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Vietnam NDC Sectoral Report

Agriculture

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On behalf of the
German Federal Ministry for Environment, Nature Conservation, and Nuclear Safety (BMU).

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Acronyms and abbreviations
Report

ADB	Asian Development Bank
ALU	Agriculture and Land-Use software
AWMS	Animal Waste Management Systems
AWD	Alternate Wetting - Drying
BAU	Business as Usual
BMU	German Ministry for the Environment, Nature Conservation, and Nuclear Safety
BUR	Biennial Update Report of Vietnam to UNFCCC
CC	Climate Change
CMA	Conference of the Parties to the Paris Agreement
COP	Conference of the Parties
CSA	Community-supported Agriculture
CO2e	CO2 equivalent
EF	Emissions Factor
FAO	Food and Agriculture Organization of the United Nations
GAP	Good Agricultural Practices
GDP	Gross Domestic Products
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GL 1996 revised	The Revised 1996 Guidelines on National GHG Inventory of the IPCC
GPG 2000	Good Agriculture Practice Guidelines and management of uncertainty in Climate change
GWP	Global Warming Potential
ICM	Integrated Crop Management
INDC	Intended Nationally Determined Contribution
IPCC	Inter-Government Panel for Climate Change

IPM	Integrated Pest Management
JOFCA	Japanese Forestry Consultants' Association
LCASP	Low Carbon Agriculture Support Program
LULUCF	Land Use, Land Use Change and Forestry
MACC	Marginal Abatement Cost Curve
MARD	Ministry of Agriculture and Rural Development
MONRE	Ministry Of Natural Resources And Environment
MRV	Measurement, Reporting and Verification
MUB	Molasses Urea Blocks
NAMA	Nationally Appropriate Mitigation Actions
NDC	Nationally Determined Contribution
SF	Scaling Factor
SRI	System of Rice Intensification
SNC	Second National Communication
UNDP	United Nation Development Program
UNFCCC	United Nations Framework Convention on Climate Change
VGGS	Vietnam Green Growth Strategy

Executive Summary

The following paper is part of a five-report series, produced in the context of the 2017-2020 revision and update of Vietnam's Nationally Determined Contribution (NDC).

Each of these works addresses a different sector, covering agriculture, energy, industrial processes and product use (IPPU), land use, land-use change and forestry (LULUCF), and waste. They all provide extensive trend analyses of a sector's projected greenhouse gas (GHG) emissions for the period of 2014-2030, which take current policy measures into consideration and assume no major changes moving ahead (business-as-usual scenario, BAU). On the basis of selected mitigation options, each paper outlines feasible mitigation scenarios that would see signification GHG emission reductions for the respective sector until 2030, as well as associated marginal abatement costs.

These five reports have informed the Government of Vietnam's updated and revised NDC, which is available at UNFCCC https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Viet%20Nam%20First/Viet%20Nam_NDC_2020_Eng.pdf. A technical background report, published by the Ministry of Natural Resources and Environment (MONRE), comprises more information.

In this study for agriculture, the IPCC Revised 1996 Guidelines on National GHG Inventory and Good Practice Guidance on National GHG Inventory in 2000 were used to develop the BAU scenario for agriculture in the period 2014-2030. The results show that GHG emissions from the agriculture sector in 2020 and 2030 will reach 104.5 $MtCO_2e$ and 112.1 $MtCO_2e$, respectively. These values are slightly higher that those of the NDC1.

The mitigation scenario was developed based on the assumption that additional action plans or policies are developed or considered. The Agriculture and Land Use (ALU) software was used for the calculation of the GHG mitigation options in the agriculture sector. The GHG mitigation options were reviewed for efficiency, incremental costs, mitigation potential and co-benefits compared to the BAU scenario. Sixteen GHG mitigation options were identified and assessed.

In the case of the unconditional contribution, there are four mitigation options: A1. AWD and SRI (where infrastructure is fully financed); A2. Mid-season drainage in rice cultivation; A3. Shifting double rice or triple rice cultivation to rice-shrimp; and A4. Shifting double rice or triple rice cultivation to upland crops at scale.

With international support, Vietnam can implement twelve additional mitigation options: A5.1. Improvement of dairy cow diets; A5.2. Improvement of dairy cow beef; A5.3. Improvement of buffalo; A6.1. Reuse of upland agricultural/crop residues as organic fertilizer; A6.2. Introduction of biochar (large scale); A7.1. ICM in rice cultivation; A7.2. ICM for annual upland crops cultivation; A8. Substitution of urea with ammonium sulphate fertilizer; A9.1. AWD and SRI (where infrastructure is partly financed); A9.2. AWD and SRI (where there is basic infrastructure), and A10. Drip irrigation combined with fertilizer for coffee. In addition to mitigation potential, these options bring back co-benefits to the economy, society, environment and climate change adaptation.

In order to achieve its mitigation targets, the study also recognized the barriers and needs for policy, technology, finance and capacity building, and MRV. The total amount of domestic funding needed is USD 1329.2 million. An additional USD 4,604.7 million would need to be mobilized from international sources in order to implement the conditional contribution.

01. Introduction

1.1. Background Information on the Paris Agreement and NDCs

The Paris Agreement on Climate Change was adopted by the states in COP 21 as the first global legal document regulating responses to climate change. The focus of the Paris Agreement is on the introduction of regulations concerning the responsibility for developing and implementing a Nationally Determined Contribution (NDC) of each of the Parties to the United Nations Convention Framework on Climate Change (UNFCCC). So far, the Agreement has been signed by 195 countries, ratified by 179 parties, and officially entered into force on 4 November 2016.

Although countries had submitted NDCs by the end of 2015, even if all NDCs are fully implemented the global average temperature may still increase by 2.9°C to 3.4°. Achieving a target of 1.5°C will require zero global GHG emissions between 2060-2080 and around 2080-2090 for the 2°C target. Therefore, Decision No. 1/CP21 of the Paris Agreement on Climate Change requires all parties to review and update their NDCs at least every five years with the expectation of increasing their ambition to contribute to mitigating GHG emissions. All States are required to submit their NDC (new or updated) by 2020 and every five years thereafter at least 9-12 months prior to the Conference of the Parties to the Paris Agreement (CMA). Consequently, countries are required to continually review their NDCs in order to identify options to raise ambition and mitigate the current contribution. The UNFCCC requires the parties to submit a revised NDC for the first time by 2020. The NDC revisions should consider a medium-term plan as well as a long-term plan to reduce GHG emissions. In addition, Article 13 of the Paris Agreement on Climate Change requires States to develop a transparent framework that requires parties to regularly submit GHG inventory reports and provide information on the NDC implementation process, support, and adaptation efforts. Technical assessments will be made for all parties to analyze the consistency of the information, identify areas in need of improvement, and strengthen capacity. The parties will also participate in facilitative, multilateral considerations of progress with respect to the respective implementation and achievement of their NDC's goals.

Recently, Vietnam planned to review and update its NDC with a view to submitting an updated NDC to UNFCCC in 2019. Thereby, Vietnam is fulfilling a requirement of the Paris Agreement - outlined in decision 1/CP21). Reviewing and updating its NDC is also an official requirement of the Vietnam Government. In 2016, the Prime Minister approved the Plan for the implementation of the Paris Agreement on Climate Change. In that plan, task No. 1 requires updating of the NDC's mitigation component and task No. 17 requires updating the NDC's adaptation component.

1.2. Overview of the Agriculture Sector in Vietnam

Vietnam was primarily an agriculture-based country 30 years ago. Vietnam'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, Vietnam 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 the agriculture sector, the average growth rate of 3.7%/year in 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 agriculture, forestry and fisheries output rose from 16.3% to 22.4%, while the share of cultivation and livestock declined from 80% to 74.9%.

Table 1: Agricultural land and crop area

Unit: hectare

	1990	1995	2000	2005	2010	2015
Total area of crop cultivation	**9,040.00**	**10,496.90**	**12,644.30**	**13,287.00**	**14,061.10**	**14,919.60**
Annual crops	8,101.50	9,224.20	10,540.30	10,818.80	11,214.30	11,674.30
Food crops	6,476.9	7,324.30	8,399.10	8,383.40	8,615.90	8,996.30
Rice	-	-	-	-	-	4,143.10
Annual industrial crops	542	716.7	778.1	861.5	797.6	676.6
Perennial crops	938.5	1,272.70	2,104.00	2,468.20	2,846.80	3,245.30
Perennial industrial crops	657.3	902.3	1,451.30	1,633.60	2,010.50	2,154.50
Fruit trees/crops	281.2	346.4	565	767.4	779.7	824.4

Source: GSO, 2017

Data in Table 1 show that the total area of crop cultivation includes food crops (includes food crops and rice and annual industrial crops, perennial crops (includes perennial industrial crops and fruit trees/crops). For the rice area, one set of statistical data is available for 2015, while for later years, data is available for three seasons a year. Annual industrial crops dropped after 2015 because of low yields, less area, and climate.

In 2017, the export value of agro-forestry-aquatic products reached USD 36.37 billion, representing a year-on-year increase of 13 percent. The export of major agricultural products was estimated at USD 18.96 billion, a year-on-year growth of 15.7 percent. There are seven key agricultural export products each with an export value of more than USD 1 billion: 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 the livelihoods and the incomes of local people in mountainous regions.

Vietnam is a typical humid tropical country with favorable conditions for agricultural 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 agricultural products will be reached in the future. This trend will create favorable conditions for countries with comparative advantages in agriculture, but also highlights competition in natural resources use for agricultural growth.

Table 2: Agro-forestry-fisheries output of the agriculture sector (1990 - 2015)

Unit: 1000 tons

Productivity	1990	2000	2005	2010	2015
I. Food crops		**34,538.9**	**39,621.6**		
1. Rice		32,529.5	35,832.9	40,005.6	45,105.5
2. Maize		2,005.90	3,787.10	4,625.7	5,287.2
3. Sugarcane		15,044.3	14,948.7	16,161.7	18,335.8
4. Cotton		18.8	33.5	12.5	1.3
5. Groundnut		355.3	489.3	487.2	454.1
6. Soybean		149.3	292.7	298.6	146.4
II. Fruit crops/trees					
1. Grape			28.6	16.7	31
2. Mango			367.8	580.3	702.9
3. Citrus			601.3	728.6	727.4
4. Longan			612.1	573.7	513
5. Lychee, rambutan			398.8	522.3	715.1
III. Industrial crops					
1. Cashew nuts	-	67.6	240.2	310.5	
2. Rubber	57.9	290.8	481.6	751.7	

Productivity	1990	2000	2005	2010	2015
3. Coffee	92.0	802.5	752.1	1100.5	
4. Tea	145.1	314.7	570.0	834.6	
5. Pepper	8.6	39.2	80.3	105.4	
IV. Livestock					
1. Production of buffalo meat		48.4	59.8	83.6	85.8
2. Production of beef		93.8	142.2	278.9	299.7
3. Production of pork		1,418.1	2,288.3	3,036.4	3,491.6
4. Production of poultry meat		292.9	321.9	615.2	908.1
5. Milk Production (mil. litre)		51.5	197.7	306.7	723
6. Eggs (million)		3,771.0	3,948.5	6,421.9	8,874.3
7. Production of honey (tons)		5,958.0	13,591.0	11,944.4	15,478.1
8. Production of silkworm cocoons (tons)		7,153.0	11,475.0	7,106.50	6,542.90
V. Fishery product		**2,250.90**	**3,466.80**	**5,142.70**	**6,582.10**
1. Exploitation (marine fisheries)		1,660.90	1,987.90	2,414.40	3,049.90
2. Aquaculture		590	1,478.90	2,728.30	3,532.20

Source: GSO, 2018

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 the 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 incomes of farmers.

Agricultural growth in Vietnam is based on intensive natural resource use. 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 GHG 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. 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 savannahs and burning of agricultural residues. The Second National Communication (SNC) identifies the agriculture sector as a key source of

GHG emissions, estimated at about 43% of total national emissions in 2000 (MONRE, 2010). The SNC, however, also forecasts that by 2010, while agricultural emissions are likely to continue to rise, rapid economic growth will cause energy emissions to rise even more rapidly. Within the agriculture sector in Vietnam, paddy rice is a key source of GHG emissions, mainly in the form of methane and nitrous oxide. However, livestock emissions are increasing rapidly due to rapid growth in animal production as a consequence of rising demand.

The Ministry of Agriculture and Rural Development (MARD) 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, Vietnam is further deepening its commitment to green growth. Within the context of the Vietnam 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.

1.3. Objectives and Scope of the Study

In 2015, under the leadership of the Ministry of Natural Resources and Environment (MONRE) and with support from the German Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) through Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the United Nations Development Programme (UNDP), Vietnam successfully submitted its Intended Nationally Determined Contribution (INDC) to the Secretariat of the UNFCCC. Vietnam's INDC is implemented at the national level in relevant sectors, including the energy, agriculture, Land Use, Land Use Change and Forestry (LULUCF), and waste sectors.

However, so far there have been a number of changes in the Vietnamese context that may affect the potential and costs of GHG reduction as well as the targets in Vietnam's INDC. Therefore, it is necessary to review and update the BAU and mitigation scenario for the agriculture sector for the period 2020-2030.

The goal of this study is to develop a plan to reduce GHG emissions for the agriculture and rural development sector to 2030 in line with commitments under the Paris Agreement. In order to reach the general objectives, the following specific objectives have been identified:

- Estimate BAU GHG emissions in the agricultural and rural development sector
- Identify options to reduce GHG emissions in the agriculture and rural development sector
- Calculate the mitigation potential and cost for each option
- Assess the economic, social and environmental benefits and co-benefits with climate change adaptation for each mitigation option
- Propose investment and implementation plans for the selected options

The scope of this study is as follows:

Sector: All sub-sectors of the agriculture sector, including: enteric fermentation; manure management; rice cultivation; agriculture soils and field burning of agricultural residues.

Base year: The year 2014 was chosen since this is the latest year for which national data was available for modelling.

Types of GHGs: This study includes Carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O).

02. Mitigation efforts in the agriculture sector

2.1. Policies Related to Mitigation in the Agriculture Sector

The Ministry of Agriculture and Rural Development (MARD) has been working to reduce GHG emissions through a new rural program that targets 20% reduction in GHG emissions, 20% growth in agricultural production and 20% reduction in poverty by 2020 (Decision 3119, 2011). In the Vietnam 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. Recently, Vietnam has issued a number of policies related to socio-economic development, green growth and low carbon agriculture (Table 3).

Table 3: Summary of recently issued policies related to GHG emissions reduction in the agriculture sector

No	Policy name	Key policies
1	Decision No. 1393 / QD-TTG dated 25 September 2012 of the Prime Minister approving the Vietnam Green Growth Strategy	Develop strategies for economic green growth with average reduction of 8-10% of GHG emissions in 2020
2	Decision No. 403 / QD-TTg dated 20 March 2014 of the Prime Minister approving the National Green Growth Action Plan for the 2014-2020 period	Action plans with list of projects that should be implemented in the planning period

No	Policy name	Key policies
3	Decision No. 124 / QD-TTg dated 2 February 2012 of the Prime Minister approving the Master Plan for Development of Agricultural Production and Rural Development	To make a plan for GDP growth for the agriculture sector in period of 2011-2020 with the following structure: agriculture (64.7%), forestry (2%), aquaculture 33.3(%) with a vision to 2030 with the structure: agriculture 55(%), forestry (1.5%), and aquaculture (43.5%)
4	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	a) Sustain growth and raise efficiency and competitiveness by increasing productivity, quality, and added value; satisfy the demands of consumers in Vietnam and boost exports. GDP growth of the agriculture sector reaches 2.6%-3% during 2011-2015, and 3.5% - 4% during 2016-2020; b) Raise the incomes and improve living standards of rural residents, ensure food security (including nutrition security) in both the short and the long term; contribute to the reduction of the poverty ratio. By 2020, incomes for rural households increase by 2.5 times in comparison to 2008; 20% of communes meet the standards of new rural areas by 2015, and 50% of communes meet such standards by 2020; c) Enhance natural resource management, reduce GHG emissions and negative impacts on the environment, utilize environmental benefits, raise capacity for risk management, enhance disaster preparedness, and increase forest coverage to 42% - 43% by 2015, and to 45% by 2020; contribute to VGGS.
5	Decision 809 / CT-BNN	Integrating climate change into the formulation and implementation of strategies, master plans, programmes, and projects on development of the agriculture and rural development sector in the period 2011-2015
6	Decision No. 3119 / QD-BNN-KHCN dated 16 September 2011 of MARD approving the action plan for GHG emissions reduction in agriculture and rural areas up to 2020	Action plan for reducing GHG emissions in agriculture to 2020, in which Crop production reduces 5.72 Gt CO2e Livestock reduces 6.3 Gt CO2e Forestry reduces/absorbs 1371 Gt CO2e Water resources reduces 0.17 Gt CO2e Rural development reduces 4.78 Gt CO2e

No	Policy name	Key policies
7	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	Strengthen capacity on climate monitoring and early warning Ensure food and water security Proactively respond to disasters; prevent inundation of big cities; strengthen security of river and sea dikes, and reservoirs Reduce greenhouse gas emissions and develop a low carbon economy Improve management capacity, finalize mechanisms and policy on climate change Raise awareness and develop human resources Develop science and technology as a foundation for formulating policies, assessing impacts and identifying measures on climate change adaptation and mitigation. Cooperate with the world to improve the status and role of Vietnam in international activities on climate change Mobilize sources and finance to respond to climate change
8	Decision No. 1775 / QD-TTg dated 21 November 2012 of the Prime Minister approving the project on greenhouse gas emissions control, managing carbon credit trading activities in the world market	Management of GHG emissions in order to implement the UNFCCC and other international agreements to which Vietnam is a party, and at the same time take advantage of the opportunity to develop a low carbon economy, green growth, and together with the international community in efforts to reduce greenhouse gas emissions, contribute to sustainable development Managing and monitoring efficiency of the purchase, sale and transfer of carbon credits generated from the mechanism inside and outside the framework of the Kyoto Protocol on the world market
9	Decision No. 819/QD-BNN-KHCN dated 14 March 2016 of MARD approving the Action Plan for Response to Climate Change in Agriculture and Rural Development 2016-2020, with a Vision to 2050	Capacity building in science, technology and policy to respond to climate change in the period 2016-2020 with a vision toward sustainable agricultural production Detail adaptation and mitigation actions for each sub-sector in the period 2016-2020 Increase activities for responding, avoiding and mitigating disasters with a vision toward 2050

No	Policy name	Key policies
10	Decision No. 1670/QD-TTg dated 31 October 2017 by the Prime Minister	Approving the environmental programme to cope with climate change and green growth in the period 2016-2020 Adapt to the impacts of climate change and reduce GHG emissions; strengthen the capacity of people and natural systems to adapt to climate change; achieve green growth, and progress towards a low- carbon economy Restructure economic institutions, encourage 'greening' and economic development using energy efficiently Actively implement international and national climate commitments Implement commitments to reduce GHG emissions after 2020 (enshrined in the Paris Agreement and Vietnam's NDC)
11	Decision No. 923/QD-BNN-KH dated 24 March 2017 of MARD on green growth	Effectively implement the VGGS; develop green agriculture while ensuring social and environmental issues and EE, using natural resources for a low carbon economy, reducing emissions and enhancing livelihoods. Enhance GHG absorption capacity in line with resources and the real situation; build eco-friendly lifestyles, contributing to adaptation to climate change Reform farming techniques and improve agricultural management to reduce GHG emissions in agroforestry and fisheries production, thereby achieving a 20% reduction of GHG emissions from the agriculture and rural development sector by 2020, compared to 2010

2.1.1. Action plan for GHG emissions reduction at sectoral level

At sectoral level, MARD issued Decision 3119/QD-BNN-KHCN in 2011 which focused on two main objectives:

- 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, reducing total GHG emissions in the agriculture and rural development sector by 20% compared with BAU; simultaneously ensure the 20% growth target for agriculture and rural development, and reduce the poverty rate according to the sectoral development strategy.

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

2.1.1.1. Crop production

- Apply improved cultivation techniques to rice production, such as irrigation and saving inputs (including systems of rice intensification (SRI), three reduction and three gains (3G3T), one obligation and five reduction (1P5G), and alternate wetting and drying (AWD)) to reduce GHG emissions.
- Collect and reuse rice straw to completely restrict its burning and directly limit incorporation of rice residues into soil that increase GHG emissions and environmental pollution.

- Apply technical solutions to enhance the effectiveness of nitrogen fertilizers to reduce N_2O emissions from paddy cultivation and other crops.

- Transform parts of the rice cultivation area with low output to short duration industrial crops with low emissions and higher economic revenue.

- Transform one rice crop from land with 2-3 rice harvests with low output along rivers and coasts to aquaculture (shrimp, fish) to obtain higher economic value.

- Apply solutions to save energy and fuel in land preparation, irrigation for industrial crops, and 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 emissions from crop residue decomposition.

2.1.1.2. Livestock

- Change the feed composition for animal and poultry raising to reduce GHG emissions 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 fuels.

- Apply composting technology to treat animal and poultry waste to reduce GHG emissions.

- Apply the VietGAP model (good agricultural practices) in livestock production.

- Replace partly raw foods with 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 treating animal waste.

2.1.1.3. Aquaculture

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

- Improve fishing techniques and technologies in fishing activities to reduce GHG emissions.

- Establish and improve models of fishing services, and protect fishing grounds to reduce GHG emissions as a result 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 for aquaculture to reduce GHG emissions.

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

- Enhance effectiveness of irrigation and drainage pumping systems to save energy and reduce GHG emissions.

- Improve irrigated systems to prevent water loss and effectively manage and stabilize irrigation systems, and explore autonomous water running systems to reduce loss 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, and to use bio-fuels, solar and other forms of renewable energy.

- Select and develop new materials, techniques and equipment to enhance production effectiveness, save inputs and reduce emissions in artisanal villages, agriculture, forest and fish processing activities.

- Transfer technologies for treatment and reuse of rural organic waste and waste from production in artisanal villages, food and wood processing plants (sawdust, by-products), fish processing, mills, and processing plants for sugar and coffee, etc.

- Develop and apply clean technology to save inputs and reduce emissions from artisanal villages and from food, fishery and forest processing activities.

2.1.2. Action Plan on Climate Change Response for the agriculture and rural development sector

MARD issued Decision No. 543/QD-BNN-KHCN on Action Plan on Climate Change Response for the Agriculture and Rural Development Sector in the period 2016-2020 with a vision to 2050. This decision aims to strengthen the capacity of the agriculture and rural development sector to mitigate GHG emissions, reduce impacts from climate change, and to promote sustainable development. The five main objectives are:

- Stabilise and 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 emissions orientation and sustainable development

- Ensure food security and the maintenance of 3.8 million hectares of paddy land, of which 3.2 milllion hectares has at least 2 crops per year.

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

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

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

- 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 nitrogen use to reduce N_2O emissions.

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

- Study the development of different kinds of feeds and change the ration of feeds in order to raise productivity and quality of animal products, with priority given to dairy cattle and ruminants.

- Transform small-scale farming methods into animal husbandry, forming a key breeding area incorporating environmental protection, biosafety and high technology application.

- Develop animal husbandry with priority to animal breeding that has highly resistant capacity to the living environment, in order to make good use of advantages and improve the livelihoods.

- Enhance the application of advanced technologies in the treatment of animal waste as bio-organic fertilizers for safe livestock and environmental protection.

- Continue to implement the biogas program, and research and select suitable filtering equipment to diversify the use. This will improve the efficiency of biogas utilization in animal husbandry to achieve triple benefits in terms of production, clean energy and reducing environmental pollution.

- Study and develop incentive policies on fishery sector development and insurance under climate change context; policies on financial support, establishment of the fund for renewable fisheries resources, shifting structure of fisheries exploitation in coastal and off-shore areas.

- Research the development and transfer of shrimp-rice, fish-rice, shrimp-mangrove models, and 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 technologies to produce bio-energy of high economic value.
- Replicate and improve the model of irrigation and drainage of rice fields, and drip irrigation and sprinkler irrigation for coffee production areas, fruit trees, shallow and vegetable crops with economic value in specialized areas.

2.1.3. Agricultural restructuring program

Decision No. 899/QD-TTg dated June 10, 2013 of the Prime Minister approving the Project on "Agricultural restructuring towards raising added value and sustainable development".

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 management efficiency and the use of resources (land, water, sea, forests); consider mutual effects and potential of resource extraction; enhance measures for reducing GHG emissions; efficient and safe use of chemicals, pesticides, and waste from breeding, farming, processing, and handicrafts; preserve biodiversity.
- Encourage the application of environmental standards together with a strict supervision mechanisms to stimulate the development of a 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 tons 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 tons in order to supply materials for animal feed production and reduce imports.
- 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, and 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 the North midlands and highlands.
- Prioritize the development of productive varieties and breeds that are able to resist pests and climate change; invest in pest surveillance projects, prevention, and control; support investment in preservation, processing, reduction of post-harvest loss, and assurance of food safety and hygiene.
- Focus investment on 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.

Table 4: Key mitigation actions in the agriculture sector

Mitigation action	Description	Implementation period	Budget	Quantitative goals	Results achieved
Biogas program for livestock	The program was widely implemented in 58 provinces/cities in Vietnam and was supported by the Government of the Netherlands. The overall objective of the program is to support the use and development of biogas technology to manage manure and animal waste while producing clean and low-cost fuel for energy, hence reducing GHG emissions	Phase I: 2003-2005 Bridging phase: 2006 Phase II: 2007-2015	EUR 41.806 million, from which EUR 9.58 million is by grant from the Government of the Netherlands; additional sources from other donors and GHG emissions reduction credit selling	i) Support to build 160,000 biogas systems for the two phases ii) Emissions reduction of 800,000 tCO2e/year for the two phases	Support for building 158,000 biogas systems Conducted training for 1,064 technicians, 1,668 biogas builders and organizing 140,000 dissemination and training workshops Provide clean energy source equivalent to 2,800 TJ/yr EUR 1.3 million received from the sale of 1,290,876 VGS credits
System of Rice Intensification Program	This program aims at development and application of an innovative rice cultivation technique "System of Rice Intensification" (SRI). This system includes new technical measures as follows: i) replanting of young rice (11-15 days); ii) replanting one line/cluster or sowing thinly; iii) alternate irrigation and drainage of exposed fields; iv) increasing the amount of organic fertilizer as much as possible to maximize air permeability of the soil and reduce the use of pesticides and chemical fertilizers. These measures will save investment costs, ensure increased rice yield and reduceGHG emissions from rice cultivation	2007 - 2016	VND 15 billion, of which VND 10 billion comes from the local budget, VND 5 billion from ODA	i) Implementation of SRI for 500,000 ha of rice ii) Reducing production inputs (seed, fertilizer, pesticides, irrigation water) iii) Reducing emissions by 2 MtCO2e/year	Emissions reduction of 4.68 tCO2e/ha per crop from SRI implementation 394,894 ha of rice fields in 23 provinces applied SRI technology in 2015 Increased average farmer incomes by USD 200/ha per crop compared to traditional farming

Mitigation action	Description	Implementation period	Budget	Quantitative goals	Results achieved
Low-carbon agriculture support program	The Low Carbon Agriculture Support Program (LCASP) project is an ADB loan project, implemented in 10 provinces, aiming to: improve the management of livestock waste and agricultural by-product waste; produce biogas to generate clean energy sources and reduce environmental pollution; and replicate successful models of cost-effective low-carbon agricultural production which reduces GHG emissions.	2013 - 2019	USD 84 million, of which USD 74 million is from an ADB loan	i) Support to build 65,000 small scale biogas systems, 40 medium and two large scale biogas systems ii) Emissions reduction of 150,000 tCO_2e/ year iii) Six studies on low-carbon agriculture and agricultural waste management iv)Seven demonstration models	By the end of 2016: Supported the construction of 43,157 small, 8 medium and 2 large scale biogas systems. Training conducted for 45,775 farmers, 375 masons, 1,125 technicians, and 10 contractors using small biogas plants Organized 1,500 training courses. Development of the database; Concessional loans provided to 335 households with a total amount of VND 135 billion (as of August 2016)

Source: MONRE, 2017

2.2. Mitigation Actions

GHG mitigation actions in the agriculture sector are mainly based on:

- The National Strategy for Green GHG emissions reduction (8-10%), the National Strategy for Natural Resources and Environment (Decision 1393/QĐ-TTG), and the Vietnam Green Growth Plan (Decision 403 / QĐ-TTG).
- GHG emissions reduction plan for agriculture and rural development to 2020 (Decision 3119/QD-BNN-KHCN) with a plan to reduce GHG emissions by 20% by 2010 and reduce poverty by 20%.

Indicative GHG emissions reduction activities have been identified in the fields of cultivation, livestock husbandry, aquaculture, and irrigation:

- Crop production and cultivation: mitigation activities include the application of advanced cultivation practices and technologies, such as short-season varieties, AWD, and crop residue management etc.
- Livestock: mitigation activities include improvement of livestock diets to reduce methane emissions from ruminant animals, animal waste management, and improvement of the production standards and regulations to ensure the complete chain from agriculture production, feed processing, livestock production and waste management appropriate with the climate change condition.
- Aquaculture: mitigation activities include optimization of feeding intake for aquaculture, reuse of pond mud, use of high-capacity boats, and improvement of cooling systems.
- Irrigation: mitigation activities include reduction of discharge to irrigation systems, water quality management, optimization of water use, and water-saving practices.

However, an MRV system has not been developed yet, so the impacts of these mitigation actions cannot be estimated comprehensively. Rather, some of these technologies are implemented as pilot experiments, with limited results.

A number of key mitigation actions implemented by MARD in the agriculture sector and their respective results are summarized in Table 4.

03. Greenhouse gas inventory of the agriculture sector in 2014

3.1. Methodology, Data, and Emissions Factors

The Revised Guidelines on National GHG Inventory of the IPCC (GL 1996 revised) were used to conduct the GHG inventory for the agriculture sector in 2014. According to IPCC, there are six sub-sectors under the agriculture sector: 4A. Enteric fermentation (CH_4); 4B. Manure management (CH_4); 4C. Manure management (N_2O); 4C. Rice cultivation; 4D. Agricultural soils; and 4E. Field burning of agriculture residues. The method to estimate GHG emissions for each sub-sector is presented in Table 5.

Table 5: The general approach to estimating GHG emissions from the agriculture sector

Sub-sector	Tier
4A Enteric Fermentation (CH4)	Tier 1
4B Manure Management (CH4)	Tier 2
4B Manure Management (N2O)	Tier 2
4C Rice Cultivation - Flooded Rice Fields	Tier 1 (CS EF)
4D Agricultural Soils	Tier 1a
4E Field Burning of Agricultural Residues	Tier 1

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

a) Methodology

According to the revised IPCC GL1996, the amount of CH_4 emissions from enteric fermentation is calculated based on the following equation:

$E= \sum_i A_i * EF_i$

Where:

E = total methane emissions from enteric fermentation (Gg CH_4/year)

EF = emissions factor for each animal type, (kg/animal/year)

A = population of animals (head)

i = animal type

b) Activity data

The animal population by type of livestock in 2014 is presented in Table 6.

Table 6: Data on animal population in 2014

Livestock	Population (number of animal head)	Source of data
Dairy Cows	227,600	Statistical Yearbook of Agriculture and Rural Development in 2015 (MARD, 2016)
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 (2016)
Buffalo	2,521,400	Statistical Yearbook 2015 (GSO, 2016)
Sheep	68,580	Numbers of sheep and goats in 2014 were calculated based on the number of sheep and goats in 2013
Goats	1,600,320	
Horses	66,678	Statistical Yearbook 2015 (GSO, 2016)
Swine	26,761,400	
Poultry	327,700,000	

c) Emissions factors

The emissions factors for calculating methane emissions from enteric fermentation are presented in Table 7.

Table 7: Enteric fermentation CH4 emissions factors for livestock

Unit: kg CH4/animal head/year

Livestock	Emissions factors	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	

3.1.2. Manure management (CH_4, N_2O) – (4B)

3.1.2.1. CH_4 emissions from manure management

a) Methodology

According to the revised IPCC GL1996, the amount of GHG emissions from manure management is calculated based on the following equation:

$$E = \sum_{ik} A_{ik} * EF_{ik}$$

Where:

E = total methane emissions from manure management (Gg CH_4/year)

EF = emissions 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

c) Emissions factors

According to the revised IPCC GL1996, the emissions factors for calculating GHG emissions from manure management was calculated based on the following equation:

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

where:

EF_i = annual emissions 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

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

b) Activity data

The activity data to estimate CH_4 emissions from manure management is presented in Table 8.

Table 8: Activity data to estimate GHG emissions from manure management in 2014

Animal type	Unit	Climate region (15-25oC)	Climate region >25oC	Data source
Dairy Cows	Head	91,100	136,500	Statistical Yearbook of Agriculture and Rural Development in 2015 (MARD, 2016)
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 (2016)
Buffalo	Head	2,263,600	257,800	Statistical Yearbook 2015 (GSO, 2016)
Sheep	Head	3,800	64,780	Numbers of sheep and goats in 2014 were calculated based on the number of sheep and goats in 2013
Goats	Head	1,006,790	593,530	
Horses	Head	66,300	378	Statistical Yearbook 2015 (GSO, 2016)
Swine	Head	18,154,700	8,606,700	
Poultry	Head	214,000,000	113,700,000	

The default value ratio of excretion of volatile solids (VS) from livestock waste (Table 9) and of the maximum methane producing capacity for manure by animal type (Table 10) were taken from the revised 1996 IPCC Guidelines.

Table 9: Ratio of excretion of volatile solids 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	
Goats	0.35	
Horses	1.72	
Swine	0.30	
Poultry	0.02	

Table 10: Maximum methane producing capacity for manure produced by animal type

Animal	Value (m^3/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
Goats	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

The default value of methane conversion factors (MCF) for each manure management system were taken from GPG 2000 and expert judgement (Table 11).

Table 11: Methane conversion factors (MCF) for each manure management system

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

Table 12: 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 13: Emissions factors for dairy cows, non-dairy cattle, buffalo and swine in each manure management system in different climate regions

Unit: kg/animal

Animal	Greenhouse gas inventory of the agriculture sector in 2014		Source
	15 – 25°C	>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 14: Emissions factors for sheep, goats, horses, poultry in each manure management system in different climate regions

Unit: kg/animal

Animal	Climate region		Source
	15 – 25°C	> 25°C	
Sheep	0.16	0.21	Table B-7, page 4.47. Revised 1996 IPCC Guidelines
Goats	0.17	0.22	
Horses	1.64	2.18	
Poultry	0.02	0.02	

3.1.2.2. N_2O emissions from manure management

a) Methodology

According to the revised IPCC GL1996, the amount of GHG emissions from manure management is calculated based on the following equation:

$$(N_2O-N)_{(mm)} = \Sigma_{(S)}\{[\Sigma_{(T)}(N_{(T)} \cdot N_{ex(T)} \cdot MS_{(T,S)})] * EF_{3(S)}\}$$

Where:

$(N_2O-N)_{(mm)}$ = 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

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

$MS_{(T,S)})$ = fraction of $N_{ex(T)}$ 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 emissions factor for an AWMS (kg N_2O-N/kg of N_{ex} in AWMS).

S = Animal waste management systems

T= Animal type.

Kg N_2O-N are converted to kg N_2O by multiplying by.

b) Activity data

The activity data to estimate N_2O emissions from manure management is presented in Table 8.

c) Emissions factors

The emissions factors to estimate N_2O emissions from manure management are presented in Table 15.

Table 15: N-excretion rate per animal

Unit: kg N/animal/year

Animal	N-excretion	Data source
Dairy Cows	60	Table B-1 Revised 1996 IPCC Guidelines
Non-Dairy Cattle	40	
Poultry	0.6	
Sheep	12	
Swine	16	
Other animals	40	

Table 16: N_2O emissions factor for each AWMS

Unit: kg N_2O– N/kg N

AWMS	N_2O emissions factor for each AWMS	Data source
Poultry manure with bedding	0.02	GPG 2000 (Tables 4.12, 4.13)
Aerobic treatment	0.02	
Composting	0.02	
Anaerobic lagoons	0.001	
Pasture range and paddock (grazing)	-	

3.1.3. Rice cultivation (CH_4) – (4C)

a) Methodology

According to the revised IPCC GL1996, the amount of GHG emissions from rice cultivation is calculated based on the following equation:

Emissions from Rice production (Tg/yr) = ∑i∑j∑k(EFijk x Aijk x 10^{-12})

Where:

EFijk = a seasonally integrated emissions factor for *i*, *j*, and *k* conditions, in g CH_4/m^2

Aijk = 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)

b) Activity data

The activity data to estimate CH_4 emissions from rice cultivation are presented in Table 17.

Table 17: Rice production area in Vietnam

Unit: hectare

	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	MARD (2014)	
1.1. Area with active water management	1,466,100	1,175,800	2,475,700	5,117,600	National Institute of Agricultural Planning and Projection (2014)	
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 Continuously flooded area	1,262,596	1,141,494	2,416,120	4,820,210	(1.1) - (1.1.1) - (1.1.2)	Continuously Flooded
1.2. 1.1. Area without water management	226,780	146,975	1,978,219	2,351,974	(1) - (1.1)	Intermittently flooded – Single Aeration
2. Upland rice	30,000	24,000	68,000	122,000	Assumptions are unchanged from 2010	Upland rice
3. Rain-fed rice	89,020	134,825	781	224,626	Total planted rice area - (1) – (2)	Rain-fed rice

Table 18: Rice ecosystems under different water management regimes in Vietnam

Unit: hectare

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
Rain-fed rice	89,020	134,825	781	224,626
Total	1,811,900	1,481,600	4,522,700	7,816,200

c) Emissions factors

Emissions and scaling factors for rice fields are taken from the revised IPCC 1996 Guidelines for upland rice and for different water regimes as shown in Table 19.

Table 19: CH_4 emissions scaling factors for rice ecosystems and water management regimes relative to continuously flooded fields (without organic amendments)

<table>
<tr><th>Category</th><th colspan="2">Water management regime</th><th>Scaling Factor (SF_w)</th></tr>
<tr><td>Upland</td><td></td><td>None</td><td>0</td></tr>
<tr><td rowspan="7">Lowland</td><td rowspan="3">Irrigated</td><td>Continuously Flooded</td><td>1.0</td></tr>
<tr><td>Intermittently flooded – Single Aeration</td><td>0.5 (0.2-0.7)</td></tr>
<tr><td>Intermittently flooded – Multiple Aeration</td><td>0.2 (0.1-0.3)</td></tr>
<tr><td rowspan="2">Rain-fed</td><td>Flood prone</td><td>0.8 (0.5-1.0)</td></tr>
<tr><td>Drought prone</td><td>0.4 (0-0.5)</td></tr>
<tr><td rowspan="2">Deep water</td><td>Water depth 5-10 cm</td><td>0.8 (0.6-1.0)</td></tr>
<tr><td>Water depth >100cm</td><td>0.6 (0.5-0.8)</td></tr>
</table>

Source: IPCC Guidelines, Reference Manual, Table 4-12.

Table 20: CH_4 emissions factors for continuously flooded regimes

Unit: g/m^2

<table>
<tr><th>Continuously flooded regime</th><th>EF</th><th>Data source</th></tr>
<tr><td>Northern region</td><td>37.50</td><td rowspan="3">Research Centre for Climate Change and Sustainable Development</td></tr>
<tr><td>Central region</td><td>33.59</td></tr>
<tr><td>Southern region</td><td>21.72</td></tr>
</table>

Table 21: CH_4 emissions scaling factors for rice ecosystems and water management regimes relative to continuously flooded fields (without organic amendments)

Category		Water management regime	Scaling Factor (SF_w)
Upland		None	0
Lowland	Irrigated	Continuously Flooded	1.0
		Intermittently flooded – Single Aeration	0.5 (0.2-0.7)
		Intermittently Flooded – Multiple Aeration	0.2 (0.1-0.3)
	Rain-fed	Flood prone	0.8 (0.5-1.0)
		Drought prone	0.4 (0-0.5)
	Deep 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 4-12.

3.1.4. Agricultural soil (N_2O) – (4D)

a) Methodology

» **Direct N_2O-N emissions from agricultural soil (Tier 1a)**

According to the revised IPCC GL1996, the direct N_2O-N emissions from agricultural soil are calculated based on the following equation:

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

Where:

$N_2O_{\ Direct}$ –N= annual direct N_2O emissions per unit of nitrogen

F_{SN} = annual amount of synthetic nitrogen fertiliser 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= emissions factor for direct emissions from N inputs to soil

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

» **Direct emissions from manure deposited during grazing**

According to the revised IPCC GL1996, the direct N_2O-N emissions from agricultural soil are calculated based on the following equation:

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

Where:

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

$N_{ex(T)}$ = 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

$EF_{3(S)}$ = emissions 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** are emitted from: 1) fraction of N_2O 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.

According to the revised GL 1996, the general equation for calculating N_2O emissions from all of these sources is:

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

Where:

$N_2O_{(G)}$ = fraction of N_2O produced from atmospheric deposition

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

$\sum_{(T)}(N_{(T)} * N_{ex(T)})$= total N excreted from animal waste, kg N/year

$Frac_{GASF}$ = fraction of total synthetic fertiliser emitted as NO_x or NH_3; Default value: 0.1 kg NH_3 –N + N_{ox}–N/kg N

$Frac_{GASM}$ = fraction of total animal manure emitted as NO_x or NH_3; default value: 0.2 kg NH_3 –N + N_{ox}–N/kg N

EF_4= indirect emissions from nitrogen volatilisation; 0.2 kg NH_3 –N + N_{ox}–N/kg N

EF_5 = proportion of nitrogen input that contributes to indirect emissions from nitrogen leaching

b) Activity data

The activity data for calculation of N_2O emissions from agricultural soils is presented in Table 22.

Table 22: Crop production in 2014

Unit: 1000 tons

Crop	Nitrogen fixation	Production	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)

3.1.5. Burning of savannah (CH_4, N_2O, NO_x, CO, NMVOC) – (4E)

a) Methodology

According to the revised IPCC GL1996, the amount of GHG emissions from burning savannah is calculated based on the following steps:

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 CH_4, CO, N_2O and NO_x emissions

N_2O emissions (Gg N_2O) = C released biomass (Gg C) × ratio of N: C loss × N_2O emissions factor × 44/28

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

CH_4 emissions = total C released × CH_4 emissions factor × 16/12

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

b) Activity data

The activity data for estimating GHG emissions from burning savannah is presented in Table 24.

c) Emissions factors

The emissions factors for calculating GHG emissions from burning savannah in Vietnam are presented in Table 25.

Table 24: Area of the burned savannah in 2014

Unit: 1000 ha

Type	2014
Pasture	1.33
Savannah	0.38

Table 25: Emissions factors used to estimate emissions from burning savannah in Vietnam

Gas	Emissions factor	Data source
CH_4	0.004	Revised 1996 IPCC Guidelines, page 4.80
CO	0.06	
N_2O	0.007	
NOx	0.121	

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

a) Methodology

According to the revised IPCC GL1996, the amount of GHG emissions from field burning of agricultural residues is calculated based on the following equation:

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

Where:

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 N_2O, NO_x, CH_4, and CO:

N_2O = biomass burned (Gg) × fraction oxidised × fraction of N in biomass × N_2O emissions factor × 44/28

NO_x = biomass burned (Gg) × fraction oxidised × fraction of N in biomass × NO_x emissions factor × 44/28

CH_4 = biomass burned (Gg) × fraction oxidised × fraction of C in biomass × CH_4 emissions factor × 16/12

CO = biomass burned (Gg) × fraction oxidised × fraction of C in biomass × CO emissions factor × 16/12

b) Activity data

The activity data for calculation of GHG emissions from field burning of agricultural residues is presented in Table 22.

c) Emissions factors

The emissions factors for calculation of GHG emissions from field burning of agricultural residues is presented in Table 26, Table 27, Table 28, Table 29, Table 30 and Table 31.

Table 26: 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 FAO (1998). The ratio of sesame, sedge and tobacco residues were taken as recommended by the IPCC GPG 2000 - Chapter 4 – Agriculture, page 457
Jute	2	
Sedge	1	
Sesame	2.1	
Tobacco	1	

Table 27: 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
Cotton	0.93	US Greenhouse Gas Inventory Report 1990-2014 (2004)
Jute	0.86	Bangladesh Climate Change Report (2010)
Sedge	0.85	Value of rice
Sesame	0.87	Value of tobacco
Tobacco	0.87	US Greenhouse Gas Inventory Report 1990-2014 (2004)

Table 28: Field burning ratios

Crop	Ratio	Data source
Maize	0.3	Expert estimate from developing SNC
Rice	0.55	Expert estimate from developing SNC
Millet	0.25	Revised 1996 IPCC Guidelines, page 4.83
Soybean	0.25	
Potato	0.25	
Sweet potato	0.1	Expert estimate from developing SNC
Cassava	0.45	Expert estimate from developing SNC
Sugarcane	0.35	Expert estimate from developing SNC
Groundnut	0.6	Expert estimate from developing SNC
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 29: Carbon fraction in crop residues

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
Sweet potato	0.4226	Default value for tomato used
Cassava	0.5	Revised 1996 IPCC Guidelines page 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	
Jute	0.45	
Sedge	0.45	Revised 1996 IPCC Guidelines, page 4.82; Global value
Sesame	0.45	
Tobacco	0.45	

Table 30: Nitrogen fraction in crop residues

Crop	Value	Data source
Maize	0.008	Le Van Can (1975)
Rice	0.004	Le Van Can (1975)
Millet	0.007	GPG 2000, Table 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)
Potato	0.003	Le Van Can (1975)
Sweet potato	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 cassava (Asher et al., 1980)
Sugarcane	0.004	GPG, Table 4.16
Groundnut	0.019	Average value for mature peanut leaf (Wang Zaixu, 1982; Cai Changbei, 1988) and stem (Wang Zaixu 1982; Cai Changbei, 1988) and stem, leaf, shell, empty seed in mature peanut (Cao Ky Son, 2002)
Beans	0.010	Used soybean value
Cotton	0.00675	
Jute	0.00675	
Sedge	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)
Sesame	0.00675	
Tobacco	0.00675	

Table 31: Emissions ratios for agricultural residue burning calculations

Compound	Ratios	Data source
CH_4	0.005	Revised 1996 IPCC Guidelines (Volume 3); page 4.84
CO	0.06	
N_2O	0.007	
NOx	0.121	

3.2. Results

3.2.1. Greenhouse gas emissions from agricultural sub-sectors in 2014

a) CH_4 from enteric fermentation

The results of methane emissions from enteric fermentation in 2014 are presented in Table 32.

Table 32: Emissions of CH_4 from enteric fermentation in 2014

Animal type	Emissions (Gg CH_4)	Emissions (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
Goats	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

b) GHG emissions from manure management

The results of methane emissions from manure management in 2014 are presented in Table 33.

Table 33: CH_4 emissions from livestock manure management in 2014

Animal	Climate region (15 – 25°C)		Climate region > 25°C		Total	
	Emissions ($GgCH_4$)	Emissions ($GgCO_2e$)	Emissions ($GgCH_4$)	Emissions ($GgCO_2e$)	Emissions ($GgCH_4$)	Emissions (Gg CO_2e)
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
Goats	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

The results of N_2O emissions from manure management in 2014 are presented in Table 34.

Table 34: N_2O emissions for each AWMS in 2014

AWMS	Emissions (Gg N_2O/year)	Emissions (Gg CO_2/year)
Anaerobic lagoons	1.58	471.60
Aerobic treatment	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
Total	27.38	8.158.74

c) Rice cultivation (CH_4) – (4C)

The results of methane emissions from rice cultivation in 2014 are presented in Table 35.

Table 35: CH_4 emissions from irrigated rice cultivation in 2014

Water management	Emissions (Gg CH_4/year)	Emissions (Gg CO_2/year)
Irrigated rice	1,708.7	42,717.8
Rain-fed rice	63.1	1,576.8
Total	1,771.8	44,294.6

d) Agricultural soil (N_2O) – (4D)

The results of N_2O emissions from agricultural soil in 2014 are presented in Table 36, Table 37 and Table 38.

Table 36: Direct N_2O-N emissions from agricultural soils in 2014

N source applied to soils	Direct N_2O-N emissions from agricultural soil (Gg N_2O–N/yr)	Total direct N_2O emissions (Gg N_2O)	Total direct N_2O emissions (Gg CO_2)
Synthetic fertilizer nitrogen (FSN)	16.03	25.19	7,507.86
Animal waste (FAW)	8.81	13.85	4,126.53
Nitrogen-fixing crops (FBN)	0.25	0.40	117.80
Crop residue (FCR)	3.57	5.61	1,671.31
Organic soils (FOS)	0.004	0.01	1.9
Total	28.67	45.05	13,425.4

Table 37: Direct emissions from manure deposited during grazing in 2014

N_2O-N emissions Nex(kg N/yr)	Emissions from grazing animals	
	Gg N_2O	Gg CO_2e
40,283,411.20	1.27	377.28

Table 38: Indirect N emissions from 1) fraction of N_2O 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 in 2014

Emission source	Indirect N_2O emissions	
	Gg N_2O	Gg CO_2e
Atmospheric deposition	5.40	1,610.57
Volatilisation from soils + leaching from soils	28.67	5,435.99
Total	34.07	7,046.56

e) Burning of savannah (CH_4, N_2O, NO_x, CO, NMVOC) – (4E)

The GHG emissions from burning of savannah in 2014 are presented in Table 39.

Table 39: GHG emissions from burning savannah in Vietnam in 2014

Gas	Emissions (Gg)	Emissions (Gg CO_2e)
CH_4	0.04	0.88
CO	0.92	-
N_2O	0.004	0.13
NOx	0.02	-

3.2.2. Greenhouse gas inventory of the agriculture sector in 2014

Based on the calculated results, GHG emissions from the agriculture sector in 2014 are shown in Table 40.

Table 40: GHG emissions from the agriculture sector in 2014

Unit: $ktCO_2e$

GHG emission source	CH_4	N_2O	Total
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
Total	**57,214.3**	**32,537.5**	**89,751.8**

04. Development of the business-as-usual scenario for the agriculture sector in the period 2020-2030

4.1. Methodology, Input Data and Assumptions

4.1.1. Methodology

Business-as-usual (BAU) emissions from agriculture and its sub-sectors were 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 plans to make projections for 2020 and 2030. However, the plans for 2020 with a vision to 2030 are quite far from reality and need to be adjusted; for example, rice cultivation area is planned to reach about 7 million ha in 2020 and 6.8 million ha in 2030, but in fact, rice cultivation area has increased to about 7.7 million ha in 2019 and may stabilize at that level in 2020.

Similar to the GHG inventory in 2014, the projection of GHG emissions from agriculture in 2020 and 2030 was also implemented applying the revised 1996 IPCC Guidelines. Further plans and policies as well as trends in production scale and technology were considered. Official data and national statistics provided by state agencies are used as operational data. For most categories, the study used default values in accordance with the IPCC Guidelines. National emissions factors were also used if available.

4.1.2. Input data and assumption

The emissions factors for estimating GHG emissions from the agriculture sector in 2020 and 2030 were the same as those used for calculating GHG emissions from the agriculture sector in 2014, as presented in Section

The projection for activity data used for estimating GHG emissions from the agriculture sector in 2020 and 2030 is presented in the following sections.

a) Livestock

The projection for livestock population in different climate regions in 2020 and in 2030 and the legal bases for these assumptions are presented in Table 41 and Table 42, respectively.

b) Rice cultivation

The projection for rice cultivation in different regions in 2020 and in 2030 and the legal bases for the projections are presented in Table 43 and Table 44, respectively.

Table 41: Projection for livestock population in different climate regions in 2020

Animal	Unit	Temperate	Humid	Data source
Dairy cows	head	200,000	300,000	Decision No. 124 / QD-TTg dated 2 December 2012 of the Prime Minister
Non-dairy cows	head	6,600,000	4,900,000	
Buffalos	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
Goats	head	2,400,000	1,471,200	
Horses	head	66,000	678	Assuming that the number of horses in 2020, 2030 is unchanged from 2014
Pigs	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 42: Projection for livestock population in different climate regions in 2030

Animal	Unit	Temperate	Humid	Data source
Dairy cows	head	320,000	480,000	Decision No. 124 / QD-TTg dated 2 December 2012 of the Prime Minister
Non-dairy cows	head	8,000,000	6,000,000	
Buffalos	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
Goats	head	2,800,000	1,666,800	
Horses	head	26,500,000	12,500,000	Assuming that the number of horses in 2020, 2030 is unchanged from 2014
Pigs	head	288,000,000	152,000,000	Decision No. 124 / QD-TTg dated 2 December 2012 of the Prime Minister
Poultry	head	280,000,000	160,000,000	

Table 43: Projection for rice cultivation in different regions in 2020

Unit: ha

	Northern region	Central region	Southern region	Total	Source	Water management 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	
1. Irrigated area	1,668,000	1,313,000	3,719,000	6,700,000	Decision No. 124 / QD-TTg dated 2 December 2012	
1.1. Irrigated rice area with active 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 GSO to DCC	
1.1.1 Partial AWD	164,812	29,488	50,964	245,264	Assuming that data are unchanged from 2013. Data are cited from the Department of Water Resources	Intermittently flooded – Single Aeration
1.1.2 Full AWD	38,692	4,818	8,616	52,126		Intermittently Flooded – Multiple Aeration
1.1.3 The continuously flooded area	1,262,596	1,141,494	2,416,120	4,820,210	(1.1) - (1.1.1) - (1.1.2)	Continuously Flooded
1.2. Irrigated rice area without active water management	201,900	137,200	1,243,300	1,582,400	(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. Rain-fed rice	70,000	118,000	2,000	190,000	(1) - (2)	Rain-fed rice

Table 44: Projection for rice cultivation in different regions in 2030

Unit: hectare

	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	
1. Irrigated area	1,693,000	1,333,000	3,774,000	6,800,000	Decision No. 124 / QD-TTg dated 2 December 2012	
1.1. Irrigated rice area with active 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 DCC	
1.1.1 Partial AWD	164,812	29,488	50,964	245,264	Assuming that data are unchanged from 2013. Data are cited from the Department of Water Resources	Intermittently flooded – Single Aeration
1.1.2 Full AWD	38,692	4,818	8,616	52,126		Intermittently Flooded – Multiple Aeration
1.1.3 The continuously flooded area	1,262,596	1,141,494	2,416,120	4,820,210	(1.1) - (1.1.1) - (1.1.2)	Continuously 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. Rain-fed rice	26,000	62,000	2,000	90,000	(1) - (2)	Rain-fed rice

The projection for rice ecosystems under water management regimes in 2020 and 2030 are presented in Table 45 and Table 46.

Table 45: Projection for rice ecosystems under water management regimes in 2020

Unit: hectare

Water management 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	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
Rain-fed rice	70,000	118,000	2,000	190,000
Total	1,768,000	1,455,000	3,789,000	7,012,000

Table 46: Projection for rice ecosystems under water management regimes in 2030

Unit: hectare

Water management 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	391,712	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
Rain-fed rice	26,000	62,000	2,000	90,000
Total	1,749,000	1,419,000	3,844,000	7,012,000

c) Agricultural soil

The projections for the amount of nitrogen fertilizer consumption in 2020 and 2030 are presented in Table 47 and Table 48, respectively.

Table 47: Projections for the amount of nitrogen fertilizer consumption in 2020 and 2030

Unit: N_{FERT}- tons

2020	2030	Data source
1,370,929,000	1,400,949,000	Multiplying the amount of fertilizer per hectare in 2020 and 2030 with total area. The adjustment factor is 1.05 for increases of yield in 2020 and 2030 compared with 2013.

Table 48: Projections for crop production in 2020 and 2030

Unit: 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	

d) Burning savannah

The projections for area of burned savannah in 2020 and 2030 are presented in Table 49.

Table 49: Area of the burned savannah

Unit: 1000 ha

Type	2020	2030
Savanah-grass/pasture	1.45	1.45
Savanah-shrub	0.34	0.34

Above-ground matter/biomass: The biomass value is a national value quoted from the “Carbon stock of vegetation cover and clump vegetation: baseline for a forest carbon and forest restoration according to clean development mechanism project in Vietnam” led by Dr. Vu Tan Phuong (Table 50). The study was conducted in Cao Phong and Lac Son districts (Hoa Binh Province) and in Ha Trung, Thach Thanh, Ngoc Lac districts (Thanh Hoa Province) in 2004 by the Research Centre of Forest Ecology in collaboration with the Japanese Forestry Consultants Association (JOFCA).

Table 50: Estimated above-ground matter/biomass

Savannah – shrub	(t/ha)
Reed - grass	20
Height from 2-3m	14
Height below 2m	10
Average	14.67
Savannah – pasture/grass plot	(t/ha)
Lophatherum gracile Brongn	6.5
Imperata cylindrica (L.) Beauv)	4.9
Lophopogon intermedius	4
Average	5.1

e) Open-field burning of crop residues

The projections for crop output in 2020 and 2030 and the legal bases for that assumption are presented in Table 48.

4.2. Results

4.2.1. BAU scenario of the agriculture sector in the period 2020-2030

Based on the calculated results and forecasting, the GHG emissions scenario of the agriculture sector to 2030 is shown in Table 51:

Table 51: BAU scenario of the agriculture sector in the period 2020-2030

Unit: $ktCO_2e$

GHG emission source	1994	2000	2005	2010	2014	2020	2030
4A Enteric Fermentation	7,070	7,730.5	9,275.1	9,467.5	10,200.6	18,842.5	22,212.5
4B Manure Management	2,710	3,447.3	8,056.2	8,560.0	8,863.4	12,099.5	14,093.7
4C Rice Cultivation - Flooded Rice Fields	32,750	37,429.7	42,511.6	44,614.2	44,294.6	41,891.2	41,535.5
4D Agricultural Soils	8,060	14,219.7	22,282.9	23,812.0	23,955.5	29,281.5	32,195.0
4E Burning of Savanah	400	590.67	3.6	1.7	1.0	1.0	1.0
4F. Field Burning of Agricultural Residues	1,460	1,672.63	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**

4.2.2. Comparison with NDC1

The revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and the GPG 2000 were also used for the development of the BAU scenario of the agriculture sector in Vietnam's INDC. The comparison between the BAU scenario in the INDC and the revised NDC is presented in Table 52.

It can be seen from Table 52 that in Vietnam's revised NDC1, according to the BAU scenario, GHG emissions in 2020 and 2030 are slightly higher than that of the NDC1. Particularly, in the revised NDC1 the forecast for GHG emissions in 2020 is 104.5 $MtCO_2e$, which is 3.7 $MtCO_2e$ higher than that of the NDC1. In 2030, the forecast for GHG emissions is 112.1 $MtCO_2e$, which is 2.8 $MtCO_2e$ higher than that of the NDC1. GHG emissions from enteric fermentation, manure management and rice cultivation in 2020 and 2030 in the revised NDC1 are higher than that of the NDC1. However, GHG emissions from agriculture soils and burning of agricultural residues in fields in 2020 and 2030 in the revised NDC1 are slightly lower than that of the NDC1. The key reason for these differences is the change in the assumptions to develop the BAU scenario for the agriculture sector.

Table 52. Comparison between the BAU scenario in Vietnam's NDC1 and the revised NDC1

Unit: $MtCO_2e$

GHG source categories	2010		2020		2030	
	NDC1	The revised NDC1	NDC1	The revised NDC1	NDC1	The revised NDC1
4A Enteric fermentation 4B Manure management	18.0	17.9	24.9	30.8	29.3	36.2
4C Rice cultivation	44.6	44.6	39.3	41.8	39.9	41.5
4D Agricultural soils	23.8	23.8	33.9	29.2	37.3	32.1
4E Prescribed burning of savannah	-	-	-	-	-	-
4F Burning of agricultural residue in fields	1.8	1.8	2.5	2.3	2.6	2.1
Total	**88.3**	**88.3**	**100.8**	**104.5**	**109.3**	**112.1**

05. Development of the mitigation scenario for the agriculture sector in the period 2020 - 2030

5.1. Assumptions, Methodology and Input Data

5.1.1. Methodology

The Agriculture and Land Use (ALU) software was used for the calculation of GHG mitigation options in the agriculture sector. 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 potential and co-benefits compared to the BAU scenario.

The Marginal Abatement Cost Curve for mitigation options was calculated following formula:

$$\text{Marginal Abatement Cost } (\$/t\ CO2e) = \frac{-\text{ Net Present Value } (\$)}{\text{Total GHG emissions abated over the life of the project}}$$

$$\text{Net Present Value} = \frac{\text{Total project cost} - \text{Total project saving}}{(1 + \text{discount rate})\ \text{project lifetime}}$$

5.1.2. Input data and assumptions

In the selection of GHG mitigation options in the agriculture sector for the revised NDC1, criteria to be used for assessment include:

- *Availability of technology*: Technologies are available and have been applied domestically and abroad, especially those that have been applied in practice and have high potential for scaling-up, bringing high efficiency.
- *Mitigation potential*: Priority is given to high potential emissions reduction options, especially those in sectors with high emissions levels and are closely linked to specific items as set out in the Sectoral Strategy and Development Plans.
- *Economic efficiency*: Selecting technology options with high economic efficiency, including low mitigation cost (USD/tCO_2eq), moderate total investment, whicg are in line with enterprises' development strategies and have fast capital recovery time.
- *Co-benefits*: The selected mitigation options also bring co-beneits to the economy, society and environment.

So far, a number of mitigation options for GHG emissions at the country and sector levels have been proposed. Based on the above-mentioned criteria, in this study, fifteen GHG mitigation options were identified 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 53.

Table 53: Assumptions for mitigation options in the agriculture sector

Mitigation options	Period	Assumptions
A1. Alternate wetting and drying (AWD), and SRI (high adoption) for rice	2015-2030	AWD technology and improved rice cultivation will be introduced on 200,000 ha of irrigated rice cultivation in 2030 with full investment in infrastructure
A2. Mid-season drainage (for rice)	2015-2030	Mid-season drainage will be introduced to apply to 1,000,000 ha of irrigated rice cultivation in 2030
A3. Shifting double rice or triple rice into Rice-Shrimp	2015-2030	Shifting 200,000 ha double rice with low productivity to rice-shrimp farming in 2030
A4. Shifting double rice or triple rice into Upland Crops	2015-2030	Shifting 200,000 ha double rice with low productivity to upland crops cultivation in 2030
A5.1.Improving diets for dairy cows	2015-2030	Improvements to the diets of 500,000 dairy cows will help reduce methane emissions caused by the rumen fermentation process in 2030
A5.2.Improving diets for cows (for meat)	2015-2030	Improvements to the diets of 700,000 non-dairy cows will help reduce methane emissions caused by the rumen fermentation process in 2030
A5.3.Improving diets for buffalos	2021-2030	Improvements to the diets of 150,000 buffalos will help reduce methane emissions caused by the rumen fermentation process in 2030
A6.1. Reusing agricultural residues/by-products	2021-2030	Upland crop residues will be collected and processed into compost for agricultural production using 25-50% of crop residues on 18 million ha of crop cultivation areas in 2030
A6.2. Produce and apply biochar	2021-2030	Agricultural residues will be collected and processed into compost for agricultural production; for example, 50% of rice residues from 3.5 million ha of rice cultivation areas. The technology is only applicable to residues during the wet season
A7.1. Integrated Crop Management (ICM) for rice	2015-2030	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 annual upland crops

Mitigation options	Period	Assumptions
A7.2. ICM for annual upland crops	2021-2030	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 efficiency. This option can be applied to 1 million ha of annual upland crop cultivation areas
A8. Substitute Urea fertilizer with Ammoniac Sulphate-(NH4)2SO4	2021-2030	Substitution of urea with SA fertilisers on an area of 3.5 million ha to reduce N2O emissions
A9.1. AWD and SRI (medium adoption)	2021-2030	With international support, AWD and SRI will be introduced/applied to 500,000 ha of irrigated rice cultivation area in 2030, with part investment in infrastructure
A9.2. AWD and drying, and SRI (medium adoption)	2021-2030	With international support, AWD and SRI will be introduced/applied to 500,000 ha of irrigated rice cultivation, which has basic infrastructure, in 2030
A10. Drip irrigation combined with fertilizer for coffee	2021-2030	With international support, drip irrigation combined with fertilizer technologies will be introduced/applied to 450,000 ha of coffee cultivation throughout Vietnam to strengthen mitigation impacts in 2030
A11. Improve technology to recycle livestock dung into organic fertilizer	2015-2030	With international support, improve technologies in waste (from 20,000,000 million tons of animal waste) treatment to produce organic fertilizer

Table 54: Plan for implementation of options to 2030

	Scale (1000 ha)	Implementation plan to 2030 (1000 ha)															
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
A1	200	40	41	42	43	44	45	40.2	45.56	67	93.8	134	147.4	160.8	167.5	187.6	201
A2	1000	150	160	170	180	190	200	201	227.8	335	469	670	737	804	837.5	938	1005
A3	200	25	30	35	40	45	50	40.2	45.56	67	93.8	134	147.4	160.8	167.5	187.6	201

	Scale (1000 ha)	Implementation plan to 2030 (1000 ha)															
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
A4	200	40	41	42	43	44	45	40.2	45.56	67	93.8	134	147.4	160.8	167.5	187.6	201
A5.1	500	50	60	70	80	90	100	100.5	113.9	167.5	234.5	335	368.5	402	418.75	469	502.5
A5.2	7000	450	460	470	480	490	500	1407	1594.6	2345	3283	4690	5159	5628	5862.5	6566	7035
A5.3	1500	0	0	0	0	0	0	301.5	341.7	502.5	703.5	1005	1105.5	1206	1256.25	1407	1507.5
A6.1	1200	0	0	0	0	0	0	241.2	273.36	402	562.8	804	884.4	964.8	1005	1125.6	1206
A6.2	3500	0	0	0	0	0	0	703.5	797.3	1172.5	1641.5	2345	2579.5	2814	2931.25	3283	3517.5
A7.1	1000	40	45	50	55	60	65	201	227.8	335	469	670	737	804	837.5	938	1005
A7.2	1000	0	0	0	0	0	0	201	227.8	335	469	670	737	804	837.5	938	1005
A8	3500	0	0	0	0	0	0	703.5	797.3	1172.5	1641.5	2345	2579.5	2814	2931.25	3283	3517.5
A9.1	500	0	0	0	0	0	0	100.5	113.9	167.5	234.5	335	368.5	402	418.75	469	502.5
A9.2	1000	0	0	0	0	0	0	201	227.8	335	469	670	737	804	837.5	938	1005
A10	450	0	0	0	0	0	0	90.45	102.51	150.75	211.05	301.5	331.65	361.8	376.875	422.1	452.25
A11	40000	50	60	70	80	90	100	8040	9112	13400	18760	26800	29480	32160	33500	37520	40200

5.2. Results

5.2.1. Mitigation scenario for the agriculture sector in the period 2020-2030

a) Unconditional contribution

Unconditional mitigation options in the agriculture sector are mostly highly-feasible options, with high availability of infrastructure or technology and funding that can be allocated by Vietnam (Table 55).

b) Conditional contribution

Conditional mitigation options in the agriculture sector are mostly options with higher costs that need international support in finance, technology and capacity building (Table 56).

Table 55: Unconditional mitigation options in the agriculture sector

Mitigation option	Mitigation potential rate ($MtCO_2e$ per ha per year)	Scale (1,000 ha, 1,000 units)	Mitigation potential ($MtCO_2e$)		Mitigation cost ($/t.$CO_2$)
			2030	2015-2030	
A1. AWD and SRI (high adoption/large scale)	-4.7	200	0.94	5.17	39.59
A2. Mid-season drainage in rice cultivation	-3.2	1000	3.20	17.60	30.0
A3. Shifting double rice or triple rice to Rice-Shrimp	-6.54	200	1.31	7.19	-293.20
A4. Shifting double rice or triple rice to Upland Crop	-7.14	200	1.43	7.85	-0.08
Total			6.88		
Compared with BAU 2030 (%)			6.13		

Table 56: Conditional mitigation options in the agriculture sector

Mitigation options	Mitigation potential rate (Mt CO_2e per ha per year)	Scale (1,000 ha, 1,000 units)	Mitigation potential ($MtCO_2e$)		Mitigation cost ($/t.$CO_2$)
			2030	2015-2030	
A5.1. Improvement of dairy cow diets	0.168	500	0.084	0.46	89
A5.2. Improvement of non-dairy cow diets	0.165	7000	1.16	6.35	89
A5.3. Improvement of buffalo diets	0.206	1500	0.31	1.70	89
A6.1. Reuse of upland agricultural/crop residues	0.10	1200	0.12	0.68	63.2
A6.2. Introduction of biochar (large scale)	5.37	3500	18.80	31.02	75

Mitigation options	Mitigation potential rate (Mt CO_2e per ha per year)	Scale (1,000 ha, 1,000 units)	Mitigation potential ($MtCO_2e$)		Mitigation cost ($/t.$CO_2$)
			2030	2015-2030	
A7.1. ICM in rice cultivation	0.50	1000	0.50	2.75	20
A7.2. ICM for annual upland crops cultivation	0.32	1000	0.32	1.76	25
A8. Substitution of urea with Ammoniac sulphate fertilizer	1.60	3500	5.60	30.80	30
A9.1. AWD and SRI (infrastructure partly financed)	4.68	500	4.68	12.87	64.96
A9.2. AWD and SRI (low infrastructure)	4.68	1000	4.68	25.74	94.9
A10. Drip irrigation combined with fertilizer for coffee	3.80	450	1.71	9.40	124.18
A11.Improved technologies to recycle livestock dung as organic fertilizer	0.17	40000	6.80	37.40	94.92
Total			**29.14**		
Compare with BAU in 2030			**25.9%**		

Among the above-mentioned mitigation options, option A.5.1. on improvement of feed diet for dairy cows, cows and buffalos has low mitigation potential, but is necessary because of co-benefits, such as increasing meat and milk as well as improving the quality of meat and milk. Other options, such as management of crop residues, ICM, substituting urea with Ammoniac sulphate fertilizer, slow release nitrogen fertilizer, AWD and SRI, and drip irrigation with liquid fertilizer application require more technology and infrastructure investment; for example, better technology for producing microbial agents for making compost in the field; technology (industrial scale) to produce biochar, so more carbon can be stored in soil as carbon sequestration and changing technology for producing slow nitrogen fertilizer to mitigate N_2O emissions and N loss. Options such as producing and applying biochar to soil has high mitigation potential. Nevertheless, this option requires a lot of technological and financial support to reduce the cost of producing biochar. Integrated drip irrigation and fertilization Technology for coffee is a highly-advanced technology with economic and adaptive water resource use. However, the investment required is very high and will grow if the system's operation is included.

c) Cost of mitigation options in the agriculture sector

Figure 1 shows the mitigation potential of each option (horizontal axis) and the cost of each technology (vertical axis). The cost is calculated based on parallel deducted input/output of mitigation production activities for conventional production activities. The chart shows that the technology for converting ineffective double rice or triple rice land into rice-shrimp has the lowest cost and the highest economic efficiency. In contrast, drip irrigation technology for coffee is the most expensive. However, this technology reduces the use of irrigation water by 40%, fertilizer by 30%, labour by 80%, and electric pump water by 60%. Therefore, this option is suitable for dry conditions; however, some co-benefits were small compared with the level of investment and some were not yet taken into account. This means the final cost for this option is still high. Option A6.2 (biochar production and application) have the highest mitigation potential; however, with this option it is difficult to choose the optimal technology or practical implementation. AWD and SRI technologies also have high mitigation potential, but the mitigation cost depends on the status of infrastructure. In the case of A1, infrastructure is fully financed and farmers just need to invest in the necessary equipment to control water; hence the cost is low. However, regarding A9.2 with low infrastructure, farmers and the community need to invest from the beginning in irrigation, drainage systems, levelling fields, water inlets/outlets and controlling system, so the investment cost will be high. The option of mid-season drainage represents both high mitigation potential and moderate costs. It also has high potential for replication and is easy to monitor/measure.

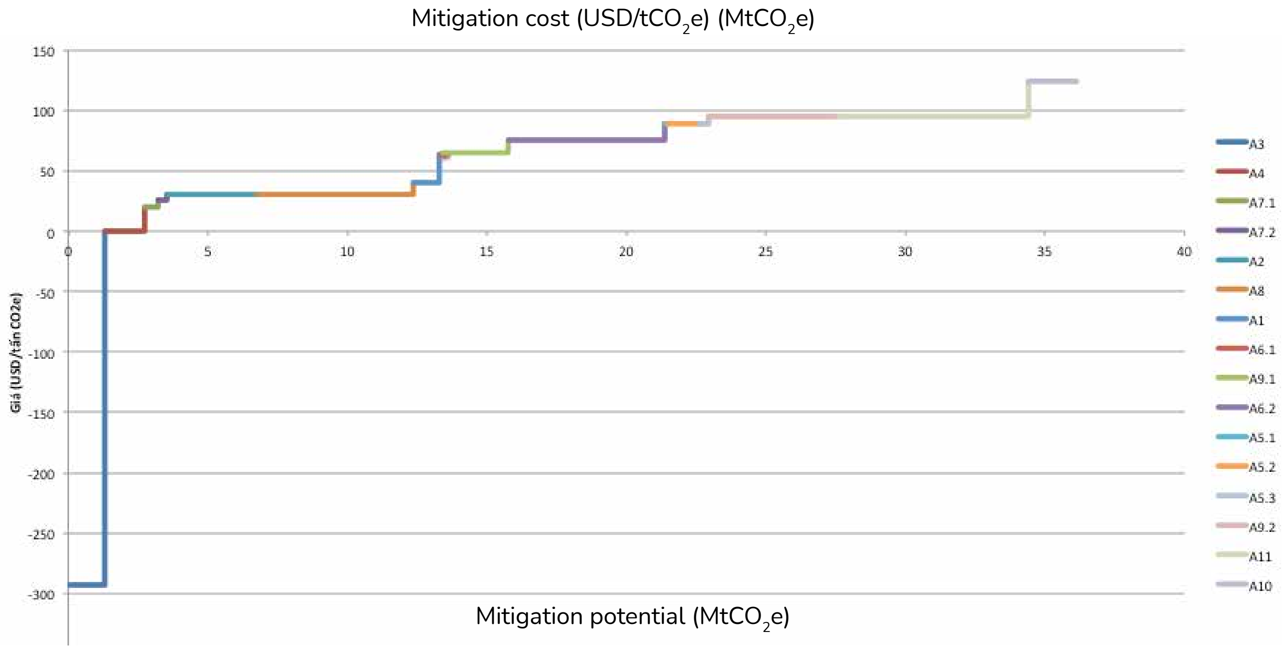


Figure 1: Cost curve for mitigation options in the agriculture sector in 2030

The investment cost for mitigation options in the agriculture sector is shown in Table 57:

Table 57: Investment cost for mitigation options

Mitigation options	Scale (1000 ha/head)	Investment cost (million USD)
Unconditional contribution		1390.2
A1. AWD and SRI (high adoption/large scale)	200	181.1
A2. Mid-season drainage in rice cultivation	1000	1027.3
A3. Shifting double rice or triple rice to Rice-Shrimp	200	181.8
A4. Shifting double rice or triple rice to Upland Crop	200	0.036
Conditional contribution		4604.7
A5.1. Improvement of diary cow diets	500	6.8

Mitigation options	Scale (1000 ha/head)	Investment cost (million USD)
A5.2. Improvement of non-diary cow diets	7000	95.5
A5.3. Improvement of buffalo diets	1500	20.5
A6.1. Reuse of upland agricultural/crop residues	1200	30.0
A6.2. Introduction of biochar (large scale)	3500	318.2
A7.1. ICM in rice cultivation	1000	9.1
A7.2. ICM for annual upland crops cultivation	1000	9.1
A8. Substitution of urea with sulfate amon fertilizer	3500	15.9
A9.1. AWD and SRI (infrastructure partly financed)	500	795.5
A9.2. AWD and SRI (basic infrastructure)	1000	2075.0
A10. Drip irrigation combined with fertilizer for coffee	450	1227.3
A11. Improved technologies to recycle livestock dung as organic fertilizer	40000	1.8

Based on the current state of infrastructure, the cost of technology and scale of project implementation, investment can be developed for each option. Some options have high cost, such as AWD and SRI, biochar and drip irrigation for coffee. However, some options also have relatively low cost: conversion of rice land to rice-shrimp and improvement of animal diets.

5.2.2. Impact assessment of mitigation options on the socio-economy and environment

Regarding the co-benefits from mitigation options, economic co-benefits are the most important in favour of expanding the development and application of technology. The second most important is adaptation to climate change, and reducing risks and damage caused by natural hazards and climate change impacts. For example, drip irrigation integrated with fertilizer for coffee is a good way to reduce GHG emissions from energy consumption and reduce N_2O from fertilization. This option is also important for saving energy pumping water, reduce fertilizer, producing stable coffee yields, and efficient use of land and water resources. Table 58 summarizes the impacts of mitigation options in the agriculture sector on the socio-economy and environment.

Table 58: Impacts of mitigation options on the socio-economy and environment

Mitigation options	Economic impact	Social impact	Environmental impact
A1. AWD and SRI (high adoption/large scale)	Save 15-20% of irrigation water, 5-10% of fertilizer and pesticides	Promote CSA, strengthen community linkages, raise efficiency and effective use of natural resources	Reduce GHG emissions, use of fertilizer and pesticide pollution
A2. Mid-season drainage in rice cultivation	Reduce irrigation water by 5-10%, 5% increase in yield	Release on-farming labour to do off-farm activities	Change soil and water environment
A3. Shifting double rice or triple rice to rice-shrimp	Increase of 230% in incomes	Diversify products, increase incomes, rational use of resources, adapt to saline intrusion and sea level rise	Reduce methane emissions, reduce inputs of fertilizers and pesticides, promote sustainable production
A4. Shifting double rice or triple rice to up-land crop	Increases of 0-200% in incomes; Reduce use of irrigation water by 50%	Increase incomes, rational use of resources, adapt to drought and flooded condition	Reduce methane emissions, reduce inputs of fertilizers and pesticides, promote sustainable production
A5.1. Improvement of dairy cow diets	Increase of 10-20% of milk yield and quality compared to using traditional diets	Increase intensive and sustainable livestock; increase the health and resistance of cows; Increase labour productivity	Reduce methane emissions
A5.2. Improvement of non-dairy cow diets	10-20% increase in yield and quality of meat	Increase intensive and sustainable livestock; increase the health and resistance of cows; Increase labour productivity	Reduce methane emissions
A5.3. Improvement of buffalo diets	10-20% increase in yield and quality of meat	Increase intensive and sustainable livestock; increase the health and resistance of cows; Increase labour productivity	Reduce methane emissions
A6.1. Reuse of upland agricultural/crop residues	Use agricultural/crop residues as organic fertilizer (1-2 tons/ha), Increase of 10% in yield and soil fertility	Use and reuse waste rationally as a resource, create jobs for people, improve productivity and incomes	Reduce open-field burning, increase organic sequestration in the soil, reduce environmental pollution caused by waste

Mitigation options	Economic impact	Social impact	Environmental impact
A6.2. Introduction of biochar (large scale)	Produce valuable biochar (1-2 tons / ha), increase of 5% in yield at initial stage; increase water retention and nutrient uptake, increase efficiency of fertilizer by 5-10%	Use and reuse waste rationally as a resource, create jobs for people, improve productivity and incomes	Reduce open-field burning, increase organic sequestration in soil, reduce environmental pollution caused by waste
A7.1. ICM in rice cultivation	Reduce seeds by 5%, fertilizer by 5%, pesticides by 5%	Organize production better, protect farmer's health	Reduce the over-use of chemicals in production, improve environmental quality
A7.2. ICM for annual upland crops cultivation	Reduce seeds by 5%, fertilizer by 5%, pesticides by 5%	Organize production better, protect farmer's health	Reduce the over-use of chemicals in production, improve environmental quality
A8. Substitution of urea with Ammoniac sulphate fertilizer			Reduce GHG emissions
A9.1. AWD and SRI (large scale)	Save 15-20% irrigation water, 5-10% N fertilizer and chemicals	Promote CSA, strengthening community linkages, raise efficiency, effective use of natural resources	Reduce GHG emissions, reduce use of fertilizer and pesticide pollution
A9.2. AWD and SRI (large scale)	Save 15-20% irrigation water, 5-10% N fertilizer and chemicals	Promote CSA, strengthening community linkages, raise efficiency, effective use of natural resources	Reduce GHG emissions, reduce use of fertilizer and pesticide pollution
A10. Drip irrigation combined with fertilizer for coffee	Reduce irrigation water by 40%, fertilizer by 30%, labour for watering by 60% and electricity costs by 60%	Organize production better, raise farmer's incomes	Reduce GHG emissions, reduce use of fertilizer and pesticide pollution
A11. Improved technologies to recycle livestock dung as organic fertilizer	Reduce costs for mineral fertilizer (Produce 6-9 million tons of organic fertilizer for cultivation)	Create jobs	Reduce GHG emissions from animal waste management

5.2.3. Comparisons with other studies

1) Vietnam INDC report

Table 59: Mitigation options in the INDC (2015)

Mitigation option	Scale 1000 unit	Reduction potential million tons CO_2e	Reduction/ha (tCO_2e/ha/year)	Mitigation cost (\$/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
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 diets	22000	-1.75	-0.08	-23.63
A12. Improvement of quality and services available for aquaculture, such as inputs and foodstuffs	1000	-0.41	-0.41	90
A13. Improvement of technologies 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
Total		**-45.79**		

2) INDC implementation plan for the agriculture sector

After the Vietnam INDC was developed and submitted to UNFCCC by MONRE, MARD issued Dispatch No. 7208/ BNN-KHCN dated 25 August 2016 on building the plan for 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 shown in Table 60.

Table 60: Mitigation options reviewed and proposed by MARD for INDC implementation in the agriculture sector

Mitigation options	Scale (1000 ha, 1000 heads of animals)	Mitigation potential (Mil. ton CO_2e)	Investment cost (bil. VND)
Unconditional contribution			
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
A15. Optimal irrigation for coffee	120	-0.24	100
A16. Mid-season drainage in rice cultivation	1000	-3.2	5000
Sub-total I:		-6.42	
Conditional contribution			
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 foodstuffs	190	-0.04	80
A14. Improved technologies in food processing and waste treatment in agriculture, forestry and aquaculture (1000 tons of agro-product)	2,000	-0.32	660
A17: Improved technologies to reuse animal waste as organic fertilizers	20,000	-3.4	7100
A18: Adjust structure of unsuitable ships and boats to aquaculture fields and replan for catching routes and exploration area	15	-0.69	3000
Sub-total II:		**-10.32**	
Total:		**-16.74**	

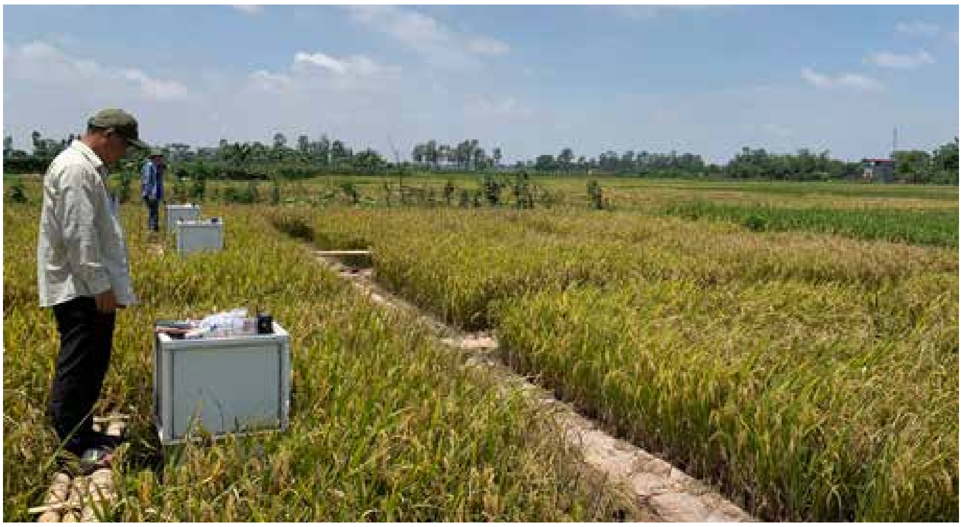
3) JICA's assessment of mitigation technologies

After the Vietnam INDC was submitted to UNFCCC by MONRE in 2015, JICA conducted an evaluation of mitigation options and assigned a list of relevant technologies as summarized in Table 61.

Table 61: JICA's assessment results of mitigation technologies

Technology	Aim	Mitigation potential (Mil. ton CO_2e)
A1. Increased use of biogas	Building biogas tanks	-6.4
A2. Reuse of agricultural residues as organic fertilizer	Techniques for composting rice straw (in fields & farms)	10.7
A3. AWD and SRI in rice cultivation (small cale)	Focus on AWD techniques	-4.39
A4. Introduction of biochar (small scale)	Improve effectiveness of equipment	50-65%
A5. Integrated Crop Management (ICM) in rice cultivation	Focus on introducing high performance pumps	-5.2
A6. Integrated Crop Management (ICM) in upland annual crops cultvation	Use biochar	50-65%
A7. Substitution of urea with sulfate amonnia fertilizer	Energy-saving gas-powered appliances	-3.2
A8. Reusing of upland agricultural/crop residues	Techniques for composting crop residues on farms	-10.7
A9. AWD and SRI (large scale)	AWD	-4.39
A10. Introduction of biochar (large scale)	Improve effectiveness of biochar-producing equipment	50-65%
A11. Improvement of livestock diets	Supplement Fat + Amino Acid (Lysine) into feed for pigs and chickens	-1
A12. Improvement of quality and services available for aquaculture, such as inputs and foodstuffs	Increase efficiency of treatment for waste water from cattle, waste water from processing seafood	-7739
A13. Improvement of technologies in aquaculture and waste treatment in aquaculture	Generators (industrial scale)	-22,806
A14. Improved irrigation for coffee	Use high-capacity refrigeration systems in freezing + wastewater treatment for livestock, food processing and fisheries	165
A15. Improved technologies in food processing and waste treatment in agriculture, forestry and aquaculture	Drip irrigation technique	-5.3

06. Requirements for the implementation of mitigation options in the agriculture sector



6.1. Policies

In order to implement mitigation options in the agriculture sector, besides the GHG mitigation supporting policies summarized in Section 2.1, the agriculture sector requires policy support on the following issues:

- Promulgation of policies to support mitigation actions in agriculture sector.
- Establishing and operating a national MRV system to support the management and control of GHG emissions from the agriculture sector.

6.2. Technologies, Finance and Capacity Building

Needs to address technology, finance, and capacity building are presented in Table 62, where each option has its own need for technology; i.e. options AWD and SRI need a procedure on alternative wet and dry, SRI, or positive irrigation system following AWD and SRI procedures – for example, the ESCALA system for monitoring irrigation and drainage. Implementation of 200,000ha of this technology will require an investment of about USD 181.1 million. It also needs documentation, guidelines, and other materials for training and guiding AWD and SRI in practice, as well as demonstrations for key people at district and province level.

Table 62: Requirements for technology, finance and capacity building for implementation of mitigation options

Mitigation option	Technology needs	Financial needs (million USD)	Capacity building needs	Barriers
Unconditional contribution				
A1. AWD and SRI (where infrastructure is fully financed)	AWD package SRI package Full irrigation and drainage system ESCALA irrigation system	181.1	Process, documents, books; training; field demonstration/ model; support for models	Field levelling; organization; high investment; small increases in incomes
A2. Mid-season drainage in rice cultivation	Active irrigation system	1,027.3	Process, documents, books; training; field demonstration/ model; support for models	Ununiformed field elevation; field levelling; Summer season and Autumn season
A3: Shifting double rice or triple rice to rice-shrimp	Building shrimp farms Process of shrimp and rice cultivation Food for shrimp Fertilizers for rice	181.1	Process, documents, books; training; field demonstration/ model; support for models	Disease; market
A4. Shifting double rice or triple rice to upland crops	Machinery for gardening, levelling fields The process of cultivation of upland crops	0.036	Process, documents, books; training; field demonstration/ model; support for models	market
Conditional contribution				
A5.1. Improvement of dairy cow diets	Diet formulas Additives for new diets	6.8	Process, documents, books; training; field demonstration/ model; support for models	Smallholder farmers; milk price
A5.2. Improvement of non-dairy cow diets	Diet formulas Additives for new diets	95.5	Process, documents, books; training; field demonstration/ model; support for models	Smallholder farmers; remote areas with grazing
A5.3. Improvement of buffalo diets	Diet formulas Additives for new diets	20.5	Process, documents, books; training; field demonstration/ model; support for models	Smallholder farmers; remote areas with grazing

Mitigation option	Technology needs	Financial needs (million USD)	Capacity building needs	Barriers
A6.1. Reuse of upland agricultural/crop residues	Process of collection and composting Method of organic fertilizer application Testing the quality of organic fertilizer	30.00	Documents, books; Training; Field demonstration/model	Collection; unfriendly use
A6.2. Introduction of biochar (large scale)	Process of biochar production Method of biochar application Testing the quality of organic fertilizer	318.2	Charcoal furnace/ gasifier Process of producing biochar Training Field demonstration/model	High cost; complicated guidelines; air pollution; implementation
A7.1. ICM in rice cultivation	ICM full package	9.1	Training Field demonstration/model	Farmer perceptions; no manure
A7.2. ICM for annual upland crops cultivation	ICM full package	9.1	Training Field demonstration/model	Farmer perceptions; no manure
A8. Substitution of urea with sulphate ammonia fertilizer	Manufacturers/ factories (NH4)2SO4	15.9	Process of fertilizer production (NH4)2SO4 Training on the above method	Cost; acidic soil; changing of industry
A9.1. AWD and SRI (where infrastructure is partly financed)	AWD package SRI package Full irrigation and drainage system ESCALA irrigation system	795.5	Process, documents, books Training Field demonstration/model Support for models	Field levelling; organization; high investment; small increases in incomes

Mitigation option	Technology needs	Financial needs (million USD)	Capacity building needs	Barriers
A9.2. AWD and SRI (basic infrastructure)	AWD package SRI package Full irrigation and drainage system ESCALA irrigation system	2,075.5	Process, documents, books Training Field demonstration/model Support for models	Field levelling; organization; high investment; small increases in incomes; low elevation fields; acid sulphate soils and saline soil
A10. Drip irrigation combined with fertilizer for coffee	Drip irrigation system and integrated fertilizer system Irrigation; fertilizer application; Fertilizers for drip irrigation	1,227.3	The benefits assessment and analysis of drip irrigation Process of watering Training Field demonstration/model	Up-front costs; durability of water pipe
A11. Improved technologies to recycle livestock dung as organic fertilizer	Technology for organic fertilizer production; factories, workshops, warehouses	1.8		Smallholder farmers; livestock decrease; farmer behaviour

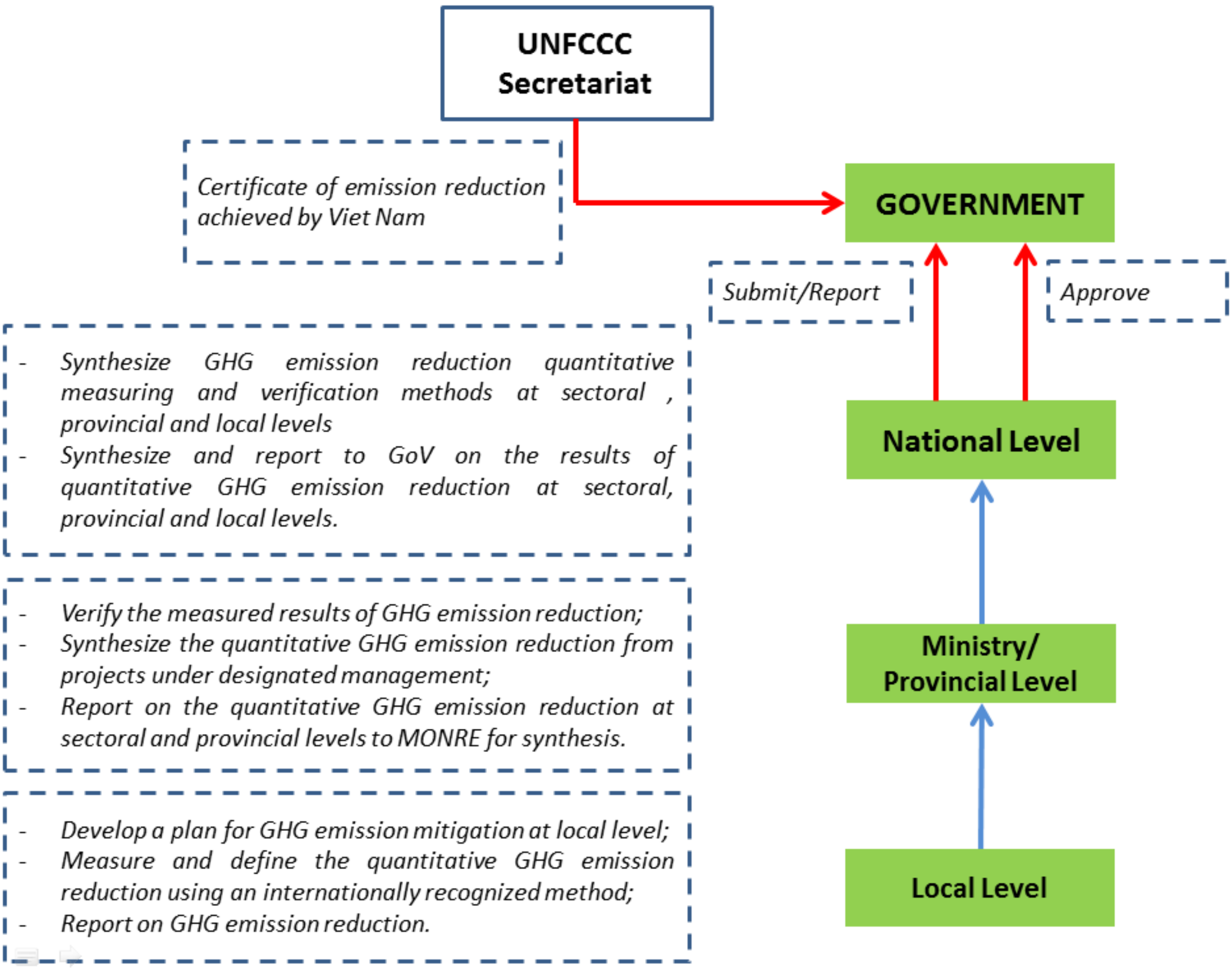
07. Measurement, Reporting, and Verification for mitigation activities in the agriculture sector

7.1. Measurement, Reporting and Verification at national level

The establishment of a Measurement, Reporting and Verification (MRV) system at national, sectoral and local levels is necessary in order to assess the implementation and impact of each action to reduce GHG emissions as well as to ensure GHG emissions reduction targets in the NDC are achieved. Decision No. 2053/QD-TTg dated 28 October 2016 of the Prime Minister approving the Plan for Implementation of the Paris Agreement stipulates the tasks to be executed in the period 2016-2020, in which the establishment of the MRV system is one of the key tasks in the period 2018-2020. The national MRV system was proposed in the Third National Communication of Vietnam, which is illustrated in Figure 2.

Figure 2: The proposed MRV system at national level

Source: MONRE, 2019



7.2. Measurement, Reporting and Verification for Mitigation Activities in the Agriculture Sector

Measurement, Reporting and Verification (MRV) is the most important activity to maintain monitoring and evaluation of the scope and extent of CC mitigation options application/ adoption. Based on the current production system and the nature of production processes, each mitigation option requires the design of a separate MRV system.

The detailted activities of each mitigation option are detailed in Table 63.

Table 63: Proposed MRV activites for mitigation options in the agriculture sector

Mitigation option	Measurement	Reporting	Verification
A1. AWD and SRI (where infrastructure is fully financed)	Monitoring the status of AWD and SRI application; degree of applicability; growth and yield of rice; measuring and quantifying of GHG emissions; economic benefits, cost	Develop report on the growth of rice applying AWD and SRI from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market

Mitigation option	Measurement	Reporting	Verification
A2. Mid-season drainage in rice cultivation	Monitoring the status of MS application; degree of applicability; growth and yield of rice; measuring and quantifying of GHG emissions; economic benefits, cost	Develop report on the growth of rice from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market
A3. Shifting double rice or triple rice to rice-shrimp	Monitoring the status of rice-rice and rice-shrimp farming systems; degree of applicability; growth and yield of rice; growth and yield of shrimp; measuring and quantifying of GHG emissions; economic benefits, cost	Develop report on the growth of rice-rice and rice-shrimp from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market
A4. Shifting double rice or triple rice to upland crop	Monitoring the status of rice-rice and upland crop farming system; degree of applicability; growth and yield of rice, upland crop; measuring and quantifying of GHG emissions; economic benefits, cost	Develop report on the growth of rice-rice and upland crop from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market
A5.1. Improvement of dairy cow diets	Monitoring the status and level of old and new formulas diet application; growth of cow and milk yield; measuring and quantifying GHG emissions; economic benefits, cost	Develop report on the growth of dairy cows from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market
A5.2. Improvement of non-dairy cows diets	Monitoring the status and level of application of the old and new diet; growth of cow and meat yield; measuring and quantifying GHG emissions; economic benefits, cost	Develop report on the growth of non-dairy cows from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market
A5.3. Improvement of buffalo diets	Monitoring the status and level of application of the old and new diet; growth of cow and meat yield; measuring and quantifying GHG emissions; economic benefits, cost	Develop report on the growth of buffalo from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market
A6.1. Reuse of upland agricultural crop residues as organic fertilizer	Monitoring the status and extent of collection and treatment of crop residues; growth and yield of crops applying organic fertilizer; measuring and quantifying GHG emissions; economic benefits, cost	Develop report on the growth of upland crops applying organic fertilizer, soil fertility from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market

Mitigation option	Measurement	Reporting	Verification
A6.2. Introduction of biochar (large scale)	Monitoring the status and extent of input material collection and production of biochar; growth and yield of crops applying biochar; measuring and quantifying GHG emissions; economic benefits, CBA	Develop report on the growth of crop applying biochar and soil fertility from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market
A7.1. ICM in rice cultivation	Monitoring the status of the ICM application; degree of applicability; growth and yield of rice; measuring and quantifying of GHG emissions; economic benefits, CBA	Develop report on the growth of rice applying ICM from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market
A7.2. ICM for annual upland crops cultivation	Monitoring the status of the ICM application; degree of applicability; growth and yield of annual upland crops; measuring and quantifying of GHG emissions; economic benefits, CBA	Develop report on the growth of crop applying ICM from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market
A8. Substitution of urea with sulphate ammonia fertilizer	Monitoring the status and level of SA application; growth and yield of crops applying SA; measuring and quantifying GHG emissions; economic benefits, CBA	Develop report on the growth of crops applying organic fertilizer, soil fertility from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market
A9.1. AWD and SRI (where infrastructure is partly financed)	Monitoring the status of AWD and SRI application; degree of applicability; growth and yield of rice; measuring and quantifying of GHG emissions; economic benefits, cost	Develop report on the growth of rice applying AWD and SRI from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market
A9.2. AWD and SRI (basic infrastructure)	Monitoring the status of AWD and SRI application; degree of applicability; growth and yield of rice; measuring and quantifying of GHG emissions; economic benefits, cost	Develop report on the growth of rice applying AWD and SRI from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market
A10. Drip irrigation combined with fertilizer for coffee	Monitoring the status and applicability of drip irrigation combined with fertilizer for coffee; growth and yield of coffee; measuring and quantifying of GHG emissions; economic benefits, cost	Develop report on the growth of coffee applying drip irrigation combined with fertilizer for coffee from bottom to top	Work with stakeholders to broaden the model; develop involvement mechanisms and connect/link with carbon-market

Conclusion

In this study, the IPCC Revised Guidelines on National GHG Inventory (GL 1996 revised) was used to conduct the GHG inventory for the agriculture sector in 2014 and project GHG emissions in 2020 and 2030. As a result, GHG emissions from the agriculture sector in 2020 and 2030 are projected to reach 104.5 MtCO_2e and 112.1 MtCO_2e, respectively.

Mitigation options for agriculture and rural development were developed based on the rule of reviewing mitigation options in the INDC, Government response to climate change, agriculture sectors, and other activities related to GHG emissions reduction. The assumptions were reviewed and analysed in the context of Government and sectoral efforts to reducing GHG emissions in the Paris Agreement. The results showed that the agriculture sector has determined 4 options for GHG emissions reduction that can implemented domestically:

#	Mitigation option	Mitigation potential in million tons of CO_2e	Required investment in USD million
A1	AWD and SRI (where infrastructure is fully financed)	0.94	181.8
A2	Mid-season drainage in rice cultivation	3.20	1027.3
A3	Shifting double rice or triple rice to rice-shrimp	1.31	181.1
A4	Shifting double rice or triple rice to upland crops on the scale of 0.2 million ha of rice, 1.1 million ha of rice, 0.2 million ha of rice-shrimp, and 0.2 million ha of upland crop with mitigation potential, respectively	1.43	0.036

With international support, the country could implement twelve further mitigation options:

#	Mitigation options	Mitigation potential in million tons of CO2e	Required investment in USD million
A5.1.	Improvement of 0.8 million dairy cow diets	0.1	6.8
A5.2.	Improvement of 7 million non-dairy cow diets	1.2	95.5
A5.3.	Improvement of 1.5 million buffalo diets	0.3	20.5
A6.1.	Reuse of 1.2 million ha upland agricultural/crop residues as organic fertilizer	0.1	30.0
A6.2.	Introduction of 3.5 million ha biochar (large scale)	18.8	318.2
A7.1.	ICM in 1.0 million ha rice cultivation	0.5	9.1
A7.2.	ICM for 1.0 million ha annual upland crops cultivation	0.3	9.1
A8.	Substitution of 3.5 million ha urea with Ammoniac sulphate fertilizer	5.6	15.9
A9.1.	AWD and SRI 0.5 million ha (where infrastructure is partly invested)	2.3	785.5
A9.2.	AWD and SRI 1.0 million ha (basic infrastructure)	4.7	2,075.0
A10.	Drip irrigation combined financed fertilizer for 0.45 million ha coffee	1.7	1,227.3
A11.	Improved technologies to recycle 20 million tons of livestock dung as organic fertilizer	6.8	1.8

In order to achieve the mitigation targets, the study recognizes the barriers and constraints on policy, technology, finance and capacity building and the human and financial resources required to overcome these barriers.

The total amount of domestic funding needed is USD 1390.2 million to implement mitigation options in the agriculture sector in case of unconditional contribution. An additional US$ 4604.7 million would need to be mobilized from international sources in order to reduce an additional 29.14 $MtCO_2e$ compared to the BAU scenario in 2030.

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