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project **Crop diversification challenges in the changing environment of the Mekong Delta, Vietnam**

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prepared by Dr Jason Condon (Charles Sturt University)

*co-authors/
contributors/
collaborators* Dr Ed Barrett-Lennard (Murdoch University)
Dr Susan Orgill (NSW DPI)
Dr Paul Kristiansen (University of New England)
Dr Sergio Moroni (Charles Sturt University)
Dr Chau Minh Khoi (Can Tho University)

approved by Robert Edis, Research Program Manager, Soil Management and Crop Nutrition

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Acronyms

AGU	An Giang University
CSU	Charles Sturt University
CTU	Can Tho University
DARD	Department of Agriculture and Rural Development
DFAT	Department of Foreign Affairs, Trade and Development
GIZ	German Corporation for International Cooperation
IAS	Institute of Agricultural Sciences for Southern Vietnam
IUCN	International Union for Conservation of Nature
JICA	Japan International Cooperation Agency
MARD	Ministry of Agriculture and Rural Development
MRD	Mekong River Delta
NSW DPI	New South Wales Department of Primary Industries
RRD	Red River Delta
SIWRR	Southern Institute of Water Resources Research
SRA	Small Research Activity
UNE	University of New England
USAID	United States Agency for International Development
WBG	World Bank Group

2 Executive summary

There is current farmer led and provincial supported demand for biophysical and socioeconomic research into viable crop and land management options to enable optimised land use diversification in the middle region of the Mekong River Delta (MRD).

Significant losses in production associated with conditions of climate change have recently been experienced in the MRD. These affects include increased saline intrusion in river networks, decreased quantities of fresh water for irrigation and land subsidence which further exacerbates saline intrusion. Within the triple rice growing areas of the MRD the Dong Xuan (winter spring) or early summer cropping seasons are most affected and farmers are seeking more reliable crop options to be grown in those times.

The ACIAR funded CLUES project demonstrated that it is possible to integrate biophysical and socioeconomic modelling to optimise land use within target zones. The work of CLUES demonstrated that crop diversification from rice is a potential mechanism for adaption to conditions of climate change. Current financial support from the World Bank Group (WBG) will provide improved spatial and temporal definition of water data for canal networks in the MRD yet localised data for diverse crop options is required to adapt CLUES modelling methodology to account for new crop diversification options.

Consultation with local farmer groups and provincial staff of the Department of Agriculture and Rural Development (DARD) has identified a strong farmer desire to grow diverse crops as a result of recent crop losses associated with climate change and the poor profit margins of rice production. Farmers seek evidence-based technical packages for new crop options and DARD staff have an urgent need for research output to create the technical packages required. A clear message from the many stakeholders consulted in Vietnam was that any research conducted must integrate plant, soil, water and market aspects of crop diversification. Diverse crops must be profitable. Profitable crops must be able to be sustainability grown and embrace labour and cost saving technologies such as mechanisation. This SRA identified a need for multidisciplinary, multi-institutional research that aims to:

1. Characterise the impact of saline water intrusion on crop-based farming systems (water, soil, crops, people, markets).
2. Assess the impact of saline intrusion on current dry season crop yield and the viability of crop diversification options (including crop selection and soil management).
3. Describe and analyse market and policy opportunities for promoting the adaptive transformation of cropping systems in the MRD.
4. Develop and promote improved management practices which build adaptive capacity and optimise farm livelihoods.

These objectives have been developed following consultation with farmers, government agencies and research institutions, private sector companies, research agencies and universities. Potential research partners have been identified from Can Tho University, the Institute of Agricultural Science of Southern Vietnam (IAS), the Southern Institute of Water Resource Research (SIWRR), An Giang University, and private sector partners; the Loc Troi and Antesco companies.

Modelling predicts large-scale decline in land capability in the MRD due to climate change. Research activities funded by the WBG, aimed to improve the resilience of the delta, target upper and coastal provinces in the MRD yet rural households in the middle delta remain vulnerable to crop losses. There is a current opportunity to conduct research to foster diversification to profitable cropping solutions for farmers in the middle delta thereby mitigating the impact of climate change on rural livelihoods.

3 Objectives

One of the main conclusions of the CLUES project was that diversification from rice to upland crops improved profitability and increased flexibility in the cropping calendar thereby mitigating some of the risks of climate change. It was stated that improved connection between the market and farmers should be supported to ensure that adaptation to crop diversity was profitable. Therefore this SRA sought to gain an understanding of the challenges to crop diversification adaptation in the MRD. The primary project aims were:

- To identify potential collaborating institutions and prioritise capacity building opportunities which will benefit the area and help future-proof agricultural profitability.
- To identify key research gaps that exist within the matrix of current development research within the Mekong Delta.

To meet those aims, activities were planned to address the following objectives:

1. To evaluate capacity within relevant research and government agencies to undertake soils related research for development.
2. To determine the key limitations to diversification likely to be diminished with successful research outcomes.
3. To determine the opportunity for private industry to enhance diversification options and extension.
4. With the input from farmers, regional extension staff, private industry and project team researchers, to identify key knowledge gaps that need to be addressed for sustainable diversification of plant-based farming systems.

4 Activities

Two study trips were made to Vietnam. In February 2017, the project team travelled to the MRD and Red River Delta (RRD) to meet with farmers, government staff, research agency representatives, university researchers and private sector companies. A workshop was conducted at CTU which was attended by more than 60 representatives from the provinces of the MRD. The extent of climate change impacts in each province, and the actions of the provincial DARD and farmers to cope with climate change were reported. Representatives stated their prioritised research needs in each province. It was clear that diversification is regarded as a productive action to deal with conditions of climate change, and that any research related to crop diversification must take account of soil, plant, water and market factors to be of value to the farmers of the MRD. The project team visited provincial DARD offices and met with farmers during farm visits. The RRD was visited in the north to understand the similarities between the two deltas and evaluate the opportunity for the transfer of research outcomes. The RRD is considered quite different to the MRD due to the advanced infrastructure present in the north allowing the ability to control and limit the movement of saline water. Following the initial trip, the broad research needs were identified and potential research collaborators were shortlisted.

A second trip was conducted in June 2017 to engage with selected potential research partners in a workshop held at CTU. Research priorities were agreed upon and the objectives of the required research were developed, a proposed project team created and geographic areas of potential research were prioritised. Visits to the DARD offices of those selected provinces were then conducted to ensure that the identified research matched the needs of the relevant DARD staff that engage with farmers. The proposed research was strongly supported and the capacity needs of the DARDs were noted. The project team travelled to Hanoi to meet with the project leader for the WBG project to inform her of the identified research needs. The proposed research outlined in this report is complementary and synergistic to the WBG project. The planned research was also reported to MARD at a meeting with the Director General of Crop Production, Prof Nguyen Hong Son who strongly supported the objectives and scope of the proposed research.

These activities provided the context and content of the research needs reported in this document.

5 Background

The majority of food production in Vietnam comes from the Vietnamese MRD and RRD. Agricultural land occupies 75% of the MRD and produces 50% of the nation’s food and more than 60% of the national export value (Kakonen 2008). The RRD is smaller in size and produces 20% of the nation’s crop.

The Vietnamese deltas face significant challenges to future food production. Production gains from research have led to improved rice yields and multiple rice crop rotations (e.g. 3 rice crops per year in much of the MRD) which have enabled Vietnam to be one the world’s largest rice exporters. Despite this success, farmers remain poor (Wade 2014) owing largely to a downturn in commodity prices and insufficient attention to quality and marketing.

Whilst coastal provinces have long ago adapted to production in saline conditions, the middle delta exhibited conditions suitable for triple rice production within the climatic seasons (Figure 1) due to favourable fresh water access in the river and canal network. Changes in hydrology and climate threaten the magnitude of current rice production and the livelihood of farmers as water availability and quality decreases, and intrusion of salinity increases.

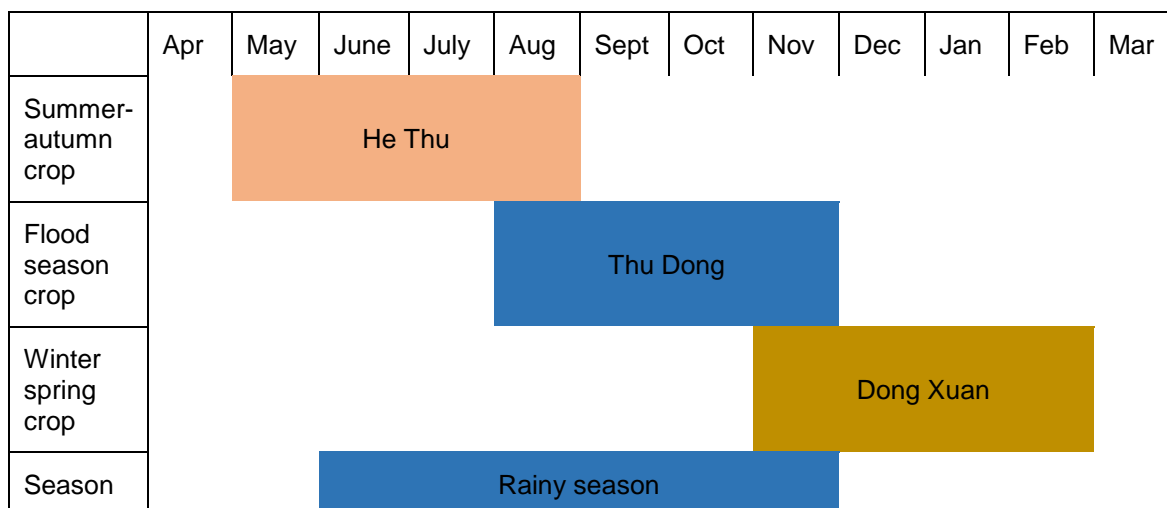


Figure 1. Cropping calendar in the 3-rice cropping region of the Vietnam Mekong Delta. The Dong Xuan season experiences temporal saline intrusion and a shortage of fresh water.

It is predicted that climate change will result in changes to the seasonal rainfall patterns and increased typhoon activity (MRC 2009). Together with sea-level rise, these changes are resulting in increases in saline intrusion to inland agricultural areas in the dry season (Figure 2). The 2016 dry season experienced the greatest saline intrusion event in recorded history and resulted in severe crop losses in several provinces. For example, in Tra Vinh, 70% of rice was salt affected and 30% of the crop yielded no grain. In Hau Giang 3,500 ha of rice was salt affected. Crop losses of these magnitudes represent a significant loss of income to farmers, and while the extent of the problem may be location-specific, it is predicted that such losses will increase in frequency, magnitude and extent into the future.

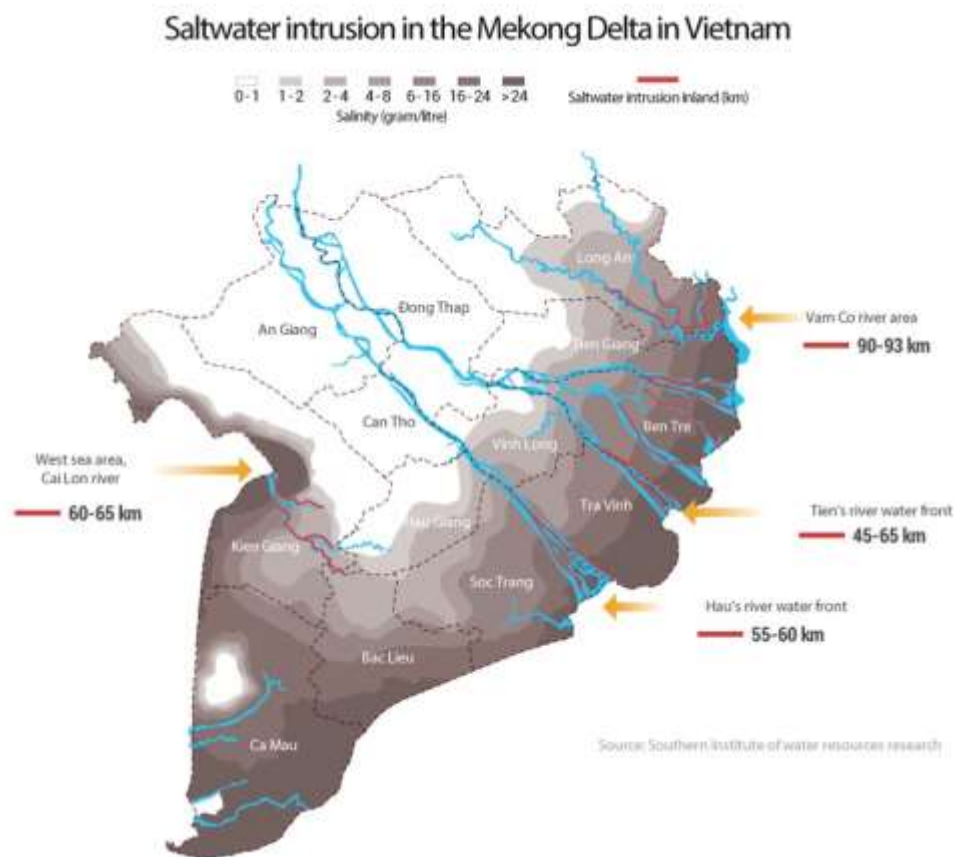


Figure 2. Saline intrusion into agricultural areas (salinity g/L) and major rivers (km inland) of the Vietnamese MRD.

(Source: Southern Institute of Water Resources Research)

Virtually all of the Vietnamese MRD has an elevation of less than 2 m above sea level and is therefore threatened by sea level rise associated with climate change (Le and Suppakorn 2011). In recent years, areas have experienced crop losses attributed to elevated salinity levels associated with high evaporation rates, lower rainfall, shorter wet seasons and modified canal networks associated with the expansion of aquaculture (Nhan et al. 2011). Changes to river flows due to upstream water use will worsen the effects of sea water rise, limiting the availability of fresh water to aid crop growth and manage soil fertility, and increasing the presence of toxic metals on acid sulfate soils. With the increasing occurrence of saline intrusion in the dry season, farmers have increased use of ground water to irrigate crops. This has resulted in a decrease in ground water height of approximately 0.3 m per year and subsidence of the agricultural land within the range of 0.28 to 3.2 cm per year (Erban et al. 2014). The continued exploitation of ground water is not sustainable and it further increases the rate of saline intrusion in the MRD. Thus, crops and soil management methods that encourage better water use efficiency are required to slow the degradation of the land and water system.

In the absence of research-based solutions to temporal saline intrusion, some provinces (Hau Giang, Soc Trang) have started to advise farmers to change from three rice crops per year to two. This represents a substantial loss to household income and farmer livelihoods but also an opportunity to introduce a short growing upland crop into the rotation. Thus, there is a current and urgent need to conduct research which provides agronomic options for agricultural productivity via crop diversification in times of environmental stress. This should include the evaluation and selection of suitable species

and land management practices which can then inform planning for land use change and prioritisation of extension resources at a provincial level.

The ACIAR funded CLUES project was successful in making advances in the prediction of land capability and land use change under modelled scenarios. This work was targeted in Bac Lieu province where land use spanned intensive shrimp to triple rice; each land use had very clear and different resource needs. However, the biophysical data used to determine land use options lacked the refined definition required to select between upland crop options. More research is required to identify the biophysical limits of potential upland crops so that this information can be included in models to inform land use change under conditions of climate change.

It is estimated that by 2030 one third of the current rice growing areas will be converted to alternative land uses such as the incorporation of rotational crops (World Bank 2016). Diversification from rice to other crops may be difficult due to the physical and chemical effects of rice production on soil structure and fertility. Increased soil strength in the subsoil and decreased nutrient availability are common limitations. In addition to these challenges, as much of the MRD contains acid sulfate soils, drying of soil can induce acidic conditions which can have direct effects on crop growth and can also potentially liberate toxic metals into the food chain. Therefore, the soil and water constraints to crop production varies within the MRD and research is required to create the agronomic foundation for site and region specific technical packages.

Opportunities for crop diversification in the MRD have historically been constrained by several factors including the land-use policies of the government (World Bank 2016). Lowland irrigated rice regions in the MRD have had restrictions in place for alternative agricultural uses. However, the Vietnamese Government recognises that diversification of agricultural production is vital if Vietnam is to meet climate and food security challenges. The government is in the process of developing an agricultural sector restructuring program which aims to create a diversified rural economy which will reduce poverty and ensure household and national food security (FAO 2013). The proposed strategy includes changes to land-use regulation, allowance for land consolidation and the facilitation of change in agricultural practice. These changes have increased the need for research into crop production and market development of diverse crop options. Provincial DARDs are aware that changes in the cropping pattern need to occur at a significant scale in order to be successful. Deregulation of land use policy removes government induced barriers to crop diversification, but agronomic knowledge and market stability remain substantial limitations to adaptation.

Upland crops offer growers substantial economic benefit. The gross margins for upland crops grown in the MRD are approximately ten times that of rice (Le and Yokoyama 2012) although it is expected that this may decrease to some extent with the expansion of upland crop production. The influence of markets is a substantial driver on farmer adaptation to diverse crops. The supply chains of various alternative crops have been studied in the MRD in the past (Nguyen and Mai 2015; Vo 2016; CLUES theme 4) and access to low cost loans has been identified as an enabling component of adaptation to crop diversity (CLUES 2016). However, successful private sector models also exist in the MRD and a better understanding of the enabling mechanisms associated with these models may improve crop diversification options. The Loc Troi Group (rice), Antesco (upland crops) Vina Milk and Dutch Lady Milk Industries (dairy) have developed successful market security models based around technical transfer, input support and the contracting of farmers.

Agricultural production in the MRD is dynamic. Farmers are facing relatively rapid changes in climate, water availability, salinity intrusion, labour availability, mechanisation and markets. The past restrictions of land-use influenced the type of research and extension conducted by government organisations within agricultural zones. The liberation of land-use regulation in areas once zoned to rice production has revealed knowledge gaps for stakeholders within the agricultural sector. There is a need to conduct research to

better understand the limitations to diversification with upland crops in this dynamic system. Multidisciplinary research spanning plant, soil, water and markets is required to provide crop diversification options to maintain livelihoods of rural communities in the MRD.

6 The urgent need for research

6.1 Current research

The loss of farm income and impact on rural livelihoods in the Dong Xuan season due to climate change is a major concern to farmers, communities and the Vietnamese Government. Due to the severity of expected climate change impacts in the Mekong Delta, several international agencies are working on R, D and E activities in the region (Table 1).

Table 1. Current research projects relevant to crop diversification in response to climate change in the MRD

Related regional projects (non ACIAR)		
Name of the program/project. Time period and funding Funding Org.	Implementing institutions/organization	Relevant data/activities/ outputs
Mekong Delta Integrated Climate Resilience and Sustainable Livelihoods Project 2016-2022 USD\$387million World Bank Group (WBG)	-Ministry of Agriculture and Rural Development -Ministry of Natural Resources and Environment	<ul style="list-style-type: none"> Diversification to handle saline intrusion and improved water management. Targeting upper MRD and coastal provinces
Soil-improving cropping systems for sustainable rice production in the Vietnamese Mekong delta 2016-2020 USD\$70,000 VLIR-UOS, Belgium	-Ghent University -Can Tho University	Rice and alternative crops: <ul style="list-style-type: none"> Building capacity to improve crop productivity, while reducing soil degradation, water and fertilizer use and greenhouse gas (GHG) emissions.
Sustainable adaptation of coastal agro-ecosystems to increased salinity intrusion. 2015-2018 Federal Ministry for Education and Research (BMBF), Germany	-University of Bonn -UN University (Germany) -Institute of Bio- and Geosciences, Germany -Can Tho University -Hanoi University of Agriculture	<ul style="list-style-type: none"> Investigation of the socio-ecological sustainability of coastal agro-ecosystems and their adaptation and adaptability to salinity intrusion and market challenges

The largest and most recent is the WBG US\$387 million investment in the Mekong Delta Integrated Climate Resilience and Sustainable Livelihoods Project (referred to in this report as the “WBG project”) which includes input from a wide series of development partners including USAID, GIZ, IUCN, JICA and DFAT to create synergy without duplication in proposed and current work. This project spans a range of activities involving engineering, financial, socioeconomic, environmental and agricultural issues. There are three project components relevant to agricultural production in the MRD:

1. Provision of a network of monitoring stations to map changes in environmental conditions throughout the MRD;

2. Establishment of a data management centre which will house and facilitate the data sharing of key institutions operating within the natural resource management sector in the MRD (to be located at Can Tho University); and
3. Funding of a series of subprojects that facilitate agricultural infrastructure and land use change to increase the resilience of the MRD to climate change.

The aforementioned subprojects include management of floodwaters (subprojects 1, 2, 3) in the upper Vietnamese MRD and adaptation to salinity (subprojects 4-10) in the coastal provinces (Figure 3, subprojects marked in orange boxes). Within the WBG project, proposed adaptation to salinity includes expansion of rice-shrimp farming in areas that are too saline to grow crops in the dry season and support for aquaculture and mangrove protection in permanently saline areas.

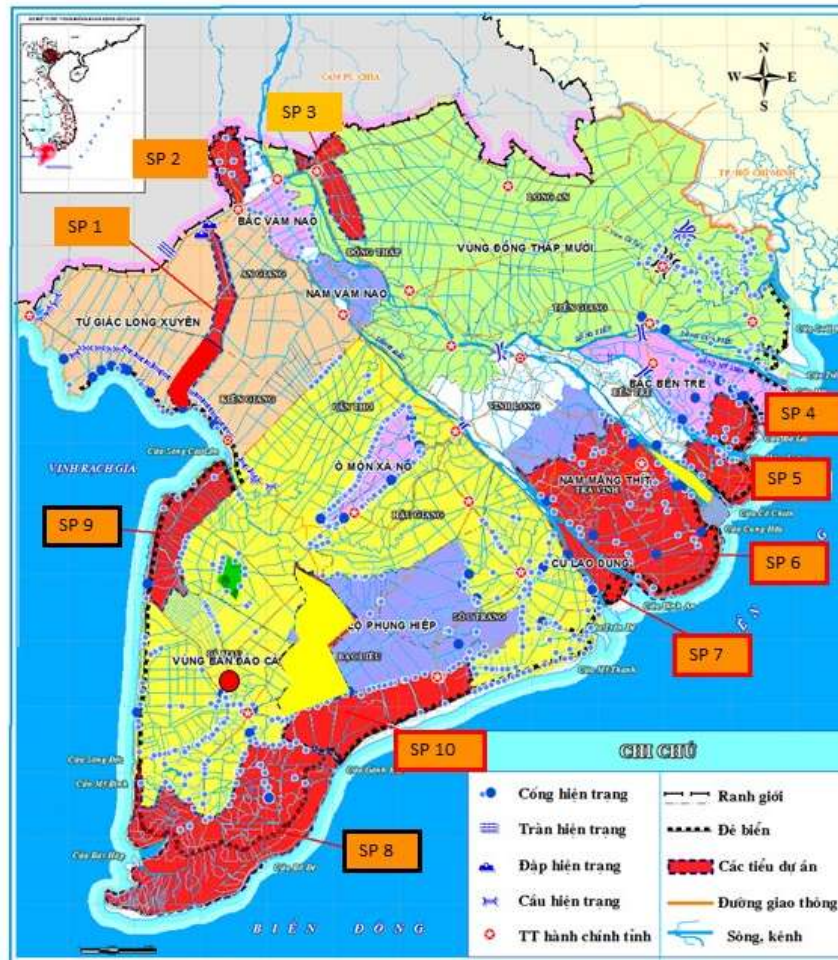


Figure 3. Location of planned agriculturally relevant activities (marked in red) of the WBG funded Mekong Delta Integrated Climate Resilience and Sustainable Livelihoods Project. Source ICRSL (2016).

6.2 The research gaps

It is important to note that the planned work of the WBG subprojects does not include the middle delta (Figure 3), an area of significant rice production where multiple rice crops are grown per year but which has only recently been affected by temporal salinity due to increased saline intrusion in the river networks. Therefore a large area, and number of farming households in this region remain vulnerable to increasing rice crop losses associated with climate change. This region of vulnerable farmers exists on the margin between regularly saline and fresh water environments (Figure 2). As the environmental conditions change with increasing effects of climate change, the region of impact expands further inland. Thus there is a constantly changing need for research and technical packages for agronomic and agribusiness support that needs to keep pace with, or precede land use capability change. The establishment of a research transect that covers the varying extent of climate change effects experienced in the middle delta will act to future-proof the middle delta by providing crop and land management options for crop diversify as conditions change.

It is predicted that as fresh water resources become limited and seasonal salinisation continues, the land and water capability to grow crops will decrease. A loss of capability will result in a loss of socioeconomic value as high value crops will no longer be suitable with the changes in resource condition. This is demonstrated in Figure 4 as Option 1 and may conceptually represent triple farming where salinisation in the Dong Xuan season results in a loss of land capability (movement to the right) such that the 3rd rice crop can no longer be grown. Under these conditions, diversification to a new crop (option 2) will be required to optimise the socioeconomic value of the farming system. It is important to note that the optimisation is not purely economic as short-term economic outcomes often have long lasting community and environmental impacts. In order to identify the optimal cropping system adaptations it is necessary to conduct research to define the interaction between land and water capability for diverse crop options, and the socioeconomic value of crop product and supply chains.

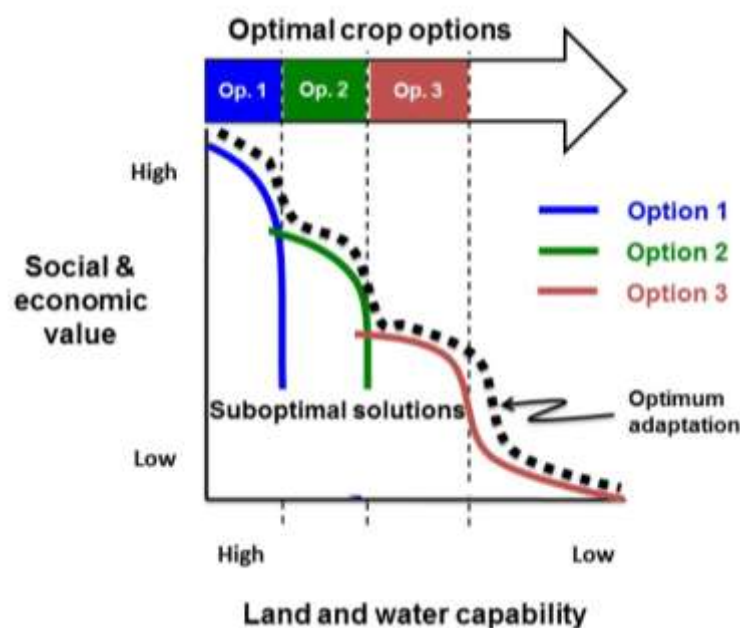


Figure 4. Conceptualisation of adaptation need for crop diversification due to resource degradation

6.2.1 Understanding the environment

Research needs:

- Develop higher temporal definition and prediction of saline intrusion in the middle delta and the influence of this on soil conditions
- Develop a detailed understanding of the temporal and spatial production limiting conditions of the soil-water environment which will be used to set criteria for crop selection
- Develop and evaluate soil management techniques that reduce or ameliorate deleterious soil conditions associated with climate change.

Significant regions of the MRD can suffer from the interaction of three abiotic stresses during the 3rd rice season – waterlogging at the start of the growing season, drought by the end of the growing season, and salinity due to saline intrusion which may occur throughout the growing season.

Soil salinity affects plant growth because the salinity of the soil solution affects plant-water relations (i.e. has osmotic effects) and has 'specific ion' (i.e. toxicity) effects (Greenway and Munns 1980). The effects on water relations occur immediately (within minutes). The ion toxicity effects take longer to become apparent: days for salt sensitive crops like beans; weeks for more salt tolerant crops like wheat and barley (Munns 2002).

With respect to salinity, we know that salt is intruding up the rivers and canals of the MRD during the second half of the third rice season and may last to the early stage of the following crop, and that this is increasing with decreased river flows from upstream, sea level rise and land subsidence. What is not known is the degree to which the water courses are linked to the agricultural land through the tidal intrusion of saline water into the shallow groundwater or through irrigation. It may be possible to change the salinisation of land simply by changing the source of water used for irrigation from river water to deep groundwater. For such management to be sustainable, crop water use efficiency must be a focus for research activities.

Understanding the timing of the salinity stress during the 3rd rice season is essential: does it commence at the start of the season (during the period of crop establishment and vegetative growth), or later (during the period of flowering, or during seed fill). Knowing this will help direct research efforts. The small amount of work conducted on the relative salt tolerance of crops (sorghum and wheat) suggests that grain production by crops is more affected by salinity during the first 30 days of crop growth than at 30-60 or 60-90 days (Maas et al. 1986; Maas and Poss 1989). Furthermore, if salinity generally occurs late in the growing season then there may be other strategies that can be used to avoid the worst of the salinity impacts; crops can either be selected that flower earlier (cf. Setter et al. 2016) or else farmers might choose to grow leafy vegetables, which could be harvested after a few weeks rather than after the time required to produce seed (90+ days).

When salinity occurs early in the growing season and coincides with waterlogging at the end of the previous two wet rice seasons, there is a risk of waterlogging/salinity interactions. There is now a reasonable body of evidence suggesting that waterlogging exacerbates the uptake of Na^+ and Cl^- , and decreases the uptake of K^+ , that these factors impact on growth (reviewed by Barrett-Lennard 2003; Barrett-Lennard and Shabala 2013). Furthermore, it is known that these adverse effects are least severe in plants with high

root porosity, the major plant defence against waterlogging (Striker et al. 2013). It is therefore possible that selecting plants for waterlogging tolerance may improve outcomes in the saline soils of the MRD.

Salinity may also coincide with drought/decreased water availability, which will exacerbate the osmotic effects on plant growth. Based on the ion composition in soils and their temperature, Barrett-Lennard et al. (2017) have developed a simple formula for estimating the solute potential (ψ_s ; units of kPa) of soils in the Ganges-Bramaputra Delta from the electrical conductivity of a 1:5 soil water extract (EC1:5; units of dS/m) and the soil water content (W; units % DM)

$$\psi_s = - 20593 \times EC1:5/W$$

It can be seen from this formula that the adverse effects of salinity on plants will double if the salt concentration in the soil (of which the EC1:5 is a measure) doubles; however, it will also double if the water content of the soil halves. Understanding how both the soil salinity and water content changes during the 3rd rice season is therefore critical to the development of upland crops as an alternative to the 3rd rice crop. A similar formula to that above may need to be developed for the MRD. The salt concentration in the soil solution and the soil moisture content may be controlled by management techniques such as mulching, additions of soil amendments, raised beds and leaching salts through the profile with fresh water. Research has been conducted in some areas of the MRD by Vietnamese collaborators but more research is required to validate previous findings in new locations (e.g. acid sulfate soils c.f. alluvial soils; highly saline c.f. moderately saline soils) and assess the agronomic potential of these methods when growing crops specifically selected for conditions experienced in the MRD due to climate change.

There is a need to increase the predictive capacity of natural resource planners and DARDs within MRD provinces. The work by conducted by ACIAR in the CLUES project in Bac Lieu and work planned in the WBG project make it possible to better predict temporal and spatial changes in water quality and flow. However, more information on plant and soil interactions under saline conditions for a range of diverse crops is required to parameterise crop growth models and better predict impacts of land use change under forecast climate scenarios.

6.2.2 Understanding variation in crop salt tolerance

Research needs:

- Identify and select crop species/varieties capable of production in the conditions experienced in the middle MRD (traits include tolerance to salt, waterlogging, drought, water use efficiency and growing season length)
- Understand the mechanism of salt resilience for selected species
- Quantify the agronomic impact of conditions associated with climate change on a range of relevant agricultural crops
- Identify the biophysical limits for selected crops to inform land use prediction models

Field observation and farmer/provincial staff meetings conducted as activities of this SRA indicate that there are a range of crops that are presently grown as diversification options in the MRD or are regarded as potential future options. The relative salt tolerance of a selection of these is shown in Figure 5. It should be stressed that these curves have been compiled from a range of experiments, in which salinity has been imposed as a mixture of salts generally soon after the plants have established. This information may therefore not be highly applicable to mid- or late-season salinity. Nevertheless, based on salt tolerance criteria alone, it would appear that sorghum, soybean and tomato might be more

appropriate short season crops than rice, and peanuts, bean and mungbean and cucumber might be less appropriate than rice. It is clear that further selection of possible crop options for the soil and water conditions experienced in middle delta is required. The marketability and profitability of these crops should also be researched, and these factors should be components of the selection framework for potential crops in proposed research.

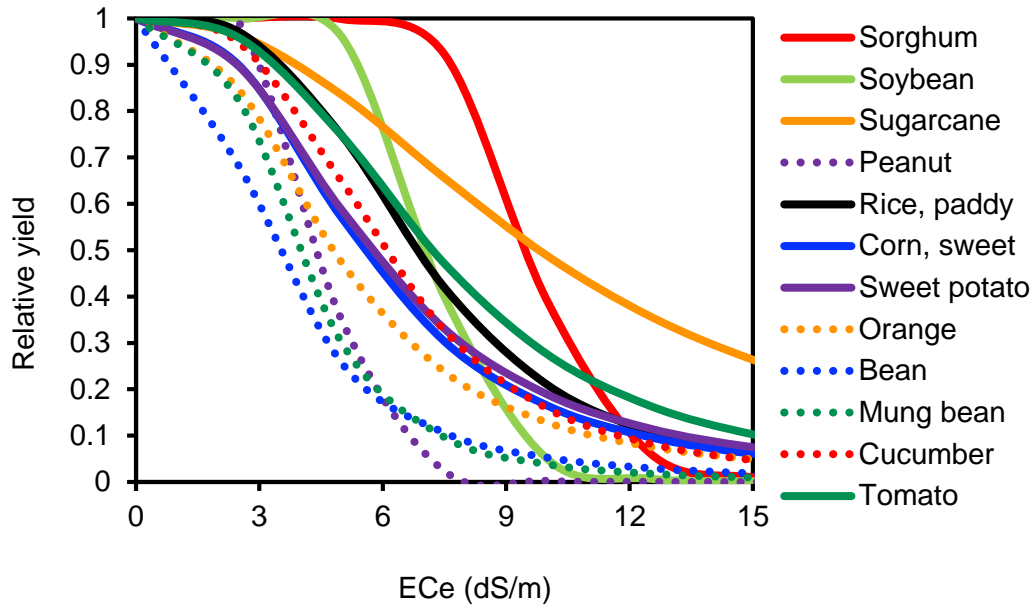


Figure 5. Relative salinity tolerance of selected crops deemed suitable for the MRD based on the relationship between salinity expressed as electrical conductivity (ECe) and yield relative to yield at ECe of 0 dS/m (based on the salt tolerance criteria of Steppuhn et al. 2005).

One issue that has arisen in the activities of this SRA in Vietnam is the potential importance of forage production. In Soc Trang, a province severely affected by temporal salinity, farmers have diversified to beef production to meet domestic demand. Thus forage production on salt affected land may be advantageous. Forage production is the major agricultural productive use of saline land in Australia (e.g. Barrett-Lennard et al. 2003) and production in the tropics has been shown to be substantial (>10 t/ha/year) from sesbania, sorghum and cowpeas (Salman et al. 2013). Therefore forage species should be considered in the list of potential crops to be screened for evaluation in the field.

It is vital that any research involving biophysical selection of suitable plant species and improved land management practices be accompanied by research of markets to ensure that profitable crops are developed.

6.2.3 Understanding components of successful markets

Research needs:

- Identify key components of successful private sector examples that have created secure agricultural markets
- Conduct up-to-date value chain and market analyses to identify key opportunities and constraints for crop diversification
- Understand the impact of larger companies in building markets and enhancing local livelihoods

Just as the farming landscape is changing in the face of climate and land use changes, national and international economic changes are causing major shifts in the agribusiness environment in the MRD. New players are entering the industry, especially medium to large corporate entities. New linkages are being established between parts of the production and value chain, from input suppliers to processors and traders. New rules are affecting agriculture including land ownership, land use policies, food safety concerns and global trade. The development of successful new cropping options for farmers in the MRD will need a clear understanding of how these new markets operate, what potential opportunities exist and what challenges need to be addressed to support equitable rural development (World Bank 2016).

While the CLUES project did not include any value chain analyses and was largely focused on rice as a cropping option, there have been several previous studies of value chains for other commodities produced in the MRD (e.g. Nguyen and Mai 2015; Vo 2016). However, markets are dynamic and there are a wide range of diversification options being considered by farmers and others in the region. Therefore, there remains an urgent need to carry out more comprehensive value chain studies both of specific commodities and of generic supply pathways such as supermarkets and exporting.

Successful private industry involvement in agriculture is occurring throughout Vietnam, including in the MRD, with national and multi-national companies seeing promising opportunities in the sector. Examples include Loc Troi Group and Antesco in crop production and Dutch Lady in dairy production. In line with MARD policies to increase the adoption of high technology agriculture, these new medium to large agribusiness companies offer a significant leap in productive capacity. These companies have developed vertically integrated business models with various combinations of input production, technical transfer, financing arrangements and purchasing contracts. Looking beyond the MRD, these companies also have the capacity to develop cross-sectoral synergies (e.g. commodities, inputs), increase investment in R&D, and contribute strongly to national brand development for export markets.

Research is needed to identify aspects of private industry led success which are transferable, and to analyse how government policy can both stimulate their activities and also ensure good social and environmental outcomes in the region. Case studies of leading agricultural companies in the MRD would enable several key rural development issues to be addressed in the context of supporting crop diversification. Such issues include the role of processing and manufacturing in creating demand for specific crops, adding value to crops produced in the region, creating alternative rural employment opportunities (both skilled and unskilled) and supporting farmers through novel extension relationships and encouraging participation.

6.2.4 Understanding barriers to diversification

Research needs:

- Understand household and community adaptive capacity (influenced by change in rural demographics, labour migration, participation of women in all aspects of the value chain, land size)
- Define the role of land use and land consolidation policies in adaptation to crop diversification
- Identify opportunities for adaptation enhancement with new digital technologies

The CLUES Theme 4 report noted that farmers are hesitant about diversification into upland crops. During this SRA, instances of upland crops such as maize and soybean being grown but being uneconomical for farmers were reported. Without reliable cropping alternatives based on sound agronomic practices and stable markets, it makes sense for farmers to be cautious. Staff from numerous DARDs and rural development agencies in the MRD affirmed the need for market research, acknowledging that a focus on agricultural production alone was not enough.

A better understanding of the market opportunities can be achieved through analyses of value chains and private sector engagement mentioned above, but further research needs exist in terms of household and community adaptive capacity. Vietnam is rapidly undergoing major demographic change as increasing numbers of people leave rural areas to seek employment in larger cities and even outside Vietnam. With industries such as construction, manufacturing, retail and hospitality offering alternative sources of income, the cost and availability of labour in rural areas for agricultural production are becoming more difficult (Vo et al. 2015). As household dynamics change, it is important to analyse the role of women and younger people in decision making about crop production and marketing choices, their participation in the value chain and acquiring new skills and knowledge. At the community level, issues of networking and cooperative engagement may need to be addressed, particularly as pressures for land consolidation grow. This type of information can assist with targeting training activities and in fine-tuning policies to promote broad participation in the agricultural economy.

Traditional extension models have served Vietnam well in creating highly productive farming systems that have ensured food security, and they are likely to persist as the major pathway for supporting farmers interested in crop diversification. However, demographic changes mean that the age and gender distribution of the farming population is changing. New technologies, such as mechanisation, are being adopted on-farm and in post-harvest processing to address the labour shortages. The rapidly developing information and communications technology sector has untapped potential to significantly influence agricultural marketing, information transfer and resource allocation. The larger agribusiness companies are now carrying out some of the functions for which government departments used to have sole responsibility. In light of these various changes, there is a need to assess how farmers' extension needs can be optimised, and how government resources and staff can be maintained, enhanced and used efficiently.

Given the extensive work carried out by the researchers in the CLUES project, there is likely to be a significant legacy of networks (farmers, DARD staff) and baseline socioeconomic data which could potentially be incorporated into future studies in the region. By extending these R&D resources, there is an opportunity to maintain and build participatory research relationships and to generate a clearer picture of the socioeconomic drivers and impacts of climate change and land use adaptation such as crop diversification.

7 Capacity needs

One of the key priorities emerging from the activities of the SRA was the need to build the capacity of extension staff, junior researchers and farmers to better enable the identification of appropriate crops and soil management, thereby enabling crop diversification. Institutional capacity needs and opportunities were also highlighted, with an improved capacity to respond to changes in climate and agricultural policy through staff up-skilling, new collaborations and experience in multidisciplinary research. Therefore capacity building activities are required to focus on strengthening both human and institutional resources.

The main capacity needs identified were:

1. Formal qualifications and post-graduate degrees, for example junior research staff from CTU, An Giang University and provincial DARD offices
2. New skills and networks, for example integrating agronomy, crop science and biophysical modelling at CTU
3. Biophysical modelling training for applied researchers from CTU and IAS
4. Training for farmers in agronomy of new crops, soil management and agribusiness
5. Training and experience for DARD extension staff in on-farm trial/demonstration design, research data collection, use and storage
6. New institutional collaborations and international experience, for example the multidisciplinary and multinational design of this project and the mentoring of smaller institutions such as An Giang University by more established in-country institutions.

Our project team is experienced in farmer-led research and participatory extension methods. Our in-country activities to date have highlighted the importance of us recognising and adjusting our capacity building endeavours based on social and cultural differences, institutional experiences and roles, and farmer needs.

8 Identification of research partners

Through the activities of the SRA a wide range of potential collaborators were engaged. Following extensive discussions of relevant environmental, socioeconomic, agricultural, research, and policy considerations, determination of capabilities and capacity opportunities potential research partners were identified. These collaborators participated in the development of the research recommendations included in this report and those vital to a successful multidisciplinary approach to the challenges of crop diversification in the MRD are included in the following table.

Institute	Key Collaborator
Can Tho University Soil Science Department Crop Science Department GIS and Land Resource Department Economics Department Environmental Economics Department	Assoc Prof Chau Minh Khoi, Assoc Prof Le Van Khoa, Dang Duy Minh, Chau Thi Anh Thy Dr Le Vinh Thuc Dr Vo Quoc Tuan, Nguyen Thi Hong Diep Vo Thanh Danh, Huynh Viet Khai Ngo Thi Thanh Truc
An Giang University	Nguyen Van Kien
Loc Troi Group	Director Duong Van Chin
Antesco Company	Huynh Ngoc Diem Thuy, Nguyen Thanh Phong
DARD Soc Trang Hau Giang Can Tho An Giang	Vice Director Huynh Ngoc Van Vice Director Ngo Minh Long Director Nguyen Ngoc He Head of Crop Production Nguyen Van Hien
Institute of Agricultural Sciences for Southern Vietnam	Deputy Director General Dr Le Quy Kha, Dr Nguyen Quang Chon
Southern Institute of Water Resources Research	Dr To Quang Toan

Importantly, these research partners build on networks established during CLUES, previous and ongoing collaboration between CSU and CTU, and build new networks between research agencies and the private sector.

9 Conclusions

Climate change and competition for upstream water resources have caused rice production losses during the Dong Xuan season in the MRD due to increasing salinity and lack of fresh water. The final report of the ACIAR funded CLUES project (2011-2016) highlighted the need for research targeting marketable options for crop diversification, capable of withstanding the negative effects of climate change for farmers in the MRD. The research conducted in this SRA has determined that the need for diversification options is now urgent. Whilst major investment by the WBG aims to improve resilience to climate change in the upper and coastal regions of the MRD, the middle delta is largely overlooked yet it represents a large area of significant production but remains vulnerable to crop loss by climate change.

Crop diversification is seen by government as an adaptation solution to changes in land capability and farmers are actively seeking alternative crops to rice. However evidence-based technical information for the selection of new crops and optimal land management for their growth is lacking at the provincial level. Substantial funding (WBG) has been allocated to water quality monitoring and land capability prediction using spatial models, yet the applications of such models are limited by a lack of research based information which will set the suitability thresholds for a range of diverse crop options. These crop options must be economically viable. Therefore soil, water, plant and market research is required to provide immediate value to farmers and DARD staff. This work will also provide vital locally produced data for models which integrate WBG project monitoring and modelling methodology applied in the CLUES project. Socioeconomic and market research is essential to facilitate efficient technology transfer, the provision of stable markets by private sector companies and to identify barriers and risks of crop diversification.

10 Recommendations

Research is urgently required to provide evidence-based marketable agronomic solutions for diverse crop options for farmers facing the challenges of climate change in the MRD. Multidisciplinary, multi-institutional collaborative research including government and the private sector will be required to achieve successful outcomes for rural households and to improve rural livelihoods. There is a need to identify optimised varieties and cultivation practices for marketable alternative crops for farmers. Therefore research should comprise varietal screening of potential crops for saline tolerance, water use efficiency and growth period; the development and assessment of improved agronomic practices; and investigate the socioeconomic factors influencing market development and farmer decision making. This work will be conducted within the context of dynamic environmental and social challenges associated with climate change. The objectives of the required research are:

1. To characterise the impact of saline water intrusion on crop based farming systems (water, soil, crops, people, markets).
2. To assess the impact of saline intrusion on current dry season crop yield and the viability of crop diversification options.
3. To describe and analyse market opportunities and policies for adaptive transformation of cropping systems in the MRD.
4. To develop and promote improved management practices which build adaptive capacity and optimise farm livelihoods.

It is essential that proposed research integrates issues of plant, soil, water and markets if real value to farmers and rural communities is to occur. Research should be targeted in the middle delta (Soc Trang, Hau Giang, Can Tho, An Giang provinces) where farmers are only now being affected by seasonal salinity due to saline intrusion associated with upstream water management, climate change and land subsidence. The needs of these regions are not addressed by other research focussing on adaptation to climate change planned for the MRD. Research and extension networks developed in the CLUES project within this region will enhance expansion of research impacts to improve rural livelihoods.

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