Theme 2: Inclusive and Sustainable SEAP

Discussion Paper No. 6

Science-Based Approach to Promoting the Adoption of Safe and Environment-Friendly Practices and Policy Directions*

The Discussion Paper Series of the Greater Mekong Subregion's (GMS) Core Agriculture Support Program Phase 2 (CASP2) is a platform for stakeholders of the GMS to examine the current and emerging development concerns affecting the subregion especially on but not limited to, food safety and quality assurance, environmental sustainability, and inclusive agro-based value chains. The papers are posted at the GMS Working Group of Agriculture's (GMS WGA) website (www.gms-wga.org).

The information and views expressed in the papers are those of the author/s and do not necessarily reflect the official opinion of the GMS WGA.

* The paper is based on a research work of the Institute of Agricultural Environment of the Ministry of Agriculture and Rural Development in Viet Nam. The paper is titled, *Sustainable Paddy in Red River Delta through Recycling Crop Residues toward Fertilizer Usage and Toward Green-House Gases Emission Reduction*. The research was one of the letters of agreement between the Asian Development Bank and the Ministry of Agriculture and Rural Development of Viet Nam and financed through technical assistance (TA 8163), Promoting the Implementation of the Core Agriculture Support Program (Phase 2). The GMS Working Group on Agriculture supervised the various letters of agreement-funded works. Highlights of this research work and their policy implications were written by Apichai Thirathon and Lourdes Adriano, Working Group on Agriculture Secretariat.

Contents

Box

Figures

Tables

Notes:
In preparing the paper, or by making any designation of or reference to a particular territory or geographic area in this document, the authors do not intend to make any judgment as to the legal or other status of any territory or area.
The symbol "$" refers to the United States dollar.

Abbreviations

ADB	—	Asian Development Bank
CFA	—	climate-friendly or smart agriculture
CH_4	—	methane
GDP	—	gross domestic product
GHG	—	greenhouse gas
GMS	—	Greater Mekong Subregion
ha	—	hectare
IAE	—	Institute of Agricultural Environment
Lao PDR	—	Lao People's Democratic Republic
LOA	—	letter of agreement
MARD	—	Ministry of Agriculture and Rural Development
N_2O	—	nitrous oxide
NPK	—	nitrogen, phosphorous, potassium
PRC	—	People's Republic of China
R&D	—	research and development
SRP	—	Sustainable Rice Platform

Executive Summary

The Ministry of Agriculture and Rural Development is seeking “climate-friendly or -smart agriculture” measures that will ensure sustainable resource management and resilience to climate change in the rice economy. Through a letter of agreement between the Asian Development Bank and the Ministry of Agriculture and Rural Development, the Institute of Agricultural Environment (IAE) undertook a technical investigation and produced the report, *Sustainable Paddy in Red River Delta through Recycling Crop Residues toward Fertilizer Usage and toward Green-House Gases Emission Reduction*.

This paper summarizes the research—its methodology, its findings, and the lessons learned from the study. Directions for research and development (R&D), and policies are discussed in the context of their implications for the strategic restructuring and repositioning of the rice economy of Viet Nam and its role in the Greater Mekong Subregion (GMS) rice value chain. The last section concludes with the way forward.

The Research Study

Project site and problems. Nam Dinh Province was selected as the pilot area for the study. Nam Dinh is situated in the Red River Delta of northern Viet Nam and is the country’s second largest rice producing region.

Farmers’ incomes from rice production have become less stable and secure as the soil has become less productive due to excessive use of fertilizers; costs of production continue to rise with the continued price increases of synthetic agrochemicals; and rice production losses have resulted from frequent flooding, drought, and salt intrusion due to climate change. Farmers lack the knowledge of viable climate-friendly or smart agriculture practices that would help them adapt, mitigate, and cope with the vagaries of climate change.

Methodology. To reduce the problem of overuse of fertilizers and lack of crop residue management, the IAE examined five fertilizer mixture menus in control tests (CTs):

- CT1—the conventional method applied prior to tests, using 100% nitrogen, phosphorus, and potassium (NPK)[1];
- CT2—75% NPK application;

[1] 100% NPK = $195N+69P_2O_5+63K_2O$ kg/ha for spring rice and $215N+83P_2O_5+42K_2O$ kg/ha for summer rice.

- CT3—compost[2] plus 75% NPK;
- CT4—biochar[3] plus 75% NPK; and
- CT5—a combination of 50% of compost applied in CT3 (5 tons/ha), 75% of biochar applied in CT4 (1.125 tons/ha), and 50% of NPK applied in CT1.

The IAE employed several approaches to find out which options produce greatest yield, lowest greenhouse gas (GHG) emissions, and greatest increase in farmers' incomes. The methods of analysis included (1) scientific approaches (farm trials, using the DeNitrification-DeComposition model for GHG emissions, geographic information systems, and statistics); (2) an interdisciplinary approach (physical science of climate change and benefit–cost analysis to determine the economic gains); and (3) a participatory approach (using focus groups and key informants). On the basis of the findings, the IAE conducted awareness-raising and capacity-building activities.

Results. The major findings are as follows:

- Applying biochar, compost, and combinations of these increased the rice yield by an average of 2.4%–11.1% over the intensive use of agrochemicals alone (CT1).
- Applying compost mixed with 75% NPK (CT3) yielded the highest productivity rise, followed by biochar mixed with compost and NPK (CT5). Reducing NPK by 25% (CT2) significantly reduced the yield, by an average of 4.5% from the conventional approach (CT1).
- Soil nutrients and water absorption improved when biochar and compost were applied (although the tests were too few and of short duration for the finding to be considered scientifically conclusive).
- GHG emissions declined significantly when applying biochar mixed with 75% NPK (CT4), followed by composting, biochar, and reduced NPK (CT 5).
- In the longer term (30–40 years), the model simulation suggested GHG emissions from Nam Dinh would increase if farmers continue to apply only chemical fertilizer for rice, but would be significantly reduced if biochar is applied with or without mixing it with compost and NPK.
- The benefit–cost ratios with biochar and compost were lower than the conventional approach's ratio because of the higher labor costs incurred for producing biochar and compost at the farm level. More research is needed in this regard.
- A 25% reduction in fertilizer use (CT2) resulted in the lowest production cost among the five CT options, and the highest net benefit–cost ratio despite garnering the lowest gross benefit among the five options.

[2] Compost made from rice straw applied at 10 tons per hectare.
[3] Biochar made from rice straw applied at 1.5 tons per hectare.

Lessons learned. Three major lessons arose from the trials. First, the present agronomic practice of intensive application of fertilizers (and pesticides) coupled with the near absence of proper agriculture residue management proved hazardous to the environment, detrimental to rice farmers' incomes and livelihoods, and contributory to GHG emissions.

Second, farmers found the options of reducing synthetic agrochemical use and replacing it partly with biochar and/or compost were desirable, because of the reduced environmental footprint and a slight enhancement of their gross revenue streams. However, the farmers were not inclined to change their current practice because biochar and compost making are labor-intensive and thus also costly. For farmers to adopt environment- or climate-friendly innovations, they would need to gain economically from the change.

Third, the IAE action of linking research with training for and awareness-raising among the farmers and government extension workers hastened the adoption process.

Research and development agenda. The recommended agenda for R&D is as follows:

- Additional R&D support is needed, initially from the government and subsequently through public–private collaboration. Experience has shown that the government should set aside at least 1% of the agricultural GDP for agricultural R&D. For example, research is needed to develop technologies for producing organic fertilizers that reduce labor inputs and are women-friendly.
- Test input mixtures that could be suitable for other agroecological zones.
- Look into the viability of commercial production and marketing of biochar and compost. Government support may be needed initially to assist the private sector in establishing biofertilizer value chains.
- Implement policies that support farmers to use biochar and enterprises to mass produce and market biochar and other biofertilizers.
- Develop an integrated and interdisciplinary approach to crop residue and natural resource management, including water-use efficiency, seed varietal development, and land-use management.
- The Vietnam National Extension System should work closely with the IAE.
- The IAE's technical expertise on climate change modeling and knowledge of economic analysis should be shared with other research institutes and extension departments in the agriculture ministries of the GMS' less-developed economies, particularly Cambodia, the Lao People's Democratic Republic, and Myanmar
- For developing sustainable rice and safe and environment-friendly agriculture products, explore knowledge sharing modalities such as the internet and networking among the GMS-based research institutes.

Policy Directions

While the government is shifting toward a more sustainable agriculture pathway, strategic restructuring and repositioning are urgently needed, especially regarding the overuse of chemical fertilizer and the low labor profitability. The following policy directions are suggested:

- A policy road map is needed with a strategic set of programs on soil nutrient development; crop residue management (including promoting biochar and composting); and integrated pest management.
- One program could be to develop centers of excellence on crop residue management innovations such as biochar and composting. Thailand has indicated its interest in developing such a center. Similarly, a consortium or networking of the research institutes, academe, national research and extension systems, and the private sector could be formed to share knowledge and expertise.
- Internationally recognized metrics for sustainable rice are needed. The Sustainable Rice Platform has recently developed a global rice standard that combines the parameters for technology and good agronomic practices with synergies among productivity, sustainability, food safety and quality assurance, and value distribution. The application of the Platform's sustainable rice standard as a basis for harmonizing the food safety and quality assurance standards for sustainable rice within GMS merits closer consideration.
- A policy on extension services is needed that ensures close collaboration between research and academic institutions on the one hand and government extension agencies on the other; triangulation of public research, extension services, and private agribusinesses; incentives for developing "on-the-ground" soil and plant "doctors" and service centers; and knowledge and expertise sharing between fairly advanced rice economies (Guangxi and Yunnan in the People's Republic of China, Thailand, and Viet Nam) and less-developed ones (Cambodia, the Lao People's Democratic Republic, and Myanmar).
- A policy agenda is needed for strengthening the farmers' links to their downstream partners in the rice value chain.
- To substantiate the GMS Strategy for 2018–2022, a road map is needed for a GMS sustainable rice value chain. The map should have the following aims: (1) improved rice productivity and diversification; (2) value chain facilitation (especially reduced wastes and losses in rice); (3) a predictable trade policy and trade facilitation services for cross-border rice trade; and (4) support for market intelligence, branding, and marketing campaigns.

Conclusion and Way Forward

Using the lessons learned from the IAE study and their implications for Viet Nam's rice economy, this paper posits the directions of the R&D and the policy agenda for influencing the change in the growth course of Viet Nam's rice subsector to one that is environment friendly, productive, inclusive, and climate resilient.

Moving forward, the restructuring of Viet Nam's rice economy needs to be contextualized as an integral part of the GMS' rice value chain. The GMS Strategy for 2018–2022 envisages the subregion as a web of interlinked supply chains for safe and environment-friendly agro-based products. One of the chains will surely be the GMS sustainable rice value chain. At this stage, it may be judicious for the GMS to develop a road map for a subregional rice value chain that is premised on the key principles laid out in the GMS strategy and with a thematic focus on food safety and quality assurance, inclusiveness, and sustainability. For Viet Nam, the urgent agenda will be moving toward producing rice with less inputs and closer links between farmers and their downstream partners, locally and at an intra-GMS level. With better connected GMS rice value chains and a rice standard that is internationally recognized, the branding of a distinctly GMS rice will be the way for the future.

1. Introduction

Since Doi Moi in 1986, agriculture productivity in Viet Nam has more than tripled, enabling the country to become the world's largest exporter of cashew and pepper; the second largest of coffee and cassava, and third largest of rice and fishery products. Viet Nam's export of rice has shifted from low-quality to fragrant rice. The country's rice exports averaged 2.5 million tons yearly in 2010–2012, contributing 40% of the country's total agriculture exports (World Bank et al. 2016).

This remarkable growth in agriculture (and especially rice) contributed to Viet Nam's graduation to a lower-middle-income country. It also served as a major driver of poverty reduction—the poverty level has dropped from 64% in 1993 to about 8.4% in 2014 (World Bank et al. 2016).

However, agriculture's growth has declined. Between 2008 and 2013 the average annual growth rate was a modest 3.2% compared with the gross domestic product (GDP) rate of 5.7%. Agriculture contributed about 19.4% of GDP during this period, a decrease from the high of 38.7% in 1990. Despite slower growth and a diminishing contribution to GDP, the sector plays a vital role in the country's socioeconomic development, providing employment for 48% of the labor force and the main livelihood source for two-thirds of the population.

For Viet Nam to move up from its present lower-middle-income status to the upper-middle rung, the country's agriculture sector, and in particular its rice subsector, will need to be reinvigorated. Agriculture growth has been attributed largely to expansion of the agricultural area and rice intensification. The sector's labor productivity has been low—lower than that of Indonesia, Thailand, and the Philippines (ADB 2017). The key challenge is to develop an agriculture growth path that will foster more efficient, inclusive, and sustainable agro-based value chains. Four areas will need to be addressed (ADB 2017). The first relates to state dominance in key value chain segments, such as input supply, postharvest processing, and marketing. Second, rural infrastructure needs expansion and integration. The third involves the adoption of sustainable resource management. And fourth is the urgent need to address the worsening impacts of climate change on the agriculture sector.

The Ministry of Agriculture and Rural Development (MARD) is searching for measures that will ensure sustainable resource management and resilience to climate change in the rice economy. MARD encourages "climate-smart or -friendly agriculture" (CFA) measures that will perform multiple tasks: increase carbon sequestration in below- and above-ground biomass, strengthen the resilience of the sector to the vagaries of climate change, improve soil health, contribute to increasing productivity, and generate higher incomes for the small-scale rice farmers.

Small-scale rice farmers increasingly rely on agrochemical fertilizers to spur production. However, the overuse of agrochemicals is adversely affecting soil health and biodiversity in general. Water quality is also deteriorating due to pollution from agrochemical residues, exacerbated by crop residues that are dumped into the inland water systems. Inefficiencies in water use lower the quantity of this precious resource, especially as agriculture uses more than 80% of the available fresh water.

The problems of deteriorating resource quantity and quality in the rice subsector are exacerbated by climate change. Viet Nam is among the world's top 10 countries whose agriculture is most vulnerable to the vagaries of climate change, such as changing seasonal weather patterns, rising temperatures, increasing frequency and intensity of extreme weather events, and rising sea level. The impact of climate change has increased the vulnerability of the sector's natural resource base to natural calamities, which have disproportionate consequences on the incomes and lives of the poor. Moreover, agriculture and forestry contribute to climate change as they are the largest sources of greenhouse gasses (GHG) emissions in Viet Nam.

The Institute of Agricultural Environment (IAE), a research arm of MARD, did a technical study of one of the CFA measures, specifically the conversion of rice crop residues into organic matter, and use of this matter to reduce agrochemical application. The study involved testing a "menu" of fertilizer mixtures including chemicals and organic matter as key ingredients to rice production. The environmental, climate change, and economic impacts of the mixtures were assessed and compared. The study aimed to contribute to agriculture innovations that would (1) reduce the use of costly and environmentally damaging synthetic agrochemicals in the production of rice, (2) significantly enhance soil health, (3) reduce the subsector's contribution to GHG emissions, and (4) improve rice farmers' incomes. It was financed in 2015 through a letter of agreement between the Asian Development Bank (ADB) and MARD under a technical assistance project (TA 8163) that supported the Greater Mekong Subregion (GMS) economies to implement their Core Agriculture Support Program, Phase 2. The IAE subsequently produced the report, *Sustainable Paddy in Red River Delta through Recycling Crop Residues toward Fertilizer Usage and toward Green-House Gases Emission Reduction.*

The current paper summarizes the research. It describes the project site, and then discusses the IAE's step-wise approach to identifying and selecting the most economically and environment-friendly methods to use biofertilizer. The results of the study are then summarized, lessons learned generated, and the research and development (R&D) agenda as well as the policy directions inferred by the research were discussed. The last section concludes with the way forward.

2. The Project

Agriculture, and especially intensive rice production, contributes significantly to GHG emissions due in part to poor crop residue management. Of the total crop residues generated in agricultural production in 2010, only 10% was used as input fuel in brick kilns and in home cooking; 5% (rice husk and bagasse) for heat generation in boilers and dryers; and 3% as feedstuff for cattle (IAE Survey in 2010, cited by IAE 2016). The bulk, or 80% of the total of crop residues, was either burned or dumped into nearby inland waters.

The IAE proposed that the residues could be converted into compost or biochar and used for soil enrichment, which would also reduce GHG emissions. Biochar application would also decrease the farmers' expenses for fertilizer. Various research has shown the benefits of biochar application, which (1) improves water holding capacity of sandy soil (Briggs et al. 2012); (2) increases the soil pH (Laird et al. 2010); (3) enhances the soil's cation exchange capacity (Peng et al. 2011; Van Zwieten et al. 2010; Yamato et al. 2006); (4) reduces nutrient leaching (Lehmann et al., 2003; Major et al., 2009) and lowers nitrous oxide (N_2O) and methane (CH_4) emissions by improving soil aggregation (Van Zwieten et al. 2009).

Moreover, compost produced from crop residues provides high-quality organic fertilizer. In Viet Nam, composting technologies using sugarcane waste, domestic waste, and waste from processing pineapples and cassava have been applied successfully. For example, the IAE has succeeded in producing microbial products (named "Compost Maker") for making high-nutrient fertilizer and reducing GHG emissions. MARD has approved the application of the compost maker in the countryside.

The IAE's proposal was to produce biochar and compost at the farm level and to examine combinations of fertilizer ingredients including mixtures that use biochar and compost through farm trial testing, scientific diagnostics using environmental and climate models, and benefit–cost analysis. The results of the study were disseminated to farmers and government extension workers to inform them about the inclusive, profitable, and sustainable merits of shifting from conventional rice production dependent on agrochemicals to farming techniques that reduce the use of agrochemicals and employ biofertilizers from recycled crop residues.

2.1. Project site: Nam Dinh

Nam Dinh Province was selected as the pilot area for the trials of different input practices. The province is in the Red River Delta of northern Viet Nam, and is the country's second largest rice-producing region. Rice is the main crop in Nam Dinh. Two crops are grown yearly: one in the dry season (January–June) and one in the rainy season (July–November). In 2013, the province produced close to 1 million tons of rice.

The province has increasingly been frequented by extreme weather occurrences such as powerful typhoons and prolonged drought. Saltwater intrusion has been a rising concern, as it has increased the salinity of rice land. This is exacerbated by farmers' excessive use of low-quality agrochemicals, which has degraded the quality of the rice land. The farmers are applying 215 kilograms (kg) of nitrogen per hectare (ha), which is more than double the optimal amount of 90 kg/ha and nearly triple the amount used by Thai rice farmers, their closest competitors in the rice business (World Bank et al. 2016).

Farmers' incomes have become more unstable and insecure as the soil has become less productive; costs of production continue to rise with the increasing prices of synthetic agrochemicals; and crop losses have increased due the frequent flooding and drought brought on by climate change. Farmers lack knowledge about CFA practices that would help them adapt, mitigate, and cope with the vagaries of climate change.

2.2. Methodology

After selecting the study site, the IAE technical staff employed a step-by-step approach that was science- and evidence-based, iterative (involving 2 cropping seasons), and participatory. The research framework is summarized in Figure 1.

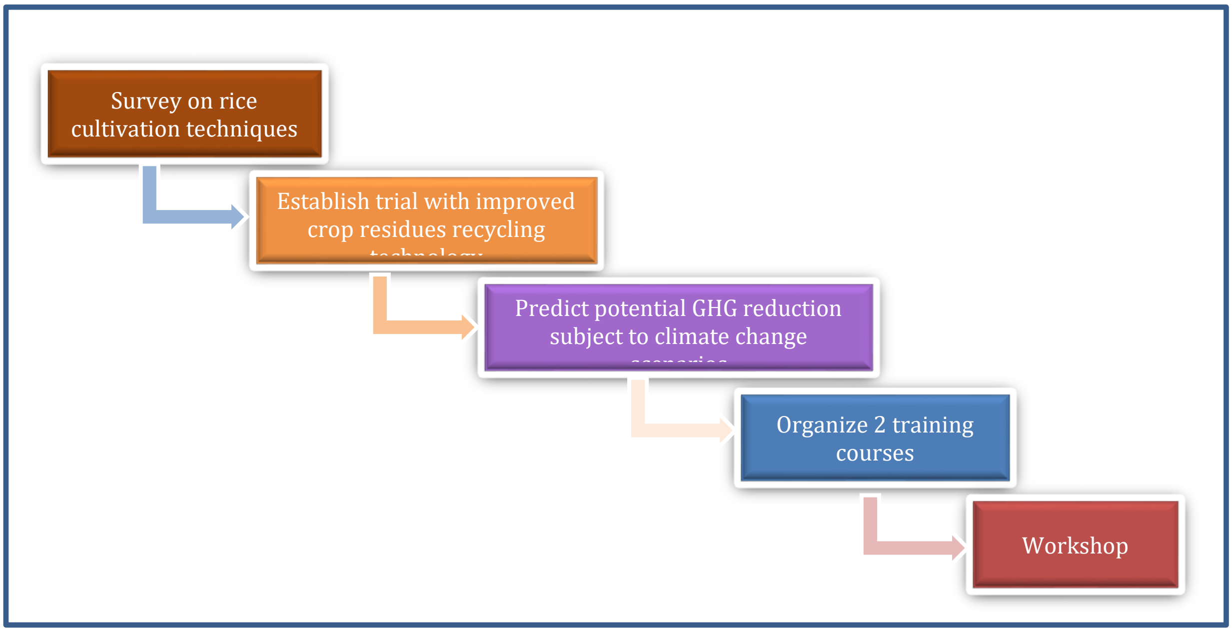


Figure 1 Research Framework

GHG = greenhouse gas.

Source: IAE, 2016

The research framework involved five steps. First, secondary information was gathered to understand the technical aspects of rice production and socioeconomic demographics of the project site (Figure 2). Key information was collected on the quantity, type, and costs of fertilizer; the extent of use of organic fertilizer, biological fertilizer, and biochar; labor use, land use, and other production-related data including weather; and farmers' awareness of climate change concerns. Rice supply, consumption, and sale data were also gathered.

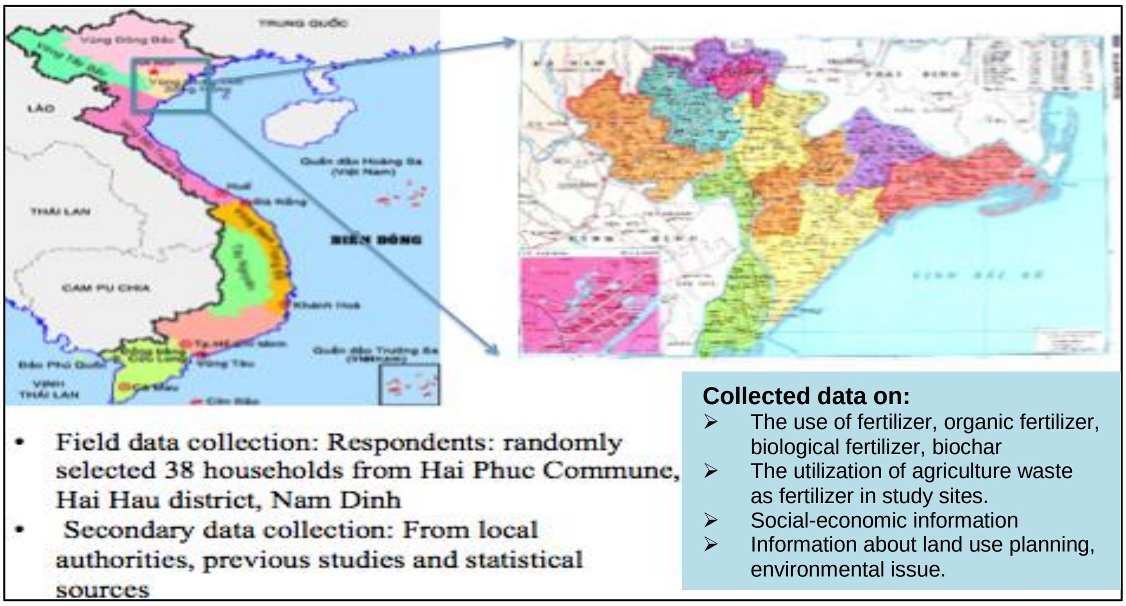


Figure 2: Study Site and Data Collection Methods

Source: IAE, 2016

The research team conducted a participatory rural appraisal in Hai Hau District, Nam Dinh Province using a combination of questionnaires, focus group discussions with 35 households, and interviews with key informants. The purposes of the appraisal were to understand the farmers' perceptions of biochar and the extent to which they use it, and the depth of their knowledge about climate change.

The second step of the research was to set up trials with 3 pilot farm households, including hands-on training on biochar and building a composting facility (Figures 3 and 4) and control testing (CT) of 5 fertilizer mixtures:

- CT1: conventional method prior to the test, which applies 100% nitrogen, phosphorus, and potassium (NPK)[4];
- CT2: 75% NPK;
- CT3: compost[5] plus 75% NPK;
- CT4: biochar[6] plus 75% NPK; and

[4] 100% NPK = $195N+69P_2O_5+63K_2O$ kg/ha for spring rice and $215N+83P_2O_5+42K_2O$ kg/ha for summer rice.
[5] Compost made from rice straw applied at 10 tons/ha.
[6] Biochar made from rice straw applied at 1.5 tons/ha.

- CT5: 50% of compost applied in CT3 (5 tons/ha), 75% of biochar applied in CT4 (1.125 tons/ha), and 50% of NPK applied in CT1.



Figure 3: Producing Biochar from Rice Straw, Using a Kiln

Source: IAE, 2016


Figure 4: Producing Compost from Rice Straw

Source: IAE, 2016

The trials covered two cropping seasons. Trials were monitored regularly at the field level using objective parameters such as crop height, number of effective panicles, yield, soil sampling and analysis of soil elements, monitoring prices of inputs, need for pesticides, volume, and markets.

Third, data were analyzed employing scientific models.

(1) The chamber method (Figure 5) was used to collect air samples for measuring actual methane and nitrous oxide emissions from different practices.

(2) Simulations of climate change scenarios used the DeNitrification-DeComposition for GHG emission model and the methodology developed by the Ministry of Natural Resources and Environment (Figure 6).

(3) The program for predicting GHG emissions from rice fields was based on actual GHG emission measurements at the field levels.

(4) Regression analysis was used to verify the accuracy and veracity of the predicted GHG emission compared to measured values.

(5) DeNitrification-DeComposition for GHG emission results were interphased with a geographic information system to produce emission maps for Nam Dinh and other provinces in the Red River Delta for 2015–2050**.**

(6) Simulations were run to predict the overall impacts of different fertilizer mixtures on GHG emissions, soil enhancement, and productivity.

(7) The effects of different fertilizer mixtures on GHG gas emissions, soil nutrient changes, and yield were subject to statistical analysis.

(8) The net income effects of the different fertilizer mixtures were determined through a simple benefit–cost analysis.

The last step was the IAE extension services—IAE conducted training courses for extension workers, farmers, and local stakeholders, and discussed with them the results of the study. The IAE also organized workshops to present the model applications to local leaders, agriculture extension staff, and farmers with the aim of raising their awareness of the environmental and economic benefits of switching from excessive fertilizer use to a practice that is environment-friendly, climate resilient, and economically beneficial to rice farmers.

Figure 5: Chamber Method for Sampling and Measuring Methane and Nitrous Oxide Emissions

Source: IAE, 2016

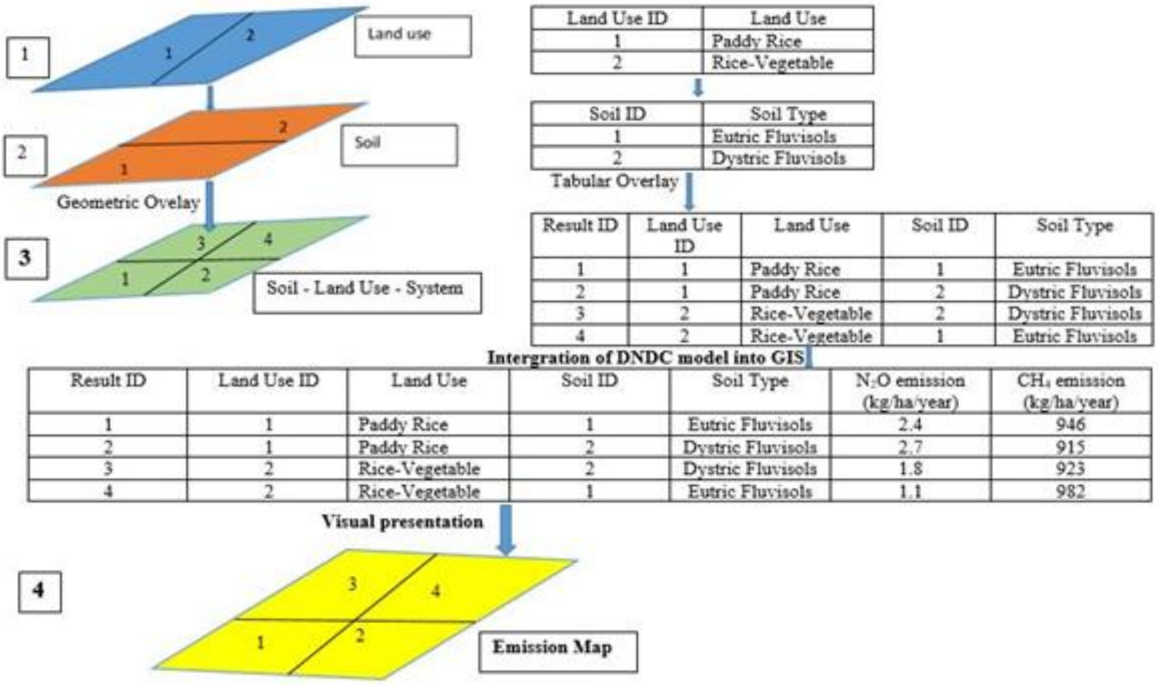


Figure 6: Calculation of GHG Emissions for Nam Dinh and the Red River Delta, Based on the DNDC Combined with GIS

DNDC = DeNitrification-DeComposition for GHG emission, GHG = greenhouse gas, GIS = geographic information system, ID = Identity

Source: IAE, 2016

2.3. Findings

The key findings from the baseline survey for the research and extension work were as follows:

- Rice farmers in Nam Dinh used large (to excessive) amounts of fertilizers, mainly urea, and a compound fertilizer of NPK.
- A majority of the farmers were aware of biochar and composting, but hardly any farmers used them.
- Farmers were aware of climate change, noting the increased frequency of flooding, drought, and salt intrusion in farmland. However, they were not aware of CFA practices such as the appropriate mix of synthetic and bio fertilizers.

The pilot trials showed the following:

- Application of biochar and compost with NPK (CT5) increased plant yield by an average of 2.4%–11.1% over CT1, the conventional intensive use of agrochemicals in rice (Table 1).
- Compost mixed with 75% NPK (CT3) yielded the highest productivity rise, followed by biochar mixed with compost and NPK (CT5). Reducing NPK by 25% (CT2) significantly reduced yield, by an average of 4.5% from the conventional approach (CT1).

- Soil nutrients improved when biochar and compost were applied (although the findings are not scientifically conclusive because of the short duration and low number of observations). Water absorption was also enhanced.

Table 1: Effect of Different Fertilizers on Rice Yield

No	Treatment	Summer Season 2015		Spring Season 2016	
		Yield (t/ha)	Change in Yield Compared with Conventional Treatment (%)	Yield (t/ha)	Change in Yield Compared with Conventional Treatment (%)
1	CT1	4.25		5.25	
2	CT2	4.11	- 3.33%	4.96	-5,58
3	CT3	4.87	+14.5%	5.66	+7,79
4	CT4	4.38	+2.75%	5.36	+2,04
5	CT5	4.58	+7.65	5.49	+4,58

CT = control test, t/ha = tons per hectare.

Source: IAE, 2016

The effects on GHG emissions of the different fertilizer mixtures are shown in Table 2. Applying compost and reduced NPK (CT3) increased GHG emissions the most, even more than the conventional approach. However, the amount of GHG emission declined significantly when applying biochar mixed with 75% NPK (CT4), followed by composting, biochar, and reduced NPK (CT5).

Table 2: Effect of Different Fertilizer Mixtures on GHG Emissions

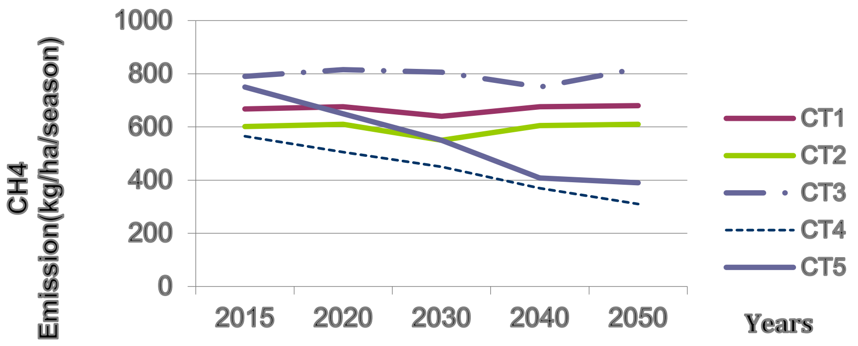
Treatment	Summer			Spring			Total CO_2e (kg /ha/year)
	CH_4 (kg/ha/ season)	N_2O (kg/ha/ season)	Total CO_2e (kg/ha/ Season)	CH_4 (kg/ha/ season)	N_2O (kg/ha/ Season)	Total CO_2e (kg/ha/ Season)	
CT1	576	0,728	14.608	416	0,508	10.559	25.584
CT2	550	0,654	13.953	406	0,472	10.302	24.662
CT3	661	0,752	16.746	464	0,446	11.725	28.935
CT4	473	0,590	11.992	265	0,374	6.727	18.984
CT5	419	0,578	10.642	316	0,432	8.022	18.980

CH_4 = methane, CO_2e = carbon dioxide equivalent, ha = hectare, kg = kilogram, N_2O = nitrous oxide.

Source: IAE, 2016

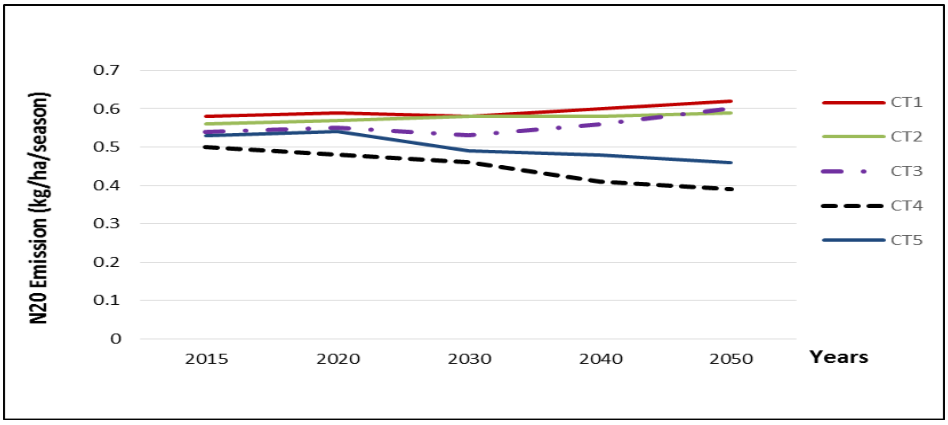
In the longer term (30–40 years), the model simulation suggests an increase in GHG emissions in Nam Dinh if farmers continue to apply only chemical fertilizer for rice cultivation, but the emissions would be significantly reduced if biochar were applied either with or without adding compost (Figure 7).

a. Methane Emissions



- CT4, CT5 decreased GHG substantially
- CT2, while lower than CT1, has the same trend as CT1

b. Nitrous Oxide Emissions



N_2O emission: highest for CT1, lowest and declining for CT4 and CT5. Emission from 2015 to 2050

CH_4 = methane, CT = control test, GHG = greenhouse gas, ha = hectare, kg = kilogram, N_2O = nitrous oxide.

Source: IAE, 2016

Figure 7: Simulation Results for Long-Term Prediction of GHG Emissions in Nam Dinh

The benefit–cost analysis showed that the investment costs of using both biochar and compost were greater than the cost of applying only chemical fertilizer (Table 4). This is due to the high cost of labor for collecting residues and for the biochar or compost making process at the farm level. More research is needed in this regard.

An interesting finding, though, was that a 25% reduction in fertilizer use resulted in the lowest production cost among the five options, and the highest net benefit–cost ratio despite garnering the lowest gross benefit among the five options.

Table 3: Benefit–Cost Analysis for 2 Crop Seasons

Treatment	Investment Cost (C)	Gross Benefit, (B)	Net Benefit, (B-C)	Ratio (B/C)
Summer 2015				
CT1	17.56	34.00	16.44	1,94
CT2	16.15	32.87	16.71	2,03
CT3	20.65	38.93	18.28	1,88
CT4	19.75	34.93	15.18	1,77
CT5	19.86	36.60	16.73	1,84
Spring 2015				
CT1	19.62	42.03	22.41	2,14
CT2	17.93	39.68	21.75	2,21
CT3	22.43	45.29	22.87	2,02
CT4	21.53	42.88	21.35	1,99
CT5	21.34	43.95	22.6	2,06

CT = control test.

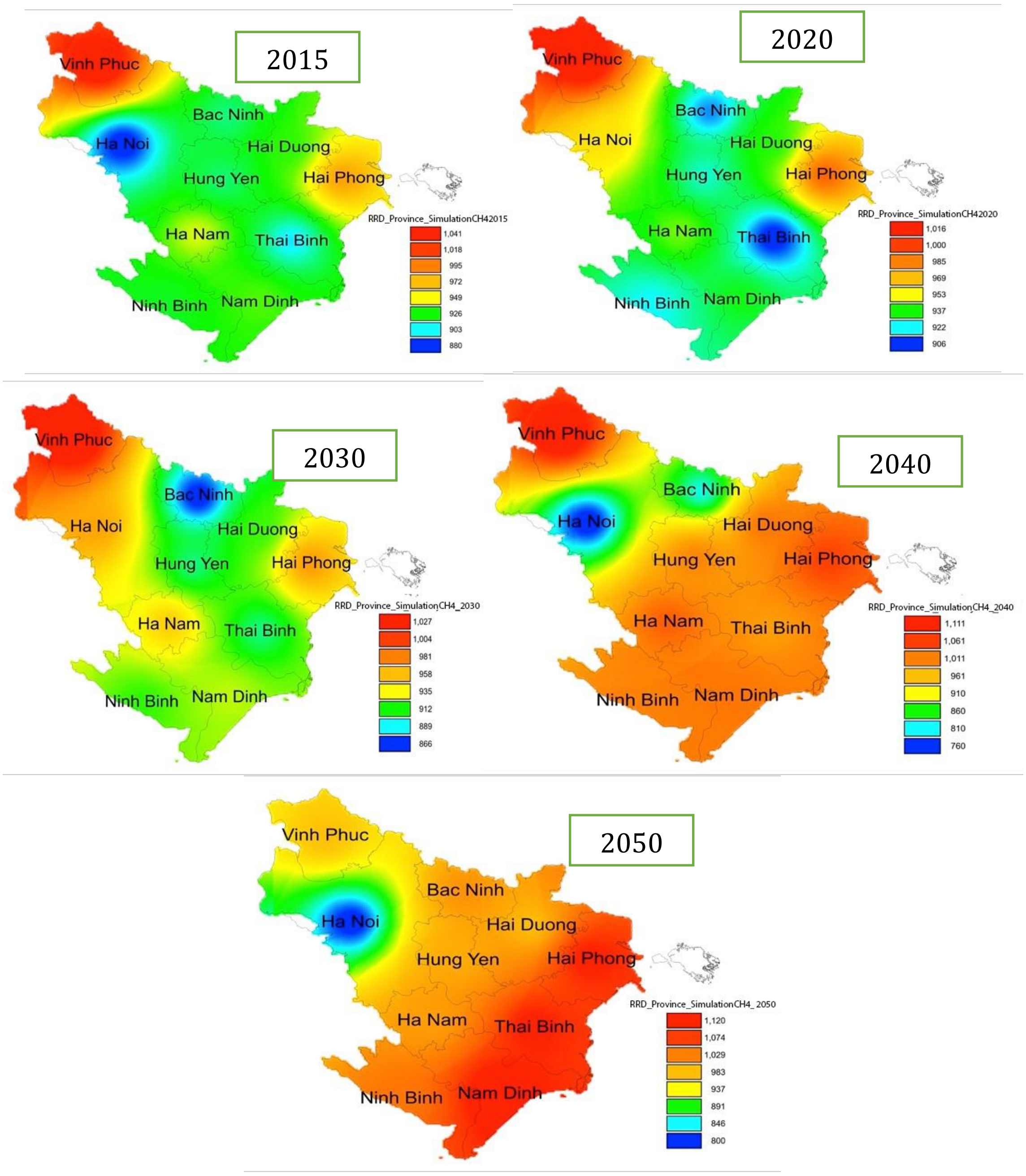
Source: IAE, 2016

After seeing the positive results on the pilot farms and noting the science-based approach for the selection and use of the input mixtures applying recycled agriculture wastes, the farmers and extension workers were favorably influenced about the proposed biofertilizers. They also appreciated that, by adopting the environment and climate friendly practices, they could contribute to averting the adverse effects of climate change. However, the higher labor costs entailed in compost and biochar production were a deterring factor for their potential widespread application in the future.

2.4. Simulation results in the Red River Delta

A status quo scenario of excessive use of agrochemicals showed the results in terms of methane and nitrous oxide GHG emissions.

Methane emissions. Methane emissions were generally predicted to increase from 2015 to 2050, except in Vinh Phuc, where methane emissions rose during 2015–2040, but declined by 2050 (Figure 8). The emission rate was on the rise especially in provinces with large rice areas, such as Hai Duong, Hung Yen, Nam Dinh, and Thai Binh. Methane emission rates climbed to critical levels in these provinces in 2040–2050.

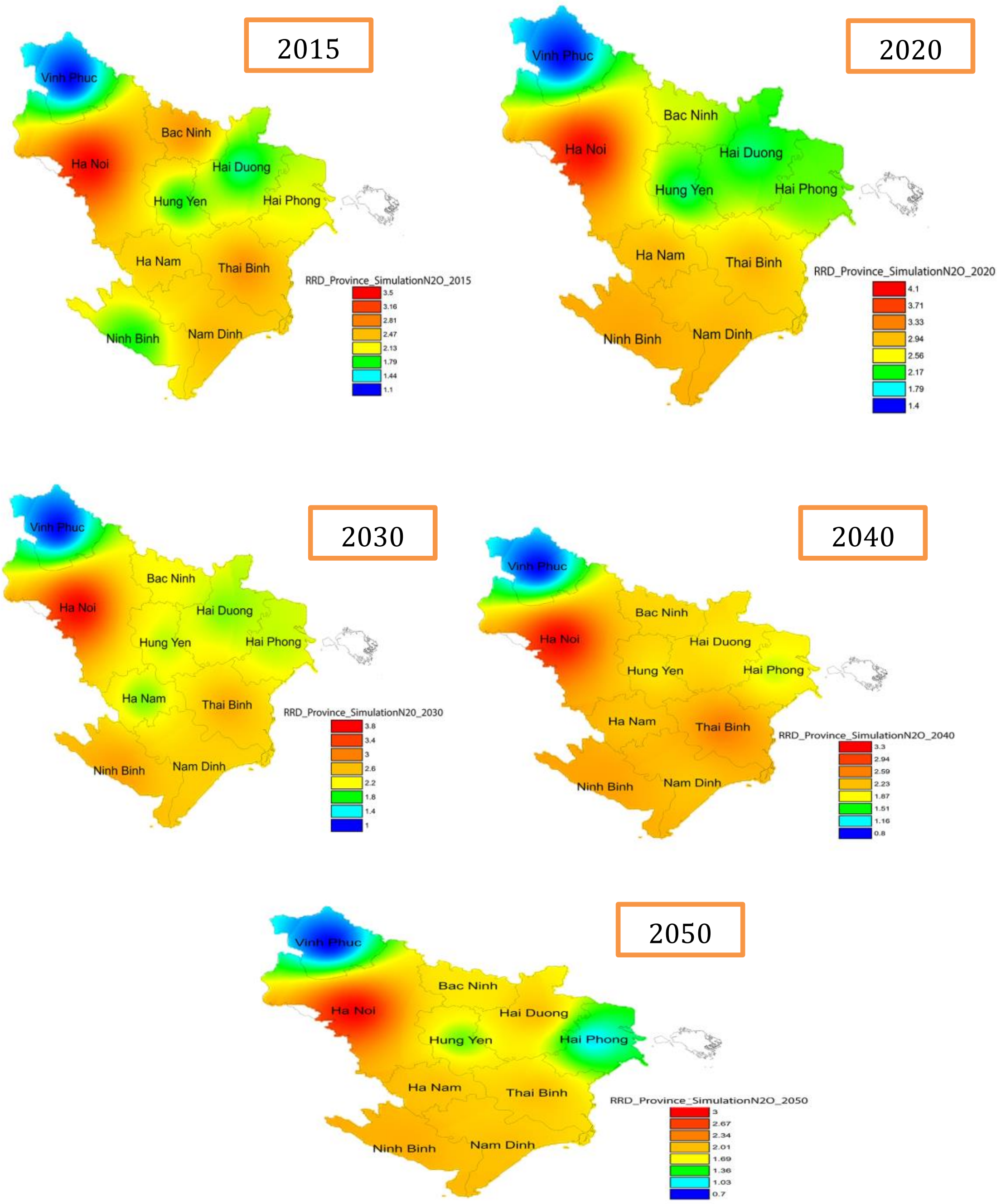


RRD = Red River Delta

Source: IAE, 2016

Figure 8: Methane Emissions, Red River Delta Provinces, 2015–2050 (kg/ha/year)

Nitrous oxide emissions. The simulation results (Figure 9) reveal that from 2015–2050, Ha Noi had the highest nitrous oxide emission, followed by Thai Binh, Nam Dinh, and Ninh Binh. The lower emission points were observed in Hung Yen, Hai Duong, and Hai Phong. Nitrous oxide emissions were rising but did not reached critical levels by 2050.



RRD = Red River Delta

Source: IAE, 2016

Figure 9: Nitrous Oxide Emissions in the Red River Delta, 2015–2050 (kg/ha/year)

3. Lessons Learned

The IAE report generated several lessons. First, the present agronomic practice of intensive rice farming of applying large amounts of fertilizers (and pesticides), coupled with the near absence of proper agriculture residue management, proved hazardous to the environment (particularly to soil quality, water, and biodiversity); detrimental to rice farmers' incomes and livelihoods and vulnerability to the effects of climate change; and contributory to GHG emissions.

Second, IAE's study demonstrated a menu of options that could replace the conventional farming practice. Farmers were interested in the options such as reduced fertilizer use, or reduced fertilizer quantities and replacement with biochar and/or composts. With the exception of CT2, the options that apply biochar and/or compost with NPK could reduce their environmental footprint and also slightly enhance their gross revenue streams through improved productivity and reduced production costs. More research will be needed to reduce the costs of labor for producing biochar and compost at the farm level. Clearly, adoption of the innovations would be facilitated if farmers will not become worse off financially as a consequence of the change.

Third, the IAE's linking of research with training and awareness-raising among the farmers and government extension workers hastened the adoption process. The farmers' hands-on involvement in capacity building reduced the pecuniary costs associated with the uncertainties from the change and the transaction costs of a first-time adoption. Performing the extension roles also enabled IAE to obtain immediate feedback on the strengths and gaps of the options. It likewise demonstrated that extension and research institutions will need to work more closely with each other for innovations to be effectively and efficiently delivered to the farmer-clients.

4. Research and Development Agenda

Research concerns. IAE's work is still unfinished—their study indicated other research concerns that need to be addressed.

Because Viet Nam has varied agroecological landscapes, input mixtures that would be suitable to other rice-producing areas should be tested.

Biochar and compost production is labor intensive, and labor cost in Viet Nam's rural areas has been rising. Labor for agriculture is becoming increasingly scarce as workers (especially male workers) prefer urban jobs. This leaves more women to do the farming activities. Research on technologies for producing organic fertilizers that reduce labor inputs and are women-friendly is vitally needed.

The pilots on biochar and compost production were done on rice farms, which are generally small (less than a hectare) and scattered. It may be more efficient and effective if the organic inputs are produced, processed, and marketed on larger scales through cluster groups (or by zones), as is being done by several private sector enterprises in Guangxi, the People's Republic of China, with support from the government. Producing biofertilizers at the farm level adds to the pecuniary costs of farmers, most importantly the inconvenience, cost of learning, and loss of flexibility through competition for the limited production space in small farms. There may be need for time-bound and transparent start-up incentive schemes for the private sector in Viet Nam to incubate the development of organic inputs on a large-scale, value chain, and commercial basis.

Perceptions of the desirable effects of reduced fertilizer use on the environment, climate change, and livelihoods would be enhanced if complemented with efficient use of irrigation water, appropriate seed varieties, integrated pest management, and other land-based and land-use practices in rice farming. While irrigation water for rice is available year-round, enabling double and triple cropping, more efficient use of water and its accessibility for other crop production are essential. Potential areas for irrigation investments are (1) upgrades of irrigation systems that allow alternate wetting and drying of fields, (2) drainage improvements for multipurpose use, (3) proper operation and maintenance, and (4) "green" water management systems".[7]

Viet Nam has started developing and using improved seed varieties for (1) resilience to extreme weather changes, (2) low-input/organic high quality rice, and (3) complementarity with crop diversification programs. India's approach to basmati rice development (including R&D) involves a strong link between the public research institutions, its Ministry of Agriculture, and the private sector's rice agribusinesses.

Research is needed on institutional land-use arrangements that encourage land consolidation, such as outgrowers' schemes, land lease schemes, and joint venture arrangements of agribusinesses with farmer groups. Other areas to investigate for rice-producing zones include rental services for technical advice, provision and delivery of biofertilizers, rice quality control, and outsourcing of labor

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[7] Green water refers to soil moisture from precipitation that is used by plants via transpiration. Water from rainfall provides essential moisture, which is stored in the root zone of the soil that in turn, is evaporated, transpired or incorporated by plants. Green water management encompasses practices that improve stewardship of this critical resource in all farming systems, but most particularly in rainfed areas. The amount of green water available and the efficiency of its use depends on: (i) occurrence of rain events and the capacity of soil to capture and store that rain, and (ii) appropriate farming practices which can optimize this precious rainfall water. An example of a green water management system is the development of ponds adjacent to farms. The pond catches and stores rainfall, for use by the farmer during the dry season.
Another type of water is "blue water" which is the freshwater: surface and groundwater. It is stored in lakes, streams groundwater, glaciers and snow.

services to undertake the tedious work of biochar and compost production and application on the farms.

Enhancing the knowledge of modeling that includes environmental, climate change, economic, and social aspects will provide important information for formulating policy and making decisions. One option may be wider use of the International Model for Policy Analysis of Agricultural Commodities and Trade developed by the International Food Policy Research Institute.

Additional support for R&D is needed, initially from government and subsequently through public–private collaboration. Experience shows that government should set aside at least 1% of the agricultural GDP for R&D of agriculture, of which at least half could be earmarked for safe and environment-friendly agriculture products such as high-quality low-input rice.

Research and development with extension. The IAE's approach of combining R&D with extension services is a novel one, and may merit emulating. The Vietnam National Extension System would need to work closely with IAE to facilitate the dissemination and adoption of research on CFA, ensure more practical and site-specific outreach of the farmers nationwide, and provide a quick feedback loop on innovations.

Policies will be needed that incentivize and support farmers to use biochar, and enterprises that mass produce and sell biochar and other biofertilizers. Incentive schemes should include requirements for action that are time bound, transparent, and accountable.

IAE's technical expertise on climate change modeling and economic analysis can be shared with their research institute counterparts and other extension departments in the agriculture ministries of the GMS' less-developed economies, particularly Cambodia, the Lao People's Democratic Republic, and Myanmar. Such knowledge sharing will enhance their research and extension capabilities, providing them with more rigorous methodology for assessing and testing technological agronomic options and providing evidence-based approaches to policy making.

Several knowledge-sharing modalities are available, e.g. the internet-based Agriculture Information Network Service system; networking of the GMS-based research institutes for developing sustainable rice and safe and environment-friendly agriculture products; and public–private collaboration through outgrowers' schemes where the private sector provides the market for sustainable rice products and partners with the research-cum-extension departments to help the farmers use sustainable rice practices.

5. Policy Directions

The significance of the IAE's research work was that it focused on major concerns for the country's rice sector in general. The country's rice strategy has been based on a high-volume, low-priced, and low-quality rice supply chain that relies on irrigation, high-yielding seeds, and extensive fertilizer use. While the government is shifting toward a more sustainable high-quality rice pathway,[8] strategic restructuring and repositioning of the rice sector is urgently needed to simultaneously

- prevent further diminution of the country's comparative edge in its suitable natural resource endowments;
- seize the opportunities accorded by urbanization and growing global demand for safe and good quality rice; and
- tackle the external challenges of climate change, price volatility, and fierce competition from more profitable crops.

The key policy agenda for the rice subsector can be inferred from Table 4. The table compares the rice farm productivity parameters of Viet Nam with Thailand, its closest competitor in the global rice economy. Relative to Thailand, Viet Nam has had higher yields in both ordinary and aromatic rice in wet and dry paddy areas, and greater cropping intensity. The two countries had similar availability of and access to irrigation, seeds, mechanization, and other inputs. What distinguishes the two countries is, first, the abnormally high use of fertilizers of Viet Nam (more than double that of the average Thai rice farmer and the technically required optimum level); and second, for Viet Nam, the much lower labor profitability (measured in yield, labor profitability in Thailand is nearly triple that in Viet Nam, and in dollars/person-day, it is more than six-fold), and lower farm gate price (the price received by Thai farmers is nearly double that in Viet Nam).

[8] Viet Nam's relevant policies include the (1) Vietnam Agriculture Restructuring Plan in the period 2016-2020; (2) Action Plan on the Green Growth of the Agriculture Sector and Rural Development to the year 2020 (Decision No. 923/QD-BNN-KH dated 24 March 2017); (3) Plan on the Reduction of Green-house Emission (GHG) in the agricultural sector to the year 2020; (4) National Action Plan on Support to Adapt to Climate Change 2012–2020; (5) Vietnam National Strategy on Green Growth; and (6) Master Plan for the Production Development of Agriculture to 2020 and Vision to 2030.

Table 4: Comparative Indicators of Rice Farm Productivity: Thailand and Viet Nam

	Measure	Indicator	Thailand	Viet Nam
Input	Access to affordable fertilizers	Urea price at farm gate, $/ton	426	357
		Ratio of price of urea to price of dry paddy	1.1	1.6
	Depth of fertilizer market	% of farmers using urea fertilizer for paddy production	100	100
		% of farmers using NPK fertilizer for paddy production	100	100
	Availability of seed	No. of new rice varieties released during 2009–2014	18	34
		% of demand met by supply of good seeds	100	100
	Depth of seed market	% of farmers using purchased seeds	60	53
Land	Land productivity	Yield, wet paddy (ordinary rice), (aromatic rice)	6.1 2.6	7.4 6.5
		Yield, dry paddy (ordinary rice) (aromatic rice)	5.0 2.2	7.4 6.0
	Seed technology used	Transplanting, % of paddy area in monsoon season	7	0
	Fertilizer use	Kg of nitrogen/ha	79	230
		Actual versus optimum fertilizer used, %	-12	156
	Extent of mechanization	% of farmers using ox power	0	0
		% of farmers using machinery for land preparation	100	100
		% of farmers using machinery for harvesting	100	100
Land profitability	Remuneration	Farm gate prices, $/ton, wet paddy (ordinary rice) (aromatic rice)	376 504	220 245
	Costs	Production costs, $/ton	849	552
	Profit	Profitability, $/ton (ordinary rice)	1,253	820
	Higher value added opportunity	% of land under aromatic rice varieties	13	28
Labor productivity	Labor intensity	Labor use, days/ha	6	23
	Labor intensity	Cost of labor, $/ha	9.5	7.2
	Labor productivity	% of hired labor in total labor	55	43
	Labor profitability	Yield/labor use, kg/ha	836	294
	Labor profitability	Profit, $/day (ordinary rice)	253.5	39.3
Farm productivity	% of dry paddy in total paddy production	% of dry season paddy in total paddy production	43	54
	Opportunity for producing second crop	% of paddy area equipped with irrigation	100	100
		% of wet paddy area irrigated during dry season	80	100
	Cropping intensity	(Paddy area in dry season/paddy area in wet season)x100	124	154

ha = hectare; kg = kilogram; NPK = nitrogen, potassium, and phosphorus fertilizer.
Source: World Bank Group and International Finance Corporation (East Asia and Pacific Region). 2016. Agriculture Global Practice, Tables 37–41.

To address the overuse of fertilizer and the low labor profitability, the following policy directions are the suggested.

Road map and programs. A policy road map with a strategic set of programs for soil nutrient development, crop residue management (e.g. promoting biochar and compost), and integrated pest management is needed. The objective would be to synergize resource efficiency, sustainability, climate change, and profitability. One program could be for developing centers of excellence on crop residue management innovations such as biochar and composting. Thailand has indicated its interest in developing such a center. Similarly, a consortium or networking of the research institutes, academe, national research and extension systems, and the private sector could be formed to share knowledge and expertise.

Standards. An internationally recognized metrics for sustainable rice is needed. The Sustainable Rice Platform (SRP) has just developed a global rice standard that combines the parameters for technology and good agronomic practices with synergies in productivity, sustainability, food safety and quality assurance, and value distribution (Box 1). The SRP is working closely with Global G.A.P. with the end-view of harmonizing its sustainable rice standard with international standards. Recently, the SRP rice standard is being tested in Cambodia, Thailand, and Viet Nam by private agribusinesses with support from government and international development partners. As Viet Nam and the GMS are generally net rice surplus economies[9], the application of the SRP sustainable rice standard merits consideration as a basis for harmonizing the food safety and quality assurance standards for sustainable rice within the GMS and leading to a "GMS brand" or trademark of GMS-produced safe, high-quality, and environment-friendly rice.

Restructuring and linking extension services. The policy on extension services for rice needs restructuring: first, ensuring close collaboration between research and academic institutions on the one hand and government extension agencies on the other; second, triangulating public research, extension, and private agribusinesses (traders, logistics providers, processors, marketers, food services, supermarkets, etc.); third, incentivizing the development of "on-the-ground" doctors and service centers (e.g. soil doctors, e-clinics like those in the Philippines and those of CABI, and India's mobile food laboratories); and fourth, knowledge and expertise sharing between fairly advanced rice economies (Guangxi and Yunnan of the People's Republic of China, Thailand, and Viet Nam) and less developed ones (Cambodia, the Lao People's Democratic Republic, and Myanmar).

Linking farmers and downstream partners. Most important is a policy agenda for strengthening the links between farmers and their downstream partners in the rice value chains. This is partly captured by the disparity in the distribution of the value addition where the farmers and rice workers receive too small a share. There are emerging trends toward Vietnamese exporters, traders, and rice mills contracting farmers directly. Incentives for responsible contract farming arrangements may be needed.

[9] GMS countries have been for decades net rice surplus economies. See Demont, M., and P. Rusaert., 2017, and World Bank, 2013

Road map for a sustainable rice value chain. To substantiate the GMS Strategy for 2018–2022, a road map for a GMS sustainable rice value chain could be developed. It would essentially be a strategy for harnessing the subregion's bright prospects for being a global supplier of safe, high-quality, and sustainable rice. The road map could include (1) improved rice productivity and diversification; (2) value chain facilitation (especially for reducing wastes and losses); (3) predictable trade policy and trade facilitation services for cross-border rice trade; and (4) support for market intelligence, branding, marketing campaigns.

Box 1 Sustainable Rice Platform

A Sustainable Rice Platform

Rice plays a critical role in global food security. It is the staple food for more than 3.5 billion people, accounting for one-fifth of dietary energy worldwide, and providing jobs to more than 140 million smallholder farmers in developing economies. With the growing demand for food, rice production needs to increase by 25% in the next 25 years. Rice farmers are most vulnerable to climate change impacts—rising sea level, salinity, flooding, drought, and increasing temperature. Paddy rice production also contributes to about 10% of the annual global greenhouse gas emissions originating in agriculture, with more than 90% of such emissions coming from developing countries, and especially Asia.

To address these concerns, the Sustainable Rice Platform (SRP) was established in December 2011. It is a multistakeholder alliance comprising 34 international and agriculture agricultural research institutions, agrifood businesses, and public sector and civil society organizations. The SRP was convened by the International Rice Research Institute and the United Nations Environment Programme. Its mission is to promote resource efficiency and sustainability in rice trade, supply chains from local to global levels, policymaking, and production and consumption through voluntary coalitions of stakeholders.

In October 2015, the SRP issued the first global standard for sustainable rice cultivation. The SRP standard consist of 46 requirements that aim at reducing the environmental footprint of rice production while improving the lives of rice farmers. The standard's requirements cover major topics on productivity, food safety and quality assurance, worker health, labor rights, and biodiversity.

The SRP is also working with Global G.A.P. toward good agriculture practices in rice production. A Working Group in SRP with Global G.A.P. as a member is currently developing a reliable and efficient assurance framework for the SRP standard.

The SRP in action includes private–public and other sector initiatives for piloting the SRP standard. Some are being tested in Greater Mekong Subregion economies.

- In December 2016, an agreement to pilot the SRP Standard for Sustainable Rice Cultivation was signed between the Loc Troi Group, the International Finance Corporation, and the International Rice Research Institute. The Loc Troi Group is one of Viet Nam's largest agrifood businesses—about 37,000 Vietnamese farmers are producing rice for the company through a contract farming arrangement. The Loc Troi Group's rice mills have an annual milling capacity of 1 million tons. The Loc Troi Group aims to develop a sustainable, high-quality rice value chain, and eventually market SRP-certified rice domestically and abroad. The 2-year project will provide training on the SRP standard initially to some 4,000 farmers to assist them to grow high-quality, high-yielding, and sustainable rice; the capacity-building support will be eventually up-scaled. It is envisaged that the use of the standard will help build for the Loc Troi Group a specific high-quality rice brand that can compete in international markets.
- In June 2017, the International Finance Corporation partnered with AMRU Rice, a leading rice exporter in Cambodia, for an advisory project to implement the SRP standard and practices in the company's supply chain, involving at least 2,000 contract farmers in Kampong Cham Province. By adopting the SRP standard, AMRU Rice will be equipped to meet the requirements of international buyers and to respond to global market trends of sourcing rice products in a more sustainable manner.
- In Thailand, the Ministry of Agriculture and Cooperative and Ministry of Commerce joined forces with the Ministry of National Resources and Environment to implement a plan for shifting from conventional to low-emission rice farming so as to reduce greenhouse gas emissions by more than 26 % within 5 years. Implementation of the plan will be funded by the multidonor Nationally Appropriate Mitigation Actions facility. The shift will involve 100,000 Thai rice farmers from six provinces adopting the SRP's rice standard. The aim is to implement the plan nationwide and, if it is successful, to implement it at level of the Association of Southeast Asian Nations.

Global G.A.P. = an internationally recognized set of farm standards dedicated to Good Agricultural Practices (GAP).
SRP = Sustainable Rice Platform.
Source: Sustainable Rice Platform. Website. http://www.sustainablerice.org/About-Us/

6. Conclusion and Way Forward

Viet Nam's rice subsector needs to be strategically restructured. The subsector's path is still operating on a business model of high-volume but low-quality rice production that applies intensive farming systems, including excessive reliance on agrochemicals, double to triple cropping, and use of year-round irrigation water for rice cultivation. The IAE study mirrored in large measure the major problems afflicting the country' rice subsector in general. The study validated that the pathway of the present growth trajectory is unsustainable and proposed pragmatic options for changing the growth course to one that is sustainable, climate resilient, inclusive, and growth inducing. Using scientific modeling, piloting, and benefit–cost analysis, the study proposed a menu of options that are better roads toward "producing more with less." The IAE also showed that a mainly research focus is insufficient, and needs to be put it into action through capacity building and awareness raising among the primary clients—the farmers and government extension workers. Farmers are responsive to innovations that bring them profits while tackling national environmental and global climate change challenges.

Using the lessons learned from the IAE study and their implications for Viet Nam's rice economy, this paper posited the directions of the R&D and the policy agenda for influencing the change in the growth course of Viet Nam's rice subsector to one that is environment friendly, productive, inclusive, and climate resilient.

Moving forward, the restructuring of Viet Nam's rice economy needs to be contextualized in its being an integral part of the GMS' rice value chain. The GMS Strategy for 2018–2022 envisages the subregion as a web of interlinked supply chains for safe and environment friendly agro-based products. One of these will certainly be the GMS sustainable rice value chain. At this stage, it may be judicious for the GMS to develop a road map for this subregional rice value chain that is premised on the key principles laid out in the GMS strategy and has a thematic focus on food safety and quality assurance as well as inclusive and sustainable rice chains. For Viet Nam, the urgent agenda will be moving toward low-input rice production and closer links between farmers and their downstream partners, locally and at the intra-GMS level. With better connected GMS rice value chains and a rice standard that is internationally recognized, the branding of a distinctly GMS rice will be the way for the future.

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About the Core Agriculture Support Program
The Core Agriculture Support Program (CASP) supports the GMS in attaining its goal of being a leading producer of safe food using climate-friendly agriculture practices. Now on its second phase, since 2012, CASP2 is committed to increasing the subregion's agricultural competitiveness through enhanced regional and global market integration and subregional connectivity.

The agriculture ministries of the six GMS countries supervise the implementation of CASP2 through the GMS Working Group on Agriculture (GMS WGA). A technical assistance (TA 8163) with financing from the Asian Development Bank, the Government of Sweden, the Nordic Development Fund, and the Water Financing Partnership Facility supports the CASP2 implementation. The GMS WGA oversaw the development of the discussion papers.

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