Agriculture Climate Investments

Investment guide for low-emission rice in the Mekong Delta, Vietnam

CGIAR RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security CCAFS

IRRI

CGIAR INITIATIVE ON Asian Mega-Deltas

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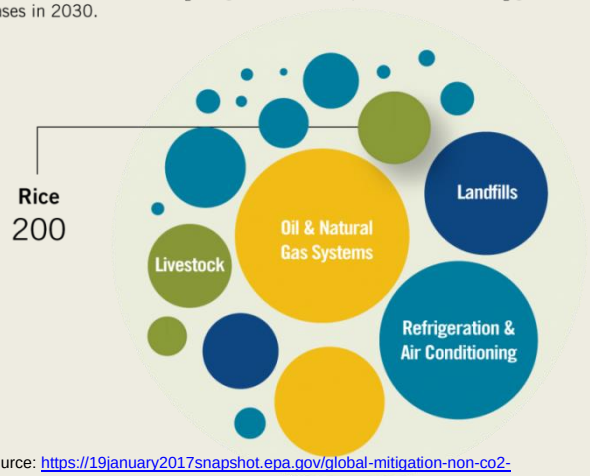
Multi-level environmental benefits from investment in low-emission rice

Opportunity: Next to animal production, rice cultivation is the second largest source of agricultural emissions, presenting **huge untapped sustainable investment potential**. Human activities in rice production influence methane (CH4) and nitrous oxide (N2O) emissions, and changes in soil organic carbon (C) stocks. When paddy fields are flooded, organic material is decomposed by methanogenic bacteria. **Changing irrigation and management practices** greatly influences soil CH4 and N2O emissions and soil C stocks. Future estimations show necessary growth in rice cultivation coupled with major losses from climate change. **Now is the time to concentrate efforts to change the trajectory for a food secure future.**

GHG abatement potential: Abatement potential for the rice sector globally is estimated at 200 MtCO2e in 2030 (26% reduction compared to the baseline). In Vietnam, we estimate a potential of **2MtCO2e of *annual* avoided emissions** with an **investment of US$722 Mil for a 10yr time horizon**.

CH_4 and N_2O Emissions from Rice Cultivation: Emissions Reduction Potential in 2030

Assuming full implementation of current technology, emissions in the rice cultivation sector could be reduced by up to 200 $MtCO_2e$ in 2030. This accounts for 4% of the 4,615 $MtCO_2e$ in global reduction potential for non-CO_2 greenhouse gases in 2030.



Source: https://19january2017snapshot.epa.gov/global-mitigation-non-co2-greenhouse-gases/global-mitigation-non-co2-greenhouse-gases-rice_.html

Multiple benefits: Aside from the obvious global benefits of decreasing GHG emissions, there are **multiple spillover benefits to water, soil, and air** that provide additional investment opportunity. However, in addition to being a large source contributing to global climate change, the **rice sector is vulnerable to climate shocks** and supply will drop while prices will rise with climate change, **affecting the poorest people**. Investors must come to terms with the inescapable need to finance both mitigation and adaptation strategies to **protect the future of global food security**.

Water: Changing from continuously flooded fields to controlled irrigation **saves nearly 4 Million liters of water/ha/yr**. Savings on this scale equate to a major re-distribution of water at the catchment level. This will **reduce salinity intrusion** in low-lying deltas to protect rice production and the saved water can be allocated for other economically productive purposes, such as industry and development.

Soil: Timely incorporation of straw residue **improves soil carbon content** while keeping GHG emissions at a minimum. And the reduced likelihood of saline intrusion also avoids severe reduction in soil fertility from salinization which threatens agricultural production on such soils. The value of healthy soil **provides long-term production benefits**.

Air quality: Straw burning is a significant source of air pollution and GHG emissions from Asia. Halting burning has **substantial human health benefits**. **Alternative uses for straw** such as bioenergy, bioplastics, straw pressboard, composting, and mushroom production represent **significant investment opportunities**.

ACTIONS FOR LOW-EMISSION RICE PRODUCTION

Rice production is an integral commodity to global food security, but it also contributes considerably to greenhouse gas emissions (GHG). There are a variety of options to mitigate GHG emissions from paddy rice production but the impacts and opportunities to finance such activities are not well-known or well-understood for global investors, and much remains to be done to ensure that international climate finance can be used to attract private sector investments into sustainable agriculture.

One of the most promising options is switching from the practice of continuous flooding to intermittent flooding practices. A technique known as alternate wetting and drying (AWD) in which fields are allowed to dry out before irrigation recommences can cut emissions in half. The package of 5 recommendations for low-emission rice production can reduce the total on-farm greenhouse gas emissions by as much as 65% seasonally. To mitigate investment risk, we assume the low-end rate of 50% GHG reduction with the low-C rice production package annually.

Low-Emission Best Practices for Irrigated Rice Production: If practiced correctly, these activities should result in reduced production costs without any loss to yield. Straw removal and sale represent an additional source of income that is currently a byproduct waste and is often burned contributing significantly to air pollution and black carbon emissions.

Low-emission practices	Scaling factor	% of max CO2e reduction potential
1) Incorporate minimal residues early in a dry field and leave fallow as long as possible followed by the shortest possible period for remaining land preparation (land soaking, tillage, and puddling)	0.9	10%
2) Grow short duration high-yielding varieties (switch from 100 to 90day variety)	0.9	10%
3) Use fertilizer as efficiently as possible (SSNM or deep fertilizer placement)	0.9	10%
4) Control irrigation using alternate wetting and drying (AWD) technique and terminate irrigation 10-15 days before harvest	0.45	55%
5) Preferably remove straw from the field for other uses OR incorporate it more than 30 days before cultivation of the next crop (see 1)	0.85	15%
ALL MEASURES TOGETHER	**Total GHG reduction of 50%**	

WHAT ARE THE OPPORTUNITIES FOR INVESTORS?

- Enable investors progress toward **carbon neutrality**, diversify sourcing of carbon offsets across sustainable agriculture-based carbon projects to reduce and mutualize investment risks
- Secure corporate investors ability to directly source, on an annual basis, **in-kind carbon offsets approved as a Clean Development Mechanism with certified emission reduction (CER) by the UNFCCC**
- Enable financial investors **early potential to lead the market through negotiated carbon markets' returns** by entering into firm and long-term carbon offset purchasing agreements with one or more carbon offset buyer(s), to monetize financial investors' carbon dividends
- Deliver **additional social, economic and environmental impact** to rural communities that meet multiple sustainable development goals.

Using global default values, the case for improving farming practices on 500,000 ha of irrigated rice production can be made solely on carbon benefits, representing **annual savings of 1.5[1] million tons of carbon dioxide equivalent ($MtCO_2e$)**. Estimates of the environmental, economic, and social benefits for carbon emission reductions, water savings, and improved air quality demonstrate high impact investment potential.

3tCO2e/ha
Seasonal abatement in double-cropping system

1.5 Million
tons of annual avoided CO2e emissions

15 Million
tons of avoided CO2e emissions over 10 years

500,000
hectares of rice under low-emission production

250,000
Households with improved incomes

8 Billion[2]
Cubic meters of water saved over 10 years

40,000[3]
tons of avoided PM2.5 pollution over 10 years

[1]2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Assuming global default values EF 1.3, Season length: 110 days, Yield: 5t/ha, 0t residue incorporated <30 days before season, Continuous flooding, 100kgN/ha, burn 0.259tCO2e/tstraw@3.2t/ha straw. Same practices for 2 seasons.

[2]Carrijo, Daniela R., Mark E. Lundy, and Bruce A. Linquist. "Rice yields and water use under alternate wetting and drying irrigation: A meta-analysis." *Field Crops Research* 203 (2017): 173-180. (Assume 2.5 cubic meters of water per kg of milled rice. Avg. 45% loss from 5000kg paddy rice/ha=2750kg of milled rice/ha*2.5m3 = 6875m3 of water used per hectare in CF. 23% water reduction average for AWD=5293.75).

[3]Lasko, Kristofer, Krishna Prasad Vadrevu, and Thanh Thi Nhat Nguyen. "Analysis of air pollution over Hanoi, Vietnam using multi-satellite and MERRA reanalysis datasets." PLoS One 13, no. 5 (2018): e0196629. (Assume 2kgPM2.5/t straw burned)

Mekong Delta, Vietnam Case Study

4tCO2e/ha[4]
of seasonal abatement in double-cropping system

2 Million
tons of annual avoided CO2e emissions

20 Million
tons of avoided CO2e emissions over 10 years

500,000ha
annually under low-emission rice production

$429USD Million[5]
improved incomes for 250,000 households over 10 years

9 Billion[6]
Cubic meters of water saved over 10 years

48,000[7]
tons of avoided PM2.5 pollution over 10 years

[4]Vo, Thi Bach Thuong, Reiner Wassmann, Van Trinh Mai, Duong Quynh Vu, Thi Phuong Loan Bui, Thi Hang Vu, Quang Hieu Dinh, Bui Tan Yen, Folkard Asch, and Bjoern Ole Sander. "Methane Emission Factors from Vietnamese Rice Production: Pooling Data of 36 Field Sites for Meta-analysis." Climate 8, no. 6 (2020): 74..
Traditional: MRD Tier 2 EF 1.718 season 1/ EF 2.797 season2, Season length: 100 days, Yield: 6t/ha, 0t residue incorporated <30 days before season, Continuous flooding, 100kgN/ha, burn 0.259tCO2e/tstraw@4.8t/ha straw. Same practices for 2 seasons.
Low-emission: MRD Tier 2 EF 1.718 season 1/ EF 2.797 season2, Season length: 100 days, Yield: 6t/ha, 0t residue incorporated <30 days before season, Multiple aeration, 90kgN/ha, No burning. Same practices for 2 seasons.

[5]Calculated costs using Rice-CBA tool with primary data collected from Mekong Delta farmersfor Winter-Spring and Summer-Autumn seasons comparing traditional rice cultivation net revenue to the net revenue from the crop management package for Sustainable Rice Platform.

[6]Traditional practice 8062.5m^3 water used per season. Improved practices 6028.13m^3 water used per season. Seasonal water savings = 1854.37m^3/ha x 500,000ha annually = 927,185,000m^2/yr x 10 years = 9.27m^3 billion water saved over project.

[7]Straw yield approx.. 80% of grain yield. MRD = 6t/ha * 0.8 = 4.8t straw/ha * 2kgPM2.5 = 9.6kgPM2.5/ha * 500,000ha = 4.8Mill kgPM2.5/yr/1000=4,800tPM2.5 x 10 yrs = 48,000tPM2.5 over project.

DE-RISKING INVESTMENT

Challenge: ***Verification and double counting***

De-risking strategy: ***Tool for monitoring, reporting, and verification developed***

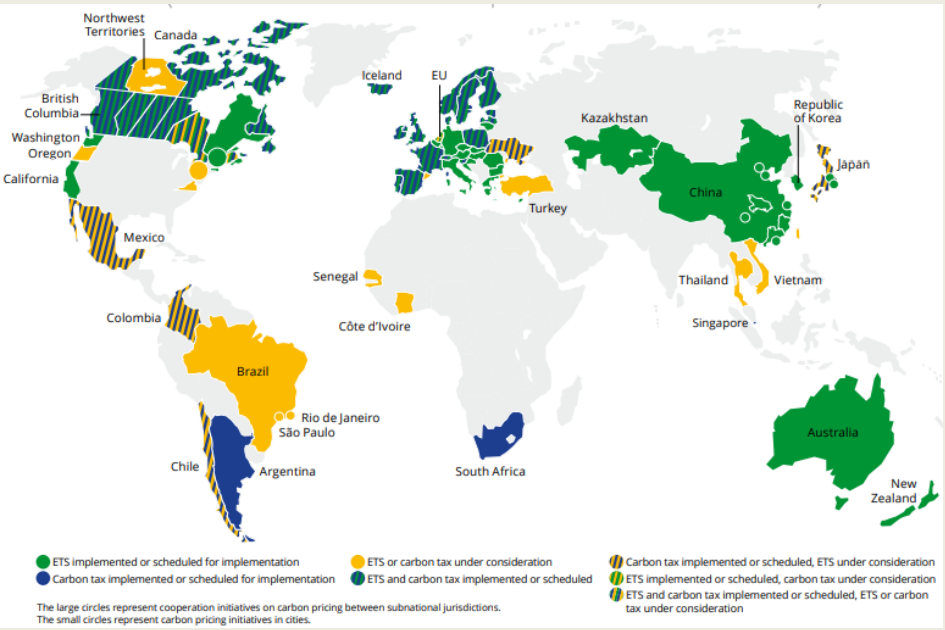
- The need for ongoing monitoring to verify area under practice will likely reduce in price as more data points are collected and the MRV system can shift from physically reported data to satellite verification and machine-learning systems. Political aspects, such as governance and involvement of stakeholders in the improvement, maintenance and management are well-established in Vietnam.

Challenge: ***Current lack of monetary market for trading carbon***

Returns are social benefits, ecosystem services, and protection of future production (supply) that are difficult to convert to tangible monetary returns on investments

De-risking strategy: ***Emissions trading system or carbon tax under consideration (World Bank, UNDP)***

- Within Southeast Asia and other major rice producing nations, Vietnam is particularly advanced in the development of a carbon market (see map below)
- A decree on a roadmap for GHG emission reduction is planned for approval, which references the use of carbon credits and a carbon policy initiative.
- Vietnam's NDC states the plan to use carbon pricing, and that the carbon pricing will be an international initiative. This includes NDCs that have been uploaded to the UNFCCC interim NDC Registry, of which low-emission rice is a major part of the agricultural NDCs[3].



Source:https://www.undp.org/content/dam/vietnam/docs/Publications/Opportunities%20for%20Carbon%20Pricing%20in%20Vietnam_Eng.pdf

- Vietnam's 'Green Growth Strategy' (2012) pursues the objective of a low-carbon economy and invokes the introduction of market-based instruments. Several measures lay the groundwork for implementing 'National Appropriate Mitigation Actions' (NAMAs) in the waste, steel, cement, chemical fertilizer, wind power, and biogas sectors. The planned MRV system and crediting NAMA will provide the experience for the implementation of a sector-based cap-and-trade program in the steel sector, which could start in 2020. Vietnam is also considering the use of market-based instruments for the waste sector starting in 2020[4].

- ***IRRI is currently working together with the government of Vietnam in defining and developing a roadmap for implementing agriculture NAMAs in the rice sector***

[3] http://documents.worldbank.org/curated/en/191801559846379845/pdf/State-and-Trends-of-Carbon-Pricing-2019.pdf
[4] https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems%5B%5D=83

INVESTMENT IN RICE SECTOR

Switching from continuous flooding practices to alternate wetting and drying (AWD) alone could achieve 65% of Vietnam's unconditional mitigation goal for crop production (2 $MtCO_2e$ of a total of 3.2 $MtCO_2e$). The study proposes an investment plan with 14 investment activities with a goal of practicing low-emission production on 500,000 hectares in the Mekong River Delta and mitigating 2 million tons of carbon dioxide equivalent ($MtCO_2e$) annually.

A blended finance budget is proposed for 722 million USD of which 81% is allocated for hard infrastructure and 18% for implementation, scaling, and MRV. The suggested investment portfolio is designed for private and public investors to finance projects that develop hard infrastructure and out-scale technology adoption.

Investors and rice traders would directly benefit from implementing low-emission rice production, both from reduction in GHG emissions and from increased revenue to farmers, protection of soil and water to ensure future production stability, and human health benefits.

Investment: To improve production practices on 500,000 ha of rice cultivation to meet low-C criteria in the Mekong Delta region of Vietnam
Baseline: 12% of total rice production in Mekong Delta (total rice production area=4.1 Mil ha) with baseline emissions of 4MtCO2e
Threats: High amounts of methane are released from continuously flooded rice production.
Monetized costs: Estimates of costs are used in the economic analysis. This captures capital expenditures (CAPEX) and opportunity expenditures (OPEX) for a range of actions: training materials; training courses; technology development for monitoring, reporting, and verification (MRV); and infrastructure development. Other cost estimates from the literature are also presented.
Monetized benefits: Estimates of benefits to farmer incomes are used. A shadow carbon price is used to quantify the monetary benefits from mitigation at a price of $36/tCO2e avoided.
Non-monetized costs: None
Non-monetized benefits: The estimated potential area of rice cultivation that could be successfully converted to sustainable rice production, reduces GHG emissions, saves water, and reduces air pollution. Without a certified carbon market, the mitigation efforts still have non-market value locally and globally. Reduced burning has community health benefits and improved production practices that save water result in better distribution and availability of water where salinity intrusion is a problem, thereby securing land area for food production that may otherwise be unproductive for crops.
NPV: The strongest investment case is made for irrigated rice cultivation that is currently under continuous flooding; and seasonal straw burning/incorporation. Assuming a carbon trading price of $36/tCO2 for 10years, an investment case is made for an area covering 500,000ha totaling $722mil (over 10yrs). The discount rate reflects a conservative central estimation for increases in carbon prices over time. Carbon values are estimated using a hybrid approach that uses both EUA futures contracts prices and a fundamental approach. For the first five years, the carbon price trajectory is based under the daily settlement prices of end of year EUA futures contracts of 2018 and 2019 vintages. From 2030 onwards, this involves estimation just under the maximum of two trajectories: Prices of EUA futures contracts are extrapolated from those in 2019 using the real discount rate of 3.8%.
Time period: 10 yrs
Key assumptions/uncertainties: The key assumptions are on the attribution of specific improvement actions across irrigated rice cultivation. The NPVs are based on average reduction in CO2 multiplied by the conservative central traded carbon values for modelling purposes (DECC, 2019). The analysis assumes that CAPEX is incurred in the first 5 years, opportunity costs incurred and benefits delivered are consistent from years 1 to 10 years.
Additionality: There are already significant rice cultivation improvement projects underway in Vietnam. Multiple government and non-government (NGO) led agricultural best practice packages have been disseminated. Extension training materials with a focus on greenhouse gas emissions for each module of production have been developed in line with scientists and the national agricultural extension center. However, the uptake at scale is limited and barriers to adoption include lack of awareness/knowledge of practices, irrigation subsidies, irrigation payment on an area-based fixed rate, and lack of motivation to conserve water. Without a significant investment, it is unlikely farmers will convert to more sustainable practices on their own.
Synergies/conflicts: Investments in irrigation management and coordination actions will also help improve the distribution of water. There is an opportunity cost associated with improving irrigation infrastructure that better infrastructure will allow for more productive systems meaning that more rice may be grown under improved irrigation, thereby increasing the net GHG emissions, although the food: GHG emissions ratio will be reduced with adoption of low-emission production practices.
Scalability: The benefits of avoiding emissions and the benefits of water regulation which are specific to individual catchments do not diminish over a large scale. The potential for scalability is broad given the savings to individual farmers realized through reduced production costs and increased efficiency.
Impact on natural capital assets: The specific natural capital assets associated with this investment are improved water distribution and improved air quality from reduced residue burning.
Distribution (over time): The investment case assumes that carbon benefits begin in the first year after the commencement of capital works and remain the same each year over 10 year period.

BUSINESS NEED

Traditional sources of capital for infrastructure investment (governments and commercial banks) are insufficient to meet capital requirement needs to 2030 (Negra et. al 2019). Capital markets targeting private capital from institutional investors, particularly pension and sovereign wealth funds, are increasingly looked to as viable actors to fill these financing gaps. Blended finance instruments and climate bonds for agriculture are appropriate investment vehicles for these investors as they are low-risk investments with long-term maturities, making them a good fit with institutional investors' liabilities. Bond financing works well for low-emission and climate-resilient infrastructure projects post-construction, as capital markets also facilitate risk management (Negra et. al 2019).

With the Mekong Delta projected to be one of the areas hardest hit by climate change over the next 20 years, rice production will suffer severely. Food trading companies such as Unilever, MARS, Coca Cola, Tesco, etc; as well as industry retailers like Ikea, Wal-Mart, Nike, etc that have large industrial operations in Vietnam can also be targeted for long-term climate bond investment. Alternatively, tapping into the bioenergy industry to explore the potential for efficiently producing energy from agricultural waste (rice straw) is a promising investment strategy.

INVESTMENT ACTION

Recommendation 1

Vietnam should consider sovereign green bonds in the development of donor fund mechanisms for climate smart rice value chains and sustainable rice landscapes.

Proposals for funding mitigation such as GEF, GCF and others should consider issuing a sovereign green bond to attract private investors to develop the rice sector towards sustainable and high quality production. The Low-emission rice production package detailed herein is a component that fits within the Sustainable Rice Platform or can stand alone as a climate smart rice product that delivers substantial carbon benefits in addition to social benefits. Meeting the requirements of Low-emission rice production can be verified and recognized as a milestone on the path of working towards sustainability for SRP. This can provide incentives for farmers and contractors that are aiming for full SRP compliance.

The government of Vietnam can leverage the support of key stakeholders that are actively investing resources and expertise in scaling low-C and sustainable rice production in the region, including the World Bank Group, the UNDP, Loc Troi, Olam, Phoenix, SNV, and GIZ as well as potential private partners such as Heineken - that operates facilities in Vietnam using electricity produced from rice husks, Ikea - that is expanding the market for rice straw products in India, Rynan - a private company producing plastic alternatives from wasted rice residues, Coca Cola – that depends on available water resources for their manufacturing, MARS – that has made a commitment that all their rice will be sourced from farmers who are working towards the Sustainable Rice Platform (SRP) standard by 2020, and many others.

Recommendation 2

Multilateral climate funds should consider supporting national governments in preparing for the planning, design and issuance of a sovereign green bond for climate-smart rice investments.

Tap into programs that support developing countries and regions to build their adaptation and resilience to the impacts of climate change, such as the CGIAR 2 Degree Initiative, and can catalyze through grant funding, the development of new climate financing mechanisms applied to adaptation in agriculture.

A sovereign green bond could help Vietnam attract international investors in Low-C rice production, unlocking capital for governments to support through blended finance mechanisms or investing in infrastructure. Such an instrument could be linked to a country's NDC, National Adaptation Plan (NAP) for agriculture, or National Agricultural Investment Plan (NAIP)'s irrigation targets.

Recommendation 3

Agribusiness and international donors can collaborate to develop and scale nature- and landscape-based solutions for sustainable rice.

The Sustainable Rice Landscapes Initiative (SRLI) should investigate the potential to use market-based climate finance mechanisms to scale forest, soil and watershed restoration in the Mekong Delta as well as facilitate the process for carbon accreditation for Low-C rice production that are ready to be traded on the carbon market once Vietnam establishes the Emission Trading Scheme or carbon tax. This could enable governments to use regulatory mechanisms to meet their NDC commitments.

Investment plan for mitigation in rice production by 2030 in Mekong Delta

No.	Outputs & activities	Scales & location	Requested budgets and proportion thru 2030	Expected results
Output I. Improved instructional and technical capacity for developing low-C rice in MRD region				
1.	Develop technical guidelines for the dissemination of low-C rice cultivation	13 provinces in MRD region	85,000 USD	10,000 manuals for AWD
2.	Develop guidelines to measure emissions, and identify GHG emission reduction potential of low-C rice production	13 provinces in MRD region	430,000 USD	2000 guidelines with field testing
3.	Develop guidelines for the implementation of the measurement, reporting and verification (MRV) system for low-C rice	13 provinces in MRD region	430,000 USD	2000 guidelines with field experiments and training
Output II. Capacity improvement for policymakers, private partners and farmers for low-C rice in MRD region				
1.	Training workshops for staff of management agencies of MARD, localities, private organizations and farmers on GHG emission reduction and priorities	Management units under MARD, 13 provinces in MRD region	215,000 USD	5000 training materials, 5000 trainees
2.	Create market support for sustainable rice products to enhance “green” production capacity and value chain pipeline	Management units under MARD, 13 provinces in MRD region	860,000 USD	200 relevant offices and green enterprises, 20 green products originating from rice, materials and database
3.	Support local partnerships, investors for climate-smart agriculture, low-emission rice production and enhancing readiness for NDC implementation	13 provinces in MRD region	430,000 USD	200 policy-makers, enterprise leaders with enhanced capacity and capability
4.	Exchange international experiences in implementing GHG emission reduction activities in NDCs for low-C rice production	Enterprises, UNFCCC member countries, global allies in rice production	215,000 USD	20 policy-makers, 60 leaders of enterprises related to rice production in the MRD region
5.	Strengthen the capacity of negotiation and access to low-C rice production in the MRD region	Management units under MARD and 13 provinces in MRD region	43,000 USD	50 management specialists and policymakers who can participate in negotiations

Output III. Improved national capacity for NDC implementation for low-C rice production				
1.	Review capacity and assess the efficiency of irrigation systems and field features that support AWD in rice production	13 provinces in MRD region	1.3 Mil USD	Spatial maps of irrigation systems (commune level, rate: 1:200.000)
2.	Investment and support for modeling and predicting climate change and intervention strategies in rice production	500,000 ha	60 Mil USD	Model scenarios GHG reduction of 1.4 $MtCO_2e$ annually
3.	Investment to improve irrigation system construction for AWD	500,000 ha (100,000 ha in 2020; 400,000 ha 2020-2025) Duration: 10 years	580 Mil USD	Completed designs, buildings, operation reports M&E reports
Output IV. Develop, pilot, launch, and maintain MRV system				
1.	Investment and support for the MRV system in rice production	500,000 ha	25 Mil USD	Designs, models, GHG reduction of 1.4 $MtCO_2e$ annually
2.	Operate MRV system for low-C rice production	500,000 ha in 13 provinces in MRD region according to identified timeline	44 Mil USD, distributed accordingly to identified periods	MRV reports on AWD from rice production, MRV report verification from AWD in MRD region
Output V. Improved coordination mechanism among the parties involved in low-C rice production				
1.	Support for policy dialogue on low-C rice production with national and international stakeholders	National level and in 13 provinces in MRD region	130,000 USD	Evaluation reports, policy evaluation report, policy mechanisms
2.	Partnership support among stakeholders from financial sponsors, banks and traders for low-C rice production	National level and in 13 provinces in MRD region	430,000 USD	Operation mechanism, financial and investment guidelines for LEDs, especially in rice production
Output VI. Certification Process for Certified Emission Reductions to issue carbon credits				
1.	Certification process and ongoing accreditation for Low-C rice projects to issue carbon credits	Certification for Low-C rice in Mekong Delta on 500,000ha	3 Mil USD including operational costs for 10 years	Registration, third-party project validation and emission reduction verification, monitoring, and certification

Investment allocation

No.	Type and activities	Total (USD mil)
I&II	Technical capacity strengthening	2.71
III.	Irrigation infrastructure and capacity	641.3
IV.	MRV system	77
V.	Partnership coordination	0.56
	Total (million USD)	721.57

NET PRESENT VALUE (NPV)

The emissions factors used in the analysis and in the calculations for this investment case come from IPCC guidelines and Tier 2 factors for the Vietnam example. On 500,000ha of irrigated rice cultivation, the range of emissions is between 1.8 to 4.4 Million tCO2e/yr. The costs are assumed to be the initial capital costs to transition rice production to the improved practices. To achieve an NPV above zero, the price of carbon should be set at $36/tCO2e. The benefit calculated was the average reduction in CO2 multiplied by the centralized short-term traded price of carbon (DECC, 2020) discounted over a period of 10 years (the assumed time over which these improvement options would provide benefits). The selling price for carbon could be reduced by removing the necessary public infrastructure investment costs or recalculating these costs to include values for the multiple public benefits provided such as reduced water usage, reduced air pollution, and increased farmer incomes, in addition to the carbon benefits.

OPERATIONAL EXPENDITURE (OPEX) AND OPPORTUNITY COSTS

The need for monitoring of the improvement process and widescale verification seasonally demands an initial investment for setting up the MRV process and ensuring its success. Opportunity costs will be higher in areas where no existing crop production reporting system exists. Although there will be ongoing opportunity costs for MRV, the system represents a source of return on investment given that any country, region, or private contracted group of farmers that wishes to claim carbon accreditation for the reduction in emissions must have a valid and approved system for verification. Therefore, an MRV system that can accurately estimate GHG savings based on satellite data represents a commodity that could be sold on the global market.

LIMITATIONS AND FUTURE RESEARCH

- The cost benefit ratio of a specific improvement activity also varies with a number of site-specific factors that are not picked up in the analysis including historic management impacts and site conditions (e.g. current ecological condition, baseline farmer practices, irrigation infrastructure, geographic location, and current and future climatic conditions).
- The required improvement actions for each of the conditions considered are assumed based on expert judgement and might not be fully reflective of the specific actions required at a specific site. For example, the costs might be shared among the activities (duplication of efforts and economies of scale), and therefore might be less costly.
- A baseline of current practices will need to be established so as not to attribute previous training successes to current investment returns. Additionally, given that the GHG savings are seasonal, the conversion timeline should be established at which an area is considered to have established a new baseline based on the assumption that after some time it is unlikely to revert back to previous practices and therefore the new starting point for savings must be established after 10 years. This also means diminishing returns over time as the amount of available land targeted for conversion to low-emission production practices is expected to decrease as more and more area adopts the practices over the time period.
- It is recognized that the shadow price of carbon figures have been developed to assess the relative cost-effectiveness of different mitigation options and programs and is designed to reflect the long-term social and political drivers for the transition to a low carbon economy. These figures are not the same as actual trading values, which for the voluntary market are significantly lower around $1-12/tCO2e.