Adapting crop production to increasing salinity in the Vietnamese Mekong Delta: Thoughts on stakeholders and roles in a potential transition process

Ayodeji O. Deolu-Ajayi and Bich Thi Ngoc Tran

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Ayodeji O. Deolu-Ajayi[1] and Bich Thi Ngoc Tran[2]

1. Agrosystems Research, Wageningen Plant Research, Wageningen University & Research, P. O. Box 16, 6700 AA Wageningen, The Netherlands
2. Institute of Environmental Science and Technology, Tra Vinh University, Vietnam

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Summary

Increasing saltwater intrusion devastates the Vietnamese Mekong Delta (VMD). Salinisation events are further exacerbated by climate change resulting in crop yield reduction and thereby, high socio-economic losses annually. The Vietnamese government has developed a master plan that supports saline agriculture in the VMD thereby facilitating improved crop production under salinized conditions. Cultivation of salt tolerant cultivars, water management and application of soil amendments are some saline agriculture strategies already used in the VMD. These strategies altogether focus on improving the soil-water-crop continuum to boost crop productivity under salty environments in the VMD.

Stakeholders play diverse, important roles in implementation and mass adoption of saline agriculture strategies. The national, regional and local government promote policies that serve as the bedrock for sustainable productivity in saline-prone areas. Academic institutions and development partners cooperate to advance knowledge and create toolbox (models, frameworks, methodologies etc) that support implementation of saline agriculture. The private sector (consisting of buyers, sellers and non-governmental organisations) as well as, farmers complete the cycle of stakeholder cooperation that is needed to facilitate upscaling of saline agriculture from just a few farms to a whole community or province.

In the context of transitioning to saline agriculture in the VMD, care should be taken to circumvent several arising challenges that may occur. The socio-economic costs and potential environmental risks associated with implementation of saline adaptation strategies should be thoroughly considered. National policies supporting saline agriculture remain somewhat unclear thus, mass sensitisation is needed for stakeholders working at different scales to fully understand and embrace these strategies. Furthermore, research on salinisation should lead to development of user-friendly, practical tools and should be complemented with capacity building of farmers. Market development and linkage should be made so that products from saline agriculture can be easily sold and purchased at the local, regional or national level, and exported to international global markets. Lastly, stakeholder coordination should be prioritised to support a systems approach where connections between the whole production value chain is made. Overall supporting upscaling saline agriculture in the VMD.

Keywords: Adaptation strategies, Saline agriculture, Stakeholders, Transition, Vietnamese Mekong Delta.

1 Background

The Vietnamese Mekong Delta (VMD) is the third largest delta and home to nearly 18 million people. The main source of livelihood in the VMD is agriculture and aquaculture. Rising sea levels, declining groundwater, drought, saltwater intrusion, and pest and disease infestation threaten agriculture and aquaculture in the VMD, and is further exacerbated by climate change (Eslami et al., 2021). In recent years, the VMD has experienced the most severe drought and salinisation events recorded in the past 100 years. These events occurred in 2015/ 2016 and even more devastatingly, in 2019/ 2020. Rice the most important crop cultivated in the VMD, is sensitive to both biotic and abiotic stresses. Saltwater intrusion occurred in 10 out of 13 provinces of the VMD during the 2019/ 2020 cropping season, affecting 58,000 hectares of rice, 6,650 hectares of fruit trees, 1,241 hectares of vegetables and 8,715 hectares of aquaculture (MARD, 2020).

The Mekong Delta is inherently affected by drought, heat and saltwater intrusion, necessitating a greater emphasis on forecasting to improve agriculture and aquaculture under these conditions. Furthermore, it is essential to modify current crop and livestock systems to become more climate resilient while also, developing solutions and constructing facilities that support restructuring of the current food system. The Vietnamese government declared a state of emergency and called for international support for sustainable agriculture in the Mekong Delta. To develop sustainable agriculture in the region, long-term adaptation measures like introduction of crops tolerant to drought, heat and salinity are critical. Thus, the government of Vietnam developed a 2021-2030 master plan for the VMD with a 2050 vision.

The master plan developed by the Vietnamese government outlines a strategy for sustainable development of the VMD in response to climate change by categorising the region into three distinct zones. The first zone, known as the core freshwater zone, is situated upstream of River Mekong and consistently maintains freshwater supply even under extreme climatic conditions. This area has been prioritised for rice and fruit cultivation, and freshwater aquaculture. The second zone is characterised by brackish or slightly saline water, experiencing seasonal variations of salt concentrations in the water. Here, rice can be cultivated during the rainy season when freshwater is accessible. However, it is essential for local agricultural practices to adapt to brackish and saline water conditions during the dry season, transforming these challenges into opportunities for saline agriculture. The third and final zone encompasses coastal areas that are subject to year-round saltwater intrusion, necessitating the development of farming systems that can effectively adapt to saline conditions.

There are several strategies to support saline agriculture. Use of tolerant crop species and varieties, adapting crop cultivation systems, use of organic or inorganic amendments, propagating halophytes, water management techniques, and remediation of salinized areas with plants or microbes are different saline agriculture strategies (van den Burg et al., 2024).

In 2022/ 2023, a study was conducted in Tra Vinh province, Vietnam to establish the effect of slightly saline or brackish water irrigation on crop growth and productivity as well as, on salt accumulation in soil. Impact of brackish water irrigation was evaluated in three crops cultivated under semi-controlled greenhouse conditions. Results from the plant experiments indicated that beetroot is more tolerant to saline conditions than maize and peanut, and may serve as an alternative crop for rice, especially during dry seasons when freshwater is limited in the VMD (Tran et al., 2025). Additionally, irrigation with water containing low salt (NaCl) levels does not negatively impact crop yield and even improved beetroot bulb quality in a single growing season. Based on these results, irrigation with brackish water containing not more than 1.5 parts per thousand of NaCl may be a salinity adaptation option for VMD farmers. As a follow-up of the crop studies, we aim to discuss what, who and how saline adaptation strategies can be adopted and implemented by farmers in the VMD. Therefore, three research questions, which are explored in the following three chapters, are defined.

1. What is the state of the art on adaptation strategies related to salinity in the VMD?
2. Who are the stakeholders required in the scaling up process, and what are their roles?
3. What is the outlook for saline agriculture in the VMD

2 Alternative approaches to support saline agriculture

Cultivated land is shrinking, soil quality is declining, and crop productivity is decreasing due to increased drought and salinity in the VMD. Pest and disease events have also increased, negatively affecting both crop and livestock production. Projections indicate that about 10% of the current area used for rice cultivation in the dry season may be completely lost by 2050 due to saltwater intrusion. Rising sea levels pose an even greater threat to arable land used for rice production in the VMD and between 22% to 58% of that area is estimated to be lost due to persistent flooding. In addition, rising temperatures, persistent drought and increased salinity are forecast to reduce rice yield in the remaining non-flooded areas by 35% to 45% (Toan et al. 2024). The Institute of Water Resources reported that overall agricultural losses due to saltwater intrusion in the last decade are estimated at 70.2 trillion VND (2.8 billion USD). These economic costs are linked to yield losses from rice, fruit tree and flower production as well as, from aquaculture (VN Express, 2024). With increasing salinity intrusion, total economic losses are expected to rise to 72.4 trillion VND (2.9 billion USD), 73.3 trillion VND (3 billion USD), and 76.5 trillion (3.1 billion USD) by 2030, 2040 and 2050 respectively (VN Express, 2024).

Saline agriculture is a group of farming practices that integrate solutions of the crop-soil-water nexus to support production in salinized areas. There are several other approaches apart from irrigation with saline and brackish water, that support saline agriculture. Some of these approaches discussed below, and applicable for the VMD are use of tolerant cultivars, water retention and desalinisation techniques, and use of amendments and biostimulants[1].

2.1 Use of salt tolerant cultivars and related management practises

Most of our food crops are glycophytes and are therefore sensitive to increasing salinisation, with yields severely affected under high salinity (Zörb et al., 2019). Crops show varying sensitivity to salt stress (Maas et al., 1977). Additionally, within a plant species, there may exist tolerant cultivars. Rice, an important crop for the VMD is salt sensitive (Lien and Duy, 2023). Coconut, soybean, sugarcane, soursop and sunflower are salt tolerant crops that have high value cultivation potential in the VMD (Blom-Zandstra et al., 2017; Verhagen et al., 2017). Interestingly, several of

[1] See also our video: https://www.youtube.com/watch?v=d_uzvK7Jy0g&t=154s

these crops that are salt tolerant are additionally resilient to other abiotic stresses such as heat, drought and soil acidity, that may occur simultaneously with salinity intrusion in the VMD (Verhagen et al., 2017). Beetroot, quinoa, and specific cultivars of tomato and spinach can grow under saline conditions and even showed improved crop quality (Atzori, 2022; Roman et al., 2020; Tahjib-Ui-Arif et al., 2019). Most cultivars with a tolerance phenotype usually trade-off with lower crop yield, compared to other high-yielding but salt sensitive cultivars (Sanwal et al., 2022). Molecular breeding via new plant breeding tools, may proffer solutions to simultaneously enhance beneficial traits of tolerance and high yield for crops cultivated in salinized areas (Linh et al., 2012; Wanga et al., 2021). Cultivating alternative salt tolerant crops, combined with management practises such as mulching and covering with plastics, may provide farmers with new income opportunities to offset rice losses (Kaveney et al., 2023).

Salt tolerant species and cultivars can serve as alternatives for rice cultivation in dry highly saline seasons when rice yields are severely affected. Adjusting cropping calendar for early rice cultivation improved crop production and farmer income in the VMD (Deb et al., 2016; Ferrer et al., 2022). Farmers in the VMD typically grow rice three times in a year to maximise productivity. Reducing the number of rice crop cycle annually is an adaptation measure to increasing salinity and drought (Kim Dang et al., 2021). Therefore, adjusting cropping calendars to include use of tolerant crops may further boost farmer income. Overall, cultivating salt tolerant species and cultivars are a practical alternative for many developing countries to cope with increasing salinisation. Other salt tolerant plants known as halophytes have capacity to grow using land and water resources unsuitable for conventional crops (Ladeiro, 2012). Halophytes have potential as a source of food, timber, landscape and soil recovery (Custódio et al., 2021; García-Caparrós et al., 2020; Sarath et al., 2021; Ventura and Sagi, 2013), although markets for halophyte products still need further development.

2.2 Water management

Salinisation inhibits freshwater availability for agriculture and other purposes. Therefore, water management in salinized areas is of utmost importance. Irrigation and drainage practises such as drip and furrow irrigation, double drainage installations and desalinisation technologies are some systems used for managing water (Bouarfa et al., 2009; Ward, 2014). Water management in the VMD focuses on conserving freshwater further impacted by increasing drought and heat while preventing flooding and saltwater intrusion on agricultural areas.

In recent years, water retention is a main water management strategy in the VMD. Large-scale reservoirs have been built to provide freshwater for communities in An Giang and Ben Tre provinces (Tran et al., 2019). At the farm level, small ditches are constructed for water storage. Additionally, dikes are also constructed in VMD communities for water management. Extensive development of high dikes that completely prevent flooding and allow the three rice cropping cycles, are expensive with negative environmental impact due to increase in downstream flooding, salinity intrusion and riverbank erosion (Tran et al., 2019). Low dikes, although not as efficient in preventing flooding like high dikes, may be better water management options. Maintaining long term water retention in the VMD requires the integration of green-grey solutions (Tran et al., 2019). For example, the combination of grey solutions like dikes and reservoirs with green solutions such as wetlands, to provide year-round freshwater for agriculture and drinking, and has positive impact on both the environmental and socio-economic dynamics.

Model simulations with SWAP (Kroes et al., 2017) indicated that having a minimum number of irrigations while simultaneously maximising the volume of water supplied at each irrigation timepoint was a good water management strategy for preventing salinisation in deep rooting perennial crops (Crescimanno and Garofalo, 2006). Water storage in cracks, especially in soils susceptibility to shrinkage and cracking, was found to promote salt-leaching thereby reducing salinity levels in the soil (Crescimanno and Garofalo, 2006). These results still need validation by testing in salinized fields of the VMD as well as, scrutiny of potential positive results by dealing with unwanted side effects such as changes to soil microbiota, vegetation and fauna, or reducing water availability elsewhere. Salt or brackish water desalinisation may be used to provide and boost freshwater availability in the VMD. Several desalinisation technologies are practical on a large scale (Curto et al., 2021). Desalinisation system with advance reverse osmosis technology has the most potential. It can be used to desalinate a wide range of low to high salinity levels to provide good quality water for drinking and agriculture, while simultaneously being cheaper and producing less brine than other desalinisation technologies (Cong, 2018).

2.3 Application of amendments and biostimulants

Soil amendments are organic and inorganic compounds that improve soil health while promoting water use efficiency and enhancing crop growth. It includes organic amendments such as manure, compost, biochar or biostimulant, and inorganic amendments such as gypsum or zeolite. Biostimulants are biodegradable amendments that can be added to the soil or directly to crops (via foliar spraying, or root dipping prior to crop transplant) to promote water use efficiency, soil health, and crop production. Although with a lot of benefits on one hand, prolonged use of organic amendments may cause greenhouse gas emission and nutrient eutrophication (Thangarajan et al., 2013).

Several studies have shown the positive impact of application of amendments on crop production under salinized conditions (Deolu-Ajayi et al., 2022; Mukhopadhyay et al., 2021). Amendments, although not always clearly defined, are widely used in the VMD. Compost and biochar application boosted rice production via improved soil health and nutrient uptake (Linh et al., 2024; Phuong et al., 2020). Addition of silicon available in zeolite and sugarcane bagasse compost also increased crop yield in bok choy grown under saline conditions (Kharisun et al., 2021). Zeolite application improves water- and nitrogen- use efficiency, and drought tolerance in crops (Wu et al., 2019), in addition to their role under salinized conditions. Biostimulants are not yet widely used to improve crop production in salinized areas in Vietnam and few studies exist. Biostimulants from salt-tolerant endophytic bacteria and seaweed extracts boosted rice seed germination and seedling growth under saline conditions (Do et al., 2023; Nguyen et al., 2024; Zaleha Abd Tahar et al., 2024).

Overall, the three discussed saline agriculture strategies have good potential to improve crop production in the VMD. Rather than implementing only one of these approaches, combining several strategies may be key to maximise the positive effects and boost crop production in salinized areas, especially during dry seasons (Dagar et al., 2016; Rouphael and Colla, 2018). Although trade-offs and synergies associated with combining multiple saline agriculture strategies needs further research (Kaushal et al., 2021), before large scale implementation under field conditions is performed. Education and sensitisation of end users on effective implementation and management of these saline agriculture strategies should be prioritised, including correct application of new and existing agricultural compounds.

3 Role of stakeholders needed in the scaling up process

To support mass adoption of saline agriculture strategies, the role of stakeholders needs to be considered. Farmers are potential end-users of technologies that support saline agriculture but there are essential activities performed by other stakeholders such as government, academic institutes and private sector, to promote large scale implementation of saline agriculture. The roles of the stakeholders vary but it is necessary that there are mutual agreements and collaboration among stakeholders for introduction of these strategies to be successful.

3.1 Government

The Vietnamese government has policies to support adaptation to climate change. A 2021-2030 master plan, specifically Resolution No. 120 supports sustainable growth of the VMD thereby promoting saline agriculture. Mission of the master plan for the VMD are summarised in eight points below.

1. Strengthen salinity forecast capacity by improving current monitoring techniques and tools.
2. Improve food security by transitioning agricultural systems from rice monocultures to systems that combine fishery, fruit and rice production. It also includes transition to cropping calendars where rice cultivation goes hand in hand with propagation of other crops such as maize and diverse vegetables.
3. Increase and improve the value and competitiveness of agricultural products while facilitating water use recycling and efficiency.
4. Transform agricultural production systems to adapt to climate-induced changes in three ecological sub regions: freshwater zone, fresh-brackish water zone and saline-brackish water zone.
5. Select crops and livestock that are better adapted to both dry and salinized conditions.
6. Build, complete and connect water infrastructures to retain freshwater in the delta. Water collection and retention from rainfall and surface water bodies (such as rivers and lake) should be prioritised.
7. Construct a sustainable water management system of sea and river dikes along the East and West seas as a long-term plan to cope with rising seawater levels.

8. Strengthen cooperation with countries in the greater Mekong subregion, and internationally to boost combined efforts for prevention and response to the negative effects of salinity intrusion and climate change.

The national Ministry of Agriculture and Rural Development (MARD) and Ministry of Natural Resources and Environment (MONRE) are especially important for supporting saline agriculture in the VMD. MARD focuses on the agricultural industry including forestry, aquaculture, water management and saline agriculture. MONRE is responsible for land-water resource use, impact of climate change including surveying and mapping, and management of islands and the sea. The regional offices of the ministries in the VMD oversee implementing and monitoring official policies. Both ministries provide information on current crop production levels and water resources as well as, propose new saline adaptation strategies in the crop-water-soil nexus suitable for the VMD. They are also involved in providing forecasts and giving early warning on salinity intrusion, drought and flooding events.

At the national level, policy makers of the ministry create long term plans and strategies. This is then taken up provincially, in terms of concrete mid-term action activities and tasks to prevent and respond to sea level rise and drought. Several infrastructures that support saline agriculture such as water management innovations are maintained at the district level. At the community level, agricultural extension officers directly support and guide local farmers to ensure polices are followed and strategies are sustainable and well developed. Extension officers serve as a link between the government and farmers (Takemura et al., 2014). Since they play important roles in agricultural development, they should have up-to-date theoretical and practical knowledge on farming techniques that support saline agriculture.

3.2 Education and research institutions

Universities, research organisations, and development partners investigate and propose salinity response solutions, raise public awareness on climate change, provide trainings and capacity building, and develop new scientific insights and toolbox that promote saline agriculture strategies. Several scientific institutions and universities in the VMD are involved in research on salinisation in that region. National and international collaboration with external parties have led to new initiatives or projects on adapting to salinisation. For example, the Mekong Salt Lab which is a cooperation between Dutch and Vietnamese partners to empower farmers with tools and skills on water management in salinized areas. Collaborators in this initiative are Tra Vinh University, Kim Delta, the Water Agency, the Salt Doctors, Saxion University, HZ University, SkillEd, and Acacia Water.

3.3 Private sector

Distributors, retailers and consumers play a crucial role in any transition process that involves changes to marketable products. Private companies and enterprises sell equipment and agricultural materials that support saline agriculture such as water management technologies, seeds, organic and inorganic amendments, and biostimulants. Non-governmental organisations facilitate local and international collaboration, fund research and development, and promote sensitisation and outreach programs on salinisation

New, more salt tolerant crop varieties have perceivable differences such as taste, texture and health benefits, compared to the commonly sold products (Johnson et al., 2022). These salt tolerant crop species and varieties require some communication with retailers and consumers regarding their properties, preparation and storage, and place in people's diets. Communication of such information may be through (social) media and education of different target audiences to effectively support the transition process. To avoid the potential risk of paternalism, co-creation should take place at various levels and be organised based on food sovereignty. To meet consumer demand, market development and respective adaptation of coordination might be required. This may also include the establishment and maintenance of suitable storage, processing and transport facilities. Newly introduced salt tolerant crops may additionally create new by-products or co-benefits for the society thus, allowing further innovation.

3.4 Farmers

Farmers' role in directly improving crop production in salinized areas may be big or small depending on relative importance of the other players in the potential transition process as outlined above. The question whether to take part or not in such transition again depends on a few factors. Internal (farmers' perceived beliefs, values and attitudes)-, external (information available, adoption behaviour of colleagues, technology, financial-and non-financial incentives)-, and social (relationship with neighbouring farmers and societal norms)- aspects all contribute to decisions about adoption of saline agriculture by farmers (OECD, 2012). To manage transition, understanding farmers' perception and behaviour (the internal aspects) towards adoption of saline agriculture is a first step. Socio-demographic and economic factors e.g., age, farming experience, credit accessibility, market linkage and level of education impacted farmer willingness to change (Ford et al., 2015; Masud et al., 2017). More experienced farmers that had access to financial aid (loans, grants or subsidies) showed better incentive to adopting new saline agriculture strategies. Overall, farmers in the VMD that received early warning on salinity intrusion and implemented adaptation measures such as use of dikes and embarkments, reducing cropping cycles, changing crop varieties, and introducing integrated agriculture-aquaculture systems, had higher yield and better productivity than those that did not adapt to the extreme climate events (Kim Dang et al., 2021; Tri et al., 2019). Farmers work closely with agricultural extension officials to receive information on new changers while the latter helps with monitoring and giving feedback on the transition process.

Participatory research involving the different stakeholders- policy makers, extension officers, scientists, industry, financial institutions, investors, retailers, executive administrators, non-governmental organisations, consumer groups, and farmers may promote mass adoption and scaling up of saline agriculture. Therefore, close cooperation and constant interaction and exchange amongst these stakeholders is paramount. Changing policies and other unexpected setbacks may cause bottlenecks resulting in delay for operationalising innovations, but many successful case studies recorded globally show opportunities and new perspectives for saline agriculture (Ladeiro, 2012; Panta et al., 2014).

4 Outlook on saline agriculture in the VMD

To facilitate saline agriculture in the VMD, several factors should be considered, summarised in 6 main points. These points are discussed as economic and environmental costs of introducing new salinity adaptation strategies, the importance of regional wide acceptance of national policy, converting results from research on fundamental knowledge to practical tools for end-users, farmer training or capacity building via farmer field schools, linkage to (inter)national markets, and stakeholder cooperation.

4.1 Costs associated with implementing adaptation strategies

Adapting to increasing sea level rise and other climate-change induced events by saline agriculture comes with some challenges. Before promoting saline agriculture, we should think about what agricultural systems currently exist and the pros and cons, including individual experiences or resistance from stakeholders, of phasing out the production system. For example, rice is the main agricultural product from the VMD. Therefore, to propagate new salt tolerant crops or halophytes as ways to adapt to salinisation, one must consider the current infrastructures that support rice production from propagation to post-harvest processing and storage. This means, who bears these technological losses and financial investments that already exist? Additionally, does saline agriculture require a completely new production set-up or can the strategies already be implemented into existing production systems? The latter is the case, since saline agriculture strategies such as use of salt tolerant cultivars, water management innovations and application of amendments are already performed in the VMD as described in section 2, although on a smaller scale.

Environmental risks are associated with salinisation. The ecological risks include pollution, poor water quality, soil degradation and impact on human health (Cañedo-Argüelles et al., 2013; Hossain, 2019; JRC et al., 2009). Several saline agriculture strategies such as bioremediation, phytoremediation and water desalinisation technologies may improve water quality or remediate poor soils thereby, reducing environmental risks in salinized areas (Cong, 2018; Delgado-González et al., 2022; Jesus et al., 2015; Singh et al., 2019).

The long-term sustainability of saline agriculture should also be prioritised when proposing these adaptation strategies for salinized areas in the VMD. Saline agriculture should be profitable: supplying food, jobs and income (economic sustainability); beneficial to society: improving nutrition and health, and have added value for vulnerable social groups (social sustainability); and have positive or neutral impact on the environment (environmental sustainability). This integrated approach is complex requiring understanding of external drivers as well as, incentives and influence of stakeholders to promote system performance (Nguyen and Neven, 2018) that can support saline agriculture. Several of these adaptation strategies require initial investments and may not be immediately profitable. Thus, saline agriculture practitioners may need subsidies or loans especially in the short term when costs may be higher. Financial institutions such as banks and credit (cooperative) unions support and fund saline agriculture investments. Funding may also be in form of grants and subsidies from governments, non-governmental organisations and private companies.

4.2 Sensitisation of national policy supporting saline agriculture

Some communities in the VMD do not yet implement Resolution No. 120 on sustainable growth of the VMD. There remains limited grasp on associating the cause of current low crop yields to salinisation and understanding the actual devastating situation of salinity intrusion by farmers in the VMD. Several communities in addition, do not prioritise agricultural zoning nor change farming practises to suit actual conditions. Here, farmers are afraid of converting to new crops and livestock, and do not see the importance of efficient use of land-water resources. Moreover, farmers in coastal areas where rice is largely produced experience tough economic situations thus, hindering their ability to make new agricultural investments, including shifting from outdated farming techniques.

Therefore, it is necessary to make the resolution contents into more concrete action plans and activities that have better link to the current reality of farmers. Furthermore, make connections on how these short and mid-term activities contribute to the long-term goal of sustainable growth of the VMD while minimising the negative effects of climate change. Farmer associations' activities at local level should be actively coordinated, and mobilise farmers to not only comply with policies and regulations but jointly develop content that suits the vision and needs of transition players. Welcoming and furthering farmer participation in movements and propagandas on salinisation and climate change adaptation is a step in facilitating the process for overall societal benefit. Production and application of synchronous technical processes should not boldly convert ineffective rice growing areas to other crops but rather first weigh the options and map the process needed for success transition to alternative production systems.

4.3 Making research practical and ready to use

Results from universities and research institutes are not always at a high technology or practical readiness level that would allow farmers to adopt research findings quickly. In some cases, results do not necessarily meet current local needs. Eventually, farming models, methods and technology should suit local saline and drought conditions and be developed into easy-to-use applications and tools. Farmers should be routinely invited for field demonstrations and whenever possible, should participate in field experiments where these saline agriculture technologies are tested, or be directly part of the research team already at the design stage.

Extension workers may serve as connections between knowledge developed in scientific institutions by explaining and introducing new adaptation strategies in simpler terms that are more practical for farmers to apply. Inadequate and inconsistent training of extension workers are commonplace (Shaffril et al., 2020). Extension officers are also sometimes completely neglected from the implementation and feedback process resulting in poor performance of the agricultural strategies over time (Ebhuoma and Leonard 2020). Therefore, extension officers should be part of the entire process and periodical training of extension workers on new tools and methods, are necessary.

4.4 Empowerment through farmer training

Farmer field schools (FFS) are informal tools used locally to facilitate peer-to-peer learning, reduce agricultural illiteracy and empower farmers with techniques and soft skills to improve their current agricultural systems (FAO, 2016). Although not mainstream, FFS exists in Vietnam and has produced positive results (van de Fliert et al. 2007) and may be a way to train farmers on implementing saline agriculture strategies in real time. Participants of FFS trained on and that implemented climate change adaptation strategies, observed increased crop and livestock productivity (Tripp et al., 2005).

Interaction of FFS with local agricultural committees help maintain knowledge on good farming techniques taught at the FFS, over time. These local committees may serve as the link to agricultural research institutions and assist farmers in further development of managerial and organisational skills (Braun et al., 2000). Investment from external bodies (both social and economic organisations) and linkage with government and policy makers are also beneficial, to produce middle and long-term impact of FFS (van den Berg and Jiggins, 2007). Linking farmers directly or via extension officers to educational and financial institutions is of necessity to facilitate the development and adoption of new techniques and promote stakeholder cooperation, leading to better farm management and improved crop productivity.

4.5 Linkage to markets

The value chain of products from saline agriculture should also be assessed from propagation until it reaches consumers. The introduction of new salt tolerant species and varieties, although promising from a production perspective, require appropriate markets in the VMD which do not yet exist in some cases, and needs to be developed. Salt tolerant crops such as beetroot and quinoa may be exported since they already have established global markets thus, connection to international markets is still needed. Product supply at the local, regional and national levels should be organised by farmer associations in cooperation with trade unions and the government to promote fair trade practises in the VMD.

Accessibility to technology (e.g., for mechanisation, irrigation, drainage and water desalinisation), agricultural inputs (seeds, organic and inorganic soil amendments, biostimulants), and specialised processing, transport and storage infrastructure may also prevent immediate adoption of new saline agriculture strategies. Linking to global markets where these technologies can be accessed may facilitate adoption of state-of-the-art tools for saline agriculture by farmers in the VMD.

4.6 Stakeholder coordination to promote a system approach

Another area that needs to be considered as part of the potential transition process to saline agriculture is countering contradictory behaviours and narratives of stakeholders as well as, dealing with inconsistent policies and regulations that may hamper success of the agricultural transitions. The out phasing of inappropriate and outdated practices and regulations need deliberate and concrete effort, and sometimes, incentives to boost changes by stakeholders.

While many activities may go on and need to happen in parallel, there could also be the need to orchestrate a sequence of activities which are dependent on each other. Finally, one or several targeted monitoring systems or quality control of the process can help to assess whether the ongoing transition is successful or where adjustments should be made to further increase overall benefit. A critical issue here is monitoring and steering potential social effects such as changes in roles, benefits and costs to vulnerable groups based on gender, age or ethnicity. Transition could offer new opportunities for inclusion and greater equity, but this needs close and continuous valuation and sometimes, strong steering by stakeholders.

In retrospect, there are certain infrastructures and processes that need to be developed to support saline agriculture. At the bedrock of this, is collaboration and cooperation among stakeholders summarised in seven steps (Verhagen et al., 2022). First analyse together to prioritise saline agriculture challenges and outcomes. Then, understand together to map the relevant elements for saline agriculture in the VMD. This is followed by prioritising targets for change together and then, co-exploration to develop the saline agriculture transition pathway suitable for the identified salinized areas. A next fifth step is creating a plan of action by co-strategizing. Acting together to implement the transition is the next step. Here, roles should be clearly defined to reach a common goal on implementing mass adoption of saline agriculture, where appropriate. Monitor, evaluate and learn together is the last step in this process.

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Corresponding address for this report:
P.O. Box 16
6700 AA Wageningen
The Netherlands
T +31 (0)317 48 07 00
wur.eu/plant-research

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