Initiative for Climate Action Transparency - ICAT

TRACKING PROGRESS OF NDC IMPLEMENTATION IN VIETNAM

APPLYING ICAT METHODOLOGY FOR IMPACT ASSESSMENT OF AN ALTERNATIVE WETTING DRYING AND SYSTEM OF RICE INTENSIFICATION

Hanoi, April 2021

Initiative for Climate Action Transparency - ICAT

Tracking progress of NDC implementation in Vietnam: Applying ICAT methodology for impact assessment of an alternative wetting drying and system of rice intensification.

Deliverable: D2.2A

Date of the deliverable: April 2021

AUTHORS

Mai Van Trinh[1], Bui Thi Phuong Loan[1], Dao Thi Thu Hang[1], Duong Linh Phuong[1], Vu Thi Hang[1], Nguyen Quang Chien[1], Ha Quang Anh[2], Nguyen Hung Minh[2]

[1]Institute for Agriculture Environment, the Ministry for Agriculture and Rural Development of the Socialist Republic of Vietnam;

[2]Center for Ozone layer protection and Low-carbon Economy Development of the Department of Climate Change, Ministry of Natural Resources and Environment of the Socialist Republic of Vietnam

PUBLISHED BY

- Institute for Agriculture Environment, Ministry for Agriculture and Rural Development (Vietnam)
- Center for Ozone Protection and Low-carbon Economy Development/ Department for Climate Change/ Ministry of Natural Resources and Environment, Vietnam.

PREPARED UNDER

Initiative for Climate Action Transparency (ICAT) project supported by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, the Children´s Investment Fund Foundation (CIFF), the Italian Ministry for Environment, Land and Sea Protection, and ClimateWorks.

The ICAT project is hosted by the United Nations Office for Project Services (UNOPS).

AKNOWLEDGEMENT

We would like to acknowledge and express gratitude to UNEP DTU Partnership (UDP) and ISPRA for their financial and technical support. Thanks to experts from Ministry of Agriculture and Rural Development (MARD), Centre for Ozone Layer Protection and Low-carbon Economy Development, Department of Climate Change under Ministry of Natural Resources and Environment of the Socialist Republic of Vietnam (MONRE) for their contribution, as well.

We also would like to take this opportunity to express our gratitude to Karen Holm Olsen and Gerardo Sanchez Martinez at UNEP-DTU, Emanuele Peschi, Federico Brocchieri, Marina Vitullo, Daniela Romano and Eleonora Di Cristofaro at ISPRA for insightful discussions and kind support to this report.

Contents

CHAPTER 1. INTRODUCTION

The Paris Agreement on climate change, adopted in December 2015 at COP21, is the first global agreement setting common provisions, applicable to all Parties, to respond to climate change, especially through the submission and regular update of Nationally Determined Contribution (NDC) every five years.

As one of the countries most severely affected by climate change, despite many resource constraints, Vietnam always shows responsibility and actively implements international commitments. Policies, solutions, research and practical actions to respond to climate change have been formulated and implemented synchronously. Vietnam submitted an Intended Nationally Determined Contribution (INDC) in 2015; signed and ratified the Paris Agreement in 2016. After ratifying the Paris Agreement, Vietnam has formalized its INDC into a NDC and has become responsible for the implementation of adequate actions.

More than any other sector, agriculture is the common thread which holds the 17 SDGs altogether. Investing in the agricultural sector can address not only hunger and malnutrition but also other challenges such as poverty; water and energy use; climate change and unsustainable production and consumption. Implementation of the global goals for climate and sustainable development implies synergies and trade-offs at national and global levels specific to the climate policies and actions undertaken (Olsen, Verles, & Braden, 2018). To maximize the positive impacts, and avoid or minimize the negative ones, assessment of the impacts of climate and development policies and actions is helpful for policy design and steering of implementation towards the desired goals (ICAT, 2018).

Vietnam has a coastline of about 3,260 km and a sea area of about one million km^2. Vietnam's mainland territory covers an area of about 331,230.8 km^2 with three-quarters of hills and mountains, the rest being alluvial deltas, of which the Mekong River Delta and Red River Delta are home to the majority of the population. Vietnam is vulnerable to climate change, especially sea level rise.

According to the statistics in 2018, the country's population is over 94.7 million people, 35.7% living in urban areas, 64.3% in rural areas; the average population density is 286 people/km^2. Vietnam has the tropical climate, monsoon with an average temperature of about 28^oC; Average rainfall in common areas ranges from 1,400mm to 2,400mm. Vietnam regularly faces storms, tropical depressions, floods, droughts, land slide. In recent years, due to climate change, extreme weather events tend to increase both in number and intensity, seriously affect the stability and sustainable development of the country. The main contents of the country's policies to respond to climate change are: Actively responding to climate change; Ensuring food security and water resources; Actively responding to sea level rise in vulnerable areas; Protection and sustainable development of forests, Increasing GHG absorption and conserving biodiversity; Mitigating GHG emission; Strengthening the leading role of the State, with active participation of the business community, organizations and individuals in responding to climate change; Building community with higher adaptation ability; Developing and applying advanced science and technology in response to climate change; Strengthening cooperation and enhancing national roles and responsibilities in response to global climate change .

The scope of the assessment is to track progress of Vietnamese NDC implementation in the agricultural sector using ICAT methodology applied to farming policy (system of rice intensification (SRI)). The main purpose of the policy to support farming, especially rice crop to ensure food secutrity by increasing the yield of rice produced in farming and contribute to mitigation objectives by decreasing the emission of greenhouse gases (GHG). Therefore, system of rice intensification combined with the alternative wetting and drying is one of the strategies which the Prime Minister issued decision to address Vietnam's organic agriculture development for the period 2020 – 2030[1]

Through the project, ICAT seeks to assist in setting up a domestic Measurement, Reporting and Verification (MRV) system to track the progress of NDC implementation in the agricultural sector in accordance with the modalities, procedures and guidelines (MPGs) for the Enhanced Transparency Framework (ETF) of the Paris Agreement.

[1] Decision 885/QD-TTg of the Prime Minister approving the Development of Organic Agriculture for the period 2020 – 2030.

CHAPTER 2. ENHANCED TRANSPARENCY FRAMEWORK REQUIREMENTS APPLICABLE TO VIETNAM

2.1. Status of the ETF and MPGs to be applied for NDC tracking of progress in Vietnam

Viet Nam is highly vulnerable to the impacts of climate change, yet its fast growing economy is dominated by fossil fuels, a trend that continues into its future climate policy plans. Agriculture contributes a large share of more than a quarter (28%) of Viet Nam's greenhouse gas (GHG) emissions and there are several programmes in place to reduce emissions in this sector. In the Vietnam updated NDC 2020, the economy wide unconditional reduction target is set to reduce GHG emissions of 9% by 2030 and the conditional target is to reduce GHG emission of 27% by 2030. Vietnam has significant potential to increase its ambition, not just of its targets but for its current policy pathway.

The latest government data (in 2014) shows agriculture represents 28% of Viet Nam's GHG emissions. Energy demand in the agriculture sector is considered in the current policy scenario. An official Decision by the Minister of Agriculture and Rural Development approved a program to reduce GHG emissions in the agriculture sector to 2020, promoting low carbon agriculture. In 2016, the Minister also approved the Action Plan to Respond to Climate Change of Agriculture and Rural Development for 2016-2020 with a vison to 2050, including mitigation projects to reduce emissions. The Green Growth Action Plan (2017) aims to achieve an emissions reduction of 20% from the sector by 2020 below 2010 levels.

The information necessary to track progress made in implementing and achieving the NDC will undergo a technical expert review (TER) in accordance with the modalities, procedures and guidelines (MPGs). However, TER teams will not be able to review the adequacy or appropriateness of the country's NDC, nor its description or the indicators chosen to track progress towards the NDC target.

Indicators are self-selected by each country and may be qualitative or quantitative, however they shall be relevant to a Party's NDC. Indicators may thus come in many formats, inter alia, net GHG emissions and removals, percentage reduction of GHG intensity, relevant qualitative indicators for a specific policy or measure, mitigation co-benefits of adaptation actions and/or economic diversification plans, as relevant.

Parties with an NDC that consists of adaptation actions and/or economic diversification plans resulting in mitigation co-benefits need to provide information to track progress on implementation and achievement of the domestic policies and measures implemented, including the sectors and activities associated with the response measures and the social and economic consequences of the response measures

2.2. Status of Vietnam's plans to supersede the existing MRV system to meet ETF requirements

According to current UNFCCC transparency requirements, Parties report through the submission of biennial reports (BRs or BURs) and National Communications. Moreover, additional instruments exist to allow information sharing on adaptation and mitigation progress and learning, . In the future, as BRs and BURs will be superseded, national reporting under the ETF will take place mainly through the submission of biennial transparency reports (BTRs). BTRs should aim, among others, to track progress towards achieving Parties' individual NDC targets including identifying good practices, priorities, needs and gaps to reduce vulnerability to climate change by building adaptive capacity and resilience; and ensure that climate change adaptation is integrated into development planning in all sectors and at all levels of planning. Further reporting vehicles on adaptation under the Paris Agreement regime may be represented by Adaptation Communications and NDCs, in addition to National Communications which will not be superseded and thus will continue to be applicable to Parties.

In their BTRs, Parties shall provide a national inventory report of anthropogenic emissions by sources and removals by sinks of greenhouse gases (GHGs) as well as information necessary to track progress in implementing and achieving Parties' NDCs. Moreover, Parties should provide information on climate change impacts and adaptation. Information on support provided and mobilized shall be included by developed country Parties, and should be included by other Parties providing support. Developing country Parties should provide information on support (financial, technology transfer, capacity building) needed and received. Adaptation communications can be submitted as a component or in conjunction with a BTR and cross-reference previously reported information. The current status of MRV system for adaptation and mitigation in agriculture now are mostly base on:

- General Statistical Office (GSO), that office is responsible for gathering data in both annual and quinquennial all activities data on crop production, livestock, aquaculture and forestry;
- Production progress reports made by vertical system of agricultural sector and sub-sectors, for example crop production, livestock, aquaculture and forestry in administration from cetral to provincial, district levels and in temporal of season and year;
- Data aslo collected by projects and programmes depend on that typical projects and programmes that we can extract.

CHAPTER 3. OVERVIEW OF REDUCTION OPTIONS IN AGRICULTURAL SECTOR IN VIETNAM

3.1. Overview of Agriculture sector in Vietnam

Vietnam was primarily an agriculture-based country 30 years ago. Viet Nam's economy was based on backward self-sufficient production; and agricultural output was insufficient to meet domestic demand for food. After two decades of growth, Viet Nam went from being a food importer to being one of the top five world leading suppliers and exporters of rice, coffee, rubber, pepper, cashew nuts and other agricultural products. In the period 2000 - 2012, the output value of agriculture, forestry and fisheries continued to increase at an average rate of 5.1% per year. In terms of the value-added of agriculture, the average growth rate of 3.7%/year of agricultural GDP during that period was relatively high and stable compared to other Asian countries (e.g. China 4.1%, Philippines 2.9%, Thailand 2.8%). The structure of agricultural production has gradually shifted towards higher efficiency and is more responsive to market demand in both crop change and production methods. During 2000-2012, the share of seafood in the total value of agricultural, forestry and fishery output rose from 16.3% to 22.4% while the share of cultivation and livestock declined from 80% to 74.9%.

Table 1. Cultivated land and crop area

Cultivated area (1000 hectares)	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2018**
Total area of crop cultvation	9,040.00	10,496.90	12,644.30	13,287.00	14,061.10	14,919.60	14,768.5
Area of annual crop	8,101.50	9,224.20	10,540.30	10,818.80	11,214.30	11,674.30	11,271.7
Food crops	*6,476.90*	*7,324.30*	*8,399.10*	*8,383.40*	*8,615.90*	*8,996.30*	*8,605.5*
Rice	*6,042.8*	*6,765.6*	*7,666.3*	*7,329.2*	*7,489.4*	*7,828..0*	
Annual industrial crops	*542*	*716.7*	*778.1*	*861.5*	*797.6*	*676.6*	*565.6*
Perennial crops	938.5	1,272.70	2,104.00	2,468.20	2,846.80	3,245.30	3,496.8
Perennial industrial crops	*657.3*	*902.3*	*1,451.30*	*1,633.60*	*2,010.50*	*2,154.50*	*2,212.5*
Fruit trees/crops	*281.2*	*346.4*	*565*	*767.4*	*779.7*	*824.4*	*993.2*

(GSO, 2019)

Data in this table show total area of crop cultivation includes food crops (includes food crops and rice and anuual industrial crops, perennial crops (includes perennial industrial crops and fruite trees/crops). For rice area, the cultivated rice are keep increasing from the paste and get maximum area in 2015, then going down gradually.. The annual industrial crops dropping after 2015 because of low yield, less area for suitability and seasonal, climate

In 2017, the export value of agro-forestry-aquatic products reached 36.37 billion USD, representing a year-on-year increase of 13 percent. The export of major agricultural products was estimated at 18.96 billion USD, a year-on-year growth of 15.7 percent. There are seven key export agricultural products each with an export value of more than 1 billion USD: cashew nuts, vegetables, coffee, rice, pepper, cassava and rubber. Some key potential agricultural products (such as tea, maize and temperate fruit) play a crucial role in livehoods and the income of local people in mountainous regions.

Viet Nam is a typical humid tropical country with favorable conditions for agriculture production in terms of climate, soil, hydrology, and variety of crops. As basic resources for agricultural production have become increasingly scarce at the global level, a new higher price level for agriculutural products will be formed in the future. This trend will create favorable conditions for countries with a comparative advantages in agriculture, but also highlights competition in natural resources use for agricultural growth.

Table 2. Crop, livestock and aquaculture production (2000-2018)

Productivity (1000 tons)	**2000**	**2005**	**2010**	**2015**	**2018**
I. Food crops	**34,538.9**	**39,621.6**			
1. Rice	32,529.50	35,832.90	40,005.60	45,091.0	44,046.0
2. Maize	2,005.90	3,787.10	4,625.70	5,287.20	4,874.1
3. Sugarcane	15,044.30	14,948.70	16,161.70	18,335.80	17,945.5
4. Cotton	18.8	33.5	12.5	1.3	0.1
5. Groundnut	355.3	489.3	487.2	454.1	457.3
6. Soybean	149.3	292.7	298.6	146.4	80.8
II. Fruit crops/trees					
1. Grape		28.6	16.7	31	25.2
2. Mango		367.8	580.3	702.9	791.8
3. Citrus		601.3	728.6	727.4	1,075.0
4. Longan		612.1	573.7	513	543.7

Productivity (1000 tons)	2000	2005	2010	2015	2018
5. Lychee, rambutan		398.8	522.3	715.1	731.8
III. Industrial crops					
1. Cashew nut	67.6	240.2	310.5	352.0	284.0
2. Rubber	290.8	481.6	751.7	1,012.7	1,167.3
3. Coffee	802.5	752.1	1100.5	1,453.0	1,678.8
4. Tea	314.7	570.0	834.6	1,012.9	1,018.4
5. Pepper	392	80.3	105.4	176.8	262.7
IV. Livestock					
1. Production of buffalo meat (thousand tons)	48.4	59.8	83.6	85.8	94.5
2. Production of beef (thousand tons)	93.8	142.2	278.9	299.7	355.3
3. Production of pork (thousand tons)	1,418.10	2,288.30	3,036.40	3,491.60	3,328.8
4. Production of poultry meat (thousand tons)	292.9	321.9	615.2	908.1	1,302.5
5. Milk Production (mil. litre)	51.5	197.7	306.7	723	986.1
6. Egg (million)	3,771.00	3,948.50	6,421.90	8,874.30	13,278.9
7. Production of honey (tons)	5,958.00	13,591.00	11,944.40	15,478.10	21,847,3
8. Production of silkworm cocoons (tons)	7,153.00	11,475.00	7,106.50	6,542.90	11,854.9
5. Fishery product (1000 tons)	2,250.90	3,466.80	5,142.70	6,582.10	7,769.1
1. Exploitation (marine fisheries)	1,660.90	1,987.90	2,414.40	3,049.90	3,606.3
2. Aquaculture	590	1,478.90	2,728.30	3,532.20	4,162.8

Source: GSO (2019)

Despite great achievements, agriculture and the rural sector are facing serious difficulties and challenges. Average agricultural GDP growth fell from 4% per year in the period 1995 - 2000 to 3.8% per year during 2001-2005 and 3.4% per year during 2006-2012. The proportion of value-added in total value of agricultural production (GDP/production value) decreased from 45.6% in 2000 to 38.1% in 2012 (at constant 1994 prices). Productivity growth of key crops including rice, and coffee has gradually declined. In the animal husbandry and aquaculture sectors, diseases have become widespread, which seriously affect both productivity and the income of farmers.

Agricultural growth in Viet Nam is based on intensive natural resource use, and misuse of fertilizers, plant protection chemicals and veterinary medicines are common. While achieving economic targets, agricultural production causes adverse environmental effects, depleting natural resources such as soil, groundwater, surface water, minerals and biodiversity. The adverse impacts of climate change on agricultural production are increasing. Agriculture is not only a sector affected by climate change but also a major source of greenhouse gas (GHG) emissions that increase global warming. Weaknesses in the management of water resources and agricultural residues also cause increasing pollution and greenhouse gas emissions. Rice cultivation, enteric fermentation, agricultural land use, animal waste management and agricultural by-product waste are major sources of GHG emissions. Thus, GHG emissions from agricultural production are significant in determining the structure of national emissions and proposing measures to reduce GHG emissions is of clear importance.

Globally, key sources of GHG emissions are rice cultivation, enteric fermentation, agricultural soils, and manure management, burning of savannas and burning of agricultural residues. The Third National Communication (TNC) identifies the agricultural sector as a key source of GHG emissions, estimated at about 27,92% of total national emissions in 2014 (TNC, 2019). Within the agricultural sector in Viet Nam, paddy rice is a key source of GHG emissions, mainly in the form of methane. However, livestock emissions are increasing rapidly, due to rapid growth in the animal production as a consequence of rising demand.

The Ministry of Agriculture and Rural Development has already initiated actions to reduce GHG emissions through its “New Rural Area” master plan, which includes a commitment to reduce GHG emissions by 20% while increasing rural productivity by 20% and reducing poverty by 20%. With the development of the green growth strategy, Viet Nam is further deepening its commitment to green growth. Within the context of the Viet Nam Green Growth Strategy (VGGS), agriculture is identified as a key sector, delivering eco-system services such as increased carbon sequestration and reliable and secure access to food, and contributing to continued economic growth.

3.2. Efforts and achievements of the sector in mitigation GHG emissions

3.2.1. Policy, investment resource mobilization and capacity building

The Ministry of Agriculture and Rural Development (MARD) planned to reduce GHG emissions through a new rural program that targets 20% reduction in GHG emissions, 20% growth in the industry and 20% reduction in poverty by 2020 (Decision 3119, 2011). In the national green growth strategy, agriculture has also been identified as a potential sector for reducing GHG emissions while also ensuring food security and safety and the provision of ecosystem services.

Viet Nam has issued a number of policies related to socio-economic development, green growth and low carbon agriculture:

Table 3. Policies of socio-economic development, green growth and low carbon agriculture

Policy name	**Key policies**
Decision No. 1393 / QD-TTG, on 25 September 2012 of the Prime Minister approving the national strategy on green growth.	Developed strateigies for green grow development with average reduction of 8-10% of GHG emission in 2020 with 3 pillars of reducing GHG emission, green production and green life
Decision No. 403 / QD-TTg, on 20 March 2014 by the Prime Minister approving the national green growth action plan for 2014-2020	Action plans with list of projects should be done in the planning period
Decision No. 124 / QD-TTg, on 2 February 2012 of the Prime Minister approving the master plan for development of agricultural production and rural development	- To make plan for GDP grow for agriculture sector in period 2011-2020 (structure of Agriculture 64,7%, forestry 2%, aquaculture 33,3%.) and vision to 2030 (structure of agriculture 55%, forestry 1,5%, aquaculture 43,5%)
Decision No. 899 / QĐ-TTG dated 10 June 2013 of the Prime Minister approving the project of restructuring the agriculture sector in the direction of enhancing added value and sustainable development	- Sustain the growth, raise the efficiency and competitiveness by raising the productivity, quality, and added values; satisfy the demands of consumers in Vietnam and boost export. The growth of GDP of agriculture reaches 2.6% – 3% during 2011 – 2015, and 3.5% - 4% during 2016 – 2020; - Raise the income and improve living standards of rural residents, ensure food security (including nutrition security) in both the short term and the long term, contribute to the reduction of poverty ratio. By 2020, income or rural households increase by 2.5 time in comparison to 2008; 20% of the communes meet the standards of new rural areas by 2015, and 50% of communes meet such standards by 2020; - Enhance natural resource management, reduce greenhouse gas emission and negative impacts on the environment, utilize environmental benefits, raise capacity for risk management, enhance disaster

Policy name	Key policies
	preparedness, increase forest coverage to 42% - 43% by 2015, and 45% by 2020; contribute to the National Green Development Strategy.
Decision 809 / CT-BNN	Integrating climate change into the formulation and implementation of strategies, master plans, programs, projects and projects on development of the agriculture and rural development sector. period 2011-2015
Decision No. 3119 / QD-BNN-KHCN dated 16 September 2011 of the Minister of Agriculture and Rural Development approving the action plan for GHG emission reduction in agriculture and rural areas up to 2020	Action plan for reducing GHG emission on agriculture to 2020, in which - Crop production reduce 5,72 Gt of CO_2e - Livestock reduce 6,3 Gt CO_2e - Forestry reduce/absorb 1371 Gt CO_2e - Water resources reduces 0,17 Gt CO_2e - Rural development reduces 4,78 Gt CO_2e
Decision No. 1474 / QD-TTg dated 5 October 2012 of the Prime Minister on the promulgation of the National Action Plan on Climate Change 2012-2020	- To strengthen capacity on climate monitoring and early warning - To ensure food and water security - To proactively response to disaster; prevent inundation for the big cities; to strengthen security of river and sea dikes, and reservoirs - To reduce green house gas emission and develop low carbon economy - To improve management capacity, to finalize mechanism and policy on climate change - To raise awareness and develop human resources - To develop science and technology as a foundation for formulating policies, assessing impacts and identifying measures on climate change adaptation and mitigation. - To cooperate with the world, to improve status and role of Viet Nam in international activities on climate change - To mobilize sources and finance to respond to climate change
Decision No. 1775 / QD-TTg dated 21 November 2012 of the Prime Minister approving the project on greenhouse	- Management of greenhouse gas emission in order to implement the United Nations Framework Convention on Climate Change (UNFCCC) and other international agreements in which Vietnam is a party,

Policy name	Key policies
gas emission control, managing the carbon credits trading activities in the market world	at the same time take advantage of the opportunity to develop low carbon economy, green growth and together with the international community in the efforts to reduce greenhouse gas emission, contributing to the implementation of the goal of country's sustainable development. - Managing and monitoring the efficiency of the purchase, sale and transfer of carbon credits generated from the mechanism inside and outside the framework of the Kyoto Protocol to the world market.
Decision No. 819 / QD-BNN-KHCN dated 14 March 2016 of the Minister of Agriculture and Rural Development approving the Action Plan for Response to Climate Change in Agriculture and Rural Development 2016-2020, Vision to 2050	- Capacity building in science, technology and policy to respond to climate change period 2016-2020 and vision toward sustainable agricultural production - Detail adaptation and mitigation actions for each sub-sectors period 2016-2020 - Increase activities of repond, avoid and mitigate to disaster and vision toward 2050
Decision No. 1670 / QD-TTg dated 31 October 2017 by the Prime Minister	Approving the environmental program to cope with climate change and green growth in the period 2016-2020 - Adapt to the impacts of climate change and reduce greenhouse gas emissions; strengthen the capacity of people and natural systems to adapt to climate change; achieve green growth, progress towards a low- carbon economy. - Restructure economic institutions, encourage 'greening' and economic development using energy efficiently. - Actively implementing international and national climate commitments. - Reducing greenhouse gas emissions, implementing commitments to reduce greenhouse gas emissions after 2020 (enshrined in the Paris Agreement and Vietnam's NDC)
Decision No. 923 / QD-BNN-KH dated 24 March 2017 of the Ministry of Agriculture and Rural Development on green growth	- Effectively implement the NGGS; develop green agriculture while ensuring social and environmental issues and EE, using natural resources for low-carbon economy, reducing emissions and enhancing livelihoods enhance GHG absorption capacity in line with resources and the real situation; buildeco-friend-ly lifestyles, contributing to adaptation to climate

Policy name	Key policies
	change; - Reform farming techniques and improve agricultural management to reduce GHG emission in agro-forestry and fishery production, thereby achieving by 2020 a 20% reduction of GHG emissions from agriculture and rural development sector, compared to 2010.

3.2.2. Action plan of GHG emission reduction at sectoral level (Decision No.3119/QD-BNN-KHCN)

- Promoting green and safe agricultural production for low emissions, sustainable development and ensuring national food security, contributing to poverty reduction and effectively responding to climate change;
- Up to 2020, to reduce by 20% the total GHG emission in the agriculture and rural development sectors compared with BAU; and simultaneously to ensure the 20% growth target for agriculture and rural development, and reduce the poverty rate according to secoral development strategy.

The main activities to reduce GHG emission in agriculture and rural development sector are as follows.

3.2.2.1. Crop production

- Apply improved cultivation techniques on rice production such as water irrigation and inputs saving (including system of rice intensification (SRI), three reduction and three gains (3G3T), one obligations and five reduction (1P5G), alternate wetting and drying (AWD) to reduce GHG emissions;.
- Collect and reuse rice straw to completely restrict its burning and limited directly incorporated of rice residue into soil which increase GHG emission and environmental pollution;
- Apply technical solutions to enhance effectiveness of nitrogen fertilizers to reduce N_2O emissions from paddy cultivation and other crops;
- Transform a part of the rice cultivation area with low output to short duration industrial crops with low emission and higher economic revenue;

- Transform one rice crop from land with 2-3 three rice harvests with low output along the rivers and seashore to aquaculture (shrimp, fish) to obtain higher economic value;
- Apply solutions to save energy and fuel in land preparation, irrigation for industrial crops, develop and apply minimum tillage to reduce GHG emissions;
- Develop and apply technology to treat and reuse crop residues from vegetable production, short duration and perennial industrial crops, and sugar cane to reduce GHG emission from crop residue decomposition.

3.2.2.2. Livestock

- Change the feed composition for animal and poultry raising to reduce GHG emission from livestock activities.
- Provide Molasses Urea Blocks (MUBs) as milk cow feed to reduce GHG emissions.
- Apply biogas to treat animal waste and produce bio-fuel to replace fossil fuel.
- Apply composting technology to treat animal and poultry waste to reduce GHG emission
- Apply the VietGAP model (good agricultural practices) in livestock production.
- Replace partly raw foods by treated food and enhance quality of fermented feed for livestock production;
- Enhance the immunity and biological control for animal and poultry production;
- Apply and use antibiotic bacteria and intestine bacteria to reduce GHG emissions from livestock production;
- Improve waste collection systems in cattle barns, and systems for storing and treat animal wastes.

3.2.2.3. Aquaculture

- Adjust the unsuitable capacity of fishing boats with fishing grounds; re-plan fishing routines and determine optimal regions to reduce GHG emission from fishing activities.

- Improve fishing techniques and technologies in fishing activities to reduce GHG emission.
- Establish and improve models of fishing services, protect fishing grounds to reduce GHG emission because of fuel savings
- Renew offering services for aquaculture such as fish varieties, feed, medicine, chemical, fertilizer and equipment supplies to reduce GHG emissions.
- Improve aquacultural technologies, techniques and waste management from aquaculture to reduce GHG emissions.

3.2.2.4. Other activities (irrigation, rural activities and occupations)

- Enhance effectiveness of irrigation and drainage pumping system to save energy and reduce GHG emission.
- Improve irrigated systems to prevent water losses and effectively manage and stabilize irrigation systems and explore autonomous water running systems to reduce losses and save irrigated water.
- Apply new technologies and equipment in constructing irrigation and drainage systems to save energy.
- Save electricity consumption from handicraft production and processing activities.
- Develop and apply suitable equipment to use energy efficiently, bio-fuel, solar and other forms of renewable energy.
- Select and develop new materials, techniques and equipment to enhance production effectiveness and save inputs and reduce emissions in artisanal villages and agriculture, forest and fish processing activities.
- To transfer technologies for treatment and reuse of rural organic waste and waste from production in artisanal villages, food and wood processing, processing plants (sawdust, by-products), fish processing, mills, processing plants for sugar and coffee, etc.
- Develop and apply clean technology to save inputs and reduce emissions from artisanal villages and food, fishery and forest processing activities.

3.2.3. Action Plan on Climate Change Response of Agriculture and Rural Development Sector (Decision No. 543/QD-BNN-KHCN)

This decision aims to strengthen the capacity of the agriculture and rural development sector to mitigate GHG emissions, as well as to reduce impacts from climate change, and to promote sustainable development. The five main objectives of the decision are:

- Stabilise, ensure safety for residents of the cities, regions, particularly the Mekong river delta, the Northern delta and the Central coastal zone

- Ensure stable production of agriculture, forestry, fisheries and salt production towards low emission orientation and sustainable development

- Ensure food security, maintenance of 3.8m ha of paddy land, of which 3.2m ha has 2 crops per year at least

- Ensure safety of the dike system, civil works, technical and economic infrastructure, that meets the requirements for natural disaster prevention and mitigation

- Keep the sector growth at 20%, poverty reduction rate of 20% and reduction of greenhouse gas emission at 20% in each 10-year period.

The action plan contains numerous detailed actions relating to mitigation activities as following:

- Scale up advanced farming models such as good agricultural practice (VietGAP), integrated crop management (ICM), farming techniques 3 reduced 3, 1 reduced 5, management of disease Integrated Pest Management (IPM), Advanced Rice Cultivating System (SRI), Minimal Soil and Plant Cover.

- Research and develop crop protection techniques and techniques to improve the efficiency of using nitrogen to reduce N2O emissions.

- Pilot the replication of models for collection, treatment and reuse of wastes in cultivation (straw, corn, corn cobs, bagasse, sugarcane leaves, coffee husk, cassava) as organic fertilizers, biochar, animal feed, materials, fillers, reducing environmental pollution and reducing GHG emissions.

- Study the development of different kinds of feeds, to change the ration of feeds in order to raise the productivity and quality of animal products, with priority given to dairy cattle and ruminants.
- Transform the small-scale farming method into a farm animal husbandry, forming a key breeding area in association with environmental protection, biosafety and high technology application.
- Change the structure of animals in line with the scales in each ecological region in order to make good use of the advantages and improve the livelihoods.
- Enhance the application of advanced technologies in the treatment of animal wastes as bio-organic fertilizers for safe livestock and environmental protection;
- Continue to implement the biogas program, research and select suitable filtering equipment and diversify the use objectives in order to improve the efficiency of biogas utilization in animal husbandry to achieve double benefits in terms of production. Clean energy and reduce environmental pollution
- Study the restructuring of fishing vessels with rational capacity and renewal of offshore fishing technologies;
- Research on the development and transfer of shrimp-rice, fish-rice, shrimp-mangrove models, aquatic-based adaptive models (EbA) to diversify livelihoods from fisheries;
- Renovate support services for aquaculture such as the supply of seeds, feeds, chemicals for environmental treatment, pollution warning, treatment, materials and fishing gear for aquaculture farms;
- Promote the preservation, processing, development and application of post-processing catfish processing technologies to produce bio-energy of high economic value.
- Replication and improvement of the model of irrigation and drainage of rice fields, drip irrigation and sprinkler irrigation for coffee production areas, fruit trees, shallow and vegetable crops with economic value in the specialized areas.

3.2.4. Agricultural restructuring program (Decision No. 899/QD-TTg)

The Decision contains some actions relating to mitigation activities, including:

- Reduce negative impacts on the environment due to the extraction of resources serving agriculture, forestry, and fisheries; enhance the management efficiency and the use of resources (land, water, sea, forests); consider mutual effects and potential of resource extraction; enhance the measures for reducing greenhouse gas emission; efficiently and safely use chemicals, pesticides, and waste from breeding, farming, processing, and handicraft; preserve biodiversity.

- Encourage the application of environmental standards together with a strict supervision mechanisms to stimulate the development of green agricultural supply chain

- Sustain and flexibly use 3.8 million hectares of paddy land to ensure food security and raise land use efficiency; rice production reaches 45 million tonnes by 2020; focus on improvement of rice varieties to raise the productivity and quality of rice; keep expanding corn areas to reach 8.5 million tonnes in order to supply materials for animal feed production and reduce import.

- Stabilize the coffee area at 500,000 hectares primarily in Tay Nguyen, the South East, Central Coast, and the North West; develop and run the program for replacing 150,000 hectares of old and unproductive coffee trees; increase rubber tree area to 800,000 hectares in the South East and Tay Nguyen; stabilize the cashew area at 400,000 hectares primarily in the South East, Tay Nguyen, the Central Coast; stabilize pepper areas at 50,000 hectares in the South East and Tay Nguyen; increase tea area to 140,000 hectares in Lam Dong and Northern midland and highland.

- Prioritize the development of productive varieties and breeds that are able to resist pests and climate change; invest in projects of pest surveillance, prevention, and control; support investment in preservation, processing, reduction of post-harvest loss, and assurance of food safety and hygiene.

- Focus investments in focal irrigation works, dyke systems, and reservoir safety; prioritize investment in upgrading and maintenance works; build reservoirs in areas that suffer from drought; develop minor irrigation works in association with hydropower in highlands; support the application of measures for saving water; enhance the efficiency of irrigation works.

3.3. Greenhouse gas mitigation actions (all from Decision 3119 / QQD-BNN-KHCN, Decision 1393 / QĐ-TTG and Decision 403 / QĐ-TTG)

GHG mitigation actions in the agriculture sector are mainly based on indicative GHG emission reduction activities which have been identified in the fields of cultivation, livestock husbandry, aquaculture, irrigation and rural areas such:

- Crop production and cultivation: mitigation activities include the application of advanced-cultivation practices and technologies such as short-season varieties, AWD, crop residue management etc.
- Livestock: mitigation activities include improvement of livestock diets to reduce methane emissions from ruminant animals, and animal waste waste management, high-tech livestock on all bread and processing…etc.
- Aquaculture: mitigation activities include optimization of feeding intake for aquaculture, reuse of pond mud, use of high-capacity boats, improvement of cooling system etc.
- Irrigation: mitigation activities include reduction of discharge to irrigation systems, water quality management, optimization of water use, water-saving practices etc.

However, because of no MRV system is developed, so that we can only recorgnize those technologies in relative number, some technologies are just implemented at pilot experiment and some technologies not fully implemented with results of less mitigation quantity.

3.4. Business as usual (BAU) scenarios

Business as usual (BAU) emissions from agriculture and its sub-sectors was calculated starting from 2000 and projecting for the future years 2010, 2020 and 2030 assuming that no policies for mitigation are implemented, taking into account only conventional production in 2010 and following existing government lans to make projections for 2020 and 2030. However, the plan for 2020 and vision 2030 are quite far from realistic and need to be updated, for example the planedf for rice cultivation should be about 7 million ha in 2020 and 6,8 million ha in 2030, but infact rice area went up and standing in a scale of about 7,7 million ha in 2019 and be stay in that scale in 2020. GHG inventory for BAU scenarios uses methods that are in line with international standards, namely the GHG Intergovernmental Panel on Climate Change

(IPCC), the revised version 1996, hereinafter referred to as the IPCC Guideline, 1996 Revision, Guidance for Good Practice and Management of Uncertainty in GHG Inventories (hereinafter referred to as GPG 2000) and Good Practice Guideline IPCC on land use, land use change and forestry.

Table 4. GHG emission in 1994, 2000, 2005, 2010, 2014, 2020 and GHG emission projections for 2030 (1000 tCO_2e)

GHG emission source	1994	2000	2005	2010	2014	2020	2030
Enteric Fermentation	7070	7,730.54	9,275.1	9,467.5	10,200.6	18,842.5	22,212.5
Manure Management	2710	3,447.30	8,056.2	8,560.0	8,863.4	12,099.5	14,093.7
Rice Cultivation - Flooded Rice Fields	32750	37,429.77	42,511.6	44,614.2	44,294.6	41,891.2	41,535.5
Agricultural Soils	8060	14,219.70	22,282.9	23,812.0	23,955.5	29,281.5	32,195.0
Burning of Savanah	400	590.67	3.6	1.7	1.0	1.0	1.0
Field Burning of Agricultural Residues	1460	1672.63	1,690.9	1,899.3	2,436.7	2,391.8	2,127.6
Total	**52,450**	**65,090.61**	**83,820.4**	**88,354.8**	**89,751.8**	**104,507.6**	**112,165.4**

3.5. Assumptions for mitigation options of the agricultural sector

So far, there have been a number of mitigation options of GHG emissions at the country level as well as sectors are proposed. Fifteen GHG mitigation options were identifed and assessed. The economic and technical parameters for each option were taken from research studies, publications and implemented projects. The assumptions for the options are presented in Table 5. Some are implemented or partly implemented as under the government policy or research results.

Table 5. Assumptions for mitigation options in the agriculture sector

Mitigation options	Assumptions
A1 (3). Alternate wetting and drying, and SRI (high adoption) – for rice	Alternate wetting and drying technology and improved rice cultivation will be introduced on 200,000 ha of irrigated rice cultivation in 2030 that fully invested for infrastructure
A2 (16). Midseason drainage (for rice)	MD will be introduced to applied on 1,000,000 ha of irrigated rice cultivation in 2030
A3. Shifting double rice or triple rice into Rice - Shrimp	Shifting 200,000 ha double rice with low productivity to rice – shrimp farming in 2030
A4. Shifting double rice or triple rice into Upland Crop	Shifting 200,000 ha double rice with low productivity to upland crops cultivation in 2030
A5.1 (11). Improving diets for diary cows	Improvements to the diets of 500,000 diary cows will help reduce methane emission caused by the ruminent fermentation process in 2030
A5.2 (11). Improving diets for cows (for meat)	Improvements to the diets of 700,000 non-diary cows will help reduce methane emission caused by the rumen fermentation process in 2030
A5.3 (11). Improving diets for buffalo	Improvements to the diets of 150,000 buffalos will help reduce methane emission caused by the rumen fermentation process in 2030
A6.1 (8). Reuse agricultural residues/by-products	Upland crop residue will be collected and processed into compost for agricultural production using 25-50% of crop residue on 11 million ha of crop cultivation areas in 2030

Mitigation options	Assumptions
A6.2 (10). Produce and apply biochar	Agricultural residue will be collected and processed into compost for agricultural production, for example 50% of rice residue from 3,5 million ha of rice cultivation areas. The technology is only applicable to residue during the wet season
A7.1 (5). Integrated Crop Management (ICM) for rice	Integration of numerous farming techniques that reduce and improve the use of inputs (3 reductions and 3 gains) in 2030. This option can be applied to 1 million ha of rice
A7.2 (6). ICM for annual upland crops	Integration of numerous farming techniques that reduce the use of inputs, such as seeds, fertilisers and growth enhancers, as well as improving productivity, quality and economic effciency. This option can be applied to 1 million ha of annual upland crop cultivation areas
A8 (7). Substitute of Urea fertilizer by Sulfate amon-(NH4)2SO4	Substitution of urea with SA fertilisers on an area of 3,5 million ha to reduce N_2O emissions
A9.1 (9). Alternate wetting and drying, and SRI (medium invested infrastructure)	With international support, AWD and SRI will be introduced/applied on 500,000 ha of irrigated rice cultivation in 2030, that partly invested for infrastructure
A9.2 (9). Alternate wetting and drying, and SRI (low invested infrastructure)	With international support, AWD and SRI will be introduced/applied on 500,000 ha of irrigated rice cultivation in 2030, that poor infrastructure
A10 (15). Drip irrigation combined	With international support, drip irrigation combined with fertilizer technologies will be introduced/applied on 450,000

Mitigation options	Assumptions
with fertilizer for coffee	ha of coffee cultivation throughout Viet Nam to strengthen mitigation impacts in 2030
A11 (17): Improve technology to recycle livestock dung into organic fertilizer	With international support, improve technologies in waste treatment to produce organic fertilizer.

3.6. Criteria for identifying greenhouse gas emission mitigation options

Criteria for identifying GHG mitigation projects are as follows:

- High potential to reduce GHG emission for common production activities
- Convenient to implement changes in production technology;
- Sustainable development;
- Co-benefit contribution between adaptation and mitigation of GHG emissions;
- Availability of technology;
- Reasonable cost
- High feasibility and acceptance/adoption

3.7. Mitigation options

3.7.1. Vietnam INDC report

Table 6. Mitigation in INDC (2015)

Mitigation option	Scale 1000 unit	Reduction potential million ton CO_2e	Reduction/ha (ton CO_2e/ha/year)	Cost for emission mitigation ($/t.$CO_2$)
A1. Increased use of biogas	500	-3,17	-6,34	-43
A2. Reuse of agricultural residues as organic fertilizer	3500	-0,36	-0,10	63,02
A3. AWD and SRI in rice cultivation (small scale)	200	-0,94	-4,70	88
A4. Introduction of biochar (small scale)	200	-1,07	-5,35	75

Mitigation option	Scale 1000 unit	Reduction potential million ton CO_2e	Reduction/ha (ton CO_2e/ha/year)	Cost for emission mitigation ($/t.$CO_2$)
A5. Integrated Crop Management (ICM) in rice cultivation	1000	-0,5	-0,50	20
A6. Integrated Crop Management (ICM) in upland annual crop cultivation	1000	-0,32	-0,32	25
A7. Substitution of urea with sulfate amonnia fertilizer	2000	-3,2	-1,60	30
A8. Reusing upland agricultural/crop residues	2800	-0,29	-0,10	73,02
A9. AWD and SRI (large scale)	1500	-7,02	-4,68	94,9
A10. Introduction of biochar (large scale)	3500	-18,8	-5,37	80,45
A11. Improvement of livestock diet	22000	-1,75	-0,08	-23,63
A12. Improvement of quality and services available for aquaculture, such as inputs and foodstuff	1000	-0,41	-0,41	90
A13. Improvement of technologies in aquaculture and waste treatment in aquaculture	1000	-1,21	-1,21	95
A14. Improved irrigation for coffee	640	-3,39	-5,30	0,46
A15. Improved technologies in food processing and waste treatment in agriculture, forestry and aquaculture	21000	-3,36	-0,16	94
Grand total		**-45,79**		

3.7.2. INDC implementation plan for the agriculture sector

After the Vietnam INDC was established and submitted to UNFCCC by MONRE, MARD issued Dispatch No. 7208/BNN-KHCN dated 25 August 2016 on building the plan deploying INDC implementation in the agriculture sector for the period 2021-2030. MARD identified feasible mitigation activities from the INDC for the agriculture and rural development sector, as follows:

Table 7. The mitigation options reviewed and proposed by MARD for INDC implementation in the agriculture sector

Mitigation options	**Scale (1000 ha, 1000 head of animal)**	**Mitigation potention (Mil. ton CO_2e)**	**Cost for investment (bil. VND)**
I. Mitigation options by domestic funding			
A1. Increased use of biogas	300	-1.91	3100
A3. AWD, and SRI in rice cultivation (small scale)	200	-0.94	2000
A11. Improvement of livestock diet	1600	-0.13	160
A14. Optimal irrigation for coffee	120	-0.24	100
A16. Mid-season drainage in rice cultivation	1000	-3.2	5000
Sub-total I:		-6.42	
II. Mitigation options by international support			
A1. Increased use of biogas	500	-3.17	3100
A8. Reuse of upland agricultural/crop residues	1200	-0.12	650
A9. AWD, and SRI in rice cultivation (large scale)	500	-2.34	4900
A11. Improvement of livestock diets	3000	-0.24	300
A12. Improvement of quality and services available for aquaculture, such as inputs and foodstuff	190	-0.04	80

Mitigation options	Scale (1000 ha, 1000 head of animal)	Mitigation potention (Mil. ton CO_2e)	Cost for investment (bil. VND)
A15. Improved technologies in food processing and waste treatment in agriculture, forestry and aquaculture (1000 tons of agro-product)	2000	-0.32	660
A17: Improved technologies to reuse animal waste as organic fertilizers	20000	-3.4	7100
A18: Adjust structure of unsuitable ship and boat to aquaculture fields and replan for catching way and exploration area	15	-0.69	3000
Sub-total II:		-10.32	
Total:		**-16.74**	

The Agriculture and Land Use (ALU) software was used for the calculation of the GHG mitigation options in the agricultural sector. The software guides an inventory compiler through the process of estimating greenhouse gas emissions and removals related to agricultural and forestry activities. This software is based on the methods in the IPCC National Greenhouse Gas Inventory Guidelines. The software simplifies the process of conducting the inventory by dividing the inventory analysis into steps to facilitate the compilation of activity data, assignment of emission factors and completion of the calculations. Estimates were developed based on the BAU scenario, assuming that new policies are developed to support GHG mitigation technologies. The GHG mitigation options were reviewed for efficiency, incremental costs, mitigation potentials and co-benefits compared to the BAU scenario.

For the GHG mitigation options identifed and analyzed, the economic and technical parameters for each option were taken from research studies, publications and implemented projects. The assumptions for the options are presented in Table 8.

Table 8. Mitigation potential and costs in the agricultural sector

Mitigation options	Mitigation potential per ha/head of animal (tons of CO2e/ha or head of animal)	Scale for implementation (1000 ha/ head of animal)	Total mitigation potential (million tons CO2e)	Cost (USD/tons CO2e)
A1 (3). AWD and SRI where infrastructure fully invested	4.7	200	0.94	39.59
A2 (16). Midseason drainage in rice cultivation	3.2	1000	3.20	30.00
A3: Shifting double rice or triple rice into Rice - Shrimp	6.54	200	1.31	-293.20
A4: Shifting double rice or triple rice into Upland Crop	7.14	200	1.43	-0.08
A5.1 (11). Improvement of diary cow diets	0.168	500	0.084	89
A5.2 (11). Improvement of non-diary cow diets	0.165	700	0.116	89
A5.3 (11). Improvement of buffalo diets	0.206	150	0.031	89
A6.1 (8). Reuse of upland agricultural/crop residues	0.10	1200	0.12	63.2
A6.2 (10). Introduction of biochar (large scale)	5.37	3500	18.80	75
A7.1 (5). ICM in rice cultivation	0.50	1000	0.50	20
A7.2 (6). ICM for annual upland crops cultivation	0.32	1000	0.32	25
A8 (7). Substitution of urea with sulfate amon fertilizer	1.60	3500	5.60	30
A9.1 (9). AWD and SRI (infrastructure partly invested)	4.68	500	2.34	64.96
A9.2 (9). AWD and SRI (poor infrastructure)	4.68	500	2.34	94.9
A10 (15). Drip irrigation combined with fertilizer for coffee	3.80	450	1.71	124.18

Mitigation options	Mitigation potential per ha/head of animal (tons of CO2e/ha or head of animal)	Scale for implementation (1000 ha/ head of animal)	Total mitigation potential (million tons CO2e)	Cost (USD/tons CO2e)
A11 (17): Improved technologies to recycle livestock dung as organic fertilizer	0.17	40000	6.80	94.92

3.8. Cost curve for mitigation options

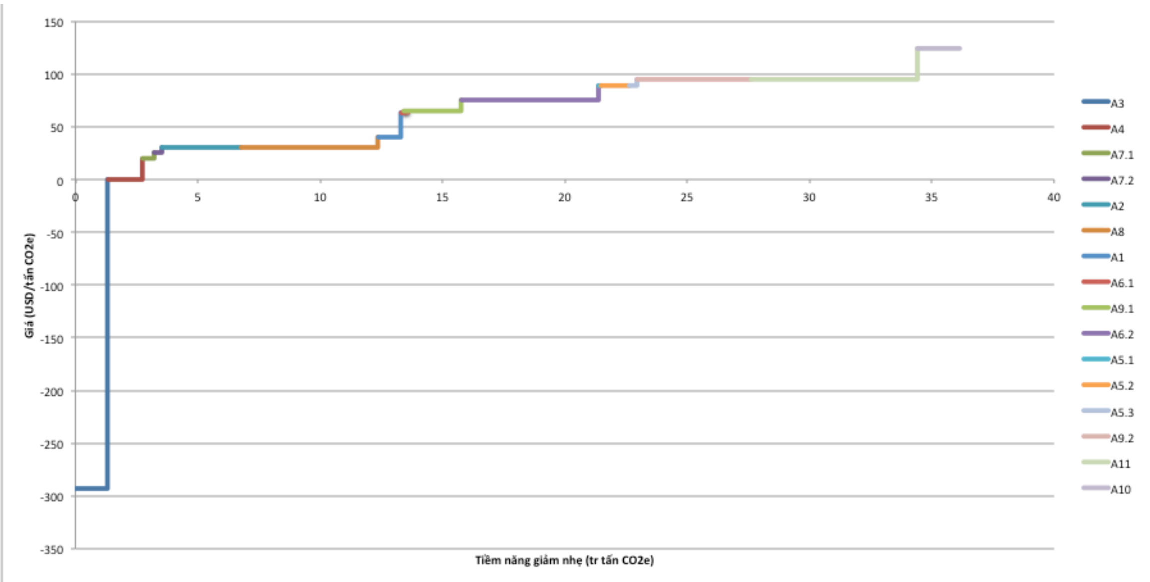


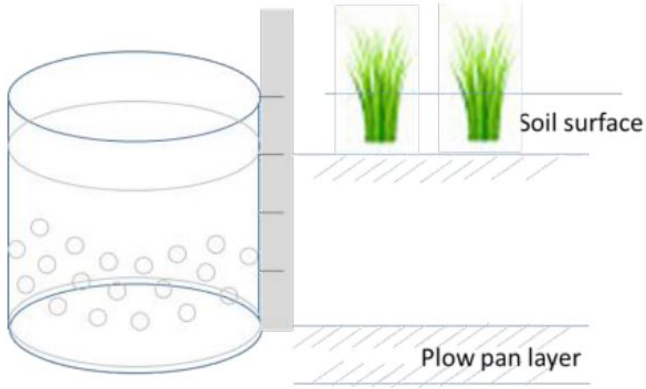
Figure 1. Cost curve for mitigation options in the agricultural sector in 2030

Figure 1 shows the mitigation potential of each option (horizontal axis) and represents the cost of each of these technologies (vertical axis). The cost is calculated base on parallelly deducted input/output of mitigation production activities for conventions production activities. The chart shows that the technology of converting ineffective double rice or triple rice land into rice - shrimp has the lowest cost and has the highest economic efficiency. In contrast, drip irrigation technology for coffee is the most expensive. However, this technology reduces 40% of irrigation water, 30% of fertilizer, 80% of labor, 60% of electric pump water so that it's suitable in dry conditions, but some co-benefits were small compare with investment, or some were not yet taken into account, so that the final cost for this option still high. The option of A6.2 (biochar production and application) give the highest mitigation potential, however, this option is difficult to choose optimal technology and practical implementation. In case of A1, infrastructure is fully invested, farmer just need to be invested for nessesary equipments for controlling water, the cost is low, but with poor infrastructure, farmer and community need to invest from begening such as irrigation, drainage system, leveling the field and water inlet/outlet and controlling system, so that prize will be high. The option of substitution of urea by sulfate amon fertilizer give the high reduction potential and has low costs, however sulfate amon fertilizer are common with plants which are acidophilic or have a high sulfur demand such as cabbage, kohlrabi, potatoes… and if using sulfate fertilizer in the long time, the soil will be acidity. The option of midseason drainage represents both high mitigation potential and moderate price, potential for high replication and easy to monitor/measure.

AWD and SRI technologies is also the technologies with high potential for mitigation, but cost of mitigation depends on the status of infrastructure. This model is essential to deal with drought. Before supplying water for sowing, it is necessary to dredge canals, construct and install water measuring equipment and works, prepare documents. During the development of rice plants, it is necessary to determine the total amount of irrigation water on the field surface in the crop by measuring the water layer on the field surface after each irrigation, the actual rainfall, excluding the evaporation factor... and determining amount of water supplied to the field. In addition, it is necessary to train and raise awareness for farmers to apply the most effective method. The difference in the investment in infrastructure for the different results in the management of emissions from rice cultivation. Therefore, the option *"Alternate wetting and drying (AWD) water management technique and System of Rice Intensification (SRI) in areas with medimum infrastructure"* is proritized that effectiveness in both the mitigation potential and adaptable cost.

3.9. Alternate Wetting and Drying (AWD) rice, and System of Rice Intensification (SRI) in areas with medium invested infrastructure option

Table 9. Brief Description of Alternate Wetting and Drying (AWD), and System of Rice Intensification (SRI) in areas with medium infrastructure option

Baseline Technology	**Suggested Low carbon technology**
Conventional continuos Flooding	**Alternative Wetting and Drying (AWD) and System of Rice Intensification (SRI)**
	
Summary of Technolgoy	Under AWD practice, rice field is drained periodically to enhance aeration of the soil, inhibiting actives of methanogen bacteria, which producing methane, thereby reducing methane emissions. Water depth of the rice field is monitored using a perforated water tube “pani-pipe”. At 1 to 2 weeks after transplanting, field is drained until the water level reaches 15cm below the soil surface. Then, the field is re-flooded to the depth of around 5cm before re-draining. This procedure is continued throughout the cropping season except from 1 week before to 10 days after flowering.
Technical Advantages	Reduces the number of irrigations significantly, thereby lowering irrigation water consumption up to 30%. Increase net return for farmers by promoting more effective tillering and strong root growth of rice plants. [2] Reduces fuel consumption for pumping water by 30 liters per hectare[3]

[2] IRRI. (2016). Overview of AWD. IRRI Brochure [http://books.irri.org/AWD_brochure.pdf]

[3] Palis FG, Cenas PA, Bouman BAM, Lampayan RM, Lactaoen AT, Norte TM, Vicmudo VR, Hossain M, Castillo GT. 2004. A farmer participatory approach in the adaptation and adoption of controlled irrigation for saving water: a case study in Canarem, Victoria, Tarlac, Philippines. Philipp. J. Crop Sci. 29(3)

Mitigation Potential	1.46 (spring-summer) - 2.93 (summer-autumn) tCO_2eq/ha/season[4] Reduces methane emission by 48% (IPCC methodology)
(Initial) Cost	20 USD/tCO_2eq (India), more than 45 USD/tCO_2eq (Philippines, China)[5]
Viet Nam's Context	Development of irrigation canal and use of high efficiency pump may be required to solve the drainage issues during the rainy season. Due to the additional labor requirement measuring the water level by plastic "pani-pipe", disparity between the standardized AWD developed by IRRI and adapted AWD being practiced also during rainy season by farmers in Viet Nam is still found[6]
Existing Policy & Measures	Legal Framework Decision No. 3119/QĐ-BNN-KHCN (2011) Decision No. 543/QĐ-BNN-KHCN (2011)
Current State of Market and Production	Very low adoption of AWD: Uptake level is increasing in Viet Nam while there are still large differences between districts. Irrigated area of rice paddy in Viet Nam in 2013 was 7.2 million ha[7].

[4] Taminato T, Matsubara E. 2014. Comparison of greenhouse gas emissions from paddy fields with two types of water-saving irrigation in the Mekong Delta

[5] Wassmann R., Pathak H. (2007) Introducing greenhouse gas mitigation as a development objective in rice-based agriculture. 11. Cost-benefit assessment for different technologies, regions and scales. Agric. Syst. 94:826-840

[6] Yamaguchi T, Tuan LM, Minamikawa K, Yokoyama S. 2016. Alternate Wetting and Drying (AWD) Irrigation Technology Uptake in Rice Paddies of the Mekong Delta, Viet Nam: Relationship between Local Conditions and the Practiced Technology

[7] MARD 2013. Statistical Yearbook of Agriculture and Rural Development 2013

CHAPTER IV. IMPACTS OF THE ALTERNATIVE WETTING AND DRYING AND SYSTEM OF RICE INTENSIFICATION IN VIETNAM

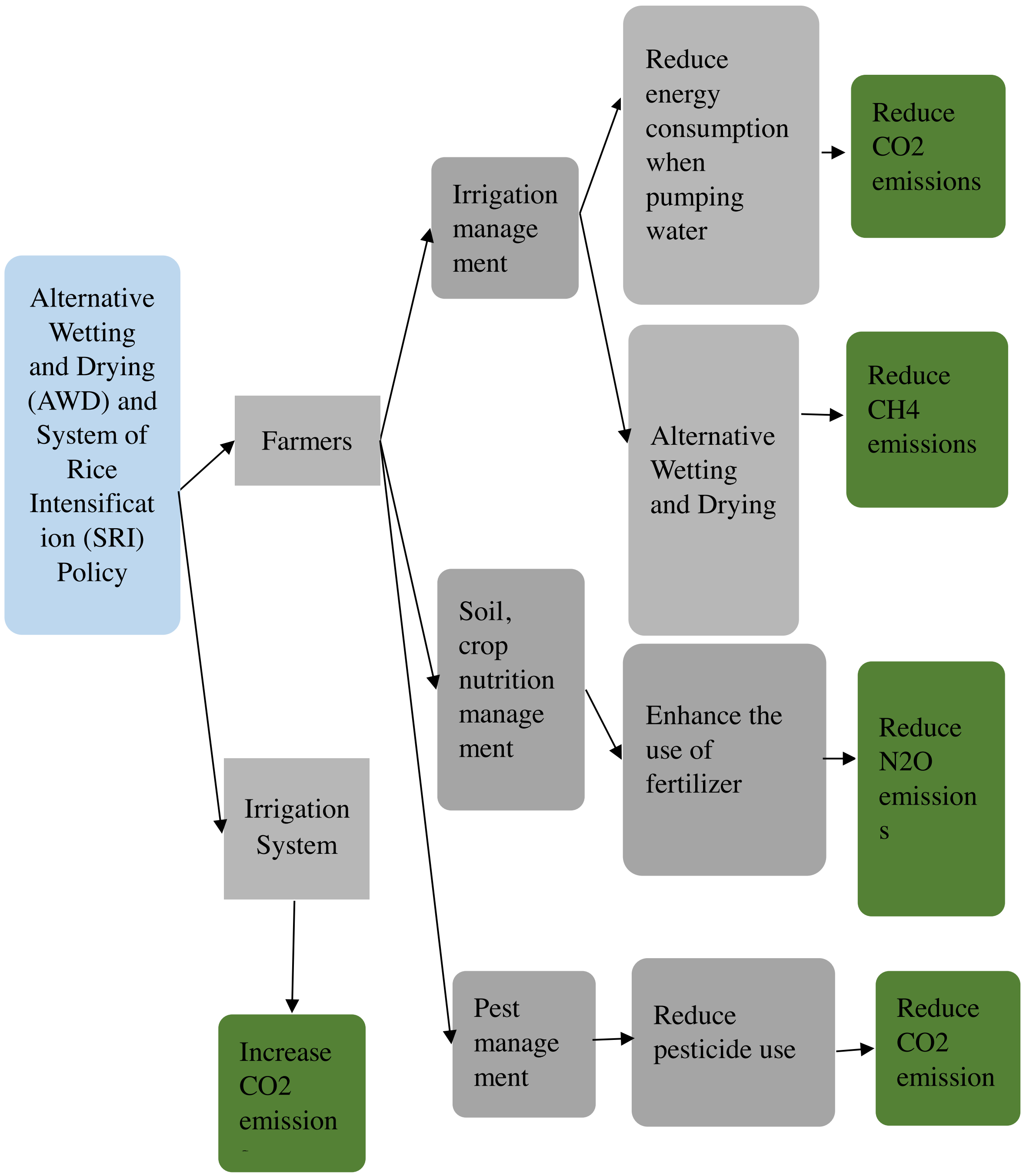
4.1. Impact categorizingAgriculture methodology is part of the series of ICAT guides for assessing the impacts of policies and actions. The series of assessment guides is intended to enable users who choose to assess GHG and transformational impacts of a policy to do so in an integrated and consistent way within a single impact assessment process. The main emphasis of the methodology is the assessment of GHG impacts. Impact assessment can also inform and improve the design and implementation of policies. Thus, intended users also include any stakeholders involved in the design and implementation of national agriculture policies and targets, NDCs, low emission development strategies and NAMAs, including research institutions, non-governmental organizations and businesses.

4.2. Identify GHG impacts

4.2.1. Develop a causal chain

As many emission reduction measures were analyzed and selected for mitigation. Alternative Wet and Dry irigation (AWD) and System of Rice Intensification (SRI) are the options to have very high mitigation potential. Because of that the detail analysis of these options can be seen as following.

Figure 2 shows a causal chain that is a conceptual diagram tracing the process by which the Alternative Wetting and Drying (AWD) and System of Rice Intensification (SRI) policy leads to GHG impacts through a series of interlinked and sequential stages of cause-and-effect relationships.


Alternative Wetting and Drying (AWD) and System of Rice Intensification (SRI) Policy
Farmers
Irrigation management
Reduce energy consumption when pumping water
Reduce CO2 emissions
Alternative Wetting and Drying
Reduce CH4 emissions
Soil, crop nutrition management
Enhance the use of fertilizer
Reduce N2O emissions
Irrigation System
Increase CO2 emission
Pest management
Reduce pesticide use
Reduce CO2 emission

4.2.2. Define the GHG assessment boundary

As the options Alternative Wetting and Drying (AWD) and System of Rice Intensification (SRI) are selected because they can significantly reduce GHG emissions compare to conventional farming technique (as showed in Table 10).

Table 10. GHG impacts and source categories included/ excluded in the GHG assessment boundary

Impact of the option	GHG	Likelihood	Relative magnitude	Included or Excluded
Reduce energy consumption for pumping	CO_2	Likely	Major	Included
Reduced water by Alternative Wetting and Drying	CH_4	Very Likely	Major	Included
Enhance the use of fertilizer	CO_2, CH_4, N_2O	Possible	Major	Included
Reduce pesticide use, reduce energy for appling pesticide	CO_2	Possible	Minor	Excluded
Building irrigation system	CO_2	Possible	Minor	Excluded

According to NDC-SDG interlinkage for use of the 2030 SDG framework to assess sustainable development impacts and interlinkages with NDC climate policies, there are 17 SDG's for evaluation of the impacts, that are: 1) No poverty, 2) Zero hunger, 3) Good health and well-being, 4) Quality education, 5) Gender equality, 6) Clean water and sanitation, 7) Affordable and clean energy, 8) Decent work and economic growth, 9) Industry, innovation and infrastructure, 10) Reduced inequalities, 11) Sustainable cities and communities, 12) Responsible consumption and production, 13) Climate action, 14) Life below water, 15) Life on land, 16) Peace, justice and strong institutions, 17) Partnerships for the goals.

However, these global goals are used for the country scale evaluation with a lot of sectors and activities. The activities/productions in this study are limited within a small scale and meet some of the small number of categories above, for example 2) zero hunger, 3) good health and well-being, 8) Decent work and economic growth, 12) responsible consumption and production, 13) climate action, 15) Life on land. Moreover, the impact is deeper analyzed to more detail in a smaller scale as presented in Table 11.

Table 11. List of the different impacts and indicators

Impacts	**Indicator**
Climate change mitigation (13)	Net GHG emissions
Soil quality (15)	Soil index
Labor for irrigation (3, 5)	Farmers' hours of irrigation
Agricultural productivity (8,12)	Rice yield
Profit of rice farmers (8)	Farmers' income
Reduce Irrigation water (8)	30% irrigation
Increase rice tolerable to pest and disease (3)	Density, Numer of treatment (spraying)/season
Increase rice quality (8, 15)	Weight of 1000 rice grain higher, color brighter, reduce % of empty grain and increase of full grain

Note: numer in bracket = SDG categories

4.3. Baseline Estimation

An analysis of the baseline scenario in the assessment is required, mostly to inform the quantitative assessment by estimating the baseline values.

4.3.1. Overview of the Baseline scenario

In Vietnam, rice is a staple crop which significantly contributes to the socioeconomic development. In the recent years, rice production has experienced the achievement in both productivity and efficiency. However, the industrialization and urbanization considerably decrease the agricultural production area in general and the rice production area in particular. The statistics data reveals that the rice production area in spring 2020 is 3,024.1 thousand ha, which decreases by 3.2% in comparison with the previous year. On the other hand, there is a slight increase in the rice productivity in all major rice regions with 55.7 quintals/ha which is higher than the previous year. The upward trend in rice productivity has been observed in recent years. This indicates the change in rice production toward the sustainability with applying the good practices as well as improving the variety quality.

In Vietnam, rice production is distinguished by regions, especially between the northern and the southern part. Its is mall area/plot with single small household is still popular in the north, while rice field area/plot and scale is larger and consolidate in the southern part of Vietnam. Most farmers keep practicing the conventional farming which is characterized with the continuously flooded season. In addition, the fertilization and pest management are also implemented traditionally with dense frequency, which results in the excessive fertilizer and pesticide. These factors, in fact, constitute the highest portion in production cost. The table below shows some components of rice production cost.

Table 12. Costs of rice production

No	**Activities**	**Cost (VND/1000 m^2/season)**
1	Tillage	116,773
2	Seed	173,080
3	Fertilizer, pesticide	1,007,791
4	Irrigation	60,926
5	Harvest	207,472

(Nguyen Thi My Linh., et al, 2017)

As mentioned above, in several years, rice production in Vietnam has developed constantly to meet the growing demand of high-quality products under the circumstances of production affected by climate change and socioeconomics thriving. In which, Climate Smart Agriculture practices are popular for irrigation management in not only rice system but also many other crop productions. There are many intensive techniques adopted in rice production such as AWD, SRI, 1M5R (one must – certified seed, 5 reductions – reduction of seed, pesticide use, fertilizer inputs, water use, and postharvest losses) and rice straw treatment contributing to the increase of production value. In 2011, the whole country cultivated 185,000 ha of SRI, mostly distributed in the North. Meanwhile, Eastern South and Mekong Delta have a production area with 1M5R of 713.000 ha.

According to MARD, after 5 years of Vietnam Sustainable Agricultural Transformation project, the rice production area applying AWD reaches 130,192 ha. This area includes of about 45,000 ha applying completed AWD irrigation (apply full guidance of AWD) and the rest of partial AWD irrigation (not always follow the guidance, hence effect is low). It means that AWD irrigation has very high range of implementation degree, called partial implementation (not fully implementation the guideline and resulted in lower GHG emission reduction), and fully implementation that fully apply AWD irrigation guideline and have highest GHG emission reduction percentage, this kind of AWD is reported as 45,000 ha. In An Giang, the rising area of rice production with AWD technique is the big achievement of the local authorities.

Table 13. The proportion of AWD area in An Giang over years

	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
% AWD application in An Giang	8.6	33.7	41.9	48	49.9	55.1	56.7	52.1

(Source: Climate change Project Conference – An Giang 2019)

4.3.2. Overview of the policy scenario

As described above, there has been a change in rice production in Vietnam recently such as the adoption of intensive farming such as AWD or SRI. That would be a scaling up of the area with AWD and SRI in several regions now.

With the application of AWD or SRI, farmers are supposed to save the production cost by cutting down several inputs. In AWD method, the irrigation is strictly managed to aim at sufficiently watering. Instead of continuously flooding, the field is intermittently flooded in each growth period. Rice does not always need to be submerged and only needs to be irrigated with a maximum height of 5cm during the tillering and flowering stages. The other stages, rice can growth well in a soil condition of moist with soil moisture content above 60% of field capacity. Therefore, normally the file is flooded with maximum of 5 cm until top tillering. From top tillering the field can be freely drained to keep the soil moist and water level go down to -15cm from soil surface. When the water level goes below -15cm level, it needs to be re-irrigated to flooed of 5 mm. At 10 days before rice flowering soil is flooded again until about 20 days before harvesting. Then the field is drain as dry as possible until harvesting. In SRI method, the farmers have to follow 5 below rules:

- Young seedling (2-2,5 leaves)
- 1 seedling/hills, sparse density
- Applying AWD
- Weeding to aerate the soil
- Applying organic fertilizer or composting to increase the fertility of soil

With the local agricultural facility nowadays, the intermittent irrigation is feasible when the water management is synchronized with a system of water drench for the whole rice production area at each local. To change the farmers' awareness in efficient fertilization as well as pest management, there's a need of authority interference in promoting the good practices and the financial issues.

These two methods have been studied to reveal their effectiveness in GHG emission mitigation in addition to the socioeconomic benefits. Many agricultural zoning documents have referred AWD and SRI as main methods to be scaled up and supported in implementation at localities, especially the Mekong delta and Red River delta.

4.4. Qualitative impact assessment

4.4.1. Climate change mitigation

Vietnam's agriculture contributes largely to total GHG emissions in Vietnam (89,751.8 thousand tons of CO_2eq/year, accounting for 27.92%). Paddy cultivation emits 43.79 million tons of CO_2eq/year, accounting for 49.35% of the total emissions of the agricultural sector and 15.42% of the total GHG emissions of the country (Source: Technical Report National GHG inventory of Vietnam, 2014) The main emission sources are from rice cultivation, enteric fegmentation, manure management, and agriculture soils. There are many factors related to GHG emissions in flood rice cultivation and fertilizer management and irrigation regimes. Therefore, the application of advanced rice cultivation methods to use water and fertilizers effectively, save and reduce GHG emissions is a strategic solution in the short term and in the long term.

SRI is an efficient and ecological rice farming method that not only increases rice yield but also reduces input costs such as seeds, fertilizers, pesticides and irrigation water. In particular, SRI requires balanced fertilizer management, integrated nutrition management along with reducing the number of chemical fertilizers will reduce N_2O, CH_4 emissions. Not only that, SRI also encourages the incorporation of bioenergy into the rice field ecosystems, limits the use of fossil energy, saves irrigation water, effectively exploits and harmonizes chemical and biological factors which contribute to reducing GHG emissions in rice cultivation. Alternate drying and drying (AWD) technique is also the most recommended water management technique in rice growing process by farming experts because it can reduce GHG emissions compared to traditional irrigation methods. SRI combined with AWD has great potential in reducing GHG emissions, having a great impact in the response to climate change in Vietnam.

4.4.2. Soil chemistry and root health

SRI is a low external input farming technology including the major agronomic principles as following: raising seedlings in a carefully managed 2 nursery; early transplanting of 8-15 days old seedling, careful transplanting just after uprooting in a shallow depth (1-2cm); single transplant per hill and wider spacing of transplants; AWD water management (avoiding flooding, keeping soil well drained and moist); regular weeding through a rotary hoe to also facilitate soil aeration, and liberal use of organic fertilisers. SRI recommends to keep paddy fields just moist at the vegetative growth stage of rice plant to increase soil aeration and enhance root development and activity This practice can significantly reduce CH4 emission from paddy rice cultivation in compared to farmer practice (continuously flooding). The benefit of reducing CH_4 emission by alternating wetting and drying may, however, be offset by increased nitrous oxide (N_2O) emission. N_2O emission is highly depended on quantity and kind of nitrogent fertilizers amended for rice plant

Application of phosphorus (P) to rice fields promotes root growth and rhizosphere activity (Cholitkul et al., 1980). Banik et al. (1995) found that in P-deficient soil, the application of fertiliser improves the growth of rice plants and consequently CH4 production may increase due to added root-derived C and increase emissions due to enhanced plant-mediated transport.

Lu et al. (1999) reported that root exudation rates in low P treatment were 2.2–2.8 times higher than in high P treatment because plant roots have to reach a deep soil layer to uptake P for plant nutrient demand, resulting in an increase in root-derived C.

While the results from CLUES project (2012-2015) the series of field experiments were conducted in An Giang (alluvisol), Hau Giang (acid sulphate soil) and Bac Lieu (saline soil) to investigated the effect of phosphate fertilizer on CH4 emission from paddy rice field. The results showed that there was not significant deference on CH4 emission among deferent single super phosphorus fertilizer doses (0-20-40-60 kg P2O5 ha-1).

However, the amendment of P through sulphate-containing P fertilisers were known to reduce CH4 emissions from soils under laboratory conditions as well as under field conditions, due to the inhibitory effect of sulphate. Achtnich et al. (1995) demonstrated

that sulphate reducers could outcompete methanogens for acetate and H2 substrates, resulting in an inhibition of CH4 formation.
Gypsum (CaSO4) is the most common soil amendment used for reclaiming sodic and/or alkaline soils for rice cultivation. Lindau et al. (1993) found that the low and high rates of calcium sulphate (1 and 2 t ha-1) significantly reduced CH4 flux by 29 and 46 % respectively compared to the control plot not amended with calcium sulphate.

4.4.3. Labor for irrigation

The application of alternating wet and dry irrigation techniques, although reducing the number of pumping times and the total amount of water, requires farmers to closely manage water level fluctuations in the field. This management often makes farmers have to spend more time and effort running to the fields to check the water level and adjust the pumps if necessary. Visual measurement also carries the risk of inaccuracies, affecting the technical application process. This makes irrigation workers an important problem to solve.

Combining AWD technology with the application of Internet of Things (IoT) technology as a pilot in Tra Vinh province is a new direction that can encourage wider application of AWD technology. Water level sensors are used to measure and report to farmers' smartphones. Helps monitor and regulate water levels more reasonably, reduce irrigation time and effort and increase accuracy. Many research results have shown that AWD in combination with IoT has the potential to save more water compared to manual AWD techniques. This is a potential model and needs to be developed more in the future. Applying AWD techniques will cause a small difficulty in solving the problem of labor for irrigation. However, if high technology is applied, this technique can solve that problem. Currently, this technique has a negative impact on labor work, although the impact is small and can be solved in the future.

4.4.4. Crop yield

Many pilot studies on the application of improved rice intensification techniques and AWD irrigation have shown many positive results in terms of improved rice yield. According to the statistics up to 2017, more than 20 provinces have applied SRI and failed to result in the increase in average productivity compared to the traditional method. Many studies have also been carried out to evaluate the effectiveness of the AWD technique on agricultural productivity, also showing positive results, high efficiency of the AWD technique, making the roots develop deeper than the traditional farming methods. This means that rice roots had to grow deep into the ground to find water and nutrients, helping to increase their resistance to falling before and during the day of harvest. The stronger roots help the rice plant increase rice yield than with the normal. This technique is completely capable of increasing crop yield. In the response plan to climate change, its impact is assessed as medium.

4.4.5. *Profit of rice farmers*

Farmers who are using it seem convinced that the wider spacing and use of a single seedling per hill are making a difference and increasing their yields. The main question most farmers still struggle with is about the amount and type of fertilizer they should use. Fertilizer helps plants to grow well, so many farmers figure that more fertilizer is better, and use as much as they can afford. Recommended by the local agricultural extension center/station at province and district levels that chemical fertilizer should be applied at three different times during the growing season, in which manure and phosphorus fertilizer usually applied at transplanting while nitrogen fertilizer is applied in all base, split1, split 2 and may be also split 3 and potassium fertilizer is normally applied at split 2 that coincide with panicle initial point. Each approach was modeled across several communes, allowing farmers to observe the resulting yields and decide for themselves which method works best.

The application of SRI in combination with AWD in rice cultivation brings many economic benefits to farmers. The improved rice intensification technique helps farmers reduce input costs in terms of seeds, fertilizers and increase yield. This reduces the cost of rice cultivation and the end-of-crop income, resulting in improved farmer profits. Meanwhile, alternating wet and dry techniques, reducing the number of irrigation pumps and reducing the amount of water for each crop. This lowers electricity bills, machinery maintenance and irrigation costs, and reduces production costs.

According to the statistics as of 2017, the country has more than 20 provinces applying SRI and obtained many outstanding results compared to traditional farming methods. The amount of seed, nitrogenous fertilizer, decreased, leading to an increase in profit per hectare and a decrease in cost per kg of paddy in the jar. Besides, irrigation costs are saved about 1/3. AWD technology is also gradually being replicated in Vietnam and also contributes to reduce the farming costs of farmers by reducing the amount of water and irrigation pump times. When applying SRI and AWD techniques, farmer’s profits are likely to improve, having an impact in the country's climate change response plan.

4.4.6. Reduce Irrigation water

In the flood cultivation, rice plants always need water from the seeding, panicle, flowering and the dough stage. Specifically, to create 1 unit of rice leaves need 400-450 units of water, creating 1 unit of rice requires 300-350 units of water. If the soil is not wet enough and the water level in the field is too high, it will not be good for tillering, soil preparation and growing rice.

The AWD technique uses alternating water draw and water cycles, keeping the water level in the field at the best level for rice growth. According to farming experts, this technique saves 30 - 35% of water use. This method has been piloted by the Plant Protection Department in four main rice growing regions of the country since the summer-autumn crop in 2005, resulting in a 50% reduction in the number of water pumping times, reducing the rate of reclining to pour. On global scale, the reduction of about 10% of water to the rice farming system would provide approximately 150,000 million cubic meters of water, equivalent to 25% of the total global non-agricultural freshwater use. Application of AWD technique is capable of reducing large amount of water in rice cultivation, having great impact in response to climate change.

4.4.7. Increase rice tolerable to pest and disease

One of the 5 principles to help rice grow best under the SRI system is Management of weeds and pests - Combination of weeding with mud, at least 2 times at 10-12 days, and 25 - 27 days after transplanting. In the SRI model, the paddy field is more open, the rice plant is healthier, increases resistance to pests and diseases and less falls. As a result, crop failure will decrease due to pests and diseases. According to farming experts, the SRI models reduce the incidence of blight in rice superiorly compared with traditional farming methods. Thanks to the popularization of SRI, farmers also better understand that the threshold for control of entrails is small during outbreaks, reducing 1 spray of blight and 1 time of spraying leaf blight. It can be seen that this method is feasible in increasing the resistance of rice pests and diseases, having impact in coping with climate change.

4.4.8. Increase rice quality

One of the factors affecting rice quality is the selection of varieties for cultivation. If following the traditional method, most farmers prefer using rice from their warehouse for seeding rather than investing for good rice seeds. In addition, the volume of rice seeds sown annually to meet the certified standards is still too small, for example, the Mekong River Delta with rice production area of over 4 million ha/year requires 490,000 tons of rice seed but in reality, only about 18.1% of that demand is used. In addition to the problem of breeds, customary production, the application of scientific and technical advances, the limited mechanization of production stages and post-harvest technology is another reason.

When cultivated under the SRI model, the input rice varieties will be selected to be high quality, stable and resistant to pests and diseases. In addition, the applied techniques also create the most optimal conditions for the growth of rice plants such as the number of strands and the transplanting distance is guaranteed to avoid damaging the seedling roots. The water and nutrition management for rice is also done effectively according to the needs of rice plants. This does not only have a good impact on the yield but also on the quality of the final rice product. The application of SRI technique in combination with AWD has great potential to improve rice quality, with moderate impact in response to climate change.

4.5. Quantitative impact assessment

4.5.1. Climate change mitigation

Many researches and field trials as well as extention demonstration reported that SRI can reduce 30% of fertilizer and pesticides, increases yields by 10-20% and reduces greenhouse gas emissions, which measured directly from field trials in many research sites with different soil type and climate, by 15-45% (IAE, 2018; Nguyen Van Thiet, 2019).

Climate Smart Agriculture (CSA) is an approach that guides farmers towards more sustainable farming techniques that increase food security and limit or reverse environmental impacts (FAO, 2019). Recently, the Government of Vietnam has acknowledged the importance of CSA, developing a variety of projects around the country (Viet Nam News, 2019). MARD has worked with other government agencies, national and international organizations, and the private sector to further develop this approach in Vietnam (Viet Nam News, 2019).

SRI increases crop productivity while simultaneously increasing resilience for adaptation and promoting mitigation, therefore becoming a form of climate-smart rice production. Recognition of these benefits made SRI as one of the productions systems regulated/promoted by the Action Plan for Green Growth of MARD (Decision No923/QD-BNN-KH). Specifically, SRI reduces water and chemical fertilizer inputs while maximizing seed and labour productivity (Jagannath et al, 2013; Ly et al, 2012). The plants grown using SRI can improve their resistance to pests and diseases, and extreme weather such as droughts and heavy winds (Chapagain et al, 2011). Additionally, SRI plants sequester more carbon and the process produces far less greenhouse gas emissions than traditional cultivation.

A study conducted Mai Van Trinh et al (2012) found less methane emissions from SRI when compared to the traditional rice cultivation. During 2016-2017, Institute of Agriculture Environment (IAE) assessed 10 ha of SRI production in Thai Binh province, finding that methane (CH_4) and nitrous oxide (N_2O) emissions were reduced by 32-35% and 4-14% respectively, when compared with traditional cultivation.

In a 2015, results from a study funded by the nonprofit organization - SNV and carried out by IAE, showed a 21.3% reduction of seed inputs, 34.8% reduction of fertilizer, and 9.7% reduction of labour, compared to the traditional cultivation. The study also found 10.6% increase in rice yield and 32.6% increase in net profit. Additionally, N_2O emissions also decreased due to a reduction use of chemical fertilizers, of course, manure was not applied as our survey showed that only 15% farmer apply manure for rice. Currently, SRI is popular in Red River Delta (Mai Van Trinh et al., 2012), although there is still an assortment of barriers its expansion.

Vu Duong Quynh and et al (2018) carried out an assessment for economic, environmental and resilience / adaptability of the SRI and the traditional rice cultivation in Binh Dinh province. The results showed that application of SRI saved 13% of of nitrogenous fertilizer, 2 times of pumping water/crop and 2 times of pesticide/crop compared to the traditional farming. The assessment also pointed out that dose of organic fertilizers showed that using the higher dose of organic fertilizers and the lesser amount of nitrogen by SRI farmers compared to those by the traditional farming farmers will contribute to reducing the risk of water pollution caused by the NO_3 leaching process (Vu Duong et al., 2018).

Table 14. Environmental impacts on SRI and CF

Technology	Crop	Fertilizer (Kg/ha/crop)				Irrigation	Plant protection chemical use
		N	P_2O_5	K_2O	Manure	No. of pumping	No. of Spray
SRI	Spring Winter	70	81	55	1,500	6	3
	Summer	44	70	50	1,500	5	4
	Average	57	75	53	1,500	5.5	3.5
CF	Spring Winter	80	63	51	800	8	5
	Summer	75	55	50	800	7	6
	Average	77	59	50	800	7.5	5.5

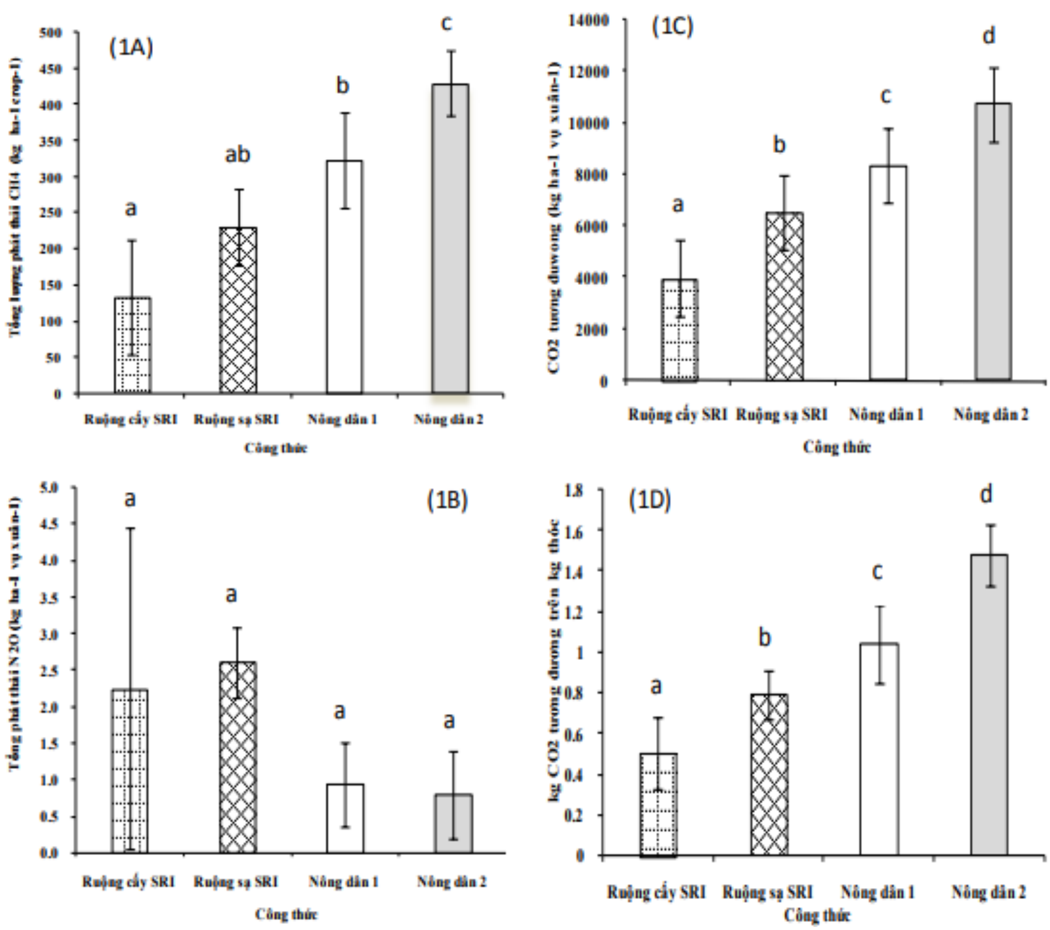


Figure 3. Effects of SRI technology (in order columns: transplanted, direct seeded, fermer 1 and farmer 2 treatments) on CH_4 (1A) and N_2O (1B), CO_2 equivalent (1C) and kg CO_2 equivalent / kg paddy (1D) compared to CF. (Source: Vu Duong and vs, 2018)

The figure 3 (1A) indicates that CH_4 emissions in SRI with transplanting was 133 kg/ha/crop and with sowing was 230 kg/ha/crop which were significantly lower than CF of farmer 1 (323 kg/ha/crop) and CF of farmer 2 (430 kg/ha/crop) from 47 - 59%. The traditional farming regime with continuous flooding is a main cause of two traditional farming formulas with high CH_4 emissions (Vu Duong et al., 2018).

Figure 3 (1B) also illustrates N_2O emissions at the treatment of SRI (both transplanted and direct seeded) are higher than control fields but in the rice condition, the different of N2O emission are not significant in term of statistic. (Figure 3 – 1D) is GHG emission converted CH4 and N2O to CO2 equivelent, shwed that both transplanted and direct seeded treatments have lower GHG emission (in term of CO2e were lower than GHG emission from farmer techniques 46 - 65%.

4.5.2. *Soil quality*

SRI rice cultivation can lead to soil improvement as being shown by increase in soil pH, available phosphorus and easily digested potassium compared to the traditional rice cultivation. The research of Vu Duong Quynh (2018) also shows that SRI improves soil physic and chemistry properties through the use of manure that improved soil porosity and pH compared to the traditional farming 42.7 and 6.1 versus 41.4 and 5.9 respectively.

The application of SRI also increased the content of phosphorus and potassium easily digestible compared to the traditional method (42.3 and 26.4 mg/kg compared with 34.0 and 18 mg/kg, respectively) (Vu Duong Quynh et al., 2018).

Table 15. Effects of SRI farming method on soil chemical and physical properties compared to traditional farming

Technology	Porosity (%)	pH_{H2O}	OC (%)	CEC Cmol/kg	Nts (%)	Available P_2O_5	Available K_2O	Fe3+	Fe2+
						mg/kg			
SRI	42.7	6.1	1.9	9.5	0.2	42.3	26.4	36.7	129
Traditional farming	41.4	5.9	1.9	8.9	0.2	34.0	18.0	37.9	122

Source: Vu Dương Quynh et al., 2018

4.5.3. Productivity

Table 16. Table of effects on SRI / traditional cultivation on net yield of some rice varieties

No.	Cultivar	Yield (quintal/ha)		Source
		SRI	Traditional farming	
1	Khang dân 18	72.3	60.7	Hoang Van Phu, 2005
2	Khang dân 18	82.3	60.8	Nguyen Hoai Nam, Hoang Van Phu, 2005
3	Nhị Ưu 838	82.8	69.3	Hoang Van Phu, 2005
4	Khang dân 18	56.9	54.3	Hoang Van Phu, 2012
5	Khang dân 18	62.5	61.3	Wei Ngoc Lan 2009
6	Q5	58.6	56.7	Wei Ngoc Lan 2009
7	Hương Thơm số 1	57.1	49.7	Wei Ngoc Lan 2009
8	Khang dân 18	58.2	44.4	Pham Thi Thu, Hoang Van Phu, 2010
9	Bao Thai	55.7	41.2	Pham Thi Thu, Hoang Van Phu, 2010
10	VTNA2	90.1	81.4	Vu Duong Quynh et al, 2018
11	VTNA2	86.3	78.1	Vu Duong Quynh et al, 2018
	Average	69.3	59.8	

Applying SRI could create the best conditions for healthy rice plant growth. The SRI saves about 20% of the irrigation water, increases the yield of 10-20% compared to the conventional farming, reduces seeds and chemical, reduce damaging environment due to using of less chemical.

4.5.4. Reduce Irrigation water

With the reduction of the number of water pumping times for irrigation, SRI can reduce irrigation costs by 20-33% (Vu Duong Quynh et al., 2018).

4.5.5. Resistance ability to unfavorable climatic condition

With the sparse transplant technique in SRI cultivation, the rice plant is transplanted with a smaller number of tillers than the traditional cultivation, so the plants have enough nutrients to help the root system grow and develop smoothly, moreover with AWD, rice cultivated under SRI is provided with sufficient oxygen to stimulate roots to grow longer, rice plants can absorb water and nutrients from deeper soil layers

(Hoang Van Phu, 2012). This is the factor that helps the rice plant stand firmly, reduce the broken rate, increase the resistance of the rice plant to adverse weather conditions such as storms, drought, salinity, etc. The study by (Vu Quynh Duong et al (2018) showed that the application of SRI increased root length from 18.5% to 68.0%, increased root biomass by 18.4% to 32.0 %, increased the burning diameter of 10.5% compared to the traditional cultivation. The results from this study are comparable to those reported by Hoang Van Phu (2012) that SRI cultivation has increased root length by 21.6% compared to the traditional farming.

4.5.6. Increase rice tolerable to pest and disease

In the study of Vu Duong Quynh et al 2018, it was found that for the Summer-Autumn crop, the rate of leaf damage caused by worms was significantly lower in the fields in the SRI model compared to the traditional cultivated fields (10.3% and 21.3%, respectively). In the Summer-Autumn season, the rate of blast disease in the traditional cultivated fields was much higher than that in the SRI model (51.0% and 22.6%, respectively). Other pests and diseases in traditionally cultivated rice fields cause severe harm than those in the SRI model.

Besides, the program namely "SRI for the advancement of small farmers in the Mekong sub-region" carried out by OXFAM USA in 6 provinces (Hanoi, Thailand. Nguyen, Phu Tho, Yen Bai, Nghe An, and Ha Tinh) have also shown that SRI cultivation increases the resistance to pests and diseases of rice.

4.5.7. Benefit for rice farmers

The research by Vu Duong Quynh et al (2018) showed that applying SRI cultivation reduced the cost of seeds by 21.3%, the cost of pesticides by 9.7% compared to the conventional farming, while fertilizer costs are similar in both forms. SRI rice cultivation has reduced labor costs compared to the traditional rice cultivation by saving 2 time of spray and 2 times of watering, while at the same time, rice yield increased 11%, net profit increased 33.2%.

Table 17 showed the research of Ngo Tien Dung (2016) which are similar to results reported by Vu Duong Quynh et al (2018). Ngo Tien Dung (2016) showed that SRI reduced 50-70% of chemicals for the plant protection, reduce 20-25% of nitrogenous fertilizer, reduce 30-35% of irrigation water, increase 10-25% of productivity, increase 10-35% of economic efficiency compared to the traditional farming.

Table 17. Benefit of this mitigation options.

Requirement	Specific description
Reduce greenhouse gas emissions / adapt to climate change	Ability to reduce GHG emission up to 45%. Potential of GHG emissions reduction: 1.46 tons CO2e / ha / spring-summer crop; 2.93 tons CO2e / ha / summer-autumn crop.
Benefit	The average of SRI is about 15-35% compare condition
Efficient use of resources	Farmers improve their knowledge, field management skills and good application of technical solutions: thinning, balanced fertilization, 4-way spraying, contributing to limiting environmental pollution. Reduction of pesticide residues in agricultural products, and safety of health for producers and consumers.
In line with development policy and national commitments	SRI has outstanding efficiency compared to traditional farming methods and almost all agricultural and extention centers to recommend farmer to apply for beter yield and quality, saving energy and reduce emission
Scalability & Commercialization	Cultivation according to SRI creates the sub-region of field ecology unfavorable for the development of pests such as: arid, yellow snail, root congestion…, and at the same time increases the resistance to pests and diseases of rice plants; saving about 30-35% of the water used; In addition, not keeping water inundated with the field surface often limits greenhouse gas emissions.
Barriers	In accordance with the orientation of intensive farming, productivity and quality improvement of rice.

Develop solutions and training documents for local stakeholder’s capacity enhancement, including Group management and facilitation skills, to archive above mentioned benefits need to focus on:

+ Solutions on propagation, training for technology managers and users.

+ Solutions on policy, mechanism for promoting stakeholder’s involvement, especially private sector and development organizations.

+ Solutions on science and technology promotion.

+ Solutions on implementation and management.

+ Expert consultation on integrated models for effective and appropriate SRI development.

4.6. Tracking progress of NDC implementation

When NDC is implemented, its progress will be tracked for MRV (Measurement, Reporting and Verification) in both scale and implementation. This activity is very important to measure or retrived its value and impacts. For the detail, some activities should be concentrated as in the following:

- Start of the project
- Project officer need to register to the authorities about his/her project where, scale (ha), what mitigation activities will be implemented
- Determine the baseline of the project
- Make pland for implementation of mitigation scenario
- Collect activity data for calculation of GHG emission for each scenario and at certail time event and time periods
- Determine emission factor for baseline and mitigation measure
- Using GACMO to calculate emission from baseline and mitigation scenarios
- Compare GHG emission from mitigation and baseline and proposal next activities

CHAPTER 5. CONCLUSION

In the agricultural sector, mitigation options have been identified in the NDCs update 2020, which are consistent with the action plan to respond to climate change of the agricultural sector.

The ICAT Series of Assessment Guidelines, particularly agricultural methodology, provides a step-by-step approach to estimating the impact of policy design features, economic and financial factors, and other barrier is to the potential for agricultural policies to reach their technical potential during the evaluation phase. To enhance the transparency frameworks for climate change mitigation options, we scanned out the all mitigation option that developed from NDC and then selected the high potential one to assess their qualitative and quantitative impacts for further implementation. We selected option of alternative wetting – drying and system of Rice Intensification (SRI) for impact assessment. The analysis results showed that SRI has many advance charateristics that both qualitative and quantitative showing high potential mitigation in term of reducing GHG emission, economic, social and environmental benefits. It is an eco-friendly rice farming method, reducing input costs such as reducing seeds, fertilizers, pesticides and irrigation water, while productivity increases thereby increasing economic efficiency compared to the traditional rice production method.

SRI increases crop productivity while simultaneously increasing resilience for adaptation and promoting mitigation, therefore making it a form of climate-smart rice production (“The System of Rice Intensification”, n.d.). Recognition of these benefits resulted in SRI being recognised as one of the productions systems regulated/promoted through the Action Plan for Green Growth of MARD (Decision No923/QD-BNN-KH). Specifically, SRI reduces water and chemical fertilizer inputs while maximizing seed and labour productivity. The plants grown using SRI experienced improved resistance to pests and diseases, and extreme weather such as droughts and heavy winds Additionally, SRI plants sequester more carbon and the process produces far less greenhouse gas emissions than traditional cultivation (“The System of Rice Intensification”, n.d.).

Rice production in Vietnam contributes high GHG emission to total GHG emission of agriculture and rural development sector. However, with very large of cultivated area, rice paddy in Vietnam can also be applied many mitigation options, high potential for implementing NAMA activities that can call all other parties to involve, especially international investments. The high potential for NAMA implementation are applying

Alternative Wet and Dry irrigation (AWD), mid-season drain, bio-char, or convert rice land into upland crop in elevated area or aquaculture in flood prone area to reduce most of methane emission from rice. These high potential of mitigation options open a way for development of NAMA projects to help us to meet GHG reduction plan and approaching carbon market.

By policy assessment and its impact will help policymakers and other decision-makers develop effective and transformative strategies for achieving GHG mitigation and sustainability goals through a better understanding of the impact of policies and actions.

REFERENCE

1. An Giang (2019). An Giang Department of Agriculture and Rural Development Report 2019 "Proposed dissemination of water saving technologies in the field". Workshop: Climate Change project. Proposing technology policies to reduce GHG emissions from rice fields in the Mekong Delta.
2. Achtinich C, Bak F and Conrad R. (1995). Competition for electron donors among nitrate reducers, ferric iron reducers, sulfate producers and methanogens in anoxic paddy soil. Biol. Fertil. Soils 19, 65–72.
3. Banik A, Sen M and Sen SP (1995). Methane emission from inundated saline paddy fields of West Bengal. Indian J. Radio Space Phys. 24, 64–68.
4. Bo N.V, Trinh M.V, Loan B.T.P, et al, Urea-agrotain and green house gas emission, 2015
5. Chapagain, Tejendra, Andrew Riseman, and Eiji Yamiji. 2011. Assessment of System of Rice Intensification (SRI) and conventional practices under organic and inorganic managements in Japan. Rice Science 18(4): 311-320. doi:10.1016/S1672-6308(12)60010-9
6. Cholitkul W, Tangcham B and Sangtong P (1980). Effect of phosphorus on N2 fixation as measured by acetylene reduction technique in Thailand long-term fertility plots. Soil Sci. Plant Nutr. 26, 291–299.
7. Decision No. 923 / QD-BNN-KH dated March 24, 2017 of the Minister of Agriculture and Rural Development. Decision on approval of action plan for green growth of agriculture and rural development sector until 2020
8. FAO, 2019. Strengthening monitoring and evaluation for adaptation planning in the agriculture sectors. Integrating Agriculture in National Adaptation Plans (NAP-Ag) Programme- Safeguarding livelihoods and promoting resilience through National Adaptation Plans, November 2019
9. Statistical yearbook of Vietnam, General statistical office (GSO) issued on 30/06/2020
10. Ha P.Q, Bo N.V, Fertilizers used in relation to food production, environmental protection and mitigation of green house gas emission, 2013
11. Hoang Van Phu, 2005. Research results on SRI (System of Rice Intensification) in spring 2005 in Thai Nguyen and Bac Giang. Journal of Science and Technology, Thai Nguyen University, No. 35, No. 3/2005

12. Hoang Van Phu, Nguyen Hoai Nam (2005). “The research results of SRI (System of Rice Intensification) in Spring 2004 in Thai Nguyen. Journal of Science and Technology, Ministry of Agriculture and Rural Development, 53 (3-4), 2005
13. Hoang Van Phu, Vu Tri Dong, 2006. Prospects of SRI (System of Rice Intensification) techniques in rice cultivation in the Northern Midlands Region. National scientific conference: Research and develop technology to serve agricultural and rural development in the Northern mountainous region, 2000-2005. March 2006.
14. ICAT. (2018). Sustainable development guidance. Guidance for assessing the environmental, social and economic impacts of policies and actions. May 2018 Version. Initiative for Climate Action Transparency (ICAT), World Resources Institute and UNEP DTU Partnership, Editors: Rich D & Olsen KH, Washington DC, US and Copenhagen, Denmark.
15. ICAT. (2018). Agriculture guidance. Guidance for assessing the greenhouse gas impact of agricultural policies. May 2018 Version. Initiative for Climate Action Transparency (ICAT).
16. Jagannath, P., 2013. Achieving More with Less: Maximizing Water Productivity with System of Rice Intensification (SRI), MPS project paper, Cornell University, Ithaca, NY, August 2013.
17. Lindau CW and Bollich PK (1993). Methane emissions from Louisiana first and ratoon crop rice. Soil Sci. 156, 42–48.
18. Low carbon technology assessment facilitates Viet Nam's nationally determined Contributions, 2018, published by Ministry of Natural Resources and Environment;
19. Ly, Proyuth, Lars Jensen, Thilde Bruun, Dominik Rutz, and Andreas de Neergaard. 2012. The System of Rice Intensification: Adapted practices, reported outcomes and their relevance in Cambodia. Agricultural Systems 113: 16-27. doi:10.1016/j.agsy.2012.07.005
20. Lu Y, Wassmann R, Neue HU and Huang C (1999). Impact of phosphorus supply on root exudation, aerenchyma formation and methane emission of rice plants. Biogeochemistry 47, 203 218.

21. Mai Van Trinh, Ly Viet Hung, Intended Nationally Determined Contribution Report of Agriculture and Rural Development (INDC), published by Deutsche Gesellschaft für, Internationale Zusammenarbeit (GIZ);

22. Mai Van Trinh, Tran van The, Bui Thi Phuong (2012) An estimation of GHG reduction for the agriculture sector in Viet Nam, project's report for United Nations development (UNDP).

23. Ngo Tien Dung and Hoang Van Phu, 2016. Summary report on SRI technology implementation in rice cultivation in Vietnam. Workshop "SRI 10 years journey in Vietnam and development prospects". Thai Nguyen, September 27 - 28, 2016.

24. Olsen,K.H.,Verles,M.,&Braden,S.(2018).Aligning the agendas. A party driven dialogue on sustainable development in context of Article 6 PA. Carbon mechanisms review. Berlin: Wuppertal Institute.

25. Oxfam America -VIE 034/0, 2008. Program "SRI for the Advancement of Small Farmers in the Greater Mekong Subregion", now "Innovative Agriculture and Climate Change Adaptation - FLAIR", real Currently, there are 6 love districts (Hanoi, Thai Nguyen, Phu Tho, Yen Bai, Nghe An, and Ha Tinh).

26. Pham Thi Thu and Hoang Van Phu (2014). The research results on the possibility of applying the System of Rice Intensification (SRI) improved cultivation to the land without water initiative in Bac Kan". Posted in Journal of Science & Technology. Thai Nguyen university. 35-40, Volume 119, Issue 05, 2014

27. Proposal on policies for mitigation options in rice cultivation in Mekong Delta, Climate change Project Conference – An Giang 2019

28. Report on SRI, 2011, Plant and Protection Department.

29. Technical Report, Inventory National GHG declaration of Vietnam in 2014, Ministry of Natural Resources and Environment, 2018

30. Truong Thi Tuyet, Hoang Van Phu and Ha Huy Hoang (2013). Energy analysis and economic efficiency analysis between traditional rice cultivation methods and improved rice intensification (SRI) in Thai Nguyen province, Vietnam". The 5th Workshop "Connecting Vietnam - Interdisciplinary Dialogue", Thai Nguyen University, Vietnam, 2013.

31. Vu Duong Quynh, Mai Van Trinh, Bui Thi Phuong Loan, Tran Tu Anh, Bui Van Minh, Nguyen Hong Son, Ha Manh Thang, Nguyen Huy Manh, Nguyen Thi Thom, Dang Anh Minh, Phan Huu Thanh, Nguyen Thi Oanh. 2018. Assessment of economic, ecological efficiency and resistant ability to unforable climate condition

of System of rice intensification (SRI) in comparison with conventional rice cultivation in Binh Dinh province. Journal of Vietnam Agricultural Science and Technology. No 6, 2018, p 27-33

32. Viet Nam News, 2019. Northern provinces urged to bring pesticide use under control. Viet Nam News, June 29. 5,000 training courses on SRI and IPM were offered to 120,000+ farmers with the expectation of bringing agrochemical use under control.

Annex 1: Methodology for GHG inventory in 2014

Table 1. The general approach to estimating GHG emissions from the agriculture sector

Sub-sector	Tier
4. A Enteric Fermentation (CH_4)	Tier 1
4. B Manure Management (CH_4)	Tier 2
4. B Manure Management (N_2O)	Tier 2
4. C Rice Cultivation - Flooded Rice Fields	Tier 1 (CS EF)
4. D Agricultural Soils	Tier 1a
4. E Field Burning of Agricultural Residues	Tier 1

1.1. Enteric Fermentation (CH_4) – (4A)

$$\mathbf{E = \sum_i A_i * EF_i}$$

E = total methane emissions from enteric fermentation (Gg CH_4/year)
EF = emission factor for each animal type, (kg/animal/year)
A = population of animals (head)
i = animal type

Table 2. Animal population data 2014

Livestock	Population (number of animal head)	Soure of data
Dairy Cows	227,600	Statistical Yearbook of Agriculture and Rural Development in 2015 (published in 2016 by the Ministry of Agriculture and Rural Development)
Non-Dairy Cattle	5,006,700	Based on the total number of cows minus the number of dairy cows. The total number of cows is taken from GSO Statistic Yearbook 2015 (published in 2016)
Buffalo	2,521,400	Statistical Yearbook 2015 (published in 2016 by the General Statistics Office)
Sheep	68,580	Numbers of sheep and goat in 2014 were calculated based on the number of sheep and goats in 2013
Goat	1,600,320	

Livestock	Population (number of animal head)	Soure of data
Horses	66,678	Statistical Yearbook 2015 (published in 2016 by the General Statistics Office)
Swine	26,761,400	
Poultry	327,700,000	

Table 3. Enteric fermentation CH_4 emission factors for livestock

Livestock	Emission factors (kg CH_4/animal head/year)	Source of data
Dairy Cows	56	Table 4-4, page 4.11 (Asia) Revised 1996 IPCC Guidelines
Non-Dairy Cattle	44	
Buffalo	55	Table 4-3, page 4.10 (developing countries) Revised 1996 IPCC Guidelines
Sheep	5	
Goat	5	
Horses	18	
Swine	1	

Table 4. Emissions of CH_4 from enteric fermentation, 2014

Animal type	Emissions (Gg CH_4)	Emission rate (Gg CO_2e)
Dairy Cows	12.75	318.64
Non-Dairy Cattle	220.29	5,507.37
Buffalo	138.68	3,466.93
Sheep	0.34	8.57
Goat	8.00	200.04
Horses	1.20	30.01
Swine	26.76	669.04
Poultry	0.00	0.00
Total	**408.02**	**10,200.59**

1.2. Manure Management (CH_4, N_2O) – (4B)

The basic equation is: $\mathbf{E= \sum_{ik} A_{ik} * EF_{ik}}$

E = total methane emissions from Manure Management (Gg CH_4/year)

EF = emission factor for each animal type based on climate zone (kg/animal head/year)

A = population of animals (head)

i = the animal type; k: climate zone

Table 5. Activity data to estimate GHG emissions from manure management, 2014

Animal type	Unit	Climate region (15-25°C)	Climate region >25°C	Data source
Dairy Cows	Head	91,100	136,500	Statistical Yearbook of Agriculture and Rural Development in 2015 (published in 2016 by the Ministry of Agriculture and Rural Development)
Non-Dairy Cattle	Head	2,918,500	2,088,200	Based on the total number of cows minus the number of dairy cows. The total number of cows is taken from GSO Statistic Yearbook 2015 (published in 2016)
Buffalo	Head	2,263,600	257,800	Statistical Yearbook 2015 (published in 2016 by the General Statistics Office)
Sheep	Head	3,800	64,780	Numbers of sheep and goat in 2014 were calculated based on the number of sheep and goat in 2013
Goat	Head	1,006,790	593,530	
Horses	Head	66,300	378	Statistical Yearbook 2015 (published in 2016 by the General Statistics Office)
Swine	Head	18,154,700	8,606,700	
Poultry	Head	214,000,000	113,700,000	

The equation for EF caculation is:

$$\mathbf{EF_i = VS_i * 365\ days/yr * Bo_i * 0.67\ kg/m^3 * \sum_{jk} MCF_{jk} * Ms_{ijk}}$$

where:

EF_i = annual emission factor (kg) for animal type i

VS_i = daily volatile solids excreted (kg) for animal type i

Bo_i = maximum methane producing capacity (m3/kg of VS) for manure produced by animal type i;

MCF_{jk} = Methane conversion factors for each manure management system j by climate region k; and

MS_{ijk} = Fraction of animal type i's manure handled using manure management system j in climate region k.

Table 6. Ratios of excretion of volatile solids (VS) from livestock waste

Animal type	Value (kg/animal/day)	Source
Dairy Cows	2.82	Table B-3 to B-7 (Asia), Revised 1996 IPCC Guidelines
Non-Dairy Cow	1.58	
Buffalo	3.90	
Sheep	0.30	
Goat	0.35	
Horses	1.72	
Swine	0.30	
Poultry	0.02	

Table 7. Maximum methane produced from manure by each animal type

Animal	Value (m3/kg of VS)	Data source
Dairy Cows	0.13	Table B-3 to B-5 (Asia), Revised 1996 IPCC Guidelines
Non-Dairy Cow	0.1	
Buffalo	0.1	
Sheep	0.13	Table B-7 (developing countries), Revised 1996 IPCC Guidelines
Goat	0.13	
Horses	0.26	
Swine	0.29	Table B-6 (Asia), Revised 1996 IPCC Guidelines
Poultry	0.24	Table B-7 (developing countries), Revised 1996 IPCC Guidelines

Table 8. Methane conversion factors for each manure management system (MCF)

AWMS	Climate region (15 – 25ºC)	Climate region (>25ºC)	Data source
Composting	1%	1.5%	Table 4.11 – GPG 2000
Aerobic Treatment	0.1%	0.1%	
Poultry manure with bedding	1.5%	1.5%	
Anaerobic lagoon	12.5%	12.5%	Expert judgement
Pasture/Range/ Paddock	1.5%	2.0%	Table 4.10 – GPG 2000

Table 9. Management of livestock waste at household level in each climate zone

Region	Manure management system (%) – Report from DLP/MARD					
	Total	Composting	Spread out	Anaerobic lagoon	Poultry/cattle manure with bedding	Others
	Manure management system (%) – GPG 2000					
	Total	Composting	Aerobic Treatment	Anaerobic lagoon	Poultry manure with bedding	Pasture range and paddock (grazing)
Total	100	55	26	10	5	4
North	100	61,85	23,11	8,25	2,97	3,82
South	100	29,96	36,56	16,39	12,43	4,66

Table 10. Emission factors for Dairy Cows, Non-Dairy Cattle, Buffalo and Swine in each manure management system in different climate regions

Animal	Emission factor (kg/animal)		Source
	Climate region (15 – 25°C)	Climate region (>25°C)	
Dairy Cows	1.59	2.52	Calculated based on VS, BO, MCF and MS
Non-Dairy Cattle	0.69	1.09	
Buffalo	1.69	2.68	
Swine	0.38	0.60	

Table 11. Emission factors for sheep, goat, horses, poultry in each manure management system in different climate regions

Animal	Emission factor (kg/animal)		Source
	Climate region (15 – 25°C)	Climate region > 25°C	
Sheep	0.16	0.21	*Table B-7, page 4.47. Revised 1996 IPCC Guidelines*
Goat	0.17	0.22	
Horses	1.64	2.18	
Poultry	0.02	0.02	

Table 12. Results of CH_4 emissions from livestock manure management

Animal	**Climate region (15 – 25°C)**		**Climate region > 25°C**		**Total**	
	Emission (Gg CH_4)	Emission (Gg CO_2 tđ)	Emission (Gg CH_4)	Emission (Gg CO_2 tđ)	Emission (Gg CH_4)	Emission (Gg CO_2 tđ)
Dairy Cows	0.14	3.62	0.34	8.61	0.49	12.23
Non-Dairy Cattle	2.00	50.03	2.27	56.77	4.27	106.80
Buffalo	3.83	95.79	0.69	17.30	4.52	113.08
Sheep	0.001	0.02	0.01	0.34	0.01	0.36
Goat	0.17	4.28	0.13	3.26	0.30	7.54
Horses	0.11	2.72	0.001	0.02	0.11	2.74
Swine	6.85	171.37	5.15	128.84	12.01	300.21
Poultry	3.85	96.30	2.62	65.38	6.47	161.68
Total	**16.97**	**424.13**	**11.22**	**280.52**	**28.19**	**704.65**

N_2O emission

The equation to calculate manure management N_2O emission factors is as follows

$$(N_2O\text{– }N)_{(mm)} = \sum_{(S)}\{[\sum_{(T)}(N_{(T)} * Nex_{(T)} * MS_{(T.S)})] * EF_{3(S)}\}$$

$(N_2O\text{- }N)_{(mm)}$ = direct N_2O- N emissions from manure management from all Animal Waste Management Systems (AWMS) in the country (kg N_2O- N/year)

$N_{(T)}$ = number of animals of type T in the country

$Nex_{(T)}$ = N excretion per year per animal (kg N/yr)

$MS_{(T,S)}$) = fraction of $Nex_{(T)}$ that is managed in one of the different animal waste management systems for animals of type T in the country

$EF_{3(S)}$ = N_2O emission factor for an AWMS (kg N_2O-N/kg of Nex in AWMS).

S = Animal waste management systems

T= Animal type.

Kg N_2O-N are converted to kg N_2O by multiplying by $\frac{44}{28}$.

Table 13. N-excretion rate per animal

Animal	N-excretion (kg N/animal/year)	Data source
Dairy Cows	60	Table B-1 Revised 1996 IPCC Guidelines
Non-Dairy Cattle	40	
Poultry	0.6	
Sheep	12	
Swine	16	
Other animal	40	

Table 14. N_2O emission factor for each AWMS

AWMS	N_2O emission factor for each AWMS (kg N_2O– N/kg N)	Data source
Poultry manure with bedding	0.02	GPG 2000 (Tables 4.12, 4.13)
Aerobic treament	0.02	
Composting	0.02	
Anaerobic lagoons	0.001	
Pasture range and paddock (grazing)	-	

Table 15. N_2O emission for each AWMS in 2014

(AWMS)	Emissions (Gg N_2O / year)	Emissions (Gg CO_2 / year)
Anaerobic lagoons	1.58	471.60
Aerobic treament	8.23	2.452.34
Daily spread	17.41	5.187.64
Anaerobic lagoons/tank	0.16	47.16
Pasture range and paddock (grazing)	Reported in Agricultural Soils	
	27.38	8.158.74

1.3. Rice cultivation (CH_4) – (4C)

Emissions from Rice production (Tg/yr) = $\Sigma_i \Sigma_j \Sigma_k (EF_{ijk} \times A_{ijk} \times 10^{-12})$

Where:

EF_{ijk} = a seasonally integrated emission factor for *i*, *j*, and *k* conditions, in g CH_4/m^2

A_{ijk} = annual harvested area for *i*, *j*, and *k* conditions, in m^2/yr

i, j, and k = represent different ecosystems, water management regimes, and other conditions under which CH_4 emissions from rice may vary (e.g. addition of organic amendments)

Emission and scaling factors for rice fields are taken from IPCC (1996) for upland rice and for different water regimes as shown in Table 19.

Table 16. IPCC default CH_4 emission scaling factors for rice ecosystems and water management regimes relative to continuously flooded fields (without organic amendments)

Category	**Water management regime**		**Scaling Factor (SFw)**
Upland	None		0
Lowland	Irrigated	Continious Flooded	1.0
		Intermittently flooded – Single Aeration	0.5 (0.2-0.7)
		Intermittently flooded – Multiple Aeration	0.2 (0.1-0.3)
	Rainfed	Flood prone	0.8 (0.5-1.0)
		Drought prone	0.4 (0-0.5)
	Dreep water	Water depth 5-10 cm	0.8 (0.6-1.0)
		Water depth >100cm	0.6 (0.5-0.8)

Source: *IPCC Guidelines*, Reference Manual

Table 17. Rice production area in Viet Nam (hectares)

	Northern region	**Central region**	**Southern region**	**Total**	**Source**	**Water management in IPCC**
Planted area	1,811,900	1,481,600	4,522,700	7,816,200	Statistical Yearbook 2014	
1. Irrigated rice area	1,692,880	1,322,775	4,453,919	7,469,574	Statistical Yearbook -	

	Northern region	Central region	Southern region	Total	Source	Water management in IPCC
					MARD 2014	
1.1. Area with active water management	1,466,100	1,175,800	2,475,700	5,117,600	The Agricultural, Forestry and Fishery Statistics 2014, National Institute of Agricultural Planning and Projection	
1.1.1 Partial AWD	164,812	29,488	50,964	245,264		Intermittently flooded – Single Aeration
1.1.2 Full AWD	36,692	4,818	8,616	52,126	Assumptions are unchanged from 2013. Data are from Department of Water Resources – MARD	Intermittently Flooded-Multiple Aeration
1.1.3 Continously flooded area	1,262,596	1,141,494	2,416,120	4,820,210	(1.1) - (1.1.1) - (1.1.2)	Continious Flooded
1.2. 1.1. Area without water management	226,780	146,975	1,978,219	2,351,974	(1) - (1.1)	Intermitetently flooded – Single Aeration
2. Upland rice	30,000	24,000	68,000	122,000	Assumptions are unchanged from 2010	Upland rice
3. Rainfed rice	89,020	134,825	781	224,626	Total planted rice area - (1) – (2)	Rainfed rice

Table 18. Rice ecosystems under different water management regimes in Vietnam (ha)

Water regime	**Northern region**	**Central region**	**Southern region**	**Total**
Continuously flooded	1,262,596	1,141,494	2,416,120	4,820,210
Intermittently flooded – Single Aeration	391,592	176,363	2,029,183	2,597,238
Intermittently Flooded – Multiple Aeration	38,692	4,818	8,616	52,126
Upland rice	30,000	24,000	68,000	122,000
Rainfed rice	89,020	134,825	781	224,626
Total	1,811,900	1,481,600	4,522,700	7,816,200

Table 19. CH_4 emission factors

Continuous Flooded regime	**EF (g/m2)**	**Dats source**
Northern region	37.50	Research Center for Climate Change and Sustainable Development
Central region	33.59	
Southern region	21.72	

Table 20. IPCC default CH_4 emission scaling factors for rice ecosystems and water management regimes relative to continuously flooded fields (without organic amendments).

Category	**Water management regime**		**Scaling Factor (SFw)**
Upland	None		0
Lowland	Irrigated	Continuous Flooded	1.0
		Intermittently flooded – Single Aeration	0.5 (0.2-0.7)
		Intermittently Flooded-Multiple Aeration	0.2 (0.1-0.3)
	Rainfed	Flood prone	0.8 (0.5-1.0)

Category	Water management regime		Scaling Factor (SFw)
		Drought prone	0.4 (0-0.5)
	Dreep water	Water depth 5-10 cm	0.8 (0.6-1.0)
		Water depth >100cm	0.6 (0.5-0.8)

Source: *IPCC Guidelines*, Reference Manual

Table 21. CH_4 emissions from irrigated rice cultivation, 2014

Water management	Emissions (Gg CH4 / year)	Emissions (Gg CO2 /year)
Irrigated rice	1,708.7	42,717.8
Rainfed rice	63.1	1,576.8
Total	1,771.8	44,294.6

1.4. Agricultural soil (N_2O) – (4D)

Direct N2O-N emissions from agricultural soil (Tier 1a)

$N_2O_{Direct}-N = [(F_{SN} + F_{AW} + F_{BN} + F_{CR})*EF_1] + (F_{OS}*EF_2)$

$N_2O_{Direct}-N$= Annual direct N_2O emissions per unit of nitrogen

F_{SN} = Annual amount of synthetic fertiliser nitrogen applied to soils after adjusting for the amount that volatilises (kg)

F_{AW} = the total amount of animal manure nitrogen applied to soils from waste management systems (other than pasture range and paddock) after adjusting for the amount which volatilises (kg)

F_{BN} = Total amount of nitrogen returned to soils from nitrogen-fixing crops

F_{CR} = Total amount of nitrogen returned to soils from crop residues

F_{OS} = Area (hectares) of organic soils which are cultivated annually

EF_1= Emission factor for direct emissions from N inputs to soil

EF_2 = Emission factor for direct emissions from organic soil mineralisation due to cultivation

Direct emissions from manure deposited during grazing

$(N_2O- N)(mm)=\sum_{(S)}\{[\sum_{(T)}(N_{(T)}* Nex_{(T)}*MS_{(T,S)})]*EF_{3(S)}\}$

$N_{(T)}$ = Population of animal (T)

$Nex_{(T)}$ = Nitrogen excreted in urine and faeces (dung) as previously determined in the nitrogen excretion for each livestock species (kg N per year).

$MS_{(T,S))}$ = Fraction of total annual excretion in the pasture range and paddock manure management system

$EF_{3(S)}$ = Emission factor for nitrous oxide from urine and faeces (dung) from Animal Waste Management System (AWMS).

S = Animal Waste Management System (AWMS);

T= Animal type.

Indirect N emissions from 1) fraction of N2O produced from atmospheric deposition; 2) from nitrogen volatilisation from soils + associated with nitrogen leached from soils; 3) N_2O from the discharge of human wastewater

The general equation for all of these sources is:

$$\mathbf{N_2O_{(G)} - N = [(N_{FERRT} * Frac_{GASF}) + \sum_{(T)}(N_{(T)} * Nex_{(T)}) * Frac_{GASM}]*EF_4}$$

$N_2O_{(G)}$ = Fraction of N2O produced from atmospheric deposition

N_{FERRT} = Amount of nitrogen fertiliser applied to soils (kgN/yr)

$\sum_{(T)}(N_{(T)} * Nex_{(T)})$= Total N excreted from animal waste, kg N/năm;

$Frac_{GASF}$ = Fraction of total synthetic fertiliser emitted as NOx or NH3; Default value: 0.1 kg NH_3 –N + Nox–N/kg N

$Frac_{GASM}$ = Fraction of total animal manure emitted as NOx or NH3; Default value: 0.2 kg NH_3 –N + Nox–N/kg N

EF_4= Indirect emissions from nitrogen volatilisation; 0.2 kg NH_3 –N + Nox–N/kg N

EF5 = proportion of nitrogen input that contributes to indirect emissions from nitrogen leaching.

Data for calculation

Table 22. Crop production in 2014

Crop	Nitrogen fixation	Production (1000 tons)	Data source
Maize		5,202.30	Statistical Yearbook - GSO
Rice		44,974.60	Statistical Yearbook - GSO
Millet		1.80	FAOSTAT
Soybean	*	156.50	Statistical Yearbook - GSO
Potato		321.70	FAOSTAT
Sweet potato		1,401.10	Statistical Yearbook - GSO
Cassava		10,209.90	Statistical Yearbook - GSO
Sugarcane		19,821.60	Statistical Yearbook - GSO
Groundnut	*	453.30	Statistical Yearbook - GSO
Beans	*	164.04	FAOSTAT
Cotton		2.90	Statistical Yearbook - GSO
Jute		0.97	Statistical Yearbook - GSO
Sedge		87.07	Statistical Yearbook - GSO
Sesame		34.75	Statistical Yearbook - GSO
Tobacco		56.50	Statistical Yearbook - GSO

Table 23. Total amount of Nitrogen fertilizer consumption 2014 (N_{FERT})

Amount	Data source
1,425,124.630	(FAOSTAT) (http://www.fao.org/faostat)

N_2O EMISSION RESULT

Table 24. Direct N2O-N emissions from agricultural soils, 2014

N source applied to soils	Direct N2O-N emissions from agricultural soil (Gg N_2O –N/yr)	Total Direct N2O emissions (Gg N_2O)	Total Direct N2O emissions (Gg CO_2 yr)
Synthetic fertilizer nitrogen (F_{SN})	16.03	25.19	7,507.86
Animal waste (F_{AW})	8.81	13.85	4,126.53
Nitrogen-fixing crops (F_{BN})	0.25	0.40	117.80
Crop residue (F_{CR})	3.57	5.61	1,671.31
Organic soils (F_{OS})	0.004	0.01	1.9
Total	**28.67**	**45.05**	**13,425.4**

Table 25. Direct emissions from manure deposited during grazing, 2014

N2O-N emissions N_{ex} (kg N/yr)	**Emission from grazing animals ($Gg\ N_2O$)**	**Emission from grazing animals (Gg CO_2 tđ)**
40,283,411.20	1.27	377.28

Table 26. Indirect N emissions from 1) fraction of N2O produced from atmospheric deposition; 2) from nitrogen volatilisation from soils + associated with nitrogen leached from soils; 3) N_2O from the discharge of human wastewater. (2014)

Emission source	Indirect N_2O emissions **($Gg\ N_2O$)**	Indirect N_2O emissions **($Gg\ CO_2\ e$)**
Atmospheric deposition	5.40	1,610.57
Volatilisation from soils + leaching from soils	28.67	5,435.99
Total	**34.07**	**7,046.56**

1.5. Burning of savannah (CH_4, N_2O, NO_X, CO, NMVOC) – (4E)

Details the activity data:

Step 1.

Biomass burned (Gg dm) = area of tussock burned annually × above-ground biomass density (t dm/ha) × fraction actually burned

Step 2.

C released biomass (Gg C) = live biomass burned (t dm) × Ratio of C loss to above ground biomass × fraction that is live biomass × fraction oxidised

Step 3.

C released biomass (Gg C) = dead biomass burned (t dm) × Ratio of C loss to above ground biomass × fraction that is dead biomass × fraction oxidised

Step 4.

Total carbon released is then used to estimate CH4, CO, N2O and NOx emissions

N2O emissions (Gg N2O) = C released biomass (Gg C) × Ratio of N:C loss × N2O emissions factor × 44/28

NOx emissions = total C released × C released biomass (Gg C) × Ratio of N:C loss ×NOx emission factor × 46/14

CH4 emissions = total C released × CH4 emission factor × 16/12

CO emissions = total C released × CO emission factor × 28/12

ACTIVITY DATA

Table 27. Area of the burned savannah in 2014 (1000 ha)

Type	2014
Pasture	1.33
Savannah	0.38

Table 28. Emission factors used to estimate emissions from Savanna burning in Viet Nam

Gas	Emission factor	Data source
CH_4	0,004	Revised 1996 IPCC Guidelines, page 4.80
CO	0,06	
N_2O	0,007	
NOx	0,121	

Table 29. The estimated emissions from Savanna burning in Viet Nam, 2014

Gas	Emissions (Gg)	Emission (Gg CO2 eq)
CH_4	0.04	0.88
CO	0.92	-
N_2O	0.004	0.13
NOx	0.02	-

1.6. Field burning of agricultural residues (CH_4, N_2O, NOx, CO, NMVOC) – (4F)

Total carbon released (tonnes of carbon) = all crop types ∑ annual production (tonnes of biomass per year), x the ratio of residue to crop product (fraction), x the average dry matter fraction of residue (tonnes of dry matter / tonnes of biomass), x the fraction actually burned in the field, x the fraction oxidised, x the carbon fraction (tonnes of carbon / tonnes of dry matter)

Annual dry matter production (t dm) = Total crop production (t) × dry matter fraction

Above ground dry matter residue (t dm) = (Annual dry matter production (t dm)/crop-specific Harvest index) - dry matter production (t dm)

Biomass burned (Gg) = Above ground dry matter residue (t dm) × Area burned as a proportion of total production area × Proportion of residue remaining after any removal × Proportion of remaining residue actually burned / 1000

Total Biomass burned is then used to estimate N2O, NOx, CH4, and CO:

N2O = Biomass burned (Gg) × Fraction oxidised × Fraction of N in biomass × N_2O emission factor × 44/28

NOx = Biomass burned (Gg) × Fraction oxidised × Fraction of N in biomass × NOx emission factor × 44/28

CH4 = Biomass burned (Gg) × Fraction oxidised × Fraction of C in biomass × CH4 emission factor × 16/12

CO = Biomass burned (Gg) × Fraction oxidised × Fraction of C in biomass × CO emission factor × 16/12

Table 30. Crop production in 2014

Crop	Nitrogen fixation	Productivity (1000 tons)	Data source
Maize		5,202.30	Statistical Yearbook - GSO
Rice		44.974,60	Statistical Yearbook - GSO
Millet		1,80	FAOSTAT
Soybean	*	156,50	Statistical Yearbook - GSO
Potato		321,70	FAOSTAT
Sweet potato		1.401,10	Statistical Yearbook - GSO
Cassava		10.209,90	Statistical Yearbook - GSO
Sugarcane		19.821,60	Statistical Yearbook - GSO
Grounut	*	453,30	Statistical Yearbook - GSO
Beans	*	164,04	FAOSTAT
Cotton		2,90	Statistical Yearbook - GSO
Jute		0,97	Statistical Yearbook - GSO
Sedge		87,07	Statistical Yearbook - GSO
Sesame		34,75	Statistical Yearbook - GSO
Tobaco		56,50	Statistical Yearbook - GSO

Table 31. Crop residue ratio as compared with crop output

Crop	Residue/Crop output Ratio	Data source
Maize	1	Table 4-16, GPG 2000
Rice	1.4	
Millet	1.4	
Soybean	2.1	
Potato	0.4	
Sweet potato	0.4	Same value as Potato
Cassava	0.4	
Sugarcane	0.2	Table 4-17, Revised 1996 IPCC Guidelines
Groundnut	1	Table 4-16, GPG 2000
Beans	2.1	
Cotton	2.76	The ratios of cotton and jute residues were derived from a study reported by FAO for Asian Countries (1998). The ratio of sesame, sedge and tobacco residues was taken as 1 as recommended by the IPCC GPG 2000 - chapter 4 – Agriculture, page 457
Jute	2	
Sedge	1	
Sesame	2.1	
Tobacco	1	

Table 32. Dry matter fraction of crops

Crop	Dry matter fraction	Data source
Maize	0.78	Mean value of ranges in Table 4-6, GPG 2000
Rice	0.85	
Millet	0.885	
Soybean	0.865	
Potato	0.45	Mean value of ranges in Table 4-17, Revised 1996 IPCC Guidelines
Sweet potato	0.45	Value for potato
Cassava	0.45	Value for potato
Sugarcane	0.15	Mean value of ranges in Table 4-17, Revised 1996 IPCC Guidelines
Groundnut	0.86	Mean value of ranges in Table 4-6, GPG 2000
Beans	0.86	Mean value of ranges in Table 4-6, GPG 2000

Crop	Dry matter fraction	Data source
Cotton	0.93	US Greenhouse Gas Inventory Report 1990-2014 (published April 2004)
Jute	0.86	Bangladesh Climate Change Report (2010)
Sedge	0.85	Value of rice
Sesame	0.87	Value of tobaco
Tobacco	0.87	US Greenhouse Gas Inventory Report 1990-2014 (published April 2004)

Table 33. Field burning ratio

Crop	Ratio	Data source
Maize	0.3	Expert guess from developing NC2
Rice	0.55	Expert guess from developing NC2
Millet	0.25	Revised 1996 IPCC Guidelines, page 4.83
Soybean	0.25	
Potato	0.25	
Sweetpotato	0.1	Expert guess from developing NC2
Cassava	0.45	Expert guess from developing NC2
Sugarcane	0.35	Expert guess from developing NC2
Groundnut	0.6	Expert guess from developing NC2
Beans	0.35	Revised 1996 IPCC Guidelines, page 4.83
Cotton	0.25	
Jute	0.25	
Sedge	0.25	
Sesame	0.25	
Tobacco	0.25	

Table 34. Carbon fraction in crop residue

Crop	Value	Data source
Maize	0.4709	Table-16, GPG 2000
Rice	0.4144	Table-16, GPG 2000
Millet	0.5	Revised 1996 IPCC Guidelines, page 4.30
Soybean	0.5	Revised 1996 IPCC Guidelines, page 4.30
Potato	0.4226	Table-16, GPG2000
Sweetpotato	0.4226	Defualt value for tomato used
Cassava	0.5	Revised 1996 IPCC Guidelinespage 4.30
Sugarcane	0.4235	Table-16, GPG2000
Groundnut	0.5	Revised 1996 IPCC Guidelines, page 4.30
Beans	0.5	Revised 1996 IPCC Guidelines, page 4.30
Cotton	0.45	Revised 1996 IPCC Guidelines, page 4.82; Global value
Jute	0.45	

Crop	Value	Data source
Sedge	0.45	
Sesame	0.45	
Tobacco	0.45	

Table 35. Nitrogen Fraction in crop residues

Crop	Value	Data source
Maize	0.008	Le Van Can, 1975. fertilizer handbook
Rice	0.004	Le Van Can, 1975. fertilizer handbook
Millet	0.007	Good agriculture practice guideline 2000, 4.16
Soybean	0.010	Soybean residue (fertilizer handbook, Institute for soils and fertilizers 2009) and stem, leaf, shell, empty seed in mature soybean (Cao Ky Son, 2002, Viet Nam)
Potato	0.003	Le Van Can, 1975. fertilizer handbook
Sweetpotato	0.003	Same as potato
Cassava	0.016	Mean value of mature cassava (fertilizer handbook, Institute for soils and fertilizers, 2005) cited by Cours (1951-1953)) and mature casava (C.J Asher, D.G.Edwards and R.H.Howeler (1980))
Sugarcane	0.004	GPG, Table 4.16
Groundnut	0.019	Average value for mature peanut leaf (wang Zaixu 1982; Cai Changbei, 1988- china) and stem (wang Zaixu 1982; Cai Changbei, 1988- china) and stem, leaf, shell, empty seed in matur peanut (Cao Ky Son, 2002, Viet Nam)
Beans	0.010	used soybean value
Cotton	0.00675	Estimated from N/C from residue. Value of N/C in residue is taken from global data (Global value) (page 4.83 – IPCC 1996)
Jute	0.00675	
Sedge	0.00675	
Sesame	0.00675	
Tobacco	0.00675	

Table 36. Emission ratios for agricultural residue burning calculations

Compound	Ratios	Data source
CH_4	0.005	Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Reference Manual (Volume 3); page 4.84
CO	0.06	
N_2O	0.007	
NOx	0.121	

Annex 2. GHG inventory for the agriculture sector

Table 37. GHG inventory results for 2014

GHG emission source	CH_4 (1000 tons CO2e)	N_2O (1000 tons CO2e)	Total (1000 tons CO2e)
TOTAL	57,214.3	32,537.5	89,751.8
4A Enteric Fermentation (CH_4)	10,200.6	0.0	10,200.6
4B Manure Management (CH_4)	704.6	8,158.7	8,863.4
4B Manure Management (N_2O)	44,294.6	0.0	44,294.6
4C Rice Cultivation - Flooded Rice Fields	0.0	23,955.5	23,955.5
4D Agricultural Soils	0.9	0.1	1.0
4E Field Burning of Agricultural Residues	2,013.6	423.1	2,436.7

A summary of the methods and sources of data used for each sector is presented in the tables below.

Livestock

Table 38. Livestock population in different climate regions (projection for 2020)

Animal	Unit	Temperate	Humid	Data source
Dairy cow	head	200,000	300,000	Decision No. 124 / QD-TTg dated 2 December 2012 of the Prime Minister
Non-dairy cow	head	6,600,000	4,900,000	
Buffalo	head	2,700,000	300,000	
Sheep	head	1,000	27,800	Decision No. 10-2008-QD-TTg dated 16 January 2008 of the Prime Minister
Goat	head	2,400,000	1,471,200	
Horse	head	66,000	678	Assuming that the number of horses in 2020, 2030 is unchanged from 2014
Pig	head	23,000,000	11,000,000	Decision No. 124 / QD-TTg dated 2 December 2012 of the Prime Minister
Poultry	head	250,000,000	130,000,000	

Table 39. Livestock population in different climate regions (projection for 2030)

Animal	Unit	Temperate	Humid	Data source
Dairy cow	head	320,000	480,000	Decision No. 124 / QD-TTg dated 2 December 2012 of the Prime Minister
Non-dairy cow	head	8,000,000	6,000,000	
Buffalo	head	2,700,000	300,000	
Sheep	head	1,000	32,200	Decision No. 10-2008-QD-TTg dated 16 January 2008 of the Prime Minister
Goat	head	2,800,000	1,666,800	
Horse	head	26,500,000	12,500,000	Assuming that the number of horses in 2020, 2030 is unchanged from 2014
Pig	head	288,000,000	152,000,000	Decision No. 124 / QD-TTg dated 2 December 2012 of the Prime Minister

Rice cultivation

Table 40. Rice cultivation – projection for 2020 (hectare).

	Northern region	**Central region**	**Southern region**	**Total**	**Source**	**Water manageme nt in IPCC**
Cultivated paddy area	**1.768.000**	**1.455.000**	**3.789.000**	**7.012.000**	Decision No. 124 / QD-TTg dated 2 December 2012 of the Prime Minister	
1. Irrigated area	1.668.000	1.313.000	3.719.000	6.700.000	Decision No. 124 / QD-TTg dated 2 December 2012 of the Prime Minister	
1.1. Irrigated rice area with actively water management	1.466.100	1.175.800	2.475.700	5.117.600	Assuming that data are unchanged from 2014. The 2014 data are cited from the Agricultural, Forestry and Fishery Statistics of the National Institute of Agricultural Planning and Statistics. Data provided by the General Statistics Office to the Climate Change Department	

	Northern region	Central region	Southern region	Total	Source	Water manageme nt in IPCC
1.1.1 Partial AWD	164.812	29.488	50.964	245.264	Assuming that data are unchanged from 2013. Data are cited from Department of Water Resources	Intermittent ly flooded – Single Aeration
1.1.2 Full AWD	38.692	4.818	8.616	52.126		Intermittent ly Flooded- Multiple Aeration
1.1.3 The continous flooded area	1.262.596	1.141.494	2.416.120	4.820.210	(1.1) - (1.1.1) - (1.1.2)	Continuous Flooded
1.2. Irrigated rice area without active water management	201.900	137.200	1.243.300	1.582.400	(1) - (1.1)	Intermittent ly flooded – Single Aeration
2. Upland/hill rice	30.000	24.000	68.000	122.000	Assuming that data are unchanged from 2010	Upland rice (no emission)
3. Rainfed rice	70.000	118.000	2.000	190.000	(1) - (2)	Rainfed rice

Table 41. Rice cultivation – vision to 2030

	Northern region	Central region	Southern region	Total	Source	Water management in IPCC
Cultivated paddy area	1.749.000	1.419.000	3.844.000	7.012.000	Decision No. 124 / QD-TTg dated 2 December 2012 of the Prime Minister	
1. Irrigated area	1.693.000	1.333.000	3.774.000	6.800.000	Decision No. 124 / QD-TTg dated 2 December 2012 of the Prime Minister	
1.1. Irrigated rice area with active water managemen t	1.466.100	1.175.800	2.475.700	5.117.600	Assumping that data are unchanged from 2014. The 2014 data are cited from the Agricultural, Forestry and Fishery Statistics of the National Institute of Agricultural Planning and Statistics. Data provided by the General Statistics Office to the Climate Change Department	
1.1.1 Partial AWD	164.812	29.488	50.964	245.264	Assuming that data are unchanged from 2013. Data are cited from Department of Water Resources	Intermittently flooded – Single Aeration

	Northern region	Central region	Southern region	Total	Source	Water management in IPCC
1.1.2 Full AWD	38.692	4.818	8.616	52.126		Intermittently Flooded-Multiple Aeration
1.1.3 The continous flooded area	1.262.596	1.141.494	2.416.120	4.820.210	(1.1) - (1.1.1) - (1.1.2)	Continuous Flooded
1.2. Irrigated rice area without active water management	226.900	157.200	1.298.300	1.682.400	(1) - (1.1)	Intermittently flooded – Single Aeration
2. Upland/hill rice	30.000	24.000	68.000	122.000	Assuming that data are unchanged from 2010	Upland rice (no emission)
3. Rainfed rice	26.000	62.000	2.000	90.000	(1) - (2)	Rainfed rice

Table 42. Rice area classified by water management regimes in 2020 (hectare)

Water management regime	Northern region	Central region	Southern region	Total
Continuous Flooded	1.262.596	1.141.494	2.416.120	4.820.210
Intermittently flooded – Single Aeration	366.712	166.688	1.294.264	1.827.664
Intermittently Flooded – Multiple Aeration	38.692	4.818	8.616	52.126
Upland /hill rice	30.000	24.000	68.000	122.000
Rainfed rice	70.000	118.000	2.000	190.000
Total	**1.768.000**	**1.455.000**	**3.789.000**	**7.012.000**

Table 43. Rice area classified by water management regimes in 2030

Water management regime	Northern region	Central region	Southern region	Total
Continuous Flooded	1.262.596	1.141.494	2.416.120	4.820.210
Intermittently flooded – Single Aeration	391.712	186.688	1.349.264	1.927.664
Intermittently Flooded-Multiple Aeration	38.692	4.818	8.616	52.126
Upland /hilly rice	30.000	24.000	68.000	122.000
Rainfed rice	26.000	62.000	2.000	90.000
Total	**1.749.000**	**1.419.000**	**3.844.000**	**7.012.000**

Agricultural soil

Table 44. Total amount of Nitrogen fertilizer consumption – projection for 2020 and 2030 (N_{FERT}- tons)

2020	2030	Data source
1.370.929.000	1.400.949.000	Calculated base on how much fertilizer apply for 1 ha in 2010, then multiply with total area, the same for 2020 and 2030, adjustment factor is 1,05 for inceasing of yield in 2020 and 2030 compare with 2013

Table 45. Crop production– projection for 2020 and 2030 (1000 tons)

Crop	Nitrogen fixation	2020	2030	Data source
Maize		7.200	8.640	Decision No. 124 / QD-TTg dated 2 December 2012 of the Prime Minister
Rice		42.000	44.000	
Millet		700	900	
Soybean	*	1.750	1.750	
Potato		11.000	11.000	
Sweetpotato		24.000	28.000	
Cassava		800	930	
Sugarcane		195	232	
Groundnut	*	50	50	

Crop	Nitrogen fixation	2020	2030	Data source
Beans	*	36	36	
Cotton		0,97	0,97	Assuming that data are unchanged from 2014
Jute		87,07	87,07	
Sedge		34,75	34,75	
Sesame		2	2	
Tobacco		322	322	

Burning of crop residues:

Table 46. Crop output – projection for 2020 and 2030 (1000 tons)

Crop	Nitrogen fixation	2020	2030	Data source
Maize		7.200	8.640	Decision No. 124 / QD-TTg dated 2 December 2012 of the Prime Minister
Rice		42.000	44.000	
Millet		700	900	
Soybean	*	1.750	1.750	
Potato		11.000	11.000	
Sweet potato		24.000	28.000	
Cassava		800	930	
Sugarcane		195	232	
Groundnut	*	50	50	
Beans	*	36	36	
Cotton		0.97	0.97	Assuming that data are unchanged from 2014
Jute		87.07	87.07	
Sedge		34.75	34.75	
Sesame		2	2	
Tobacco		322	322	

Crop residue ratio:

Crop residue ratio as compared with productivity for each crop is derived from the default value in GPG 2000 and the IPCC 1996 Guidelines.

Table 47. Crop residue ratio as compared with crop productivity

Crop	Residue/Crop Product Ratio	Data source
Maize	1	Table 4-16, GPG2000
Rice	1.4	
Millet	1.4	
Soybean	2.1	
Potato	0.4	
Sweetpotato	0.4	

Crop	Residue/Crop Product Ratio	Data source
Cassava	0.4	
Sugarcane	0.2	Table 4-17, The revised version of the IPCC Guidelines 1996
Grounut	1	Table 4-16, GPG2000
Beans	2.1	
Cotton	2.76	The ratios of cotton and jute residues were derived from the study reported by FAO for Asian Countries (1998). The ratio of sesame, rush and tobacco residues was taken as 1 as recommended by the IPCC. CPG 2000 - chapter 4 – Agriculture, page 457
Jute	2	
Sedge	1	
Sesame	2.1	
Tobaco	1	