiding principle of improved livelihoods gives the rationale for this indicator. The assumption is that increased productivity leads to increased household food security, an increase in marketable surplus, and increased national and international food security.
Net profit	This indicator measures profitability or farmers' net income from rice cultivation. The indicator follows the SRP guiding principle of improved livelihoods. Increased net income leads to increased household capacity to pay for food and health services. It also enhances the attractiveness of rice cultivation and provides increased ability to invest in the farm. Net income is calculated as gross income from the sale of rice crops and alternative products minus total fixed and variable costs. The calculation should also include opportunity cost of family labor.
Benefit cost ratio (BCR)	This indicator measures economic profitability of CSA models.
Input use	This indicator measures the efficiency of input use of CSA models.
Nutrient use efficiency	Reduced cost for fertilizer defines the nutrient use efficiency. The assumption is that improved nutrient management leads to improved yield or decreased input costs, higher profitability, increased food security, less nutrient loss to the environment, reduced eutrophication of waterways, lesser emission of GHG from paddy fields, and decreased energy consumption and GHG emissions from the production and transportation of fertilizers.
Water use efficiency	Water use efficiency is defined as the reduced cost for pumping water for cultivation. The assumption is that improved water use efficiency results in decreased input costs, higher production profitability, and higher resilience to climate change, especially droughts.

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Table 3 continued

Indicators	Description/Purposes
GHG emission	A tool called GrowAsia Counter, developed by Winrock International, calculates the GHG emissions of the selected models. The counter allows estimating the GHG emissions of different agricultural management scenarios for cocoa, coffee, tea, maize, rice, potato, and vegetables/horticulture. Required input information for calculating GHG includes tillage and other soil management practices, nutrient management practices, liming, crop residue burning and decomposition, pesticide and herbicide use, agroforestry practices, fossil fuel use, and rice irrigation. GHG emission is measured in terms of total annual emission of carbon dioxide equivalents or CO_2e.
Applicability	Literature review and expert consultation aided the development of indicators for applicability of CSA practices. These indicators focus on suitability to local natural, economic, and social conditions, local infrastructure, and local planning. Other issues considered include suitability of production technique to local culture and the ability to recover after climate shocks.

Step 2. Scoring of CSA model's applicability

To assess the applicability of CSA models, sub-indicators were employed: (1) suitability of models to local natural, economic, and social conditions; (2) risks in early application; (3) access to labor/tools/equipment; (4) suitability of production technique to local culture; (5) high marketability potential in local markets; (6) ability to recover after climate shocks; (7) high potential of employment generation; (8) conformity/suitability of the model to local planning of socioeconomic development; and (9) suitability of the model to local infrastructure (irrigation and field characteristics). Local authorities, officials, and experts were asked to score from 1 to 6 (where the least suitable, lowest potential, most risky = 1; the most suitable, with highest potential, and least risky = 6).

Step 3. Prioritization and ranking of CSA models

The total score of the five selected CSA models formed the final prioritization. Each indicator was scored from 1 to 6, with 6 for the highest percentage of increase and 1 for the lowest percentage of increase compared to the control group (i.e., triple rice). These scores were combined with the scores in step 1 to form the final total scores. The CSA model with the highest score would receive the highest priority among the five CSA options.

RESEARCH RESULTS

Table 4 summarizes the performance of selected CSA models in comparison with the control group based on eight assessment indicators. Regarding rice yield, the 1M5R model recorded the biggest improvement followed by the 3R3G model. On the other hand, rice yield of the rice-shrimp rotation, rice-upland crop, and rice-lotus rotation was not different from their control groups.

In terms of net profit, the rice-shrimp model had the highest performance. Its net profit was two times higher than the second highest rice-vegetables model. This high net profit of rice-shrimp can be attributed to high profit from shrimp. In contrast, the 1M5R had the smallest improvement in net profit.

Table 4 shows that the efficiency of investment in the rice-shrimp model is the highest, while that in the rice-vegetables model is the lowest. Particularly, the BCR of the rice-shrimp model improved by 108 percent compared to the control group. The second and the third most efficient models are the rice-lotus and the 3R3G (72.8 percent and 59.5 percent, respectively). In contrast, the figure for the 1M5R model was relatively low at 7.7 percent. It is noticeable that the BCR for rice-vegetables model decreased by 11.2 percent, showing that this model has lower investment efficiency than the control group.

Table 4 also shows that the seed use efficiency of the rice-lotus, 1M5R, and 3R3G models

Table 4. Comparison CSA performance and control group

Indicator	Performance	1M5R	3R3G	Rice-Shrimp	Rice-Vegetables	Rice-Lotus
Rice yield	Net value (ton/ha/season)	8.14	7.92	6.94	6.94	6.94
	Difference from control group (%)	4.84	1.80	0	0	0
Net profit	Net value (VND million/ha/year)	40.14	53.37	89.10	64.40	51.90
	Difference from control group (%)	5.62	40.44	131.40	67.33	34.86
Benefit cost ratio	Net value (times)	4.00	6.00	7.00	3.00	5.87
	Difference from control group (%)	7.86	59.48	108.00	−11.18	72.81
Seed use efficiency	Net value (kg/ha/season)	110.00	110.00	150.00	150.00	40.5
	Difference from control group (%)	15.00	15.000	0	0	72.96
Nutrient use efficiency	Net value (VND million/ha/year)	10.49	10.49	5.30	11.97	7.86
	Difference from control group (%)	22.00	22.00	50.00	−12.77	25.95
Water use efficiency	Net value (VND million/ha/year)	1.10	1.10	0.64	1.03	0.88
	Difference from control group (%)	22.00	22.00	50.00	19.00	30.70
GHG emission	Net value (Tons CO2e/ha/year)	7.79	7.79	7.02	6.52	5.73
	Difference from control group (%)	46.00	46.00	48.00	52.00	58.00

increased by approximately 73 percent, 15 percent, and 15 percent correspondingly. On the other hand, the figures for the rice-shrimp and rice-vegetables models are equal to zero, indicating that applying these models did not help increase seed use efficiency.

The results also present that nutrient use efficiency of CSA models was significantly higher than that of conventional ones, except for the rice-vegetables model. The rice-shrimp model had the biggest improvement of 50 percent, followed by rice-lotus, 1M5R, and 3R3G models (more than 20 percent). In contrast, nutrient use efficiency of the rice-vegetables model decreased by nearly 13 percent compared to its control group.

Regarding water use efficiency, all CSA models showed improvement in this category. Rice-shrimp model topped the list (50 percent) followed by rice-lotus, 1M5R, and 3R3G models (20 percent each). The least water use efficient CSA model is rice-vegetables, but still attaining water use efficiency improvement close to 20 percent over its control group.

All CSA models produced less GHG emissions than the traditional practices according to the analysis. Rice-shrimp and rice-lotus models achieved the highest percentage of GHG emission reduction (52% and 58%, respectively) compared to its control group. The 1M5R and 3R3G models had the smallest reduction (46 percent each), but still a significant difference from the control groups.

Regarding applicability, Table 5 indicates that the 1M5R model had the highest score, followed by the 3R3G, rice-shrimp, rice-lotus, and rice-vegetables models, respectively.

The highest prioritized CSA options are rice-shrimp and rice-lotus models (Table 6). The rice-shrimp system is considered as an effective measure to cope with severely prolonged drought and salinity intrusion, while the rice-lotus model is being expanded due to its suitability to socioeconomic conditions in the VMD. Other potential models for up-scaling are 3R3G and 1M5R. The 3R3G and 1M5R models are being applied prominently in VMD provinces. The rice-vegetables model is at the bottom of prioritization ranking for up-scaling because of its low economic efficiency and low resilience to climate change (i.e., droughts and salinity intrusion).

Table 5. Applicability evaluation results of selected CSA practices

Indicators	3R3G	1M5R	Rice-Shrimp	Rice-Vegetables	Rice-Lotus
Suitability of models to local, natural, economic, and social conditions	5	6	4	3	2
Risks in early application	6	5	2	3	4
Access to labor/tools/equipment	6	5	4	1	3
Suitability of production technique to local culture	6	5	4	2	3
High marketability potential in local markets	2	3	4	1	6
Ability to recover after climate shocks	3	4	2	5	6
High potential of employment generation	5	6	4	3	2
Conformity/suitability of the model to local planning of socioeconomic development	5	6	4	3	2
Suitability of the model to local infrastructure (irrigation and field characteristics)	5	6	4	2	3
Total	**43**	**46**	**32**	**23**	**31**

Table 6. Scoring results of analysed CSA models

Indicator/Model	1M5R	3R3G	Rice-Shrimp	Rice-Vegetables	Rice-Lotus
Rice yield	6	5	2	2	2
Net income	2	4	6	5	3
BCR	3	4	6	1	5
Input use efficiency	2	2	1	1	6
Nutrient use efficiency	2	2	5	1	4
Water use efficiency	2	2	5	1	4
GHG emissions	1	1	3	4	5
Applicability	6	5	4	2	3
Total score	**24**	**25**	**32**	**17**	**32**
Rank	**4**	**3**	**1**	**6**	**1**

DISCUSSION

CSA is a new concept despite the evolution of CSA-related agricultural models for a long time. Many stakeholders in Vietnam still express difficulty in understanding CSA and in clearly distinguishing between CSA and other related terms. Awareness of CSA is limited at both national and local levels. In addition, few studies have worked on developing a comprehensive set of CSA evaluation indicators applicable to Vietnam despite a remarkable progress in establishing CSA assessment framework in the world.

The set of indicators proposed in this study is crucial to provide guidance and connect farmers to policymakers who institutionalize evidence-based policies to support CSA implementation, farming practices, attracting investments, and encouraging application of new science and technology. Compared to other CSA evaluation indicators, the proposed set of indicators here has the following advantages:

1. It can provide decision makers with a comprehensive view of a CSA model. As these indicators cover all four pillars (productivity, adaptation, mitigation,

and applicability), decision makers can carry out multidimensional evaluation of CSA models under different time frames (short-term, medium-term, long-term) and different scale (micro, meso, macro).

2. The proposed indicators are highly flexible, collectible, and measurable, facilitating measurements and calculations. In case the information/data is unavailable, practitioners can change to other indicators. Thus, this set of indicators are usable for a wide range of decision-making process.
3. For policymakers and governors, they can use these indicators to design policies to promote CSA, as well as to integrate CSA into socioeconomic strategies at the national and local levels. Donors, investors, and banks can also use this framework to select eligible agricultural and rural investment projects. Researchers can employ these indicators for academic purposes.

Nevertheless, there were some problems encountered in this study during indicator testing. First, not all indicators were collected and calculated due to constraints in information availability and limited awareness of CSA-related issues among stakeholders (local authorities, officials, and farmers). Second, this set of indicators was only tested for a specific type of CSA—the rice-based system—while there were several CSA models in livestock, fishery, agroforestry, and other sub-sectors. Thus, further research is necessary to validate and finalize the set of indicators for these CSA types.

CONCLUSION

This research developed a comprehensive set of CSA evaluation indicators by customizing international tools and approaches to Vietnam's conditions. It focused on quantitative indicators to facilitate measurements and calculations. The set of indicators consists of specific indicators in food security, adaptation, mitigation, and applicability.

The testing result of five rice-based CSA models shows that the indicators are able to compare and rank models, which is relatively close to real practice and awareness. The rice-shrimp model, which ranked first, is considered as one of the most effective measures for adapting to climate change in the VMD. However, this prioritization order is only suitable for the VMD, particularly for An Giang province. The application of the prioritized CSA models to other regions would need further research since the CSA prioritization varies across regions, depending on site specific conditions. Nevertheless, this study can be used as a guide in developing indicators for other regions.

CSA options are potentially suitable for long-term gain, particular the rice-shrimp rotation practice. Moreover, the CSA can contribute to more sustainable and climate resilient agricultural development, although in some cases, it may reduce immediate and short-term income of farmers. Therefore, to upscale CSA practices, support policies and strategies are necessary.

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