The drought and salinity intrusion in the Mekong River Delta of Vietnam

Assessment Report

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Contents

Acronyms

ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
Bioversity	Bioversity International
CC	Climate change
CCAFS	CGIAR Research Program on Climate Change, Agriculture & Food Security
CLRRI	Cuu Long Delta Rice Research Institute
CLUES	Climate Change Affecting Land Use in the Mekong Delta: Adaptation of Rice-based Cropping Systems
CSA	Climate-smart agriculture
CSV	Climate-Smart Village
DARD	Department of Agriculture and Rural Development
DRAGON	Delta Research and Global Observation Network Institute
ENSO	El Niño Southern Oscillation
GHG	Greenhouse gas
GIS	Geographic information system
ICRAF	World Agroforestry Centre
ICT	Information and communication technologies
ILRI	International Livestock Research Institute
IRRI	International Rice Research Institute
IWMI	International Water Management Institute
MAB	Marker-assisted breeding
MARD	Ministry of Agriculture & Rural Development
MAGIC	Multi-parent advance genetic inter-crosses
MRD	Mekong River Delta
NIC	National Intelligence Council
QTLs	Drought-tolerant traits
R4D	Research for development
SEA	Southeast Asia
UNDP	United Nations Development Programme
VAAS	Vietnam Academy of Agricultural Sciences
VIFEP	Vietnam Institute of Fisheries and Economic Planning

Rationale

As an impact of the ongoing El Niño Southern Oscillation (ENSO) phenomenon, severe drought and salinity intrusion has been occurring in Mekong River Delta (MRD) of Vietnam and has caused varying degrees of damage to agriculture, fisheries and the livelihoods of people in the region. On 15 March 2016, the Vietnamese government and the United Nations Development Programme (UNDP) organized a meeting with donors, international organizations and other partners to discuss joint efforts for drought response and recovery. Another meeting was presided by the Ministry of Agriculture and Rural Development (MARD) Minister Cao Duc Phat and the UN Resident Coordinator on 30 March 2016 to report on the recent rapid assessments of current natural hazards and call for immediate, medium- and long-term support from the international community. MARD recognizes that this crisis and its subsequent effects (e.g. inundation after the drought) will recur in the future, and that there is a need to prepare and plan for necessary response measures.

In response to this urgent call, the CGIAR Centers operating in Vietnam, in collaboration with MARD, organized a joint field assessment in the MRD to have a first-hand observation and assessment of the effects of the drought and salinity intrusion currently experienced by the region. The CGIAR interventions recommended based on the assessment may support the short-, medium- and long-term planning in response to the impacts of climate change. The strength that the CGIAR could contribute is in downscaling some of the global data and analyses to Vietnam scenarios and forecasts for their planning, recommending climate-smart agriculture (CSA) options for integration in current and future donor/development interventions, and identifying opportunities in research for development (R4D) for future preparedness.

Objectives

The assessment and evaluation activity aimed to achieve the following objectives:

1. Conduct a first-hand observation and assessment of the degree and extent of the drought and salinity intrusion crisis in the MRD;
2. Provide location-specific and integrated recommendations to the current problems in the region that will improve the preparedness and coping capacity of the affected areas;
3. Identify possible CSA options for incorporation in current and future donor/development interventions; and
4. Identify R4D actions of CGIAR centers in the region.

Expected Outputs

An assessment report enumerating possible CGIAR contributions to the development of integrated responses to the drought crisis (short-, medium-, to long-term), CSA options for integration in ongoing and future interventions, and follow-up joint actions of the CGIAR.

Background of the Mekong River Delta

General Information

The MRD covers an area of about 39,000 km^2 and roughly forms a triangle west of Ho Chi Minh City (Saigon). It stretches from My Tho City in the east, Chau Doc City and the town of Ha Tien in the northwest, and Ca Mau province at the southernmost tip of Vietnam, including Phu Quoc island (Figure 1).

Figure 1. The 3 provinces visited by the assessment team in the Mekong River Delta, Vietnam.

The MRD is an agro-ecological region covering 13 provinces in the south of Vietnam. The formation history of the MRD links to changes in sea level and hydrology of the Mekong River. In the Holocene, the coastline was close to Phnom Penh, Cambodia, however since 7,000 years ago, the delta started expanding southeastwards due to the alluvial deposition from the Mekong River. At present, the MRD has a flat terrain with an average elevation of less than 1 masl (meter above sea level) (ADB, 2012).

With a total population of 17.5 million people (about 19% of the national population), the MRD is home to the Kinh, Khmer, Hoa and Cham ethnic groups (GSO, 2014). Kinh is the dominant ethnic group (90%), followed by Khmer (6%), Hoa (2%) and Cham (2%). In comparison to other regions of Vietnam, the population growth rate of the MDR is relatively low, between 0.3% and 0.5%, for which the main reason is out-migration.

Agriculture, Fishery and Forestry

The total area of agricultural land in the MRD is 2.6 million hectares. With this land resource, the region produces about 50% of the total amount of food in Vietnam and ensures food security and livelihoods for approximately 70% of the region's population. Agricultural products of the MRD are also exported to the international market. Thus the development of agriculture sector of MRD directly correlates with poverty reduction.

The main agricultural products of the MRD are rice, fruits, fish and shrimp. It contributes 30% of the agricultural production value, 57% of total rice production and 41% of aquaculture production of the whole country (GSO, 2010). More than 2 million ha of agricultural land are dedicated to rice production. There are only 150,000 ha of cash crops (vegetables, soybean, maize, sugar cane, etc.) and 320,000 ha of perennial crops (durian, coconut, mango, longan, etc.).

Agricultural land of the MRD can be segmented into sub-regions with distinct characteristics: (a) the eastern part (from the Tien River toward Ho Chi Minh City), which has low agriculture potential due to its acid sulfate soils; (b) the central part (between the Tien River and the Hau River), which is the horticultural production area; and (c) the western part, which is the area for rice and aquaculture production. The western sub-region is also often affected by salinity intrusion.

Ninety percent Vietnam's exported rice comes from the MRD, which has helped Vietnam become the world's second largest rice exporter. In 2014, the rice production of the region was 24.5 million tons (55% of national value). The provinces with the largest rice area are An Giang, Kien Giang and Dong Thap provinces. These provinces yield almost 50% of the MRD rice production.

Among the three provinces that were assessed, Kien Giang, which is situated in the northwest of the MRD, has the largest total agricultural land and the biggest portion of paddy fields (377,370 ha). Ben Tre province, which has a relatively flat terrain, has a total of 97,710 ha of paddy fields, while Tra Vinh has 38,120 ha (General Statistics Office of Vietnam, 2012).

The table below shows a summary of crops planted in the three provinces of Ben Tre, Tra Vinh, and Kien Giang, which were selected for the assessment.

Table 1. The area and production of major crops planted in the three provinces (Ben Tre, Tra Vinh and Kien Giang) covered in the assessment in 2014. (Units: Area - 1000 ha; Production - 1000 tons)

Items	Province					
	Ben Tre		Tra Vinh		Kien Giang	
	Area	Production	Area	Production	Area	Production
Annual planted crops	70.8		252.4		759.5	
Annual food crops	67.3	321.6	241.2	1,356.60	753.7	4,523.20
1. Paddy rice	66.6	318.9	235.8	1,326.90	753.6	4,522.50
1st Rice season (Winter-spring rice/December-March)	18.1	105	66.4	446.2	305.9	2,207.60
2nd Rice season (Summer-Autumn rice/April-July)	19.3	82.5	80.2	407	385.3	2,034.60
3rd Rice season (vụ Mùa - lúa vụ 3/August-November)	29.2	131.4	89.2	473.7	62.4	280.3
2. Maize	0.7	2.7	5.4	29.7	0.1	0.7
3. Root crops and tubers						
Sweetpotato	0.1	1.3	1.5	24.7	1.1	29
Cassava					0.7	0.7
4. Annual industrial crops	3.5		11.2		5.8	
Sugarcane	3.5	279.3	6.6	715.8	5.8	395.3
Groundnut			4.6	23.5		

Source: Department of Planning, MARD, 2014

The environment zones along the MRD favor the expansion of fishing and aquaculture of the three provinces. The MRD also contributes a large share to the fishing and aquaculture production of Vietnam. Nearly 50% of offshore fishing production comes from the region, mostly in Kien Giang, Ben Tre, Ca Mau, Tien Giang and Bac Lieu. Fishery and aquaculture production of the region grew rapidly from 1.84 million tons in 2005 to 3.168 million tons in 2015 (USTH, 2016). Vietnam's largest fishery producers are in Kien Giang, Ca Mau, Dong Thap, An Giang, and Ben Tre, and about two-thirds of the region’s fishery production (2.485 million tons) comes from aquaculture. In 2012, Ben Tre province produced 226,928 tons of aquaculture products, while Kien Giang province produces more than 450,000 tons of seafood per year.

The MRD has only 300,000 ha of forest (7.7% of the total area) (GSO, 2011). The provinces with largest forests are Ca Mau and Kien Giang, which accounts for two-thirds of the region's forest area. Forests cover less than 5% of the area of all of the other eleven provinces and cities.

Water Management

The construction of dikes and sluices for rice intensification was significant to the economic development of Vietnam, particularly in the MRD. Before 1975, the irrigation systems were not yet developed, and rice cultivation was strongly affected by salinity intrusion. The only traditional rice crop per year during the rainy season (June to late November) had an average yield of about 2 tons/ha. Between 1975 and 1980, primary canals and some dams were built. Consequently, areas affected by salt water intrusion were reduced and farmers started to cultivate a second rice crop using high-yielding varieties.

From 1980 to 1995, the irrigation infrastructure was further developed through dyke developments, as the government aimed for food security and livelihood improvement. In the Mekong delta, many dyke systems were developed with new secondary and tertiary canals to control floods in the upper areas and salinity intrusion in the coastal regions. The improved system provided freshwater to a larger agricultural area, and increased the area of double rice cropping. Rice yields also increased from 2.0 to 3.5 tons per hectare during that period.

From 1996 to present, a number of projects on flood and salinity controls have been implemented. These interventions have created suitable conditions for intensifying and diversifying agricultural production. Irrigated areas in the Mekong River Delta cropland rapidly increased from 52% in 1990 to 91% in 2002. As a result, average rice yields increased from 3.5 tons per hectare in 1995 to 4.5 tons per hectare in 2010, and the area of double and triple rice cropping expanded. Besides rice, upland crops and fruit trees are also now planted widely (Ut and Kajisa, 2006). Improvement of water management in the MRD led to significant increase of rice production, from 6.3 million in 1985 to 22 million tons in 2015.

The Water Resource Master Plan developed in 1999 had been recently updated to address climate change issues, especially sea level rise. Accordingly, high ring dikes will be built to protect urban and intensive agriculture areas, including the northern part of the Mekong Delta, the Plain of Reeds, the south of the Nguyen Van Tiep canal and the areas between the Tien and Hau Rivers. The dikes will also partly protect the areas from early floods at the end of August.

Climate Change Issues

The effects of climate change are now substantially manifested in the MDR, through sea level rise in low lying areas at the mouth of the delta, increased rainfall, increased number of extreme weather events, rising average temperatures and increased salinity intrusion. The sea level around the Mekong River Delta has also risen by 20 cm since 1901. Data from the Vung Tau monitoring station indicates an average sea level rise of 3 mm per year over the last 30 years. This finding is concerning, given the low elevation of the Mekong Delta.

In addition to sea level rise, rainfall has increased by as high as 177% during winter in Soc Trang, and a 30% annual increase has also been observed. The timing of annual rainfall in the Mekong River Delta has shifted as well. The Delta Research and Global Observation Network (DRAGON) Institute at Can Tho University stated that rainfall has increased at the end of the rainy season but decreased at the beginning of the rainy season over the last 10 years. Shifting rainfall patterns such as these can have an adverse effect on the agricultural productivity of the Mekong Delta.

The number of typhoons and tropical depressions has continually been increasing from seven to eight per year. Damages by storms and floods have increased in parts due to increasing population and settlements in vulnerable areas. Though preventive measures have been taken, losses and damages from disasters are still severe and increasing. In the last 10 years alone, natural disasters have cost Vietnam around 800 lives and 1.5% of GDP each year (Padilla, 2011).

Average temperatures in the Mekong River Delta have increased in recent years as well. Records of the Institute for Meteorology, Hydrology and Environment (IMHEN) show an average temperature rise of 0.5^{o}C for 1955-2005 across Vietnam. Can Tho City and the DRAGON Institute have reported an average temperature increase of 0.5^{o}C for Can Tho over the last 30 years.

Salinity intrusion, which resulted from rising sea levels, has also increased in the MRD. According to the 2009 Mekong River Delta Climate Change Forum Report, saline intrusion is reaching further inland and affecting wider areas of the region. For example in Dai Ngai, salinity levels reached a maximum of 8.6% during 1980-1989 and continually rose to 13.1% from 2000-2009. Indeed, “as sea levels rise and storm surges increase, salt water intrusion is a growing risk to agricultural production, hastened by upstream damming and mangrove decline” (Padilla, 2011). Salinity intrusion is also caused by the construction of dams further upstream on the Mekong River and dams on the lower Mekong River, which reduce water flow and prevent the renewal of the delta silt deposits.

Impacts of El Niño

El Niño (ENSO) is a phenomenon consisting of changing ocean temperatures in the equatorial Pacific. The warmer waters essentially slosh, or oscillate, back and forth across the Pacific similar to water in a bath tub (NCSU, 2016). El Niño is considered as one of the main drivers of extreme climate variations, including changes in the space-time patterns of floods, droughts, cyclone/severe storms activity, cold/hot spells etc (Subiah & Kishore, 2005).

In the Mekong Delta, experts found that the hydrological dynamics of the Mekong River, especially the hydrological processes in the southern and central part of the basin, were significantly influenced by El Niño events (Nauditt). Scientists from the National Center for Hydro-Meteorological Forecasting expect the 2014-2016 El Niño to be as serious as the 1997-1998 one, as it could be one of the longest warming events ever. The center has also anticipated a high possibility of an end to the El Niño, and they anticipate that the El Niño will bounce back to a neutral state during June–July 2016.

According to recent data (DWRM, 2016a), the water discharge in upstream of Mekong river declined by $900m^3/s$. Meanwhile, water levels in middle and downstream of Mekong River increased by 0.1 – 1.5m due to tidal rise. Salinity intrusion led to increased salinity of water in rivers and irrigation canals. Salinity (4g/l) expanded through Tien and Hau Rivers by up to 45-65km and 55-60km, respectively. The drought has thus resulted in the decrease of groundwater levels and the most extensive salinity intrusion in last 90 years. (DWRM, 2016b).

Elicited by the El Niño, the drought has resulted in effects, such as reduced agricultural production, which limit the livelihoods and aggravates food insecurity in poor and vulnerable communities (Nguyen, 2016). The severe drought and salinity intrusion strongly affected 11 of the 13 provinces in the MRD. Some 400,000 ha of cropland have been affected, of which 25,900 ha were left fallow. Rice areas affected by drought and salinity intrusion rapidly increased from 139,000 ha in mid-March 2016 to 224,552 ha by mid-April 2016. The MARD report updated on 15 April 2016 showed 208,394 households lacked freshwater for domestic use. Water shortage and salinity intrusion have also affected 13,000 ha of cash crops, 25,500 ha of fruit trees and 14,400 ha of aquaculture. Other major challenges include increases in climate-related diseases and decreases in food supply, especially for the children and women.

Methodology

Site Selection

The sites visited by the assessment team were selected based on the scope and level of damage on agricultural and fisheries production as reported by MARD and the provinces in the MRD. Initially, the three provinces (Ben Tre, Tra Vinh and Kien Giang) in the target region were identified as most affected by drought. Land use maps from 2010 were then used as references to identify the most affected areas and districts in each of the three provinces. The two districts in each province that had the largest area of affected agricultural products were then selected for on-site assessment. The itinerary and program of the assessment team are listed in Appendix 2.

The Assessment Team

The CGIAR team was composed of experts in rice crop management and climate change research (IRRI), tree-integration/agroforestry (ICRAF), agrobiodiversity (Bioversity), aquaculture and agricultural economics (WorldFish & VIFEP), water management (IWMI) and local experts on rice production (IAS-VAAS). The members of the team are listed in Appendix 3.

Information Collection Methods

Following a review of literature, the assessment collected information from field observations, key informant interviews with the leaders/official of the provincial/district levels of the Department of Agriculture and Rural Development, the provincial level of the Department of Water Resources and its line department, face-to-face interviews with households and leaders /officials of the Commune People’s Committees.

Key guide questions asked during the field visits

1. How extensive is the drought and salinity intrusion in the affected provinces?
2. What are the most widely observed indicators of drought and saline intrusion in the locality? How long have these been observed?
3. Which agricultural products (e.g. crops, livestock) are most affected? Who are most vulnerable?
4. What is the possible relation between intensity and incidence of drought and saline intrusion and the bio-physio characteristics of the province?

5. Are there existing techniques/practices being applied by farmers and/or local organizations to cope with drought and salinity intrusion?
6. What has been the effect of the practice/technique?
7. What are the potential areas/ entry points where drought and saline intrusion could be effectively addressed in the locality? What would be required to make this happen?
8. What action plans do farmers/local authorities intend to implement to cope with drought and saline intrusion in the future? What support/contribution will be needed from other stakeholders (e.g. government, private sector, research community)?
9. Are the local authorities/its department aware of the La Niña forecast towards the end of this year?
10. Have the local authorities prepared an action plan to cope with flooding due to La Niña?

Limitations of the assessment

The assessment team only visited the locations identified prior to the visit as most affected by the drought and salinity intrusion, and relied on secondary data, the results of key informant discussions, and the knowledge about the region of the participating experts. The assessment team did not conduct a detailed collection of data (e.g. household survey questionnaire) that can be used for in-depth analysis. The recommendations focused on the possible climate smart agricultural practices and technologies that are suitable and feasible in the region.

Key Observations and Findings

The key observations of the assessment team listed below are the basis for the subsequent recommendations. For a deeper understanding of these key observations, please refer to the detailed daily highlights of the field assessment in Appendix 1.

Salinity Intrusion

- Salinity intrusion is associated with low water discharge from upstream of the Mekong River. This is caused by the below average rainfall in the Mekong basin due to the El Niño. With insufficient upstream water flow to push back seawater, salinity intrusion increased in concentration and duration this year. It was also aggravated by the drought and high temperature in the region.
- Farmers and local officials did not experience this level of severity of drought and salinity intrusion before; as a result both farmers and officials underestimated the serious impacts of climate change and did not prepare well for coping/adapting aquaculture and agriculture crops to climate change impacts. The factors that cause damages in crops and aquaculture are shown in Fig. 2.
- Normally, the salinity level in the Mekong river system will start to rise by the end of December, reach its peak in March or April and decline afterwards. However this year, salinity increase peaked two months earlier, intruded further inland and remained longer during the dry season.
- In February 2016, the salinity intrusion reached beyond the dykes for the first time. Despite warnings, both local officials and farmers underestimated the risks. This is because the profit to be obtained encouraged farmers to keep planting even in high risk areas with increased threats of drought and salinity-related problems.
- Leakage problems and sluice gate operation issues also contributed to increased salinity in the canal systems. Farmers were already warned that the 2015-2016 salinty intrusion will come earlier than usual. However, at the beginning of the dry season in December 2015, when salinity concentrations increased in a short span of time, the sluice gates were not immediately closed.

Rice Production

- Vast tracks of land planted with rice were affected by salinity intrusion and drought at the reproductive stage. Yields were reduced by 50-100%, or total loss.

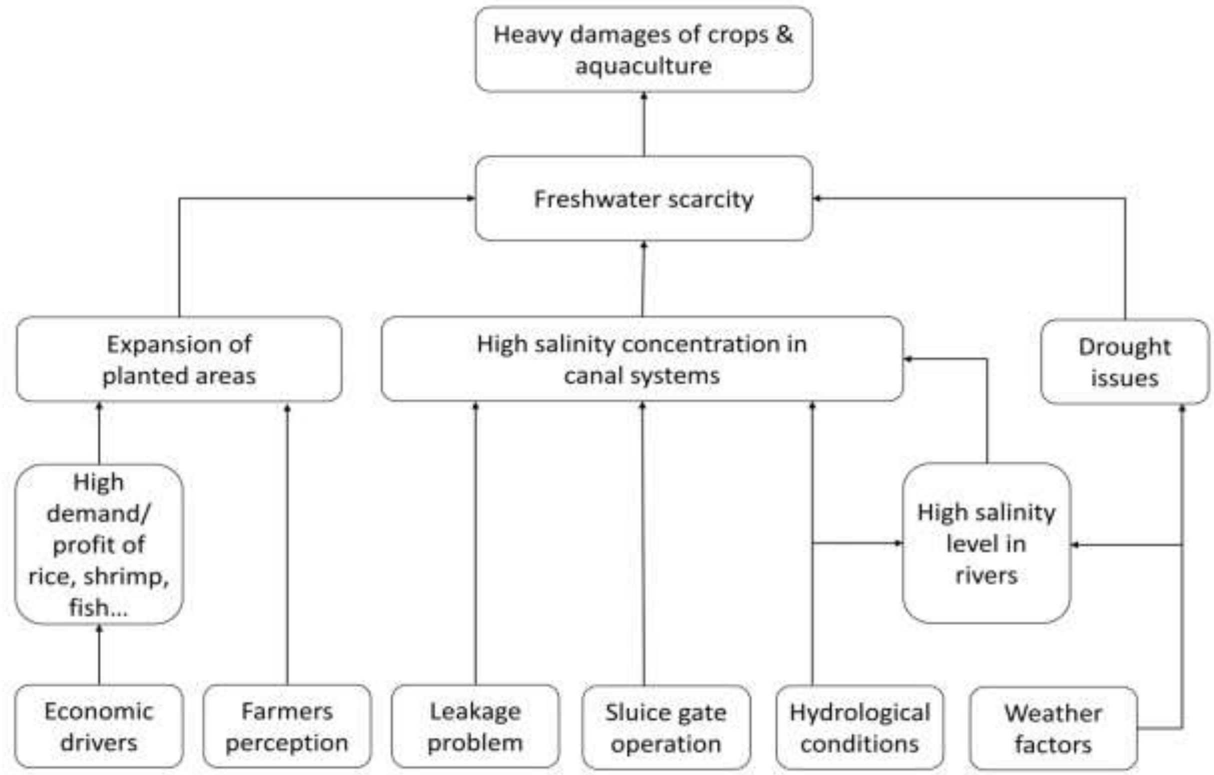

Figure 2: Causal diagram of serious damages of affected rice areas by salinity related problems in the 2011 dry season in Tra Vinh province (Nguyen Thanh Binh, 2015)

- Most of the salinity intrusion occurred during the late vegetative or early reproductive periods of the rice crop (February and March). This rendered salinity-tolerant varieties ineffective, as their tolerance to salinity is only during the seedling/vegetative stage. Farmers who irrigated their fields with saline water suffered “burnt” fields, and those that did not suffered from drought.
- Farmers’ knowledge and adoption of salinity- and drought-tolerant rice varieties is also limited, as these have seedling stage tolerance and are appropriate for the spring-summer cropping. The rural extension networks in many places were also not aware of such varieties.
- Farmers who almost lost their complete crop were still optimistic, as they were at least able to harvest the straw. Developing markets for by-products could be one option to reduce vulnerability of the farmers.

Aquaculture

- Aquaculture operations in the Mekong Delta provinces experienced different levels and scales of climate change impacts and losses. Aquaculture farming areas, such as oyster farming and extensive shrimp farming, which depend on natural water movements, experienced greater impacts. In addition, these aquaculture operations are associated with poor and small-scale/vulnerable farmers with lower financial and technical capabilities. Rich farmers who operate intensive farming systems were less likely to experience negative impacts and were able to harvest part of their crop.

- With climate change impacts, especially sea level rise and salinity intrusion, the water quality of current brackish water farming areas might decline. Salinity might increase too, which would reduce shrimp growth rates, increase pond construction costs and cause other negative effects. Some agricultural areas will experience permanent salinity intrusion and farmers would likely diversify their crops by growing shrimp cultures in the dry season. As observed in rice-shrimp culture areas in An Khanh Dong, An Minh, Kien Giang province, this adaptation options can still be negatively affected if the severity of the salinity increases beyond the tolerance limits of the farmed crops and species.

- Rice-shrimp areas were badly hit, with the high salinity mostly affecting the shrimp crop. On average, each rice-shrimp farming household lost 15-30 million VND. The amount lost may be small compared to capitals of intensive farming, which are estimated at 400 million VND/ha. However these losses are critical to small-scale and poor farmers. One farmer cried, she could not identify future options for continuing her household farms, as both her rice and shrimp crops lost in 2015/2016.

Mixed farming systems

- Most of the farming systems visited were monocultures. Some of the practices in diversifying farming systems included horticulture, annual and perennial trees combined with livestock. These however depend on a stable supply of water for irrigation. The most common species grown on saline and acid sulfate soils were coconut and pineapple. Some farmers have shifted from rice farming to coconut/fruit tree farming and growing fodder grasses.
- Farmers also had a local variety of salinity-tolerant soursop (*Annona glabra*) that could have higher-yielding varieties grafted onto it. This illustrates the potential for systematically identifying local stress-tolerant varieties.
- Other trees and crops that are salinity- or drought-tolerant included mango, citrus, banana, sugarcane, and papaya, which are planted on the banks of canals or on raised bed systems (ditch system). These crops also grow well on salty acid sulfate soil.
- Some trees observed that are known to be:
    - drought-tolerant: mango;
    - salt-tolerant (moderately tolerant): coconut, papaya, tamarind, guava, guinea grass, nipa palm, jackfruit, mangrove, eucalyptus;

- flood-tolerant: guava, coconut, *Melaleuca cajuputi;*
- acid sulfate soil: *Melaleuca leucadendra* ;
- rather sensitive species : banana ;
- conflicting opinions on sensitivity : longan, sugar cane (said to be salinity-tolerant during trip, but sensitive according to literature); and
- moderately sensitive to salt (according to literature): tomato, sugar cane, maize.

Early Warning Systems

- The capacity of Vietnamese agencies to provide accurate information for drought and salinity forecasting and early warning systems is limited. This is aggravated by poor mechanisms for coordination, sharing of data and standardization of collected data among relevant ministries, line departments, local authorities, farmers and water users. For example, different teams from provincial departments are doing the roving monitoring of water quality in the provinces, but data from these teams could not combined with salinity monitoring at commune levels because of problems in coordination and inconsistence in monitoring methods.

- The distribution of updated information on salinity levels is slow. It takes a long time until salinity measurements reach the farmers. Collected information has to first be elevated to and approved by high-level decision makers before it is distributed to the local level. Thus, farmers get outdated information on salinity. It would be beneficial if the process would be smoother and the information flow more direct without passing many entities.

- Despite warnings last October/November 2015, farmers and local authorities did not anticipate high level of salinity. Thus, they were unable to deal with the situation. Farmers continued planting rice and rearing shrimp. They also irrigated their areas with brackish water/saltwater, which was considered better than having no water at all.

- Warnings of an exceptionally dry season and likely salinity problems were announced to the farmers early on, mostly before farmers started sowing. However, alternative planting practices were lacking and farmers are only eligible for subsidies if they plant rice. Therefore, many farmers planted rice even though they know that it was risky. Hence, the competition for scarce water increased and resources, like seeds and fertilizer, were wasted.

Water management

- Ground-water for sprinkler irrigation without schedule is unsustainable. Salinization reduces the amount of freshwater in many areas and the prolonged drought results in the exhaustion of underground water sources. In many areas, farmers have to drill wells up to 90-100m in depth to get freshwater.

- Salinity has not only affected farming but also the daily life activities of local people. The water is too salty for domestic activities. This situation has rarely/never been encountered in these areas before.

- Farmers in a village in Kien Giang province organized meetings with an extension worker and formed self-help groups, where they could ask questions and seek advice for avoiding large damages. Communal officers also measured salinity levels of water.

- The presence of acid sulfate soils complicates water management in salinity-affected areas. In these areas, saline water is detrimental to the plants, but a dried-up field can also result in acid toxicity by capillary action to the surface, which could then affect the next cropping.

- Some of the advice technicians provided to farmers in the affected areas may not be suitable. For example, immediate plowing of fields after the crops are harvested is recommended to cut down the capillary rise of acid toxicity in acid sulfate soils in Kien Giang. However, burning the stubbles may be better, because evaporation from plowed fields is very high, especially in April (roughly 4 mm/day). This can convey the toxicities in acid sulfate soils more quickly. Burning, however, has environmental implications and contributes to greenhouse gas (GHG) emissions.

Policies

- Inconsistencies were observed in subsidy policies being implemented. During the winter-spring season, farmers were recommended to reduce their planted areas to avoid losses. However, subsidies were only provided to farmers who had planted rice regardless of the warnings. The farmers who followed the recommendations did not receive any subsidy and/or support.

- The role of entrepreneurs in supporting farmers in aquaculture and rice production in the salinity- and drought-affected areas is not clear, even though assistance and collaboration of rural creditors and traders is needed during crises like this.

Recommendations

Addressing the drought and salinity intrusion challenges in the MRD requires integrated and holistic planning of hardware (infrastructure) and software (management, practices and technology) interventions. Rice and aquaculture production is expected to continue as a livelihood option for the people in MRD, even in high risk areas. It is thus important to consider suitable management measures and research and development interventions that can help cope with current and foreseen challenges. CGIAR Centers are ready to work closely with MARD and other research and development organizations to improve existing, and formulate new short-, medium- and long-term response options. Based from the assessment that was conducted by the team and the earlier recommendations from IRRI (Appendix 4), the following recommendations are offered.

Salinity Intrusion

Severe salinity intrusion in the MRD at end of Dong Xuan season (i.e. salinity intrusion in February) is predictable in a way, thus allowing for preparations to be carried out at the start of the season. El Niño forecasts and advisories given several months ahead can be used to predict risks of salinity intrusion in the MRD. These are also powerful tools for planning/management purposes.

Historically, severe salinity intrusions have occurred in the years with strong El Niño, such as in 1998 (after 1997 El Niño) and 2010 (after 2009 El Niño). Salinity intrusion is more serious during drought when freshwater shortage occurs in all places, and not only in the coastal provinces experiencing salinity intrusion. During such periods, regional integration and coordination for water sharing should be instituted rather than just encouraging people, particularly those in upper parts of the MRD closer to freshwater sources, to store as much freshwater as they can for their farm and household use. This is because increased access and storage of freshwater can cause deeper and more serious salinity intrusion in the coastal provinces.

Early Warning Systems

Due to increasing uncertainties and complexities exacerbated by climate change and other factors, no agency can guarantee accurate information for drought and salinity forecasting. Nonetheless, the development of an improved climate monitoring and early warning system should be prioritized to help mitigate negative impacts induced by climate change in the Mekong Delta. Improved early warning systems can disseminate forecasts and early warning messages to local communities and farmers. These can also be used to disseminate technical advisories for drought and salinity preparedness, and recommended adaptation measures (e.g. cut-off dates for rice transplanting/sowing or rearing shrimp, suitable drought and saline-tolerant varieties, appropriate farming techniques and practices).

In enhancing the efficiency of existing monitoring and warning system, it is important to improve coordination and collaboration (data sharing, standardization of protocols and downscaling of information) among relevant ministries, line departments, local authorities, farmers and water users. Furthermore, building the capacity of local technical advisory groups at the provincial and district levels in analyzing and interpreting outputs of the monitoring and warning systems and developing technical advisories and recommendations for farmers is needed.

In addition, advanced modeling and GIS techniques should be used in developing high spatial and temporal resolution maps of areas at risk for salinity and drought. These will be used at the commune, district and province levels. The quality and resolution of these downscaled–risk maps can be continually validated and improved over time by provincial and district DARD.

Delivering accurate timely updates on salinity levels in different districts is another important consideration. Processes to deliver this information must be fast and smooth. Reduced bureaucracy and fewer institutions involved in the process would allow for more direct information flow. Modern information and communication technologies (ICTs) such as cellphones can improve the speed of information delivery. Extracting lessons learned from the Salinity Advisory as a Location-specific Timely Service for Rice farmers (SALTS) project funded by BMZ and implemented by IRRI and Can Tho University could be useful in identifying successful approaches.

The specific recommendations are the following:

Short-Term Interventions:

1. *Downscale available hydrological modeling and geographic information system (GIS) analyses, which identify high salinity-risk and drought and flood prone areas, into risk maps that the commune, district and province can use to provide early warnings for farmers.* The risk maps should indicate low, medium, and high risk areas. The Department of Agriculture and Rural Development (DARD) can continually validate the map and improve the quality and resolution over time.
2. *Enhance environmental monitoring and early warning systems to provide available information and knowledge timelines.* These would help local authorities to actively formulate local action plans for responding to the impacts of salinity intrusion and drought. This

includes integrating and standardizing the different salinity monitoring activities from commune, district and provincial levels to provide more consistent information to the farmers.

3. *Improve awareness and compliance of local farmers on climate/water monitoring and early warning systems*. Many local farmers do not follow warnings and instructions of local authorities based on rice cultivation calendars, climate and weather forecasts. This requires building mutual trust between farmers, local officers and researchers, providing consistent agro-advisories and supporting policies, and integrating local knowledge in response scenarios to seasonal weather forecasts (including drought and flood situations)..
4. *Join the Monsoon Forum*. Vietnam though MONRE can join Monsoon Forum managed by RIMES for training and access to and sharing of early warning/seasonal forecast. This can be a tool to improve water management coordination between provinces, as well as connecting with upstream Cambodia which also takes part in the Monsoon Forums.

Medium- and Long-Term Interventions

1. *Implement real-time, location-specific salinity monitoring and advisory systems for farmers and local authorities through the use of ICTs/mobile phones*. The SALTS project of IRRI and Can Tho University could provide lessons learned on such processes. Establishing a real-time monitoring system for soil and water salinity throughout the season will help identify periods of high salt intrusion and also guide farmers in making irrigation management decisions. This will reduce the risk of crop losses from use of saline irrigation water, as high salinity can destroy the rice crop.
2. *Map high-risk areas in high spatial and temporal resolutions with advanced modeling and GIS techniques*. Dissemination of response strategies can thus be planned in a much more targeted way than previously possible. These techniques can be supplemented by an early-warning system derived from the salinity monitoring network and mobile phone applications (e.g. SALTS project of IRRI). Collectively, these various approaches from recent and ongoing IRRI projects will allow for well-planned response strategies over different time horizons.

The Salinity Advisory as a Location-specific Timely Service for rice farmers (SALTS) project

Existing national, regional and provincial salinity information systems are effective for managing irrigation infrastructure to access both saline and fresh water at the macro level. However information is insufficient to warn rice growers in time when water management infrastructure fails or is unable to protect their fields. If farmers measure and disseminate information about salinity variability in their immediate environment in cooperation with local authorities, communities can make collective decisions and put strategies in place to minimize the risks of salinity intrusion in their rice fields. This is the rationale of the SALTS project led by IRRI.

The project is developing in cooperation with DARD officials a real-time salinity monitoring and advisory service in selected salinity-affected communes in Bac Lieu and Hau Giang provinces. IRRI is currently testing a modern communication platform using mobile phones linked to a web application. The software is capable of collecting salinity and water level measurements in tertiary canals and inlets into farmer fields with a cheap device worth 2 USD. It can also send location-specific warnings and crop management advisories through SMS and voice messages to commune authorities, rice farmers and rice-shrimp producers. The first version of the application can be accessed through a public website address to DARD water management and plant protection units. This IRRI communication platform can handle thousands of measurements per day and send the same number of messages to prevent heavy production and income losses. The IRRI communication application can be a main channel as well for the dissemination of information on modern salinity-tolerant rice varieties to farmers.

Rice Production

Although official warnings of expected salinity and drought problems during the Dong Xuan season generally reach farmers early, these warnings did not translate into adjusted agricultural production on a large scale. Warnings have been ignored, either because the expected severity wasn't communicated strongly enough or because of a lack of alternatives greater than the production subsidy given to farmers. The current subsidy system might have even increased the problem in some areas, as more farmers planted rice and increased competition for already scarce water resources.

High salinity during the late stage of rice growth (around maturity) was also a major problem during the 2016 salinity crisis. Early cut-off dates for harvesting rice can help avoid stretching the crop into periods of high salinity by late March and April. Suitable short-duration varieties for the adjusted growth window thus need to be identified and promoted. Additional investments should be made to further improve those varieties, and to improve late-stage salinity tolerance.

IRRI and the Cuu Long Delta Rice Research Institute (CLRRI) have a good working collaboration on this aspect.

The current salinity crisis has shown that a regional water management approach is crucial for minimizing damage to rice production. This includes better coordination and communication of measures across different provinces of the MRD, as well as strengthening cooperation with other riparian states of the Mekong River. Hydraulic modeling is a powerful tool to assess implications of interventions on a basin level and to assist land use planning under different scenarios (e.g. the impacts of switching from three rice crops per year back to two in some areas). The Southern Institute for Water Resource Planning and IRRI have developed salinity maps under different scenarios for the MRD that can be refined and improved by adding more details.

In the long term, all popular varieties planted in the MRD should carry multiples tolerances to abiotic stresses (i.e. salinity, drought and heat stress) and fit for the new cropping system. A forward-looking breeding program should be designed for the development of new 'designer' varieties that fit the new cropping systems and carry the package of traits required for climate resilience, such as combining tolerance to current and foreseen abiotic stresses like salinity, drought and heat stress. It should be noted that these recommendations are considered in the new rice master plan recently approved by the MARD Minister as part of the Prime Minister's decision (Decision No. 899/QD-TTg dated 10 June 2013) to restructure Vietnam's agricultural sector.

The specific recommendations are the following:

Short-Term Interventions

1. *Fast track the evaluation and deployment of locally developed salinity-, drought- and flood-tolerant varieties, and evaluate varieties developed for similar conditions in other countries for immediate release and use in affected areas*. Seed multiplication should be expedited for best performing materials to ensure rigorous evaluation and to support subsequent commercialization. CLRRI and Can Tho University have already developed local varieties that can meet the requirements of the southern Vietnam. Furthermore, IRRI can provide elite materials tolerant to salinity, submergence, stagnant flooding, drought and varieties with dual tolerance. IRRI has developed 12 lines with salinity- and submergence-tolerance and six lines with drought- and submergence-tolerance. It will be critical to speed up production and distribution of a sufficient amount of seed of these elite materials through local seed multiplication chains. MAGIC (multi-parent advance genetic inter-crosses) populations recently developed at IRRI could be used as

another source of elite material that could be evaluated in affected areas. These lines have multiple abiotic and biotic stress tolerances with high yield and good grain quality.

2. *Determine the cut-off date for Dong Xuan season (i.e. the latest date of harvest of Dong Xuan) to avoid late season salinity*. Vietnam has successfully implemented the cut-off date to avoid flooding/submergence in flood prone areas (An Giang, Dong Thap), and a similar approach should be applied to saline areas.

Medium- and Long-Term Interventions

1. *Identify which areas would benefit from a re-design of cropping systems*. With the cut-off date imposed for Dong Xuan, it may be more appropriate for some areas to have two crops of medium duration each year than having three short duration crops/year. It may be important to re-design the cropping systems to avoid risks of salinity without compromising total annual rice production.
2. *Design new varieties based on the identified cut-off dates*. A more comprehensive program is needed to assess current land-use plans and zoning, and adjustments must be made to minimize the impact of worsening environmental conditions. New cropping systems could allow for appropriate changes in the cropping patterns (e.g. switching from three crops of rice in some areas to only two, or introducing non-rice crops of good market value to enhance farmers' income). Redesigning cropping systems is necessary to avoid risks associated with salinity without compromising total annual rice production and farmers' income.
3. *Fast-track the development and delivery of good-quality short-duration rice varieties that have enhanced salt- and drought-tolerance to particular areas*. IRRI has identified some major drought-tolerant traits (QTLs) for both early- and late-stage salinity-tolerance. Combining salinity-tolerance traits in short-duration varieties will have a dual value of protection against mild stress in early stages and severe stress at later stages. This can be done through marker-assisted breeding (MAB) methods that have been used by Vietnamese and IRRI scientists in recent collaborative projects (e.g. Climate Change Affecting Land Use in the Mekong Delta: Adaptation of Rice-based Cropping Systems or CLUES project funded by the Australian Centre for International Agricultural Research or ACIAR, and DANIDA). A program that builds on this progress and capitalizing on the expertise of IRRI and of local institutions can speed up the development and deployment of these varieties within five years. Vietnam has also experienced severe drought events, in addition to problems with salinity, in the past. Introgression of QTLs into short-duration varieties should also be aimed for and combined with salinity-tolerance. This will result in more resilient varieties that will protect farmers during disastrous incidences and environmental stresses.

4. *Design a forward-looking breeding program for the development of new 'designer' varieties that fit the new cropping systems and carry the package of traits required for climate resilience.* These varieties should have optimum maturing periods (duration) based on available windows of opportunities and should also combine tolerance of current and foreseen abiotic stresses, such as salinity, drought, and heat stress.

Aquaculture

With increasing severity and intensity of climate change effects, such sea level rise and increasing droughts and temperatures, aquaculture/fisheries can be negatively affected by climate change. Poor and vulnerable farmers, especially women, are likely to experience more severe impacts. As observed during the rapid assessment, a multiple/integrated cropping strategy can be a promising adaptation option for farmers to reduce risks associated with climate change.

For aquaculture farming areas, which experience increasing climate change (e.g. sea level rise and increasing saline water intrusion), alternative species/cropping methods should be explored. For salinity-affected agricultural areas, farmers could autonomously consider aquaculture integration as an adaptation option for diversifying their farming crops and reducing risks. However the rapid assessment also revealed that converting rice monoculture farming areas into to integrated systems, such as rice-fish or rice-shrimp aquaculture, should be carefully evaluated because this may actually be more disadvantageous to the livelihoods of the farmers and the ecosystem of the area. Land conversion should follow local zoning plans and approved by concerned local authorities. In aquaculture areas prone to climate change impacts, water environmental monitoring should be more carefully and frequently enforced to improve system resilience for both stocking and growing-out stages.

For long-term adaptation, economic incentives should be further considered by different stakeholders within the seafood value chains. Seafood processing companies, aquaculture cooperatives and input suppliers should play a core role in providing production direction for small-scale farmers. Better risk management strategies to cope with increasing negative climate change impacts should also be enhanced for small-scale producers with active support from local authorities and extension centers. Crop diversification and home gardens, which can provide additional household income and savings for small scale producer, should also be encouraged as a risk management strategy.

The specific recommendations are the following:

Short-Term Interventions

1. *Improve effectiveness of environmental monitoring and early warning systems to mitigate crop loss in aquaculture*. Farmers can adopt timely adaptation actions if they are forewarned. For instance, the snakehead fish farms in Tra Vinh or oyster farming areas in Ben Tre experienced poor water quality in their ponds, rivers and water supplying sources, which was caused by saline intrusion and droughts. Negative impacts could have been mitigated if timely environmental quality information were made available to farmers.
2. *Consider detailed assessment and planning for farming systems conversion/diversification from mono-rice to integrated systems, such as rice-fish or rice-shrimp aquaculture in areas with high levels of salinity intrusion.* Local authorities should provide support to farmers wanting to convert salinity-affected rice fields (i.e. rice fields with low productivity due to salinity intrusion and droughts) into integrated rice-shrimp aquaculture systems based on approved and detailed planning.
3. *Monitor frequently the water quality and salinity in ponds and supply channels, especially before deciding on the stocking period for shrimp.* For shrimp farming areas, local farmers should frequently monitor water quality and salinity in ponds and supply channels, especially before deciding on the period for stocking shrimp. Shrimp stocking calendars have to be adjusted accordingly, as the rainy season comes later and freshwater supply declines. Shrimp seeds should also only be stocked in ponds which have freshwater sources for salinity control or in ponds wherein the salinity levels fluctuate within the optimal range for shrimp growth.

Medium- and Long-Term Interventions

1. *Develop various platforms to support small-scale producers and farmers organized into effective value chains linking to other leading actors.* With increasing severity and impacts of climate change, aquaculture and agricultural production costs are likely to increase and profit margins will become thinner. To ensure high quality input supplying and effective product marketing, various platforms should be created to support small-scale producers and farmers organized into effective value chains linking to other leading actors (i.e. processing companies, shrimp cooperatives, input suppliers).
2. *Encourage farmers to adopt better risk management strategies to cope with increasing negative climate change impacts.* At the farm level, farmers can adopt a multiple species cropping strategy or rotate crops grown. At the household level, different livelihoods and cropping options should be considered. When climate and environmental conditions are not favorable for aquaculture and or agricultural cultivation, farmers' capital can be stocked in banks or saving accounts to avoid risks of losing this. This requires changing

the mentality of farmers through concerted efforts of development organizations and the concerned government offices.

Diversification

It is clear that monocultures pose an increasingly high risk to smallholder farmers. Diversification strategies, such as agroforestry-(small) livestock systems as innovative integrated systems for intensification, need to consider the efficient use of natural resources (in particular, land and water) as well as the market situation. This involves identifying context-specific multi-purpose stress-tolerant tree and crop species that function under different climatic and environmental stresses, contribute to regulating and restoring environmental functions and provide stable livelihoods. It is also important to identify whether it is the species and/or the technology which is causing the sensitivity of the farming system (e.g. as witnessed in the farms growing coconut intercropped with pineapple or grass. These appear to have more benefits than respective monocultures).

Evidence from other places in Vietnam shows that longer-term policies are vital in the adoption of perennial systems(Simelton et al., 2015a,b). Intermediate and longer-term socioeconomic and environmental trade-offs can be simulated with various computer models to guide investments. Land use plans for perennial species need to consider climatic and environmental risk assessments. Assessing risk of diversification should be implemented to determine the risks suffered by different species combinations during extreme climate changes. For perennial crops like coconuts which have salinity-tolerance and high economic value, plantations can be re-designed to allow the establishment of multi-cropping systems and to use improved varieties with salinity- and drought-tolerance. At the community level, new policies could be introduced to bring smallholder (e.g. coconut) farmers together to avail of better services, such as product processing and marketing.

A longlist of relevant trees and crops based on local and scientific ecological knowledge can be derived and evaluated together with local leaders for formulating coherent supporting policies (Duong et al. 2016). For example, climate smart agriculture, including agroforestry is recognised in the updated National Adaptation Policy Decision 819/2016-QD-BNN-KHCN dated March 14 2016 ("Phê duyệt kế hoạch hành động ứng phó với biến đổi khí hậu (BĐKH) ngành nông nghiệp và phát triển nông thôn giai đoạn 2016-2020, tầm nhìn đến năm 2050"). Mixed farming systems can provide income throughout the year, over a longer period of time. It may take time, however, before perennial species start to produce and provide income to the farmer. Farmers can be supported by organizing production groups to reach appropriate markets and processing industries and by provision of insurance solutions.

Promoting diversification entails increased use of a range of information outlets, e.g. farmer field schools and crop-pest doctors, free-call services, more localised weather forecasts and agro-advisories provided through television/phones. Successful examples, such as grafting on local stress-tolerant species, can also be highlighted to farmers. Environmental benefits or impacts of practices, such as diversification or the increase of pesticide use, should be explained clearly.

The specific recommendations are the following:

Short-Term Intervention

- *Adopt and promote risk diversification strategies*. In aquaculture, the poor farmers in the MRD are struggling to cultivate their crops. Introducing/adopting multiple species farming methods, farming alternative species (at the crop level) to diversifying home gardens/alternative livelihoods and income sources (at the household level) should be promoted.

Medium- and Long-Term Interventions

1. *Promote multistory tree-crop systems for reducing farmers' risks, regulating micro-temperatures and maintaining soil moisture.* Land use conversions are taking place already into more salt tolerant cultivations, e.g. coconut plantations with fodder grass is more efficient than monoculture.
2. *Diversify farming with short-term crops that can be adjusted according to seasonal predictions and changes of planting dates due to previous seasons.* Drought-/salinity-tolerant crops (for El Niño) and flood-tolerant crops (for La Niña) should be promoted. One potential adaptation strategy is the combination of coconut monocultures and growing of salt-tolerant grasses. Instead of coconut monocultures, farmers could develop coconut agroforestry with an understory of either salinity-tolerant N-fixing grasses and/or vegetables. Grasses could regulate soil moisture, reduce evaporation to some degree.
3. *Include environmental costs for irrigation-demanding horticulture systems in the establishment and promotion of new industrial farming models.*

What needs to be done to promote agricultural diversification?

In order to support diversification, a level playing field in terms of policy support like remunerative prices for the crop, assured marketing for alternatives, value addition, and processing is needed. Supportive policies could also include the removal of subsidies for some crops, encouraging land-use zoning and introducing differential land tax systems. Adoption of modern technologies (e.g. biotechnology) needs to be strengthened to increase productivity.

A major challenge for the implementation of diversified agricultural systems for farmers is finding the appropriate balance of diversification within the farm system to satisfy both production and protection values. As climate change variability increases, the value of resilience will also increase, especially in production systems that are sensitive to climate variation. A farmer's decision to move toward diversified agricultural systems will be highly influenced by the ability of the diversification strategy to support the economic resilience of farms. Finding win-win solutions that account for farmers' various production and protection goals is necessary to develop long-term, viable strategies. Developing tools that can help managers understand best practices on a farm, field or landscape scale can significantly enhance diversification. At the farm field level, techniques such as crop modelling will be useful. Economic models that can predict threshold prices at which farmers begin to adopt environmental land-use practices or payments for ecosystem services can be highly effective in encouraging farmer adoption of diversified agricultural systems. Development of larger-scale diversified landscapes that support and improve ecological resilience in agricultural systems requires a more in-depth analysis of farm business and landscape-level scenario modelling for on-farm diversification possibilities. Stakeholder involvement and participatory research are useful tools in developing adaptation options that will have higher likelihood of uptake by the local community.

Water Management

Conjunctive water use, or the sustainable use of both surface and groundwater, needs to be considered. Linkage between surface water and groundwater should be understood. Developing systematic monitoring networks to observe variations of groundwater levels in wells and surface water levels in streams could feed into surface and groundwater maps. Understanding their linkages will be very useful for planning and managing water resources and uses in the region.

The findings from the CLUES and DANIDA projects show that levels of salinity intrusion are very sensitive to upstream conditions. They observed that the increased salinity intrusion in 2016 (as in other El Niño years) was due to decrease in upstream flows. This thus emphasizes the importance of upstream flow management (i.e. working with countries upstream of the Mekong Delta). Furthermore, there is a need to strengthen regional integration and coordination in implementing water-saving technologies throughout the MRD, particularly in upstream provinces (e.g. An Giang, Can Tho, Dong Thap) to reduce water withdrawal and allow higher water flow to coastal provinces. Another method for increasing the groundwater volume for irrigation in the dry season and reducing the damage by floods during heavy rains is the underground taming of floods for irrigation (UTFI) proposed by IWMI(http://utfi.iwmi.org/)

Short-Term Interventions

1. *Promote appropriate water management practices during periods of high salinity (i.e. based on EC testing of irrigation water) in addition to use of salt tolerant, short maturing rice varieties.* This will reduce the risks such as irrigation with saline water, which results in "burnt" rice fields. In addition, high salinity just before and after flowering can complexly destroy the crop.
2. *Implement water-saving technologies in upstream provinces (e.g. An Giang, Can Tho, Dong Thap) to reduce water withdrawal and allow for higher water flow to coastal provinces.* This would reduce salinity intrusion in the region.

Medium- and Long-Term Interventions

1. *Manage upstream flow of the Mekong River.* It is very important to maintain upstream flows in the future through upstream flow management (i.e. working with countries upstream of the Mekong Delta). It should be noted that increased salinity in 2016 (as in other El Niño years) was due to decreasing upstream flows, not sea level rise. This is reinforced by the findings from the CLUES and DANIDA projects that salinity intrusion is very sensitive to upstream flows.
2. *Explore the method of underground taming of floods for irrigation (UTFI) proposed by IWMI(*http://utfi.iwmi.org/*) as an alternative for increasing the groundwater volume for irrigation in the dry season and reducing the damage by floods during heavy rains.* In this method, groundwater aquifers are artificially recharged by simple and low cost measures rather than just natural recharging. The first phase is the selection of suitable locations, such as the sand dunes in the coastal provinces, as pilot sites for learning, before out-scaling to larger areas.

Other Recommendations

Short-Term Interventions

1. *Disseminate information on CSA*. CCAFS has continuous efforts to out- and up-scale CSA options and the concept of Climate-Smart Villages (CSVs) to improve the resilience and adaptive capacities of local communities for dealing with extreme climate events in the region. Other measures, such as demonstrations, participatory evaluation, communication and media, can be utilized to enhance out-scaling of varieties and relevant interventions.

2. *Improve/adopt sustainable resource management practices (water, soil, and crop management)*. In the three provinces visited, farmers extracted and over-used freshwater illegally, which can reduce freshwater availability for vulnerable communities in coastal areas.

Medium- and Long-Term Interventions

1. *Out-scale and up-scale of CSA and CSV concepts to improve the resilience and adaptive capacities of local communities to extreme climate events*. This should also be considered part of medium- and long-term measures.
2. *Improve/adopt sustainable resource management practices (water, soil, and crop management)*. In the three provinces visited, farmers extracted and over-used freshwater illegally, which can reduce freshwater availability for vulnerable communities in coastal areas.
3. *Trial, and if successful, out-scale insurance (e.g. weather-index based, remote sensing-based) programmes to protect smallholder farmers and agricultural businesses.* The insurance programmes should respond to multiple climate stressors such as drought, typhoons and floods. Considering the limited application of agricultural insurance in Vietnam, more research on the appropriate schemes addressing the multiple climate stressors imp5acting smallholder livelihoods is needed. Programmes may also address risks related to crop or livestock production, and could possibly extend to other non-conventional sources of risk in these systems.

Summary and Conclusions

Salinity intrusion in the MRD of Vietnam, which is associated with low water discharge from upstream of the river, has worsened due to the ENSO phenomenon and drought. Local authorities and farmers alike underestimated the drought and salinity intrusion conditions, thus rendered them unprepared for the impacts on aquaculture and agricultural production. Rice production, a main agricultural activity, was reduced by 50-100%, in affected areas due to salinity intrusion, lack of freshwater and drought. Negative effects of climate change were experienced more severely by small-scale farmers and producers who have lower financial and technical capabilities to adapt to the changes.

We recommend several short-, medium- and long-term solutions for increasing the adaptive capacities and resilience of communities in the MRD. These mainly revolve around promoting CSA (and CSV concepts), such as ICT based early warning and climate information services, climate smart "designer" rice varieties, adjusting cropping calendars and cropping intensity, proper natural resource management (water, soils, aquaculture and crops), diversification (rice-shrimp, fruit tree intercrop, multi-species fish culture, and other schemes), and improved information and knowledge dissemination. Different innovations and practices developed and promoted by CGIAR Centers were also identified as potential adaptation strategies for the communities. The CGIAR centers can provide technical support utilizing experiences and tested technologies and practices. Entrepreneurs and other actors, such as processing companies, input suppliers and cooperatives, should also play roles in providing production direction for small-scale farmers. Developing and improving on policies that support small-scale producers and farmers are needed in addressing current and foreseen changes in the climate.

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Appendix 1. Highlights of the Field Assessment

Day 1 - 25th April - Bến Tre province

Thua Duc commune – Binh Dai District (Estuarine oyster farming areas lost due to salinity)

Box 1: Estuarine oyster farming in Thua Duc commune:

- Investment: 100 million VND/1000 m^2.
- Employment creation: 50 labor/1000m^2; wage rate: 800,000 VND/person/day (for harvesting and preparing substrates for oyster farming).
- Farming method: cleaning of area & launch of substrates made from concrete --concrete tiles=> natural oyster seed attached to concrete tiles=> protection and growth for 1.5 years=> harvest of oysters=> sell to local traders=> processing by company or local markets =>consumers.
- Restart the same steps during the next farming season.

Mr. Nguyen Van Dom, the Vice-chairman of Thua Duc commune said that in this area, 19 ha of oyster farms in Thua Duc commune were destroyed, resulting in an estimated loss of 47.3 billion VND (in which: 30.4 billions = 1600 tons of young/small oysters or 9-10 oysters in each kg; 16.8 billions = 730 tons of big oysters or three to four oysters in each kg). This affected more than 350 farm households in the commune. Although the local authorities have not confirmed the reasons for the massive death of the oysters, farmers said the main reason was the serious salinity influx combined with high daytime temperatures and cold night temperatures. The optimum salinity level for oyster farm ranges from 15-25%. However at the beginning of March 2016, the salinity levels of the Cong Be estuary where live oysters feed measured at 35% - 37%, which is a 10% increase from the 2015 levels.

Mr. Bui, Deputy Director of the Ben Tre DARD, said that the provincial and district DARD sent representatives to measure the salinity levels at the beginning of the oyster farming season. They also issued warnings to the affected communes about the imminent saline intrusion which would be the worst in recent history. However, the oyster farmers did not actively adopt the necessary measures to reduce losses, as one farmer who has relied on oyster farming for so many years related that they had never experienced salinity levels over 30% in their area. Another farmer in Thua Duc commune said he lost a total of 100 million VND (US$4000) for each hectare of oyster farm within five months because all his oysters died. To compensate the affected aquaculture-households, Mr. Bui said the government will provide financial support of 7 million VND per hectare of damaged aquatic farming.

The following are two adaptation options the aquaculture farmers could adopt in their farms:

- ✓ Estuarine oysters (Hàu cửa sông) and estuarine cockles (Sò cửa sông) can be farmed in the affected areas. Cockles have greater adaptive capacities to changing climate and environments as they can move to better locations if the water environment changes.
- ✓ Oyster farming in saline intrusion estuarine areas can provide local farmers alternative livelihoods and income sources. However it largely depends on climatic and environmental conditions. Improved climate monitoring and early warning services could support farmers adapting to the impacts of climate change.

Pictures 1: *Interviews in the oyster farm damaged by sever salinity in Binh Dai district, Ben Tre.*

Pictures 2: *Oyster death due to sever salinityr at Binh Dai district, Ben Tre province*

An Binh Tay commune – Ba Tri district & An Hiep commune - Ba Tri district (Area of rice lost/affected due to drought & salinity)

Based on the October 2015 warnings of predicted drought and saline intrusion, an estimated 2000 ha of paddies will lack water for cultivation. Despite this warning, local farmers still planted 1,900 ha of paddy lands. Both commune officials and local farmers underestimated the risks of drought and saline intrusion. One farmer in the An Binh Tay commune related in these areas, transplanting started in December 2015 and was expected to be harvested by March 2016. However, the rice plant started to dry up in February and the farmers had to harvest the green straw for feeding their cows to avoid further loss. The total rice output of the 2015-2016 Winter-Spring crop decreased by 70% from the same period last year.

Mr. Nguyen Thanh Lam, the Vice-head of the district DARD, said this is the first time salinity had reached beyond the dykes, with increased salinity levels in February-March 2016. This is why they have little experience in alternative options for coping and adaptation responses.

In the recent years, farmers prepare land for the summer-autumn rice season every April. However, the next rice season for 2016 has been delayed due to a long and intense drought and saline intrusion. Local authorities do not yet have a clear response plan. For the meantime, the provincial agricultural sector has tried to carry out measures to cope with the changes. Mr. Nam, Head of the provincial Department of Water Resources Management, said the affected households will receive financial aid of 1-2 million VND per hectare of rice and food crops and 2-4 million VND per hectare of fruit plantations. This would support farmers in buying seeds for the next farming season.

Pictures 3: *Rice field affected severe drought and salinity intrusion in Ba Tri district, Ben Tre*

Pictures 4: *IRRI scientist inspecting the sign of severe drought in the rice field in Ba Tri district, Ben Tre.*

In Giong Ao village of An Hiep commune, some farmers are shifting from rice planting to coconut farming and growing local fodder grass (cỏ tây) for goats. Livestock and drought-tolerant fodder grass can be grown on acid sulphate soils. Observations show that coconut-farmers could benefit from farming systems, like multistorey plantations, and landscape design, including dikes/channels, to optimise land and water resources.

Pictures 5: *Rice field shifting to coconut farming in An Hiep commune, Ba Tri district, Ben Tre.*

Pictures 6: *Local fodder grass's grown on acid sulphate soils for goat in An Hiep commune, Ben Tre*

Pictures 7: *Rrice field lost to severe drought at Ba Tri district, Ben Tre.*

Pictures 8: *Salty crusts appearing in acid-sulfate soils of rice field in Ba Tri district, Ben Tre*

Day 2 - 26th April - Trà Vinh province

Phien village - Hiep Hoa commune, Cau Ngang district (Pilot site of the project for adaptation to climate change in the Mekong delta province- funded by IFAD).

Mr Dzung, the Vice-Head of the provincial Department of WRM, said the Tra Vinh province has planned to allow land use change between rice paddies and other crops. About 9,000 ha of paddy land with inefficient production will now be shifted to: upland crops, such as chili, bitter gout/melon, Gac fruit - *Momordica cochinchinensis Spreng*, etc.); animal feed crops, such as potato, maize, cassava; fruits and vegetables; aquaculture; and other higher value production activities. In this area, ground-water is pumped to irrigate farms with upland crops because of the rapid exhaustion of freshwater in ponds. The drought is so severe that even the bamboo plants are wilting. Irrigation was previously done during midday without measuring the amount of water used, hence a large portion of the water evaporates before entering the soil.

Pictures 9: *Gac fruit-chilli model of IFAD-funded project planted by farmers in Cau Ngang district, Tra Vinh.*

Pictures 10: *Farmer's pumping groundwater for irrigating chilli field in Cau Ngang district, Tra Vinh.*

Giong Dai village –Hiep My Tay commune, Cau Ngang district (Intensive shrimp farming affected due to high salinity level)

In February, the salinity level of the canal system in this area was reported to be as high as 25%, whereas the optimum salinity level for shrimp is at 12-15%). This is the most severe situation the shrimp farmers have ever experienced. As a result, the production and growth of shrimp was reduced, with dead shrimp accounting for 25-30% of the total production. This is a 10-15% increase in the losses from last year. Currently, the farmers measure the pH and base levels every day. District extension workers also monitor salinity levels from 11 salinity monitoring stations, which were established to serve 2000 ha of rice-shrimp and 8000 ha of shrimp-shrimp.

Box 2: Intensive shrimp farming in Hiep My Tay commune:

- Farm size: 7ha; area for shrimp ponds: 5ha; water stabilization pond: 1ha; pond banks and others: 1ha.
- Years of shrimp farming experience: 10; Investment costs for intensive shrimp farming: 400 million VND/ha;
- Average grow-out pond size: 2000 m^2; Stocking density: 200,000 shrimp fingerlings/pond (20 pieces/m^2);
- Productivity: 2tons/pond – 10tons/ha; Food conversion ratio (FCR): 1.2; Average harvest size: 60 shrimps/kg;
- Farm gate price-whole sale: 120,000 VND/kg;
- Social and environmental credit: VietGAP certification obtained; Freshwater supply: ground water pumping (with limited supply and exchange);
- Employed labor: 8 fulltime persons; Daily wage rate: 150,000 VND/labor/day; Monthly wage rate: 4 million VND/month for three months of stocking period;
- Cost structure of shrimp farming: Seed, feed, bio-products for shrimp health management, electricity and fuel, labor (stocking, managing and harvesting shrimps).

Pictures11: *Intensive shrimp farming in Hiep My Tay commune, Cau Ngang district, Tra Vinh*

Pictures 12: *Assessment team interviewing the head of intensive shrimp farming in Cau Ngang district, Tra Vinh.*

Pictures 13: *Vegetable's growing alongside the shrimp pond in Cau Ngang district, Tra Vinh*

Pictures 14: *Papayas' growing on the bunds of shrimp pond in Cau Ngang district, Tra Vinh*

Ta Rom B village – Don Chau commune , Tra Cu district (Area of rice lost due to drought & salinity)

In these areas, the dried rice plants in many field plots can be observed. Drought and salinity intrusion led to a lack of freshwater, which prevented the growth of the rice grains and resulted in poor productivity.

Despite warnings from the local authorities given last October to November 2015, local farmers still irrigated their rice fields with brackish water thinking that it would be better than nothing. When their rice plants dried up, they burned the straw because these were also too salty to use as cow feeds. In addition, acid sulfate soils are forming as salty crusts on the soil surface in some areas, because of high salinity levels of the water.

According to a young farmer, it was the first time the salinity in their area reached 8-9 ppt during the months of February and March. The farmers are not used to these conditions, which is why they still planted rice despite the warnings. They also had little experience in coping with saline intrusion.

Mr Dzung said affected households will receive 1-2 million VND per hectare of rice paddy as subsidy for buying and planting seeds for the next season. The policies on subsidies as implemented by the local authorities therefore contradict one another. Farmers who did not follow the given recommendations to reduce areas for rice production received subsidies, while those who did not plant and followed the warnings of DARD did not receive any aid.

Pictures 15: *Drought damaged rice field in Don Chau commune, Tra Vinh*

Pictures 16: *The sign of serveve drought effect in the rice field in Don Chau commune, Tra Vin*

Pictures 17: *Signs of salinity intrusion in Don Chau commune, Tra Vinh.*

Pictures 18: *Salty crusts formed on the soil surface of rice field in Don Chau commune, Tra Vinh province*

Long Hung village – Luu Nghiep Anh commune, Duyen Hai district (Aquaculture affected due to high salinity level)

Snake-head fish farmers in Long Hung village are nervous as their fish keep on dying. Local farmers think the fish deaths could be due to serious salinity intrusion in the rivers, hot weather and diseases. One farmer stated that this year for the fish farming in their commune, which has hundreds of hectares of fish ponds, 30-40% of their fish died after salinity intrusion. DARD has already sent technical workers to measure water quality and to provide medicine but the fish are still dying. According to Mr. Thai Van Dien, a fishing farmer in Long Hung village, local agencies have yet to confirm the exact reasons for the fish deaths.

Pictures 19: *Intensive snake-head fish farm in Duyen Hai district, Tra Vinh province*

Pictures 20: *Dead snake-head fish keep*

Pictures 21: *Mixed cropping (Casava-banana) grown by a farmer on banks of a fish pond in Duyen Hai district, Tra Vinh.*

Pictures 22: *The mixed cropping (Casava-banana-coconut) growing in acid-sulfate soil in Duyen Hai district, Tra Vinh.*

Day 3 - 27th April - Kiên Giang province

Minh Tan village, Minh Hoa commune, Chau Thanh district (Area of rice lost/affected due to drought & salinity)

Among the provinces in the Mekong Delta, Kien Giang province possesses the largest area of rice paddy that has been affected by drought and salinity intrusion. Local farmers are rushing to take measures to tackle drought and salinity intrusion.

Mr. Do Vy Thanh, head of a farmers' group in Minh Hoa commune, said that his family has been living in the area for nearly 30 years now but this is the first time they experienced such extreme weather. During the recent winter-spring season, local farmers cultivated rice in more than 600 hectares. Large scale drought and salinity intrusion hit the fields after the first month of the rice crop. Thus, rice production of winter-spring season has been reduced by an estimated 30-50%.

A farmer in Minh Hoa commune said that salinity unexpectedly intruded deeply into their freshwater aquifers. Technical staff from the commune already warned the farmers that salinity had already intruded into the canal but none of them was aware of the associated problems. Thus, pumping water to irrigate their rice fields resulted in loss of crops.

According to a farmer leader in Minh Hoa Commune, nearly 330 ha of summer-autumn rice seedlings are affected by drought and salinity intrusion. The district and commune officials have recommended farmers not to grow rice at this time but they still did. Mr. Huy, a technical staff of provincial fishery department measured the salinity levels of the water in canal and rice fields, which are now at 7% and 4% respectively. In comparison, the optimum salinity level for rice is 2%. Farmers did not attempt to pump water from the canals because the salty water will make the rice seedlings die more quickly.

With every passing day, more and more rice seedlings become at risk of being wiped out. As the situation gets worse, the damage is expected to increase. In addition, as the farmers and local authorities did not expect such high levels of salinity, they were unable to deal with the situation. Clarity of the warnings from the local authorities is needed for the farmers to understand the implications. One good example is of a Khmer village in Kien Giang, where farmers held meetings with an extension worker and formed self-help groups. Thus, they were able to ask questions and seek advice to avoid big damages in their farms.

Pictures 23: *Provincial technical staff's measuring salinity level in a rice field in Chau Thanh district, Kien Giang.*

Pictures 24: *Summer-autumn rice seedling's affected by salinity intrusion*

Temporary dams and structures to protect from further salinity intrusion were built to help farmers cope with saline intrusion in their rice fields. However, impacts of these ad-hoc interventions were not known. The temporary dams were maintained for a month and removed after that period for water movement. In total, 114 temporary dams, of which 13 was in Chau Thanh district, were built in Kien Giang province to prevent saline water intrusion.

An Thanh village, Binh An commune, Chau Thanh district (Coconut- Pineapple demonstration)

In the An Thanh village, coconut (*Cocos nucifera*) was planted on acid sulfate soils, instead of rice, as coconut can be grown successfully on saline sandy soils. Farmers also planted pineapple (*Ananas comosus*) on raised beds under the coconut tree lines. The raised bedding system (ridge and ditch) is appropriate for acid sulfate soils, especially in areas where freshwater is very limited. In addition, pineapples can close their stomata during day and are therefore more tolerant to drought. They can grow well on acid sulfate soils, with yields reaching up to eight tons per hectare per year. The farmer estimated that integrating pineapple with coconuts could raise profits by 40-60%, compared to coconut monocultures.

Pictures 25: *Coconut- pineapple demonstration at Chau Thanh district, Kien Giang.*

Pictures 26: *Coconut-pineapple's growing in acid sulfate soils in Chau Thanh district, Kien Giang.*

Ngoc Thanh village, Van Khanh Dong commune, An Minh district (Rice-shrimp rotation farms affected due to high salinity level)

The current severe drought and salinity have hit fish-rice farming, thus badly affecting the livelihoods and daily activities of farmers in An Minh, a coastal district in Kien Giang province.

In February and March 2016, the salinity levels of water in the canal and shrimp-rice field reached 36-40%. At the day of survey, the salinity level in the shrimp field plot was measured at 36% (salinity levels the same time of the previous year ranged from 18-20%). According to Mr. Vo Tri Nguyen, a farmer from Van Khanh Dong commune, farmers are now experiencing the highest salinity levels of water since they have lived and relied on shrimp-rice farming in the village.

Box 3: Intensive shrimp farming in Van Khanh Dong commune:

- Its location is approximately about 5 km from the sea. It is difficult to tap the ground freshwater, even with drilling 150-200 m in depth. Farmers in Ngoc Thanh have to buy freshwater transported by boats from other locations for their domestic use.
- Area for aquaculture: 3803 ha of which 2,438 ha are for rice-shrimp farming, 784 ha for shrimp monoculture areas, 350 ha for improved shrimp farming areas and 231ha for mangrove shrimp farming areas.
- The area has been used for shrimp and rice farming in rotation since 2003.
- Farming pattern/calendar: rice field/area preparation for shrimp crop in January; shrimp seeds stocked in January-February; shrimp crops last from February to July; harvest of shrimps in August/September; rice crop from September to December each year.
- Crops harvested in a best farming scenario: shrimp production: 150-180kg/ha; rice production: 4 tons/ha.

Mr. Le Van Quy, official of the DARD of Kien Giang province, related that of the 3,800 ha of Mot Bui Do rice (a salt-tolerance rice variety) in winter-spring season, 30-70% of yield were lost or seriously affected (the average yield is now 1 ton/ha) because of the lack of rain from August to September 2015. Local farmers did not have any alternative sources of freshwater during those months.

According to the Agri-fishery extension station of An Minh district, annual salinity intrusion often ends at the middle of May. However this year, salinity intrusion could continue in the region up to July. A serious shortage of freshwater at the end of June is therefore inevitable.

Farmers were warned that they should wait for the rain before feeding the shrimps, to avoid high water salinity levels but none of them took the warnings seriously. Pumping saltwater into their shrimp fields resulted in loss of shrimps. Some households, like Mr. Nguyen Van Nhien's, tried to grow shrimps again in one month. However the shrimps were still not able to survive the high levels of salinity.

It was estimated that 891 ha of shrimp farming area were completely lost due to severe climate change impacts. On the average, each rice-shrimp farming household lost 15-30 million VND. The amount lost is small, compared to intensive farming capital levels, which are estimated at 400 million VND/ha. However, this loss is critical to small-scale and poor farmers in the area. Shrimp crop damage reports were compiled and submitted to local authorities for ad-hoc support. An amount of 7.5 million VND/ha was requested to support farmers in restocking their shrimp crops.

The increased level of salinity in farms has not only affected farming but also the daily activities of the local people. Increased salinity has rarely been experienced in this area, thus the people have never been concerned about shortage of freshwater. Water now is too salty for domestic use, especially for drinking and cooking. The people now have to buy freshwater (with the price of 35,000 VND/m^3) for drinking and cooking, and also have to store water in numerous ceramic jars. This situation will likely continue for the next two months. The poor households who have been using saline contaminated water and have shortage of clean water for drinking and cooking are the most vulnerable as they face health risks from long-term use of saline water for drinking.

Pictures 27: *Interviewing a rice-shrimp farmer in An Minh district, Kien Giang.*

Pictures 28: *Rice-shrimp farm in Van Khanh Dong commune, An Minh district, Kien Giang.*

Appendix 2. Field visit program

24th April, Sunday	
Arrival day	Travel to Ho Chi Minh City *(Participant is expected to arrive in HCM City before 16.00 (4 pm))*
16.30-18.30	Group Meeting at the Hotel (all participants) *(SAIGON HOTEL - 41 - 47 Dong Du St., Dist 1, HCM City, Viet Nam)*
18.30-20.00	Dinner (all participants)
	Stay overnight at Ho Chi Minh City
25th April, Monday	
07.00-09.30	Travel from HCM to Bình Đại district (**Bến Tre province**)
09.30-12.00	Visit to Bình Đại district (Aquaculture lost/affected due to salinity)
12.30-13.30	Lunch at Bình Đại
13.30-14.30	Travel to Ba Tri district
14.30-17.00	Visit to Ba Tri district (Area of rice & fruit tree lost/affected due to drought & salinity)
17.00-19.00	Going to Trà Vinh City
	Stay overnight at Trà Vinh City (Trà Vinh province)
26th April, Tuesday	
07.30-08.30	Travel to Trà Cú/Cầu Ngang district (**Trà Vinh province**)
08.30-11.00	Visit to Trà Cú/Cầu Ngang district (Area of rice lost/affected due to salinity & drought)
11.00-12.00	Travel to Duyên Hải district
12.00-13.30	Luch at Duyên Hải district
13.30-16.00	Visit to Duyên Hải district (Aquaculture lost/affected due to salinity)
16.00-19.00	Travel to Cần Thơ City
	Stay overnight at Cần Thơ City
27th April, Wednesday	
07.00-09.30	Travel to Châu Thành district (**Kiên Giang province**)
09.30-11.30	Visit to Châu Thành district (Area of rice & fruit tree lost/affected due to drought & salinity)
11.30-12.30	Travel to An Minh district
12.30-13.30	Luch at An Minh district
13.30-15.30	Visit to Anh Minh district (Rice & aquaculture lost/affected due to salinity)
15.30-18.00	Travel back to Cần Thơ City

	Stay overnight at Cần Thơ City
28th April, Thursday	
08.30-10.30	Group meeting and discussion (Hotel in Cần Thơ) – with participation of CTU's experts
	Go to Cần Thơ Airport (*for particpants who are coming back to Hanoi*)
	Travel back to HCM City (*for others*)

Appendix 3. Members of the assessment team

Name	Position/ Organization
Dr. Leocadio Sotor Sebastian (Team Leader)	Regional program leader , CCAFS-SEA; Country representative to Vietnam, International Rice Research Institute (IRRI)
Dr. Bjorn Ole Sander	Scientist, IRRI
Dr. Elisabeth Simelton	Scientist, World Agro-Forestry Center (ICRAF)
Dr. Sijun Zheng	Scientist, Bioversity International - China
Dr. Chu Thai Hoanh	Principal Scientist, International Water Management Institute (IWMI)
Dr. Tran Nhuong	Scientist, Worldfish Center
Dr. Bui Chi Buu	Professor, Vietnam Academy of Agricultural Sciences (VAAS)
Dr. Cao Le Quyen	Deputy Director General, Vietnam Institute of Fisheries and Economic Planning (VIFEP)
Mr. Ngo Duc Minh	Associate Scientist, CCAFS-SEA, IRRI

Appendix 4. IRRI Recommendations

IRRI response to the salinity and drought problem affecting rice areas in Vietnam

Over the last few years, IRRI coordinated two important collaborative projects in Vietnam:

- ACIAR-funded CLUES (*Climate Change Affecting Land-Use in the Mekong Delta: Adaptation of Rice-based Cropping Systems*) project, and
- DANIDA (*Improving Rice Tolerance to Submergence and Salinity to Cope with Climate Change in Coastal Areas in Vietnamese Deltas*) project on breeding varieties tolerant of salinity and submergence.

IRRI has also launched a new project, funded by BMZ, on real-time monitoring of salinity levels in combination with mobile phone technology for early warning in coastal delta provinces (*Salinity Advisory as a Location-specific Timely Service for rice farmers, or* SALTS).

These recent and ongoing projects can build on IRRI's collaborative work in Vietnam that started in the 1960s. Several projects on rice development and rice-based systems have been completed since then that targeted rice environments in the Mekong Delta. These environments are either affected by salinity or at risk of aggravated salinity in the future.

Given recent problems reported on drought and salinity intrusion in the delta, we feel prompted to outline a strategy for IRRI engagement with the Vietnam government and other development agencies to tackle challenges from said environmental stresses and the impact of these on rice-based system productivity. Some recommendations have been made based on outcomes of recent projects and other IRRI initiatives in Vietnam.

Preempts:
Recent high salinity intrusion in the Mekong Delta was, to some extent, anticipated. Severe salinity intrusions have occurred in the past, following years of strong El Niño events, e.g., in 1998 after the 1997 El Niño and in 2010 after the 2009 El Niño.

As El Niño can be forecast, the information can also be used to predict risks of salinity intrusion in the Mekong Delta and as a powerful tool for planning and management. In the last 50 years, 2015 ranked as the second strongest El Niño episode, only after the 1997 one (http://www.el-nino.com/). A lesson we have learned is that we can foresee severe salinity stress in the Mekong Delta at the end of dry (dong xuan) season as a consequence of salinity intrusion in February. Such forecasting should allow preparations to be carried out at the start of the season.

It should be noted that increased salinity in 2016, as in other El Niño years, was caused by decrease in upstream flow and not by sea-level rise. This is supported by findings of the CLUES and DANIDA projects, implying that levels of salinity intrusion are very sensitive to upstream flow. It is, therefore, important to maintain upstream flow in the future through watershed and other management options, e.g., working with countries upstream of the Mekong Delta.

Response strategies

a. Hydraulic modeling and real-time monitoring system

As undertaken in the CLUES and DANIDA projects, hydraulic modeling can help identify areas at high risk of salinity and drought under current climate as well as in the future. Increased salinity in 2016, as in other El Niño years, can be attributed primarily to decrease in upstream flow and not as an immediate effect of sea-level rise. This is supported by findings of the CLUES project, implying that levels of salinity intrusion are very sensitive to upstream flow. It is, therefore, important to maintain upstream flow in the future through its management, e.g., working with countries upstream of the Mekong Delta.

Advanced modeling and GIS techniques allow mapping of high-risk areas in high spatial and temporal resolutions. Dissemination of response strategies can thus be planned in a much more targeted way than previously possible. These techniques can be supplemented by an early-warning system derived from the salinity monitoring network and mobile phone applications of the SALTS project. Collectively, these various approaches from recent and ongoing IRRI projects will allow well-planned response strategies over different time horizons.

b. Management options

In areas at high risk of salinity where rice continues as an option, management measures are required that can include one or a combination of several options and focused research is important to establish suitable responses:

- **Appropriate water management practices to maximize use of freshwater and reduce the impact of salinity.** Establishing a real-time monitoring system for soil and water salinity throughout the season will help farmers avoid planting during periods of high salt intrusion and will also provide them with tools to guide irrigation management decisions. This will help reduce risks to yield resulting from the use of saline irrigation water. High salinity right before and after flowering can completely destroy the harvest.

- **Adjustment of cropping systems based on trends in the climate.** Determining proper sowing and cut-off dates for each season will help minimize the harmful effects of salinity and drought to the crop, e.g., setting proper cut-off dates for the dong xuan season to avoid late-season salinity. Vietnam has successfully implemented cut-off dates in flood- prone areas (e.g., An Giang, Dong Thap) and a similar approach should be taken in salt-affected areas. New varieties should also be designed based on these cut-off dates. A more comprehensive program is needed to assess current land-use plans and zoning, and adjustments must be made to minimize the impact of worsening environmental conditions. The new cropping systems could allow appropriate changes in the cropping patterns, e.g., switching from 3 crops of rice in some areas to only 2, or introducing non-rice crops of good market value to enhance farmers' income. Redesigning cropping systems is necessary to avoid risks associated with salinity without compromising total annual rice production and farmers' income.

c. Crop improvement

Development of varieties with desired agronomic traits (duration, yield, quality), resistance to biotic stresses, and tolerance of emerging abiotic stresses such as salinity and drought. These varieties will provide (A) a means for farmers to address or cope with these challenges and (B) insurance to encourage them to invest in a more productive system. The following strategies can be adopted:

- *Short-term strategy*: Evaluation of locally developed salt- and drought-tolerant varieties, as well as varieties developed for similar conditions in other countries, for selection and commercialization in affected areas.

- *Medium-term strategies*: Hasten the development and delivery of good-quality short-duration rice varieties that have enhanced salt and drought tolerance for particular areas. IRRI has identified some major QTLs for both early- and late-stage salinity. Combining salinity tolerance traits in short-duration varieties will have a dual value of protection against mild stress in early stages and severe stress at later stages. This can be done through marker-assisted breeding (MAB) methods that have been used by Vietnamese and IRRI scientists in recent collaborative projects (ACIAR-funded CLUES, and DANIDA). A program that builds on this progress and capitalizing on the expertise of IRRI and of local institutions can speed up the development and deployment of these varieties to within five years.

  Vietnam had also been through severe drought events, in addition to problems with salinity. Introgression of drought-tolerant traits (QTLs) into short-duration varieties should also be aimed for and combined with salt tolerance. This will result in more resilient varieties that will protect farmers during disastrous incidences of these environmental stresses.

- *Long-term strategies*: Designing a forward-looking breeding program for the development of new 'designer' varieties that fit the new cropping systems and carry the package of traits required for climate resilience. These varieties should have optimum maturing periods (duration) based on available windows of opportunities and combine tolerance of current and foreseen abiotic stresses such as salinity, drought, and heat stress.

d. Dissemination

Outscaling and upscaling of the Climate-Smart Agriculture (CSA) and Climate-Smart Village (CSVs) concepts to improve the resilience and adaptation capacity of local communities in extreme climate events. This should also be considered part of medium- and long-term measures.

e. Training and capacity strengthening

IRRI will work closely with MARD and other research and development organizations to address these issues as well as other medium- and long-term challenges from climate change. The technical assistance program recently drafted by MARD and IRRI aims to address these issues. It includes development of new climate-smart rice varieties of high quality that meet the future market for Vietnam rice, with corresponding crop and natural resource management packages. Support for these initiatives could be solicited from other donors.