What can farmers do to adapt to climate change in the Mekong River Delta?

Final report of the case study on the Mekong River Delta within the project 'Deltas under Pressure'

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WAGENINGEN UNIVERSITY & RESEARCH

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Wageningen, July 2023

Report WPR-1244

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This report documents the activities carried out in the case study Mekong River Delta as part of the Deltas under Pressure project. At the overall project level, we developed guidelines to facilitate food system transition. At the case study level, we described the situation of food system transition in the Mekong Delta and how our project contributed to it. In the cluster "Breeding for tolerance to abiotic and biotic stresses", we conducted pot experiments in Wageningen. In the cluster "Adaptation of crop-livestock farms to stresses from salinity, drought, flooding, and heat", we conducted focus group discussions and in-depth interviews with households to explore differences and similarities between farmers and related stakeholders in analysing their situation and how they currently or potentially cope with existing stresses. A net house experiment was set up to test the response of crops to different amounts of saline irrigation. In the cluster "Concern for water quality and quantity with rising sea level", we addressed issues of water management, desalination technologies, rainwater harvesting techniques, and food security.

Keywords: salinity, farming systems, water quality, water quantity, plant breeding, Vietnam

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Photo cover: Tran Thi Ngoc Bich

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1 Short Introduction to the Nature and Goals of the KB Project 'Deltas under Pressure'

The Vietnam case study reported here is part of the overarching project 'Deltas under Pressure', which ran from 2019 to 2022. The project is part of the 'Water and Food Security' programme of the Dutch research line 'Kennisbasis Onderzoek', commissioned by the Dutch Ministry of Agriculture, Nature and Food Quality (LNV). The analytical framework of the programme was the Food System Approach (UNEP 2016, van Berkum et al 2018). Two deltas, Bangladesh and the Vietnamese Mekong River Delta, formed the case studies for the Deltas under Pressure project. The goal for both case study areas was to examine and build on the current situation, and define actions and changes in the food system that support transition towards a sustainable and climate-resilient food system. Current and envisaged changes in the deltas of Vietnam and Bangladesh are connected to ongoing developments and planning processes and concentrate on agriculture in the context of urban development and climate change.

The project consisted of detailed analysis and collaborative research in the two case study areas of Vietnam and Bangladesh. This includes increasing crop adaptation to abiotic stress, specific integrations between plant and livestock activities, management of water quality and quantity, livestock management under saline conditions, integrating shrimp-mangrove farming systems; and joint team work to get a clearer picture on the future of specific food systems in deltas, and facilitating food system transition via interaction with and among stakeholders. The research collaboration of the Vietnam case study started in 2019 with an explorative joint field visit in the second half of that year. Due to Covid-19 restrictions in 2020, 2021, and partly still in 2022, online interactions and desk work were prevalent and combined with incipient field work, where feasible.

The WUR teams of the two case study areas met regularly to exchange information on progress and opportunities. Scientific output has been publicly shared at conferences (such as Circular@WUR, 2022) and published in various international journals, including a special issue of the International Journal on Water Governance (forthcoming). Besides collaboration within the project, interaction with stakeholders at different levels, such as farmers or the CGIAR research program 'Mega Deltas in Asia' occurred. In the Vietnam case study, partners from Wageningen and Vietnam met regularly online to discuss project content and decide on next steps. This report summarizes the status of the Vietnam case as of December 22, 2022.

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2 Guidelines to Facilitate Food System Transition

2.1 How to facilitate transition in the delta's food system?

The Guidelines to Facilitate Food System Transition (Verhagen et al., 2022) had been prepared by members of the project team 'Deltas under Pressure' (DUP) to structure activities and increase impact of *potential* food system transition pathways in deltas. The overall aim was to present an overarching framework that clarifies linkages between the different disciplines involved in analysing such pathways. Placing research in context, the framework helps to increase the impact of research activities by making connections between the different research activities and critical intervention points more evident. The framework is equally helpful for other stakeholders such as policymakers, private sector parties, NGOs, farmers groups, and individuals involved in conceptualising, analysing, monitoring, planning and implementing food system transitions.

This work was also supported by the 'Transition Pathways' project which is part of the same research programme 'Food and Water Security'.

Download #1

The Guidelines report can be downloaded for free at https:/doi.org/10.18174/557946

SCAN ME

2.2 How we used the guidelines in our case study

Figure 1 depicts the steps as described in the Guidelines and how we applied those to the case study of the Mekong River Delta, Vietnam.

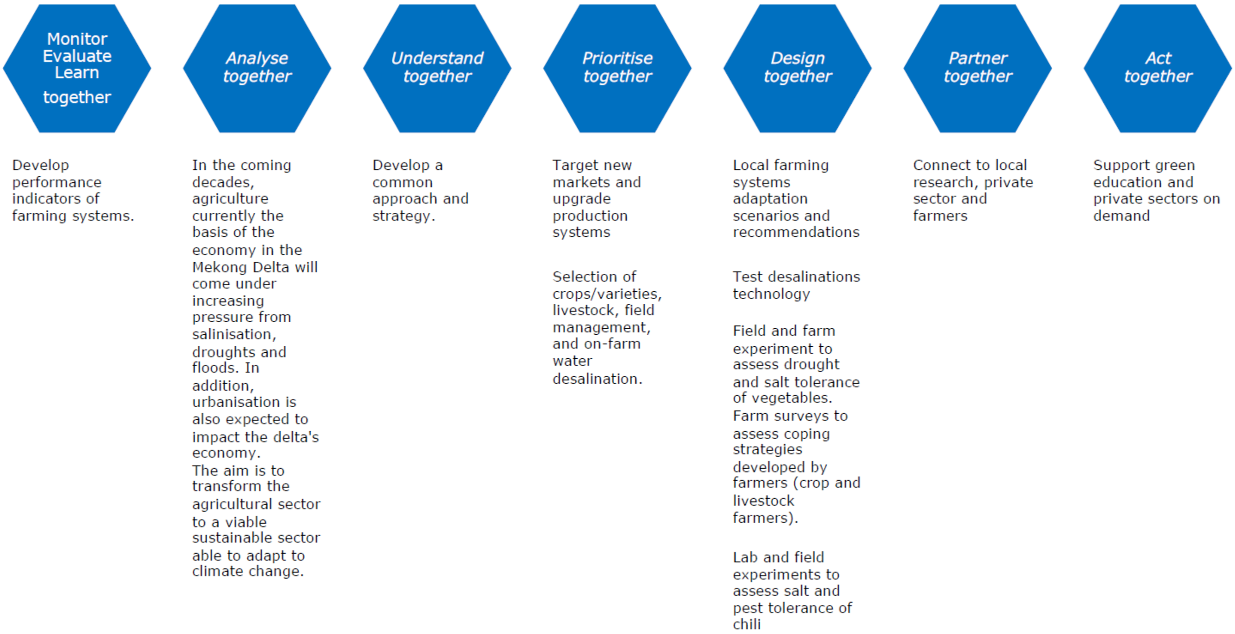

Figure 1 *Suggested stepwise process to contribute to the development of food system transition pathways in the Mekong River Delta within the 'Deltas under Pressure' project (Source: Verhagen et al., 2022).*

Through the case study, we depicted entry points to increase resilience and improve the production systems of local farmers to make them future-proof. We strived to find viable solutions via targeted field and laboratory experiments with local researchers, the private sector and farmers. In this 'Agricultural Knowledge and Innovation System', farmers are the key stakeholders, as particularly farmers' livelihoods depend on primary production and their relations within the value chain. The main objective of the "Deltas under Pressure" case study in Vietnam was to use a food systems approach to explore the building blocks of transition pathways for agricultural production systems to adapt to the negative impacts of climate change in order to safeguard farmers' livelihoods.

3 What is our Case about?

3.1 Embedding of our case study within Vietnamese politics

The Mekong Delta Plan concluded that a shift towards agri-business focused on *specialisation* is vital for a safe and sustainable socio-economic development of the Mekong Delta. This conclusion is in line with the Vietnamese Governments 'Resolution 120' from October 2017. This resolution aims at the development of key agricultural value chains by making them highly sustainable and export-oriented, thereby boosting the agricultural sector. This includes optimising related business services and establishing an enabling environment (institutions) to support these chains. The Vietnamese government promotes the transformation of the agricultural economy under "new normal" situations, e.g., shifting to increased value and increased resilience to changes in the climate and markets.

In 2019, a Memorandum of Understanding on the Mekong Delta Agricultural Transformation Program was signed by the Vietnamese (VN) Prime Minister Nguyen Xuan Phuoc and the Netherlands (NL) Prime Minister Mark Rutte. This Memorandum started the next phase of the VN-NL strategic partnership in the Mekong River Delta. The Agricultural Transformation Program aims to facilitate and support the Vietnamese Government to assist in agricultural transformation towards a viable modern sustainable, market-oriented agricultural sector that provides fair opportunities to all relevant actors (from farmers to consumers) in the food system. The Mekong River Delta is a major agriculture and aquaculture production hub in Vietnam. The delta is a major rice exporter and a significant exporter of aquaculture products. Fruit and vegetable exports are also rising.

3.2 The umbrella story of pressure and transition, our theory of change

Agriculture in the low-lying areas of the Mekong River Delta has to cope with climate change. The low-lying delta is particularly vulnerable to sea-level rise and associated saltwater intrusion. Saltwater intrusion has steadily increased in the last decades. About 45% of the land area in the Vietnamese Mekong River Delta is affected by salinity, this is expected to increase by another 10 to 20% by 2040. Not only will coastal erosion and flooding pose significant safety risks, combined with changing rainfall patterns, the upper and middle deltas will also face more frequent and severe flooding. Climate change is expected to exacerbate existing stresses and have a high impact on food and feed production via increasing salination, drought and pests, at the expense of increasing global food demand. Farmers involved with arable farming, livestock husbandry and freshwater aquaculture will have to adapt to changes in rainfall patterns and increased events of flooding, drought, saltwater intrusion, and pests and diseases. Agriculture is the biggest contributor to the Mekong River Delta economy, and is currently affected by increased pressures from floods, salinity, drought, but also urbanisation (described in more details in Section 3.3).

Most development problems cannot be addressed simply with an intervention based on a single solution or *pathway*. Agricultural transformation towards a sustainable but also a viable, modern, market-oriented agricultural sector – that provides fair opportunities to all relevant actors (from farmers to consumers) in the food system – is complex. This complexity is exacerbated as transition pathways necessitate the integration of adaptation strategies to cope with increased levels of salinity, and longer and more intense periods of drought. We know that supporting the response to development and climate change-related challenges will require a) institutional, b) organisational, c) economic, d) social, and e) technical changes at different levels of the food system. The Vietnam case has embraced this 'whole system' approach, accepting that *monitoring and learning together* 'as we go' will need to be the most important 'trademark' of our approach.

Points of departure for the Mekong River Delta case in Vietnam
A team of researchers from Wageningen University & Research, Can Tho University, Tra Vinh University, and the Tan Loc Path seed company, focused on water, farming systems, and crops related to the agri-food domain while also connecting to transition processes needed to support the learning-by-doing approach.

The following underlying assumptions were made: 1. Saltwater intrusion is expected to increase (Section 3.3); 2. The occurrence of droughts, floods and pests will increase (Section 3.3); 3. Population growth and urbanisation will increase pressure on land use, while at the same time local (i.e., within the delta region), national and global food demand will increase (Section 3.3.); and 4. Food system changes are not based on one simple intervention, but require societal change, and therefore a multitude of pathways (that, in turn, can reinforce or hinder each other) and a step-by-step approach based on *multi-stakeholder reflection and learning*.

These assumptions or hypotheses underpin the 'domains of change' that have been prioritised as basis for development and design of the transition pathways towards more sustainable agri-food systems in the Mekong River Delta of Vietnam. These domains of change can be understood as broad priority areas where adaptation is necessary; and have been labelled as 'water and desalination', 'farming systems', 'crops' and 'delta specific transitions' (Figure 2).

The domains (or priority areas for change) mentioned are *points of departure or entry points* for further development and design of transition pathways. We deliberately highlighted here 'points of departure' for the development and design of transition pathways since the Mekong River Delta case study has been dedicated in collaborative analysis (i.e., by conducting on-farm trials and/or lab tests) and shared *understanding in* following the process suggested in the guidelines (see Chapter 2).

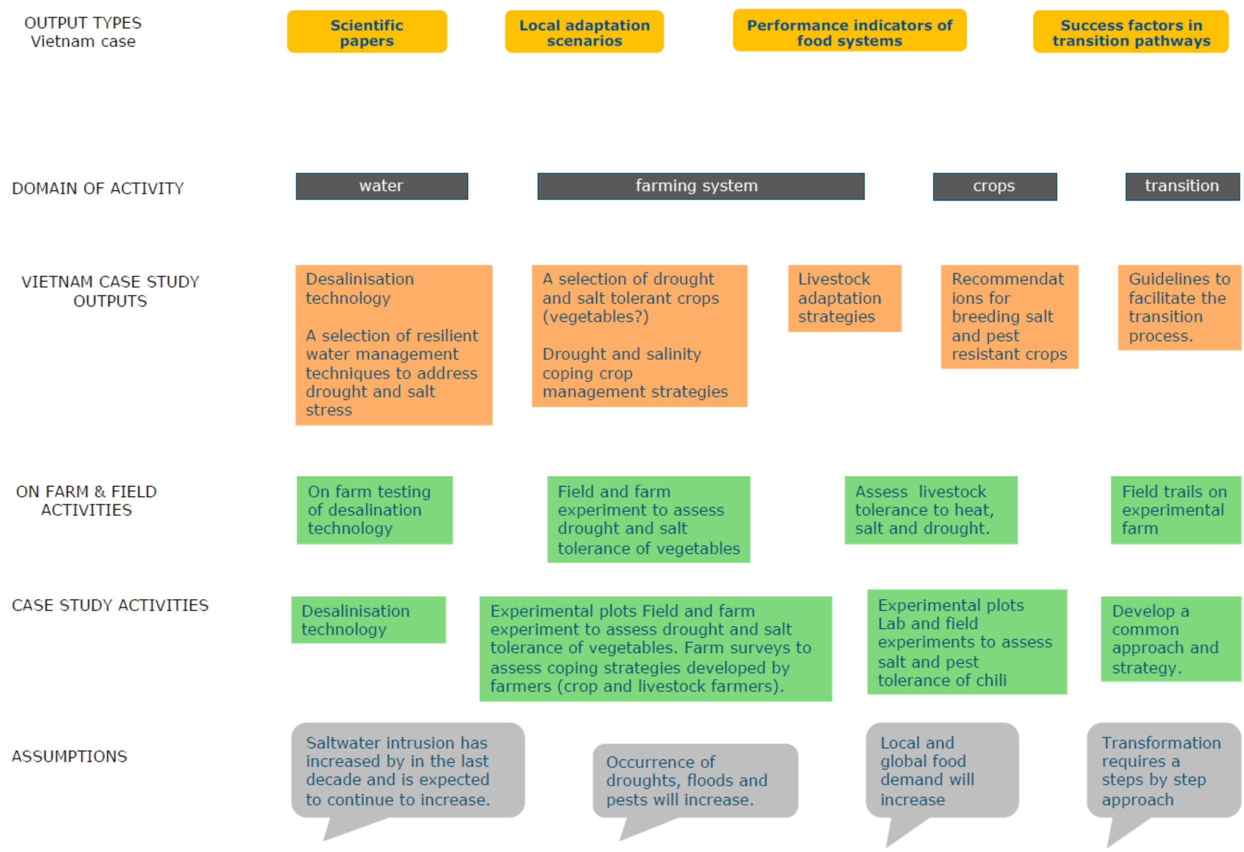

Figure 2 *Theory of change for the Mekong River Delta in the 'Deltas under Pressure' project.*

The current Theory of Change and case study activities
The priority areas of change will be further discussed in dedicated chapters.

Breeding for tolerance towards abiotic and biotic stresses is explored in Chapter 4. Lab (Section 4.1) and field (Section 4.2) tests dedicated to assessing the impact of different levels of salinity on a specific pest 'whitefly' on chillies are summarised. Chapter 5 is dedicated to field and farm experiments to test salt and drought tolerance of specific crops (Section 5.2) and describes the surveys (Section 5.1) and literature review (Section 5.3) that have been conducted to assess the coping strategies of crop farmers. Adaptation strategies of livestock farmers and the assessment of livestock tolerance to heat, drought and salinity is also explained in Chapter 5. Farmers with integrated systems to tackle increased salinity and drought circumstances are addressed. Chapter 6 focuses on water management choices and on-farm testing of desalination technologies.

According to the research team, developing and designing transition pathways and facilitating transition processes that consider delta dynamics requires a dedicated process using a 'whole system' approach (Chapter 2). Conclusions within the sections further outline follow-up steps needed for the actual design of transition pathways in the specific domains and how different pathways currently relate to and potentially reinforce each other.

3.3 Drivers and pressures affecting food systems in the Mekong River Delta, Vietnam

A scoping mission, including a workshop, was conducted from 17 to 28 November 2019 by seven Wageningen Research (WR) staff to Vietnam, Can Tho University/ Mekong Delta Development Research Institute (MDI). WR and MDI developed a joint research agenda towards sustainable food systems during the workshop. After a mapping of disciplines, a field visit was used to trigger exchange between disciplines and develop ideas about common issues to work on.

Selected key-conclusions from the workshop are:

- A major socio-economic driver is a change in (sub-)national policy; the focus shifted from rice cultivation to the production of fruits, vegetables and livestock.
- There is a need for adaptive and integrated farming systems, including context-specific innovative techniques, to ensure resilient systems, adapting to climate change.
- Current climate change scenarios foresee an increase of pests and diseases.
- Gender and youth need attention, particularly while formulating possible transition pathways.

Main challenges of the Mekong River Delta:

- Increased, and increasingly varying, salinity.
- Increased drought, leading to a lack of fresh water, in turn leading to an increase in ground water extraction, leading to conflicts (e.g., between saline and fresh water food production).
- Reduced crop yields (e.g., rice) – due to increased climatic stresses.
- Increase in pest and disease prevalence for vegetables, fruit, shrimp and livestock.
- Price fluctuation (local + international) and market saturation.
- Environmental pollution in the form of chemical fertilizers, pesticides and antibiotics.
- Low quality of fodder / livestock feed, and trade-offs between crop and livestock components.
- Increasing livestock production without increasing GHG emissions.

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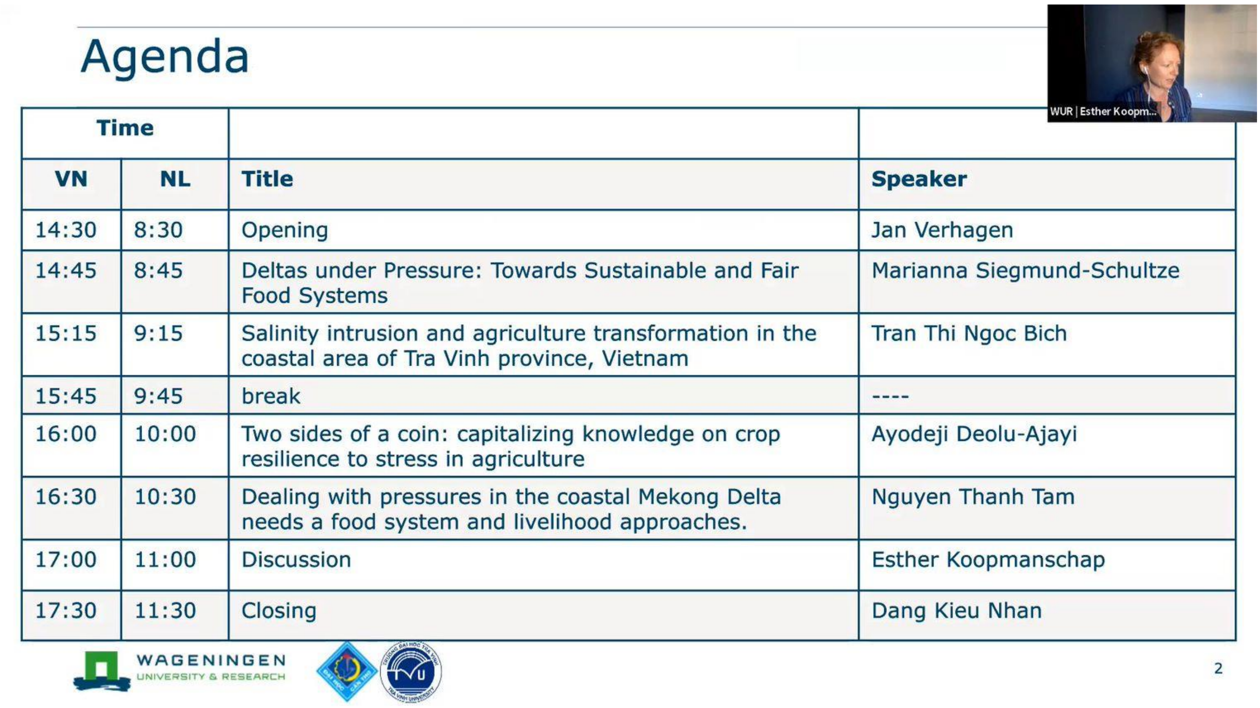
The report can be downloaded at https://edepot.wur.nl/514244

3.4 A video conference about adaptation to climate change at the farm level

On 5 August 2022, we held a multiple-time zone online conference with several presentations and subsequent general discussion. The schedule of the half-day event is shown below (Figure 3).


Agenda

Time			
VN	NL	Title	Speaker
14:30	8:30	Opening	Jan Verhagen
14:45	8:45	Deltas under Pressure: Towards Sustainable and Fair Food Systems	Marianna Siegmund-Schultze
15:15	9:15	Salinity intrusion and agriculture transformation in the coastal area of Tra Vinh province, Vietnam	Tran Thi Ngoc Bich
15:45	9:45	break	----
16:00	10:00	Two sides of a coin: capitalizing knowledge on crop resilience to stress in agriculture	Ayodeji Deolu-Ajayi
16:30	10:30	Dealing with pressures in the coastal Mekong Delta needs a food system and livelihood approaches.	Nguyen Thanh Tam
17:00	11:00	Discussion	Esther Koopmanschap
17:30	11:30	Closing	Dang Kieu Nhan

Figure 3 *Agenda of the video conference about adaptation to climate change at the farm level in the Mekong River Delta, held on August 5, 2022.*

The discussion about major topics to be investigated was lively and broad. We talked about labour and migration: young people rather than those established migrate. People who migrate have opportunities to obtain income from renting out their land. There are reservations by farmers to change their farming systems. Several farmers do not want to change from rice to rice-shrimp systems since they have already accumulated experience on the former. Nevertheless, the negative impact of climate change may threaten the feasibility of continuing with the status quo. Although farmers believe that they have mastered the production aspect, (scientific) support is welcome in the areas of institutions, access to markets and governance. Agricultural and aquaculture products need to reach the consumers via markets and this needs further research. Still, provinces of the Mekong delta are also not all the same, getting more insight about provinces beyond the studied ones is equally beneficial.

The Vietnamese Resolution 120 put forward a shift in production priorities. While earlier #1 was rice, #2 orchard (fruit production) and #3 fishery, now fishery is #1, followed by #2 orchard and #3 rice. Still, there is some concern about sufficient rice production for domestic and international markets since rice production is further reduced. From the local context, where to buy rice if people quit growing it; and that the production costs should not be too high when focusing on international (bulk) markets.

We aim at science for impact: apply and implement, apart from paper publishing. Although we focus on the Vietnamese Mekong River Delta, these studies also link to livelihoods in similarly low lying areas. We apply the food system approach and look into innovation, policy impact, and practical application. The nexus of water-soil-crop/feed is central. The landscape level is relevant for agricultural transformation which is motivated by climate change. We aim at income and job generation locally along with the whole production chain, rather than stimulate migration. While primary production capacities are already high, some practices deserve investigation such as the focus on synthetic fertilisers, while applying organic matter receives apparently too little attention. Other practical information like the dealing with water pests equally calls for attention. We aim at a workshop in Tra Vinh province to show and discuss results with local stakeholders. Our ultimate aim is to serve society.

3.5 New projects that we acquired related to salinity in Vietnam

1. Asian Development Bank Masterclass on saline agriculture. NL water partnership: J. Snethlage, A.O. Deolu-Ajayi
2. TKI SMP "Seaweed cultivation in Vietnam for feed and methane reduction": A. O. Deolu-Ajayi, W. Muizelaar and A. van der Werf. Final report available at https://edepot.wur.nl/566553.
3. KB34 2023/ 2024 project "Dealing with salinization": A.O. Deolu-Ajayi, I. van der Meer, A. van der Werf, M. Tangelder, M. Poelman, G.J. Wilbers and J. Snethlage.

4 Breeding for Tolerance to Abiotic and Biotic Stresses

4.1 Insect problems in a changing environment

Climate change has profound effects on crop production, for example through more salt intrusion in deltas. In addition, pest and disease pressure will change. Both salinity and insect problems can cause large yield losses in plants. Currently, the main way to prevent losses caused by insects is through frequent application of pesticides. However, pesticide use is detrimental for humans and the environment, and alternatives are needed. To reduce pesticide use and to increase yield stability even under saline conditions, growers would benefit from plant varieties that are both resistant to pests and tolerant to salinity stress. Importantly, abiotic and biotic stresses interact, and should not only be considered as independent problems. In this study, our objective was to identify pepper (*Capsicum* sp.) varieties that are salt-tolerant, and/or resistant to the silver leaf whitefly, *Bemisia tabaci*, one of the most damaging insects on pepper. In addition, we aimed to study the interaction of salinity stress and insect resistance. In our study, we grew 26 pepper accessions in the greenhouse, applied a salt treatment for two weeks, and then evaluated the plants for resistance to *B. tabaci*. To study the effects of salinity stress on plants, plant weight and height were measured. Salt treatment had a clear effect on growth of plants, and resulted in biomass reduction for almost all pepper accessions. Three accessions show no or very little growth reduction when grown under saline conditions, and could be further studied as potential salt-tolerant plants. Plant resistance to *B. tabaci* was investigated by measuring survival and reproduction of the insects. Significant differences were observed among accessions for adult survival and reproduction, and five accessions with low survival of *B. tabaci* were selected as resistant. However, the salt treatment invariably resulted in increased survival and reproduction of whiteflies on all plants. In other words, plants that were resistant to whiteflies became susceptible when grown under salinity stress. Currently, we are studying which mechanisms underlie the reduction of plant defences under salinity stress. Importantly, our results indicate that problems with insects may increase in plants grown under salinity stress. However, genetic variation underlying salt tolerance and whitefly resistance may be used to breed for new cultivars with improved performance to both stresses. Studying the interaction between both stresses may result in tools to grow plants that are stable and resistant in changing conditions.

This research was presented at Circular@WUR 2022 on 13 April 2022, and to an audience of representatives from Asian breeding companies at a visit from the Asia Pacific Seed Association to WUR on Friday 30 September 2022.

Source of the abstract: https://edepot.wur.nl/568843

Caarls, L., Enigimi, E.F., Strijker, M.F., van 't Westende, W.P.C., Voorrips, R.E., & Vosman, B. (2022). 4s2b: Insect problems in a changing world: reduce pesticide use by breeding for insect resistant plants under salinity stress. In I. de Boer, A. Muller, D. van Apeldoorn, J. Kjerulf Petersen, & S. Doornbos (Eds.), Circular@WUR 2022: 4. Partnerships: Governance of transitions Wageningen University & Research. https://library.wur.nl/ojs/index.php/CircularWUR2022/article/view/18403

4.2 Follow-up experiments on salt–whitefly interaction

In 2022, the results as described in 4.1 were followed-up in a greenhouse experiment to study the interaction of salinity and whitefly infestation in more detail. In this experiment, our question was how salinity affects plant cellular processes that than influence whitefly survival and reproduction. To this aim, five accessions were selected that showed highest resistance to whitefly, and or low reduction of growth in saline conditions in the 2021 experiment. Next, we grew the pepper accessions in the greenhouse, applied a salt treatment for two weeks, and then evaluated the plants for resistance to B. tabaci. In addition, plant material was harvested after 24 hours of whitefly infestation, to study accumulation of plant hormones, gene expression and ion concentrations, in plants either treated with or without salt, and or whitefly. Analysis of these data will give insight into why plants that experience salinity stress are less adapted to dealing with the whitefly infestation.

4.3 Report about activities with the Tan Loc Phat company

Tan Loc Phat (TLP) is a small Vietnamese vegetable breeding company (http://www.tanlocphatseeds.com/bvct/chi-tiet/1/about-us.html). They have implemented an evaluation method for identifying whitefly resistant chilli pepper accessions. A protocol, adapted to their local situation, was developed in close collaboration with WUR.

To carry out the experiments, a whitefly (*Bemisia tabaci*) rearing was set up on Eggplant. After an initial attempt in which they got acquainted with the methodology, a first real experiment was carried out in early 2021. The method used was a no-choice assay in which female whiteflies were forced to feed on a particular plant (Vosman et al., 2018). Seventeen chilli accessions were used in the experiment with five plants per accession. Each plant received two clip cages with five female whiteflies each. Survival and oviposition were determined after five days.

Significant differences in oviposition were observed among the accessions, ranging from 3.4 to 13.9 eggs/ female/ day, which is promising results. Although there are differences in oviposition, the values are still too high to have a major effect on whitefly population development. Therefore the search for more resistant materials that ideally also affect survival of whiteflies, will continue.

TLP continued the research by carrying out a choice test, which is less laborious and will allow them to identify clearly susceptible materials. Putatively resistant materials will have to be re-tested using a no-choice test. The choice assay was started recently on 50 chilli accessions.

Besides being a learning project for TLP, it is also important information for WUR because their situation is different from ours (different whitefly biotype, different conditions). We see e.g. that their whitefly reproduction is also much higher than ours.

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4.4 Conclusions Cluster Breeding

In the experiments conducted in the cluster breeding, we have identified salt-tolerant and whitefly-resistant accessions, both at WUR and in Vietnam by Than Loc Phat. These accessions can be further used in follow-up research and breeding. In addition, we have learned more about the interaction between salinity and whitefly, results which may be used to develop tools and make informed decisions on water and pest management in the Delta's.

The collaboration with the Vietnamese company Than Loc Phat may be followed-up by establishing a durable connection.

The results on whitefly resistance in pepper where also used to recruit a PhD student from Indonesia, with funding by the Indonesian government, which will start at WUR in March 2023. A scientific publication on the results of experiments performed in 2021 and 2022 will have to be written and send for publication in 2023.

5 Adaptation of Crop-Livestock Farms to Stresses from Salinity, Drought, Flood and Heat

5.1 Adaptation of farming systems to climatic stresses in the coastal area of the Mekong River Delta: a gap between governmental plans and farmer reality

Summary
Current smallholder farming systems, especially those in coastal areas of the Mekong River Delta, have to cope with several pressures. (i) Increasing levels of saltwater intrusion hamper (short to mid-term) the continuation of multiple-rice production systems since rice is salt sensitive. (ii) Farmers get low prices for rice in wholesale markets. (iii) Introducing upland crops, i.e. vegetables and annual fruits, requires new knowledge, skills and a different set of agricultural inputs. (iv) The Vietnamese government favours a broad and quick transition towards salinity-based systems.

A study was set up to explore differences and similarities amongst farmers and related stakeholders in analysing their situation, and how they currently or potentially deal with the existing pressures.

We selected three study sites (1: Vinh Kim commune – Cau Ngang district, 2: My Long Bac commune – Cau Ngang district, 3: Ngoc Bien commune – Tra Cu district) in the two mentioned districts of Tra Vinh province. Site 1 represented salinity-based farming (rice-shrimp) on alluvial soils. Site 2 is rice-based farming on sandy soils, nearby the river, with a potential shift to introducing vegetables and fruits. Site 3 is a farming system based on vegetables (upland crops) and rice.

We used key informant panels, including community heads, representatives of farmer associations and policemen, to get an idea of land use dynamics and potential drivers and plans. A comprehensive identification of households was performed using existing household lists (407, 538 and 288 households in sites 1, 2 and 3, respectively). Three key informants per community classified the households according to criteria of the Vietnamese government (article 07/2021/ND-CP, issued 27 of January 2021) into classes from poor to rich. Their results were averaged and outer groups clustered together, resulting in three main classes from which the two extremes were considered for participation. Participants were randomly selected by drawing lots.

Thirteen focus group discussions (FGD) were carried out with 6 to 10 participants each (99 participants in total, including farmers and district staff). Participants were clustered into 5 groups: 1) worse-off farmers (one FGD per site), composed of mainly men and few women; 2) better-off farmers (one FGD per site), almost equal number of men and women; 3) women only (one FGD per site), household heads and household participants from different wealth strata; 4) People who do both farming and service provision (hereafter 'Service', one FGD per district); 5) District staff (one FGD per district). People were asked about perceived current and future drivers for change, pressures, and concerns. Detailed household data was collected from about half of FGD participants (n=52) in an ad hoc selection. Livelihood assets, agricultural activities and water uses were main issues here. Participants were asked to rank the categories, as previously defined by key informants, according to their own perceived importance from 1 to 9. Physical objects (stones) were used for the rankings. Each person used up to nine stones, and assessments were written down by our Vietnamese partners. Tables were presented either with pictograms or in writing.

Besides descriptive statistics, a factor analysis was performed to derive principal factors from the five drivers and 15 concerns used in the individual ranking exercises. The factors were named according to the variables which dominated each factor. The selected nine principal factors were: Farm profit from vegetable produce, Crop production chains, Diseases & risks, Credit & waters, Inputs and outputs markets, Natural stresses,

Farm technology & biodiversity, Eco-technological infrastructure, Adaptation & environment. A discriminant analysis was performed on the first four factors. SPSS and Statistica were used for the analyses.

Figures 4 and 5 show basic household characteristics. All farms are small; and major inter-site differences were observed in site 3. Farmers in all groups have off-farm income, which accounts for up to almost half of their total household income. Income from livestock is particularly important in the service farmer group, and also in the poor farmer group. The better-off farmer group earns more than half of their agricultural income from crops, where rice is more important than upland crops (vegetables - peanut, maize, pumpkin, sweet potato, chilli).

Figure 4 *Farm size by site and wealth group (n=1232).*

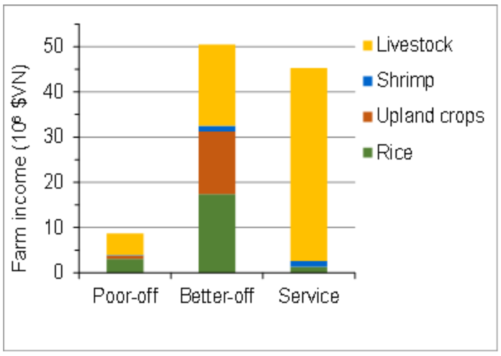

Figure 5 *Agricultural income in 2021 by wealth group (n=52).*

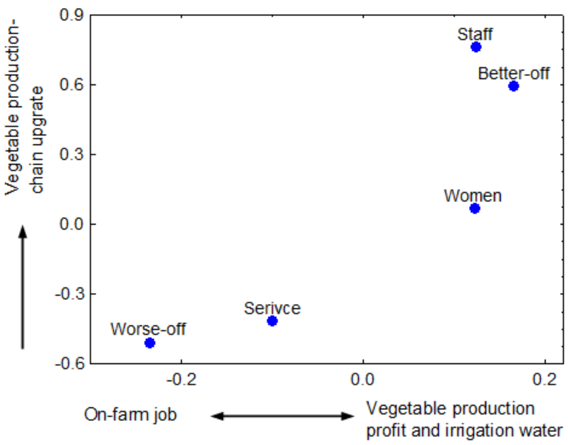

Figure 6 *Factors 1 and 2 compared for participant group (n=52).*

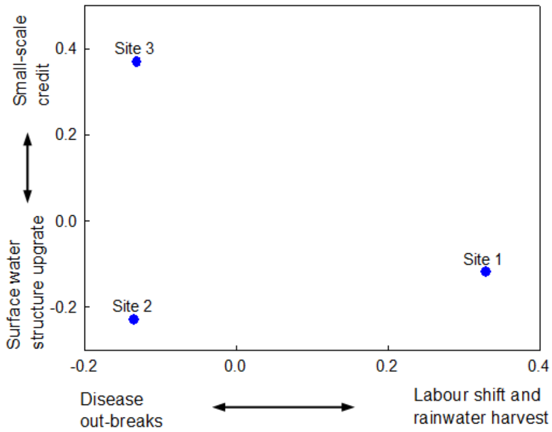

Figure 7 *Factors 3 and 4 compared for differences among sites (n=52).*

The worse-off and service providing farmers are less involved or interested in vegetable production (Figure 6). The district staff group showed similar assessments as the better-off farmers: giving value to upgrading their vegetable value chain. Women see scope in vegetable production and irrigation, while they are rather neutral towards value chain development. Farmers in sites 2 and 3 suffered most from the COVID-19 outbreak; and those in site 1 showed shifts in labour demand and supply, and options for rainwater harvesting (Figure 7). Site 3 farmers were keen on credits (probably to buy inputs for their vegetable production) and sites 1 and 2 farmers interested in surface water and infrastructure upgrade.

New questions were raised and partly answered during the study, such as:

1. Rice-shrimp systems require little labour, while vegetables are labour intensive. Vegetable production is typically a women's activity. For what farmer group is which farming system more accessible and adequate? And what implications have such system changes on household members, labour allocation, and satisfaction?
2. Poorer farmers achieve (by definition) little income – they also have less opportunities (e.g., less land area). Are climate change-adapted farm activities possible and helpful for poorer farmers? Can a different farming system reduce poverty even when farm size limitations still remain? How many farmers can completely live off their allocated land area? A slight increase of individual farm area appears to be useful. To achieve this, some farmers would have to give up land for others. Most present farmers do not see this as an option for themselves but rather for the next generation.
3. The suggested drivers and concerns were ranked differently by stakeholders. The agri-food systems are site and group-specific.
4. A priority for action is the improvement of present farming systems. Drought and salinity are affecting farmers already, along with volatile prices.

In conclusion, a system perspective is required to understand the implications of new farming systems. At the local level, differences between farmer groups need to be considered. Policy implementation must take into account the situation at the local level.

We are preparing a manuscript for a peer-reviewed paper that presents and analyses the results of the focus group discussions and the in-depth household interviews. Part of the data will be additionally used in a water-issues-specific paper. The study was designed in partnership. The field work was led by Can Tho in collaboration with Tra Vinh colleagues.

5.2 On-station experiment about crop response to salinity levels in irrigation

Summary

Climate change has resulted in prevailing saline and drought conditions and these events have become increasingly severe in the last decade. The Vietnamese Mekong River Delta is a major hub for rice production, fruit cultivation and fisheries that is responsible for a large portion of the country's GDP. Salinity intrusion due to the effect of climate change and poor management of arable land has greatly impacted the livelihood of millions of farmers in the Vietnamese Mekong River Delta. Thereby, threatening the future of agriculture in most coastal provinces. Although several management strategies to improve crop cultivation under saline conditions have been proposed, most of these techniques and tools have not yet been adopted in Vietnam. Studies on using salt tolerant cultivars and species that grow under increasing soil salinity and water-deficient conditions, and the use of compounds to boost cultivation under saline conditions, remain limited. Previous studies on promising high value crops in the Mekong River Delta e.g., maize and peanut, indicated the need to increase knowledge on saline agriculture[1,2]. The goal of the experimental study was to assess the effect of saline irrigation on growth and development of high value crops. This study serves as the basis for improving crop cultivation under saline conditions, and to establish thresholds on use of saline water for irrigation.

The experimental setup at Tra Vinh University (TVU), Vietnam consisted of soil pots in a 18 m x 9 m net house covered with white plastic tarpaulin to prevent the impact of rainfall. Soil-compost ratio was 1:1, salt watering involved dissolving NaCl in water to the desired concentrations and application to the soil, and not directly on the plants. Three crops namely beetroot, maize and peanut were exposed to salinity adaptation and shock experiments. The adaptation experiments involved increasing salt concentrations in the soil by a factor of 0.5 over time until the defined salinity levels are reached and maintained for the duration of the experiments. Here, nine different NaCl concentrations i.e., 0 ppt (control), 0.5 ppt, 1 ppt, 1.5 ppt, 2 ppt, 2.5 ppt, 3 ppt, 3.5 ppt and 4 ppt were established. Shock experiments were replicated by irrigation with defined salt concentrations i.e., 1 ppt, 2 ppt, 3 ppt or 4 ppt, at specific crop developmental stages e.g., seedling, flowering and fruit setting.

Several physiological traits (different vegetative traits per crop type) were measured every three days for the duration of the salinity experiments, and yield and crop quality traits assessed at the end of the experiments.

Preliminary results from the adaptation experiments with beetroot showed a significant reduction in crop yield at higher salt concentrations (Figure 8A) and a significant negative correlation between crop yield and the measured soil EC (Figure 8B). Our observations align with previous results where low to moderate salt concentrations had no significant effect on growth and development of beetroot, while severe salt stress drastically inhibited crop growth and yield[3]. Therefore, beetroot is a moderately salt-sensitive crop and may withstand irrigation with saline water containing low to moderate salt levels. For crop yield to not be affected, the salt concentrations in the soil should not exceed 3 dS/ m.

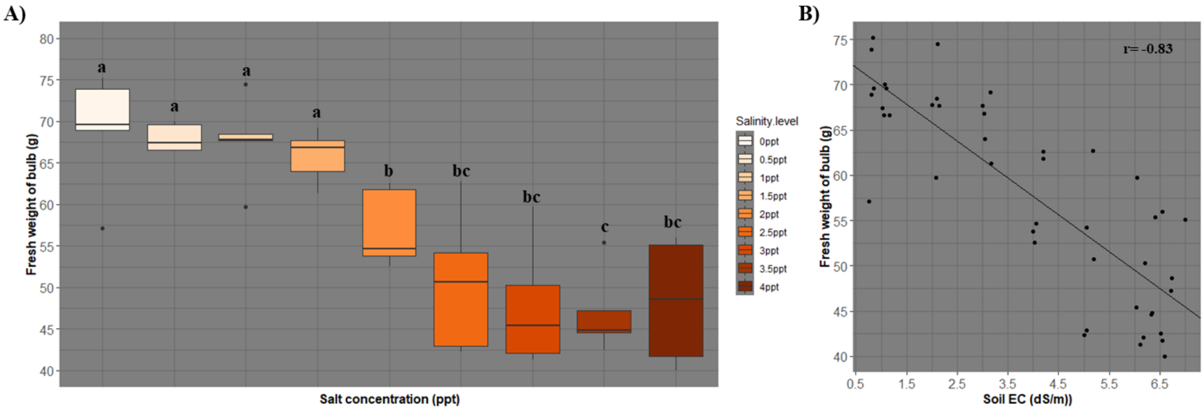

Figure 8 *Beetroot adaptation to different salt concentrations. Fresh weight of 12 week old beetroot bulbs exposed to specific increasing salt concentrations (A), and correlation between fresh weight of the bulb and measured soil EC (B). Analysis was performed on crops exposed to 11 weeks of saline irrigation, and box plots represent 5 replicates per salinity concentration. Statistics was by one-way anova with Dunnett's Post Hoc, where alphabets represent p-values 0.05. Pearson correlation was used to determine association between fresh weight and soil EC.*

The beetroot results are promising and indicate thresholds on the use of saline water for irrigation. Data on adaptation experiments on maize and peanut are currently being analysed while the shock experiments are still ongoing and expected to round up by December 2022, with data analysis continuing afterwards. These experiments are the first steps in determining crop responses to salt intrusion in the Vietnamese Mekong Delta. Studies on crop adaptation strategies that boost crop growth and yield under saline conditions e.g., the use of biostimulants[4], complement the current experiments and proffer solutions for improving saline agriculture in the Mekong Delta.

Author Contributions

Experimental design and work was performed by Tran Thi Ngoc Bich, Nguyen Hong Ung (TVU); and Nguyen Minh Phuong, Dang Kieu Nhan, Nguyen Hong Tin, Nguyen Thanh Tam, Ho Chi Minh Thinh, Nguyen Van Quý (CTU). Support on data analysis and text summary was provided by Ayodeji O. Deolu-Ajayi.

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5.3 How knowledge on crop resilience to abiotic stress can be capitalised in agriculture

Abstract
Increasing population, negative impact of climate change and declining arable land all contribute to global food insecurity. Abiotic or environmental stresses of salinity and drought account for huge crop losses annually further reducing food availability, thereby increasing pressure on food insecurity. Although fundamental studies on these abiotic stresses have been substantial to an extent, successful translation into usable strategies or techniques at the farm level has been lacking. This opinion paper bridges the gap between fundamental research and farming practice by instead highlighting practical application of salinity and drought stress adaptation strategies and important steps to create smooth transition on the farm. An analysis of adaptation strategies that have focused on dealing with salinity and drought gives an overview on to what extent current strategies are adopted at the farm level. By critically discussing positive outcomes, limitations, and recommendations of the case studies, we highlight knowledge transferrable for similar situations or adaptable for other farming systems. The variation in context, location, and size/ scale of the discussed case studies present opportunities for wider application of the abiotic stress adaptation strategies. To better understand the fit of the strategies to realistic conditions, we focus on the impact of field and farm adaptation strategies in the food system by indicating essential components that favour or inhibit implementation of the strategies to alleviate abiotic stress. The food systems perspective clearly shows that several actions by diverse stakeholders must take place, and that responsibility for success does not only depend on farmers themselves when implementation of new crop adaptation strategies occurs (Figure 9).

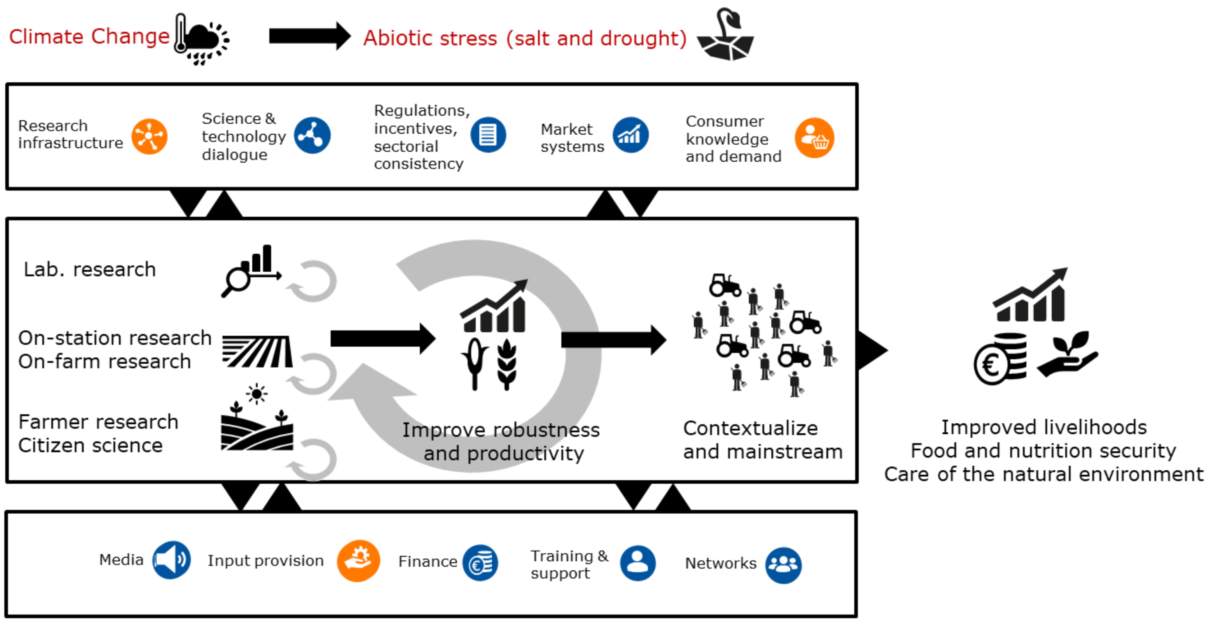

Figure 9 *Knowledge renewal for agricultural climate change adaptation in the food system context. Several types of research are undertaken to improve the robustness and productivity of crops and livestock in an iterative process, where ideally exchange and knowledge integration amongst the types of research occur. When primarily addressing abiotic stress, knowledge renewal should be compatible with multiple objectives at farm to food system levels. We highlight side activities and frame conditions that are crucial for a broad renewal process to successfully take place. The orange symbols refer to food system factors, while the blue symbols represent socio-economic factors. Figure adapted from van Berkum et al. 2018.*

The paper was presented at Circular@WUR on 13 April 2022: https://edepot.wur.nl/568842.

Deolu-Ajayi, A.O., Pronk, A.A., Siegmund-Schultze, M.G.R., Verhagen, J.H.G., & Blom-Zandstra, M. (2022). 4s2b: How Knowledge on Crop Resilience to Abiotic Stress can be Capitalised in Agriculture. In I. de Boer, A. Muller, D. van Apeldoorn, J. Kjerulf Petersen, & S. Doornbos (Eds.), Circular@WUR 2022: 4. Partnerships: Governance of transitions Wageningen University & Research. https://library.wur.nl/ojs/index.php/CircularWUR2022/article/view/18405

The paper has been submitted to the International Journal on Water Governance: https://journals.open.tudelft.nl/ijwg

5.4 Adaptation of livestock production to salinity/climate change in the Mekong River Delta

Freshwater is essential for food production in the Mekong delta; to grow crops for feed and food and for animals to drink. At the same time, freshwater is necessary for healthy ecosystems as it supports crop and animal production. However, freshwater is limited while on average 80% of the total amount freshwater worldwide is used for agriculture, but still a substantial part of the global population is undernourished due to freshwater shortages. It is expected that more freshwater is needed in the future due to an increasing demand of food products, in particular animal products from increasing welfare in developing countries and increasing population.

Livestock production has an important role in food systems of the Mekong River Delta. They contribute by providing protein and income to households. Even more, animals can convert biomass unsuitable for human consumption (or unwanted by people) into protein and energy products, such as dairy, meat and draft power and as a source to fertilize soils.

To produce animal products freshwater is required as service and drinking water and, indirectly, for feed production. However, livestock can also create negative environmental impacts such as the global contribution to greenhouse gas emissions, emissions to surface waters and depletion of water and land resources. Research shows that on global scale, about 40% of the global crop calories are used as livestock feed (we refer to this ratio as crop balance for livestock) and about 4 kcal of crop products are used to generate 1 kcal of animal products (embodied crop calories of around 4).

Worldwide, feed production is competing with food production for the same resources, water, and land. Albeit there are strong differences depending on the suitability of the land and availability of water resources. For instance, green water that is used for grass production on marginal land has less opportunity to be used for food production compared to blue water used to irrigate crops for feed. Strong differences also occur between livestock systems. On the one hand, systems have become more efficient which reduces the amount of water used to produce one unit of animal product. On the other hand, in improved livestock systems many crop residues and by-products have been replaced by primary crop products which increases water use to produce one unit of animal product.

Farm systems in the Mekong delta are challenged by increased demands of animal products and effects of climate change, particular in delta areas. Longer and extremer periods of drought, heat, flooding, and salinity affect farmers from intensive to subsistence farm systems. Current farm management practices and animals are not designed to tackle these effects. This also accounts on the regional and water basin level. Since severity of climate change effects will only increase it is crucial to develop adaptation strategies.

Within this project several activities have been carried out:

1. An overview was made on the 'waste' streams in the Mekong River Delta that can directly or indirectly serve as feed sources: https://miro.com/app/board/uXjVO2VSP2U=/ (Figure 10). This activity was combined with another project for RVO. Production systems scrutinized were: fruit trees and palms (coconut, durian, longan, mango, banana, pitaya, pomelo), field crops (rice, maize, cassava, sweet potato, peanut, soybean, sugar cane), fungi, livestock (dairy cattle, beef cattle, buffalo, goats, poultry, pigs), freshwater aquaculture (frog, pangasius), insects (black soldier, flies, meal worms, crickets), and brackish zone systems (mangrove, shrimp, flathead grey mullet).
2. A crop-livestock calendar was discussed with university staff and farmers. Based on the feedback the calendar was improved and will be used for fieldwork beginning of 2023. The calendar can be used to adapt and mitigate to climate change on the farm and regional level.
3. Interviews with pig, poultry, dairy and beef farmers have been conducted in the Mekong delta. This has been done together with De Heus, a big feed company, and the Can Tho University. Results of the interviews will be further processed in December 2022 and January 2023. Based on the interviews a survey is now in preparation for 90 farmers in the Mekong River Delta. According plans, the survey will be conducted in December 2022 and January 2023.
4. Collaboration and follow up activities have been established between WLR and Can Tho University, ILRI (Hanoi) and Hue University.
5. Students are involved in the collaboration and give input in dialogues and during the survey in 2022 and 2023.
6. A PhD will start in 2023. The PhD proposal development has started and will be completed in 2023 March.
7. Dialogues have been held with professors at the Can Tho University on circular food production systems and the role of animals.

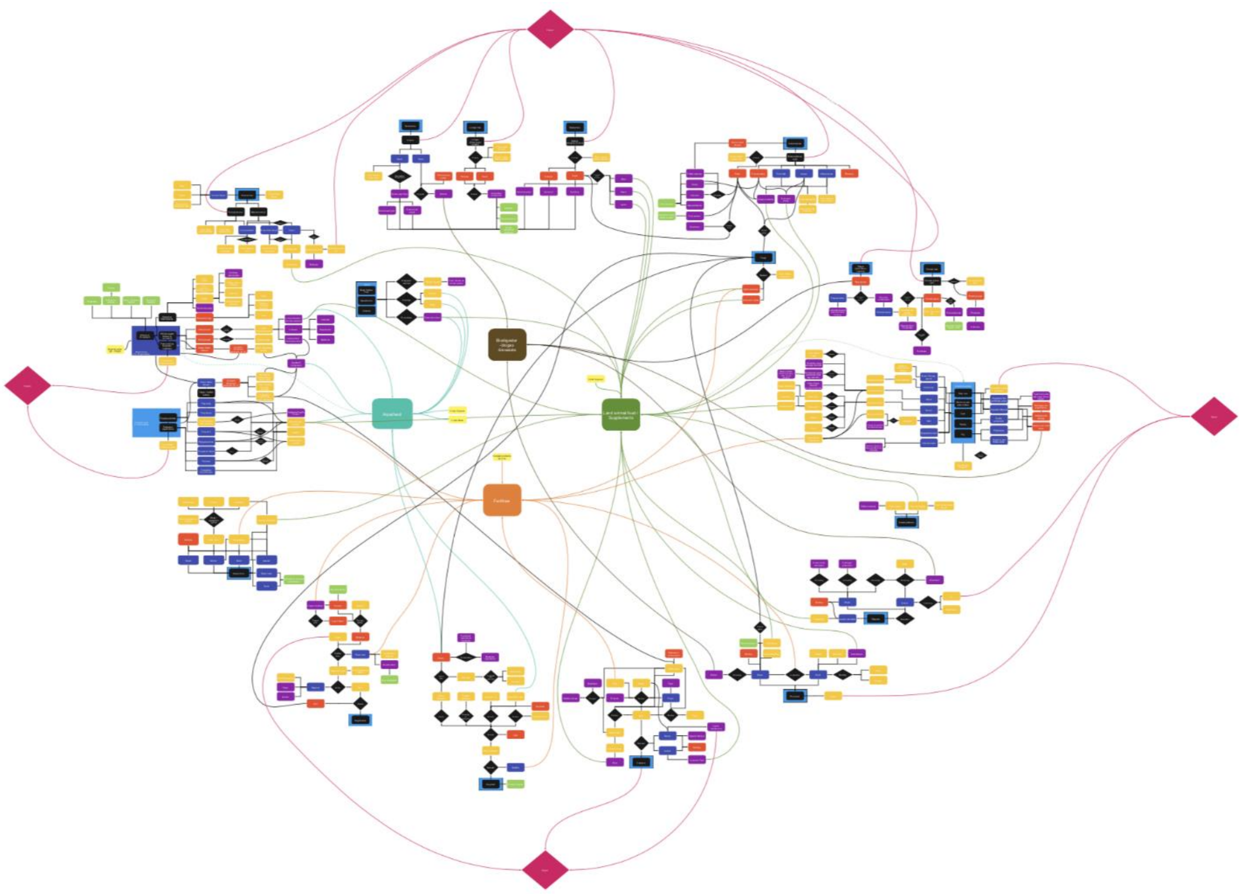

Figure 10 *The potential of production systems of the Mekong River Delta to deliver feeds for livestock and aquaculture, feedstock for biodigesters and fertilizer for crop production (overview of figure in Miro). The symbols depict processes (black diamond), waste streams (red), existing products (orange), inputs (yellow), services (green), intermediates (blue), potential uses (purple), main productions (black rectangular), and export (reddish diamond).*

Most important overall findings of the interviews
Farmers indicate that salinity is creating huge impact on their daily farm practices. Salinity levels are in some cases tested with EC and sometimes indicated by testing by drinking it themselves. For each animal type these effects are problematic and mainly experienced in the dry season. In order to cope with salinity farmers have developed certain measures and strategies.

First of all, instead of using surface water groundwater is used. As the quality of drinking water decreases farmers create their own water filter to reach the desired quality of water for their animals. A second strategy farmers indicate to cope with increasing water levels is water harvesting, not individually but done in farmer cooperations. And recently farmers started to buy water from water companies. This is often done through farmers cooperations or by a village.

Besides salinity, heat stress and the combination between salinity and heat is creating health problems to the animals. This accounts for all type of animals, in particular lactating cows and poultry. In September 2022 the news stated that there was a shortage of eggs in the market due to the extreme heat.

It is necessary to identify and develop strategies on the animal, farm and regional level and align those strategies to prevent lock-ins or create negative consequences from one spatial level to the other. Additionally, farmer systems could shift to areas where current food production is not possible any longer. Also, integration or replacing livestock in current food production for, and with, other types of animals or products could be a possibility to continue or improving food security for specific communities.

As livestock systems are highly complex, effects can be caused by a single factor or multiple factors depending on different conditions such as management of the farmer, feed quality, spatial and temporal differences and restrictions and environmental conditions. Strategies can therefore only be effective by first understanding the problem in its context.

5.5 Visioning transition in the Mekong River Delta

In a visioning exercise for the Mekong River Delta, in the frame of a related project, we followed a market-oriented agricultural transition looking at the Agro-Business Industrialisation scenario described in the Mekong delta plan. Economic development, in the scenario, is expected to move fast, and the Mekong River Delta will develop into a major agricultural hub. Based on this vision, a spatial outline was developed taking into account future needs and markets. The set time horizon was 2050, moving the vision to the next generation.

Starting from three market visions: i) high-end export markets (EU and Asia), ii) high-end domestic markets (urban), and iii) bulk domestic and export markets, several options for agriculture are presented. Besides the markets, the landscape and unique conditions related to the low-lying delta, combined with the impacts of demographic development and climate change, will co-determine the options for agriculture.

Figure 11 presents the landscape using four types: Estuary (with pronounced saltwater intrusion), the coastal zone (including and adjacent to mangroves), and the middle and upper delta. Current urban centres will grow, with Ho Chi Minh remaining the main urban area in the region. Climate change combined with land subsidence and sea level rise will cause problems affecting mainly the estuary and coastal areas with saltwater intrusion. Flooding in the middle and upper delta will remain an issue.

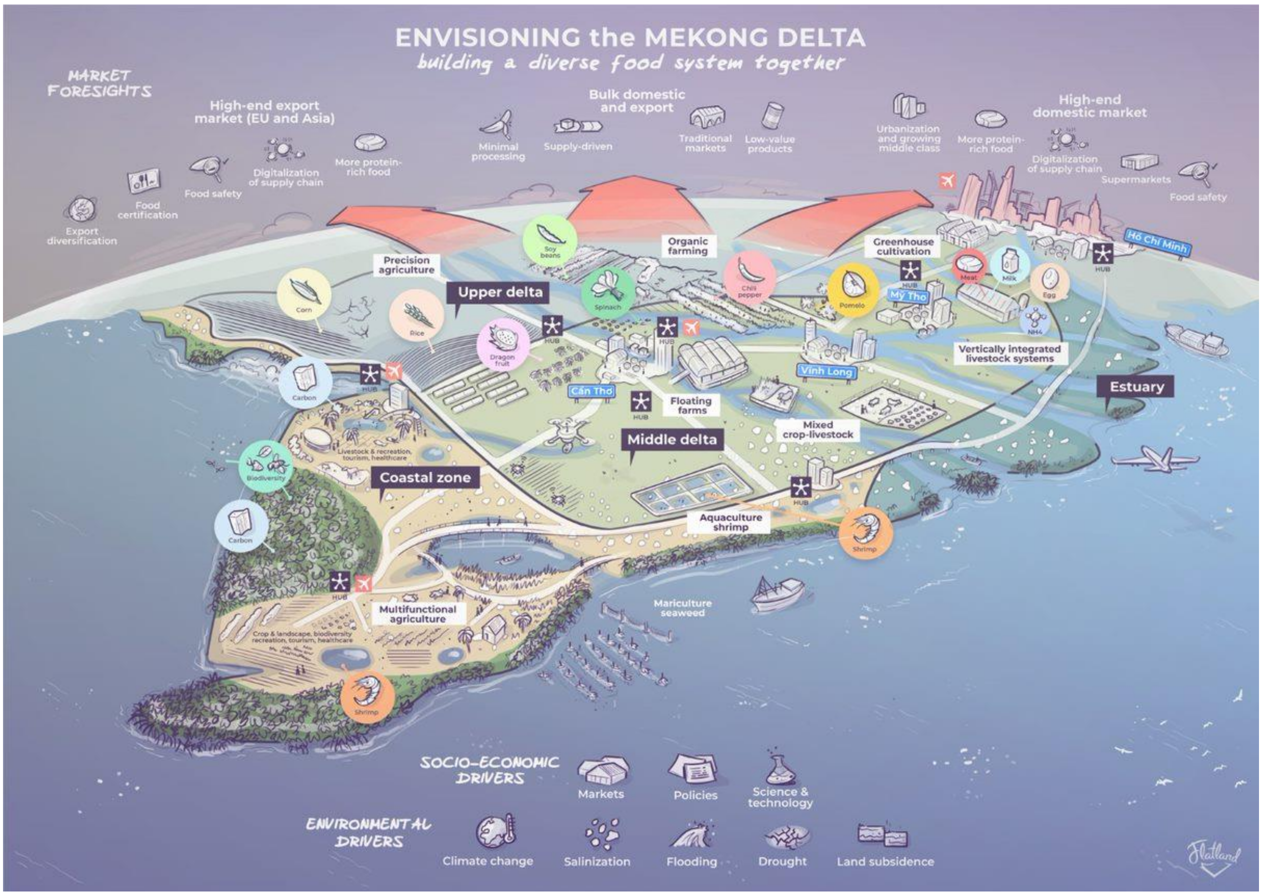

Figure 11 *How agricultural transformation pathways could look like in the Mekong River Delta. It will be a diverse food system featuring various types of production systems serving high-end export markets, domestic and export bulk markets, and high-end domestic markets.*

How and where agricultural systems will develop is not predetermined, but some types fit specific frame conditions better than others. For example, greenhouse cultivation is probably better suited to be localized near urban areas, while multifunctional agriculture can also flourish in places distant from towns.

Technological-oriented systems such as precision farming require high investments, so low-risk environments are favoured. Other low-technology and low-investment systems that depend more on natural processes, such as organic farming, will allow for different risk profiles. Other options include mixed farming, combining arable and livestock agriculture, or combining farming with tourism, recreation and environmental services. Several farming systems might develop depending on local conditions and the ambitions of individual farmers. Mariculture seaweed and aquaculture shrimp are the production systems which are among the most geographically tied. The latter also harbours the risk of irreversibly changing the landscape and making a reverse transition back to other systems difficult.

The presented vision emphasizes room for different paths, attending different types of markets and consumers. The envisioned markets again differ in requirements and development opportunities for producers up to consumers, offering various opportunities for job creation and livelihood options.

6 Concern for Water Quality and Quantity with Rising Sea Level

6.1 The role of water management in a food transition system

Climate change driven sea level rise is causing increased water and soil salinity in the Vietnamese Mekong Delta (VMD). Anthropogenic influences like upstream hydropower dams, upstream dyke construction and over-exploitation of groundwater also contribute to this problem. This is a major concern for agricultural production systems as the current system, mainly based on rice and freshwater aquaculture mixed with livestock, is vulnerable with respect to elevated salt concentrations in water. A main response from the government is the transformation of the agricultural production system towards increased salt tolerant systems such as shrimp and fruits, instead of rice. Although this is an effective strategy with respect to salinity adaptation, the current agricultural production system needs to be (partially) maintained in order to produce staple food products like rice and not be dependent on food staple food importation in the future. The current agricultural water management system, which is mainly based on flood irrigation via continuous flow from discharges of the Mekong River and its branches, and natural rainfall in the wet season, need to be revised in order to halt and/ or minimise further drought and soil salinization of the VMD. Currently, farmers are already experiencing the negative effects on increased water and soil salinity.

A focus group discussion and interviews with 99 farmers (see 5.1) indicated multiple cases where farmers applied adaptive measures to address the raised salinity levels in their fields. Most interventions focus on shifting from surface water to fresh groundwater; a temporary solution only, since groundwater sources will also become more saline in the future. Some farmers even indicated no crop cultivation in dry seasons since salinity levels were too high for sufficient production.

As a result, improved water and soil management strategies are therefore required. These should focus on i) increasing water productivity to maintain sufficient discharge to downstream regions to halt the saline intrusion through irrigation modernization, ii) fresh water storage as a buffer in dry season (see 6.2) and iii) basic water treatment options to make brackish/ saline water suitable for livestock (see 6.3). Furthermore, the soil organic carbon content should be increased to improve soil water retention and reduce impacts of salinity on crops. In upstream regions, measures should be particularly focused on increasing water productivity such as applying alternate wetting and drying in rice, and modern irrigation techniques like drip and sprinkler among other agricultural innovations. In coastal regions, increased emphasis should also be given to water storage and retention and in-situ treatment solutions. Organic mulching is seen as an option to both maintain moisture within the soil, as well as increase soil organic content. Although multiple options are available to achieve improved water and soil management, the selection of appropriate water- and soil related measures, as well as its adequate installation and operation depend on local socio-economic and environmental conditions. As such, it is recommended to test multiple applications of improved water- and soil management on farm level in representative regions in the VMD – at least upstream and coastal zones - through pilots, lighthouse farms and/or demonstration sites.

A joint manuscript to be submitted to a peer-reviewed journal is under preparation.

6.2 Desalination of (surface) water for irrigation in the Mekong Delta

Introduction
Due to the increasing salinity on surface water, especially in the dry season, the water quality becomes insufficient for both cattle and crop use. There are different options to cope with this problem:

1. Transition to more salt resistant crops and cattle.
2. Desalination of water.
3. Application of other fresh water sources.
4. Combination of options 1-3.

In this section, the focus is on the application of desalination of surface water.

Desalination technologies
In [1,2] an overview of physical-chemical desalination technologies is given.

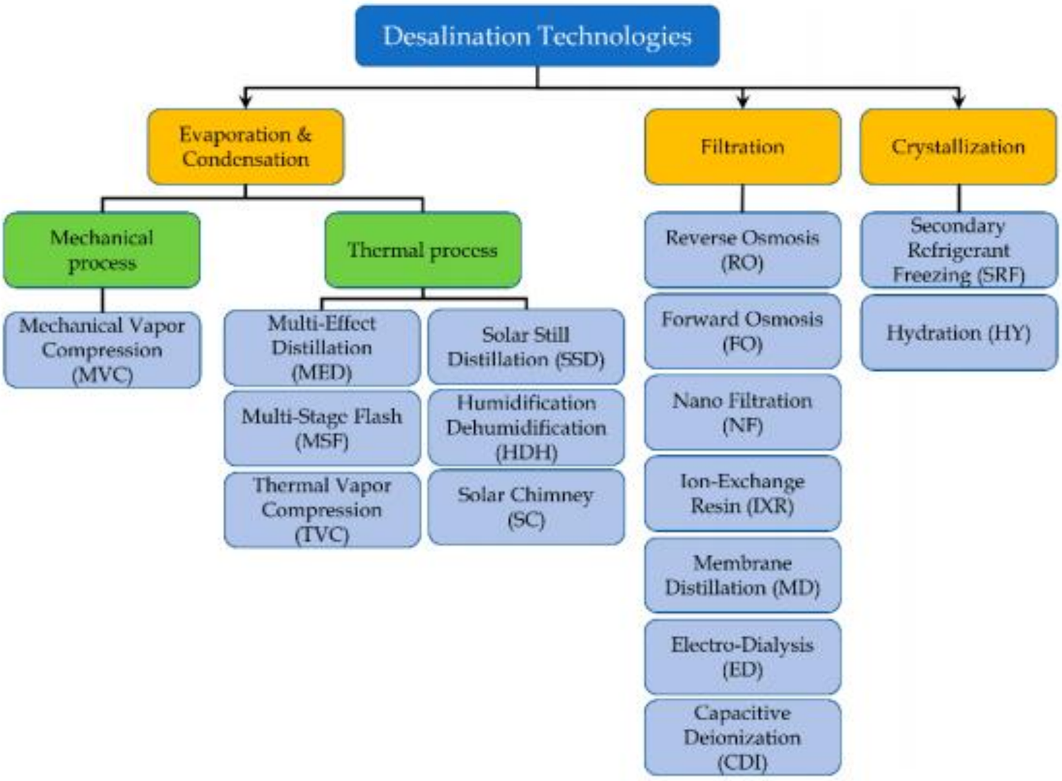

Figure 12 *The classification of desalination technologies by working principle.*

In Figure 12, desalination technologies are classified based on their working principle. In large scale seawater desalination, the conventional thermal evaporation processes like MED and MSF are more and more replaced by membrane processes like RO. Another classification of the technologies can be made based on the type of energy required for the desalination process (Figure 13).

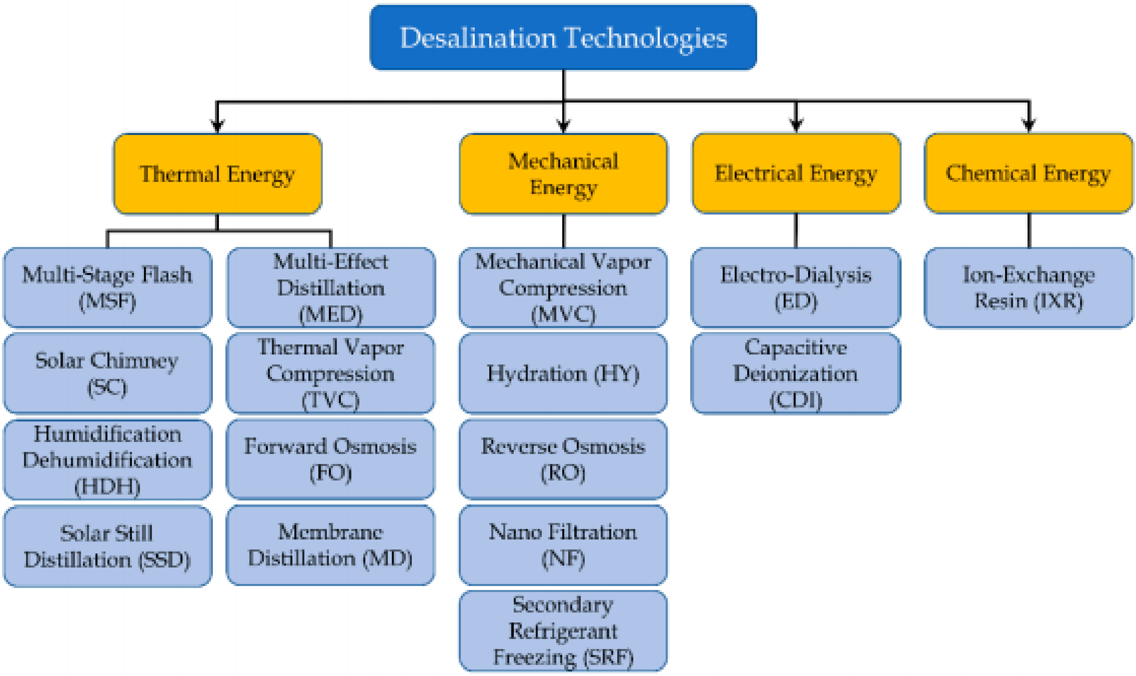

Figure 13 *Classification of type of energy required for desalination.*

The mechanical energy mentioned in Figure 13 is often generated by electrical energy (e.g. pressure for RO). So far, most of the energy required for the desalination process is generated from fossils. However there are options to use renewable energy sources as shown in Figure 14.

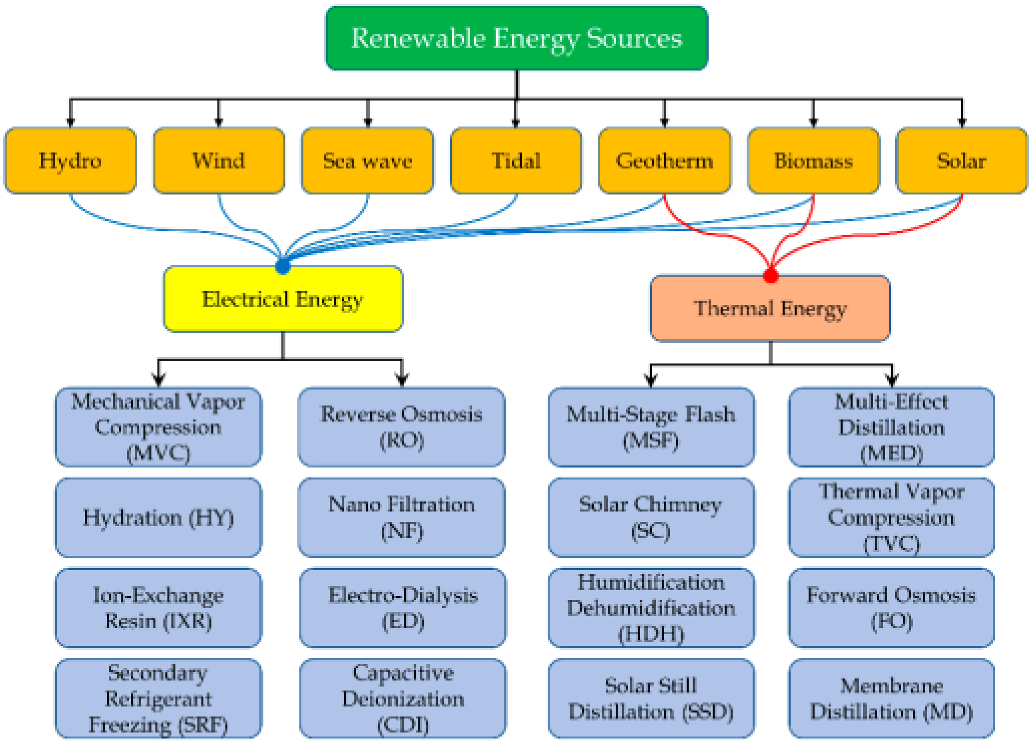

Figure 14 *Possible coupling between desalination technologies and renewable energy sources.*

An indication of the energy requirements for different desalination technologies is shown in Table 1. In Table 2, an indication of total costs of some desalination technologies is given. In Table 3, the advantages and disadvantages of the technologies are given.

Table 1 *Energy requirements for different desalination technologies [3].*

Desalination technology	Water type	Energy consumption (kWh/m^3)	Thermal energy (kWh/m^3)	Operation temperature (°C)
MSF	Seawater, Brackish water	2.5–3.5	12	90–110
MED	Seawater, Brackish water	1.5–2.5	6	70
TVC	Seawater, Brackish water	1.6–1.8	14.6	63–70
MD	Seawater, Brackish water	0.6–1.8	54–350	80
RO	Seawater, Brackish water	3.5–5	–	Ambient
ED	Brackish water	1.5–4	–	Ambient
NF	Brackish water	2.54–3.35	–	Ambient
MVC	Seawater, Brackish water	7–12	–	–

TVC, thermovapor compression; *MD*, membrane distillation; *NF*, nanofiltration; *MVC*, mechanical vapor compression.

Table 2 *Indication of the total costs of some desalination technologies [4].*

Process	Investment cost (\$/m^3)	Operation cost (\$/m^3)	Life time (years)	Water recovery (%)
Reverse osmosis	1,627–2,543	0.5–1.0	5–7	65–75
Electrodialysis	580–3307	1.01–2.85	7–10	80–90
Ion exchange resins	1,718–5,643	0.92–1.22	2	90
Electrochemical process	436–2487	0.76–2.14	8–10	90

Table 3 *Advantages and disadvantages of several desalination technologies.*

Technology	Advantages	Drawbacks	Status
MED	- High water quality - Low energy consumption	Scaling on the pipes	Commercial
MSF	- Maintenance operations to remove the scaling are simpler than in MED - High water quality - High rated capacity	- High energy demand - Huge investment - Corrosion problem - Slow start up - The entire plant is stopped for maintenance	Commercial
MVC	- High water quality - Low energy consumption	Low production capacity	Commercial
RO	- Only electrical demand - Low investments - Couplable with many renewable energy sources - Modular structure of plant	- Lower water quality - High costs for membranes and chemicals - Subject to biofouling	Commercial
FO	Low thermal energy	No drinking purpose (ammonia carbon dioxide) in industrial production	Special applicatio (hydration bags) In development
NF	Low energy demand	Produces soft water (a diluted saline solution)	In development at t dual-stage unit fo seawater
ED	- High purity of freshwater - Energy consumption proportional to salt concentration	- Only for brackish water (up to 2000 ppm) - Bacterial contaminants not removed by system	Commercial
CDI	Potentially more efficient than ED	Only for brackish water (up to 2000 ppm)	In development
HY	Potentially more efficient than commercial technologies	High costs	In development
SRF	Potentially more efficient than commercial technologies	Ice removal	In development
MD	- No applied pressure - Low operating temperature	- Fouling of membrane - Pretreatments are required	Commercial for fooc application
IXR	Electricity required only for pump water	Only for brackish water	Commercial for demineralized wate
SSD	- Run by solar radiation - Realizable with poor materials	Usable only for small applications	Commercial for smal application
SC	Run by solar radiation	Huge extensions are required	In development
HDH	- Low operating temperature - Simple operation	Optimization of thermodynamic cycle and flow rates Three circuits: air, water, freon	In development

Besides the physical chemical desalination technologies presented here, bio-desalination technologies are also under development [5]. Here, algae are used to lower the salt content of brackish water. The principle is shown in Figure 15.

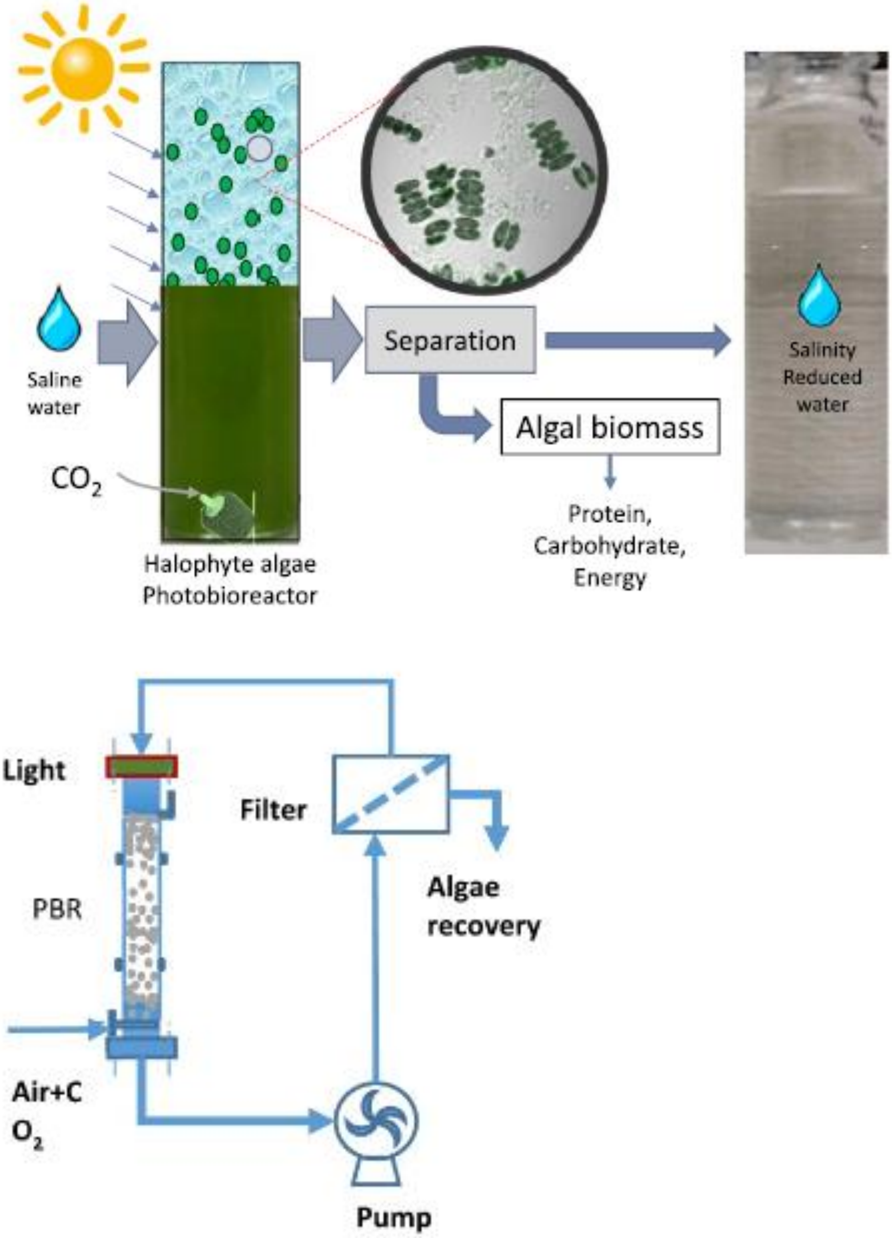

Figure 15 *Principle of desalination by algae.*

A salt reduction up to 70% was reported. The harvested algae may be used as a protein source, or an energy source for biofuel. One of the major challenges is the separation of the algae from the water. The principle of using algae for desalination is still at early stages.

Application of water desalination for irrigation in Vietnam

In Annex 1 some water consumption figures were given by individual farmers. Based on these figures, an individual farmer uses at least 100 m^3 of irrigation water daily. Looking at the costs of physical chemical desalination technologies (at least 0.5 €/m^3 for seawater and about half that costs for brackish water on a very large scale and increasing at a lower scale [6]), this means that desalination will cost at least 25 €/day and will be higher at a scale of 100 m^3/day (Table 4).

Table 4 *Production costs of BWRO (Brackish Water RO) systems with different production capacities.*

Production (m^3/day)	Typical costs ($/$m^3$)
< 20	5.6 – 12.9
20 - 1200	0.8 – 1.3
6,000 – 30,000	0.1 – 0.3
Large scale	0.2 – 0.4

About half of the cost is spent on the energy demand. Of course this varies depending on the energy costs of a specific country, but the energy costs in Vietnam are still ~ 0.07 €/ kWh. An energy requirement for mild desalination of brackish water is around 2 kWh. Looking at the options for renewable energy sources, solar energy seems the most appropriate source for Vietnam. Solar energy can be used just as a heat source or as an electricity source by converting the solar energy to electricity by PV panels. In general, the costs for water desalination are still higher than using fossil sources due to the relatively high investment costs for PV systems (including energy storage). Taking into account the above considerations, it seems that physical-chemical desalination technology is much too expensive for irrigation purposes (in Vietnam), certainly at a farm scale. Bio-desalination might be an attractive alternative, but this technology is still in a premature development phase, so more insight is needed to perform a technical economic evaluation of the technology.

Besides desalination of the surface water, the removal of other components such as pesticides, may be required from the viewpoint of food safety. Applying membrane technology (reverse osmosis) for removal of these components is a technological solution, but will probably not be economically feasible (costs comparable with the costs for desalination of brackish water, but removal combined with desalination in the membrane process). Alternative (natural) solutions are required for the removal. Well-known examples are constructed wetlands for the removal of organic components and heavy metals. The disadvantage of the constructed wetlands is the space required, which cannot be used for crop cultivation. An alternative method may be the application of natural wetlands instead of constructed wetlands, e,g, the application of paddy fields for water purification [7]. The research indicates that paddy fields can reduce pesticide concentration in the water, depending on the type of pesticides. However, additional research is needed to clarify the mechanism. Also, clarification on whether the removed pesticides accumulate in the edible parts of the rice still needs to be elucidated.

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6.3 Options for rainwater harvesting on farm scale in Vietnam Mekong Delta

Introduction

Due to increasing salination of surface water, especially in the dry season, the quality of the water becomes insufficient for both cattle and crops. There are different options to cope with this problem:

1. Transition to more salt resistant crops and cattle.
2. Desalination of water.
3. Application of other fresh water sources.
4. Combination of options 1-3.

In this section, the focus is on the application of other water sources, in particular the use of rainwater. Information was partly gathered in a separate project from EKN in Vietnam, led by the Dutch company WIC (Water Innovation Consulting, Albert Jansen) in cooperation with WFBR (Raymond Creusen), CTU in Vietnam (Dr. Dang Kieu Nhan, Dr. Nguyen Hieu Trung, Dr. Dinh Diep Anh Tuan, Dr. Nguyen Hong Tin) and the Vietnamese company Stepsvn (Dr. Hoang Hong).

Precipitation data

In order to investigate the possibility of rainwater harvesting, it was necessary to collect information regarding the local precipitation. Climate information was obtained from the website: https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/can-tho_vietnam_1586203. The Meteoblue climate diagrams were based on 30 years of hourly weather model simulations. The dry season runs from December 1 to the end of April. The average annual rainfall is 1,600 mm. Can Tho rainwater day to day data in 2018 (Annex 1) was supplied by Dr. Nguyen Hieu Trung (CTU, Research Institute for Climate Change). These data show a dry period of 3 months (95 days from February until April). This data will be used as input for a model to evaluate the scale of harvesting and required storage volumes.

Water demand

To get an idea about the amount of water needed during the dry season, an estimation of the water demand during the dry season (December-May) was performed. There is water demand for crops (depending on the type of crops), for livestock and for human consumption. Figures concerning water demand were collected from different farms in the Mekong Delta in extensive interviews performed by staff from CTU. The results of these interviews are given in Annex 2. From the figures, it is clear that the amount of water needed for crops does not match with the amount of rainwater stored for dry seasons. However rainwater storage might be applied for livestock and domestic use. The interviews also showed that some farmers were not willing to use rainwater because of its poor quality. The quality of the rainwater at the countryside in the Mekong delta is mainly impacted by contamination (metals, dirt, etc. [1]) from the roof, the method of the rainwater storage, and rainwater treatment before using it.

Based on the water quality regarding salinity for livestock, some figures are given in Table 5. The quantity of water needed for the dry season depends on the amount of livestock and people on a farm. A typical farm has a 75 m^2 roof with 4 people and 4 head of livestock. Their water demand for domestic use and livestock is typically 300 L/day. For sustenance without rainfall for a period of 150 days, 45 m^3 of rainwater should be stored.

Table 5 *Tolerances of livestock to total dissolved solids (salinity) in drinking water (mg/L).*

Stock	Desirable maximum concentration for healthy growth	Maximum concentration at which good condition might be expected*	Maximum concentration that may be safe for limited periods*
Sheep	5,000	5,000–10,000	10,000–13,000
Beef cattle	4,000	4,000–5,000	5,000–10,000
Dairy cattle	2,500	2,500–4,000	4,000–7,000
Horses	4,000	4,000–6,000	6,000–7,000
Pigs	4,000	4,000–6,000	6,000–8,000
Poultry	2,000	2,000–3,000	3,000–4,000

* The level depends on the type of feed.
Adapted from Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000.

Source: June 2014 Primefact 326 third edition, Agriculture NSW Water Unit, Australia.

Water supply
Electrical conductivity measurements in different water sources at different farms have been executed by CTU. The results are shown in Table 6 and Figure 16.

Table 6 *Electrical conductivity and pH measurements at different locations in the Mekong delta.*

No	Sites	Water samples	EC (mS)	PH
1	1	Canal	2.87	7.4
2	1	Canal	2.38	7.5
3	1	Deep well	0.09	7.3
4	1	Deep well	0.01	7.5
5	2	Canal	3.32	7.6
6	2	Deep well	0.02	7.7
7	3	Canal	2.56	7.7
8	3	Deep well	0.09	7.7
9	4	Canal	1.36	7.8

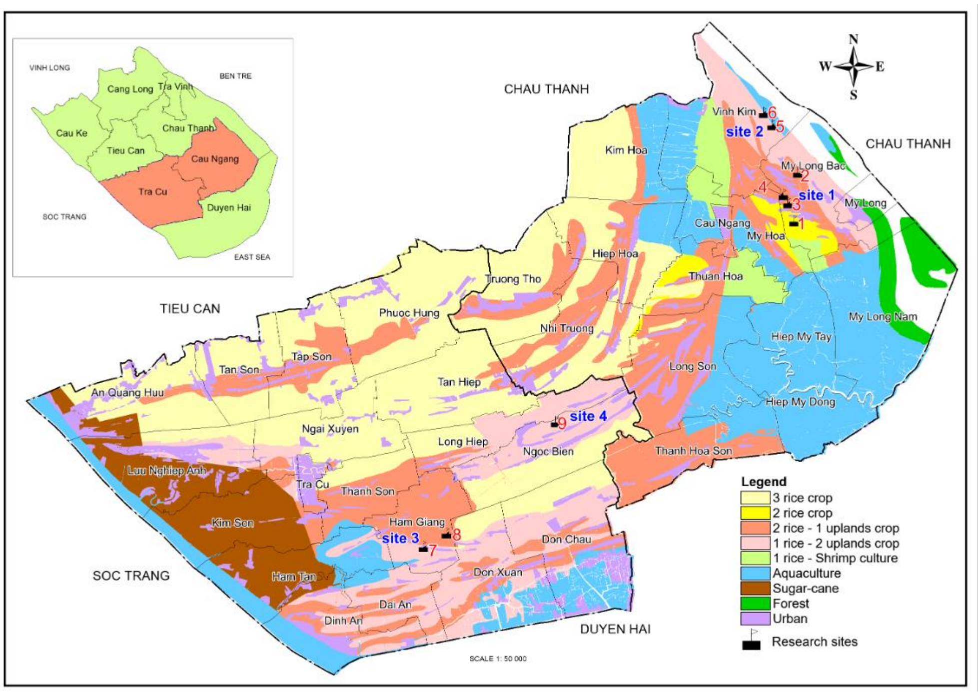

Figure 16 *Farming and aquaculture systems in two selected districts in Tra Vinh province, Mekong River Delta.*

Well water is often originating from a depth of 90 - 150 m. The lesser the depth of the well, the more the water becomes salty due to salt intrusion from the sea. Multiplying the conductivity in mS/cm will give the TDS in g/l. TDS in river water varies between 0.9 and 2.2 g/L, while the TDS concentration in well water is very low. The surveyed areas are closed with dykes and sluices from salt water estuaries at the end of the rainy- and during the dry- season, when freshwater is not available. Salt concentrations may also increase during the dry season due to evaporation of the stored water in the canals.

Figures concerning harvested rainwater and drinking water standards are given in Table 3 [1]. In general the conductivity of rainwater is below 0.1 mS/cm.

Beside the quality, the quantity of water that can be stored is also of importance. For rainwater harvesting, the quantity that can be stored is dependent on the roof area, the amount of precipitation and the storage capacity. The maximum amount of water that can be collected on a roof with a surface area of 75 m^2 at an annual rainfall of 1.5 m^3/m^2 per year is 112.5 m^3/year.

Correlation between water demand and water supply
For sustainability during the dry period for an average farmer, the amount of water needed for livestock and domestic use is 45 m^3. So the amount of water that is collected should be enough to fulfil this demand. For collection of water, 9 storage tanks of 5 m^3 are required.

The conductivity of the water is low enough for domestic and livestock application. A point of concern is the quality of the stored rainwater. Based on the data in Table 7, special attention has to be given to heavy metal content and microbiological quality for drinking water purposes. Heavy metal content will be largely determined by the type of roof from which the rainwater is collected. The microbiological quality will remain a concern, during storage of the water. Therefore it is important to clean the water as much as possible before storing rainwater.

Table 7 *Results of household harvested rainwater quality compared with WHO and Vietnamese drinking water guidelines.*

	N	Median	Range	WHO[a] guidelines	Vietnam[b] guidelines	% WHO exceeded	% Vietnam exceeded
Physical-chemical parameters							
Total Dis. Solids (mgl^{-1})	41	29.0	5.0–113	1 800[d]	1000	0	0
pH (–)	36	7.1	4.3–8.2	6.5-8.5[d]	6.5-8.5	19	19
Turbidity (FTU)	53	2	0–10.1	5[d]	2	17	71
COD (mgl^{-1})	53	3.0	0.1–23.2	–	–	–	–
Nutrients							
Ammonium (mgl^{-1})	31	0.040	0.007–0.403	EU[c] 0.5	3	0	0
Nitrate (mgl^{-1})	53	0.7	0.1–3.9	50	50	0	0
Nitrite (mgl^{-1})	53	0.005	0.004–0.091	3 (0.2)	3	0	0
O-Phosphate (mgl^{-1})	33	0.05	0.03–0.28	–	–	–	–
Metal(loid)s							
Arsenic (μgl^{-1})	78	<2.0	<2.0–2.0	10	10	0	0
Barium (μgl^{-1})	78	2.2	0.2–70.1	700	700	0	0
Cadmium (μgl^{-1})	78	0.2	<0.1–1.3	3	3	0	0
Chromium (μgl^{-1})	78	0.5	<0.4–2.4	50	50	0	0
Copper (μgl^{-1})	78	0.9	<0.3–8.1	2000	1000	0	0
Iron (μgl^{-1})	78	13.2	2.3–84.6	300[d]	300	0	0
Mercury (μgl^{-1})	78	<1.2	<1.2–1.7	6	1	0	1
Magnesium (μgl^{-1})	78	148.0	28.0–6294.9	–	–	–	–
Manganese (μgl^{-1})	78	2.0	0.1–85.3	400	300	0	0
Sodium (μgl^{-1})	78	124.6	2.5–2693.9	200 000	200 000	0	0
Nickel (μgl^{-1})	78	0.4	<0.4–28.6	70	20	0	1
Lead (μgl^{-1})	78	5.0	<1.0–16.9	10	10	17	17
Zinc (μgl^{-1})	78	83.8	0.1–2208	3 000[d]	3000	0	0
Microbial indicators							
E. coli (CFU 100 ml^{-1})	78	0	0–4650	0	0	35	35
Total coliforms (CFU 100 ml^{-1})	78	1600	0–102 500	0	0	92	92

< Detection limit of water quality parameter.
[a] Drinking water guidelines WHO (WHO, 2011).
[b] Vietnamese drinking water quality standards (Ministry of Health, 2009).
[c] European Union quality guidelines for water intended for human consumption (EU, 1998).
[d] Secondary WHO drinking water quality guidelines.

Some figures for dairy cattle are shown in Tables 8 and 9 [2].

__Table 8__ Guideline for use of saline water for dairy cattle.

Total dissolved solids	Comments
(ppm)	
Less than 1,000	Presents no serious burden to livestock
1,000 to 2,999	Should not affect health or performance, but may cause temporary mild diarrhea
3,000 to 4,999	Generally satisfactory, but may cause diarrhea, especially upon initial consumption
5,000 to 6,999	Can be used with reasonable safety for adult ruminants; should be avoided for pregnant animals and baby calves
7,000 to 10,000	Should be avoided if possible; pregnant, lactating, stressed or young animals can be affected negatively
More than 10,000	Unsafe; should not be used under any conditions

ppm = parts per million

__Table 9__ Generally considered safe concentrations of some potentially toxic nutrients and contaminants in water for cattle.

Item	Upper-limit guidelines
	(ppm)
Aluminum	0.50
Arsenic	0.05
Barium	10.0
Boron	5.0
Cadmium	0.005
Chromium	0.010
Cobalt	1.0
Copper	1.0
Fluoride	2.0
Iron	2.0
Lead	0.015
Manganese	0.05
Mercury	0.01
Nickel	0.25
Selenium	0.05
Vanadium	0.10
Zinc	5.0

ppm = parts per million

When the figures in Table 9 are compared with the figures in Table 7, it is obvious that there is a risk of exceeding the upper limits for heavy metal content in rainwater. This can be largely avoided by selection of roofing materials that facilitate cleaner rainwater collection.

Water treatment

To prevent (microbial) contamination in the stored rainwater, measures have to be taken to remove e.g. bacteria and viruses from the water, before storage. An example of a treatment facility is shown in Figure 15. The water treatment is in twofold: 1) a separation method to remove particles, leaves, dirt etc. and 2) a molecular separation with a biofilter to remove ammonia (nutrient), and ultra-filtration (UF) membrane technology to remove bacteria and viruses and store it for use during dry periods. The whole system works based on gravity.

Economics

For economics, different types of water sources have to be taken into account:

1. Piped water: quality of piped water is not always sufficient for domestic use due to insufficient treatment or bad maintenance of the piping system [3]. Besides the quality, poor farmers are not able to pay for the piped water (current price about € 0,0002/l (VD5,5/l) and connection costs (ca. € 50).
2. Surface water: This is usually canal water or water stored in ditches. In general, too poor quality for domestic and livestock use.
3. Well water: the quality is in general good at a depth of 90-150 m. Due to well water extraction for industrial and irrigation purposes, the quality will deteriorate (salt intrusion).
4. Bottled water: this is expensive (€ 0.05/l).
5. Rainwater: It is in principle cheap if you only have to collect and store it (Figure 17). However to secure the quality of the water treatment before storage is recommended. A preliminary estimation of the rain water costs using a system described above shows that the operational costs will be around € 0.003/l, but the investment costs for installation for an average farmer will be around € 9000. This investment is at this moment for most Vietnamese farmers too high. Investment costs can be reduced per m^3 of water if there is e.g. a cooperative collection of water on buildings with a large roof area, e.g. schools, touristic lodges, etc.

Figure 17 *'Water from Heaven' concept for storage of rainwater.*

Policy

The Vietnamese government promotes developing medium-scaled water-supply stations (1000 – 2000 m^3/ day) and reducing small/individual-scale wells. Because the price of the piped water is 10 times lower than treated rainwater, it will compete with rainwater harvesting. Disadvantage of the current piped water systems is the quality of the water. Due to insufficient treatment (especially salt content) and poor maintenance of the system (microbial infestation), the quality of the water is poor and not appropriate for human consumption. The main concern of groundwater extraction is its continuous use for agricultural (irrigation of crops) and industrial purposes resulting in a limitation in the near future.

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6.4 Hazardous contaminants in water

Summary

Salinization and e.g., climate change also result in transitions in the types of water that are applied in agriculture production systems. For the Vietnamese Mekong River Delta, salinity is a major issue as mentioned above (see 6.1) especially the transition from surface water (e.g., river water, water from estuary) to fresh groundwater is currently occurring, although this is only a temporary solution. Another proposed water management option is to increase the possibilities to store fresh water (e.g., rainwater) as a buffer for dry(er) periods.

The quality of water is linked to food safety, not only when used as drinking water but also for food production purposes. Hazards that can be present in water can end up in the food chain when the water is used, and thus result in (human) dietary exposure via multiple routes. For example, via 1) outside contact with crops; 2) uptake via roots and leaves of the crops; and 3) consumption of animal food products such as meat, milk and eggs with prior exposure to contaminants. Multiple hazards can be present in water, including both chemical hazards and microbiological hazards that are the most relevant ones for human health. The type and quantity of the hazards differ between and within types of water originating from various sources, and both the characteristics of the hazard itself as well as the quantity (and thus amount of exposure) determine the possible effect on human or animal health [1]. For example, river water can potentially be polluted with several types of chemicals originating from industry (e.g., heavy metals, industrial chemicals), agricultural processes (e.g., (veterinary) drugs, plant protection products, fertilisers) and human and household waste (e.g., pharmaceuticals, disinfectants) etc; and with microbiological hazards originating from human and animal waste (e.g., *Salmonella spp.*, *Escherichia coli* etc). Fresh groundwater (being the aforementioned substitute of surface water) on the other hand seems to have potentially less but not zero potential chemical and microbiological hazards. For example, naturally occurring elements could be present in high levels (e.g., lead, arsenic) and groundwater can potentially be polluted as well both with chemical and microbiological contaminants due to e.g., leakage from the surface environment. The probability and number of chemical and microbiological hazards that are potentially present in freshwater (e.g., rainwater) seems to be limited, but when stored for usage at a later time period, contamination can occur. Not only via leakage or contact with storage materials (e.g., lead, asbestos) but also when a microbiological contamination occurs, this can potentially result in the formation of high quantities of microbiological contaminants when growth occurs.

To gain insight into the actual presence and quantity of chemical and microbiological hazards in different water sources, (analytical) measurement of collected water samples should be performed. How the water is to be used, e.g., under what hygienic circumstances, can impact the exposure of possible chemical and microbiological hazards as well. To evaluate the impact of food system transitions on, for example water usage, and the belonging impact and effect on food safety, it is relevant to consider both concerns for human

and animal health. The development of a food safety framework focusing on these aforementioned transitions can be helpful for farmers to gain insight into their impact on food safety.

References

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Annex 1 Background information for options for rainwater harvesting on farm scale in Vietnam Mekong Delta

1) Precipitation data 2018 for Can Tho.

Tên trạm Cần Thơ

Năm 2018

mm

	Tháng 1	Tháng 2	Tháng 3	Tháng 4	Tháng 5	Tháng 6	Tháng 7	Tháng 8	Tháng 9	Tháng 10	Tháng 11	Tháng 12
1									0	19.6		
2						20.1	0	1.2	0	0.8		
3					0.9	0.1		3.2	2.9	0		
4					5	0.1	24.4	6.1	0.7	67.2		
5	0.1				0.8	20.6	14.5	1	7.3	3.6	19.6	
6					0.2	3.8	7.8	17.4	14	3.5	29.2	
7					0.8	10.6	32.8	0.9			0	
8	0			6.7	5.9	0.5	0	9.7	0	3.3	0	0
9					2.9	10.6	0	35.3	0.4			
10	1.1				36.8	2.1	6.8	31				
11	16					3.2	5.6	1.7	2.3			0
12	0					1.5	10	9.8	0		1.3	
13						0	2.2	6.2	5.6	54.2	11.8	0
14						0	6.1	16.5	2.1			
15	0		2.9		9	0	3.1	1.5	0.9			0
16					0	0	0.8		4.9		3.9	
17					0.5	11.3	31.6	0	23.6	1.7	46.6	
18	0	3.4				45.9	20.2	4	8	0.9	8	
19	21.3				39	6.9	14.6	1.1	0	26.9	3.5	1.2
20					23.8	2.2	4.4		22.2	10.8		
21					3.6		5.8	0	0	34		
22	0		40.2		16.6	0	0.2	1.3	11.2	5.2		
23			0.6		0.4		0.1	8.3	2.3			7.8
24	0.2				27.4					22.3	0	9.5
25					0		6.5	0.2	0		4.1	0.6
26	0				3	7	2.4	2.2		0.1	1.1	24.5
27	0				13.4	12.5	4	6.1				0
28	58.6				19.9		0.2			0.1	0	64.5
29	0.1				45.9		0		19.3	0.1		1.9
30				2.8			6.8		1.7	0.1		2
31	4.5									0		

2) Result of interviews with Vietnamese farmers in the Mekong Delta.

No	Interviewers	Date	Hamlet	Commune	District	Province	1st Crop	2nd Crop	Farming area (m2)	Livestock	animal heads	Total water uses (m3/day)	For crop irrigation (m3/day)	Livestock drinking (m3/day)	Domestic uses (m3/day)	Minimal water volume need in the dry season (m3/day)	Dry period (days)
1	Ho Chi Thinh	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	rice	groundnut	1500	cattle	2	120	120	0.04	0.15	100	90
2	Ho Chi Thinh	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	chili	corn	1500	cattle	2	130	128	0.05	0.2	110	120
3	Dang Kieu Nhar	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	rice	?	3000	cattle	3	240	235	0.06	0.15	150	100
4	Ho Chi Thinh	19-12-2020	Giong Lon	Vinh Kim	Cau Ngang	Tra Vinh	rice	water melon	2000	cattle	4	200	150	0.08	0.16	180	90
5	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	pumpkin	corn	5000	duck	20	145	140	0.02	0.5	100	120
6	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	corn	pumpkin	3000	cattle	4	210	200	0.08	0.4	200	120
7	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	pumpkin		1000	cattle	2	150	145	0.04	0.4	100	120
8	Dang Kieu Nhar	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	rice	pumpkin	2000	cattle	5	180	170	0.1	0.5	120	120
9	Ho Chi Thinh	21-12-2020	Rach Bot	Ngoc Bien	Tra Cu	Tra Vinh	rice	pumpkin	5000	cattle	3	250	240	0.05	0.02	200	120
10	Dang Kieu Nhar	22-12-2020	Rach Bot	Ngoc Bien	Tra Cu	Tra Vinh	rice	groundnut	15000	cattle	13	420	400	0.3	0.08	300	120
11	Ho Chi Thinh	15-1-2021	Ninh Hoa	An Tuc	Tri Ton	An Giang	rice		10000	cattle	6	56		0.6	50	45	180
12	Ho Chi Thinh	15-1-2021	Ninh Hoa	An Tuc	Tri Ton	An Giang	rice		5000	cattle	4	40		0.02	39	35	180
13	Ho Chi Thinh	15-1-2021	To Ha	Nui To	Tri Ton	An Giang	rice		7000	cattle	8	60		0.08	55	50	190
14	Ho Chi Thinh	15-1-2021	To Ha	Nui To	tri Ton	An Giang	rice		4000	cattle	5	40		0.06	38	35	180

No	Interviewers	Date	Hamlet	Commune	District	Province	Have captured rain water?	If yes, for what uses?	water containers	storage capacity (m3)	If no, why ?	House roof area (m2)	Roof materials
1	Ho Chi Thinh	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	no				not clean	60	cement fibro
2	Ho Chi Thinh	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	no				not clean	75	cement fibro
3	Dang Kieu Nhar	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	no				not clean	60	metallic
4	Ho Chi Thinh	19-12-2020	Giong Lon	Vinh Kim	Cau Ngang	Tra Vinh	no				not clean	80	cement fibro
5	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	no				not clean	120	cement fibro
6	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	no				not clean	100	cement fibro
7	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	no				not clean	85	nipa leaves
8	Dang Kieu Nhar	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	no				not clean	120	cement fibro
9	Ho Chi Thinh	21-12-2020	Rach Bot	Ngoc Bien	Tra Cu	Tra Vinh	no				not clean	72	nipa leaves
10	Dang Kieu Nhar	22-12-2020	Rach Bot	Ngoc Bien	Tra Cu	Tra Vinh	yes	domestic	jar	0.2		100	cement fibro
11	Ho Chi Thinh	15-1-2021	Ninh Hoa	An Tuc	Tri Ton	An Giang	yes	domestic/livestock	metalic tank	1.5		144	cement fibro
12	Ho Chi Thinh	15-1-2021	Ninh Hoa	An Tuc	Tri Ton	An Giang	yes	domestic/livestock	metalic tank	1.5		120	nipa leaves
13	Ho Chi Thinh	15-1-2021	To Ha	Nui To	Tri Ton	An Giang	yes	domestic/livestock	metalic tank	2		100	metallic
14	Ho Chi Thinh	15-1-2021	To Ha	Nui To	tri Ton	An Giang	yes	4	metalic tank	2		90	nipa leaves

No	Interviewers	Date	Hamlet	Commune	District	Province	Canal water EC (mS)	Canal water pH	Well water EC (mS)
1	Ho Chi Thinh	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	2.9	7.4	0.09
2	Ho Chi Thinh	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	2.4	7.5	0.01
3	Dang Kieu Nhar	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	2.9	7.4	0.01
4	Ho Chi Thinh	19-12-2020	Giong Lon	Vinh Kim	Cau Ngang	Tra Vinh	2.7	7.2	0.01
5	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	2.6	7.7	0.09
6	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	2.6	7.4	0.01
7	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	2.6	7.7	0.09
8	Dang Kieu Nhar	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	2.6	7.7	0.09
9	Ho Chi Thinh	21-12-2020	Rach Bot	Ngoc Bien	Tra Cu	Tra Vinh	2.6	7.7	0.09
10	Dang Kieu Nhar	22-12-2020	Rach Bot	Ngoc Bien	Tra Cu	Tra Vinh	1.4	7.8	0.07
11	Ho Chi Thinh	15-1-2021	Ninh Hoa	An Tuc	Tri Ton	An Giang			
12	Ho Chi Thinh	15-1-2021	Ninh Hoa	An Tuc	Tri Ton	An Giang			
13	Ho Chi Thinh	15-1-2021	To Ha	Nui To	Tri Ton	An Giang			
14	Ho Chi Thinh	15-1-2021	To Ha	Nui To	tri Ton	An Giang			

Annex 2 Background Information to Desalination of (Surface) Water for Irrigation in the Vietnam Mekong Delta

Result of interviews with Vietnamese farmers in Mekong Delta.

No	Interviewers	Date	Hamlet	Commune	District	Province	1st Crop	2nd Crop	Farming area (m2)	Livestock	animal heads	Total water uses (m3/day)	For crop irrigation (m3/day)	Livestock drinking (m3/day)	Domestic uses (m3/day)	Minimal water volume need in the dry season (m3/day)	Dry period (days)
1	Ho Chi Thinh	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	rice	groundnut	1500	cattle	2	120	120	0.04	0.15	100	90
2	Ho Chi Thinh	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	chili	corn	1500	cattle	2	130	128	0.05	0.2	110	120
3	Dang Kieu Nhan	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	rice	?	3000	cattle	3	240	235	0.06	0.15	150	100
4	Ho Chi Thinh	19-12-2020	Giong Lon	Vinh Kim	Cau Ngang	Tra Vinh	rice	water melon	2000	cattle	4	200	150	0.08	0.16	180	90
5	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	pumpkin	corn	5000	duck	20	145	140	0.02	0.5	100	120
6	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	corn	pumpkin	3000	cattle	4	210	200	0.08	0.4	200	120
7	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	pumpkin		1000	cattle	2	150	145	0.04	0.4	100	120
8	Dang Kieu Nhan	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	rice	pumpkin	2000	cattle	5	180	170	0.1	0.5	120	120
9	Ho Chi Thinh	21-12-2020	Rach Bot	Ngoc Bien	Tra Cu	Tra Vinh	rice	pumpkin	5000	cattle	3	250	240	0.05	0.02	200	120
10	Dang Kieu Nhan	22-12-2020	Rach Bot	Ngoc Bien	Tra Cu	Tra Vinh	rice	groundnut	15000	cattle	13	420	400	0.3	0.08	300	120
11	Ho Chi Thinh	15-1-2021	Ninh Hoa	An Tuc	Tri Ton	An Giang	rice		10000	cattle	6	56		0.6	50	45	180
12	Ho Chi Thinh	15-1-2021	Ninh Hoa	An Tuc	Tri Ton	An Giang	rice		5000	cattle	4	40		0.02	39	35	180
13	Ho Chi Thinh	15-1-2021	To Ha	Nui To	Tri Ton	An Giang	rice		7000	cattle	8	60		0.08	55	50	190
14	Ho Chi Thinh	15-1-2021	To Ha	Nui To	tri Ton	An Giang	rice		4000	cattle	5	40		0.06	38	35	180

No	Interviewers	Date	Hamlet	Commune	District	Province	Canal water EC (mS)	Canal water pH	Well water EC (mS)
1	Ho Chi Thinh	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	2.9	7.4	0.09
2	Ho Chi Thinh	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	2.4	7.5	0.01
3	Dang Kieu Nhar	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	2.9	7.4	0.01
4	Ho Chi Thinh	19-12-2020	Giong Lon	Vinh Kim	Cau Ngang	Tra Vinh	2.7	7.2	0.01
5	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	2.6	7.7	0.09
6	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	2.6	7.4	0.01
7	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	2.6	7.7	0.09
8	Dang Kieu Nhar	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	2.6	7.7	0.09
9	Ho Chi Thinh	21-12-2020	Rach Bot	Ngoc Bien	Tra Cu	Tra Vinh	2.6	7.7	0.09
10	Dang Kieu Nhar	22-12-2020	Rach Bot	Ngoc Bien	Tra Cu	Tra Vinh	1.4	7.8	0.07
11	Ho Chi Thinh	15-1-2021	Ninh Hoa	An Tuc	Tri Ton	An Giang			
12	Ho Chi Thinh	15-1-2021	Ninh Hoa	An Tuc	Tri Ton	An Giang			
13	Ho Chi Thinh	15-1-2021	To Ha	Nui To	Tri Ton	An Giang			
14	Ho Chi Thinh	15-1-2021	To Ha	Nui To	tri Ton	An Giang			

No	Interviewers	Date	Hamlet	Commune	District	Province	Have captured rain water?	If yes, for what uses?	water containers	storage capacity (m3)	If no, why ?	House roof area (m2)	Roof materials
1	Ho Chi Thinh	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	no				not clean	60	cement fibro
2	Ho Chi Thinh	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	no				not clean	75	cement fibro
3	Dang Kieu Nhar	19-12-2020	My Thap	My Long Bac	Cau Ngang	Tra Vinh	no				not clean	60	metallic
4	Ho Chi Thinh	19-12-2020	Giong Lon	Vinh Kim	Cau Ngang	Tra Vinh	no				not clean	80	cement fibro
5	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	no				not clean	120	cement fibro
6	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	no				not clean	100	cement fibro
7	Ho Chi Thinh	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	no				not clean	85	nipa leaves
8	Dang Kieu Nhar	20-12-2020	Nhue Tu B	Ham Giang	Tra Cu	Tra Vinh	no				not clean	120	cement fibro
9	Ho Chi Thinh	21-12-2020	Rach Bot	Ngoc Bien	Tra Cu	Tra Vinh	no				not clean	72	nipa leaves
10	Dang Kieu Nhar	22-12-2020	Rach Bot	Ngoc Bien	Tra Cu	Tra Vinh	yes	domestic	jar	0.2		100	cement fibro
11	Ho Chi Thinh	15-1-2021	Ninh Hoa	An Tuc	Tri Ton	An Giang	yes	domestic/livestock	metalic tank	1.5		144	cement fibro
12	Ho Chi Thinh	15-1-2021	Ninh Hoa	An Tuc	Tri Ton	An Giang	yes	domestic/livestock	metalic tank	1.5		120	nipa leaves
13	Ho Chi Thinh	15-1-2021	To Ha	Nui To	Tri Ton	An Giang	yes	domestic/livestock	metalic tank	2		100	metallic
14	Ho Chi Thinh	15-1-2021	To Ha	Nui To	tri Ton	An Giang	yes	4	metalic tank	2		90	nipa leaves

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