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Climate change affecting land use in the Mekong Delta: Adaptation of rice-based cropping systems (CLUES) SMCN/2009/021

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prepared by

Ngo Dang Phong, Postdoc Fellow, IRRI,
Reiner Wassmann, Senior Scientist, IRRI

co-authors/ contributors/ collaborators

Le Quang Tri, Director, Climate Change Institute, CTU

Nguyen Xuan Hien, Director, SIWRP

Nguyen Thi Lang, Head of Plant Breeding, CLRRI

Le Van Hoa, Dean of Faculty of Agronomy and Applied Biology, CTU

Dang Kieu Nhan, Vice Director, Institute of Mekong Delta Research, CTU

Nguyen Hieu Trung, Dean of Faculty of Environment and Natural Resources, CTU

Cao Van Phung, Head of Soil Science Department, CLRRI

International consultants:

Abdelbagi Ismail, Principal Scientist, IRRI

Russell Reinke, Scientist, IRRI

To Phuc Tuong, Principal Scientist, IRRI

Thelma Paris, Senior Scientist, IRRI

Bennet Macdonald, Senior Scientist, CSIRO

Peter Brown, Senior Scientist, CSIRO

Chu Thai Hoanh, Senior Scientist, IWMI

approved by	Robert Edis Research Program Manager| Soil Management and Crop Nutrition, ACIAR
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1 Acknowledgments

The project "Climate Change affecting land use in the Mekong Delta: Adaptation of rice-based cropping systems" (CLUES) was funded by the Australian Centre for International Agricultural Research (ACIAR) from March 2011 to September 2015.

We are grateful to the Department of Agricultural and Rural Development, Extension Center, and local authorities in An Giang, Bac Lieu, Can Tho, and Hau Giang provinces for their support and technical assistance for the project.

We acknowledge and appreciate the collaboration and support from GIZ Bac Lieu that raised the value of collaboration in the project and made it successful.

Last but not least, we appreciate the collaboration of farmers at the experimental sites and surrounding areas in four provinces (An Giang, Hau Giang, Can Tho, and Bac Lieu), which have been valuable to CLUES.

2 Executive summary

The CLUES project aimed at improving the adaptive capacity of rice-based farming systems for effectively managing impacts associated with climate change, with emphasis on capacity building, cooperation among CLUES members and local stakeholders, and internal and external information flows.

The report includes main results of the six themes derived from their final reports as well as additional information from the reports on the semi-final review and final review of CLUES. It focuses on technical and policy aspects during interactions among scientific advisors, team members of CLUES, local stakeholders, and policymakers during the implementation of project research activities.

In the theme on plant breeding, the project used marker-assisted backcrossing (MABC) to develop high-yielding rice cultivars that are tolerant of single or combined stresses of submergence, stagnant flood, and salinity. Through participatory varietal selection at multiple locations and in multiple seasons, some promising lines were identified and submitted for varietal release: OM3673 (short growth duration, tolerant of anaerobic seedling stage), OM10252 (submergence- and salinity-tolerant), and OM6328 and OM6677 (high yield and salinity-tolerant).

Through farmer participatory approaches, the project identified crop management technologies that help farmers to cope with climate variability and enhance their ability to adapt to climate change. The water-saving irrigation technique of alternate wetting and drying (AWD) is a win-win technology. It helped farmers to cope with water scarcity and reduced methane emissions from paddy fields up to 50% compared with continuous flooding conditions. Replacing the triple-rice system by double rice plus upland crops offered advantages such as increased farmers' income due to the high value of the upland crop and reduced irrigation water demand. Moreover, the short duration of the upland crop allowed site-specific adjustment of the crop calendar as a means to reducing risks stemming from salinity (in coastal zones) or floods (in flood-risk zones).

In terms of fertilization, farmers in the Mekong River Delta (MRD) have applied too much phosphorus fertiliser, resulting in substantial P accumulation in the soil. Farmers in An Giang, Can Tho, and Bac Lieu can reduce the P rate to a third of the current rate without compromising rice yield. Decreasing P applications increases farmers' net income and limits the environmental footprint of rice production. In the saline zone of Bac Lieu Province, traditional rice farming is based on long-duration local variety Mot Bui Do. Introducing short-duration high-yielding varieties not only avoids salinity risks, but is also a prerequisite for the shrimp-rice system, which increases income to farmers. Shorter rice duration also allowed more time for land preparation for the next shrimp phase.

The promising stress-tolerant rice varieties, rice-farming technologies, and their extension pathways have been assessed by CLUES with the participation of farmers and extension staff at four study sites. Participation of key local stakeholders and community-based organizations ensured the scaling of promising technologies by incorporating CLUES technologies into existing development programs.

A new conceptual model for land use analysis through a multiple-goal linear programming approach was developed for Bac Lieu Province as a coastal area of the MRD. It enhanced understanding of the current biophysical and socioeconomic conditions and adaptation opportunities for the study area under the impacts of current and future climate change (CC) and sea level rise (SLR). Simulation results showed that current brackish areas in Bac Lieu Province are the most sensitive to changes in future hydrological conditions and water management.

To increase greenhouse gas (GHG) awareness and climate change mitigation for local authorities and farmers, four training courses were held on GHG measurement for CLRRI staff, scientists, and students of Can Tho University (CTU). The first course was held at Hue University in June 2011 and the other three were conducted at CLRRI from the end of 2011 to mid-2012.

CLUES trained 3,960 farmers (3,260 men and 700 women) on participatory rice varietal selection (PVS). Farmers can use the attained knowledge in selecting varieties for their production. Four PhD theses and18 MSc theses of CTU were financed, supported, and supervised by CLUES. Two staff members at CTU were promoted to associate professor in 2015. Most CLUES staff working at CTU can use new knowledge in their teaching career. Some 64 publications with 31 peer-reviewed papers, 5 books and 15 leaflets were completed. CLUES have also increased the CC awareness of 2,979 local farmers and local government staff (including 862 females) through participatory discussions on CLUES activities.

The visibility of project activities and information has been maintained through the website of CTU or IRRI (http://irri.org/networks/climate-change-affecting-land-use-in-the-mekong-delta).

3 Background

The Mekong River Delta (MRD) is often referred to as Vietnam's "rice bowl," which accounted for 54% of Vietnamese rice production (and for ~90% of export rice volume) in 2005. Overall, Vietnam is the third-largest rice exporting country in 2015, with annual exports of 4.5 million tons, accounting for ~23% of rice annually traded globally (Nathan, 2016).

The agro-ecological zones of the MRD can be characterized by a combination of distinct soil types and hydrological features (Fig. 1). About 25% of the soils of the MRD can be classified as alluvial with relatively high soil fertility; the remaining soils are either acid sulfate (AS) soils or saline soils. Although AS soils can be found in different sections of the MRD, saline soils are confined to the coastal areas and result from reoccurring salinity intrusion in the dry season. The upper end of the Delta comprises flood-prone areas that could be either alluvial or AS soil.

Fig. 1. Map of soils in the Mekong Delta based on an atlas published by the Ministry of Education and Training in 2002 (source: www.delftcluster.nl/website/files/WAOP/Draft_final_report_Roads_and_Floods_-_Annexes.pdf). Target areas are indicated in blue (Omon), yellow (Hoa An), white (An Giang), and black (Bac Lieu)

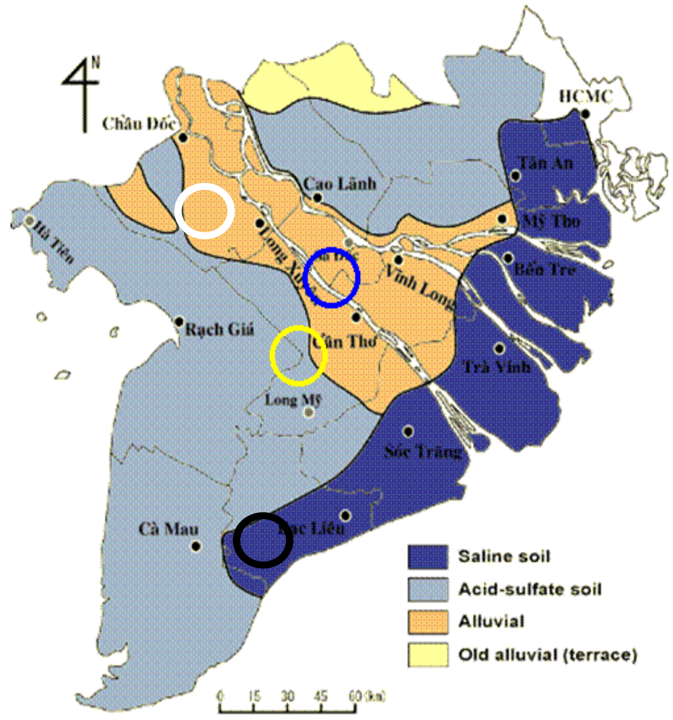

Fig. Distrubution of soil status in Mekong Delta

Climate change impacts in Vietnam's Mekong Delta region

Preliminary modelling has shown the changes to floodwater levels caused by sea-level rise that is discernible up to the Cambodian border (Wassmann et al 2004) and this will change Mekong Delta agro-hydrological zones. The changes to flooding and salinity at the scale predicted will directly threaten food security in the MRD.

Although seasonal flooding, droughts, and salinization directly affect agricultural production through exacerbating stresses to rice plants, a number of secondary impacts are also significant. A large part of the MRD is composed of AS soils in which elemental cycling is controlled by the seasonal fluctuation of the water table, so that a modification of the hydrological cycle due to climate change could cause significant changes, including dissolution and leaching of metals. Another secondary impact is changed nutrient (NPK) availability, with phosphorus being the key factor for productivity in the MRD.

Additionally, upstream dam development for hydro-electricity and irrigation supply will significantly alter the Vietnamese downstream flow and discharge characteristics of the

Mekong River. This will further affect the regional and national economy directly through the disruption of the agriculture, aquaculture, and forestry sectors and directly threaten the livelihoods of 10 million people who live within the MRD.

Over the last 30 years, Vietnamese farmers have been adapting to the changing environmental conditions by modifying and diversifying their production systems and water management. But, the recent and forecasted agro-hydrological changes threaten the viability of these farming and social systems and subsequently food security within Southeast Asia. Significant constraints that limit the ability of farmers to adapt to the new hydrological regime include the availability of suitable cultivars, soil nutrient management options, the lack of knowledge of the potential threats from acid sulfate soil inundation, and planning tools.

Research questions

The direct and indirect impacts of climate change will become a major challenge for maintaining food security in the near future, mainly through aggravating salinity and flood problems driven by hydrological dynamics of the Mekong River. Two meetings of the project proponents (November 2009 and July 2010) also identified a number of sub-issues and research questions:

1. What is the resilience of existing rice cultivars in terms of stagnant flood, salinity stress, and anaerobic conditions during germination? Could marker-assisted backcrossing be used for the introgression of these plant traits into popular varieties in the Mekong Delta varieties?
2. What will be the specific consequences of climate change in acid sulfate soils? Will intrusion by saline water reverse previous amelioration of this abundant soil of the MRD? What is the best management approach to prevent the mobilization of metals into the food chain?
3. What will be the best management strategy for optimizing soil nutrient cycling and maintaining high productivity under more extreme climatic events? To what extent can we learn from farmers’ experiences in dealing with drought, flood, and salinity problems in recent years?
4. What are the main biophysical, social, and economic factors that determine the capacity of farmers to adapt to climate change? How do we improve the adaptive capacity of farmers and policymakers?

4 Objectives

The overall aim of the project was to improve the adaptive capacity of rice-based farming systems for effectively managing impacts associated with climate change.

To satisfy this aim, the project had the following objectives:

Objective 1: Location-specific impact and vulnerability assessment

The geo-spatial component will analyze flooding and salinity risks under different sea-level scenarios and implications for different land use options backed up by considering direct climate impacts.

Objective 2: Improvement of salinity and submergence resilience of locally adapted rice varieties and elite lines

The plant breeding component will improve the tolerance of rice germplasm of a variety of direct and indirect impacts of climate change, namely,

- complete submergence through transfer of the *SUB1* gene into locally developed lines;

- Partial stagnant flood through further identification and development of germplasm tolerant of these conditions, and investigation of the physiological mechanism conferring adaptation;

- flooding during germination through transfer of stage-specific tolerance to anaerobic conditions; and

- Salinity through transfer of the *Saltol* gene into varieties of suitable maturity and adaptation, separately and in combination with *SUB1* for coastal areas experiencing both stresses.

Objective 3: Managing resources for resilient rice-based systems coping with rapidly changing environments

The crop and NRM component aims at developing and refining management options for different agro-ecological zones and new decision support tools for CC-resilient rice-based systems through improved understanding of element cycling and soil-plant and cropping system responses to altered hydrology.

Objective 4: Analysis of farming systems and socioeconomic settings in rice farming households

The socioeconomic research component of the project will aim to identify the biophysical, social, and economic factors that determine the capacity of farmers to adapt to climate change, understand the role of key institutions in influencing farmers' decisions and capacity to adapt. It also aims to evaluate the benefits of the new rice varieties in terms of the extent of the adaptive capacity they are likely to confer under projected future climate and socioeconomic conditions.

Objective 5: Integrated adaptation assessment of Bac Lieu Province and development of adaptation master plan

The in-depth study on the coastal area will explore possible adaptation through land use planning through one case study (Bac Lieu Province). Based on detailed inventories of soils, hydrological features, and land use, yields and financial returns of different options will be compared using crop models coupled with GIS. Finally, this information will be used to optimize land use at the provincial scale derived from a multiple-goal linear programming approach.

Objective 6: Capacity building for assessing GHG emissions

The GHG component will provide training and scientific infrastructure facilitating initial GHG emission measurements in rice systems and recording baseline emissions from conventional management and adaptation technologies.

Coordination and integration

The coordination component will create a sound infrastructure for all project activities, ensure internal and external communication flow, supervise progress of activities, and organize workshops.

5 Methodology

5.1 Research and/or development strategy and relationship to other ACIAR investments and other donor activities

A matrix multidisciplinary × multi-location approach (Fig. 2) was developed to address research questions and objectives of the project. One axis of the matrix comprises the six themes, each referring to the scientific objectives 1–6 above. The scientific activities were carried out in four target areas, each of which represents a specific agro-ecological zone of the Mekong Delta. The target areas represent a cross-section through the most important agro-ecological zones (Fig. 1). Derived from the area-specific settings, the project deployed a flexible approach in terms of field experiments (Table 1 and Fig. 1 for study site locations). However, a set of uniform field experiments performed in all target areas ensures the compatibility of results obtained in the different zones. In the context of this proposal, a target area comprises an experimental farm plus the surrounding villages, which were used for socioeconomic studies as well as participatory research.

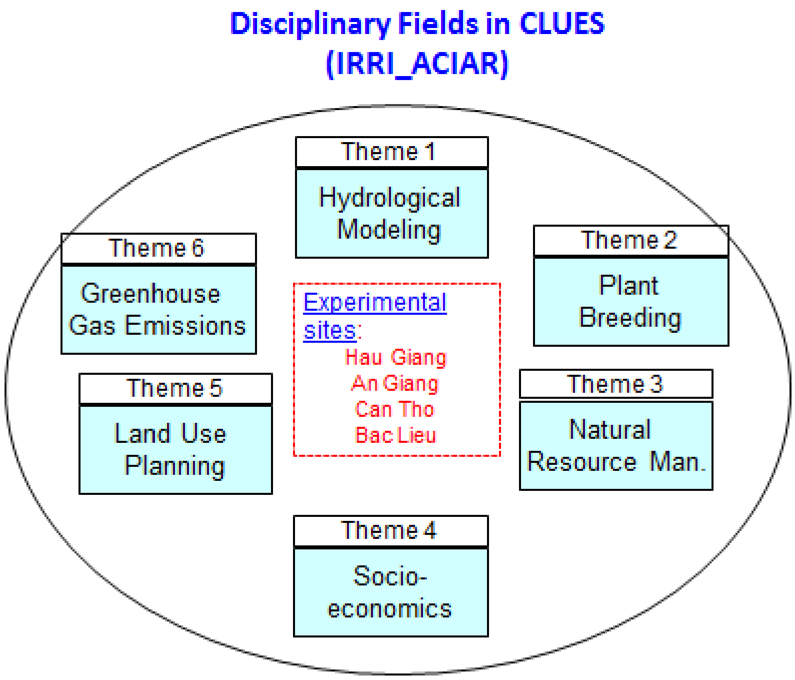

Fig. 2. Diagram of Themes and linked activities at four experimental study sites in CLUES.

In the first step, the project encompassed a comprehensive baseline survey as a joint activity of the project teams dealing with NRM, socioeconomics, and land use planning. The results of this survey were used for further definition of the activities within the respective objectives, for example, biophysical production constraints identified in the surveys were incorporated into the field design for improving NRM technologies. This project strategy for farm experiments was based on a “mother–baby trial” methodology (MBT) in which a researcher-driven trial was undertaken to generate statistically robust data and deliverable technologies.

In the next phase, the most promising options (varieties or management) were selected and further tested through “baby trials.” These smaller baby trials were replicated and managed by farmers on their own farms. This generated more data while allowing farmers to experience and refines which genotypes or agronomic practices best suit their needs. This strategy has been employed previously by researchers in this current project and in ACIAR Project LWR/2002/032.

The socioeconomic work of this project had close links with other ACIAR projects on "Developing multi-scale climate change adaptation strategies for farming communities in Cambodia, Laos, Bangladesh, and India" (LWR/2008/019), in which some of the livelihood assessment and adaptive capacity work was developed during the scoping stage (LWR/2008/015; Roth et al 2009) and was based on the livelihoods framework of Ellis (2000).

The project did not develop and impose a rice adaptation model for the Mekong Delta. Instead, the project researched and developed new technologies and plants to improve overall resilience in rice-based production systems. The outcomes represented "a resilience toolbox," which local farmers and land managers can use to innovatively design production systems for the changing climatic and hydrological conditions. The development of the "resilience toolbox" enhanced capacity within and strengthened collaboration between the Vietnamese and Australian research communities.

Given the extensive amount of research needed to be undertaken, it is envisioned that an Advisory Committee (or Operational Board) will be formed to provide governance for many of the in-country activities (Table 1). The consortium will explore options for funding additional PhD and MSc student positions—either from Vietnam for studies in Australia or from Australia for field work in Vietnam—to further aid capacity building and address specific research questions.

Table 1. Matrix of links of work assignments between theme leaders and site managers in CLUES.

			Activities per site			
	Theme and objectives		An Giang	Hau Giang	Can Tho	Bac Lieu
Study sites involved in Theme activities (scientific)	1	Geo-Spatial component: Location-specific impact and vulnerability assessment	x	x	x	x
	2	Stress-tolerant rice varieties on improving salinity and submergence resilience of locally adapted rice varieties and elite lines	x	x	x	x
	3	(NRM component): Managing resources for resilient rice-based systems coping with rapidly changing environments	x	x	x	x
	4	(Socioeconomic component): Analysis of farming systems and socioeconomic settings in rice farming households	x	x	x	x
	5	Integrated adaptation assessment of Bac Lieu Province and development of adaptation master plan				x
	6	Capacity building for assessing GHG emissions	x	x	x	x

5.2 Theme 1: Objective 1 (Geo-Spatial component): Location-specific impact and vulnerability assessment

Activities of Theme 1:

- Activity 1.1 Literature review and meta-analysis of available data and documents on climate change projections for the MDR to identify potential production constraints to future production
- Activity 1.2: Assessing hydrological impacts of different sea-level rise scenarios in the MDR region (hydraulic and salinity modelling)
- Activity 1.3: GIS mapping of flooding depth and salinity levels within the MDR as a function of sea-level rise and envisaged upstream development projects for different land use options
- Activity 1.4: Comparative assessment of climate change impacts on rice production in the four target areas (An Giang, Can Tho, Hau Giang, and Bac Lieu)
- Activity 1.5: Mapping (delta-wide) of vulnerability and potential "hot-spots"

Theme 1 employed the following methods in this study:

- Data collection and synthesis.
- Modelling and simulation method (mathematical models, statistics, forecast) to study water balance and assessment of hydrological and hydraulic changes.
- Applying remote sensing, GIS, and software of database management to systematize and map computed results.

The "Vietnam River Systems and Plains" (VRSAP) model is a hydraulic model to simulate mainly one-dimensional hydrodynamic river flow or quasi two-dimensional flow on floodplains. Applying an implicit finite difference scheme for solving one-dimensional Saint-Venant equations, VRSAP is able to simulate water flow in complex branched and looped river networks. It is also designed to simulate dissolved or suspended particulates in water (e.g., salinity, acidity, etc.) using the scheme of implicit finite difference for the advection-dispersion equation. Updated data on hydrology, topography, and infrastructure system data for baseline year 2008 were used for model verification.

Detailed mathematical schemes have been constructed for the MRD with the updated data on rivers and sluice systems in 2008. The scheme of this model includes 3,486 nodes, 5,611 segments, and 2,666 plains. The total area simulated in this model is about 5.5 million ha (Fig. 3).

Upstream boundary: flow at Kratie; downstream boundary: water level and salinity; climate in the MRD and upstream.

Main outputs: hourly water level, flow, and salinity.

The impact and vulnerability assessment capitalized on a suite of models and GIS databases for a geo-spatial assessment of climate change and sea-level rise impacts in the MRD.

In this study, we used projected climate data from SEA-START (based on the PRECIS model developed by the UK Hadley Centre with A2/B2 scenarios) from 2010 to 2100. However, those data have no bias correction.

The MRC did bias correction for upstream (up to Kratie) and computed river discharge und CC scenarios; these data were used in the BDP2 project (MRC, 2011).

The representative years for time windows, namely, dry, normal, and wet years in the duration 2030 window (2020-35) and 2050 window (2036-50).

River discharge was computed for those selected years with a specific SLR for a given time window (17 cm for the 2030 window and 30 cm for the 2050 window based on the

MONRE's scenarios for SLR in the years of 2030 and 2050, respectively, with specific values for the East and West Sea (MONRE, 2012).

All computations were in three different representative years of the respective time windows of the 2030s and 2050s. A total of 27 scenarios were simulated for assessment, which combine many factors of SLR, CC, Upstream Development, and the Land Use Plan in the Mekong Delta.

Flood scenarios were computed from July to December, whereas salinity scenarios were computed from January to June for the entire MRD.

The scenario outputs used GIS software to present the flooding map and salinity maps in raster format.

The detailed methodology is referred to in Appendix 1 (the Theme 1 final report).

The following criteria for hot-spot delineation were used in the assessment for flooding and salinity risks:

Flood risk onset date is identified as the water level in a canal that is 0.4 m higher than the level of the field in a period from 7 to 15 consecutive days.

Flood risk recession date is defined as the water level in a canal that is +0.2 m lower than the field level.

Flood risk duration: Time when flooding appears – Time when flooding ends.

Salinity risk onset date: Date salinity commenced was identified as salinity of more than 3 dS/m in a canal lasting at least 7 days in a period of 15 days.

Salinity risk end date: date when salinity in a canal was less than 3 dS/m.

Salinity risk duration: Time when salinity appears – Time when salinity ends.

Potential for gravity irrigation: The area is capable of a gravity brackish-water supply if it satisfies the following condition: maximum daily water level in a canal is more than 0.25 m higher than the level of the field and, on the same day, maximum salinity in a canal is more than 9 dS/m. The area meets the above condition at least 7 days in February, which is the period that has the highest water demand and is considered as the area of potential brackish-water supply by gravity.

The area is capable of gravity freshwater supply if it satisfies the following condition: maximum daily water level in a canal is more than 0.25 m higher than the level of the field and, on the same day, maximum salinity in a canal is less than 3 dS/m. The area meets the above condition at least 7 days in February and is considered as the area of potential freshwater supply by gravity.

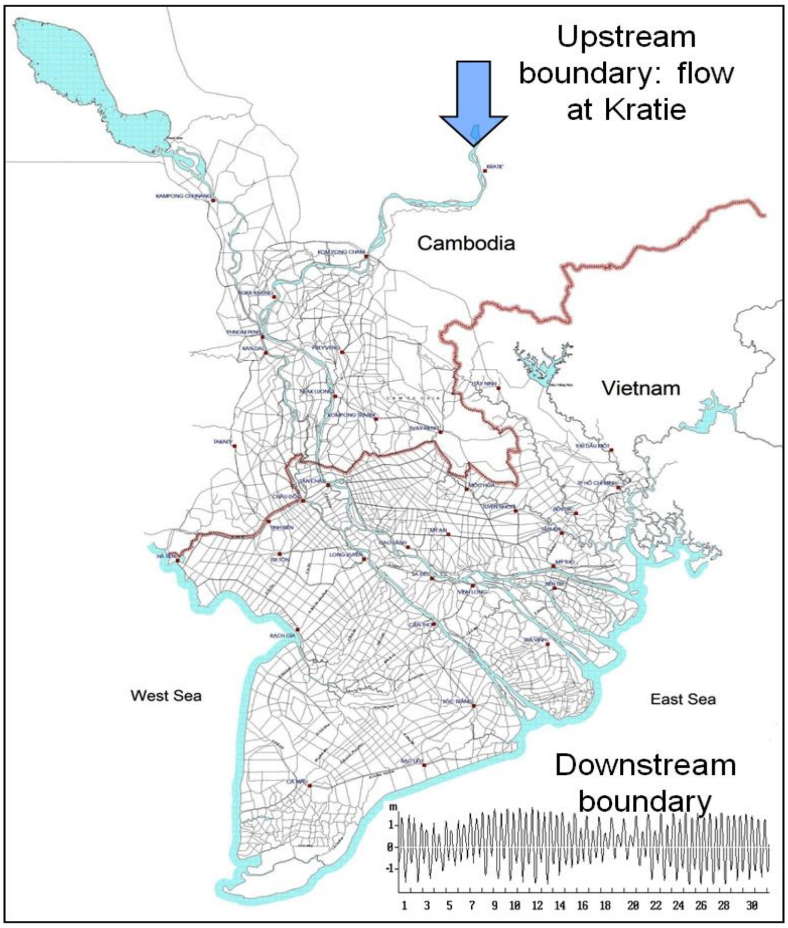

Fig. 3. Mathematical scheme of VRSAP.

5.3 Theme 2: Objective 2 (Stress-tolerant rice varieties) on improving salinity and submergence resilience of locally adapted rice varieties and elite lines

The strategy of germplasm development is to incorporate tolerances of specific abiotic constraints into locally adapted varieties and elite lines. This uses and transfers technology developed at IRRI, building capacity and setting in place the capability in Vietnam to rapidly introgress adaptive traits into future varieties and elite lines, in response to emerging threats. Objective 2 of Theme 2 employed the following approaches:

Marker-assisted backcrossing (MABC) for transfer of genes with tolerance of salinity (*Saltol*) and flooding (*SUB1*) and tolerance of anaerobic conditions during germination into locally adapted lines. The traits were transferred both separately and in combination.

Molecular approaches were implemented to select for the target loci (foreground), minimize linkage drag (flanking regions), and select for the background of the recurrent parents (background markers), which saves considerable time and results in the recovery of the genetic background adapted to the target environment.

Saltol was transferred into two Australian varieties (i.e., a temperate japonica background) and *SUB1* into a single Australian variety at IRRI. Broadly adapted Australian varieties were selected to receive the traits for direct variety improvement and to provide a repository of the traits in a temperate japonica background for future breeding.

Screening was conducted for the identification of donors for tolerance of partial stagnant flood to benchmark tolerance in existing traditional lines against current popular lines.

Local scientists received degree and non-degree training in MABC, both in-country and via exchange visits.

Activity 2.1 (Identify locally adapted varieties and elite breeding lines as recipients of *SUB1* and *Saltol).*

More than 200 landraces and current varieties were screened under anaerobic conditions, and promising lines identified. Then, F_2 populations between susceptible and tolerant lines were developed for QTL analysis.

Activity 2.2 (Generate and disseminate improved rice lines tolerant of temporary (complete) submergence through transfer of the *SUB1* gene into local popular varieties and newly developed elite breeding lines).

A total of 108 BC_3F_4 lines from the cross OM1490/IR64-Sub1 and 200 BC_3F_4 lines from the cross OMCS2000/IR64-Sub1 were genotyped for the presence of the *SUB1* QTL and tested under submergence stress to confirm the tolerance.

Activity 2.3 (Generating and disseminating improved rice lines tolerant of salinity through transfer of the *Saltol* gene into varieties of suitable maturity and adaptation, separately and in combination with *SUB1).*

Recipient lines identified: more than 100 BC_4F_3 lines have been selected from two backcross populations. *Saltol* was introgressed into two locally adapted materials from Vietnam and two to three varieties from Australia. These lines were genotyped for the *Saltol* QTL and screened under salinity at concentrations of EC = 8 and 15 dS/m.

Selected lines that matched the recipient parents were tested for release. Seed of BC_2F_4 populations was sent to Australia Plant Quarantine.

Activity 2.4 (Generating improved rice germplasm resilient to stagnant (partial) flood through further identification and development of germplasm tolerant of these conditions, and investigation of the physiological mechanism conferring adaptation).

Screening of germplasm: 100 landraces and 100 current varieties benchmarked.

Generating improved rice germplasm resilient to stagnant (partial) flood.

Testing of breeding lines under naturally occurring stagnant flood conditions: A total of 12 rice genotypes with a degree of tolerance of stagnant flood together with an additional farmer’s variety were evaluated in selected farmers’ fields in Hau Giang Province. Similarly, 12 stagnant-flood-tolerant rice genotypes and an additional entry of a farmer’s variety were evaluated in selected farmers’ fields in Can Tho.

Activity 2.5 (Exploring improvement of rice germplasm resilient to flooding during germination and early seedling establishment through investigation of tolerance of anaerobic conditions during germination).

A total of 14 rice varieties were tested with check variety IR64-Sub1. All experiments were evaluated in selected farmers' fields in An Giang Province.

About 20 submergence-tolerant and high-yielding genotypes along with two standard checks plus a farmer's variety were evaluated in this trial under naturally occurring stagnant and submergence conditions in farmers' fields in An Giang.

Each experiment was evaluated for agronomic traits, including days to heading, plant height, panicle length, and number of panicles per plant, percent sterility, grains per plant, 1,000-grain weight, and yield per plant.

Reaction to disease stress in the field was evaluated based on the standard evaluation system of IRRI, including brown plant-hopper, blast, stem borer, leaf blight, and rice tungro disease.

5.4 Theme 3: Objective 3 (NRM component): Managing resources for resilient rice-based systems coping with rapidly changing environments

Crop and natural resource management for CC adaptation were addressed by agronomic field trials in combination with process studies and modelling approaches. The promising technologies, including those involving non rice crops, were identified by participatory rural appraisal (PRA). When field trials produced acceptable results, these technologies were further tested by local farmers for wider dissemination. These steps are described in detail below.

Activity 3.1: Participatory rural appraisal

The PRA was carried out in the first year of the Project (2011) to investigate the prevailing cropping systems and resource profile of the target area of CLUES, how they were related, and to assess how cropping systems and management were affected by past extreme weather variability as well as farmers'/local authorities' strategies to cope with future climate change.

PRA surveys were carried out in the four target regions. In each region, two communes were selected; where one commune's biophysical conditions are unfavorable for agricultural production while the comparative site is a favorable one. In each commune, the PRA comprised two parts:

(i) Focus group discussions with local governments, extension workers, water users' associations, and irrigation water service providers.
(ii) General discussion with farmers, in groups or as individuals.

During these discussions, a series of questions were raised by project team members, with the aim of obtaining information and farmers' perceptions on (1) the baseline status of farming systems and yield gap analysis, (2) retrospective analysis of losses in rice production during years with climate-related extremes (drought, flooding, salinity), (3) assessment of agronomic vulnerability and adaptive capacity of rice-based farming systems, and (4) suggestions for strategies, what is needed to cope with increasingly unfavorable climatic events (i.e., possible climate change).

Activity 3.2: Field experiments

(i) Site selection and experimental design (derived from PRA)

Based on the PRA, constraints analysis and an experimental field program were conducted in each zone and this is generally described below (Tables 2 and 3). The cropping calendar at four study sites can be seen in Appendix 9.

Table 2. Climate change production threats identified by participatory rural appraisal for each ecological zone and season.

<table>
<tr><th>Ecological zone</th><th>Winter-spring (Dong Xuan) season</th><th>Summer-autumn (He Thu) season</th><th>Autumn-winter (Thu Dong) season</th></tr>
<tr><td>Deep flooded
(An Giang sites)</td><td rowspan="2">- Submergence (early season)
- Water scarcity (late season)
- Acidity</td><td rowspan="2">- Water scarcity (early season)
- Acidity
- Lodging</td><td rowspan="3">- Poor establishment (rain)
- Poor pollination (due to rain)
- Lodging
- Stagnation flood
- Submergence</td></tr>
<tr><td>Acid sulfate soil, intermediate flood
(Hau Giang sites)</td></tr>
<tr><td>Intermediate flood with alluvial soil
(Can Tho sites)</td><td></td><td>- Water scarcity (early season)
- Lodging</td></tr>
</table>

Saline zone (Bac Lieu, 3-rice system) (Bac Lieu, shrimp-rice system)	- Water scarcity - Salinity	- Salinity - Lodging	- Poor establishment (rain) - Stagnation flood
	(no rice)	*(no rice)*	- Poor establishment (rain) -Salinity at establishment - Salinity at end of season - Stagnation flood
All zones	- Low economic resilience (farms <1–2 ha) - Labor scarcity		

Table 3. Promising technologies to alleviate climate change production threats and related research questions in the Mekong River Delta (MRD).

CC-related production threats	Promising technologies	Related research questions in the MRD
Water scarcity	AWD, drought-tolerant variety	Is AWD safe in ASS and saline-risk soils? Can "safe AWD" maintain high yield and increase water productivity of winter-spring rice crop and farm productivity? How would P fertiliser be managed in AWD**?**
	Replace rice by upland crop	Technical and financial feasibility of introducing upland crop in rice system? How will these farm management changes affect acid sulfate soil properties?
Poor pollination; stagnation flooding and submergence (for Thu Dong crop, and He Thu for 2-rice crop)	Advance Autumn-Winter crop by replacing 3-rice systems with 2-rice + 1 upland crop	
	Advance Autumn-Winter crop by reducing fallow period after Winter-Spring and Summer-Autumn. Use stagnant flood- and submergence-tolerant varieties.	How to reduce drying period without rice burning (pollution) and not creating organic toxicity in rice plants?
Acidity	Reduce soil drying after Winter-Spring	
Lodging	AWD, Transplanting	How would AWD help reduce lodging? How can transplanting be done cost effectively vis-à-vis labor scarcity?

Salinity at establishment and near harvest (shrimp-rice system)	Enhance leaching, liming	Would land preparation and liming help leach salt from soil?
	Use short-duration rice. Use salinity-tolerant varieties.	What is the optimal (for rice and shrimp) date of rice seeding in combination with different maturity duration?
Low economic resilience	Diversification, intensification, lowering input costs, increasing yield	Do the CLUES farm management experiments reduce input costs and increase yield? How to increase annual productivity in 2-rice crops/year zones?

(ii) Site characterization

A soil survey was conducted at each site. Soil properties from each experimental field were monitored through routine biophysical analysis in the Soil Science Department at CTU. Weather and water conditions of the experiments were also monitored during the experiment. Methodologies for sample collection and analyses are reported in the final report of Theme 3.

(iii) Implementing field trials with promising rice varieties (from the MRD) and crop management strategies

Based on the PRA, an experimental field program was conducted in each zone and this is generally described below (Table 4).

Table 4. Experiments on integration of upland crops in rice-based cropping systems.

No.	**Field experiment**	**An Giang**	**Can Tho**	**Hau Giang**	**Bac Lieu**
Act. 2 a, b	Alternate wetting and drying and P reduction in triple- and double-rice production systems	x	x	x	x
Act. 2 c	Management of rice straw in acid sulfate soil			x	
Act. 2 d	Salinity management and use of short-duration varieties in shrimp-rice production systems				x
Act. 4	Insertion of upland crops into double-rice production systems	x	x	x	x

a. Is alternate wetting and drying suitable for acid sulfate and saline-risk soils?

Changed rainfall dynamics and SLR under CC will affect the salinity of the Mekong River in the dry season, thus further increasing water scarcity and the potential risk to production from drought.

Alternate wetting and drying (AWD) irrigation is a field water management technique developed by IRRI to improve water use efficiency in rice production. Most of the AWD field experiments that have been trialled successfully in non-saline soils have significantly decreased water use and increased farm profitability. Total water inputs (irrigation and rainfall) decreased by 15–30% without a significant impact on yield. In these studies, it was concluded that rice yield remained satisfactory if irrigation was re-supplied when the soil water tension was around –10 kPa or when the perched water table reached a threshold value of –15 cm below the soil surface.

Our experiments were implemented to investigate AWD-related questions listed in Table 2.

AWD experiments were conducted at all four sites (Table 3), in four cropping seasons during the first two years of the project. In these experiments, irrigation was applied in three treatments: (1) W1: Continuous flooding (CF): irrigate when the water level is at around 1 cm on the soil surface; (2) W2: AWD, irrigate when the water level percolates at about –15 cm; and (3) W3: AWD, when the water level is at –30 cm below the soil surface. In all water treatments, irrigation was applied to bring the field water level to 5 cm above the soil surface. Irrigation water was pumped from nearby canals.

Details of the field experimental design can be seen in Appendix 3, Theme 3 Final Report.

b. How would P fertiliser be managed in AWD and can P rates be reduced?

In the MRD, farmers have often applied very high P rates during rice production for three decades, mostly for a single crop of rice. Increasing to two or three rice crops per year recently might lead to a high substantial accumulation of P in the soil. Decreasing P fertiliser will directly improve farm profitability. However, the alternating REDOX conditions under AWD could affect soil P dynamics and subsequently yield. Understanding P dynamics under alternating REDOX conditions will also be beneficial to coping with CC, when drought stress may increase in frequency and intensity.

At each site, the effect of P rate was tested in combination with three levels of water management (W1, W2, and W3) as described above. Water management was the main plot factor. P rate was the subplot factor, ranging from 0 kg P_2O_5/ha to the farmers' practice, with one or two intermediate rates = half or a third of farmers' rates.

c. How to reduce drying period without rice burning (pollution) and not creating organic toxicity in rice plants?

The issue in Hau Giang Province is this long period of fallow, which causes soil drying and the burning of straw and stubble after REDOX increases acidity of the topsoil. Removal of the straw during fallow also results in increased soil evaporation, which brings acidity to the soil surface by capillary rise. If it is possible to reduce the fallow period between crops, it will be possible to move the crop forward by up to 3 weeks and potentially avoid flooding at the end of the He Thu season. The flooding risk has been predicted to increase with CC.

Residue management needs to be modified to enable shortening of the fallow period and maintenance of soil health.

Experiments on timing of seeding after plowing with the straw treatments (burning or incorporation or spraying rice straw and stubble with chemical *Trichoderma)* were carried out in Hau Giang Province before the summer-autumn crop in 2012 and 2013 at the CTU field station.

The two objectives addressed in the experiment were

- To identify the suitable fallow periods between the harvest of the previous crop and the establishment of the following crop.
- To identify improved straw treatments to facilitate rice growth and improve yield on acid sulfate soil.

The treatments were timing of seeding (1 day, 3 weeks, 6 weeks after plowing) and straw treatments (burning stubble, incorporation of rice straw, spraying the rice stubble with *Trichoderma)*. This experiment was carried out in Hau Giang Province during the SA crop in 2012 at a location near the CTU field station and again during the Summer-Autumn crop in 2013 at a new location.

d. How can productivity in shrimp-rice systems be improved with a high-yielding short-duration rice variety and enhanced salinity leaching?

Shrimp-rice cropping is an important production system in the coastal areas of the Mekong Delta. In this system, brackish-water shrimp are raised from January to August, when salinity in the field is >7 g/L. Rice is established in about mid-September.

More than 90% of the farmers grow traditional rice varieties that were harvested in mid-January. Late harvest exposes the rice crop to high salinity at the end of the rice season. Shortening rice growth duration could help minimize the risk of crop failure caused by salinity and shortage of irrigation water. Short-duration rice will also give farmers more time for them to grow shrimp, which brings the main income for farmers from the whole system.

Before rice crop establishment, farmers leach the residual salt on the field by rainwater and sometimes with irrigation. Reducing leaching duration could minimize the risk of drought and salinity when rice is established. The risk is aggravated with the anticipated sea-level rise and CC. There is a need to enhance the effects of leaching.

An experiment was carried out in Phuoc Long, Bac Lieu Province, with the overall objective of optimizing soil and crop management in a shrimp-rice cropping system to help farmers increase their income and their adaptability to possible sea-level rise and CC. We hypothesized that plowing and liming can enhance the effects of leaching before the start of the rice season.

Specific objectives include the following:

- To assess the possibility of introducing short-duration HYVs to replace the local traditional PS variety in the shrimp-rice system.

- To determine the effects of applying lime and plowing (solely and in combination) on soil salinity leaching and consequently on rice yield.

Activity 3.3: Process studies (pot experiments)

Stress responses in target regions through pot and column experiments (in Vietnam) and incubation studies (in Australia). A pot experiment was set up to assess the effect of different environmental stresses on element cycling and nutrient availability. Given the diversity of target areas, the pot experiment was designed as a site-specific trial under a range of environmental conditions (depth of flood and/or salt content) from the soil and plant(s). Measurements encompassed soil as well as plant parameters.

There were four process studies:

1. *Effect of salinity on carbon and nitrogen cycling*. Work was carried out in Australia. Soils from Australia were placed in incubation studies to assess the effect of salinity on carbon and nitrogen element cycling. Nitrous oxide, methane, and carbon dioxide measurements were made during the experiment.

2. *Effects of straw management on survival of IR64-Sub1 subjected to submergence at young seedling stage*. Alluvial soils with different residue treatments (no residue, Incorporation of burned residue, and Incorporation of fresh residue) from Omon were used to assess the survival of IR64-Sub1 seedlings (4 days) under submergence for a duration of 15 days.

3. *Enhancing salt leaching of shrimp-rice soil*. Soil columns were used to understand leaching processes and the effect of ameliorated techniques on salinized soils in shrimp-rice systems in Bac Lieu. The treatments were arranged in a randomized complete block, being seven combinations of (i) number of leaching, (ii) with and without lime, and (iii) with and without surface soil (0–5 cm) turnover (using a spatula). Further details are described in Phong N.H (2014).

4. *Soil P adsorption characteristics after seven crops at fixed P supply*. Soil samples at the end of each of the seven consecutive rice crops, from WS 2012 to WS 2014, in the P experiment in Bac Lieu (described in section iii b above) were taken to determine the maximum P adsorption. This determination aimed at elucidating how different P rate

application affects the amount of P adsorption, how much soils were buffered with P, and how long a reduced P application could be maintained without decreasing rice yield. Soil samples were equilibrated with phosphate solutions of known concentration for 24 hours at 20 ^{o}C. At the end of the process, the concentration of the phosphate remaining in the solution was determined. The quantity of P adsorbed per quantity of soil was calculated from the difference in phosphate concentration at the beginning and the end of the process.

Details of process studies can be seen in the Theme 3 Final Report.

Activity 3.4: Non rice crops in rice-based systems for climate change adaptation

Water shortage often occurs in the summer-autumn (SA) season in deep and medium flooded zones (An Giang, Can Tho, Hau Giang) and in the winter-spring (WS) season in saline-affected areas (Bac Lieu). The rice crop in the autumn-winter season is exposed to heavy rains during flowering, stagnant flooding at the latter stages of the crop in all zones, and submergence in deep-flooded zones. These climate risks will be aggravated in the foreseen CC.

We hypothesized that replacing one rice crop (WS rice in Bac Lieu or SA rice in other areas) with a short-duration upland crop would increase the economic resilience and CC adaptation via (i) increasing farmers' income, (ii) reducing the water requirement and hence the risk of water shortage in SA or WS seasons, and (iii) reducing the risks of partial flooding or submergence by advancing the establishment/harvest date of the SA cropping season.

A set of experiments (Table 5) was carried out to (i) explore the feasibility of an upland crop replacing SA rice in flooded zones and replacing the WS rice crop in saline-affected areas, (ii) quantify different upland crop management on crop performance and soil properties, and (iii) compare the economics of the triple-rice system vs the two-rice + upland crop system.

Table 5. Experiments on integration of upland crops in a rice-based cropping system.

	Bac Lieu (Lang Giai)	**Hau Giang (Vi Dong)**	**Can Tho (Thoi Tan)**	**Can Tho (CLRRI)**	**An Giang (Ta Danh)**
Cropping season with upland crop replacing rice	Winter-Spring 2011-12 and Winter-Spring 2012-13	Summer-Autumn 2012 and 2013	Summer-Autumn 2012 and Summer Autumn 2014	Summer-Autumn 2013	Summer-Autumn 2014
Upland crops tested	Soybean, mungbean, sesame, hybrid corn and pumpkin	Cucumbers and sticky corn	Sesame	Mungbean	Sesame, soybean, and sweet corn
Treatments of upland crops	N, P, K doses	Plastic cover, N fertiliser, and biological fertiliser (only in 2012)	Sesame varieties and fertiliser doses	P-fertiliser and residual effects of water management of the previous season	Crop varieties

Further details of the experiments are described in Chon et al (2015) and the Theme 3 Final Report (Appendix 3).

5.5 Theme 4: Objective 4 (Socioeconomic component): Analysis of farming systems and socioeconomic settings in rice farming households

The socioeconomic research theme in this project aimed to bring together a number of research components step by step as shown in Figure 4. Details of the methodology used in Theme 4 are referred to in Appendix 4 (the Theme 4 final report).

All aspects of the socioeconomic research will have a strong focus on stakeholder participation and look to include rice growers, researchers from both the wider project team and in-country institutions, and senior policymakers relevant to the research focus.

The socioeconomic baseline livelihood assessments (Act. 4.1) were conducted in the four study target areas (An Giang, Hau Giang, Can Tho, and Bac Lieu) in close consultation with Act. 3.1 (PRA) in 2011. Target communities (villages), social groups, and households, including representative farming systems, were identified through participatory community appraisals with agro-ecosystem analysis and wealth ranking.

The household survey was designed to assess the current status of (male-/female-headed) household livelihoods, problems/constraints, vulnerability factors, risks, and adaptation strategies of farmers (considering gender issues) to cope with problems/risks, giving more attention to weather variability/climate change (past, present, and future). Building on findings from the participatory community appraisals, household surveys were conducted by interviewing 480 households involved in major rice-based farming systems at eight study sites. In total, seven farming systems are considered: (1) double-rice cropping, (2) double-rice–fish integrated farming, (3) double-rice–upland crops rotational farming, (4) rice-shrimp rotational farming, (5) triple-rice cropping, (6) triple-rice–fish integrated farming, and (7) triple-rice cropping and upland crops. For each farming system at the respective study site, based on a list of households provided by commune officers or extension staff, farmers were randomly selected for interviews. Collected data include (1) the household's livelihood assets (human, natural, physical, financial, and social assets), (2) the communication pathway for accessing new farming technologies, (3) risk management strategies for natural hazards, (4) the household’s livelihood determinants and intents, and (5) farming inputs and outputs. In addition, gender issues in rice production and livelihoods were investigated with 205 male and female farmers involved. A pilot survey was carried out to finalize the questionnaire before full-scale surveys were conducted in all of the study communes

The sustainable livelihood and adaptation strategy assessment (Act. 4.2) used a self-assessment process for the impacts of extreme weather/hydrological changes on local farmers through focus group discussions (FGDs) (Roth et al 2009). It also explored the reactions to anticipated changes of local people and quantified the impacts of their strategies on representative farmers. Twenty-three local workshops at eight study sites were held to assess capacity and to identify the livelihood strategies of smallholders to adapt to climate change. Focus group discussions followed by individual in-depth interviews were conducted with a total of 233 participants involved. For each farming system per site, two groups—one with relatively larger farmers (>1 ha) and the other with relatively smaller farmers (<1 ha), with 7–15 participants per group—were interviewed. In addition, to investigate gender issues on adaptive capacity for climate change, three women’s groups, whose households practiced rice-based farming systems, at an unfavorable site in Hau Giang Province were invited to participate in the discussions. Local participants identified key indicators of their human, social, natural, physical, and financial assets that enabled or constrained their ability to manage their rice-based farming systems under climatic and non-climatic changes. They rated each indicator on a scale from 0 to 5 according to the degree to which the indicator was likely to be supporting adaptation in the future.

Policy and institutional arrangement analysis (Act. 4.3) employed stakeholder and institutional analysis for describing institutional structure (legal systems, policies, and organizational structure) and the external influencing factors at both national and local scales that enable the participants to improve their livelihoods and to adapt to past, present, and future weather variability/climate change.

To identify policy and institutional gaps in supporting the adaptive capacity of rice farmers, we collected information from eight local workshops (two workshops per province) with participants from the relevant sectors' officials (DARD, DONRE, DIT, and DOST), agricultural extension staff, community-based organization representatives at the district and provincial level, and service suppliers. In each workshop, we split the participants into two groups, one with governmental sector officials and another with extension staff, community-based organization members, and service suppliers. We applied PRA techniques to collect information from group discussions such as brainstorming, Venn diagram, and scoring.

We addressed the following four concerns:

(1) Important drivers and issues in developing the adaptive capacity of rice farmers in the present and future;

(2) Effectiveness, enablers, and constrainers of policy implementation in improving livelihood, particularly the capacity of farmers to adapt to climate change-induced effects;

(3) Policy and institutional gaps between the current stage and farmers' needs; and

(4) Relevant stakeholders and their roles in enhancing the adaptive capacity of rice farmers and in scaling out and scaling up promising technologies created from CLUES.

The fine-tuning of project-generated technologies (Act. 4.4) employed a participatory technology development approach (PTD) considering technological, socioeconomic, and environmental aspects, and suggestions for development and further improvement of selected technologies. This was accomplished during the course of the project (at the end of 2014 and the beginning of 2015) with close participation of local farmers, traders, extension workers, and government managers. For workshop assessments, the tested technologies were assessed through scoring the feasibility, in terms of technical, economic, social, and environmental aspects on a scale of 1 (low), 2 (medium), and 3 (high feasibility), and they were ranked in the order of importance or priority for out-scaling. Partial budgeting analysis was applied for assessing the economic viability of the tested technologies.

Possible extension pathways of research findings were explored (Act. 4.5) through regional workshops, printing materials/documents, public media, and training extension workers and potential farmers in four target areas in 2015. These workshops led to recommendations for scaling out research findings of the project to other areas. Given the feasible technologies of the project identified from the assessments, extension pathways of the technologies were determined through participatory impact pathway analysis (PIPA) (Douthwaite et al 2007). The PIPA was conducted with two local workshops in each province with participation of local stakeholders. The first workshop focused on problem analysis and stakeholder analysis and the second workshop addressed extension pathways and technology adoption by farmers, using an extension logic model and the ADOPT simulation model. Results of the extension logic model include technology extension methods and tools, target areas, target farmers, relevant stakeholders and their roles, and important assumptions.

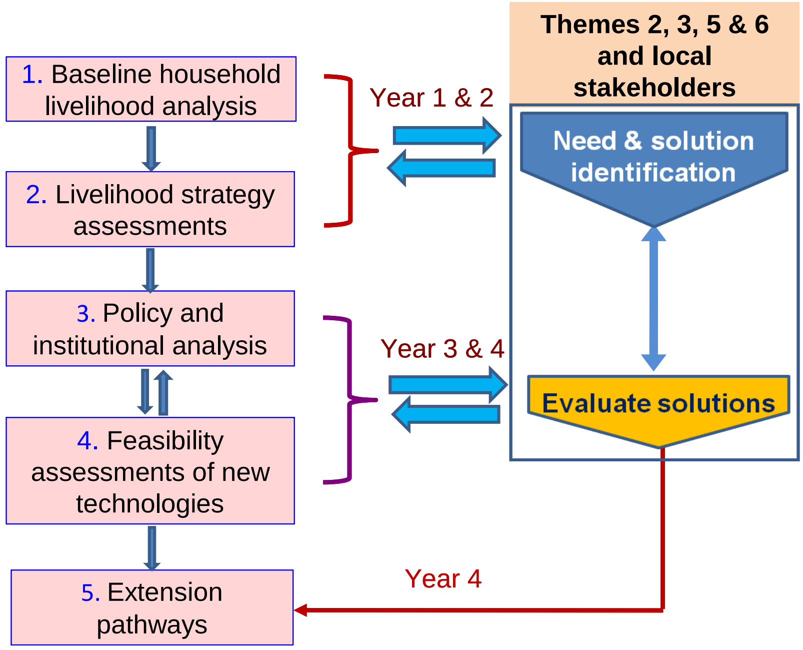

Fig. 4. Study framework of the socioeconomic team (Theme 4).

5.6 Theme 5: Objective 5 (Land use planning component): Integrated adaptation assessment of Bac Lieu Province and development of adaptation master plan

This study applied the Land Use Planning and Analysis System (LUPAS) methodology. (van Ittersum et al 2004) to examine the questions "what would be possible?" or "what would have to be changed?" in the analysis of different land use strategies under CC + SLR and socioeconomic conditions.

An interactive multiple-goal linear programming model (IMGLP) was developed in GAMS modelling language. The model allows interactively running a number of optimization scenarios. Figure 5 presents the model structure. The model has three main components: (i) biophysical land evaluation (BLE), (ii) socioeconomic analysis (SEA), and (iii) scenario analysis with IMGLP (SA).

The data were integrated and input into an IMGLP model (developed in GAMS software) for scenario analysis.

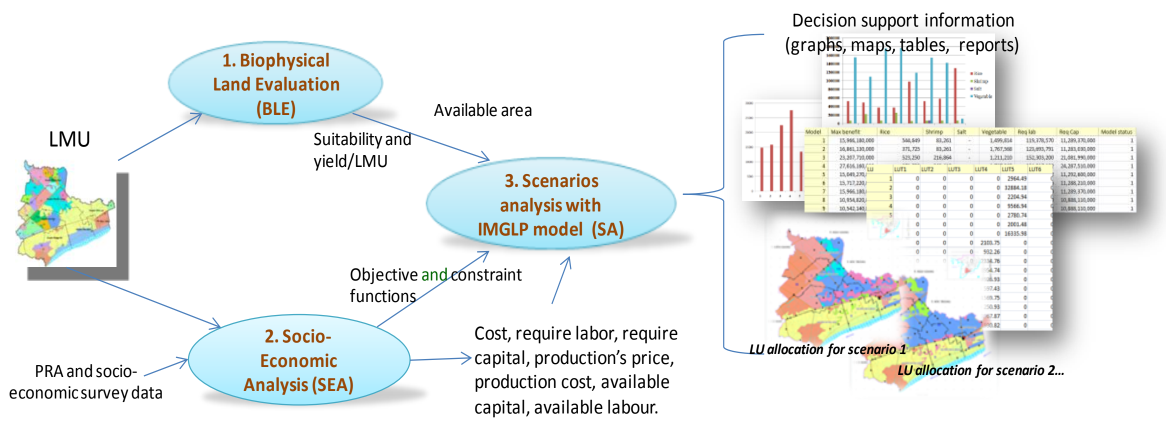

Fig. 5. The IMGLP model for land use adaptation strategy development.

Seven activities were defined for implementing the research:

In activity 5.1, the hydraulic model VRSAP (Vietnam River Systems and Plains, developed by the SIWRP) was calibrated and used to simulate the hydrology (water level, flow, salinity) under present conditions and different CC + SLR scenarios in three representative hydrological years based on flow from Kratie: (i) low water year (1998), (ii) average (normal) water year (2004), and high water year (2000). The model was also applied to analyze adaptation options (e.g., sluice operations and land use scenarios). Mapinfo software was used for the analysis of salinity intrusion and inundation boundaries under current and projected SLR + CC and sluice operations.

Activity 5.2 analyzed the impacts of potential improvements in hydraulic infrastructure using VRSAP. Information on water control infrastructure and its operations was collected at operation stations of the Water Resource Management Company in Bac Lieu and analyzed and reported.

Activity 5.3 (Fine-mapping of soils and current land use in Bac Lieu Province through remote sensing and ground-truth) used soil surveys and checking with recent satellite maps to update the current soils and land use map of Bac Lieu Province.

Activity 5.4 analyzed biophysical land suitability for rice-based land use systems under different SLR + CC and infrastructure development scenarios.

It determined resource availability (land area, water availability, soil and water qualities, labor, and capital), identifying promising land use types (LUT) and possible technical levels applied in each land mapping unit (LMU) at present and in the future.

Activity 5.5 interacted with stakeholder of all levels to identify socioeconomic constraints to the adoption of more resilient farming systems and to recommend institutional/policy changes.

This is linked with Act. 4.3 of Theme 4, which encompassed intensive stakeholder interactions through participatory workshops and policy recommendations in the case of Bac Lieu Province. (See detailed description of the method of Theme 4 in section 5.5 of this report.)

Activity 5.6 applied the IMGLP for land use planning and defining a master plan on climate change adaptation.

The objective functions in IMGLP were formed based on development targets such as rice production for food security and income per capita. In the study, the main development objectives proposed from the local stakeholders are to increase provincial benefits and to achieve the production targets (e.g., rice, shrimp). The constraints are land area that is suitable for each LUT (which varied with the biophysical conditions under CC and SLR scenarios), labor and capital availability, and market demand. Scenarios were built to explore future land use under changing biophysical and socioeconomic conditions or development goals.

During modelling work, meetings and workshops were organized to receive feedback from local stakeholders on the model results.

Activity 5.7 (Derive “lessons learned” from this case study for future development of adaptation master plans in other provinces). Through the scenario analysis (Activity 5.6), adaptive opportunities for Bac Lieu Province were established for different proposed land use maps corresponding to scenarios. The second-round modelling, including climate change impact analysis and adaptation strategies, was continued until August 2014.

See detailed method in Appendix 5 (the Theme 5 Final Report).

5.7 Theme 6: Objective 6: Capacity building for assessing GHG emissions

The emission theme was mainly conceived for capacity building, but still encompassed genuine research questions related to GHG emissions from rice fields under different technologies. Details of activities of the Theme follow:

Activity 6.1: Establishing a laboratory for gas analysis and training of researchers at CLRRI

An analytical lab for gas analysis was established at CLRRI. In the first year, the analytical operations of this new lab will be streamlined with the help of regular inter-calibration with the IRRI lab as a means of quality assurance.

Activity 6.2: Training in Theme 6 for researchers and students in flux sampling

Once the CLRRI staff were trained, they themselves trained others to set up and make flux measurements. To increase awareness of GHG emissions, CC, and emission mitigation, four workshops were held in the target zones.

Local staff were trained to do manual gas sampling of gas emissions (CH_4 and N_2O) deploying a “closed chamber” technique. Emissions measured in the project were sampled in field experiments implemented by Theme 3.

The project team conducted training courses and lectures on GHG emissions and mitigation strategies for students, researchers, and extension officers from CTU and other institutions in the MRD. These events used CLRRI facilities including dormitories. The project team also strived to incorporate students from CTU for thesis work. Students used lab facilities in their thesis work.

Activity 6.3: Conducting flux measurements

In the first 2 years, emission measurements were limited to the field sites of CLRRI and Hoa An station; emission rates were recorded at weekly intervals. Exploratory studies in Bac Lieu and An Giang followed in years 3 and 4 to allow comparative analysis. Gas samples were analyzed by gas chromatography, which was newly established in the gas chromatography lab. Gas samples from other target areas were shipped to CLRRI in air-tight vessels and were analyzed within a 24-hour period after sampling.

Activity 6.4: Assessing gaseous C and N emissions for a comprehensive analysis of element cycling and budgets

Greenhouse gas emissions were measured from samples in each of the four agro-ecological zones and were used to examine the mitigation potential of AWD, tillage, and residue management. Statistical analyses of data were performed by SAS 9.1 (SAS Institute 1988).

Activity 6.5: Deriving emission factors and spreadsheet tools from field data for quantifying GHG emissions in rice systems of the MRD

A spreadsheet tool was developed to allow the calculation of gas emissions from the concentrations of the collected gas samples using linear regression. The spreadsheet tool corrects the data for pressure and temperature effects, and instrument calibration, and performs and assesses the linear regression. Emission factors were developed for each agro-ecological zone.

See detailed method in the Theme 6 Final Report (Appendix 6).

5.8 Theme C: The Project Office: Coordination and integration

Theme C was established to create a sound infrastructure for all project activities, to ensure internal and external communication flows, to supervise progress of activities, to organize in-country training, seminars, forums, and workshops, and to establish linkages and partnerships with local governments, nongovernment organizations, private entities, and international institutions with similar programs on climate change (CC) within the Mekong River Delta (MRD).

Activity C.1: Creating sound logistics in the Project Office and target areas, establishing efficient administrative procedures, and organizing regular project meetings

To facilitate the activities of the project, the Project Office (PO) was established in Can Tho University (CTU). The PO facilitated the organization of the operational team composed of the national project director, national project coordinator, IRRI project facilitator, project assistant, theme leaders, and representatives from Provincial Departments of Agriculture and Rural Development of An Giang, Can Tho, Hau Giang, and Bac Lieu provinces. Project staffs were hired for the project assistant and routine operations were established for the whole of the CLUES project.

Themes were supported by international consultants from IRRI, CSIRO, IWMI, and ACIAR. Their activities had been coordinated through several operational team meetings, regular meetings of six theme leaders and members, training, field visits, and technical advice during its second year of operation. The operational meeting (OM) was organized in the PO bimonthly.

Activity C.2: Generating efficient pathways of information fluxes for internal purposes and public visibility

These activities were carried out by establishing a home page for CLUES, creating Dropbox and Google accounts for file sharing among team members, and writing frequent news articles in the IRRI Bulletin, ACIAR newsletter, and IRN Asia news.

The project coordination team applied up-to-date Internet technologies to establish a project home page separated into internal access for data exchange and communication as well as public access for high visibility of the project. The private area was used as the central information and communication platform, which provided ample space for exchange of data, ideas, and results. Access to the intranet for posting and updating information was granted to all groups involved in the project.

The public area contained all relevant information, including, among others, manuscripts and the latest publications of the project, information about upcoming meetings and educational programs, meeting reports, lists of methods and techniques available within the project, and links to relevant websites.

Activity C.3: The progress of individual tasks and the performance of project-derived adaptation packages to define eventual adjustment of activities were monitored by regular operational meetings, regular field monitoring and evaluation, and a semi-annual and annual project review.

Activity C.4: The relevance of project findings for other rice production environments, in particular, for other regions in Vietnam and for the Australian rice industry. This was comparatively assessed by stress-tolerant rice and best management practices developed and identified in the locality. Rice genotypes provided by international counterparts; this was carried out by Themes 2 and 3.

Activity C.5: Reporting and publications were carried out by a team through organizing semi-annual and annual technical and financial reports. The PO also wrote frequent news articles in the IRRI Bulletin, ACIAR VN, and IRN Asia news, plus publications in refereed journals.

6 Achievements against activities and outputs/milestones

Theme 1: Location-specific impact and vulnerability assessment

Act. 1.1. Literature review and meta-analysis of available data and documents on CC projections for MRD to identify potential production constraints to future production

No.	Activity	Outputs/ milestones	Scheduled completion date	Comments
1.1.1	Review existing and ongoing studies on CC projection for Mekong river, especially upstream boundary and SLR	Collecting and reviewing studies in MRD region (SIWRP)	2/2012	Done as planned
1.1.2	Review projected data (temperature and precipitation) of the Mekong Delta based on projected data of PRECIS	Projection data	2/2013	1 year later than as planned because of the study on simulated downscaling data on climate change in Vietnamese MRD. They are also input data of VRSAP
1.1.3	Adjust projected data from Regional Climate Model for hydraulic calculation	Adjusted data	2/2013	As above

Act. 1.2. Assessing hydrological impacts of different sea-level rise scenarios in MRD region (hydraulic modelling)

No.	Activities	Outputs/milestones	Scheduled completion date	Comments
1.2.1	Collecting and processing hydro-meteorological data, sluice operation schedule, and land use for baseline year 2008 and for three years of 1998 (dry year—low water), 2004 (normal year—average water), and 2000 (wet year—high water)	Data for 1998, 2004, 2000	2/2012	Completed as planned
1.2.2	Field surveys for checking existing data on land use, sluice operation, and other infrastructure		10/2011	Completed 4 months later than planned
1.2.3	Establishing projected scenarios, based on SLR scenarios (MONRE 2012).	Set of projected scenarios for SLR	8/2011	Finished as planned

1.2.4	Simulating salinity and flooding depth for recent year 2008 with current land use and sluice operation. Analysing results of simulation and writing report.	Result maps of salinity and flooding	12/2011	Finished 2 months later than planed
1.2.5	Simulating salinity and flooding depth for projected scenarios in normal, wet, and dry years with current land use and sluice operation. Analysing results of simulation and writing report.	Result maps of salinity and flooding	9/2011-6/2012	Finished in 4/2013, late due to waiting for simulated downscaling data on climate change in Vietnam MRD. They are also input data of VRSAP.

Act. 1.3. GIS mapping of flooding depth and salinity levels within the MRD as a function of sea-level rise and envisaged upstream development projects for different land use options

No.	**Activities**	**Outputs/milestones**	**Scheduled completion date**	**Comments**
1.3.1	Applying VRSAP model for different land use options for dry year (1998), normal year (2004), and wet year (2000) at different SLRs and upstream development. Analyzing results of simulation and writing report.	Result maps of salinity and flooding	12/2013	Finished as planned

Act. 1.4. Comparative assessment of CC impacts on rice production in the four target areas (An Giang, Can Tho, Hau Giang, and Bac Lieu)

No.	**Activity**	**Outputs/milestones**	**Scheduled completion date**	**Comments**
1.4.1	Finding out the trend of yield, productivity, and area changing from 2000 to 2010	Report	3/2014	Completed
1.4.2	Developing rice cropping pattern maps	Series of result maps	3/2014	Completed
1.4.3	Overlay rice cultivation map of each province with different sea-level rise, depth, and salinity scenarios to find out the effect of CC on rice production in four target areas	Time series of mapped hydrological conditions	4/2014	Completed for the entire Delta so that information for target areas can be derived from there
1.4.4	Field survey for checking the specific threats in the four target areas	Time series of mapped hydrological conditions	5/2014	Completed for the entire Delta so that information for target areas can be derived from there
1.4.5	Assessment of common and specific threats in each target area	Comprehensive report on common and specific threats in each target area	6/2014	Completed for the entire Delta so that information for target areas can be derived from there

Act. 1.5. Mapping (delta-wide) of vulnerability and potential "hot-spots" of flooding and salinity damage

No.	Activity	Outputs/milestones	Scheduled completion date	Comments
1.5.1	Collecting satellite images (MODIS images from 2000 to 2010)	Set of 1,082 MODIS images	2/2013	Incorporated into detailed land use map
1.5.2	Developing set of NDVI maps from 2000 to 2010 Initial rice sowing map in Mekong Delta	Set of 920 NDVI maps	4/2013	Incorporated into detailed land use map
1.5.3	Investigate current land use and time of rice sowing in Mekong Delta	List of data for validation	1/2014	Completed as planned
1.5.4	Overlay current land use map of MRD with maps of water depth and salinity under different CC and SLR scenarios	GIS map on risks completed	1/2014	Completed as planned
1.5.5	Mapping of vulnerability and potential "hot-spots" according to different scenarios	GIS map on risks completed	4/2014	Completed in 2015

Theme 2: Improvement of salinity and submergence resilience of locally adapted rice varieties and elite lines

Act. 2.1. To transfer the SUB1 *QTL into adapted germplasm*

No.	Activity	Outputs/ Milestones	Scheduled completion date	Comments
2.1.1	Identify locally adapted varieties and elite breeding lines as recipients of *SUB1*	Recipient lines identified	April to August 2011	Completed as planned
2.1.2	Generate and disseminate improved rice lines tolerant of temporary (complete) submergence through transfer of the *SUB1* gene into local popular varieties and newly developed elite breeding lines	*SUB1* introgressed into two locally adapted materials from Vietnam and one variety from Australia	March to December	Completed as planned
2.1.3	Backcross *SUB1* into Australian rice genetic background	Backcross populations produced and selected	April 2015	Seed of BC_2F_4 populations sent to Australia Plant Quarantine

Act. 2.2. To improve tolerance of partial stagnant flood

No.	Activity	Outputs/ Milestones	Scheduled completion date	Comments
2.2.1	Screening of germplasm	100 landraces and 100 current varieties benchmarked	December 2013	Three landraces demonstrated good survival and recovery-stage growth in Mot Bui Do, Tep Hanh, and Tai Nguyen Duc. Also, three improved varieties (OM10252, OM3673, and OM10276) had good survival and recovery.
2.2.2	Generating improved rice germplasm resilient to stagnant (partial) flood	Testing of breeding lines under naturally occurring stagnant flood conditions	March 2015	A total of 12 rice genotypes with some tolerance of stagnant flood together with an additional farmers' variety were evaluated in selected farmers' fields in Hau Giang Province. The farmers preferred five varieties (OM7347, Can Tho 2, Hau Giang 2, Can Tho 3, and OM6L) and three of these are already included in seed multiplication in 2014. Similarly, 12 stagnant-flood-tolerant rice genotypes and additional entries of farmers' varieties were evaluated in selected farmers' fields in Can Tho.

Act. 2.3. To investigate anaerobic germination

No.	Activity	Outputs/ milestones	Scheduled completion date	Comments
2.3.1	Screening of germplasm	Landraces and current varieties tested for tolerance of anaerobic germination	May 2012	More than 200 landraces and current varieties were screened under anaerobic conditions, and promising lines identified.
2. 3.2	Exploring the genetic basis of tolerance of anaerobic conditions during germination to facilitate improvement	F_2 populations between susceptible and tolerant lines were developed for QTL analysis	May 2014	Two significant QTLs associated with the AG trait were detected from cross Tai Nguyen/Andabyeo. They were located on chromosomes 1 and 11, respectively. In particular, the QTL on chromosome 1 had an LOD score of 7.45.

Act. 2.4. To transfer salinity tolerance into adapted germplasm

No.	Activity	Outputs/ Milestones	Scheduled completion date	Comments
2.4.1	Identify locally adapted varieties and elite breeding lines as recipients of *SUB1* and *Saltol*	Recipient lines identified	April to August 2011	Completed
2.4.2	Generating and disseminating improved rice lines tolerant of salinity through transfer of *Saltol* gene into varieties of suitable maturity and adaptation, separately and in combination with *SUB1*	*Saltol* introgressed into two locally adapted materials from Vietnam and two to three varieties from Australia	April 2015	More than 100 BC_4F_3 lines have been selected from two backcross populations: OM1490*4/Pokkali and OMCS2000*4/Pokkali. These lines have been genotyped for the *Saltol* QTL and screened under salinity at concentrations of EC = 8 and 15 dS/m. Selected lines that match the recipient parents can be tested for release.
2.4.3	Backcross *SUB1* into Australian rice genetic background	Backcross populations produced and selected	April 2015	Seed of BC_2F_4 populations sent to Australia Plant Quarantine

Theme 3: Managing resources for resilient rice-based systems coping with rapidly changing environments

Act. 3.1. To identify climate change-related stresses that will affect future production

No.	Activity	Outputs/ Milestones	Scheduled completion date	Comments
3.1.1	Participatory rural appraisal (PRA) for constraint analysis of cropping systems and identifying promising solutions for CC adaptation	CC-related stresses identified by constraint analysis	Mar. to Dec. 2011	Salinity and flooding are mostly identified stresses; besides that, AS is also the problem at the Hau Giang site.
		Promising solutions to CC-related stresses	Dec. 2011-Aug. 2013	Promising technologies proposed and being tested by experiments
3.1.2	Literature review of relevant research issues and testable hypotheses	Literature reviews completed and submitted	Mar. 2012-Aug. 2013	Two literature reviews on salinity and flooding affecting rice cultivation were reported
		Research proposal for each site completed and submitted	Aug 2011 - Dec 2013	Protocols were submitted before starting each experiment

Act. 3.2. To develop, test, and refine management options for different agro-ecological zones

No.	Activity	Outputs/ Milestones	Scheduled completion date	Comments
3.2.1	Field experiments (a) Site selection and characterization	Testing in villages and fields identified in different agro-ecological zones.	Mar. 2012	Completed as planned
		Experimental fields characterized	Mar. 2013	Completed as planned
	(b) Designing experiments	Experimental design completed for all four target zones	Aug. 2012	Completed as planned
	(c) Implementing experiments	Experiments in each of the target zones (BL, AG, HG, CT) started and completed	Sep. 2014	Completed as planned
3.2.2	Training on soil and water sampling and statistical design	Training workshop	Mar. 2012	Completed as planned
3.2.3	Soil and plant samplings and analyses	Data on soil and plant analyses for the trial crops in the first to fourth years	Dec. 2014	Completed as planned

Act. 3.3. To improve understanding of element cycling, soil-plant, and cropping system responses caused by the different management options

No.	Activity	Outputs/ milestones	Scheduled completion date	Comments
3.3.1	Processing studies on stress responses in target regions through pot experiments and column experiments	(a) Initial scoping document for process-based studies. Identification of key stressors and processes. (b) Review of experimental design. Inputs required from all participants. (c) Design column and pot experiments.	Mar. 2014	(a) Scoping document completed. (b-c) Mr. Minh has been awarded a John Alright Fellowship and will research nitrogen and carbon emissions using pot experiments. (c) Pot and column experiments on residue management and salt leaching, respectively, started and completed.

Act. 4. To assess the role of non-rice crops in rice-based systems for climate change adaptation

No.	Activity	Outputs/ milestones	Scheduled completion date	Comments
3.4.1	Selection of stress-tolerant upland species and testing them in rice-based systems	- Experimental designs and land preparation for field experiments - Assessment of integrating upland crop in rice-based systems	Jan. 2012-May 2013	Experiments were carried out in all target zones.
3.4.2	Field trials for transferring identified techniques to the farmers		Jan.-May 2014	In Hau Giang and Can Tho, it was possible to insert two cucumber (or sesame) crops in Summer-Autumn for increasing economic resilience of farmers.

Theme 4: Analysis of farming systems and socioeconomic settings in rice farming households

Activities	Sub activities	Outputs/milestones	Scheduled completion date (mm/yy)	Comments
4.1. Baseline livelihood assessments	- Participatory community appraisals on bio-physical and socio-economic constraints at community level - Household surveys on livelihoods - Household surveys on gender issues	- Well-trained team members with methods and skills of data collection - Identification of problems and constraints of physical and socio-economic setting at different levels and with different options - Roles and needs to enhance capacity of women to adapt to climate change	Mar. 2013	- Completed - Inputs to activities 4.2, 4.3, and 4.4, and themes 2, 3, and 5 - Manuscripts for publication in preparation
4.2. Sustainable livelihood and adaptation strategy assessments	- Self-assessment workshops with farmer groups in each study zone Through group discussions and in-depth interviews	- Well-trained team members with methods and skills of data collection - Identification of enablers of and constrainers to adaptability by households	Mar. 2013	- Completed - Inputs to activities 4.3 and 4.4 and themes 2, 3, and 5 - A manuscript for publication in preparation
4.3. Policy and institutional analysis	- Organize local workshops with participation of local extension staff, government officials, and	- Identification of policy and institutional gaps that influence capacity of farmers	Sep. 2014	- Completed - Inputs to activities 4.4 and 4.5

	service suppliers	and adoption of new technologies by farmers - Identification of opportunities for mainstreaming climate change adaptability measures into local and national development programs		
4.4. Participatory fine tuning of project-generated technologies and assessing benefits in terms of adaptive capacity	- Participatory evaluation of on-farm-tested rice varieties (PVS) - Feasibility assessments of on-farm-tested rice farming technologies with local stakeholders	- Agronomic criteria expected by farmers for future rice varieties by zone - Feasibility rank of tested technologies by zone - Improved management practices for new adaptation technologies in line with farmers' requirements	Sep. 2014	- Completed - Inputs to activity 4.5 and themes 2, 3, and 5; - Improved management practices for new technologies not achieved due to limited time
4.5. Explore possible extension pathways of research findings of the project	- Training and workshops with local stakeholders and project researchers on impact pathway and extension pathway analysis of CLUES' promising technologies - Simulation of adopting feasible technologies by farmers by zone	- Well-trained extension staff with impact pathway and extension pathway analysis methods - Identification of ways and options and recommendations for out-scaling and up-scaling of feasible technologies	Nov. 2014	- Completed - Feedback to activities 4.1, 4.2, 4.3, and 4.4 and themes 3 and 5.

Theme 5: Integrated adaptation assessment of Bac Lieu Province and development of adaptation master plan

No.	Activity	Outputs/ Milestones	Scheduled completion date	Comments
5.1	Fine mapping of salinity borders in high spatial and temporal resolution in different sections of Bac Lieu Province under current and projected sea level and sluice operations	GIS maps of salinity and flooding in scenarios: dry year (1998), normal year (2004), wet year (2000); dry, normal, and wet years + future CC + SLR + sluice gates operation schemas.	Mar. 2012	Completed as planned.

5.2	Determining the benefits from potential improvements in infrastructure (sluice and dike system) in terms of salinity and flooding risks	Report on the existing water management infrastructure and its operational schemas.	Mar. 2012	Completed as planned.
5.3	Mapping of soils and current land use in Bac Lieu	Updated GIS maps of soil, land use, and land mapping unit of Bac Lieu Province	June 2012	Completed as planned.
5.4	Analyze biophysical land suitability for rice-based land use systems under different CC, SLR, and infrastructure development scenarios	GIS maps on land suitability and descriptions (present and future scenarios of SLR + CC + sluice gates operation schemas)	Mar. 2013	Completed as planned.
5.5	Identify socioeconomic constraints to the adoption of more resilient farming	- Five workshops with policy and institutional stakeholders in Bac Lieu Province - A report on socioeconomic constraints of current agricultural land use patterns in Bac Lieu Province	Aug. 2013	Completed as planned.
5.6	Apply multiple-goal linear programming for land use planning and define a master plan on climate change adaptation	Optimized adaptation of land use options at provincial scale for different scenarios (biophysical and socio-economic constraints, development goals, and adaptation options)	Dec. 2014	Completed as planned.
5.7	Derive “lessons learned” from this case study for future development of adaptation master plans in other provinces	- Six scientific papers (5 in Vietnamese, 1 in English), one national work presentation, and one international workshop presentation. - Three training courses (40 participants, 15 females) with guidelines and tools available for developing adaptation master plans in other provinces of the MRD. - Three workshops with policy and institutional stakeholders.	April 2015	Completed as planned.

Theme 6: Capacity building for assessing greenhouse gas (GHG) emissions

Act. 6.1. Establishing a lab for gas analysis and training of researchers at CLDRRI

No.	Activity	Outputs/ Milestones	Scheduled completion date	Comments
6.1	Establishing a lab for gas analysis and training of researchers at CLRRI for GC operation, maintenance, and use of PeakSimple software for GHG analysis	Routine operations for efficient gas analysis (incl. calibration and accuracy cross-checks)	30 September, 2011	-GC lab upgraded and equipped with air conditioner to maintain room temperature at 25 °C. -Seven researchers at CLRRI are able to operate GC for GHG analysis. -20KVA UPS was also installed for GC operation continuously. -Dehumidifier was equipped to maintain RH at 60%.

Act. 6.2. Training of researchers and students in flux sampling at all benchmark sites

No.	Sub activities	Outputs/ Milestones	Scheduled completion date	Comments
6.2.1	Training of researchers and students in flux sampling at Hue University	First training course for two researchers of CLRRI and two lecturers of Can Tho University	4 June 2011	Three-day training course organized at Hue University.
6.2.2	Training on GC principle and GHG analysis	Second training course for CLRRI, Can Tho University and An Giang and Vinh Long extension staff	23-25 November 2011	Three scientists from CLRRI and 14 from Can Tho University will conduct Theme 3 experiments at four benchmark sites.
6.2.3	Training on flux sampling by closed chamber method	Third training course for students of An Giang, Cuu Long, and Can Tho Universities	4-5 May 2012	Two-day training on closed chamber fabrication and flux sampling for 16 students.
6.2.4	Flux sampling by closed chamber method	Fourth training course for six extension staff of Tra Vinh Province	16 November 2012	CLUES project supports GIZ Tra Vinh to evaluate GHG emissions from paddy rice under SRI model and farmers' routine practice method.
6.2.5	Flux sampling by closed chamber method	Fifth training course for seven extension staff of Long An Province	7 March 2013	CLUES project supports WINROCK Long An to evaluate GHG emissions from paddy rice under SRI model and farmers' routine practice method.

6.2.6	Workshops in Soc Trang, Vinh Long, and An Giang on GHG emissions from rice	79 extension workers participated	May-June 2014	Theme 6 in cooperation with the national project BĐKH.2014.57 on "Rational use of acid soils for CC adptation" and Provincial Extension Center.

Act. 6.3. Conducting flux measurements

No.	**Sub activities**	**Outputs/ Milestones**	**Scheduled completion date**	**Comments**
6.3.1	Conducting intensive flux measurements at CLRRI to study effects of cultivation methods on GHG emissions	Baseline emissions from Can Tho site. Cultivation methods and effects on GHG emissions.	Winter-Spring 2012-13	Can Tho site (shallow flooded alluvial soil)
6.3.2	Conducting intensive flux measurements at CLRRI to study effects of water management and fertiliser/manure on GHG emissions	Baseline emissions from Can Tho site. Water management and fertiliser/manure effects on GHG emissions.	Winter-Spring 2012-13	Water management on experimental plots could not be done properly in Mekong Delta soil because of high percolation and leaching.
6.3.3	Conducting intensive flux measurements in Hau Giang and An Giang	Baseline emissions at An Giang and Hau Giang sites	Summer-Autumn 2013	Hau Giang (acid sulfate soil) and An Giang (deep flooded alluvial soil)
6.3.4	Conducting intensive flux measurements in Bac Lieu	Baseline emissions in Bac Lieu	Summer-Autumn 2014	Lang Giai-Bac Lieu (salt-infected soil)

Act. 6.4. Assessing gaseous C and N emissions for a comprehensive analysis of element cycling and budgets

No.	**Activity component**	**Outputs/ milestones**	**Scheduled completion date**	**Comments**
6.4.1	Conducting intensive flux measurements on shrimp-rice cropping system in Bac Lieu	Baseline emissions from saline soil in Bac Lieu	Autumn-Winter 2013	Phuoc Long-Bac Lieu (saline soil)
6.4.2	Conducting intensive flux measurements on SRI model in Tra Vinh Province	Baseline emissions in Tra Vinh	Winter-Spring 2012-13	Tieu Can and Cau Ke districts-Tra Vinh (alluvial soil)
6.4.3	Conducting intensive flux measurements on SRI model in Long An Province	Baseline emissions in Long An	Summer-Autumn 2014	Tan Thanh and Chau Thanh districts-LA (acid soil)
6.4.4	Conducting intensive flux measurements on cropping systems at Can Tho site	Baseline emissions from R-R-R/R-mungbean-R or R-R-R/R-sesame-R	Summer-Autumn 2014	Thoi Lai District-Can Tho (shallow flooded alluvial soil)

Act. 6.5. Deriving emission factors and spreadsheet tools from field data for quantifying GHG emissions in rice systems of the MRD

No.	Sub activities	Outputs/ milestones	Scheduled completion date	Comments
6.5.1	Calculation of C and N cycling and budget for pilot study in Soc Trang	GHG emissions and C and N budget in Soc Trang	Dec. 2014	One MSc thesis from Can Tho University

Theme C: Coordination and integration

Activity	Outputs/ milestones	Scheduled completion date	Comments
1. Creating sound logistics in PO and target areas, establishing efficient administrative procedures, and organizing regular project meetings	Established Project Office and hired project staff. Organized operational team. Conducted routine operations in PO and in target areas.	July 2011-Sep. 2011	The database manager and the documentation and dissemination manager were hired from CTU.
2. Generating efficient pathways of information fluxes for internal purposes and public visibility	Home page established. Dropbox and Google account file sharing established. News articles in IRRI Bulletin, ACIAR newsletter, and IRN Asia news published.	Nov. 2011-June 2012	Technical references available from CLUES project: - As of this date, the PO has 210 technical reference materials of all kinds, including electronic files. Exchange data and information: • CLUES webpage at CTU: http://websrv.ctu.edu.vn/news_det.php?mn=4&id=619 • CLUES webpage at IRRI: http://irri.org/our-science/climate-change/climate-research/clues-project • Google file sharing: https://sites.google.com/a/irri.org/clues-file-sharing/home?pli=1 • Dropbox with e-mail: Cluesproject@yahoo.com • Data, reports, and other documents received from different themes
3. Monitoring progress of individual tasks and the performance of project-derived adaptation packages to define eventual adjustment of activities	Regular operational meetings. Regular field monitoring and evaluation. Semi-annual and annual project review. Capacity building.	Nov. 2011-June 2015	• 25 technical staff of CLUES project from Cuu Long Delta Rice Research Institute (CLRRI) and Can Tho University (CTU) participated in the training workshop on economic, social, and environmental assessments of new

			technologies. • Four operational meetings and 15 individual meetings of themes and international consultants to strengthen activities of CLUES. • 18 field visits with theme leaders, theme members, and ICs at four target study sites in four provinces.
4. Assessing the relevance of project findings for other rice production environments, in particular, for other regions in Vietnam and for the Australian rice industry	Stress-tolerant rice and best management practices developed and identified in the locality	Jan. 2012-June 2015	Rice genotypes provided by international counterparts. This is being carried out by Themes 2 and 3.
5. Reporting and publications	Semi-annual and annual technical and financial reports. News articles in IRRI Bulletin, ACIAR VN, and IRN Asia news. Publications in refereed journals.	Oct. 2011-June 2015	Scientific reports of themes in August 2012 and March 2013. Semi-annual and annual reports of themes, including financial reports. Ten news articles published.
6. Completion activities in no-cost extension duration	Publication, Internal Review and local workshops and reports	July-Sept 2015	- 10 leaflets, 3 books, 6 final theme reports and 1 synthesis final project report finished. - 2 CTU staffs was promoted as Assoc. Professors - 8 local workshops of internal review and evaluation organized at four provinces - The report on internal evaluation of performances of CLUES themes
7. Policy, planning and investment implications workshops	Workshops for stakeholders at National and District levels in Hanoi and Can Tho	Sept. 2015	Workshops successfully conducted

7 Key results and discussion

The details of the final reports of the six themes appear in Appendix 1 to 6. Below is a compilation of short narratives of accomplishments of the different themes.

Theme 1: Geo-spatial component

Some key results and discussion

In Theme 1, we conducted a wide range of scenario analyses that produce a highly differentiated and complex setting for our results:

1. SLR baseline plus 2 different SLR scenarios (15 and 30 cm) with and without Climate Change
2. River discharge baseline plus discharge reduction scenario
3. all SLR scenarios have been simulated for years with high, medium and low water levels; the river discharge scenario has only been simulated for the year with low water level

Thus, we are unable to show ALL maps/ scenarios of this study, but limit this report to the highlights. In a nutshell, the hydrological scenario analysis revealed the following:

- CC and SLR impacts on flood-related stress are more pronounced than on salinity stress.
- CC and SLR impact on flood-related stress:
    - Partial stagnant flood will become more prevalent.
    - It will be more pronounced in Ca Mau Peninsula than in the current flood-risk zone.
    - It will negatively affect rainy-season crops (Summer-Autumn and Autumn-Winter crops).
- CC and SLR impact on salinity-related stress:
    - Higher salinity and longer duration will occur in 9% of the currently salinity-intruded area.
    - It will be more pronounced in the main Mekong estuaries along the East Sea.
- Not all CC and SLR impacts are negative. SLR will facilitate freshwater accessibility and support gravitational irrigation.
- Adaptation to CC and SLR requires both “hard” and “soft” strategies. Climate-smart agriculture plays a central role.

1. Hydrological characteristics of the Mekong Delta in present situation (baseline)

Figure 6 indicates the differences of maximum salinity of channel salinity that existed among the simulated salinity intrusion in areas in the MRD for 3 years of low, average, and high water. In areas that have a salinity control system such as Quan Lo–Phung Hiep (QLPH), Lower U Minh, South Mang Thit, and Go Cong, the difference in salinity is generally insignificant.

Figure 7 shows the flood-risk depth (maximum channel water level above the average ground) increased in the year of high water and decreased in the year with low water. The flood-risk depth was most significant in upstream areas of the MRD (near the border with Cambodia). Coastal areas such as Ca Mau Peninsula were minimally affected by the flow of the Mekong River. They were mainly affected by tidal regimes of both the East and West Seas, local rain, and the current drainage system.

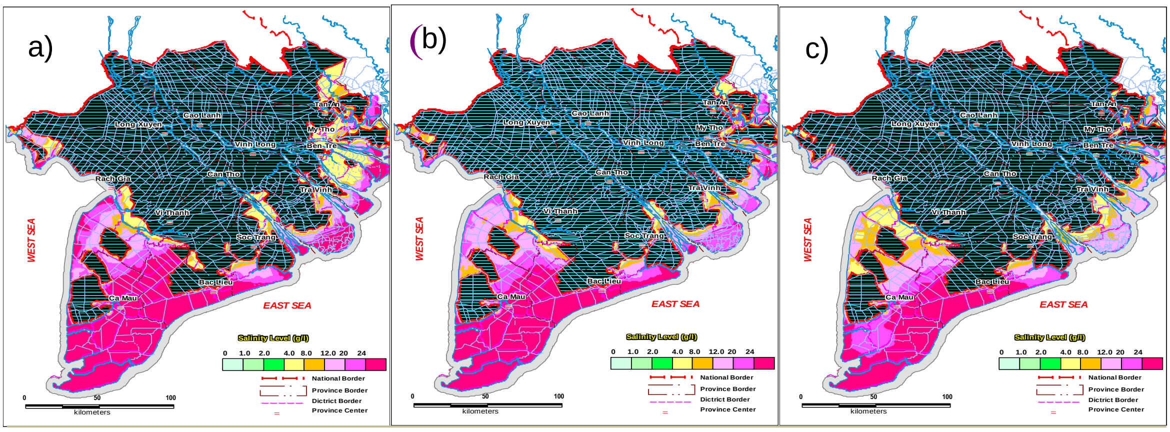

Fig. 6. Maximum salinity of channel water in the dry season without SLR in years of a) low water (1998), b) average water (2004), and c) high water (2000).

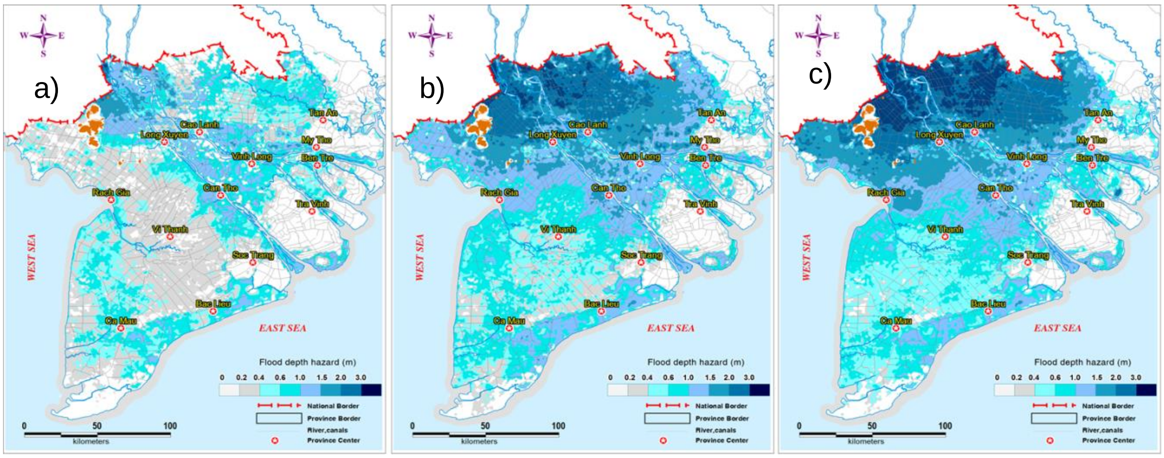

Fig. 7. Flood-risk depth (maximum water level above average ground) in rainy season without SLR in years of (a) low water (1998), (b) average water (2004), and (c) high water (2000).

Figure 6 indicates the differences of maximum salinity of channel salinity that existed among the simulated salinity intrusion in areas in the MRD for 3 years of low, average, and high water. In areas that have a salinity control system such as Quan Lo–Phung Hiep (QLPH), Lower U Minh, South Mang Thit, and Go Cong, the difference in salinity is generally insignificant.

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In the normal year, the saline-affected area is about 33% of the MRD, corresponding to 1.3 million ha of the MRD, and the affected area by flooding is about 50% of the MRD, corresponding to 2.0 million ha of the MRD.

2. Effect of SLR and CC on salinity and flooding risks in the Mekong Delta

2.a Flood risk

Generally, flood-risk depth in the 2030s and 2050s increased compared with that in current conditions.

The incorporated effect of CC with SLR has increased the risks of flooding or submergence in the MRD, especially in years with low water. The flood-risk depth increased significantly, especially in the 2050s, with flood-risk area approximately 190,000 ha at flood depth greater than 1 m.

Figure 8 presents the effects of CC and SLR on the advance of the flood-risk onset date (when flood-risk depth is >0.4 m continuously for more than 7 days). The flood-risk onset date in a high water year and climate change in 2050s were sooner from 1 to 30 days in deep-flooded risk areas (in the center of the Plain of Reeds and Long Xuyen quadrangle). In Ca Mau Peninsula, the flood-risk onset date was at least 30 days sooner than that in the baseline stage.

Figure 9 shows the effect of CC and SLR on the time of flood-risk recession. In the 2050s, the time of flood-risk recession was later than at least 30 days for areas in the center of Ca Mau Peninsula and quicker than from 1 to 30 days for shallow-flooded areas (in the center of the Plain of Reeds and Long Xuyen quadrangle).

Figure 10 indicates the flood-risk duration in the 2050s under SLR and CC compared with baseline conditions. It could be from 15 to 60 days.

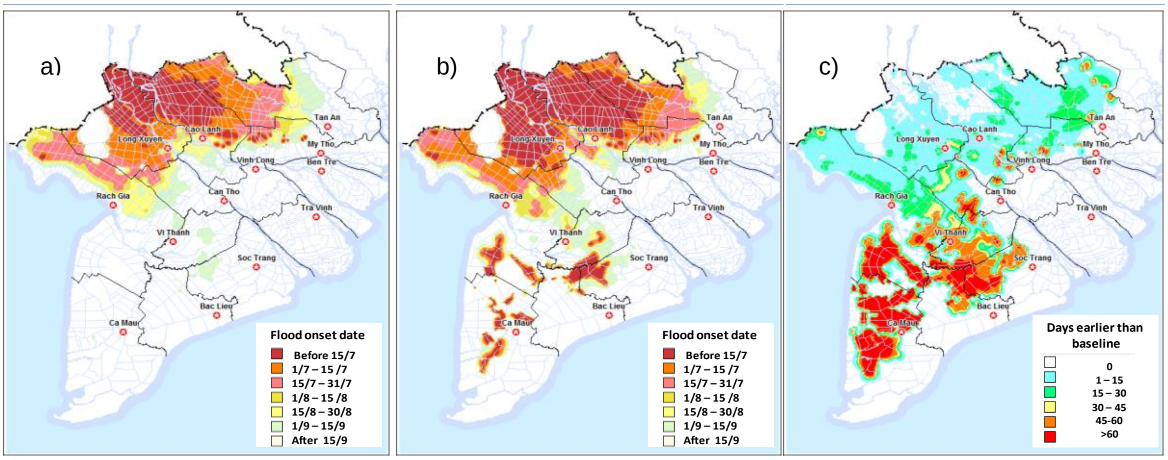


Fig. 8. Flood-risk onset date in (a) baseline year (no SLR and CC in high-water year), (b) 2050s with SLR 30 cm and CC, and (c) change in number of days earlier in 2050s from the flood-risk onset date in baseline year.

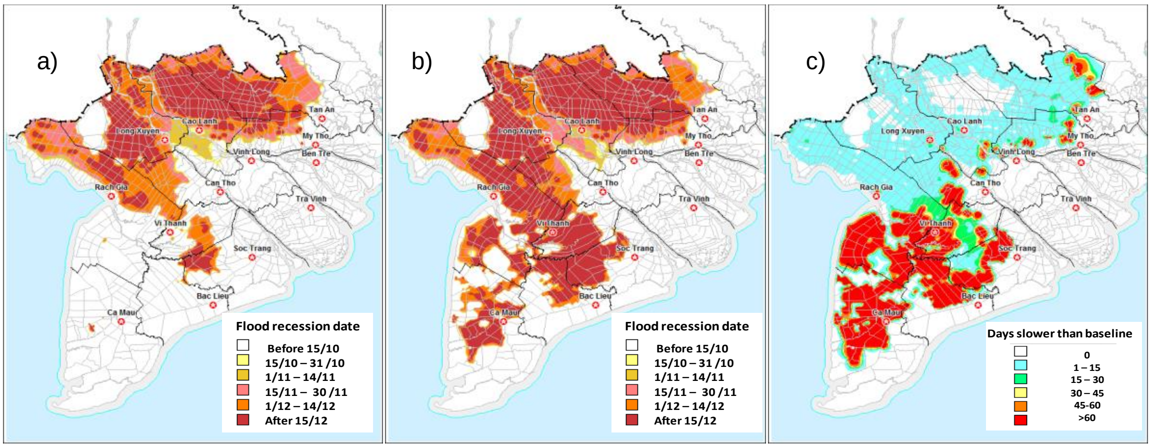


Fig. 9. Flood-risk recession date in (a) baseline year (high-water year without SLR and CC), (b) 2050s with SLR 30 cm and CC, and (c) change in number of days delayed in 2050s from the flood-risk recession date in baseline year.

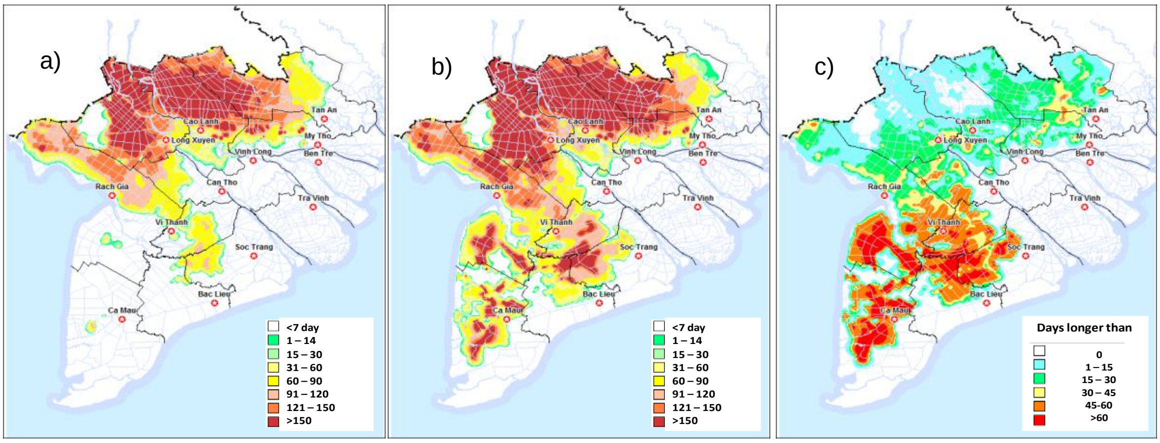
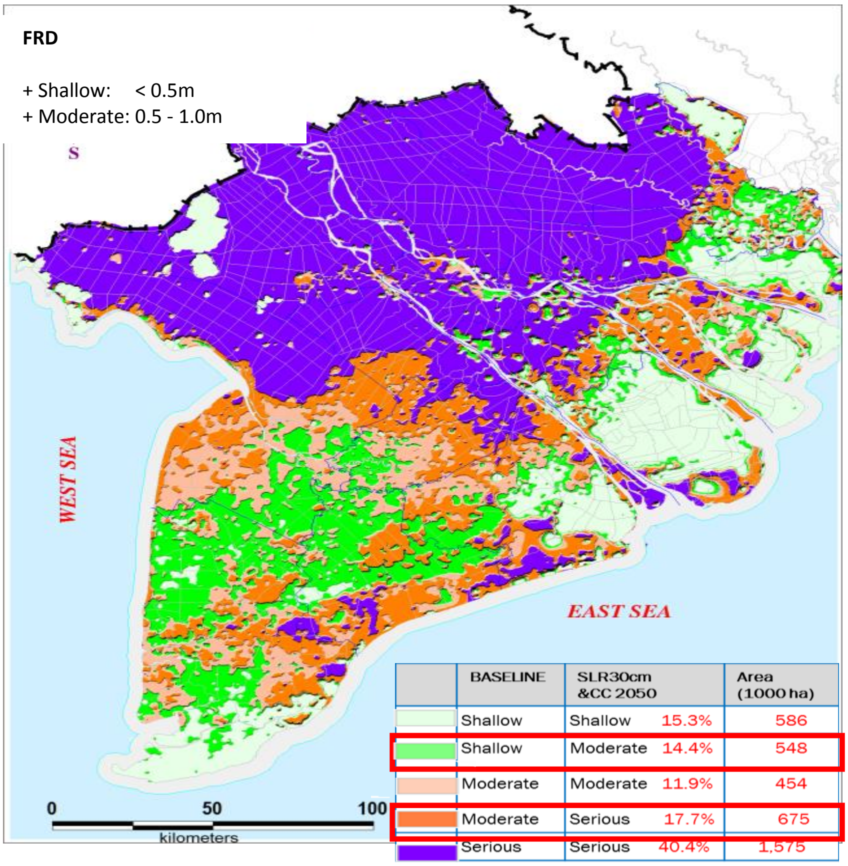


Fig. 10. Flood-risk duration in (a) baseline year (in high-water year without SLR and CC), (b) in 2050s with SLR 30 cm and CC, and (c) change in flood-risk duration between scenarios (a) and (b).



	BASELINE	SLR30cm &CC 2050		Area (1000 ha)
	Shallow	Shallow	15.3%	586
	Shallow	Moderate	14.4%	548
	Moderate	Moderate	11.9%	454
	Moderate	Serious	17.7%	675
	Serious	Serious	40.4%	1,575

Fig. 11. Variations and hotspots in flood-risk depth (FRD) in 2050s with CC and SLR 30 cm from baseline year (without CC and SLR).

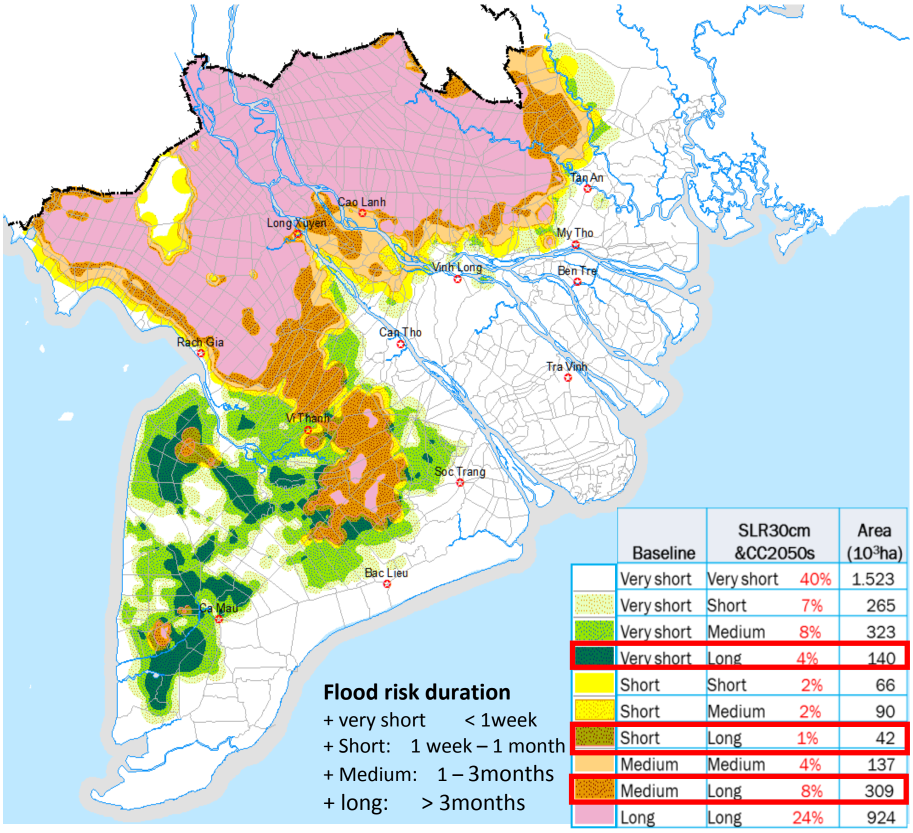


Fig. 12. Variations and hotspots in flood vulnerability duration from baseline year (without CC and SLR) to 2050s with CC and SLR SLR 30 cm.

Figure 11 shows the changes in flood-risk depth from present conditions (baseline year) to the 2050s under the effect of SRL 30 cm and CC, where areas highlighted by red boxes in the legend indicate that the flood-risk area in the 2050s changed from shallow (<0.5 m) to moderate (0.5 to 1 m) and from moderate to serious (>1 m).

Furthermore, figure 12 presents the changes in flood-risk duration from present conditions (baseline year) to the 2050s under the effect of SRL 30 cm and CC, where areas highlighted by red boxes in the legend indicate that the areas of flood-risk duration changed from short (<1 week) to medium (1 to 3 months) and from medium to long (>3 months).

2.b Salinity risk

SLR increased average water levels in the dry season. The increase decreased gradually toward the upstream.

When CC is considered with SLR, the affected areas with salinity of more than 4 g/L clearly increased compared with the baseline. The increase in salinity area was lower in the high-water year than in low- and average-water years.

Figure 13 shows maximum salinity under present conditions and in 2050s with CC and SLR SLR 30 cm in the low-water year. The hotspots of salinity variation are shown in Figure 13 with attention to the salinity increase from fresh (<2 g/L) to brackish (2–4 g/L) and brackish to saline (>4 g/L) (highlighted by the red boxes in the legend). These hotspots, covering about 9% of the saline area, are mainly located at the interface between fresh and saline water along the coastal provinces, in particular on the East Sea side where tidal variation is higher than on the West Sea side.

By 2050, salinity in Northern Mang Thit and Ben Tre provinces might be much higher. In the normal and low-water years, the most areas with salinity of >4 g/L were in Ben Tre, Vinh Long, and Tra Vinh provinces. Salinity in central Ca Mau Peninsula decreased to less than in current conditions.

Figure 14 shows areas in the MRD with medium and long duration of salinity of >4 g/L in current conditions of the baseline scenario, which occupied 35% (or >1,300,000 ha). A few areas had short duration of salinity (4% or 142,000 ha). Most of the freshwater area in the protected infrastructure (dikes, dams, or sluices) along the East Sea are scarcely affected by salinity in 1 week and occupy 44% (or >1,690,000 ha).

Under the impacts of CC and SLR 30 cm in the 2050s, the areas with longer duration of salinity of >4 g/L from 1 to 3 months increased 7% (or 231,000 ha) and small risky areas with salinity longer than 3 months increased 2% (or 88,000 ha). These areas were found in the coastal provinces of Ben Tre Tra Vinh and Tien Giang.

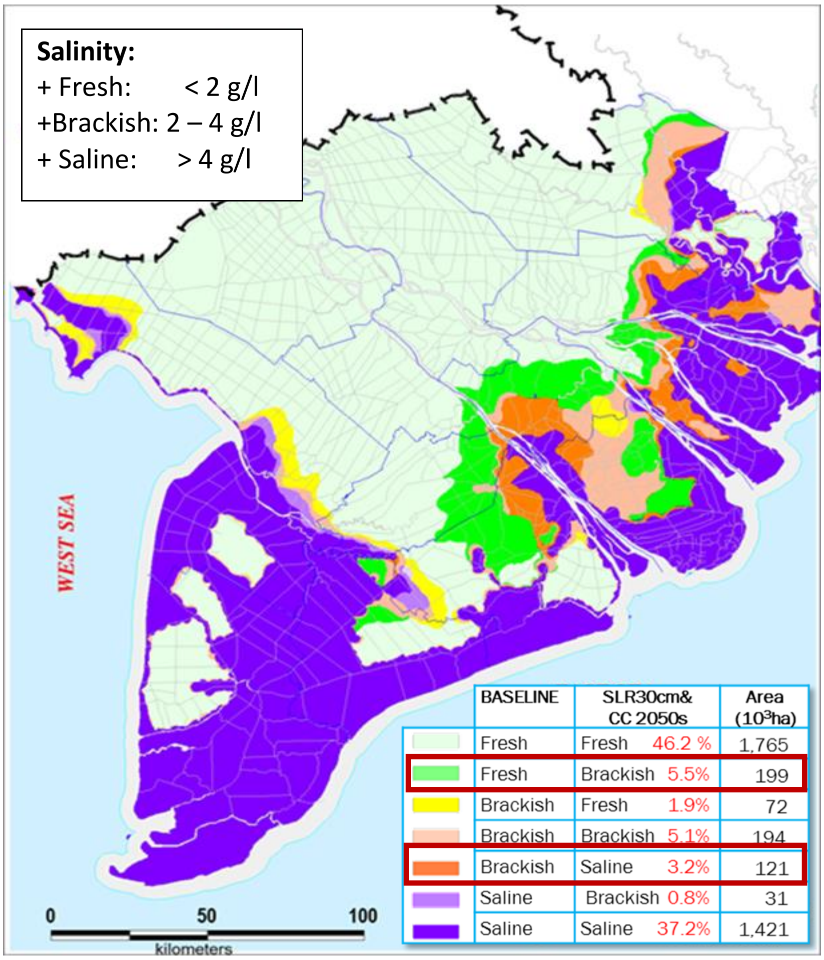


Fig. 13. Variations and hotspots in salinity under baseline year and in 2050s (with CC and SLR 30 cm).

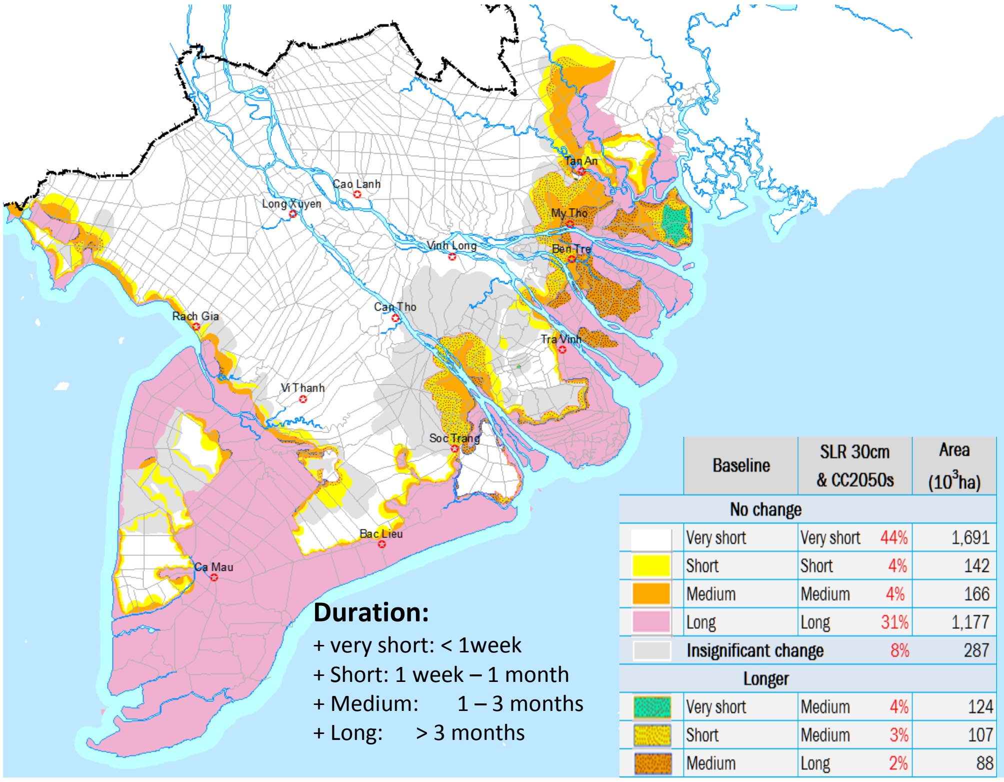


Fig. 14. Salinity vulnerability duration under present conditions and CC 2050s and 30 cm SLR in the high-water year.

The length of salinity intrusion in the main rivers increased considerably in the low-water year with SLR and CC 2050s. The length of salinity intrusion (with salinity of 4 g/L) in the Bassac River varied from 69 km in 2030 to 72 km in 2050 (Fig. 15). In the topography conditions of the baseline scenario, the change in length of salinity intrusion in the main streams is influenced by main factors such as topography of the stream, upstream flow, SLR, and CC.

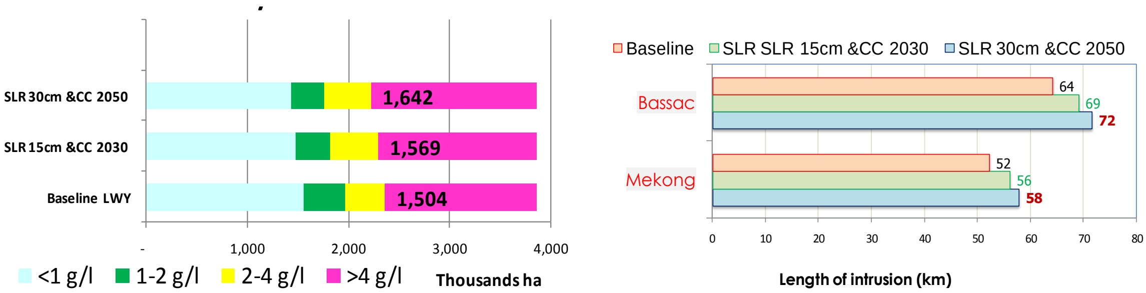


Fig. 15. Change in length of saline intrusion (>4 g/L) in main rivers in scenarios of SLR and CC 2050s in the year of low water.

3. Changes in potential area of gravity irrigation

Figure 16 shows the area irrigated by gravity increased significantly under the impact of SLR and CC. The freshwater area irrigated by gravity could increase from 369,000 ha in current conditions to 780,000 ha (more than a 411,000 ha increase) in 2050s.

The expansion of gravity irrigation areas in MRD in 2050s was mainly a result of SLR. The additional effect of CC on gravity irrigation is only marginal and affected only around 1,000 ha.

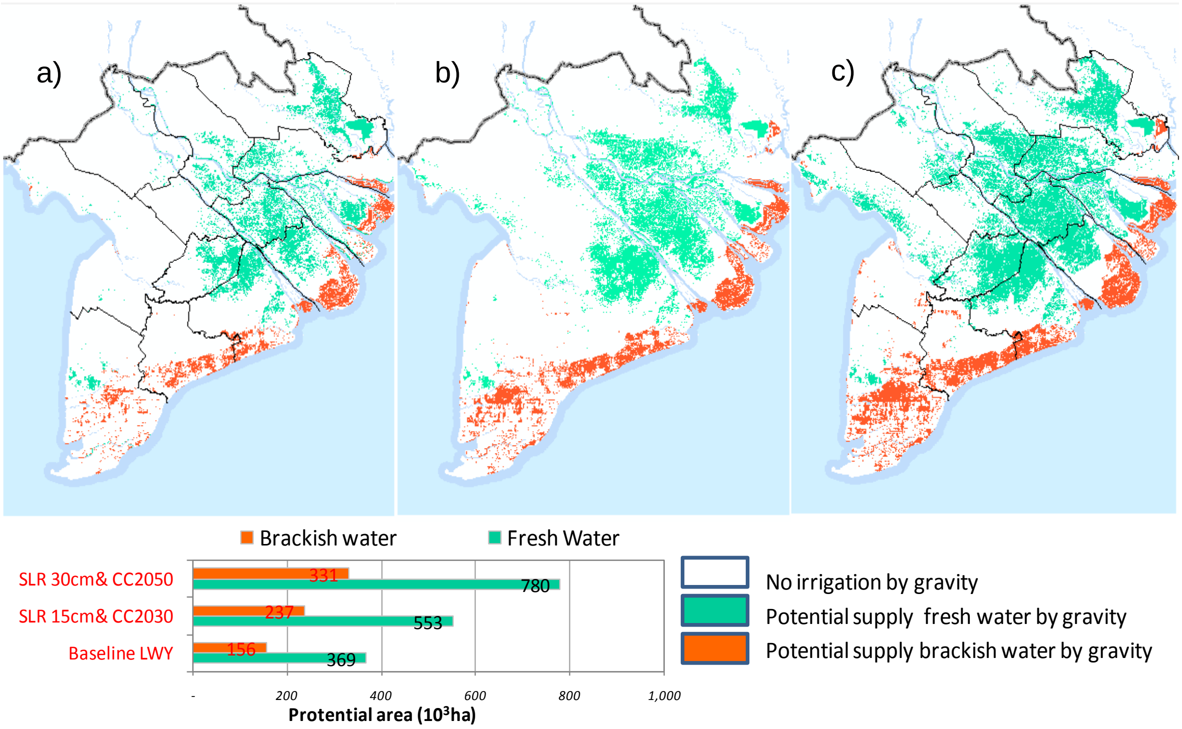


Fig. 16. Potential area of gravity irrigation in low-water year in (a) baseline year and with SLR and CC in (b) 2030s and (c) 2050s.

4. **Comparing impacts of SLR vs upstream flow reduction**

The upstream development of Mekong river basin including building dams and expansion of upstream irrigation in China, Laos and Cambodia will undoubtedly alter the flow regime in the delta (MRC, 2011). However, there is large uncertainty on the precise impacts of these changes – and if those will affect rice production in a positive or negative way. The initial source of uncertainty derives from the questions (i) how many dams will be build and (ii) how big the reservoirs will be in the future. But even if these figures are taken as given (based on incumbent development plans), the crucial question will be (iii) how they will be operated in terms of discharge in the dry vs. wet season.

Obviously, these uncertainties pose serious methodological problems in any assessment of future hydrological conditions in the MRD. After assessing different options, we decided to conduct a sensitivity analysis of changes in river discharge vis-à-vis the changes in SLR+CC. For this purpose, we assumed a 20%-reduction of river discharge at the Kratie gauge which is located 100 km upstream from the Vietnam/ Cambodia border. We conducted this simulation for Low Water Year, namely using the baseline condition of 1998.

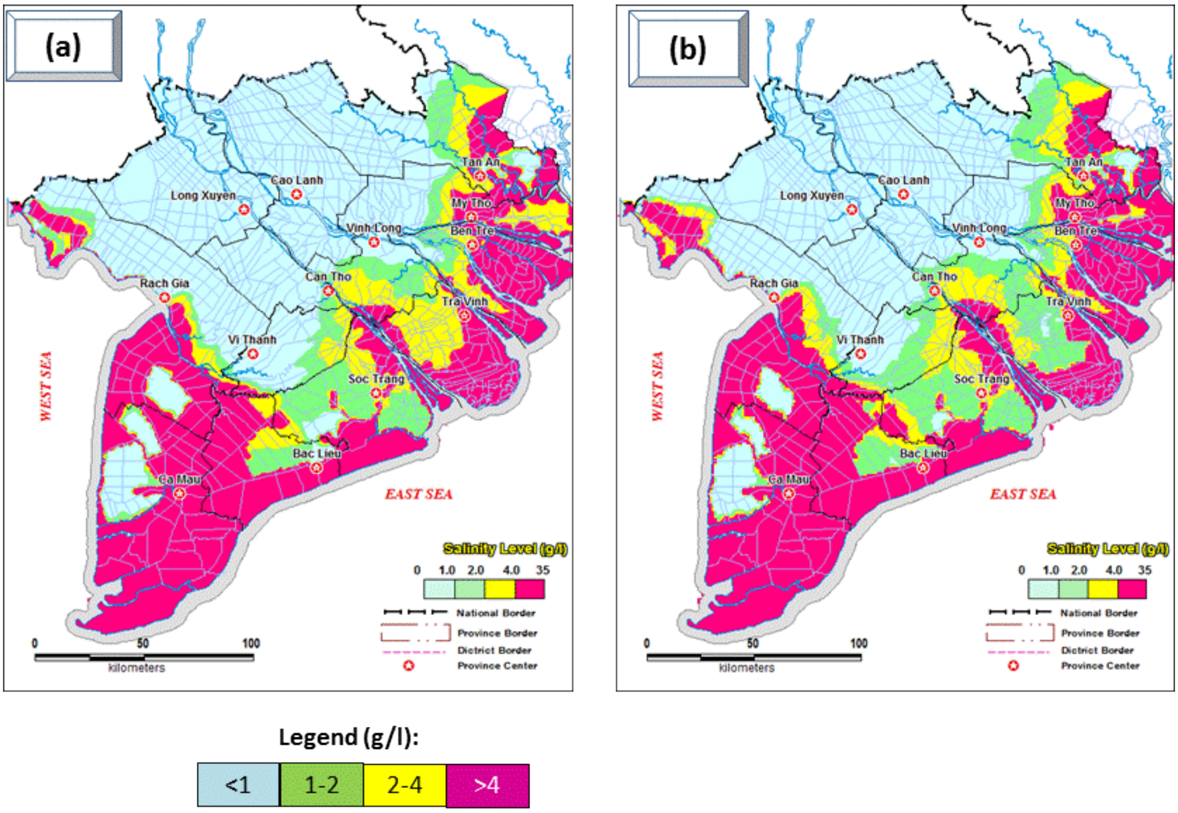


Figure 17: (a) Salinity levels in low water year under SLR scenario; (b) under reduced discharge scenario (-20% discharge at Kratie)

The juxtaposition of the maps in Fig. 17a/b clearly shows that the impact of a 20% reduction is comparable to the projected conditions under SLR – without any changes in river discharge. In turn, it seems simplistic to limit the assessment of future hydrology to SLR while these changes may drastically be aggravated by upstream development.

As we are unable to show all these scenarios/ maps within the scope of this report, it should highlight that we can expect an expansion of saline area in MRD is 1.6 mil ha over the next decades (under SLR of 15cm and reduced river discharge of 9%). This corresponds to about 5% increase in saline area compared with 1.5 mil ha in 1998 of low water year. This increase in area corresponded with an inland shift of the salinity contours in the big river branches. The salinity affected stretches of the Bassac and Mekong branches expanded from 52 to 57 km and 64 to 69 km, respectively.

Under the CC and SLR effects on salinity intrusion and flooding in MRD, intensity and duration of salinity and flooding risks will be changed and they are the main concerns for production and livelihood of habitants in MRD. To cope with these constraints, some adaptation options have been suggested in Table 6.

Table 6. Some adaptation strategies to cope with flooding and salinity impacts under effect of CC and SLR

CC and SLR effects	Strategies
Increased Flood-Risk Depth and Duration	Improve flood control structures
	Deploy submergence-tolerant varieties
Increased salinity	Improve salinity control structures
	Deploy salinity-tolerant varieties

Reduced gravity drainage capacity	Rely more on pump drainage
Shortened cultivation windows	Shorten the turnaround time between crops, for example, with better residue management
	Use short-duration varieties Use (mechanized?) transplanting to reduce the time of the crop in the main fields
	Replace dry-season rice with a short-duration upland crop
Prolonged and high field water level	Deploy partially flood-tolerant varieties and salinity-tolerant + partially flood-tolerant varieties

Note: Detailed results of Theme 1 can be found in the Theme 1 Final Report (Appendix 1).

Theme 2: Stress-tolerant rice varieties

The development of improved rice varieties in Theme 2 was undertaken by using the backcross method as well as through conventional bi-parental and complex (3- and 4-way) crosses, coupled with subsequent marker-assisted selection and screening under controlled and natural stress conditions to develop improved breeding lines and varieties.

In total, 36 single and multiple crosses have been made to combine submergence tolerance, salinity tolerance, stagnant flood tolerance, and high grain quality into high-yielding genetic backgrounds. Two of these crosses were made to combine genes for tolerance of both submergence and salinity stresses. Pedigree generations were grown under controlled submergence conditions at CLRRI, and under natural stagnant water conditions.

A second component of the project was to test breeding lines and varieties under a range of seasons and environments to validate the performance of the new lines and to offer farmers the opportunity to participate in the observation and selection of new varieties. To date, more than 27 participatory varietal selection (PVS) trials have been conducted using 78 varieties throughout An Giang, Hau Giang, Bac Lieu, and Can Tho provinces.

- Two crosses were made specifically to combine genes for tolerance of both salinity and submergence and progenies from these crosses were advanced to BC_3F_4 using the combined effects of marker-aided selection and screening under stress conditions. Pedigree generations were grown under controlled submergence conditions at Cuu Long Rice Research Institute (CLRRI); under natural stagnant flood conditions at sites in Can Tho, Hau Giang, and An Giang provinces; and under salinity stress in Bac Lieu Province. In total, 108 progenies were selected from BC_3F_4 populations, and 239 plants from the F_4 generation were tested for two stress tolerance genes (*SUB1* and *Saltol*) in combination. A further 12 backcross populations were developed to transfer *SUB1* and *Saltol* into adapted genetic backgrounds of rice varieties from Australia, and lines selected from these populations were transferred back to Australia under the necessary quarantine protocols.

Some main results

- Existing genetic material (landraces, modern varieties, and breeding lines) with greater stress tolerance was also evaluated throughout the term of the project, using PVS procedures, and many beneficial lines were identified. Under rainfed lowland conditions in Can Tho Province, five advanced lines/varieties as OM10041, Can Tho 1, OM3673, OM4488, and OM8108 demonstrated improved productivity following exposure to submerge under 0.8–1.0-m water depths for

15–20 days, and producing 4–5 t/ha yield. As the same time, the common check variety IR64-Sub1 demonstrated yield of 4 t/ha. Similarly, under submergence stress conditions in An Giang Province, the lines/varieties OM8928, OM10179, and IR64-Sub1 demonstrated yields in excess of 4 t/ha.

- In Bac Lieu Province, where the predominant stress is salinity, OM6328, OM3673, and OM10252 were shown to be best-bet varieties for famers. In Hau Giang Province under a combination of submergence stress and acid sulfate soils, OM8928, OM8108, and OM3673 showed improved yield stability from 2011 to 2014 that were ranged from 6 to 7.6 ton/ha in Summer Autumn compared to the yield of 5 to 7.2 ton/ha of other popular varieties and of common checked varieties AS966 and IR64-Sub1.
- In areas currently suffering from the individual or combined effects of salinity and submergence, the provision of nucleus seed of improved breeding lines/varieties can speed adoption. A total of 5 tons of seed of beneficial lines/varieties was distributed during the term of the project within each of the targeted provinces, including Bac Lieu (990 kg of eight lines), Hau Giang (990 kg of eight lines), Can Tho (1,276 kg of four lines), and An Giang (a total of 1,725 kg comprising four lines).
- The breeding component of the CLUES project sought to increase the impact of such varieties with enhanced stress tolerance, which can be amplified by distributing seed to target areas and multiplying quantities of seed of available varieties on-farm for immediate distribution. Although beyond the scope of this component, impacts could be further amplified by establishing seed multiplication facilities in target areas for further multiplication.
- Four varieties were submitted to DARDs for release during 2014, and was confirmed by trails in the four target provinces in 2015 as the final year of the project, including OM3673 with short growth duration and improved anaerobic germination, OM10252 with tolerance of submergence and salinity, and OM6328 and OM6677 with improved salinity tolerance and high yield potential.

Theme 3: Natural Resource Management (NRM)

The PRA undertaken in March 2011 identified potential CC-related threats (Table 2). At each site during the winter-spring (WS) and summer-autumn (SA) season, water scarcity and lodging were identified as key future threats (Table 2). This water scarcity could cause increased acidification through the further oxidation of acid sulfate soils and salinization through capillary rise. During the wet-season crops, stagnant flood and submergence were identified as key threats (Table 2). Across all sites and seasons, labor scarcity and low economic resilience due to small farm size were identified as current and future problems that challenge current production methods.

The CLUES research team identified promising technologies and research questions. Prior to implementation and testing, meetings were held, which included the research group leaders, farmers and extension officers, and local government officials at each site. At these meetings, the merits of each technology and research question were discussed and areas were selected for field testing (Table 3). Major findings of the experiments are described below.

The direct and indirect impacts of climate change (CC) and sea-level rise (SLR) will become a major challenge for maintaining food security in the near future, mainly through aggravating salinity and flood problems driven by hydrological dynamics of the Mekong River. After nearly four years conducting experiments and field trials to improve profitability and resilience to environmental stress, the results show the following.

Alternate wetting and drying (AWD) irrigation is a win-win water management technology. It reduces water application by 30% to 50% and pumping costs and GHG emissions.

A key advantage of the technology is that it has an immediate impact on farm profitability. Economic analysis shows that the reduction in pump hours increases farm income by reducing fuel and labor costs (Table 7) relative to traditional continuously flooded rice.

Table 7. Average income (in VND 1,000 per hectare) from three water management regimes in Ta Danh, An Giang (Nhan et al 2015).

Water management regimes	DX 2011-12	HT 2012
W1	15,191	24,678
W2	19,926	26,254
W3	17,723	25,957

Our experimental trials indicated that AWD with threshold –15 cm (free water at 15 cm below the field surface) could be a good solution for overcoming water scarcity under current and future conditions in all soil tested. The use of this technology by farmers will potentially increase MRD rice production by making systems more resilient to water scarcity. AWD will also directly increase farm profitability by reducing fuel and labor costs associated with irrigation.

Water delivery and management were a constraining factor at all sites throughout the field campaign; for example, in Lang Giai during successive seasons, upland crop trials were flooded and saline water was pumped into the field. A principal consideration for future climate change management is improving the delivery and management of irrigation water and drainage.

Farmers are over-fertilizing and it is possible to reduce fertilization. It is recommended that farmers can reduced the fertiliser P application to 40 kg P_2O_5/ha to maintain the balance of P input and P removed from soil and to sustain soil P supplying capacity and rice yield.

In combination with AWD, this increased farmers' income in each rice crop by about VND 4 million (~ US$200) per ha. The increased profitability allows farmers to become more resilient to CC. Reducing P also alleviates the environmental footprint of rice production.

Farmers can improve yield by using the existing cultivars suited to farm environmental characteristics. For example, replacement of the traditional varieties in Phuoc Long, Bac Lieu, with a high-yielding variety (HYV) directly increased profits from the rice phase but, more importantly, it shortened the rice season and lengthened the shrimp season.

In Phung Hiep District, Hau Giang Province, residue management, AWD, and P field trials failed because of commune-level water management and acid sulfate soils. In the future, changed climatic conditions could exacerbate acid sulfate soils and generate further acidity.

The trials on replacing one rice crop (winter-spring (WS) rice in Bac Lieu or summer-autumn (SA) rice in other areas) with a short-duration upland crop increased the economic resilience and CC adaptation via (i) increasing farmers' income, (ii) reducing the water requirement and hence the risk of water shortage in SA or WS seasons, and (iii) reducing the risks of partial flooding or submergence in the AW season by advancing the establishment/harvest date of the AW season.

Note: Detailed results of Theme 3 can be found in Appendix 3.

Theme 4: Socio-economic component

The theme focused on scientific impacts, policy and institutional analysis, feasibility assessments, and impact pathway analysis of new technologies implemented by Themes 2 and 3. Linkages with field activities of Themes 2 and 3 and Theme 4 enhanced the fine-tuning and scaling out of tested technologies at the project sites. The following are the theme's outputs:

- Rice farmers in the study zones have faced multiple threats and problems, not only climatic threats but also harmful pests and other socioeconomic factors.
- Poorer farmers are considered more vulnerable because of relatively lower livelihood capacity than better-off farmers. Diversification by rotating upland crops (in freshwater areas) or shrimp (in saline-water areas) with rice helped farmers earn higher income but this option was constrained by the unavailability of off-farm labor, poor accessibility to and instability of output market systems, and poor irrigation or drainage systems.
- To enhance the adaptive capacity of rice farmers to changes in the study zones, not a single solution but a package of solutions is needed, including rice farming technologies, structural measures, and socioeconomic measures with respect to specific contexts.
- Informal farmers' groups, informal in-kind credit, and availability of telephone and television in households are enablers of the livelihood capacity of farmers. Women play an important role in rice farming and household livelihood. However, their knowledge on climate change and their participation in extension activities were relatively poorer than that of their husbands.
- Feasible rice farming technologies need to satisfy important criteria such as the ease of practice, economic viability, and the availability and stability of markets for outputs. Target areas of feasible farming technologies created by the project require relatively favorable conditions of soil and water (i.e., alluvial or slightly acidic soils with available irrigation and drainage systems), except for an appropriate P application technique in the acid sulfate zone.
- Single-component technologies such as appropriate P application or AWD practice were ranked as a high priority.
- Future rice varieties should be not only tolerant of water-related threats and major pests but also have high yield potential and good grain quality for eating and marketing.
- The rice-upland crop rotation and rice transplanting technique, which are considered promising under water-related threats, were ranked a lower priority for the current stage from intensive-labor input and/or limited markets for outputs.
- Farmer cooperation is an important enabler of the out-scaling of the feasible technologies, for instance, AWD practice, while rice transplanting and rotation of upland crops with rice require farmers to have availability of on-farm labor or accessibility to local off-farm labor, or availability of output markets.
- The ease of practice and economic viability are important determinants of the adoption of technologies by farmers.
- Effective out-scaling and up-scaling of promising technologies created by CLUES need effective coordination and participation among key governmental actors together with community-based organizations, and incorporation into local existing development programs. New technologies from CLUES will need constant adjustments and improvement in order to adapt to the changing needs of farmers. DARD and its agencies are important actors in the out-scaling and up-scaling of the technologies. In addition, other actors related to services for inputs and outputs and farming cooperation play an important role.
- The Vietnamese government has promulgated several policies relevant to rice production, rice trade, and rice farmers' livelihoods. However, the implementation of the policies at the local level was not as effective as expected. Weak integration, inflexibility, and unsuitability of the policies in local contexts caused difficulties in institutional coordination in policy implementation.

Note: Detailed results of Theme 4 can be found in the Theme 4 Final Report (Appendix 4).

***Theme 5:* Integrated land use planning**

This study was conducted through an integrated land use planning approach to explore possible adaptations to climate change and sea-level rise of the coastal area of the MRD. Some main results follow:

- *Soil and land use*

Soil and land use maps of the province have been updated to 2012. In general, the main soil problem of the province is that more than two-thirds of its area is acid sulfate soil and saline soil (see Theme 5 final report (Appendix 5)).

Sixteen land use types were delineated, including triple, double, and mono rice crops, rice-shrimp, aquaculture (shrimp), forest, salt field, and urban (see Theme 5 final report).

- *Land mapping unit maps*

The agro-ecological zone (AEZ) maps of Bac Lieu Province, in different CC and SLR and water management scenarios, were mapped as a result of overlaying terrain, soil, and water maps of the corresponding scenarios. Each zone in the map is described by its saline intrusion period, saline value range, soil type, irrigation capacity, cultivation period, and cropping pattern. This is very important information for biophysical land use suitability analysis. The current AEZ map of Bac Lieu is presented in Figure A4 of Appendix 2 Theme 5 Final Report.

In order to integrate socioeconomic information with biophysical information, land mapping units (LMUs) of the province were built by overlaying the AEZ maps on the administrative boundary maps (village). Since AEZs depend on hydrology, AEZs will change under the impacts of CC and SLR.

- *Land suitability*

Land suitability maps of Bac Lieu Province under CC and SLR in a dry year, normal year, and wet year were developed.

The biophysical suitability of the promising LUTs in different SLR and hard measure (infrastructure) intervention scenarios was evaluated. Nine promising LUTs were selected for land suitability evaluation. The selection was done based on stakeholders' perceptions as a result of SWOT analysis.

The selected promising LUTs are triple rice, double rice, shrimp-rice, shrimp, rice-vegetable, vegetable, forest-shrimp, shrimp-fish, and salt-fish.

- *Socioeconomic constraint analysis*

Farmers in the study area consider increasing income as the most important objective. Farmers also consider water (both quantity and quality) and bio-diversification as the most important environmental factors that affect crop yield.

Farmers are highly concerned about markets for agricultural and aqua cultural products. Production price fluctuation strongly affects their income.

Through key informant interviews in each LMU, farming inputs and outputs were estimated. These are important input data for the land use optimization analysis.

The study identified constraints and room for further improvement of existing farming systems and for adaptive planning of agricultural land uses under anticipated changes.

Constraining factors of the farming systems differed among the zones and included not only technical and hydraulic structural factors but also service for inputs and outputs and production organization.

Agriculture, particularly shrimp and rice production, played an important role in the economy of Bac Lieu Province. Rice and shrimp production developed into intensive resource uses. Rice yield and income did not differ significantly among cropping systems in the freshwater zone while a large variation in yield and income occurred among shrimp farming patterns in the brackish and saline zones.

In the freshwater zone, rotational upland crops with rice gave high income but were labor-intensive.

The income of extensive shrimp farming patterns could be improved with appropriately increased feed input levels and refuge pond areas for shrimp.

Semi-intensive shrimp culture had high economic returns with high external inputs and high economic risks. Shrimp yield and income were highly influenced by several factors because they are not sensitive to both technological and environmental factors.

Technical efficiency in terms of yield and income was higher in rice cropping systems in the freshwater zone than in shrimp production patterns in the brackish and saline zones. Attainable yields and income of extensive shrimp culture are lower, because of low input levels, than in semi-intensive shrimp culture.

These results reflect the higher stability of income of farming systems in the freshwater area than in the brackish and saline water areas.

Rice and shrimp income variation by yield change was larger than that by output price, reflecting significant impacts of farming technologies on sustaining the farming systems in Bac Lieu.

- *Optimized adaptation of land use options at the provincial scale in different scenarios*

The data were integrated and input into an MGLP model (developed in GAMS software) for scenario analysis.

The data for component BLE are the LMU map and land use requirements. The results of this component are land suitability, yield estimation for each LUT/LMU, and available area. These results will be the input data for component SA.

The component SEA evaluates the PRA and socioeconomic survey data to provide required labor, required capital, production cost, and production price of each LUT per LMU. SEA also calculates the available capital and labor, and defines the constraint and objective functions for component SA.

Based on detailed inventories of the present and anticipated CC and SLR, affected soils, hydrological features and land use, yields and financial returns, a CC adaptation land use strategy for Bac Lieu Province has been proposed through an MGLP approach.

Applying the model for Bac Lieu Province, the results from scenarios imply the following:

- Capital and farming technique limitations are main constraints to provincial rural income;
- The current imposed production targets reduce provincial land use effectiveness and would be infeasible in the future under the impacts of CC and SLR;
- Optimizing the use of available resources would reduce the negative impacts of CC and SLR; and
- Operation of the new proposed Ninh Quoi sluice gate would improve the biophysical condition of the province. However, the hard measure is less economically effective than improvement of farming technical level and increasing capital investment combined with an optimal operation of the existing sluice and dike system.

Therefore, in the medium term, the adaptation strategy of Bac Lieu Province (up to the 2030s under CC and SLR) follows:

- Improve farming technology.
- Provide farmers with higher financial support.
- Base land use decisions on optimal use of available resources and market orientation rather than on production targets.
- Optimize the use of available resources (both biophysical and socioeconomic) based on the land use options proposed by the model.
- Improve the operational scheme of the existing sluice system.

The model also provides detailed information on the levels of the achievement of objectives, the total input requirements, and total production (see Appendix 2, Theme 5 final report).

- *Guidelines and tools available for developing adaptation master plans in other provinces of the MRD*

Based on the developed IMGLP model or provincial adaptation plan, Theme 5 has prepared and carried out three training courses with guidelines and tools. The training courses have been conducted for both technical staff and district/provincial managers. More than 40 people have been trained, with 15 female participants. The participants are not only from Bac Lieu Province but also from Hau Giang and An Giang provinces. Technical staff of the Integrated Coastal Management Program in Bac Lieu Province also attended the training courses. These courses are ready for further activities in the Mekong Delta.

Note: Detailed results of Theme 5 can be found in Appendix 5.

Theme 6: GHG component

- Capacity building was accumulated through training and collaboration with other projects. Training was held for eight staff from the Centre of Agricultural Extension of Long An Province and six students of Cuu Long University in carrying out pot experiments on the effect of N rates and nitrification inhibitors on N_2O emissions from rice growing on alluvial, acid sulfate, and saline soils.
- AWD is a promising option for reducing methane emissions in paddy rice. On average, methane emission rates under continuous flooding (CF) were about two times higher than in AWD conditions under all P treatments. CH_4 emissions were significantly lower (46%, 40%, and 70%) in AWD treatment compared with CF treatment at three study sites in An Giang, Hau Giang, and Bac Lieu, respectively.
- Cumulative N_2O emissions varied from 0.1 to 4.5 kg N_2O/ha/season. There were no significant differences in N_2O emissions among different phosphate fertiliser doses as well as between AWD and CF treatments in An Giang (alluvial soil), Hau Giang (acid sulfate soil), and Bac Lieu (saline soil). As reference, the global Emission Factor given by IPCC (IPCC 2006) is 1% of the fertiliser N applied, so that this would correspond to approximately 1 kg N_2O/ha/season.
- Different soil types induced methane emissions differently. Methane emissions increased in the order deep-flooded alluvial soil (An Giang) > shallow-flooded alluvial soil (Can Tho) > acid sulfate soil (Hau Giang) > saline soil (Bac Lieu, Ca Mau, Kien Giang). In alluvial soils at CLRRI (Can Tho), AWD treatment significantly decreased CH_4 emissions (54%) compared with CF treatment.
- The most striking result in the SA 2013 cropping season was that the triple-rice system emitted significantly higher CH_4 than the rice-maize-rice system at CLRRI. The reverse was true for N_2O.

- Seasonal variations in methane emissions were observed in the MRD. Methane emissions from rice paddies were highest in autumn-winter and lowest in the summer-autumn crop.
- The introduction of upland crops into the triple-rice system reduced methane emissions significantly. Mungbean or soybean reduced methane flux by 75% but sesame or maize could decrease it by up to 95%. The beneficial effect of methane mitigation was also observed for sucessive rice crops on upland by about 30%.
- Overall N_2O emissions increased in mungbean-rice system by 88% in comparison with the rice-rice system at the CLRRI (Can Tho) study site but there was no significant difference in N_2O emissions between the rice-rice system and the sesame-rice system at the Thoi Lai (Can Tho) study site.

Note: Detailed results of Theme 6 can be seen in the Theme 6 Final Report (Appendix 6).

<u>Theme C</u> (or Coordination and integration theme)

This theme has been established to create a sound infrastructure for all project activities; ensure internal and external communication flow; supervise progress of activities; organize in-country training, seminars, forums, and workshops; and establish linkages and partnerships with local governments, nongovernment organizations, private entities, and international institutions with similar programs on climate change within the Mekong River Delta.

The CLUES project management encompassed closely overseeing the implementation of work plans and activities of six themes and four experimental sites. Activities of these components have been implemented and coordinated at the same time. For each activity, protocols and reports were completed and submitted to the theme leader and the PO.

At each site, site managers had an important role in overseeing the linkage activities between themes and with local people (local authorities and farmers in the provinces). Their frequent reports to the PO and operational meetings were important to carry out all activities of CLUES at four target sites smoothly.

Frequent meetings and visits between the PO and field sites or themes helped facilitate the activities of CLUES. Local workshops were organized yearly for the exchange of results and activities of CLUES with local stakeholders.

Until the end of the project, the PO organized and coordinated 20 official operational team meetings, 10 other individual meetings with team members or collaborative partners, 3 project training events, 16 project workshops including mid-term and final review workshops (see Fig. 18 for the third CLUES annual review workshop), and nearly 50 field visits at four study sites of CLUES. The PO also organized more than 25 visit trips for international consultants of CLUES and five visits of other overseas and national projects, and journalists.

The collaboration with the GIZ project in Bac Lieu was also important for CLUES in out-scaling technology of AWD and P reduction. There were 41 demonstrations and training on AWD for 1,418 farmers who were trained on AWD. The assessment report and workshop on AWD were also accomplished successfully by CLUES, GIZ Bac Lieu, and local staff of Bac Lieu DARD.

Until this time, the spontaneous network of CLUES team with local stakeholders and institutes have been remained fruitfully for other coming projects that were after CLUES.

More than 330 references and documentation of CLUES were available for use by the project team. A CLUES database has been established for use among the CLUES team.

Of 64 papers, 31 were peer reviewed. Three books in Vietnamese and English were published. Eleven leaflets were produced and distributed to team members and other partners. Two CLUES videos were made by CIAT and IRRI. Bi-annual news was published in ACIAR newsletters.

Fig. 18. The Third Annual Review and Planning Workshop of CLUES on 1-3 April 2014.

8 Impacts

8.1 Scientific impacts—now and in 5 years

Actors in CLUES that were influenced by scientific engagement include researchers of CTU, SIWRP, IRRI, ANU, and CSIRO; MSc and PhD students of CTU and other universities; ongoing projects in Bac Lieu Province such as the Integrated Coastal Management Program; and provincial and local staff of DARD and DONRE.

During the project, some current impacts were found in the target areas and nationally:

1. The methodology of assessing CC and SLR impact on hydrology has been improved and presented in different scientific venues. The method has been applied in an ongoing DANIDA-funded project to assess the impact of SLR on flooding and salinity in the Red River Delta (2014). In the future, the methodology can be more widely used in other areas.

2. The project used marker-assisted backcrossing (MABC) to develop high-yielding rice cultivars, which are tolerant of single or combined stresses of submergence, stagnant flood, and salinity. Enhanced understanding of the extent to which major QTLs such as *Saltol* and *SUB1* could contribute to abiotic stress tolerance has been used for breeding programs by CLRRI beyond CLUES. In the next five years, the presence of these genes/QTLs in more varieties more broadly adapted to the Mekong Delta region will facilitate their further movement into lines adapted to all provinces. In the next five years, further fine mapping of these genes will allow them to be transferred readily into new varieties, thereby being added to the suite of stress tolerances built into new lines.

3. Then, the PVS methodology has been used at multiple locations and in multiple seasons in four target provinces of the project. The study on stress-tolerant rice varieties had a great impact on local staff and farmers in four provinces who were invited to attend farmers' field days (or PVS) to select the rice genotypes they most preferred. By applying PVS, seeds of the most preferred rice genotypes and varieties were distributed to farmers. In 2011-15, a total of 5 tons of seed of beneficial lines/varieties was distributed during the term of the project within each of the targeted provinces, including Bac Lieu (990 kg of eight lines), Hau Giang (990 kg of eight lines), Can Tho (1,276 kg of four lines), and An Giang (a total of 1,725 kg comprising four lines). During the project, some promising lines were identified and prioritized by farmers. Some rice varieties have been submitted for varietal release, such as OM3673 (short growth duration, tolerant of anaerobic seedling stage), OM10252 (submergence- and salinity-tolerant), and OM6328 and OM6677 (high yield and salinity-tolerant).

4. One of techniques studied by IRRI and introduced by CLUES, the water-saving irrigation technique of alternate wetting and drying (AWD), is a win-win technology. It helped farmers to cope with water scarcity and reduced methane emissions from paddy fields by up to 50% compared with continuous flooding. GIZ, in collaboration with CLUES, organized 41 training classes: 1,418 farmers with areas of 30 demo sites of 30 ha. The activities of GIZ were also integrated with large-scale fields in Vinh Loi (439 ha).

5. A new model tool for land-use analysis through a multiple-goal linear programming approach was developed in Bac Lieu Province as a coastal area of the MRD. It enhanced understanding of the current biophysical and socioeconomic conditions and adaptation opportunities for the study area under the impacts of current and future CC and SLR.

6. The study on salt leaching in the rice-shrimp system (applying lime, plowing, and leaching frequencies solely or in combination) enhances salt leaching in the rice-shrimp farming system. It has been applied to another rice-shrimp system of similar

conditions in the Mekong Delta within the project "Improving the sustainability of rice-shrimp farming systems in the Mekong Delta, Vietnam" funded by ACIAR (SMCN/2010/083).

7. CTU has developed and submitted a new scientific proposal investigating soil microbial community functioning in greenhouse gases emissions under AWD application. The new scientific collaboration was established with the Division of Soil Microbiology in the Swedish University of Agricultural Sciences to study the soil microbial community under different soil amendments in the rice-shrimp system.

8. CLUES proposed a new modelling tool for land-use planning that supports better use of natural resources in Bac Lieu Province. At present, the tool can be applied for other provinces in the MRD.

9. The study on GHG measurements in Vietnam using a closed chamber for flux samplings in CLUES has been out-scaled to other projects such as GIZ–Tra Vinh and WINROCK–Long An. They have applied the same method in CLUES to measure GHG emissions from paddy rice. CLUES also participated in three MRV workshops organized by the Institute of Agricultural Environment initially supported by WINROCK-Vietnam to formulate protocols/guidelines for studying GHG emissions from the rice crop in Vietnam.

10. Scientific publications (see section 10.2 for details).

As of this date, the PO has more than 250 technical reference materials of all kind, including electronic files of data, reports, and other documents received from different themes.

Sixty-four publications that include nine peer-reviewed international papers, 22 papers in Vietnamese, and 10 presentations at international conferences.

Seven posters were presented at international conferences and 20 posters in CLUES workshops.

It is expected in the next 5 years that at least six papers will be published in national and international journals, and four to five new research proposals that will build on scientific knowledge from CTU partners of CLUES will be prepared.

8.2 Capacity impacts – now and in 5 years

Stronger linkages and exchange of knowledge have been found through project networks (such as CTU, SIWRP, Sub-NIAPP) on a broad range of approaches in climate change-related research. Furthermore, the active involvement and proper training of partners through this project eventually guarantee the relevance of the project to their needs and continued impact beyond the project timeframe. Most of the beneficiaries were CLUES team members, local staff in four provinces, and university students.

The main capacity impacts through the project network are summarized as the following:

1. Expanding understanding of the impact of climate change on hydrology, salinity, and rice production in the Mekong Delta and target provinces in CLUES. It also enhances the understanding and skill of staff about GIS and remote sensing in delineating and manipulating spatial data.

2. Enhanced capacity of local partners, such as CLRRI, in applying MABC to simultaneously select for well-characterized genes conferring tolerance of abiotic stresses, while recovering the genetic background of the recurrent parents (popular varieties or elite breeding lines). MABC could then be incorporated as part of national breeding programs to introduce genes of agronomic importance as they become available.

3. Established laboratory facilities (gas chromatography) for GHG emission studies in the MRD and supplied necessary field equipment (closed chambers) and training for emission records in agricultural systems.

4. A cadre of experts formed on climate change adaptation and mitigation that could initiate and steer future climate change projects in the Mekong Delta and liaise with Vietnamese groups in charge of National Communication to the UNFCCC.

5. Enhanced capacity of young scientists by taking on roles in different aspects of the project and through participation in various training workshops and scientific visits.

6. Men and women farmers, NGOs, and extension personnel at selected sites trained on-site in aspects of participatory research and evaluation, and in providing feedback during different stages of the project, for eventual impact and relevance.

7. Within the socioeconomic component of the project, this includes training to conduct household surveys, running and facilitating workshops, incorporation of biophysical modelling into livelihood assessments, analysis and write-up of data for publications, and presentations at scientific meetings.

8. Findings from the project have been shared with local extension workers and farmers, which provide them with new insights and adopting capacity toward new techniques feasibly applied in the management of rice-based natural resources.

9. Impacts in the next five years would extend to the technical staff of the Mekong Delta provinces, new projects in Bac Lieu such as the Climate-Smart Agriculture/Village (CCAFS, CGIAR), and other researchers and students in the Mekong Delta.

10. Trainees and activities from CLUES training activities from March 2011 to June 2015 are summarized in Tables 8 and 9, where gender is also recognized. Some 3,960 farmers attended PVS training on rice varieties (see Appendix 10) and another 111 individuals were trained on other themes or related activities of CLUES. Some 733 women participated in training activities, representing 19% of the total of trainees from CLUES.

Table 8. List of non-degree training from March 2011 to June 2015 and expected outcomes in the next 5 years.

Theme	Name of activity	Date	Length of activity	No. of people involved	Males	Females	Expected outcome and what will change in the next 5 years
1	Guidance on using the inundation and salinity risk maps in the Mekong Delta at CTU	28 Feb. 2014	1 day	21	15	6	
3	Soil and plant sampling methods at CLUES, CTU	Dec. 2011	1 day	20	15	5	(Lecturers: Đông, Tường, Phong)
3	Sampling methodologies for soil solution, sediment and field experimental design and statistical analyses atCLUES, CTU (funded by the Crawford fund)	Mar. 2012	5 days	30	20	10	(Lecturer: Ben Macdonald)
3	Agricultural research management in IRRI, Philippines	2014	5 days	3	3	0	(Bac Lieu site)
3	Research data management & scientific communication in IRRI, Philippines	2015	5 days	1	1	0	(Hau Giang site)

3	Research data management & scientific communication in Australia	Feb-Mar 2015	40 days	1	1	0	(Bac Lieu site)
4	Technology assessment	1 Dec. 2013	1 day	24	16	8	Perceptions and attitude on promising rice-shrimp farming systems
4	Participatory Adaptation Research Refresher Course at CTU	Nov. 2011	4 days	5	4	1	Applying the approach and methods in farming technology evaluation at CTU and CLRRI
4	Assessments on technical, socioeconomic, and environmental impacts of new technologies at CTU	Sep. 2012	1 day	4	3	1	Applying (and developing) the approach and method to relevant research projects at CTU
4	Agricultural research management program (the John Dillon Fellowship) in Australia	Feb.-Mar. 2013	40 days	1	1	0	Improved individual and team's scientific writing and presentation skills, leadership, and research management; Improved achievements and sustainability of later research projects
4	English training (the John Allwright Scholarship by ACIAR for PhD candidate) in HCMC	Oct. 2012-Mar. 2013	6 months	1	1	0	English communication in research
4	Research data management at IRRI, Philippines	Nov. 2014	4 days	1	1	0	Sharing with colleagues to apply methods and tools in research data management
5	Training on "Tool for support of decision making on land use under conditions of climate change" at CTU	11-14 Mar. 2014	4 days	17	13	4	Identify and analyze the problem before decision making
6	Training on flux sampling at CLRRI	7 Mar. 2014	1 day	7	6	1	Set up closed chambers and do sampling for quantifying GHG emissions
6	Workshop on SRI model demonstration at Cau Ke , DARD Tra Vinh	23 April 2013	1 days	30	24	6	GHG mitigation under SRI model
Total				**111**	**84**	**27**	

Table 9. List of staff that participated in degree training from March 2011 to June 2015 and expected outcomes in the next 5 years.

Theme	Name of activity	Date	Length of activity (years)	No. of people involved	Males	Females	Expected outcome/what will change In the next 5 years
5	Mr. Pham Thanh Vu. Title of study: Strategic planning for sustainable use of land resources by the Mekong Delta coastal areas: a case study in Bac Lieu Province	2011	4	1	1		PhD in land management
4	MSc theses in rural development at CTU	Dec. 2013 -Oct. 2014	10 months	3	3		Improved career of graduate students and increased performance of their employers. Develop new research project building on results from the theses by MDI.
4	Mr. Hua Hong Hieu, awarded the John Allwright Fellowship by ACIAR for PhD studies at the Australian National University (2013-17)	Sep. 2013 -Sep. 2017	4 years	1	1		Improved career of Mr. Hieu and performance of MDI/CTU. Further improved network between CTU and ANU/CSIRO.
3	Mr. Dang Duy Minh, awarded the John Allwright Fellowship in 2012 for his research on nitrogen and carbon emissions using pot experiments. He is currently enrolled in the Australian National University and is based at CSIRO Black Mountain.	2012	4	1	1		PhD in soil science Improved career of Mr. Minh and performance of CTU. Further improved network between CTU and ANU/CSIRO.
2	Mr. Bui Phuoc Tam enrolled in the University of the Philippines Los Baños for his MSc program in plant genetics (from October 2013 to	2013	2	1	1		MSc in plant breeding

	October 2015)						
2	Ms. Tran Thi Nhien enrolled in the University of the Philippines Los Baños for her MSc program in plant genetics (school year October 2014 to October 2016)	2014	2	1		1	MSc program in plant genetics
2	Mr. Chau Thanh Nha enrolled in the University of the Philippines Los Baños for his MSc program in plant genetics (school year June 2012 to April 2014)	2012	2	1	1		MSc program in plant genetics
2	Ms. Vo Thi Tra My enrolled in the University of the Philippines Los Baños for her MSc program in plant genetics (school year June 2012 to April 2014)	2012	2	1		1	MSc program in plant genetics
2	Mr. Bui Thanh Liem enrolled in Scuola University, Italy, for his PhD program in plant breeding (school year April 2012 to March 2015)	2012	3	1	1		PhD in plant breeding
1, 5	Students enrolled in Can Tho University with research theses related to the study of Themes 1 and 5.	2011 -15	1	12	8	4	MSc
3	Students enrolled in Can Tho University with research theses related to the study of Theme 3		2	14	10	4	MSc
3	Students enrolled in Can Tho University with research theses related to the study of Theme 3		4	1	1		PhD
3	Students of Australian universities, Ms. Temma Carruthers-Taylor and Ms. Leah Garnett, were awarded a Crawford Fund training fellowship to undertake their honors thesis work in Bac Lieu, Hau Giang, and An	2013	0.25	2		2	MSc

	Giang.						
	Total			**40**	**28**	**12**	

The list of CLUES publication can be found in section 10.2 of this report.

8.3 Community impacts – now and in 5 years

The connections among staff of the project themes, the PO, and local DARD counterparts were closer at the end of CLUES. Partnership and exchange of expertise between organizations have been enhanced through local workshops or training.

8.3.1 Economic impacts

The results of CLUES have increased the capacity of farmers and communities to mitigate the negative impacts of climate change by making use of different adaptation options that are economically feasible for their characteristics. Some economic impacts expected from CLUES follow:

1. Significant economic benefits to breeding programs and to farmers from the use of MABC. Both *Saltol* and *SUB1* could be incorporated into popular varieties within two to three years, thus considerably reducing the duration required using conventional methods. In addition, the incremental economic benefits of using MABC for both traits over the long run could be enormous (estimated at US$50 to $900 million over 25 years; Alpuerto et al 2009).

2. The use of short-maturing varieties, together with effective NRM practices and efficient cropping systems, has increased annual productivity, enhanced farmers' income, and provided more opportunities for sustainable livelihood options. The economic impacts of these activities will be realized in future years as farmers adopt stress-tolerant and improved varieties.

3. The results from field experiments on AWD and reduced fertiliser P application showed that a lower fertiliser P application in combination with AWD (irrigating when the water level is at –15 cm from the soil surface) is feasible to reduce the investment cost for fertilization and irrigation and consequently bring more income to farmers. Soil resources in the MRD under intensive rice cropping supply sufficient available P to meet the demand for P nutrient for 2 years, equivalent to six sequential crops. For long-term P nutrient management, it is necessary to take into consideration the balance of soil P in fertiliser P application. AWD application in the winter-spring crop could save 50% of the irrigation cost and reduce methane emissions by 85% compared with CF (Tinh et al 2015). Net profit in AWD was US$350 higher than in CF.

4. In addition, in rice-shrimp farming systems, feasible techniques applied to efficiently remove salt from soil after the shrimp season would lead to a better following rice crop that in turn sustains the whole cropping system, consisting of both rice and shrimp. Replacing local varieties with short-duration and high-yielding rice varieties would help to shorten the rice standing period, thus extending the following period of shrimp cultivation, which brings more income for farmers.

5. Upland cropping could significantly increase farm income and profitability, thus improving farm economic resilience to climatic stresses. The cost-benefit ratio for upland cropping is double the ratio for triple-rice cropping. However, without carefully planning and connecting to the market, there is a potential risk for market oversupply. Under the

direction of MARD on restructuring agriculture to increase profit for farmers, upland crops (maize, soybean, sesame, etc.) are promoting high-profit crops. Recent information from Thoi Lai District-Can Tho City indicated that area under sesame has expanded nearly two times from 800 to 1,500 ha simply because the profit from sesame was much higher than that from rice (4–10 times).

6. Assessments of farmers' perceptions in socioeconomic surveys:

No.	Actors	Current impacts	Indicator(s)	Expected in next 5 years
1	Farmers use improved rice varieties	350 farmers participated in rice variety evaluation and have changed their knowledge, perception, and attitude (KPA)	Survey data from the Plant Seed Centre and Agricultural Extension Centre	3,500 farmers will use improved rice varieties (3,500 ha × VND 0.5 million = VND 1.75 billion per year)
2	Farmers apply new farming technologies (AWD, P application, soil salinity management, and rice-UC cropping system)	157 farmers participated in technological assessment and have changed their KPA	Survey data from Agricultural Extension Centre, farmers	1,570 farmers will apply new technologies (1,570 ha × VND 1 million = VND 1.57 billion per year)

8.3.2 Social impacts

Social impacts are the outstanding achievement of CLUES. A lot of local farmers and staff participated in the project activities. Awareness and participation of local stakeholders have increased through participatory discussions and assessments, and the verification of research results.

1. The reduced vulnerability to climate change impacts of rice-based production systems within the Mekong Delta has prevented the collapse of this important food-growing area.

2. Empowerment of the community through better access to knowledge through posting distilled recommendations and policies on IRRI's and Vietnamese web-based knowledge banks, and the provision of printed materials as policy briefs, posters and handbooks, and CDs to ensure efficient technology transfer and adoption, and speeding up the extension of the project outputs within and beyond the target sites.

3. Securing food supply and providing diversity of livelihood through CLUES technical options have reduced drudgery for women by reducing male migration and encouraging investments in children's education and health care, thus improving the well-being of the community. The project helped strengthen community-based local seed systems to ensure effective and efficient production and the timely distribution of sufficient high-quality seeds to farmers, which will in turn, contribute to higher yields and income.

4. Reduced vulnerability and social inequity by enhancing farmers' portfolio of options to better manage risk in a climate change context and providing adaptation options to the most disadvantaged groups.

The socioeconomic theme of CLUES addressed gender issues by involving women farmers in the early stages of the project phase, thus helping more women to be more confident and recognized as "farmers" rather than farm helpers. Details of the impacts are presented in Table 10.

Table 10. Farmers' participation in CLUES and expected change in the next 5 years.

Site	Actors/workshops/ training	Date	Length of activity	No. of people involved	Males	Females	Expected change in next 5 years
Study sites	Farmers participated in livelihood capacity assessments and gender analysis	2011-12	0.5 day	1,312	1,010	302	Enhanced capacity of farmers and participation in livelihood assessments and improved KAP on gender equality
Study sites	Farmers participated in participatory rice varietal assessments	2012-14	0.5 day	1,407	897	510	Empowering farmers and their participation, particularly women, in rice varietal evaluation, local extension activities, and local community development plan using participatory approaches
Study sites	Farmers participated in rice farming technology assessments	2013-14	0.5 day	157	125	32	Empowering farmers and their participation, particularly women, in agricultural technology feasibility assessments, local extension activities, and local community development plan using participatory approaches
Study sites	Local extension staff participated in assessing technological feasibility and exploring impact and extension pathways	2014	1 day	45	33	12	Improved effectiveness and efficiency of extending new technologies from CLUES and other projects
Study sites and CTU	Governmental officials/officers participated in workshops on institutional analysis, farmers' livelihood capacity, and out-scaling/up-scaling of new technologies	2012-14	1 day	58	52	6	Improved effectiveness and efficiency of policy implementation on better uses of natural resources, enhanced capacity of farmers' livelihood, further scaling up of new technologies from CLUES and other projects
	Total			**2,979**	**2,117**	**862**	

8.3.3 Environmental impacts

The project was not expected to have any negative impacts on the environment, yet, considerable gains are expected, including the following:

1. The use of salt- and submergence-tolerant varieties will help bring back land and water resources that are currently underused or not being used, and this could free precious water resources in other areas for alternative uses, including environmental services.
2. Providing alternative income sources and livelihood options will help prevent overexploitation of natural resources and ease environmental degradation in these highly vulnerable coastal areas.
3. Careful assessment of the consequences of climate change in these areas will help formulate policies and practices to reduce undesirable impacts of climate change and facilitate designing proper coping strategies to mitigate likely harmful consequences.
4. Judicious NRM and improved technologies will reduce pollution load (acidity, agrochemicals) in the surrounding water and greenhouse gas losses to the atmosphere.

The environmental impacts of adaptation options will be examined through an assessment of the overall livelihood responses likely with climate change. Consideration will be given to important trade-offs.

8.4 Communication and dissemination activities

Users of information essentially included stakeholders (farmers, scientists, extension personnel, and policymakers) and the scientific community. The existing and new means being made available at IRRI, in Vietnam, and in Australia were used to disseminate project information to target audiences. The outcomes follow:

1. Communication took place with engaged activities at four study sites of CLUES, and liaison units for target zones/provinces were established composed of representatives from the Department of Agriculture and Rural Development (DARD), provincial and district offices, and CLUES site managers. Liaison units have facilitated regular communication among CLUES members, selected farmers, and local agricultural staff during the experiment.

The findings of CLUES have been evaluated and disseminated by CLUES team members with local growers, seed production companies, local governments, and farmers through demonstration farmer fields, workshops, and training courses.

2. Community participation in activities of CLUES: Communication activities have been frequently done within the socioeconomic component with other themes and local counterparts during the implementation of project activities. Field or PVS days of technology feasibility assessments would facilitate the gradual dissemination of feasible rice varieties and farming technologies with the communities where on-farm trials were established.

3. Communication outputs:

CLUES webpage at IRRI: http://irri.org/networks/climate-change-affecting-land-use-in-the-mekong-delta.

Google file sharing: https://sites.google.com/a/irri.org/clues-file-sharing/home?pli=1.

Dropbox of CLUES for internal exchange of data and documents.

A total of 10 news articles were published locally or internationally (*IRRI Bulletin, ACIAR VN*).

Thirteen leaflets (in English and Vietnamese) and five technical books (in Vietnamese) were produced by the themes and disseminated.

Media: There were three visits to CLUES project sites by journalists and communication staff of CCAFS (May 2013), to CIAT (in March 2014), and to IRRI (in November 2014) for photos, documentation, and farmer interviews. Two videos about CLUES and climate change were made by IRRI (2015) and CIAT (2014).

4. Project facilitation: For consistency of documentation in CLUES, uniform templates for all theme progress reports, semi-annual and annual reports, posters and oral presentations, and scientific reports were applied. Uniform templates for data collection from field experiments as well as experimental protocols were also developed and shared with the researchers involved in CLUES.

5. Collaboration with GIZ-Bac Lieu and others: Collaboration has been good between CLUES and GIZ-Bac Lieu on rice production improvement (2012-14). Some activities follow:

2011: A study tour on AWD in An Giang Province was organized by the CLUES office for GIZ and local people in Bac Lieu.

2011: Through facilitation provided by the CLUES Project Office, the socioeconomic component collaborated with the GIZ Project and PPS Bac Lieu to conduct a survey on assessment of AWD techniques in rice production in Bac Lieu.

2012: A training course on stress-tolerant rice cultivation by experts from IRRI and CLUES.

2013-14: In response to this, GIZ supported 30 ha of AWD demonstrations and training.

AWD was applied by farmers on 701.53 ha during winter-spring 2013-14.

6. The CLUES database on GHG emissions will be used in the national MRV network. At least three journal articles will be published in 2015 on effects of soil type, cultivation method, and cropping system on methane and nitrous oxide emissions from paddy in the Mekong Delta. Interacting will be done with national agencies (Institute of Agricultural Environment) for GHG mitigation and inventories (e.g., Task Force for National Communication to UNFCCC).

7. Interaction with the ACIAR research project on rice-shrimp systems (SMCN/2010/083). The staff of CLUES have also participated in the rice shrimp project. So their experiences and results from CLUES can be useful for that project.

8. Workshops in Hanoi (15/9/2016) and Can Tho (11/9/2016) at the end of the project to communicate with stakeholders, particularly national and district level policy makers about what the implications of the project are for policy, planning and investment.

9 Conclusions and recommendations

Different conclusions and recommendations have been made by themes.

9.1 Conclusions

Impact of CC and SLR in the MRD

Hydro-climate-related problems in the MRD show a complex matrix in time and space encompassing a variety of distinct constraints to rice production:

- SLR + CC aggravate both flood-related and salinity stresses in the MRD.
- Impacts on flood-related stress are more widespread than on salinity stress.
- Adaptation to CC and SLR cannot be seen in isolation from upstream development.
- Adaptation to CC and SLR requires both hard and soft strategies. Climate-smart agriculture plays a central role.
- Not all SLR + CC impacts are negative. SLR raises the water level higher inland in the dry season, which facilitates freshwater accessibility and supports gravitational irrigation.

Developing stress-tolerant rice varieties

- Through the use of innovative breeding methods such as marker-assisted backcrossing (MABC), good progress was made in developing submergence- and salt-tolerant varieties. The key varieties chosen to receive the *SUB1* QTL were OM1490 and OMCS2000. QTL analysis was also performed to identify QTLs associated with tolerance derived from Vietnamese variety Tai Nguyen (TN) under anaerobic conditions during germination.
- Four varieties were submitted for release in 2014: OM3673 with short growth duration and tolerance of anaerobic seedling stage, OM10252 with tolerance of submergence and salinity, and OM6328 and OM6677 with salinity tolerance and high yield.

Natural resource management

- The findings from AWD experiments in three years (2012-14) proved that sole application of AWD or reduced P fertilization did not have an adverse effect on soil capacity in supplying available P as well as the growth and production of rice. AWD irrigation can be applied well at An Giang and Bac Lieu sites.
- Upland crop diversification in the rice-based farming system improved profitability and increased flexibility in the cropping calendar, which mitigates the risks of CC. The connection between the market and farmers should be supported to ensure the integration of upland cropping into double- and triple-rice production systems.
- Short-duration and high-yielding rice varieties that were tested in the rice-shrimp farming system could replace local rice varieties and give more time for the shrimp season.

Socioeconomics

- Most of the feasible farming technologies created by the project (AWD, P reduction) suit alluvial or slightly acidic soils with available irrigation and drainage systems, except for appropriate P application technique in the acid sulfate zone (Hau Giang Province).

- The out-scaling of the AWD practice is more preferable to cooperative irrigation management or a “large-scale” field model.

- Rotation of upland crops into rice-based systems, which needs an intensive labor input and/or limited markets for outputs, was not considered as a high priority.

- DARD and its agencies are important actors in the out-scaling and up-scaling of the technologies. In addition, farmers’ groups, business enterprises, and agricultural and rural development banks play an important role. Successful extension of the promising technologies needs necessary enablers such as availability and accessibility of formally favorable loans, improved irrigation and drainage systems, farmers’ cooperation, zoning and services for inputs and outputs, mechanization, and an effective extension program.

GHG emissions

- CH_4 emissions were significantly lower (46%, 40%, and 70%) in AWD treatment compared with CF treatment at three study sites in An Giang, Hau Giang, and Bac Lieu, respectively.

- There were no significant differences in N_2O emissions among different phosphate fertiliser doses as well as between AWD and CF treatments in An Giang (alluvial soil), Hau Giang (acid sulfate soil), and Bac Lieu (saline soil).

- Different soil types induced methane emissions differently. Methane emissions increased in the order deep-flooded alluvial soil (An Giang) > shallow-flooded alluvial soil (Can Tho) > acid sulfate soil (Hau Giang) > saline soil (Bac Lieu, Ca Mau, Kien Giang). In alluvial soils at CLRRI (Can Tho), AWD treatment significantly decreased CH_4 emissions (54%) compared with CF treatment.

- Seasonal variations in methane emissions were observed in the Mekong Delta. Methane emissions from rice paddies were highest in autumn-winter and lowest in the summer-autumn crop.

- The introduction of upland crops into the triple-rice system reduced methane emissions significantly.

9.2 Recommendations

- The study delineates the extent of vulnerable area under different levels of depth of flooding and of salinity on different land-use types, which should be considered in the levels of damage and crop yield losses or levels of vulnerability under different climate change scenarios.

- Future efforts should focus on further collection and evaluation of local germplasm to identify landraces with greater tolerance of submergence and salt stress and drought stress as sources of new genes or alleles for breeding.

- Additional breeding efforts such as exciting developments in the field of genomics and additional resources and efforts should be directed toward the identification of QTLs and genes underlying tolerance of the multiple stresses experienced in the problem soils of the Mekong Delta, for their subsequent integration into modern varieties and elite breeding lines through marker-aided breeding. Fine mapping of these genes will allow them to be transferred readily into new varieties, thereby adding to the suite of stress tolerances built into the new lines.

- Acidity and salinity management plans for upland cropping must be considered. These plans should be regularly evaluated and modified.

- A methodology for appropriate land-use strategy for climate change adaptation of the coastal area of the Mekong Delta was applied in a case study in Bac Lieu Province, one of the most CC-vulnerable provinces of the Mekong Delta. To assure successful development of the CCA strategies, the following studies are essential:
  - Risk management on crop failure (by disease, water pollution, extreme weather) and on market fluctuation.
  - Land- and water-efficient use (e.g., the large-farm model).
  - Changes in rural labor (both quantity and quality) due to migration and mechanization.
  - Longer term impacts of CC and SLR and additional impacts of land subsidence on salinity and flooding in the Mekong Delta.
  - An appropriate platform to support innovation practices in Mekong Delta rural development (financial, manufacturing, enterprise, distributor, and farmer innovation, etc.).

9.3 Intellectual property

Four varieties developed by CLUES were submitted by CLRRI to DARDs at four target provinces of CLUES for release in 2014. Then CLRRI (Nguyen thi Lang) submitted document for release to Ministry of Agricultural and Rural Development – Vietnam in 2015:

- OM3673: short growth duration, salinization time, and tolerance of anaerobic seedling stage.
- OM10252: tolerance of submergence and salinity.
- OM6328 and OM 6677: salt tolerance and high yield.

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Nguyen Quang Chon, Tran Dang Dzung, Tran Duy Viet Cuong and Mai Thanh Truc and others. 2015. Integration of upland crop production in lowland rice-based cropping systems for climate change adaptation. Theme 3 CLUES Project Report.

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Phong N. H. 2014. Effects of liming, plough and salinity washing increasing on soil salinity removal and rice yield in shrimp-rice cropping system in Phuoc Long District, Bac Lieu Province”. Master thesis in Soil Science. College of Agriculture and Applied Biology, Can Tho University.

van Ittersum M, Roetter R, van Keulen H, de Ridder N, Hoanh C, Laborte A, Aggarwal P, Ismail A, Tawang A. 2004. A systems network (SysNet) approach forinteractively evaluating strategic land use options at sub-national scale in South and South-east Asia. Land Use Policy 21:101-113. doi: 10.1016/j.landusepol.2004.02.001.

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10.2 List of publications produced by CLUES project

Eight peer-reviewed papers of CLUES were published in international and national journals in 2013-15:

10.2.1 Refereed publications

Refereed papers in English

1. Nguyen Thi Lang, Pham Thi Thu Ha, Chau Thanh Nha, Nguyen Van Hieu, Doan Van Hon, A. Ismail, R. Reinke, and Bui Chi Buu. 2013. Introgression of Sub1 gene into local popular varieties and newly developed elite breeding lines in the Mekong Delta adapted to climate change. Omon Rice 19 (2013):27-39.

2. Nguyen Thi Lang, Nguyen Van Hieu, Tran Thi Nhien, Bui Phuoc Tam, Vo Thi Tra My, Bui Chi Buu, R. Labios, A. Ismail, R.Reinke, and R. Wassmann. 2013. Enriching gene pool to enhance rice productivity under submergence and medium stagnant water stress in Mekong Delta. Omon Rice 19 (2013):89-96.

3. Ngo Dang Phong, To Phuc Tuong, Nguyen Dinh Phu, Nguyen Duy Nang, and Chu Thai Hoanh. 2013. Quantifying source and dynamics of acidic pollution in a coastal acid sulphate soil area. Water, Air and Soil Pollution *224:1765*.

4. Ngo Dang Phong, Chu Thai Hoanh, Tran Quang Tho, Nguyen Van Ngoc, Tran Duc Dong, To Phuc Tuong, Nguyen Huy Khoi, and Nguyen Xuan Hien. 2014. Impact of sea level rise on submergence, salinity and agricultural production in a coastal province of the Mekong River Delta, Vietnam. In: C.T. Hoanh, V. Smakhtin, and R. Johnston (Editors). Climate change and agricultural water management in developing countries. CABI Climate Change Series. CABI Publishing, UK.

5. Ngo Dang Phong, Chu Thai Hoanh, To Phuc Tuong, and Hector Malano. 2014. Effective management for acidic pollution in the canal network of the Mekong Delta of Vietnam: a modeling approach. Journal of Environmental Management 140 (2014):14-25. DOI: 10.1016/j.jenvman.2013.11.049.

6. Ngo Dang Phong, Chu Thai Hoanh, To Phuc Tuong, and Reiner Wassmann. 2014. Sea level rise effects on acidic pollution in a coastal acid sulphate soil area. In: Ames, D.P., Quinn, N.W.T., Rizzoli, A.E. (Eds.), Proceedings of the 7th International Congress on Environmental Modelling and Software, June 15-19, San Diego, California, USA. ISBN: 978-88-9035-744-2.

7. Nguyen Thi Lang, Bui Phuoc Tam, Nguyen Van Hieu, Chau Thanh Nha, Abdelbagi Ismail, Russell Reinke, and Bui Chi Buu. 2014. Evaluation of rice landraces in Vietnam using SSR markers and morphological characters. SABRAO Journal of Breeding and Genetics 46 (1):1-20.

8. Nhan P. P., Hoa L.V., Qui C.N., Huy N.X., Huu T.P., McDonald B.C.T. and Tuong T.P.. 2015. Increasing profitability and water use efficiency of triple rice crop production in the Mekong Delta, Vietnam. Journal of Agricultural Science. doi:10.1017/S0021859615000957.

Refereed publications in Vietnamese

1. Nguyen Thi Lang, Bui Thanh Liem, Vo Thi Tra My, Chau Thanh Nha, Bui Chi Buu, Russell Reinke, Abdelbagi Ismail, Reiner Wassmann. 2012. Selection of varieties to adapt to salt – marsh in Mekong Delta. Science and Technology Journal of

Agriculture and Rural Development. Topic on plant and animal breeding. Book 1. February/2012, 5–10. (In Vietnamese.)

2. Nguyễn Thị Lang, Bùi Thanh Liêm, Võ Thị Trà My, Châu Thanh Nhã, Bùi Chí Bửu, Rusell Reinke, Abdelbagi Ismail và Reiner Wassmann. 2012. Chọn lọc các giống lúa thích ứng với vùng biến đổi khí hậu ngập mặn tại Đồng Bằng Sông Cửu Long. *Tạp chí Nông Nghiệp và Phát Triển Nông Thôn,* chuyên đề giống cây trồng vật nuôi. Tập 1. Tháng 2/2012, trang 5–10.

3. Pham Phuoc Nhan, Cu Ngoc Qui, Tran Phu Huu, Le Van Hoa, B. McDonald, and T. P. Tuong. 2013. Effects of alternate wetting and drying irrigation, crop establishment methods, and reduced phosphorus application on OM5451 growth and yield in 2012 Winter Spring Crop Season. Journal of Science Can Tho University. Part B: Agriculture, Aquaculture and Biotechnology 28 (2013):103-111. (In Vietnamese.)

4. Pham Thanh Vu, Nguyen Trang Hoang Nhu, Vuong Tuan Huy, and Le Quang Tri. 2013. Determination of socio-economic and environment factors that affect the selection of farming models in Bac Lieu province. Journal of Science Can Tho University. Part D: Science, Politics, Economics and Law 27 (2013):68-75. (In Vietnamese.)

5. Phạm Thanh Vu, Le Quang Tri, Vương Tuan Huy. 2013. Adaptation of farmers on change farm model in Bac Lieu province. Science and Technology Journal of Agriculture and Rural Development 15 (2013):24-31. (In Vietnamese.)

6. Truong Thi Ngoc Chi, Thelma R. Paris, Tran Thi Thuy Anh, Chau Chieu Y, Huynh Nhu Dien, Tran Quang Tuyen, Romeo Labios, and Nguyen Thi Lang. 2013. Male and female farmers' participation in varietal selection. The First National Conference on Crop Sciences on 5-6 Sept. 2013. Agriculture Publisher, Ha noi, 2013:1336-1342. (In Vietnamese.)

7. Vuong Tuan Huy, Van Pham Dang Tri, Pham Thanh Vu, Le Quang Tri và Nguyen Hieu Trung. 2013. Application of Aquacrop model to simulate rice yield in the context of climate change in the northern area of the national road 1A. Bac Lieu Province. Science and Technology Journal of Agriculture and Rural Development 13 (2013):48-53. (In Vietnamese.)

8. Nguyen Thi Lang, Bui Phuoc Tam, Pham Thi Chuc Loan, Nguyen Trong Phuoc, Tran Bao Toan, Bui Chi Buu, Abdelbagi M.Ismail, Glenn Gregorio, Russell Reinke, and Reiner Wassmann. 2014. Screening gene tolerant to salinity on short-term rice in the seedling stage. Journal of Vietnam Agricultural Science and Technology. No. 4 (50) 2014:23-28 (ISSN-1859-1558). Published by Vietnam Academy of Agricultural Sciences. (In Vietnamese.)

9. Nguyen Thi Lang, Nguyen Van Hieu, Pham Thi Thu Ha, Bui Chi Buu, and Abdelbagi M. Ismail. 2013. Quantitative trait loci (QTLs) mapping with submergence tolerance in rice (*Oryza sativa* L.) at Mekong Delta. In: Proceedings of Biotechnology Conference 2013 at National Conference Center in Hanoi, Vietnam, 27 September 2013. Volume 2. Molecular Biotechnology and Plant Biotechnology. Science and Technology Publisher. p 893-895.

10. Pham Thanh Vu, Le Quang Tri, Nguyen Hieu Trung, and Nguyen Huu Kiet. 2014. Optimization for land use planning option in Bac Lieu province. Science and Technology Journal of Agriculture and Rural Development 8 (2014):13-20. ISSN 1859-4581. (In Vietnamese.)

11. Pham Thanh Vu, Le Quang Tri, Nguyen Hieu Trung, Vuong Tuan Huy, Nguyen Tan Đat, and Le Thi Nuong. 2014. Using multi-criteria decision analysis in agricultural land uses in Bac Lieu province. Journal of Science Can Tho University 31 (2014):106-115. (In Vietnamese.)

12. Pham Thanh Vu, Nguyen Hieu Trung, and Le Quang Tri. 2014. Exploitation of scenarios for strategic land use option for agricultural development. Scientific Conference. Journal of Science and Technology. ISBN: 978-604-6703655. (In Vietnamese.)
13. Truong Thi Ngoc Chi, Tran Thi Thuy Anh, and Thelma Paris. 2014. Gender roles in household, constraints, risk-coping mechanisms in response to climate change. Journal of Vietnam Agricultural Science and Technology. No. 4 (50) 2014:73-79. ISSN-1859-1558. Published by Vietnam Academy of Agricultural Sciences. (In Vietnamese.)
14. Truong Thi Ngoc Chi, Tran Thi Thuy Anh, Thelma Paris, Le Duy. 2014. The gender dimensions of the relationship between climate change and rice-based farming systems: an exploratory assessment in the Mekong Delta. Omon Rice (in press). (In Vietnamese).
15. Truong Thi Ngoc Chi, Tran Thi Thuy Anh, Thelma Paris, Le Duy, Dang Tuyet Loan, and Nguyen Thi Lang. 2014. Farmers' feedback on rice varieties tested under farmer-managed trials. Omon Rice (in press). (In Vietnamese.)
16. Vo Van Tuan, Le Canh Dung, Vo Van Ha, and Dang Kieu Nhan. 2014. Adaptive capacity of farmers to climate change in the Mekong Delta. Journal of Science Can Tho University 31 (2014):63-72.
17. Nguyen Thi Hong Diep, Vo Quang Minh, Phan Kieu Diem, Pham Quang Quyet. 2014. Observing changes of aquacultural land in An Giang province from 2008 to 2012 using remote sensing and GIS. Journal of Science Can Tho University. Volume 30a (2014):78-83. ISSN: 1859-2333. (In Vietnamese.)
18. Nguyen Thi Ha Mi, Vo Quang Minh. 2014. Assessing the impact of climate change on rice farming in An Giang province. Journal of Science Can Tho University. Special issue: Agriculture. Volume 3 (2014):42-52. ISSN: 1859-2333. (In Vietnamese.)
19. Nguyen Quang Trung, Vo Quang Minh, Phan Kieu Diem. 2014. Assessing the changes of rice cropping in An Giang province in the period 2000-2013 on the basis of using MODIS image. Proceedings of Application of Nationwide GIS Conference 2014, Can Tho City, Vietnam, 28-29 November 2014. Cantho University Publisher: p 41-49. ISBN: 978-604-919-249-4. (In Vietnamese.)
20. Nguyen Thi Hong Diep, Vo Quang Minh, Phan Kieu Diem, Nguyen Van Tao. 2014. Climate change impact on land use in the coastal area of the Mekong Delta. Proceedings of Application of Nationwide GIS Conference 2014, Can Tho City, Vietnam, 28-29 November 2014. Cantho University Publisher: p 88-94. ISBN: 978-604-919-249-4. (In Vietnamese.)
21. Le Minh Hop, Tran Thi Hien, Vo Quang Minh, Nguyen Thi Hong Diep, Phan Kieu Diem. 2014. Application of MODIS image for monitoring the rice cropping pattern changes for services in agricultural management in Mekong Delta. Proceedings of Application of Nationwide GIS Conference 2014, Can Tho City, Vietnam, 28-29 November 2014. Cantho University Publisher: p 169-180. ISBN: 978-604-919-249-4. (In Vietnamese.)
22. Nguyen Van Phuc, Nguyen Thi Ha Mi, Phan Kieu Diem, Vo Quang Minh, Le Quang Tri, Nguyen Xuan Hien. 2014. Assessing the impact of climate change scenarios to current land use and land use planning in Hau Giang province. Proceedings of Application of Nationwide GIS Conference 2014, Can Tho City, Vietnam, 28-29 November, 2014. Cantho University Publisher: p 845-854. ISBN: 978-604-919-249-4. (In Vietnamese.)

10.2.2 Presentations

Presentations at international conferences

1. Nguyen Hieu Trung, Pham Thanh Vu, and Van Pham Dang Tri. 2014. An interactive approach to support natural resources use policy: a case study in the Vietnamese Mekong Delta coastal areas. *Proceedings of the International Symposium on GeoInformatics for Spatial-Infrastructure Development in Earth & Allied Sciences (GIS-IDEAS)*. Da Nang City, Vietnam, 6-9 December 2014. Available at http://gisws.media.osaka-cu.ac.jp/gisideas14/viewabstract.php?id=479.

2. Nguyen Thi Lang, Phạm Thị thu Hà, Nguyễn Văn Hiếu, Nguyễn Ngọc Hương, Bùi Chí Bửu, Russell Reinke, Abdelbagi M. Ismail, and Reiner Wassmann. 2014. Generating and disseminating improved rice lines tolerant of temporary (complete) submergence -- through transfer of the Sub1 gene into local popular varieties and newly developed elite breeding lines in rice *Oryza sativa* L. *8th Asian Crop Science Association Conference (ACSAC8): "Sustainable Crop Production in Response to Global Climate Change and Food Security."* Vietnam National University of Agriculture, Ha Noi, 23-25 September 2014. Book of abstracts. p 38.

3. Nguyen Thi Lang, Pham Thi Thu Ha, Nguyen Van Hieu, Tran Thi Nhien, Bui Chi Buu, Russell Reinke, and Abdelbagi M. Ismail. 2014. Gene pyramiding of salt and submergence gene and relevant genes in rice *Oryza sativa* L. *8th Asian Crop Science Association Conference (ACSAC8): "Sustainable Crop Production in Response to Global Climate Change and Food Security."* Vietnam National University of Agriculture, Ha Noi, 23-25 September 2014. Book of abstracts. p 36.

4. Nguyen Thi Lang, TranThi Nhien, Nguyen Van Hieu, Bui Phuoc Tam, Chau Thanh Nha, Tran Minh Tai , Bui Chi Buu, Russell Reinke, Abdelbagi M. Ismail, and Reiner Wassmann. 2014. Identify locally adapted varieties and elite breeding lines as recipients of *Sub1* and *Saltol* in rice. *8th Asian Crop Science Association Conference (ACSAC8): "Sustainable Crop Production in Response to Global Climate Change and Food Security."* Vietnam National University of Agriculture, Ha Noi, 23-25 September 2014. Book of abstracts. p 59.

5. Pham Phuoc Nhan, Le Van Hoa, Nguyen Truong Giang, To Phuc Tuong, and Ben Macdonald. 2014. Effects of alternate wetting and drying irrigation and phosphorous fertiliser rates on the growth and yield of rice in double rice cropping system at An Giang province. *Oral presentation in the 8th Asian Crop Science Association Conference (ACSAC8): "Sustainable Crop Production in Response to Global Climate Change and Food Security."* Vietnam National University of Agriculture, Ha Noi, 23-25 September 2014.

6. Pham Phuoc Nhan, Phan Thi Be Sau, Le Van Hoa, and Ben McDonald. 2014. Residue management effects on survival rate, growth and yield of rice cultivar IR64-Sub1 subjected to submergence at young seedling stage in pots. *Oral presentation in the 8th Asian Crop Science Association Conference (ACSAC8): "Sustainable Crop Production in Response to Global Climate Change and Food Security."* Vietnam National University of Agriculture, Ha Noi, 23-25 September 2014.

7. Reiner Wassmann and Ngo Dang Phong. 2014. Climate change affecting rice production in the Vietnamese Mekong Delta: potential and constraints of adaptation options. Invited presentation at the Mega Delta Symposium, 4th International Rice Congress, Bangkok, Thailand, 27 October–1 November 2014. International Rice Research Institute, Los Baños, Philippines. IRC14-1137.

8. To Phuc Tuong, Chu Thai Hoanh, Tran Quang Tho, Ngo Dang Phong, Nguyen Van Ngoc, Tran Duc Dong, Nguyen Huy Khoi, Nguyen Xuan Hien, and Reiner Wassmann. 2014. Climate change and sea level rise effects on rice-based production systems in the Mekong River Delta. Invited presentation at the Mega Delta Symposium, 4th International Rice Congress, Bangkok, Thailand, 27 October–1 November 2014. International Rice Research Institute, Los Baños, Philippines. IRC14-0497.

9. Vo Quoc Thanh, Chu Thai Hoanh, Nguyen Hieu Trung, and Van Pham Dang Tri. 2014. A bias-correction method of precipitation data generated by regional climate model. *Proceedings of the International Symposium on GeoInformatics for Spatial-Infrastructure Development in Earth & Allied Sciences (GIS-IDEAS)*. Da Nang City, Vietnam, 6-9 December 2014. Available at http://gisws.media.osaka-cu.ac.jp/gisideas14/viewabstract.php?id=505 or http://gisws.media.osaka-cu.ac.jp/gisideas14/viewabstract.php?id=505.

10. Vo Quang Minh, Huynh thi thu Huong, Nguyen Thi Hong Diep. 2012. Monitoring and delineating rice cropping calendar in the Mekong delta using Modis images. Proceedings of International Conference on Geo-Informatics for Spatial Infrastructure Development in Earth and Allied Sciences (GIS-IDEAS 2012). Ho Chi Minh City, 16-20 October 2012. JVGC (Japan-Vietnam GeoInformatics Consortium) Technical Document No. 8. p 150-156.

Presentations at national conferences

1. Nguyen Quang Trung, Phan Kieu Diem, Vo Quang Minh. 2014. Assessing the changes of rice cropping in An Giang province in the period 2000-2013 on the basis of using MODIS image. *Proceedings of Information Technology for Climate Change in developing exportable agricultural products in Vietnam.* Kien Giang Province, Vietnam, 29 September 2014. Science and Technology Publisher. ISBN: 978-604-6703655. (In Vietnamese.)

2. Vo Quang Minh, Phan Kieu Diem, Nguyen Xuan Hien, Le Quang Tri. 2014. Application of Geographic Information Technology (GIS) to identify vulnerable areas under the impact of climate change in the Mekong Delta. *Proceedings of Information Technology for Climate Change in developing exportable agricultural products in Vietnam.* Kien Giang Province, Vietnam, 29 September 2014. Science and Technology Publisher. ISBN: 978-604-6703655. (In Vietnamese.)

3. Temma Carruthers-Taylor, Gary Owens, Seija Tuomi, Ben Macdonald and Nasreen I. Khan. 2014. Application of the Molybdenum Blue method for Arsenic Determination: In Vietnamese Acid Sulphate Agricultural Soils. Proceedings Australian National Soil Science Conference

4. Leah Garnett, Jason Condon, Chau Minh Khoi, Ben Macdonald. 2015. Phosphorus fertiliser requirements of rice under alternate wetting and drying irrigation in the Vietnamese Mekong Delta. Proceedings of the 17th ASA Conference, 20 – 24 September 2015, Hobart, Australia. Web site www.agronomy2015.com.au.

10.2.3 Posters

Posters at international conferences

1. Chau Minh Khoi, Nguyen Van Qui, Nguyen Minh Dong, Bennett Macdonald, and To Phuc Tuong. 2014. Possibility of introducing high-yielding, short-duration rice varieties to replace local traditional photoperiod sensitive variety in the shrimp-rice cropping system in the Mekong Delta, Vietnam. Poster presented in 4th International Rice

Congress, Bangkok, Thailand, 27 October–1 November 2014. International Rice Research Institute, Los Baños, Philippines. IRC14-0841.

2. Chau Minh Khoi, Nguyen Van Qui, To Phuc Tuong, and Bennett Macdonald. 2014. Effects of alternate wetting-drying irrigation management on soil phosphorus availability and rice growth in the Mekong Delta, Vietnam. Poster presented in 4th International Rice Congress, Bangkok, Thailand, 27 October–1 November 2014. International Rice Research Institute, Los Baños, Philippines. IRC14-0855.

3. Nguyen Thi Lang, Pham Thi Thu Ha, Bui Phuoc Tam, Trinh Thi Luy, Tran thi Nhien, Nguyen Van Hieu , Nguyen Hoang Thai Binh, Bui Chi Buu, Romeo V. Labios, Russell Reinke, and Abdelbagi M. Ismail. 2014. Participatory varietal selection (PVS) for salt tolerance in rice in Mekong Delta. Poster presented in 4th International Rice Congress, Bangkok, Thailand, 27 October–1 November 2014. International Rice Research Institute, Los Baños, Philippines. IRC14-0692.

4. Nguyen Thi Lang, Nguyen Van Hieu, Pham Thi Thu Ha, Bui Chi Buu, and Abdelbagi M. Ismail. 2014. Backcrossing analysis to detect quantitative trait loci (QTLs) related to submergence tolerance in rice (*Oryza sativa.* L) in Mekong Delta. Poster presented in 4th International Rice Congress, Bangkok, Thailand, 27 October–1 November 2014. International Rice Research Institute, Los Baños, Philippines. IRC14-0273.

5. Nguyen Thi Lang, Pham Thi Thu Ha, Bui Phuoc Tam, Tran Thi Thanh Xa, Trinh Thi Luy, Tran Thi Nhien, Nguyen Van Hieu , Nguyen Hoang Thai Binh, Bui Chi Buu, Glenn Gregorio, Russell Reinke, and Abdelbagi M. Ismail. 2014. Breeding the rice varieties tolerant to salt by molecular markers. Poster presented in 4th International Rice Congress, Bangkok, Thailand, and 27 October – 1 November 2014. International Rice Research Institute, Los Baños, Philippines. IRC14-0265.

6. Pham Phuoc Nhan, Le Van Hoa, Tran Phu Huu, Nguyen Giang Truong, Danh Phuc Viet, Benett Macdonald, and To Phuc Tuong. 2014. Profit improvement in rice production by alternate wetting and drying irrigation and phosphorous reduction. *Poster presented in 4th International Rice Congress*, Bangkok, Thailand, 27 October–1 November 2014. International Rice Research Institute, Los Baños, Philippines. IRC14-0356.

7. Vo Quang Minh, Tran Thi Hien, Phan Kieu Diem, Nguyen Thi Ha Mi, Nguyen Xuan Hien, Le Quang Tri, Ho Van Chien. 2014. Rice crop monitoring for early warning pest occurrence using remote sensing and geographic information systems. Poster presented in 4th International Rice Congress, Bangkok, Thailand, and 27 October-1 November 2014. International Rice Research Institute, Los Baños, Philippines. IRC14-xxxx.

10.2.4 Leaflets of CLUES

- Thirteen leaflets about the products and technologies developed by the themes in the Final Review Workshop 2015 are available for dissemination (in both Vietnamese and English).

10.2.5 Publications In preparation

Refereed paper

1. Le Canh Dung, Vo Van Ha, Vo Van Tuan, Dang Kieu Nhan, John Ward, and Peter Brown. 2016. Financial capacity of rice-based farming households in the context of climate change in the Mekong Delta, Vietnam. The Asian Journal of Agriculture and Development. Submitted. Under review.

2. Ngo Dang Phong, Tran Quang Tho, To Phuc Tuong, Chu Thai Hoanh, Reiner Wassmann, Nguyen Huy Khoi, and Nguyen Xuan Hien. 2016. Flood and salinity

dynamics in canal network of the Mekong River Delta under climate change and sea level rise. (In preparation)

3. Khoi C.M., Qui N.V., Macdonald B.C.T., Tuong T.P. 2015. Improving phosphorus fertiliser use efficiency in salt affected intensified rice lands of the Mekong Delta. Agronomy Journal. Submitted. Under Review.

Conferences

1. Vo Quang Minh, Nguyen Thi Ha Mi, Tran Thi Hien. 2016. Monitoring changes of cultivated area of rice cropping in Mekong Delta by remote sensing. Proceedings of Application of Nationwide GIS Conference 2015, Ha Noi, Vietnam, 2015. (Under review.)

2. Nguyen Thi Ha Mi, Vo Quang Minh, Thai Thanh Du. 2016. Application of GIS technology in assessing the impact of climate change on rice farming in Mekong Delta. Proceedings of Application of Nationwide GIS Conference 2015, Ha Noi, Vietnam, 2015. (Under review.)

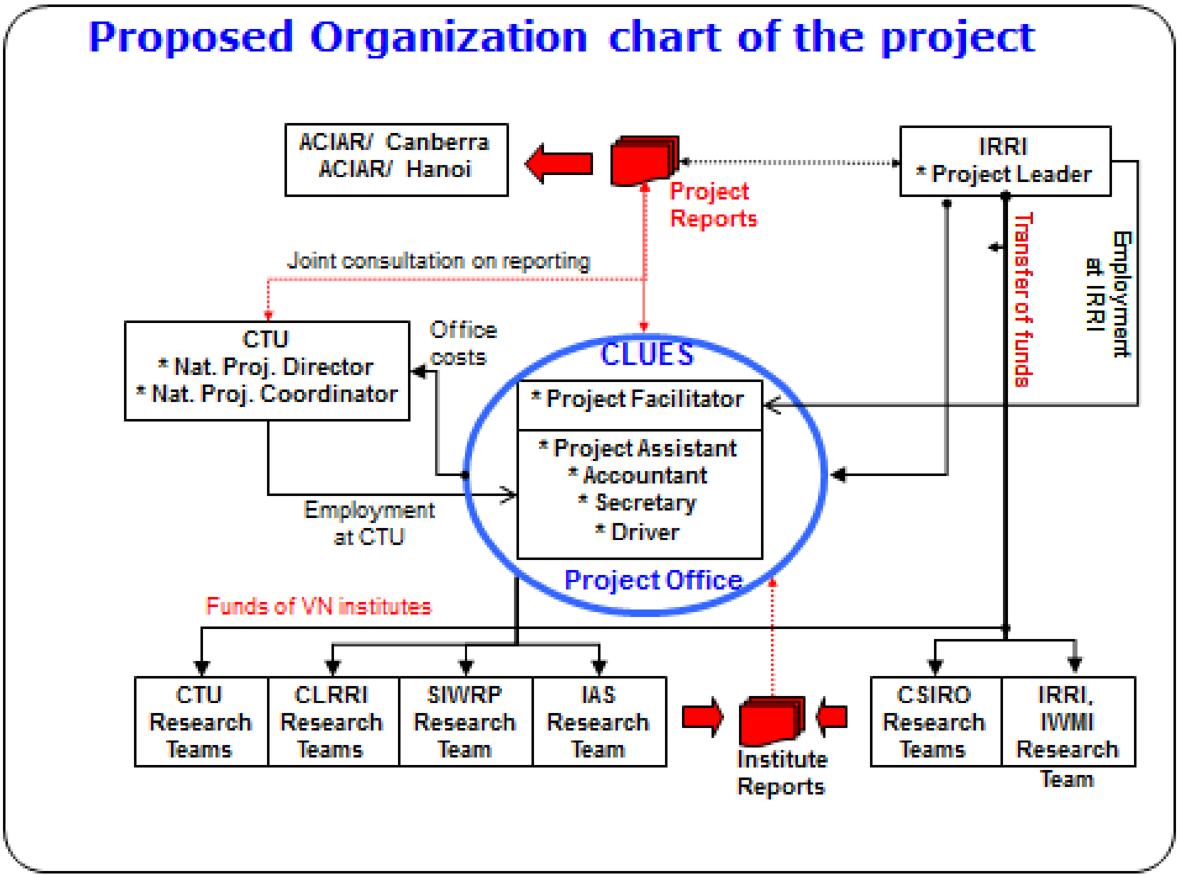
3. Thai Thanh Du, Nguyen Thi Ha Mi, Vo Quang Minh. 2016. GIS in the assessment of variation of rice crops under impacts of climate change in Bac Lieu province. Proceedings of Application of Nationwide GIS Conference 2015, Ha Noi, Vietnam, 2015. (Under review.)

11 Appendixes

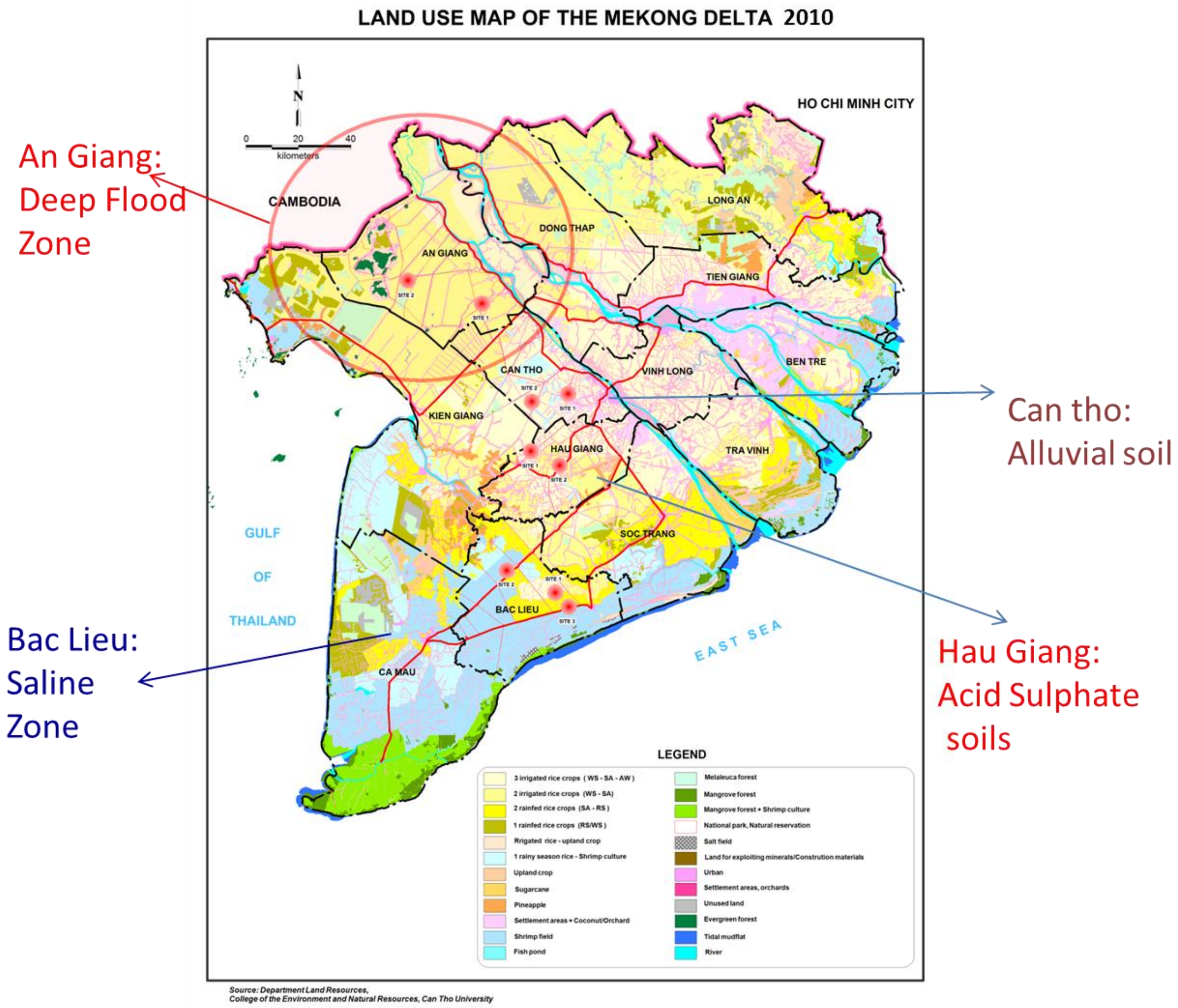
Appendixes 1–6. Six Theme Final Reports

(Included in other files)

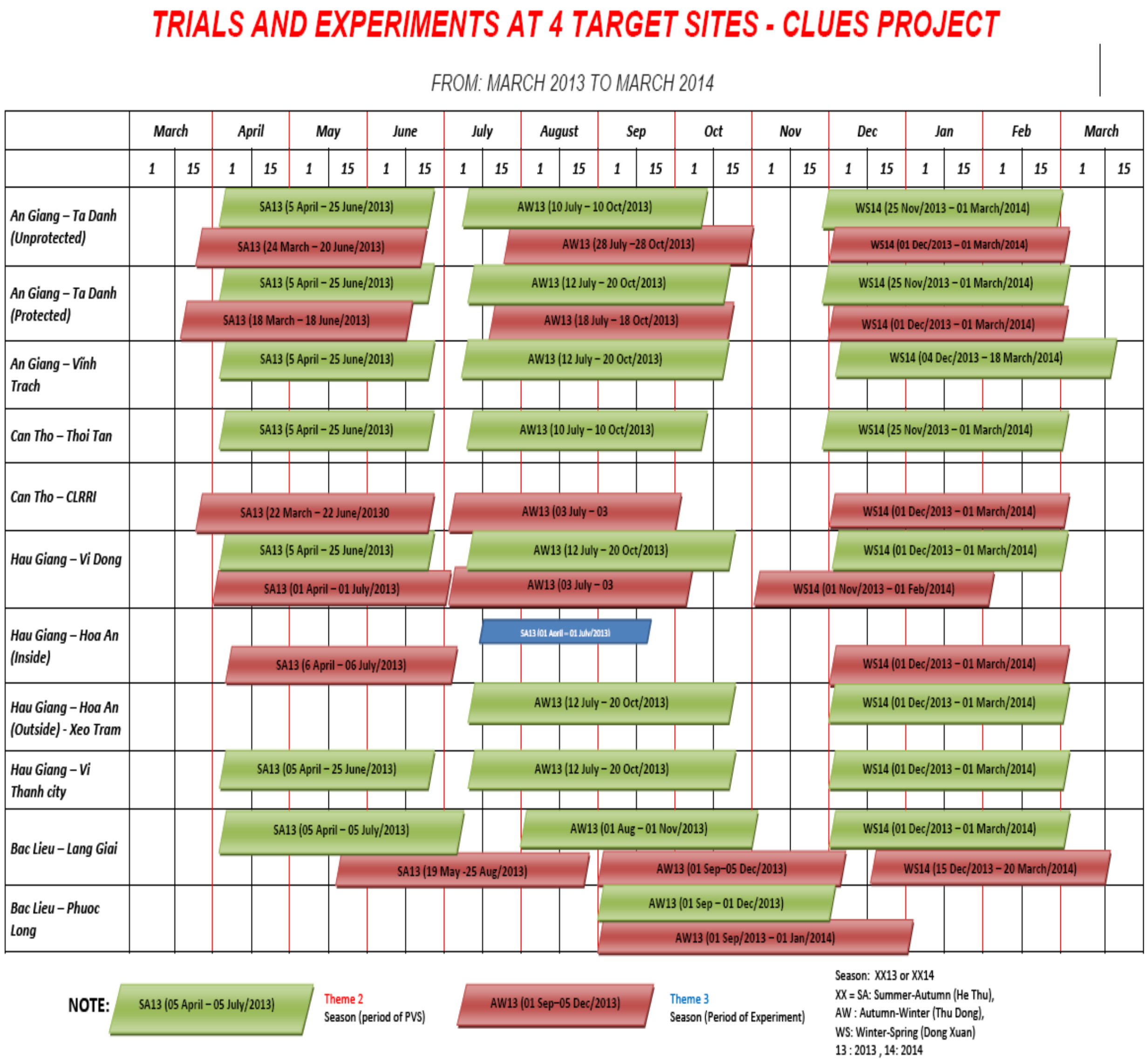
Appendix 7. Structure of organization of CLUES



Appendix 8. Location of study sites of CLUES



Appendix 9. Cropping calendars of experiments at study sites of CLUES



Appendix 10. Capacity building by Theme 2 (Plant breeding component)

10.1 Bac Lieu Province

No.	Name of activity	Date	Length of activity	No. of people involved	Males	Females	Expected outcome
	2012						
1	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Hòa Bình, Bạc Liêu	5 April 2012	1	55	43	12	A hands-on training in phenotype for selected new varieties Good land preparation and land levelling Fertiliser application and soil improvement Pest control (IPM) Selected some new OM 6677 OM 4900 OM 8104 OM 10252 OM 6328
		18 August 2012	1				OM 8105 OM 90L OM 10041 OM 8108 OM 10252
2	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Minh Diệu, Hòa Bình, Bạc Liêu	10 December 2012	1	49	33	16	A hands-on training in phenotype for selected new varieties Good land preparation and land levelling Fertiliser application and soil improvement Pest control

							(IPM) Selected some new OM 90L OM 4488 MNR1 OM 10252 OM 6677
3	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Phước Thạnh, Diệu, Phước Long, Bạc Liêu	18 December 2012	1	59	38	21	OM 6677 TLH 1 OM 8105 OM 10252 OM 5629
Year 2013							
4	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Minh Diệu, Hòa Bình, Bạc Liêu	22 March 2013	1	28	22	6	A hands-on training in phenotype for selected new varieties Good land preparation and land levelling Fertiliser application and soil improvement Pest control (IPM) Selected some new OM 90L OM 4488 MNR1 OM 4900 OM 6677
5	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Bạc Liêu	12 August 2013	1	35	26	9	OM 3673 OM 5629 OM 6162 OM 6677 TLH1
		20 December 2013		27	27	0	A hands-on training in phenotype for selected new

							varieties Good land preparation and land levelling Fertiliser application and soil improvement Pest control (IPM) Selected some new OM 5629 TLH1 OM 6677 OM 8105
6	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Phước Long, Bạc Liêu	24 December 2013		31	20	11	OM 5629 TLH2 OM 10252
	Year 2014						
7	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Láng Giài A, Hòa Bình, Bạc Liêu	22 April 2014	1	26	21	5	A hands-on training in phenotype for selected new varieties Good land preparation and land levelling Fertiliser application and soil improvement Pest control (IPM) Selected some new OM 4900 OM 3673 OM 6070 OM 6677 OM 5629
8	Training Workshop in Participatory Varietal Selection (PVS)	12 January 2015		30	20	10	OM10252, OM8108 OM3673

	for Enhanced Varietal Development Láng Giài A, Hòa Bình, Bạc Liêu						
				340	250	90	

10.2 Can Tho City

	Name of activity	Date	Length of activity	No. of people involved	Males	Females	Expected outcome
1	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development	5 March 2012	1	126	89	37	A hands-on training in phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties in Thoi Tan Village: 1. OM4488 2. OM 10041 3. Can Tho 2 4. OM 6L 5. OM 8928 Truong Xuan A Village: 1. OM 4488 2. OM 10041 3. Can Tho 2 4. OM 8928 5. OM 7L
2	Training Workshop at CLRRI	22 Feb. 2012	1	283	260	23	Information on new varieties for next season Need to change varieties or multiply new varieties
3	Training Workshop	26 June	1	30	20	10	A hands-on training in

	in Participatory Varietal Selection (PVS) for Enhanced Varietal Development	2012					phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties in Thoi Tan village: 1. OM 8108 2. OM 4488 3. Can Tho 2 4. OM 8928 5. OM 10041
4	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development	11 October 2012	1	30	25	5	A hands-on training in phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties in Thoi Tan village: 1. OM 8108 2. OM 96L 3. OM 4488 4. IR64-Sub1 5. OM 10418
5	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development	22 February 2013	1	30	26	4	A hands-on training in phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties in Thoi Tan Village: 1. OM 8108 2. OM 10040 3. OM 10041

							4. OM 4488 5. OM 4900
6	Training Workshop at CLRRI	3 March 2015	1	200	180	20	Information on new varieties for next season. Need to change varieties or multiply new varieties.
7	Training Workshop at CLRRI	22 August 2013	1	312	289	23	Information on new varieties for next season. Need to change varieties or multiply new varieties.
8	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development	4 October 2013	1	30	27	3	A hands-on training in phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties in Thoi Tan Village: 1. OM 7L 2. TLR375 3. OM 4488, OM 8928 4. OM 8108 5. OM 70L
9	Training Workshop at CLRRI	10 March 2013		210	179	31	Information on new varieties for next season. Need to change varieties or multiply new varieties.
10	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development	15 March 2014	1	30	26	4	A hands-on training in phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties in Thoi Tan Village: 1. OM 6161 2. OM 8108 3. Can Tho 1

							4. OM 10041 5. TLR 392
11	Training Workshop at CLRRI	22 July 2014	1	109	69	40	Information on new varieties for next season. Need to change varieties or multiply new varieties.
12	Training Workshop at CLRRI	2 November 2014	2	120	99	21	OM 10373, OM 8108, OM 3673
	Total			1,510	1,289	221	

10.3 An Giang Province

No.	Name of activity	Date	Length of activity	No. of people involved	Males	Females	Expected outcome
	Year 2012						
1	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Tân Thuận, Xã Tà Đảnh, Huyện Tri Tôn, An Giang	7 March 2012	1	50	30	20	A hands-on training in phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties: 1. OM 10040 2. OM 4900 3. OM 10041 4. OM 10000 5. OM 7347
2	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Trung Bình Tiến, Xã Vĩnh Trạch, Huyện Thoại Sơn, An Giang	7 March 2012	1	45	23	22	A hands-on training in phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties: 1. OM 10000 2. OM 7347 3. OM 10041 4. OM 10040 5. OM 8108
3	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Tân Thuận, Tà Đảnh, huyện Tri Tôn, An Giang (inside dyke system)	23 July 2012	1	54	31	23	1. OM 7347 2. OM 4900 3. OM 8108 4. OM 10000 5. OM 8928 6. OMCS 2012
4	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development (Workshop at Tân Thuận, xã Tà Đảnh, Tri Tôn, An	23 July 2012	1	54	31	23	1. OM 4900 2. OM 8108 3. OM 8104 4. OM 7347 5. OM 10041 6. OM 10000

	Giang (outside the protection dyke system)						
5	Workshop at Trung Bình Tiến, xã Vĩnh Trạch, huyện Thoại Sơn, An Giang	23 July 2012	1	55	35	20	1. OM 7347 2. OM 10000 3. OM 8928 4. OMCS 2012 5. OM 8104
6	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Tân Thuận, xã Tà Đảnh, huyện Tri Tôn, An Giang (inside the flood protected dyke system	7 November 2012	1	55	35	20	1. OM 8928 2. OM 90L 3. OM 7347 4. TLR 402 5. OM 8108
7	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Trung Bình Tiến, xã Vĩnh Trạch, huyện Thoại Sơn, An Giang	7 November 2012	1	43	32	11	1. OM 8928 2. OM 90L 3. OM 10040 4. OM 7347 5. OM 10000
Year 2013							
8	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Tân Thuận, xã Tà Đảnh, huyện Tri Tôn, An Giang inside the flood protected dyke system	15 Feb. 2013	1	52	35	17	A hands-on training in phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties: 1. OM 4900 2. OM 7347 3. OMCS 2012 4. OM 8108 5. IR64-Sub1 5. OM 8928
9	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Tân Thuận, xã Tà Đảnh, huyện Tri Tôn, An Giang outside the flood protected dyke system	15 Feb. 2013	1	52	35	17	1. OM 4900 2. OM 7347 3. OMCS 2012 4. OM 8108 5. IR64-Sub1

10	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Tân Thuận, xã Tà Đảnh, huyện Tri Tôn, An Giang outside the flood protected dyke system	20 Sept. 2013	1	50	25	25	A hands-on training in phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties: 1. OM 3673 2. OMCS 2012 3. OM 10179 4. OM 10418 5. OM 7347
Year 2014							
11	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Vĩnh Trạch, Huyện Thoại Sơn, An Giang	1 April 2014	1	52	32	20	A hands-on training in phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties: 1. OM 10179 2. TLR 596 3. OMCS 2012 4. OM 10252 5. MNR 5
	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Vĩnh Trạch, Huyện Thoại Sơn, An Giang	12 December 2014		50	38	12	TLR 10373 TLR 596
	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Tri Ton			70	45	25	OM 10252 OM 4488 TLR 596

	Total			682	427	255	

10.4 Hau Giang Province

No.	Name of activity	Date	Length of activity	No. of people involved	Males	Females	Expected outcome
	Year 2012						
1	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Hòa Đức, Hòa An, Phụng Hiệp, Hậu Giang	18 March 2012	1	39	15	24	A hands-on training in phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties: 1.OM 6162 2.OM 6161 3.OM 6677 4.MNR2 5.AS 996
2	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Ấp 3, Vị Đông, Vị Thủy, Hậu Giang	1 March 2012	1	48	41	7	Selected some new varieties: 1.OM 7347 2.OM 6L 3.Can Tho 2 4.OM 6161 5.OM 6162
3		14 June 2012	1	50	36	14	1.OM 8108 2.OM 6L 3.OM 8928 4.OM 7347 5.OM 6162
4		24 Sept. 2012	1	51	39	12	Selected some new varieties: 1.OM 6161 2.OM 8108 3.OM 6L 4.OM 10041 5.OM 7347
	Year 2013						

5	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Hòa Đức & Xẻo Trăm, Hòa An, Phụng Hiệp, Hậu Giang	7 March 2013	1	40	31	9	A hands-on training in phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties: Xẻo Trăm: 1.OM 3673 2.TLR 397 3.OM 6677 4.OM 6063 5.OM 6161 Hòa Đức: 1.OM 7L 2.MNR4 3.OM 6677 4.OM 6161 5.OM 10252
6	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Xẻo Trăm, Hòa An, Phụng Hiệp, Hậu Giang	28 June 2013	1	31	25	6	Selected some new varieties: 1.OM 3673 2.OM10418 3.OM 6063 4.TLR 397 5.OM 6677 & OM 10252
7	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Ấp 3, Vị Đông, Vị Thủy, Hậu Giang & TP. Vị Thanh, Hậu Giang	16 Feb. 2013	1	41	31	10	Selected some new varieties: Ấp 3, Vị Đông, Vị Thủy: 1.OM 6L 2.OM 6161 3.OM 7L 4.OM 6162 5.OM 4900 6.OM 8928 TP. Vị Thanh:

							1.OM 3673 2.OM10174 3.OM10179 4.OMCS 2012 5.TLR 375
8	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Ấp 3, Vị Đông, Vị Thủy, Hậu Giang	25 May 2013	1	25	22	3	A hands-on training in phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties: 1.OM 8108 2.OM 8928 3.OM 7L 4. OM 3673 5.OM 6161
9		9 Sept. 2013	1	33	20	13	1.OM 8108 2.OM 3673 3.OM 8928 4.OM 7L 5. OM 10097-2
	Year 2014						
10	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Xẻo Trăm, Hòa An, Phụng Hiệp, Hậu Giang	27 March 2014	1	25	21	4	Selected some new varieties: 1.OM 3673 2.TLR 397 4.OM 4488 5.OM 6161 & OM 6677
11	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Ấp 3, Vị Đông, Vị Thủy, Hậu Giang & TP. Vị Thanh, Hậu Giang	5 March 2014	1	39	31	8	A hands-on training in phenotype for selected new varieties Good land preparation and land leveling Fertiliser application and soil improvement Pest control (IPM) Selected some new varieties:

							Vị Thủy: 1.OM 8108 2.OM4488 3.OM 10041 4.OM 7347 5.OM 8928 & OM 3673 Vị Thanh: 1.OM 4488 2.TLR 437 3.OM 10418 4.OM 6691 5.OM 10174 & TLR 378
12	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Ấp 3, Vị Đông, Vị Thủy, Hậu Giang	3 June 2014	1	27	21	6	Selected some new varieties: 1.OM 3673 2.OM 10097-2 3.OM 8928 & OM 8108 4. OM 10179 & OM 4488
	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Ấp 3, Vị Đông, Vị Thủy, Hậu Giang	12 September 2014		40	29	11	OM 6L OM 8108
	Training Workshop in Participatory Varietal Selection (PVS) for Enhanced Varietal Development Ấp 3, Vị Đông, Vị Thủy, Hậu Giang	1 January 2015		39	32	7	OM 4900 OM 6L OM 3673
	Total			528	394	134	