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Vulnerability and risk assessments of agriculture sectors in Viet Nam

Contents

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Authors
Janto S. Hess (UNDP) led the writing of this case study with inputs from Beau Damen (FAO), Shanali Pethiyagoda (FAO), Morgane Rivoal (UNDP), and Tran Van The (Institute for Agricultural Environment). Contributors to the case study include: Bui Viet Hien (UNDP), Binh My Bui (ICD), Hang Thi Thanh Pham (FAO), and Theresa Wong (FAO). This publication was reviewed by Rohini Kohli (UNDP) and Subhi Shama (UNDP).

This publication is based on, and summarises, the vulnerability and risk assessments for the crops, livestock, and aquaculture sectors in Viet Nam undertaken by Tran Van The, Bui Thi Phuong Loan, Le Thi Thanh Huyen, Cao Le Quyen, Do Thanh Dinh, Hoang Thi Ngan, Nguyen Thu Thuy, Le Tien Dung, Do Van Duc, Han Anh Tuan, Trinh Quang Tu, Le Thi Thu Huong, and Hoang Van Cuong, as well as for the water resource sector undertaken by Nguyen Thanh Long, Do Hoai Nam, and Nguyen Quoc Dinh. All assessments were conducted under the supervision of Chu Van Chuong (MARD), Bui My Binh (ICD/MARD), Nguyen Trung Thong (FAO), Nguyen Thai Anh (FAO) and Bui Viet Hien (UNDP).

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Acronyms

CHR	Central Highland Region
CEA	Cost-effectiveness analysis
CBA	Cost-benefit analysis
CMIP5	Coupled Model Intercomparison Project 5
FAO	Food and Agriculture Organization of the United Nations
BMU	Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety
GIS	Geographic information system
GDP	Gross Domestic Product
GoV	Government of Viet Nam
GSO	General Statistics Office
NAP-Ag	Integrating agriculture in National Adaptation Plans Programme
IPCC	Intergovernmental Panel on Climate Change
IKI	International Climate Initiative
AR4	Intergovernmental Panel on Climate Change Fourth Assessment Report
AR5	Intergovernmental Panel on Climate Change Fifth Assessment Report
IRR	Internal Rate of Return
MRD	Mekong River Delta Region
MCA	Multi-criteria analysis
MARD	Ministry of Agriculture and Rural Development
MONRE	Ministry of Natural Resources and Environment
NAP	National Adaptation Plan
NEM	Northeast Mountainous Region
NPV	Net Present Value
NDC	Nationally determined contributions
NWM	Northern West Mountainous Region
NCR	Northern Central Coastal Region
O&M	Operation and Management
RCP	Representative Concentration Pathways
RRD	Red River Delta Region
SCR	South Central Coastal Region
SER	Southeast Region
THI	Temperature-Humidity Index
UNDP	United Nations Development Programme
VI	Vulnerability Index/Indices
IMHEN	Viet nam Institute of Meteorology, Hydrology and Climate Change
VRA	Vulnerability and Risk Assessment
WCRP	World Climate Research Programme

This case study chronicles Viet Nam's experiences in conducting vulnerability and risk assessments (VRAs) of selected agriculture sectors at the national level and a cost-benefit analysis (CBA) to support sectoral adaptation planning, budgeting, and policy formulation. Lessons learned from these endeavours can provide insights for other countries who are seeking, like Viet Nam, to develop an evidence-based and climate risk-informed National Adaptation Plan (NAP) and/or adaptation plans for the agriculture sector.

Highlights

- VRAs were conducted for the crops, livestock and aquaculture sectors and the water resources sector to inform the design of sector-specific measures for Viet Nam's NAP. The studies adopted similar approaches to prepare vulnerability indices based on an assessment of more than 80 indicators, including 7 climate change exposure indicators, 25 climate change sensitivity indicators and 18 climate change adaptive indicators for crops, livestock and aquaculture, as well as 30 indicators for water resources infrastructure.

- Based on climatic, socio-economic and agricultural data, a unique vulnerability index (VI) was developed for 6 crops (rice, maize, sugarcane, coffee, fruits, cassava), 5 livestock (pig, poultry, cattle, buffaloes, dairy), and 2 aquaculture varieties (fish, shrimp). In addition, a VI was developed for 53 813 water resources infrastructure assets (8 594 reservoirs, 9 108 pumping stations, 11 916 weirs, 18 874 canals and 5 428 sluices).

- The aggregated climate VIs allow for better targeting of adaptation measures by providing a spatially explicit overview of the climate risk faced by each sector at district level. The VIs show that the most vulnerable regions by sector are the Northern Central Coastal Region (NCR) (for crops and aquaculture sectors), the Southeast Region (SER) (for aquaculture), the Mekong River Delta (MRD) (for aquaculture and crops), the Northern West Mountainous Region (NWM) (for crops), and the Red River Delta (RRD) (for livestock).

- The VRA of water resources infrastructure shows the VIs and measures the overall risk to specific infrastructure assets. Over 36 percent of sampled reservoirs were classified to be very highly or highly vulnerable to climate change and almost 57 percent of pumping stations assessed were classified to be of very high or high vulnerability.

- Adaptation measures to address the climate risks were identified for each sector and cost-benefit analysis (CBA) was conducted. Together with the VIs, the outcomes of the CBA were used to prioritise potentially promising adaptation measures in the crops, aquaculture and livestock sectors such as rice intensification and integrated cassava and peanut cultivation. In the water resources sector, the CBA helped prioritise infrastructure assets where adaptation measures would both improve their resilience to climate change and minimise potential climate change impacts on society.

- The developed VIs proved useful for targeting regions at particular risk from climate change and identifying possible adaptation measures. The overview of VI rankings between different provinces and districts allowed a general comparison of potential priority areas in need of interventions. It could also inform future public adaptation planning and budgeting processes, ensuring that required support to cope with climate change-induced risks is being provided.

- However, while ground-truthing the computed VI-results, the study teams found that there is a need to verify computed results and proposed measures with communities. Ultimately, different users at community and sector levels require tailored vulnerability and risk assessment information to make more evidence-based decisions about climate change and adaptation. Thus, it is essential to complement these indices with field observations and consultations with end-users.

The context

Viet Nam is considered to be among the most vulnerable countries to climate change globally (German Watch, 2017). Its agriculture sectors (i.e. crops, livestock, fisheries, and aquaculture) are particularly susceptible to the impacts of climate change. This poses significant risks to the country as the sectors employ approximately 35 percent of Viet Nam's labour force, contribute 15 percent of its gross domestic product (GDP) (in 2019) and support the livelihoods of 65 percent of the Vietnamese population living in rural areas (GSO, 2019). In order to understand climate-induced risks, the Integrating Agriculture in National Adaptation Plans (NAP–Ag) programme provided financial support to the Ministry of Agriculture and Rural Development (MARD) and conducted, between December 2016 and December 2018, comprehensive climate change vulnerability and risk assessments (VRAs) at national level for the crop, livestock, aquaculture, and water resources sectors. The assessments can be used to identify and subsequently prioritise adaptation actions, as well as develop recommendations and actions for the agriculture sectors' inclusion in Viet Nam's National Adaptation Plan (NAP). Alongside the VRAs, a cost-benefit analysis (CBA) of a range of adaptation options was undertaken to facilitate the prioritisation of these options.

Climate change impacts on agriculture sectors in Viet Nam

Viet Nam is located at the south-eastern tip of the Eurasian continent and has a total land area of about 331 051 km^2. The country has an extended coastline of 3 444 km. In the coastal areas there are two major deltas, the Red River Delta (RRD) in the North and the Mekong River Delta (MRD) in the South, which are the most productive agricultural areas of the country. In contrast to these low-lying deltas and coastal regions, the northern part is characterised by mountainous and hilly areas, and there are some elevated plateaus in the middle of the country. Viet Nam's varied topography is associated with a range of different climates, for which diversified changes can be observed. For example, annual rainfall decreased by 5.8 percent to 12.5 percent in the North, while it increased by 6.9 percent to 19.8 percent in the South between 1958 to 2014 (MONRE, 2016).

The country already experiences a range of natural hazards with damages caused by floods, droughts, landslides, erosion, cyclones, and tropical storms. Climate change is projected to exacerbate existing climate-induced risks, which can pose significant threats to the country's development. Over the past two decades, disasters in Viet Nam have caused more than USD 6.4 billion of property damage and economic losses, and led to 13 000 deaths (World Bank, 2017). A major flood in 2016 alone accounted for USD 227 million in total damages and losses, out of which 46 percent occurred in the agriculture sector and 31 percent in the transport sector (World Bank, 2016). Due to the location of the roughly 300 000 km of road infrastructure in mountainous landscapes and along the coastline, the transport sector is particularly vulnerable to climate change-induced erosion, floods, and land-slides, impacting essential networks for agriculture sector value chains. In coastal regions, saltwater intrusion in soil and groundwater poses another challenge. In 2016, saline intrusion was recorded reaching 90 km inland resulting in damages of 400 000 hectares of cultivated areas, of which 30 000 hectares were not replanted (Khoi *et al*., 2018). Increased salinity is partly caused by climate-induced sea level rise. In one tested scenario model, sea level rise is projected to reach a maximum level of 37.8 centimetres by 2050 (Neumann *et al*., 2012). This poses significant risks to 70 percent of Viet Nam's population living in coastal areas and low-lying deltas (Banga-lore, Smithand Veldkamp, 2016). It is estimated that a one-metre sea level rise could lead to USD 2 billion in road damages and that millions of people's livelihoods, especially in the Mekong Delta, will be affected (Arndt *et al*., 2015).

Vulnerability and risk assessments and sectoral adaptation planning

VRAs are an integral part of the national adaptation planning process and listed among the methodologies to be used within Element B: Preparatory Elements of the Supplementary Guidelines on 'Addressing Agriculture, Forestry and Fisheries in National Adaptation Plans' (NAP-Ag Supplementary Guidelines) to enable climate change risk-informed adaptation planning and implementation (see FAO, 2017).

The need for vulnerability and risk assessments in sectoral adaptation plans

Element B of the NAP-Ag Supplementary Guidelines focuses on analysing climate change scenarios, risks and vulnerabilities in the agriculture sectors and identifying, selecting and prioritising medium– to longterm adaptation options. VRAs help to determine how production systems, ecosystems and ecosystem-dependent communities will be affected by climate change. They can thus inform local and national policies and actions that will reduce vulnerabilities and facilitate adaptation. In practice, VRAs can often cover a number of the outputs that fall under Element B of adaptation planning (Box 1) – as will be illustrated in this case study.

Box 1

Main outputs under Element B: Preparatory Elements of the NAP-Ag Supplementary Guidelines

- an assessment of climate change impacts on agricultural systems based on climate change scenarios;
- risk and vulnerability assessments, including a ranking of risks and vulnerabilities;
- identification, appraisal and prioritisation of adaptation options for the agriculture sectors;
- agricultural adaptation perspectives compiled into a specific agriculture component (or programme) that feeds into the NAP;
- initiation of processes for integrating adaptation into agricultural development plans and programmes and national and subnational planning, including the strengthening of institutional capacities.

As adaptation needs can differ by sector and location, assessments of climate vulnerability and/or risks to the agriculture sectors and/or agriculture-producing regions are an important element to develop adequate climate change response strategies. During the initial phase of undertaking a VRA, it is important to define the scope, purpose and appropriate methodological approach through considering a range of aspects (see Box 2). When reflecting on these initial considerations of the different scales and approaches of VRAs it becomes apparent that there is no universal methodology, but that the most suitable approach is highly dependent on context. Likewise, there are different frameworks that are used by practitioners and researchers to describe the core concepts related to climate change vulnerability, risk, and impacts. The most common conceptual frameworks used are the ones outlined in the Assessment Reports by the Intergovernmental Panel on Climate Change (IPCC).

Box 2

Considerations for defining the scope, purpose and appropriate methodological approach of a vulnerability and risk assessment (VRA)

Focus and Scope

- Hazard/impact (e.g. floods, droughts)
- Location (e.g. national, sub-national, asset level)
- System/unit (e.g. sectors, sub-sectors, water infrastructure)
- Attributes at concern (e.g. yields, income, flood resistance of infrastructure, coverage of irrigated areas)
- Time scale (e.g. current, future, dynamic)

Purpose

- Define vulnerability of system/unit of concern
- Define hazard magnitude
- Inform decision-making
- Develop policies
- Raise awareness
- Prioritise adaptation actions
- Monitor risks and adaptation interventions

Approach/Method

- Top-down or bottom-up consultations
- GIS-based
- Participatory
- Quantitative/qualitative

Approach will be determined by:

- Data quality
- Access to information, technologies, and stakeholders
- Budget
- Expertise

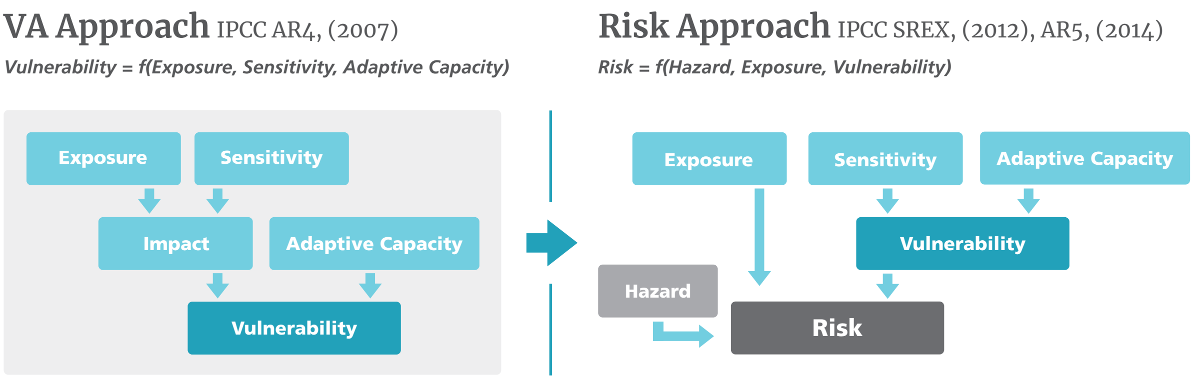
Conceptual foundations of climate change vulnerability and risk assessments

Having a clear conceptual understanding of climate change vulnerability and risks is an important underpinning of effective VRAs. These concepts are not static and evolve based on improved availability of climate science and the way that the climate and climate change interact with geophysical, biophysical and social systems. An important evolution relates to the expression and use of the term vulnerability. According to the IPCC's Fourth Assessment Report (AR4), **vulnerability** is '*the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes*' (IPCC, 2007). The degree of vulnerability is derived from a given system's exposure and sensitivity to changes in climate and climate variability, the potential impact that relates to that change, and the adaptive capacity of the system to cope with this impact (Lavell *et al.,* 2012). Figure 1 provides a simplified comparative overview of the climate risk frameworks outlined in AR4 and AR5.

With IPCC's Fifth Assessment Report (AR5), vulnerability to climate change was integrated into a conceptual framework focused on **climate risk.** This term refers to the risk of climate-related impacts resulting from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability of human and natural systems (Oppenheimer *et al.,* 2014). Under this framework, hazards refer to changes in the climate and their effects on geophysical systems such as floods, droughts, sea level rise, and increasing temperatures, while vulnerability refers to the characteristics of human or socio-ecological systems exposed to hazardous events and trends (Oppenheimer *et al.*, 2014). Several assessments that are drawn upon to inform NAP processes use the conceptual elements of the AR4 and the AR5 frameworks and both approaches can provide useful insights to support adaptation planning.

Figure 1

Comparison of the components of climate change vulnerability (AR4) and climate risk (AR5)



Box 3 below provides definitions of key terminology/concepts crucial to analysing climate change-induced risks taken from IPCC's AR5. Risk refers to the probability of occurrence of hazardous events or trends (hazards) multiplied by the impacts of these events or trends (exposure x vulnerability). Using this framework, to assess the risk of a negative climate change impact to a given farmer we need to understand the probability and magnitude of a given hazard occurring (hazard), whether the farmer is going to be affected by this hazard (exposure) as well as the farmer's sensitivity to the hazard and his/her capacity to adapt (vulnerability). Considering a rice farmer as an example, longer dry periods are a climate change-related hazard that can negatively impact upon production. To understand the full risk to the farmer arising from this hazard we would need to know whether the farmer's rice paddies are in locations likely to be affected by longer dry periods as well as how sensitive his/her farms are to this hazard (i.e. irrigated farms would be less sensitive than rain-fed); as well as the resources the farmer has to switch to drought-tolerant crops or grow future crops to mitigate or cope with the effects (adaptive capacity).

Box 3

Key terminology used in IPCC's AR5 (2014)

Adaptive Capacity: The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.

Risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognising the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard.

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

With support from the NAP-Ag Programme led by the United Nations Development Programme (UNDP) and the Food and Agriculture Organization of the United Nations (FAO), two VRAs were conducted in Viet Nam, one VRA for the crops, livelihoods, and aquaculture sectors that leans on the AR4 framework, and one VRA for water resource infrastructure assets that builds upon the AR5 framework and concepts. Some of the findings generated are being made publicly available on the internet (See Box 4) which was developed with support from the NAP-Ag Programme as well as other UNDP projects. The open-source website is an interactive platform enabling easy access to tailored climate change risk information, by hazard at district level.

Box 4

Viet Nam's Climate Risk Index

Viet Nam's Climate Risk Index (www.climaterisk.org.vn) provides a platform for geospatial information, indices, and easily accessible maps of climate risks. It provides the consolidated findings of the most comprehensive vulnerability and risk assessments in Viet Nam. The interactive maps on the website cover all 712 districts across the country's 63 provinces. These provide a user-friendly visualization of the results, displaying key hotspots of vulnerabilities and major agricultural sectors at risk.

The key aims of the Climate Risk Index include:

- providing an open source platform with the best data freely available;
- enhancing transparency and collaboration among policy-makers and scientists;
- enhancing public-private partnerships for investment in climate compatible solutions;
- incentivising policies for building climate resilience, codes, standards, and practices;
- building national capacity on understanding climate change-related risk;
- promoting integrated climate risk-informed planning.

The target audience of the website includes policy and decision-makers in ministries, municipalities, the private sector, civil society organisations, as well as researchers. The platform is meant to be a dynamic knowledge base that will be updated to reflect new research and insights. As Viet Nam moves forward with its NAP process, the Climate Risk Index will host new analysis in additional sectors such as health and transport. Currently, the website is maintained by UNDP Viet Nam and in the near future, plans have been made to transfer the management of the platform along with the data to the Viet Nam Disaster Management Authority under MARD.

Viet Nam's Climate Risk Index has been developed by joint projects between UNDP, MONRE, and MARD. The projects are financed by UNDP, GEF/SCCF and the BMUB funded joint UNDP-FAO NAP-Ag Programme.

Approach of Viet Nam’s vulnerability and risk assessments

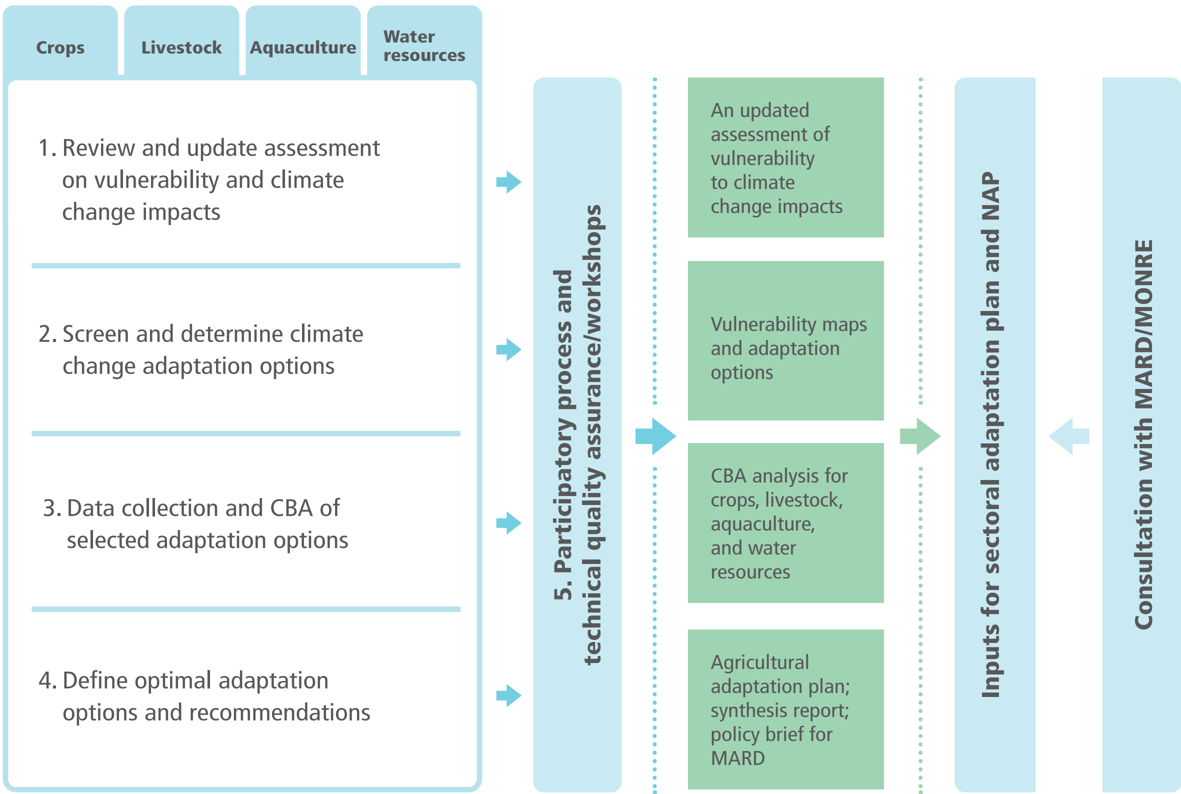
The VRAs summarised in this case study were part of two larger studies conducted to assess vulnerability as well as to identify and propose feasible adaptation options for the four agriculture sectors. The assessments covered districts or infrastructure assets across the crops, livestock, aquaculture and water resources infrastructure sectors as follows:

- 706 districts in 63 provinces for the **crops** and **livestock** sectors;
- 698 districts in 63 provinces for the **aquaculture** sector; and
- 714 districts with 53 813 constructions of water resources infrastructure (8 594 reservoirs, 9 018 pumping station, 11 916 weirs, 18 874 canals, 5 428 sluices) for the **water resource infrastructure sector.**

Results from the VRAs will support the preparation of an agriculture sector adaptation plan which will contribute to Viet Nam’s NAP, as well as the country’s expressed long-term goal of a climate-compatible development pathway. The conceptual framework underpinning the assessment process is provided in Figure 2 (the framework shows common steps undertaken for both studies). Figure 3 shows a timeline of the VRA process and indicates key milestones that were achieved.

Figure 2

Conceptual framework of the two VRAs (the framework shows common steps undertaken for both studies)

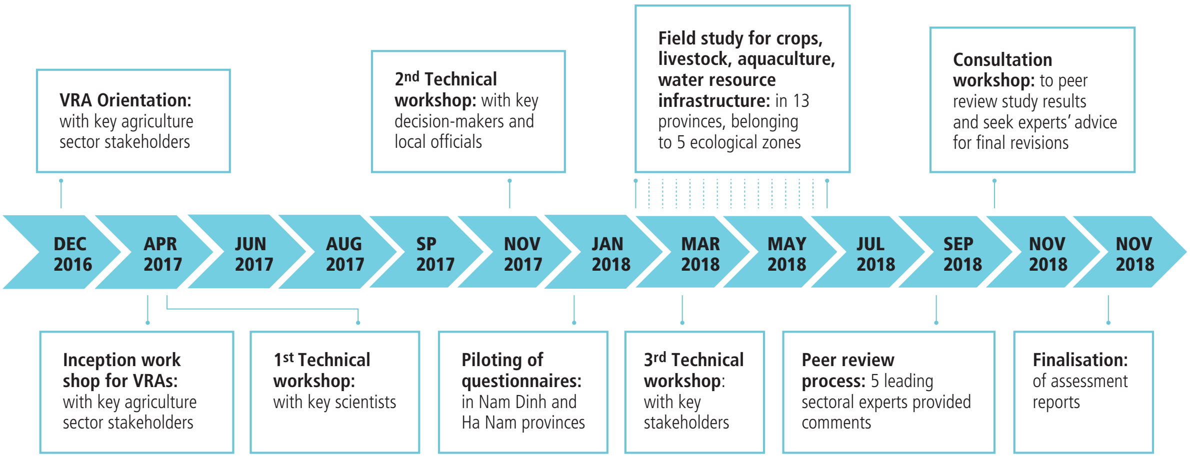


Source: Institute for Agricultural Environment (IAE), under Viet Nam's Academy of Agricultural Science (2018).

The two VRA assessments covered four distinct agricultural sectors. Two separate methodologies and sets of indicators were developed for the crops, livestock, aquaculture, and water resources sectors. In addition, the assessment for the productive sectors was based on earlier methodologies and guidelines focusing on the development of vulnerability indices (the IPCC’s AR4), whereas the assessment for the water resources sector encompassed approaches which are more in line with the IPCC’s AR5 concepts (see Figure 2) and investigated the overall risks, encompassing the vulnerability. The methodologies and indicators applied are described in the next section.

Figure 3

Timeline of vulnerability and risk assessments with key milestones



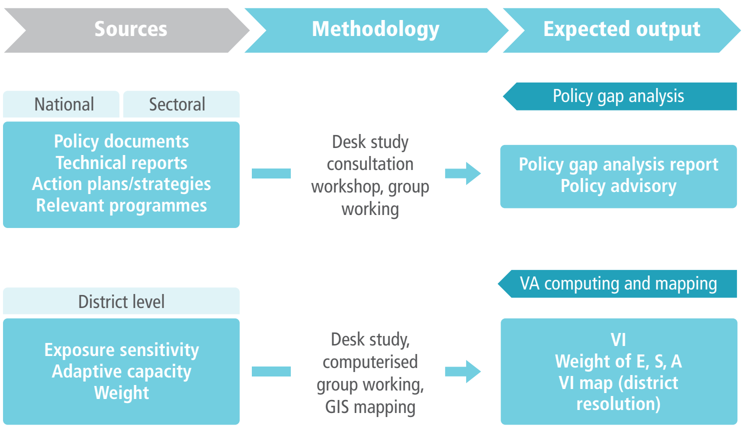
Vulnerability and risk assessment methodology for the crops, livestock, and aquaculture sectors

VRAs for the crops, livestock, and aquaculture sectors built on an extensive literature review. This helped to identify the most pressing climate change-related impacts for the sectors, as well as international best practices to conduct the assessment. In addition to the literature review, a range of experts and key stakeholders were consulted and interviewed to confirm assumptions and get valuable insights.

Figure 4 shows the schematic process of how the available data sources and inputs for the assessments were used for different methods to develop specific outputs, namely a policy gap analysis (meeting other objectives of the study) and a ranking different districts that were then displayed in Geographic Information System (GIS) maps. The data sourcing combined the utilisation of national and sectoral level information (such as action plans and policy frameworks influencing the vulnerability of the different sectors), as well as localised (district level) information that provided more detailed insights about the exposure, sensitivity, and adaptive capacity of the sectors in the different districts. This combination of different sources of information is essential. Regulations and policies, for example for the aquaculture sector, can provide insights into how (according to the law) certain fish farms need to be designed or if regulations already stipulate certain measures that reduce the overall vulnerability of the farms (e.g. obtaining insurance coverage), whereas localised data allows an understanding of how many producers, e.g. fish farms, are located in areas that might be exposed to cyclones, coastal inundations, or salinity.

Figure 4

Schematic process of methodologies for the VRA for crop, livestock, and aquaculture sectors



Source: Institute for Agricultural Environment (IAE), under Viet Nam's Academy of Agricultural Science (2018).

As indicated in the previous section, there are a variety of concepts and terminologies describing the vulnerability of a system/unit to climate change. In this VRA, different components were evaluated, including proportions and contributions of climate change exposures, sensitivity, and adaptive capacity of crops, livestock, and aquaculture. These components of vulnerability play important roles in determining the quality and degree of vulnerability in agriculture.

Previous VRAs in Viet Nam used a range of indicators, which were reviewed, and the relevant ones adapted and updated to develop indicators and compute the VIs for crops, livestock and aquaculture at the district level. A total of 50 indicators were selected out of which 8 are exposure indicators, 25 sensitivity indicators, and 18 adaptive capacity indicators. Table 1 provides a non-comprehensive overview of the indicators. It is important to note that the relationship of each indicator with climate vulnerability was computed in relation to the positive or negative impact on the overall scoring. For example, a high ranking in adaptive capacity indicators led to reduced vulnerability (e.g. more diversified income generated would in theory reduce the farmer's vulnerability as he/she has higher financial resources to cope with potential negative impacts on agriculture), whereas a high ranking for exposure and sensitivity indicators leads to higher vulnerability (e.g. a higher number of households dependent on aquaculture-related livelihoods in one area leads to more people being affected if a hazard impacts aquaculture production in that location).

Table 1

Selected indicators for updating and computing VIs in crops, livestock and aquaculture at the district level

					Relationship with climate vulnera- bility (+/-)[1]		
No	Indicator groups	Code	Unit	Time span	C	L	A
I.	**EXPOSURE INDICATOR**						
	Temperature (max)	E1	0C	2001–2014	+		
	Temperature (min)	E2	0C	2001–2014	+		
	Drought index	E3	number	2001–2014	+	+	+
	Annual rainfall	E4	mm	2001–2014	+		
	Storm index	E5	number	2001–2014	+	+	+
II.	**SENSITIVITY INDICATOR**						
	Loss in rice areas due to climate disaster	S2	ha	2010–2015	+		
	Proportion of ethnic minorities	S3	%	2010–2015	+	+	
	Ratio of multi-dimensional poverty	S4	%	2010–2015	+	+	+
	Cultivated rice area	S5	ha	2010–2015	+		
	Livestock density	S12	TLU/ha	2010–2016		+	
	Dairy density	17	head/ha	2010–2016		+	
	Aquaculture area	S18	ha	2010–2016			+
	Number of aquaculture households	19	Number	2010–2016			+
	Aquaculture production	S23	tons	2010–2015			+
III.	**ADAPTIVE CAPACITY**						
	Gross value of crops output per hectare	A2	M.VND/ha	2010–2016	-		
	Rice yield	A3	ton/ha	2010–2016	-	-	
	Growth rate of pig output	A10	%	2010–2016		-	
	Growth rate of milk output	A14	%	2010–2016		-	
	No. of livestock industrial farms	A15	Farm	2020–2016		-	
	Output value per hectare of surface water	A16	M.VND	2010–2016			-
	Aquaculture product value (fixed price in 2010)	A17	M.VND	2010–2016			-

* Source: Institute for Agricultural Environment (IAE), under Vietnam's Academy of Agricultural Science (2018)

[1] C= Crop production; L = Livestock; A= Aquaculture, (+) is positive affected to VI, (-) is negative affected to VI, blank is not applicable.

In the next step, the data for each indicator was collected, either through field research or desk-based activities (standardisation of geographical information, downscaling of statistical data sets, developing density maps per district), in order to have sufficient district-level information for all 63 provinces in Viet Nam. This data set was used to compute the vulnerability of the different sectors at the district level. This includes a more detailed analysis of key sectors, such as for crops (e.g. maize, rice, coffee, and sugarcane) or aquaculture (e.g. fish and shrimps).

The generated VIs were subsequently used to develop maps to highlight and communicate the results. For this exercise, the GIS software ArGIS (version 10.4) was used. The developed maps show all districts in 63 provinces with 16 GIS layers. The landuse map (issued by MONRE) was used as the base map. The spatial maps of VIs for crops, livestock, and aquaculture were developed through: (i) standardised maps of the same 48UTM coordinate system (appropriate format and standard); (ii) using Thiessen polygon tools to calculate meteorological data downscaling for district levels; (iii) overlaid density of crops, livestock, and aquaculture in maps; and (iv) overlaid VIs from all determined districts.

To validate the initial findings, a peer-review process was facilitated with key sector specialists who shared their observations during technical workshops thereby enabling results to be cross-checked and revised if needed.

Vulnerability and risk assessment methodology for the water resources sector

While the overall approach for the water resources sector VRA (creating an index based on indicators and developing maps) was similar to the approach for the other sectors, the nature of the water resources sector demanded the development of a different set of indicators and methodology. Furthermore, the analysis assessed the overall level of risk by considering the vulnerability ranking and the level of threats posed by climate change-induced hazards.

The indicators to determine the vulnerabilities of the investigated water resources infrastructures were identified through an extensive literature review and on the basis of guidelines developed by UNDP/MARD in 2016. In total, 9 indicators were applied for reservoirs, 8 indicators for pumping stations, 8 indicators for sluices, 8 indicators for canals, and 8 indicators for weirs. These indicators for the different water resources infrastructures covered aspects such as capacity, quantity of infrastructure, used material, construction age, year of applied designing code, real capacity vs. designed capacity, operation and management (O&M), and evaluation of current condition of infrastructure. It also included social factors such as the poverty ratio, ethnicity ratio, proportion of working-age population, and coverage of irrigated areas.

The data input for the calculation for each indicator came mostly from secondary data sources, whereas the weighting of each indicator was based on the UNDP/MARD guidelines. The computed VI rating for each indicator ranged from 0 to 1 (1 being the highest vulnerability). In order to simplify the communication and further processing of the data, five vulnerability categories were developed including very high (≥0.9), high (0.7-0.9), medium (0.5-0.7), low (0.3-0.5) and very low (≤0.3) levels. Due to the different types of indicators used, namely continuous and categorical, a harmonisation and transformation of all indicators into categories have been undertaken. For continuous indicators, the normalised value is equal to the value of the indicator subtracted by the minimum observed value divided by the difference between the maximum and minimum observed values. All categorical data indicators were assigned to a transformed value. The value was decided based on expert opinions proposed in UNDP/MARD VRA guidelines. In the scope of this study, three major hazards namely droughts, storms, and floods were considered. A range of hazard maps was developed, including:

- *Drought maps,* which were developed according to secondary data of the General Statistics Office (GSO) drought indicator by district level.
- *Storm maps,* which were developed based on maps of storm tracks from January 1956 up to December 2017. The historical storm tracking data was collected from Unisys Weather Information System.[2]
- *Flood maps,* which displayed the flood/flood depth area caused by strong or superstorm typhoons identified in a study by MARD in 2016.

[2] Available at http://Weather.unisys.com

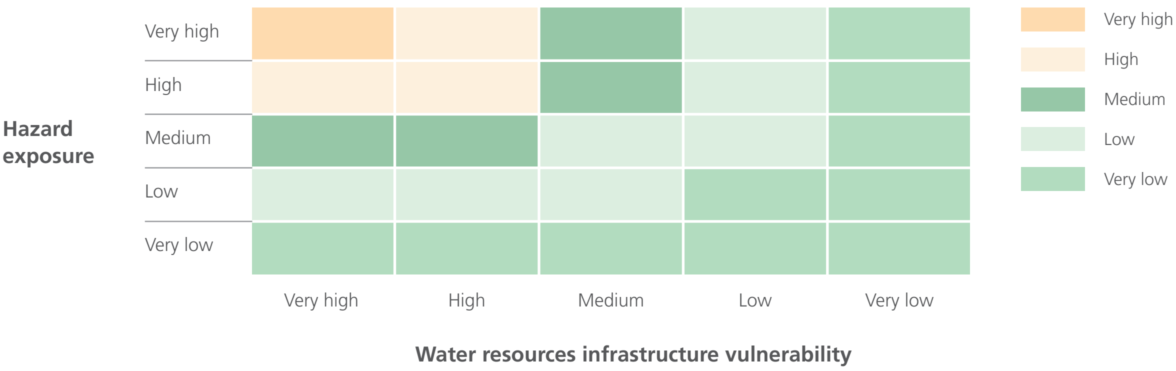
In addition, other hazards i.e. rainfall, temperature as well as inundation caused by sea level rise according to climate change scenarios Representative Concentration Pathways (RCP) 8.5 in mid-21st (2050) created by the Viet Nam Institute of Meteorology, Hydrology and Climate Change (IMHEN) in 2018 were considered. In particular:

- *Maps of changes in annual average rainfall* according to climate change scenario RCP 8.5 in mid-21st century were gathered from IMHEN (2018).
- *Maps of changes in average annual maximum temperatures according* to climate change scenario RCP 8.5 in mid-21st century were gathered from IMHEN (2018).
- *Inundation maps with a sea level rise of 50cm/ 100 cm were gathered from IMHEN (2018).*

The overall risk for irrigation infrastructures was determined by considering the likelihood over a specified period of severe alterations in the normal functioning of infrastructure due to hazardous physical events interacting with vulnerable infrastructure (*'Disaster risk = Hazard exposure x Water resources infrastructure vulnerability'*). The level of disaster risk was determined based on the disaster risk matrix proposed by Carroll and Malone (2008), as shown in Figure 5.

Figure 5

Disaster risk matrix (adapted from Carroll and Malone, 2008)



Source: Institute for Agricultural Environment (IAE), under Viet Nam's Academy of Agricultural Science (2018).

The overall disaster risk map of water resources infrastructures was developed based on overlaying hazard maps and vulnerability maps and associated risk classifications. Through this approach, a range of risk maps were developed, including:

- drought risk maps for water resources infrastructures;
- storm risk maps for water resources infrastructures;
- flood risk maps for water resources infrastructures;
- risk maps of changes in annual average rainfall for water resources infrastructures (based on RCP 8.5 by 2050);
- risk maps of changes in annual average temperature for water resources infrastructures (based on RCP 8.5 by 2050); and
- inundation risk maps for water resources infrastructures with sea level rise, scenarios of 50/100 cm.

Results of vulnerability and risk assessments per sector

Based on these indices, a range of maps was prepared. Due to the scope and objective of this case study, the following sections provide a snap-shot of selected results from the assessments per sector. A more comprehensive view is beyond the scope of the present case study, but would be of great value in informing adaptation planning in Viet Nam.

Selected results for the crops sector

For the crops sector, the vulnerability for a range of most important crops was assessed. These crops included rice, maize, sugarcane, coffee, and fruits. In addition to the indices per crop, an aggregated crops vulnerability index value was developed for each province.

Aggregated Crops VI from all key crops are shown in Figure 6. The VI of the crops sector is calculated from the VIs of all investigated crops, including rice, maize, cassava, sugarcane, coffee, and fruit trees. The results show that the districts with the highest VI index of the crops sector are Nghi Loc (Nghe An); Quan Hoa (Thanh Hoa), Muong Lat (Thanh Hoa), Phu Cat (Binh Dinh), Krong Bong (Dak Lak), Cư M'Gar (Dak Lak).

For the **sugarcane** production, most of the districts with high VI rankings (with more than 0.4) are located in Quang Ngai and Thanh Hoa provinces. Currently, Thanh Hoa is the province leading the country in sugar cane production with 4 sugar factories with a total capacity of 19,000 tons of cane per day. The assessment shows that current productivity hotspots are most vulnerable to climate change-induced hazards. Figure 7 provides a visual overview of the VI for sugarcane for the whole of Viet Nam. In this map it is possible to see that districts with no sugarcane production areas were excluded from the analysis.

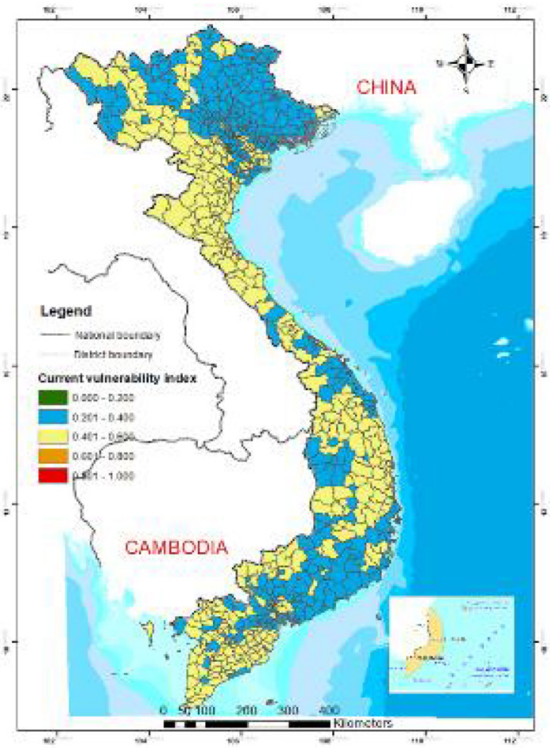
Rice is the most important crop in Viet Nam, especially in RRD and MRD. The top five districts with the highest VI rating, varying from 0.358-0.475, included Tuy Phuoc (Binh Dinh), La Gi (Binh Thuan), Ham Tan (Binh Thuan), An Nhon (Binh Dinh); Ba Tri, Giong Trom (Ben Tre), Phu My (Binh Dinh), Sam Son (Thanh Hoa), Duc Pho (Quang Ngai), Son Ha (Quang Ngai), Thach Ha, Can Loc, Nghi Loc (Ha Tinh) and Vi Thuy (Hau Giang province). Different factors contribute to this vulnerability. In Quang Ngai, for example, climate change-induced rainfall variability leads to extreme floods during the rainy season and drought periods in the dry season (leading to desertification processes). In addition, the Quang Ngai province is affected by incrementally increasing salinisation of soils and groundwater lenses. Comparable processes are being observed in other provinces, which poses significant risks to Viet Nam's rice production.

For **maize**, the second most important food crop, the districts with top five of the highest climate-vulnerable districts are Ham Tan (Binh Thuan), La Gi (Binh Thuan), An Hoai (Binh Dinh), Phu My (Binh Dinh), and Da Bac (Hoa Binh), Muong Lat, Quan Hoa (Thanh Hoa), Bac Ai (Ninh Thuan). Maize received an overall higher VI rating than rice because of the ecological features (like sloping land) of the area used for cultivation.

For the **cassava** production, the top five of the districts with highest climate vulnerable ratings are Minh Long, Son Ha, Ba To (Quang Ngai), Krong Bong (Dak Lak), Quan Hoa (Thanh Hoa), Phu Ca (Binh Dinh), Bac Ai (Ninh Thuan), Quang Binh (Ha Giang), Da Bac (Hoa Binh). It was found that vast areas (60 percent of the crop area) used for cassava production are highly dependent on irrigated water. This makes the crop particularly vulnerable to climate change-induced water shortages due to changing precipitation patterns.

Figure 6

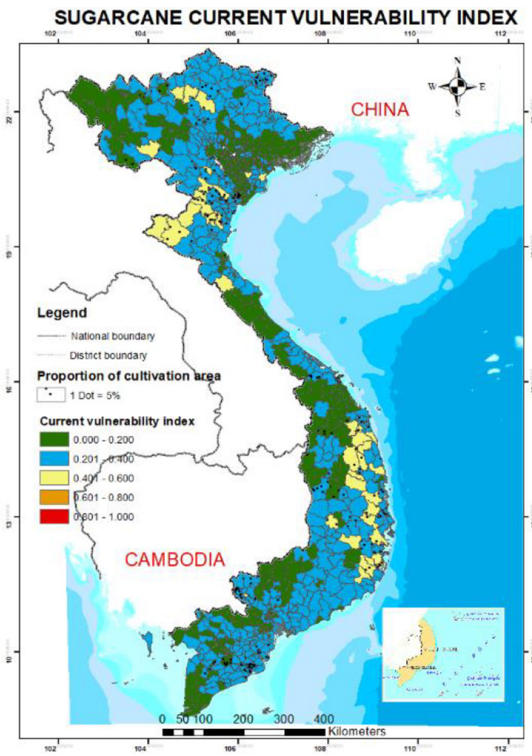
Spatial maps of Vulnerability Index of aggregated production (2010-2016)



Source: Institute for Agricultural Environment (IAE), under Viet Nam's Academy of Agricultural Science (2018). Map conforms to UN. 2020. Map 4170, Rev. 19. [https://www.un.org/Depts/Cartographic/map/profile/world.pdf]

Figure 7

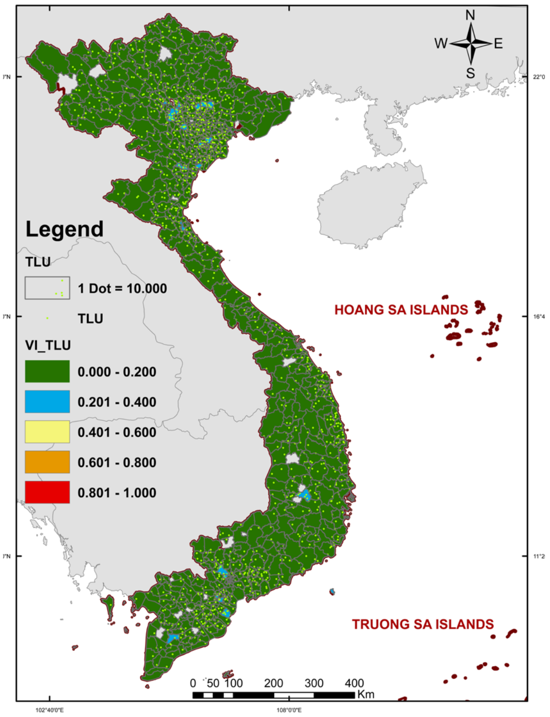
Overlaid sugarcane density and VI Index of sugarcane production



Source: Institute for Agricultural Environment (IAE), under Viet Nam's Academy of Agricultural Science (2018). Map conforms to UN. 2020. Map 4170, Rev. 19. [https://www.un.org/Depts/Cartographic/map/profile/world.pdf]

Figure 8

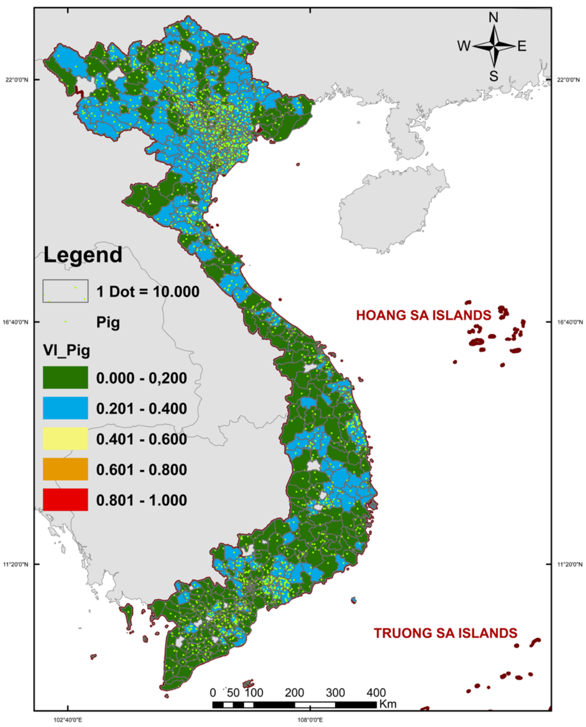
Spatial maps of VI for aggregated livestock production (2010-2016)



Source: Institute for Agricultural Environment (IAE), under Viet Nam's Academy of Agricultural Science (2018). Map conforms to UN. 2020. Map 4170, Rev. 19. [https://www.un.org/Depts/Cartographic/map/profile/world.pdf]

Figure 9

Overlaid pig density and VI on pig production (2010-2016)



Source: Institute for Agricultural Environment (IAE), under Viet Nam's Academy of Agricultural Science (2018). Map conforms to UN. 2020. Map 4170, Rev. 19. [https://www.un.org/Depts/Cartographic/map/profile/world.pdf]

For **coffee** production, the districts in Dong Nai, Dak Lak, and Lam Dong province have the highest VI. This rating reflects observed impacts on agricultural productivity by natural hazards in Dak Lak. According to data from Dak Lak Department of Agriculture and Rural Development from 1996 to 2011, the annual loss from natural disasters in Dak Lak was more than 681 billion VND, of which losses caused by drought accounted for 80 percent.

Fruit production was found to be most vulnerable in Binh Dinh, Ben Tre, Khanh Hoa, Dak Lak, and Ninh Thuan provinces with VI ratings greater than 0.46 (ranged from 0.225-0527). These regions are heavily affected by natural disasters such as floods and storms (Ben Tre). Moreover, fruit trees take a long time from planting to harvesting, resulting in low yields.

Selected results for the livestock sector

The VI was estimated for pig, poultry, cattle, buffalo and dairy production and aggregated livestock. The VI was calculated for 706 districts in 63 provinces.

For **aggregated livestock** production, the highest VI is found in Ky Anh district (Ha Tinh province), following by Tam Duong districts of Vinh Phuc province and Quan Hoa (Thanh Hoa province (see Figure 8). The results showed that Bac Giang, Dong Nai, Thai Binh and Hanoi are quite vulnerable with 2 to 3 districts registering the highest VI value.

The highest VI for **pig** production was found in Ham Tan district (Binh Dinh province), followed by Hoai Nhon and Hoai An districts (Binh Dinh province), Ky Anh town (Ha Tinh) and Phu My (Binh Dinh province) (see Figure 9). Those are mainly the districts with high exposure to climate change hazards, such as high number of hot days with temperature in excess of 35°C. Pigs are raised in high density which makes them vulnerable to extreme heat.

The highest VI for **poultry** production was shown in Xuan Loc (Dong Nai) and Ham Tan districts (Binh Thuan province), followed by Hoai Nhon and Phu My districts (Binh Dinh province). Poultry farms in these districts experience to high temperatures and humidity. Many districts rank high in the temperature-humidity index (THI) of several months during the year.

The highest VI for **cattle** production was shown in Ham Tan district (Binh Thuan province), followed by Phu My, Hoai Nhon and Hoai An districts of Binh Dinh province. These districts and provinces have big or moderate cattle herds but cope with climate change impacts such as increases in drought duration or cold temperatures affecting the green feed resources for cattle.

The highest VI was found for **buffalo** production in Ham Tan district (Binh Thuan province), followed by Phu My, Hoai Nhon and Hoai An districts (Binh Dinh province). In general, the map shows that high VI figures could be seen mainly located in the northern part of the country, which aligns with locations with the biggest buffalo herds.

The highest VI is found for **dairy** production in Ham Tan district (Binh Thuan province), followed by Hoai Nhon, Phu My and Hoai An districts (Binh Dinh province).

Selected results for the aquaculture sector

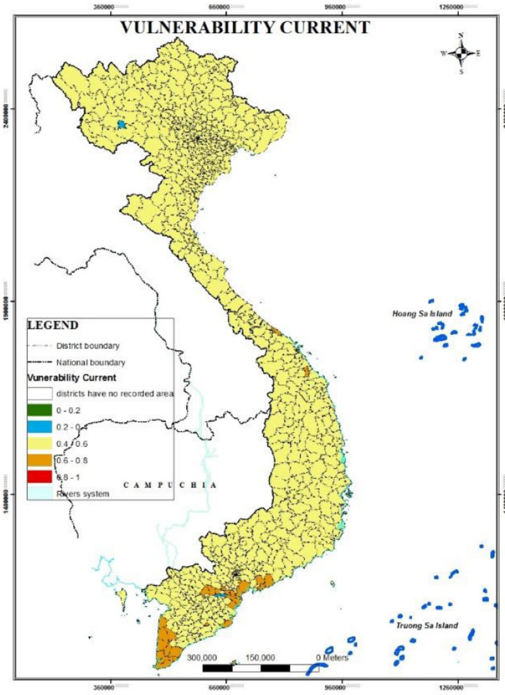
As cultured shrimp and fish species are two of the most popular and important aquaculture practices in Viet Nam, their farming activities were analysed to assess the level of vulnerability to climate change impacts.

The **aggregated aquaculture** sector vulnerability index shows the highest rating in districts in the four provinces in the Mekong River Delta (MRD) (Ca Mau, Tien Giang, Ben Tre and Kien Giang province), and the Southeast Region (Ba Ria – Vung Tau province (see Figure 10). High sensitivity indicators, as well as high exposure scores led to high overall VI scores. The MRD, for example, scored high in six out of seven sensitivity indicators, such as the area of aquaculture, the total fish and shrimp consumption per province, the damages to aquaculture areas caused by natural disasters and aquaculture production, and ranks highest for the overall VI. Moreover the MRD is a lowland that is vulnerable to climate change-induced sea level rise, salinisation, and coastal inundations. All of these pose significant risks to livelihoods of the people in the Mekong River Delta.

The fish production districts with the highest computed vulnerability were also found in the MRD in the districts of U Minh, Nam Can, Dam Roi, and Tran Van Thoi (Ca Mau province), Go Cong Dong, Tan Phu Dong (Tieng Giang province). High vulnerability ratings in these provinces relate to damages caused by natural hazards, which are projected to intensify due to climate change.

Figure 10

Spatial maps of aggregated VI on aquaculture (2010-2016)



Source: Institute for Agricultural Environment (IAE), under Viet Nam's Academy of Agricultural Science (2018). Map conforms to UN. 2020. Map 4170, Rev. 19. [https://www.un.org/Depts/Cartographic/map/ profile/world.pdf]

The VI for **shrimp** varied from 0.306 to 0.715, which was much higher than crops and livestock because shrimp farming in Viet Nam is mostly located in coastal areas which are highly vulnerable to the impacts of climate change. These include increased frequency and intensity of storms, salinity intrusion due to drought and changing rainfall patterns. Shrimp production is also affected by the increase in the number of excessive hot days during the year (Hargreaves and Tucker, 2003; Bui Quang Te, 2003 & Cao Le Quyen, 2015). It was verified through this computed index that the vulnerability of shrimp production is highest in districts located in the Mekong River Delta which has the highest incidence of shrimp farming and shrimp consumption per province and is exposed to the most severe impacts from salinity intrusion.

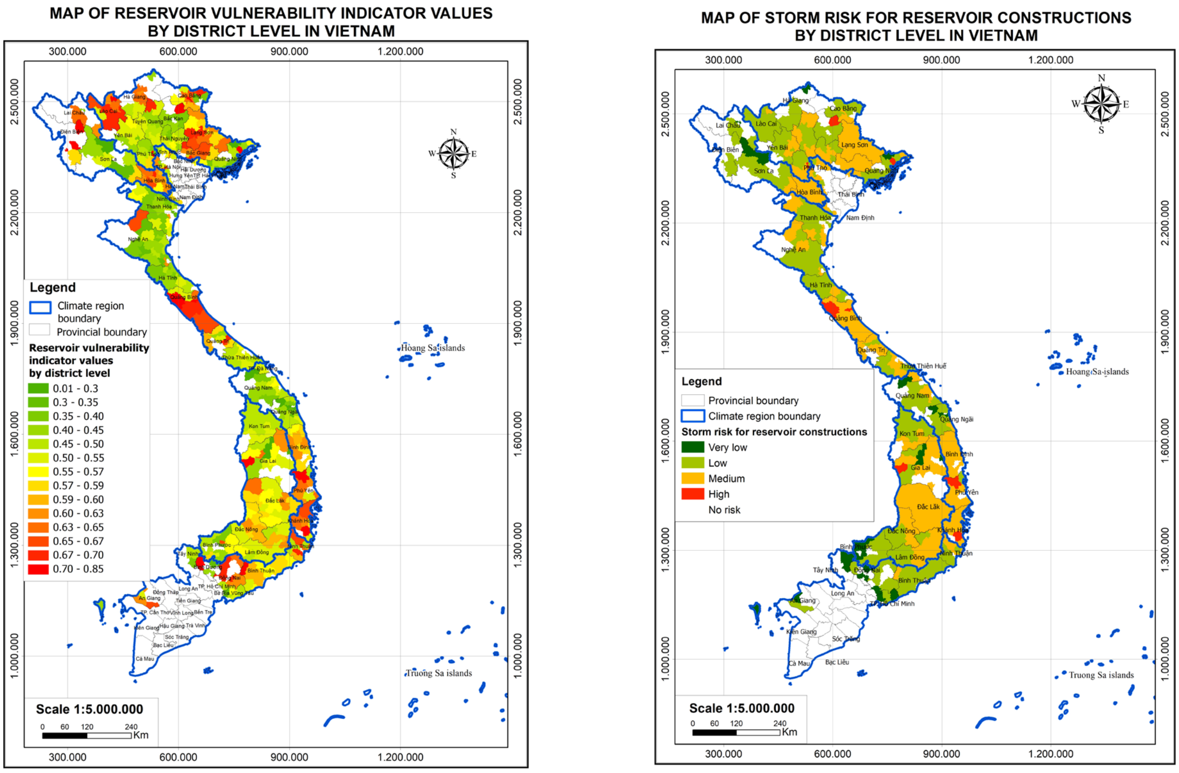
Selected results for the water resources sector

The assessment determined the VI rating for a range of water resources infrastructures and developed a range of spatial maps. In addition, the overall disaster risk of water resources infrastructures was assessed based on overlaying hazard maps and vulnerability maps and associated risk classifications.

The computed VI for **reservoirs** varied from 0.01 to 0.85, resulting in an overall ranking of reservoir infrastructure vulnerability as follows: 1 255 reservoirs (14.60 percent) were categorised as having high vulnerability; 4 251 reservoirs (49.46 percent) having medium vulnerability; 1 681 reservoirs (19.56 percent) having low vulnerability; and 1 407 reservoirs (16.37 percent) having very low vulnerability. Figure 11a provides the vulnerability map for water reservoirs by district. Figure 11b displays the risk map, which is a result of the risk matrix categorisation reflecting the computed vulnerability ranking as well as a storm hazard ranking for each district.

Figure 11

Vulnerability map (a; left) and risk map (b; right) for reservoirs at the district level of Viet Nam



Source: UNDP Viet Nam in collaboration with Viet Nam Institute for Geosciences and Mineral Resources, under MONRE (2018). Maps conforms to UN. 2020. Map 4170, Rev. 19. [https://www.un.org/Depts/Cartographic/map/profile/world.pdf]

The assessment for **weir** found that the infrastructure located in the north western and north eastern regions are ranked the highest for their computed vulnerability. The VI of weirs completely depend on their construction parameters (weir material, age, year of applied designing code, evaluation for current weir condition, etc). The analysis demonstrated that most of the weirs are located in the northern part of Viet Nam. Several historical weir constructions have been degraded, thus resulting in the highest VI in the following districts; Binh Gia, Cao Loc, Van Lang, etc in Lang Son province; Muong Khuong, Van Ban in Lao Cai province; Bat Xat, Van Chan, Muc Cang Chai, etc in Yen Bai province; Trung Khanh in Cao Bang province; Ha Hoa, Doan Hung in Phu Tho province; Chiem Hoa in Tuyen Quang province; etc.

The **sluice** vulnerability maps by district level based on the VRA were conducted for 5,428 infrastructures located in 133 districts. The results indicate that 252/5,428 sluice constructions (4.6 percent) are ranked as highly vulnerable (< 0.7). They are mostly concentrated in the following provinces: Binh Dinh, Tra Vinh, Thai Binh, Nam Dinh, Khanh Hoa, Tay Ninh, Hau Giang, Quang Tri.

The results indicate that 11 **canal** constructions (located in Pac Nam district /Bac Kan province, Bac Me and Dong Van district/Ha Giang province, and Tua Chua district/Dien Bien province) are very highly vulnerable, while 625 constructions (3.3 percent) are highly vulnerable.

The **pumping stations** with the highest vulnerability are located in the RRD, followed by the southern central coast and southern provinces. Considering the specific hazards, 155 districts (43 percent of evaluated risk districts) attained medium storm risk of reservoir constructions by district level, whereas the infrastructure located in districts in the southern region showed a lower risk profile for storms.

Cost-benefit analysis (CBA)

Alongside the VRAs for the different sectors, a preliminary CBA was conducted for a range of adaptation options. A CBA is commonly used when efficiency, expressed in monetary terms, is the only criteria considered to prioritise an adaptation option in decision-making (UNFCCC, 2011). It often provides a basis for prioritisation processes and can be utilised alongside multi-criteria analysis (MCA) or cost-effectiveness analysis (CEA). With regard to the prioritisation of adaptation options, these methodologies can generate meaningful insights on which adaptation actions are most feasible in different locations. CBA, in particular, uses a single metric (funds) to determine the economic benefits of different adaptation options. However, it is necessary to precisely outline how aggregated values are being calculated, while it can be challenging to calculate reliable estimates of options with values outside traditional capital markets (e.g. environmental goods and services or the preservation of cultural values). More information can be found in the NAP-Ag Briefing Note, titled "Cost-benefit analysis for climate change adaptation policies and investments in the agriculture sectors" (FAO, 2018).

CBAs conducted in the context of the VRAs under the NAP-Ag Programme in Viet Nam applied different methodologies for the four sectors. For the crop, livestock, and aquaculture sectors, more than 100 adaptation measures were considered, out of which 11 adaptation measures appeared to be particularly promising (5 from crop production, 3 from livestock, and 4 from aquaculture).[3] These 11 measures were explored in greater detail during a field survey in 11 provinces of 5 ecological zones to generate data that allowed a CBA to be used for these different measures. The analysis helped identify adaptation options that are economically viable, utilising a range of monetised indicators for costs (e.g. inputs, labour, rent) and benefits (e.g. reduced damages/losses, increase in feed conversion ratio for livestock). The results, for example, showed that it is more beneficial for local farmers to raise local chicken with high tolerance compared to conventional chicken farming techniques, as farmers raising local chickens earned more than VND 649.51 million for 5 000 chicken while conventional chicken provided only VND 425.73 million (included risks and portability rate).

For the water resources sector, a field study and desk research provided the required information to enable a CBA of different infrastructure types (e.g. reservoirs, canals, sluices, pumping stations, weirs) to identify the most suitable (cost-effective) adaptation options for different local contexts. For each infrastructure type, a range of adaptation options was considered, and preferred options identified based on calculated costs and benefits. Table 7 below shows an example of three prioritised adaptation options to enhance the climate change resilience of a water reservoir. These prioritised options were then used to develop an economic valuation of implementing such measures in specific water reservoirs using calculations of the net present value (NPV) and internal rate of return (IRR) (Table 8).

Table 7

Defining costs and benefits for three selected adaptation options for water reservoir

No	Adaptation Options	Priorit	Costs	Monetarise	Benefit	Monetarise
1	Increased maintenance and operation (O&M)	Very High	Additional budget to the regular O&M to perform more frequent inspection of dam to detect evidence of seepage; spillway to ensure the flood path is clear; grass cover and cutting and irrigating regimes to ensure grass is not lost during wet or dry periods.	3% of initial investment	Avoided cost of emergency response in case of extreme events.	1% of initial investment cost (every year)
					Reduced or postponed costs from upgrade/ rehabilitation.	5% of initial investment cost (every 5 years)
					Increased yield of crops through the increased irrigated area (approximately 10%) Additional revenues generated through taxes on increase production.	Output prices using market prices
2	Plant Bermuda grass on the downstream slope of the embankment for erosion protection	Very High	Cost for the seeding	1.5 USD/m2	Avoid the risk of slope erosion and do not have to replant the grass.	Save 1.5 USD/m2 for replanting the grass in every 5 years
3	Raise embankment (dam) crest for larger reservoir storage	High	Capital works	20% of initial investment	Increased yield of crops through the increased irrigated area (approximately 20% depending on reduction in rainfall in the dry season in the region).	Output prices using market prices

Source: Long, T. 2019.

[3] The identified measures include a system of rice intensification, intercropping maize and beans, Viet Nam GAP pomelo, intercropping cassava and peanuts, inte grated coffee cultivation, improving cattle kraals for pigs and biogas; local chicken with high tolerance, green forage crop for meat-cow raising, integrated aquaculture, mixed rice and shrimp, and mangrove – shrimp (inside dykes) and biosecurity – security shrimp farming.

Table 8

Example of an economic valuation for individual adaptation options for reservoirs

			Internal Rate of Return			Net Present Value (mil.VND)		
Name of reservoir	**District**	**Province**	**Increased O&M**	**Raise dam crest**	**Plant Bermuda grass**	**Increased O&M**	**Raise dam crest**	**Plant Bermuda grass**
Hồ Pa Khoang	TP. Điện Biên Phủ	Điện Biên	120	55	7	193 373	451 923	367
Suối Dầu	Cam Lâm	Khánh Hòa	120	55	7	352 096	418 029	2 217
Hồ Hoá Chu Phùng	Si Ma Cai	Lào Cai	120	55	7	14 274	16 947	110

Source: Long, T. 2019.

Lessons learned

Undertaking VRAs for these four agriculture sectors was a complex but important exercise. During the process, the study team and key stakeholders gained insights into key factors influencing the quality of VRAs, and identified several barriers. The following are a number of challenges, success factors, and lessons learned that were identified throughout the process of developing the assessments:

- **Access to data to assess specific indicators is key** – Access to quality data is particularly important when undertaking a risk assessment at the national level. Even moreso when the aim is to provide a sufficient level of detail to allow a validated determination of the overall vulnerability at the provincial level. A lack of synchronisation amplified by the fragmentation of data within different ministries is a severe challenge in undertaking VRAs. Viet Nam's Climate Risk platform aims to provide an effective response to this barrier in the form of a centralised open-access database for numerous sectors.
- **Ground-truthing of computed results is important** – Preparation of the VIs proved useful for targeting regions at particular risk from climate change. However through the peer-review process, it became apparent that some of the computed results needed to be verified as misleading findings can occur when solely relying on computed methods (e.g. the Mekong Delta was displayed in one model as being not highly impacted for crops, despite general knowledge that they face significant climate change-related impacts). Therefore, it was important to verify all results with key stakeholders.
- **Field research is necessary to identify suitable adaptation options** – Related to the point above, adaptation planning requires actionable information on specific risks and current adaptation behaviour that is not discernible from indices. Identifying workable adaptation options and raising awareness about climate change risk and vulnerabilities requires the involvement of local stakeholders through interviews, group discussions, and workshops. This helped to verify the information communicated by the indices and more accurately take stock of adaptation options and further prioritise through CBA.
- **Different sectors require tailored risk and vulnerability and risk assessment methodologies** – Stakeholders from different sectors have different information needs at different geographical and political levels (e.g. local or national). VRAs need to be aware of and cater to these needs and apply flexible approaches. Nevertheless, approaches to harmonise the conceptual foundations and outputs of VRA at different scales and across sectors will help to improve the comparability of findings and facilitate support from decision-makers that may not have time and resources to understand the differences in possible VRA approaches and their implications for adaptation policies and plans.

Conclusions and recommendations

The VRAs provide a solid knowledge base indicating highly vulnerable areas (and infrastructures) of Viet Nam's crops, livestock, aquaculture, and water sectors. They provide valuable information for climate change adaptation planning in the agriculture sectors, and the basis for more detailed, sub-national level analysis. The findings will inform the update and development of sectoral adaptation plans, as well as Viet Nam's NAP. The key conclusions and recommendations resulting from these assessments include:

- **Risk identification and adaptation planning is an iterative process and requires continuous updates to reflect changing conditions and priorities** – These extensive VRAs allowed the identification of areas where the agriculture sectors are particularly vulnerable to climate change. The study team recommends conducting regular and in-depth assessments of vulnerability for these prioritised sectors and/or districts. These should be monitored regularly, and the results of the assessments made publicly available.
- **Integrate insights from VRAs into adaptation planning** – The government should clarify mandates for crops, livestock production, aquaculture, and water resources to develop annual and five-year adaptation plans. These adaptation plans should be integrated into sectoral development programmes in order to mainstream climate change response strategies and ensure budget allocations to fund adaptation action.
- **Conduct VRAs at the national level for other high-priority sectors that will be identified in Viet Nam's NAP** – The government should consider developing VRAs for other sectors that are identified as being particularly vulnerable to the impacts of climate change and require specific attention in adaptation planning processes, such as forestry or tourism.
- **Use VRA findings to quantify potential Nationally Determined Contribution (NDC) targets for the agriculture sectors** – Viet Nam is in the process of updating its NDC under the Paris Agreement. The information on the feasibility, costs and benefits of different sector-specific adaptation options can be used to inform the updated NDC and to develop more robust NDC implementation plans at the sector level. The NAP-Ag Programme is using the findings of this assessment to support Viet Nam in updating its NDC and to access different sources of domestic and international finance.

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Further information

NAP-Ag

www.fao.org/in-action/naps/partner-countries/thailand
www.adaptation-undp.org/naps-agriculture/partner-countries/thailand

Guidelines:

- UNFCCC National Adaptation Plan – Technical guidelines for the national adaptation plan process (2012)
- Addressing Agriculture, Forestry and Fisheries in National Adaptation Plans – Supplementary guidelines (2017)

Thailand:

- Thailand Climate Change Master Plan 2015-2050
- Intended Nationally Determined Contribution (2015)
- National Disaster Prevention and Mitigation Plan (2015)
- Agriculture Strategic Plan on Climate Change (ASPCC) 2017-2021
- Strategic Plan on Climate Change 2008-2012
- National Adaptation Plan NAP (2018-2037)

United Nations Development Programme (UNDP)
www.adaptation-undp.org/naps-agriculture
Rohini.Kohli@undp.org

Food and Agriculture Organization of the United Nations (FAO)
www.fao.org/in-action/naps
FAO-NAPs@fao.org

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www.bmu.bund.de

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