Seven Steps in Identifying Local Climate Change Responses for Agriculture in Vietnam

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Summary

This study presents a seven-step approach to identify and support local climate change (CC) responses in agriculture. The following seven steps comprise this approach:

1. *Analyse past trends on the climatic factors and model the future trends.*
2. *Simulate the possible impacts of CC on the selected system(s) or product(s).*
3. *Present and discuss the predicted impacts with the local stakeholders.*
4. *Identify and rank CC responses together with the local stakeholders.*
5. *Elaborate plans to develop and test the highest ranked response(s).*
6. *Evaluate the results of the tests and recommend implementation or changes.*
7. *Report the results to the involved authorities and suggest ways to implement the responses and/or advise new tests if the first ones were not able to sufficiently deal with the impacts.*

Six pilot studies in Vietnam were funded through two projects led by Wageningen University & Research. The first addressed several production systems in one southern province, and the second in three more northern districts, each with different problems. This paper reflects and communicates the seven-step approach in order to make local CC responses accessible to the larger rural development communities. Most of the identified solutions can spread autonomously, while others will require specific planned interventions.

Résumé

Sept étapes pour identifier des réponses locales aux changements climatiques dans l'agriculture vietnamienne

Cette étude présente et discute une approche structurée en sept étapes pour identifier et développer des réponses locales aux changements climatiques (CC) affectant le secteur agricole. Ces étapes sont les suivantes:

1. *Analyser les tendances historiques du climat et simuler les futures tendances.*
2. *Simuler les impacts éventuels des CC sur le(s) systèmes/produits choisis.*
3. *Présenter et discuter les impacts identifiés avec les acteurs locaux.*
4. *Identifier et hiérarchiser les réponses aux CC ensemble avec les acteurs locaux.*
5. *Elaborer des plans pour développer et tester les réponses préférées.*
6. *Evaluer les résultats des tests et modifier les réponses ou bien recommander leur mise en œuvre.*
7. *Rapporter les résultats aux autorités impliquées et suggérer des voies de mise en œuvre des réponses et/ou conseiller de nouveaux tests, si les essais préliminaires n'ont pas suffisamment atténués les impacts des CC.*

Six études pilotes au Vietnam étaient financées par deux projets menés par l'Université de Wageningen. Le premier projet traitait de plusieurs systèmes de production dans une province au sud et le second dans trois districts plus au nord, chaque fois avec des problèmes différents. Cet article reflète l'approche en sept étapes afin de rendre les réponses locales aux CC accessibles aux institutions de développement rural. La plupart des solutions identifiées pourront être diffusées d'une manière autonome, tandis que d'autres demandent des interventions spécifiques planifiées.

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Introduction

Globally, Vietnam is among the five countries most threatened by sea level rise due to climate change (11). In response to climate change impact, Vietnam, like most countries, has assessed Climate Change (CC) impact and prepared its mitigation and adaptation plans at the national level. However, at the local level (region, province/district/commune), these adaptation plans for CC hardly exist. Adaptation can refer to natural or socio-economic systems; it can be reactive or anticipatory relating to their timing, and can be planned or spontaneous, depending on the degree of spontaneity (44). Frankhauser *et al.* (15) adopted the definition of autonomous adaptation from Carter *et al.* (3) as the "natural or spontaneous adjustments in the face of a changing climate," and consequently defined planned adaptation as "requiring conscious intervention" (e.g., large-scale flood protection works). The hypothesis of the present study is that conscious anticipatory actions can stimulate autonomous adaptations at community and/or farm household level, and reduce pressure on planned large-scale infrastructural interventions. Even though the national level authorities inform their local counterparts on adaptation and mitigation measures, if local authorities are not engaged in implementing measures that stimulate autonomous adaptations, related plans then become useless. Autonomous adaptations involve the local population and are done by institutes, companies and (farm) households; without these local partners, autonomous adaptations are impossible to do.

In Vietnam, the districts, the lowest administrative level of the agricultural extension services, serve as one of the sources of programs for communes, villages and hamlets. For autonomous responses to happen, for example, among farm households, they would need support from institutions/authorities, like the districts, to assist them to identify and test solutions. This study describes and analyses a seven-step method to stimulate autonomous adaptations through case-studies from six districts in four provinces of Vietnam. Before describing and discussing examples of the steps, we give the main characteristics of the sites. Before concluding we discuss the seven steps more broadly.

The study sites

In all six districts in four provinces, namely from south to north: three in Soc Trang, one in Quang Nam, one in Thanh Hoa and one in Nam Dinh, options on CC responses among farm households and rural communities were identified and tested. All pilot sites focused on agriculture, either for food or cash crops; but in some cases, the solutions went beyond the sector.

Soc Trang province

Soc Trang is one of the provinces in the Mekong Delta in the south of Vietnam where the monsoon season last from May to November (Figure 1). The Mekong delta faces four major threats: sea level rise (17, 43, 48), land subsidence (18, 14, 23), reduced fresh water flow (33) and salinity intrusion (5, 43, 48). Land subsidence is due to groundwater use and flood prevention dikes (14, 22). Taken all together, these threats impact on fresh water availability. The study in Soc Trang province was done on three different agricultural practice systems in three different agro-ecological zones: (i) applying alternate wetting–drying irrigation for rice in Nga Nam, a freshwater-dominated area, (ii) diversifying terrestrial crops on dikes by using rain water in rice-shrimp rotation system in My Xuyen, a brackish water area and (iii) applying mangrove-shrimp integrated system in Vinh Chau, a saline water-dominated area (9).

Dai Loc in Quang Nam

In the centre of Vietnam, Dai Loc district in Quang Nam province has, since 1977, experienced water shortage for rice cultivation in the summer-autumn season (May-September). Most rains normally fall between September and January. Here, drought has affected rice production in 11 of the 18 communes, or a total of 143 ha of land area. Thus, there are more frequent conflicts occurring around the water-sharing system between rice cultivation and other uses of water (e.g., for other crops, drinking water and hydro-power). This situation has forced some farmers to turn to crops requiring less water (21).

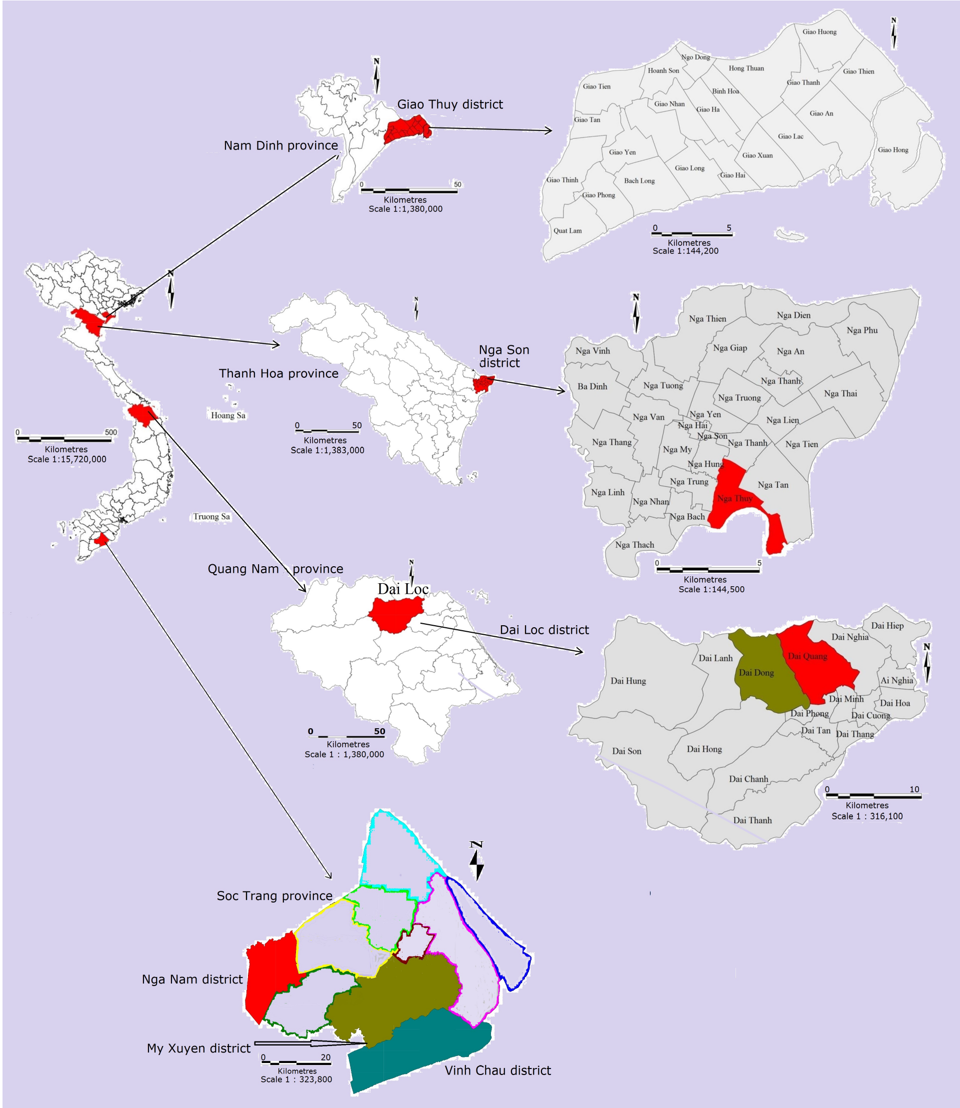


Figure 1: The geographical location of the six districts that were supported to develop Climate Change responses.

Nga Son in Thanh Hoa

Nga Son district in the northeast of Thanh Hoa province where the warm rainy season lasts usually from July to October/November, is well known for its fast-growing sedge or papyrus (*Cyperus* sp.). Sedge is a raw material for making handicraft products, such as sleeping mats to be gifted to wedding couples. The sedge cultivation area of Nga Son represents 20% of the country's total sedge cultivation area (about 13,800 ha).

However, since some years back, sedge production remarkably declined; e.g., in Nga Thuy commune in 2012, the total sedge yield was more than halved (1,470 tons) compared with that in 2002 (3,180 tons), thus reducing the handicraft employment (36).

Giao Thuy in Nam Dinh

The most northern site, Giao Thuy district is located in the coastal area of the Red River delta where most rains fall in the warm season between April and November. Its agricultural production focuses on aquaculture, rice, vegetables, melon and some animal husbandry. However, these livelihood options do not provide a decent income to many farm households and some options are impacted by CC (10).

Applying the seven steps to CCA

To increase the chances of broad adoption of feasible local CC responses, researchers used several participatory tools to embed the proposed seven-step approach. In a preliminary step, the team made an agreement with all relevant local authorities of each province and pilot district. The seven-step approach is summarized as follows:

1. Analyse the trends of selected climatic factors (rainfall and temperature min-max) in the past and present to model their future trends and effects on the patterns of flooding and salinity intrusion when relevant.
2. Model the predicted impacts of climate change on the selected issue(s), e.g., the present and future cropping calendar.
3. Present the predicted impacts and discuss in Focused Group Discussions (FGD) with the local stakeholders (local decision-makers and representatives of producers).
4. Hold separate FGDs with different types of stakeholders, e.g., considering position in society (i.e., farmers and leader-officers) and gender (i.e., women and men) to identify and rank solutions to respond to the CC impacts; use several criteria to assess each of the solutions on its feasibility to be implemented, either autonomously or with support from outside.
5. Elaborate plans to develop and test the highest ranked response(s).
6. Evaluate the responses and recommend implementation or changes in case the tested responses seem insufficient to deal with the predicted impacts.
7. Report the results to the local communities, the district and provincial authorities who approved the study in the pilot district, as well as in other provinces with the same agro-ecological conditions.

Step 1: Analyse and model climatic trends. The teams analysed trends on climatic factors, such as rainfall, minimum and maximum temperatures, and subsequent impacts on flooding periods and flood-depths and land-use by conducting a four steps approach:

(i) collect information on the past trends,
(ii) assess the trends in a GIS-based local climate change impact model (CCIM),
(iii) validate the outcomes of the model and
(iv) explore future trends by modelling.

This four-step-approach was applied by using three different methods and the choice of the methods depended on the availability of a CCIM. First of all, the teams checked whether a GIS-based local CCIM, including hydrological models of the water bodies, flooding levels and periods, was available. Such models may be available at the local or national institutions (universities, international projects, regional or non-governmental organizations).

In Dai Loc district, Quang Nam province, a local CCIM was not also available; thus, the Dai Loc team used an approximated method (Box 1).

A CCIM was not available for both Nga Son (Thanh Hoa province) and Giao Thuy district (Nam Dinh province), but digital maps and databases were. Both teams collected secondary data to make the local CCIM for the past, and then calibrated the model (Figure 2). The Giao Thuy team developed a local CCIM based on the GIS database available from previous projects of VNUA (37).

The teams collected data for DEM and the historical data from years with high and normal flooding and drought. Nga Son, for example, was hit by a storm with high amount of rainfall that caused severe floods in 2007; at Len river, the water level reached 6.95 m which was 0.15 m higher than that of the previous highest flood in 1973 (28). After calibrating the models, the teams modelled the impact of CC on the district's flooding (period, duration and height), drought and salinity intrusion by using Vietnam's B2 scenario.

For the entire Mekong delta, a CCIM was available but the local impacts for the three sites in Soc Trang province were lacking. The CCIM of the higher aggregation level was used as a starting point to make the local CCIM. The team then collected secondary data on climate change and extreme climate events and subsequent impacts on agriculture and aquaculture from provincial reports, and primary data on the digital elevation model (DEM) from the Mekong River Commission (48).

Box 1

The drought assessment method used in Dai Loc district.

Interpreting secondary data: Available reports and data were collected at Dai Loc district, Dai Quang and Dai Dong communes, Quang Nam province's Office of CCA, agricultural cooperatives, irrigation teams, hydrological and meteorological stations in the region, and statistical offices. These secondary data covered the issues mainly at provincial level. Then, water situation and its impacts on rice production were visualised on GIS-based water resource and irrigation network map; the team analysed rainfall and evaporation data and the discharge of rivers. In addition, other methods, such as "drought index - TPI" were used (31, 22).

Participatory mapping: The researchers, together with irrigation workers of the agricultural cooperative, commune staff and farmers (both male and female) mapped the water resources, irrigation systems and drought-prone areas in more detail at district and commune levels. Using these maps at 1:10,000 for the communes and 1:25,000 for the district showing streams, lakes, rivers and drought-prone rice production areas, stakeholders discussed the drought issues. Also the local hydro-power plant and drinking water companies were invited to join in the analysis. Then, the maps were checked by using a GPS device and were validated by the stakeholders. This participatory GIS mapping increased all the stakeholders' awareness on water management and drought-related issues.

Diagnosing rice effect on rice yield: To diagnose the overall situation of rice production, water resources, irrigation systems, water shortage and droughts, the project team interviewed 15 officials in charge of agriculture, irrigation, environmental resources at commune and district levels. Interview results disclosed the role of stakeholders in the management and the use of water resources. The collected information revealed that conflicts on water management and water use both at the communal and the district levels exist between two communes.

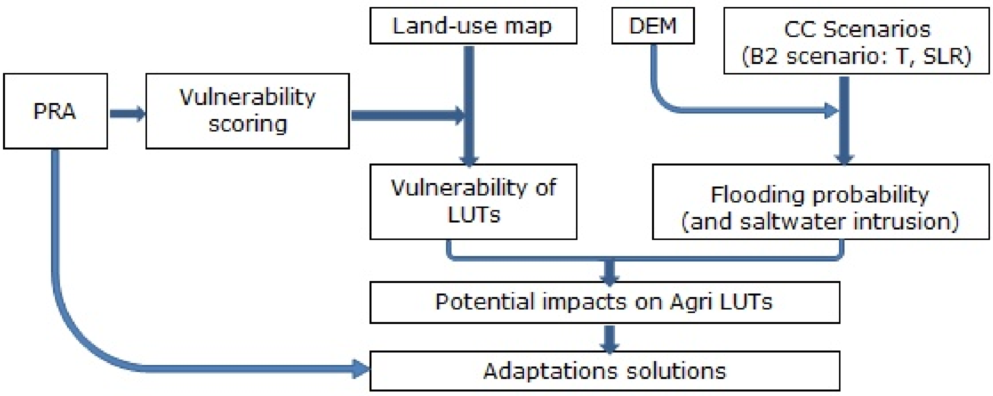


Figure 2: The framework for assessing the impact of flooding on agricultural land uses in Giao Thuy district (38).

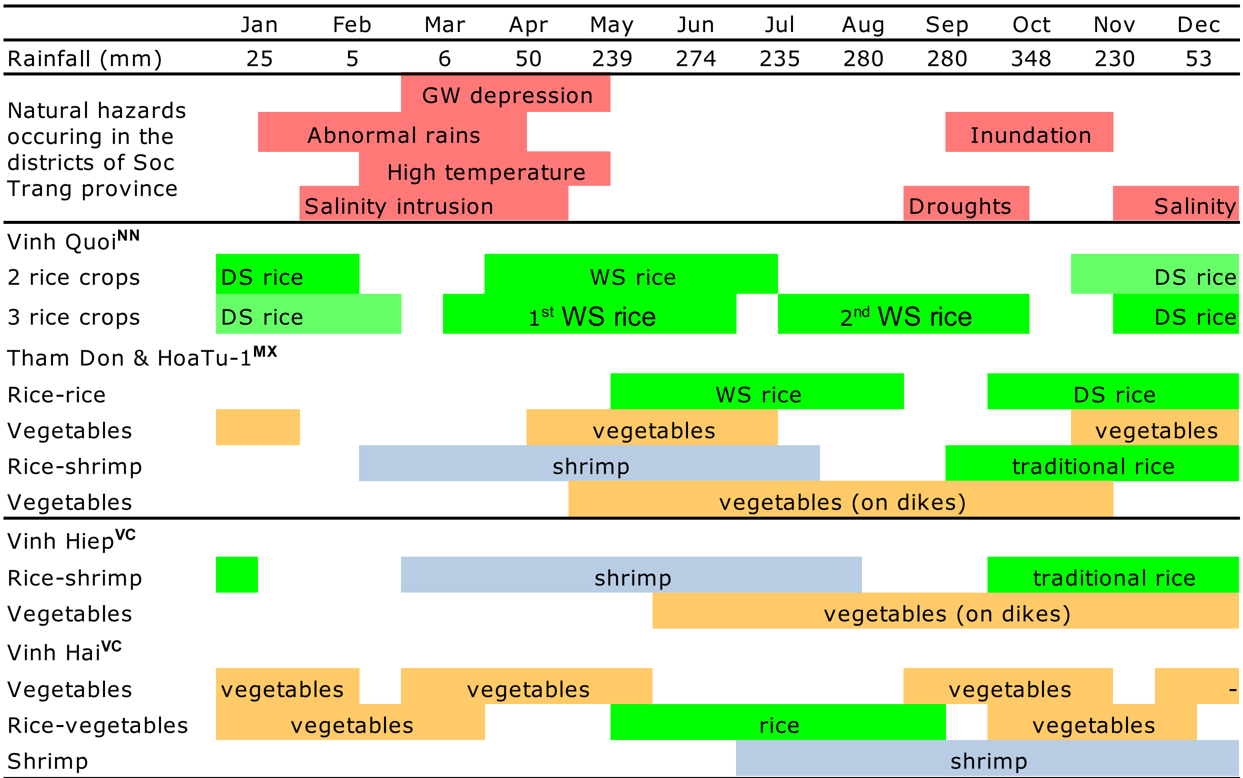
The next step was to validate the secondary data by collecting in-situ data focusing on climatic impacts on existing farming systems and trend of changes. Thereafter the past events were simulated in the CCIM by using a year with extreme flooding (2000) and a year with extreme salinity intrusion (1998) as references for impact of climate change. The CCIM produces maps based on the past trends. The model's simulation results on the impact of past climatic events were validated with the local stakeholders. After this ground truthing, the models were adjusted and fine-tuned as needed.

Step 2: Assess CC impact on land use

Using participatory tools (4, 20), such as calendars, maps, cause-effect trees, and FGDs, the stakeholders assessed CC impacts, for example, flooding characteristics and/or salinity intrusion on their crops. The cropping calendars were superimposed on the predictions of rain and flooding (Figure 3).

To ensure that gender concerns, among others, are included in the analysis of impact, all teams were given a complementary training on FGDs and on gender inclusion in research protocols and methods. Sampling of household was not random but based on representativeness of poor, well-off and rich households (4). Therefore, the work in the hamlets started with wealth ranking, and in the Mekong Delta, within three social groups: (i) old men, (ii) old women, and (iii) mixed young men and women. After the FGDs by wealth category and social group (gender), in-depth interviews were held.

The impact assessments on agriculture were either general, or related to a specific land-use activity in the districts, according to the agreement with the authorities. In Dai Loc and Nga Son, the assessments focused on rice and sedge, respectively. In Giao Thuy and Soc Trang, the assessments concerned all food production systems that were under threat.



Legend: GW= groundwater; DS= dry season; WS= wet season.

Figure 3: The monthly rainfall distribution (mean over 2005-2010) and major natural hazards in the study sites (13), and the cropping calendars of the principal farming system practiced in selected communes in Nga Nam (NN) and My Xuyen (MX) and Vinh Chau (VC) districts (9).

Nga Nam district is dominated by rice paddies that were planted twice or on a limited scale thrice a year. The rice paddies are already threatened by sea water intrusion in the dry season; thus, adaptations in this zone will need either shifting from triple to double rice-crop cultivation with crop diversification, or storing irrigation water in communal canal systems and applying good irrigation practices, in the dry season. In addition, the adaptation strategy aimed to spread the economic risk by diversifying freshwater-based ventures using rainwater, e.g., for growing prawn concurrently with rice, or growing dryland crops and grasses for cattle on the farm dikes.

In My Xuyen district, the main production systems were rice farming (two crops per year) and both freshwater and brackish water aquaculture. Based on the FGDs, however, the brackish water shrimp aquaculture is restrained by water quality issues and less than optimal fluctuating salinity concentrations leading frequently to disease outbreaks and yield losses. The adaptive strategy aims to introduce sediment settlement and "green water" filter basins through which the water is sourced before supplying to the shrimp pond for refreshment (47). To function well, this system requires a combined water ponding surface area (both settlement and green filter ponds) to shrimp pond area ratio of 1:4. If this is a considerable constraint for smallholder shrimp farms, the "green water" ponds to prepare the water might be jointly implemented and managed by a group of shrimp farmers. In addition, the adaptation strategy aimed to spread the economic risk by diversifying freshwater based ventures by using rainwater for e.g. growing prawn concurrently with rice, or growing dryland crops and grasses for cattle on the dikes of the farm.

Vinh Chau district has, next to the dominant intensive brackish shrimp aquaculture, zones with protected mangrove forest, mixed mangrove-shrimp production system and vegetable and fruit production systems, including salt production. Cultivation of vegetable (and to some extent, fruits) has been promoted, but is entirely dependent on the deep phreatic fresh groundwater, which is an unsustainable production stray, as over exploitation of the groundwater will lead to higher pumping costs, increased competition and eventual collapse of the water resources base. The latter is characteristic for those parts of the Vietnamese coasts having narrow elevated sandy strips (Giao Thuy is another example), which are not suitable for aquaculture and deprived of surface freshwater supplies, particularly during the dry season. Dai Loc district, the concern of authorities and farmers was the diminishing rice (*Oriza sativa*) production. This was due to drought, (temporary) abandonment of rice farming and changes in land-use.

In Nga Son district, the issue was on the reduced production of sedge (*Cyperus tegetiformis*). In 2010, sedge farms suffered drought and widespread pest infestation. In general, the yield and quality of the crop declined; thus, in several commune, farmers abandoned sedge farming (28). FGDs and in-depth interviews revealed that, next to the yield, the length of the sedge was also reduced, which consequently resulted in lower farm-gate prices.

In Giao Thuy district, various adaptation responses were tested, such as cultivating salt-tolerant rice varieties, fattening pigs, producing community-based clams, putting up community-based homestay tourism, culturing earthworm, growing fruit with microbial fertilizer and growing mixed fruits, such as new varieties of apple, dragon fruit and grapefruit. Part of these aimed at diversifying the rice-farming to improve farm household livelihoods. During their testing period, these models proved to be effective, but they had limited practical impact, probably due to lack of active participation by the stakeholders during the testing phase.

Step 3: Present the predicted impacts

The predicted impacts should be presented to and discussed with the local stakeholders. Three steps are recommended:

i. Prepare the local climate change impact maps for all or the selected production system(s) in a format which can be shared with local level people;

ii. Consult experts and literature to acquire background data on the local farming systems, their problems and a preliminary list of solutions;

iii. Present the impact maps to the local stakeholders by using FGDs. Participants of the FGDs are local farmers and the local agents in charge of the processes in the concerned hamlet. Hold separate FGDs for each of the following: staff of government, NGOs and private sector, local decision-makers and leaders and male and female producers.

Thus the team needs as many facilitators as the number of groups. When team members have no experience in facilitating FGDs, a short training is provided and after the workshop in a first commune, facilitators and trainers should review the process. FGDs of step 3 should confirm:

(i) description of the local farming systems,

(ii) past impacts and

(iii) expected impacts. When the causes of the impacts are not clear, a complementary study might be needed; this was the case for the sedge value chain in Nga Son (Table 1).

Step 4: Identifying and ranking solutions

After having reached an agreement on the problem analysis with the local stakeholders, the teams review related literature and consult experts to complete the list of solutions. This list was used as a background for the FGDs with the local stakeholders: farmers (women / men), leaders and officers. If no new problems are listed and the list of solutions is comprehensive, then the ranking can be done at the same meeting as the identification. FGDs are then used for stakeholders to complete the list, agree on the solutions and rank the solutions (Tables 2 & 3). The chosen solutions should focus on autonomous adaptation to the CC impacts, i.e., responses to CC that could be implemented at the local level with little or no external assistance.

Criteria to Assess and Rank Solutions

Each solution is assessed for its feasibility of whether or not the stakeholders can implement it autonomously among themselves, or with support from outside based on five to eight criteria. At least the following five criteria should be used: financial, technical, management and labour capacity of the stakeholders to implement the solution, and the expected effectiveness (benefit) of the solutions. These could also be summarized as efficiency, feasibility (3 or 4 issues), and effectiveness. The financial capacity can be assessed for the local (farmer) level, but the extent of support required from outside can be assessed as well (Table 2).

Next to these, the criteria, such as the solution's possible side effect, robustness and flexibility (i.e., ability to combine with other measures) were used by some teams, while neglecting the financial capacity and the need for support from outside (Table 3). The latter led to high ranking of solutions that could not be carried out autonomously. A report should not provide the final ranking only but include the scoring for all criteria, in order to be able to re-assess the ranking. The table which focused on their capacity (Table 2, and Table in (28)) , increased the stakeholders' insights and provided them with a comprehensive information for decision making on actions they can take without depending on external support mechanisms after the test period. The highest ranked solutions could be analysed further by listing the enabling and constraining factors, and suggestions to relieve these constraints.

The ranking of results

Districts which focused on a product (Dai Loc for rice and Nga Son for sedge) had a different way of ranking solutions from those with generic cases. The solutions for the products included both planned (water sharing) and autonomous (changing crop) measures to adapt; including both types of measures that allow stakeholders to plan options for short- and long-term adaptation. The solutions of the generic cases aimed more at the (re)design of production systems. In Soc Trang, improving the efficiency of using fresh water sources to increase farm benefits, was the main goal of all tests.

Table 1

Causes of the reduction of sedge yields based on FGD in Nga Thuy commune and Nga Son district, and percentage of the participants agreeing on the cause (Source: 29).

Causes	Agreement (%)
Market price decrease	98
Fresh water shortage	98
Salt intrusion	92
Extreme weather events (storms, drought, flood)	80
Changes in climate pattern	78
Pests and diseases	74

Table 2

Ranking of solutions based on six criteria of feasibility and financial support from outside (yes/no) for drought-affected rice culture in Dai Loc district (Source: 22).

Solutions	Finance		Technical	Management	Labor	Benefit
	Local	Outside				
Dredging of canals, streams						
- Large scale	Weak	Yes	Weak	Weak	Weak	Strong
- Small scale	Strong	No	Medium	Weak	Strong	Strong
Sheet pile along the river	Strong	No	Strong	Strong	Strong	Strong
Intensive plantation	Weak	Yes	Weak	Medium	Weak	Strong
Scattered plantations	Strong	No	Weak	Strong	Strong	Strong
Water-sharing mechanism	Strong	No	Strong	Strong	Strong	Strong
Changing crop patterns	Medium	Yes	Medium	Medium	Strong	Strong
Drought–tolerant rice	Weak	Yes	Weak	Medium	Strong	Strong

Table 3

Ranking solutions for responses to reducing sedge yield based on average scores for Effectiveness, Reducing the impact of CCA, Side effects, Economic efficiency, Feasibility, ability to combine, Conditions enforcement and Flexibility (Source: 29).

Solution	Average	Ranking
Improve irrigation system	8,6	1
Build and upgrade coastal dike system and fresh water dam	8,3	2
Improve sedge cultivation techniques for better yield & quality	8,1	3
Restructure crop and livestock patterns	7,8	4
Strengthen connection between producers, traders and users	7,6	5
Find a new market for sedge and its products	7,3	6

In Giao Thuy, from among a range of problems, the stakeholders decided to focus only on two solutions that can be realized at the household level. The first solution was for farmers to grow a new melon variety by using compost to recycle waste, while simultaneously linking them to the value chain for the inputs, techniques and marketing (37). The second solution was to test an ecological aquaculture pond management technique to produce white shrimp in polyculture with red tilapia (27).

Step 5: Testing prioritized solutions

For the highest ranked solution(s) the team elaborated experimental plans together with the local stakeholders. Testing these solutions on-farm can either be simple, but may also require training or assistance from specific experts, as in the case of Giao Thuy (value chain) and Dai Loc (participatory water management). To prepare the teams for the on-farm trials, researchers provided training on the conception of research embedded in sustainable rural development to some team members.

Farming in coastal Mekong Delta

The test to improve water productivity in irrigated rice farming systems through the Alternate Wet/Dry rice farming was very successful in Nga Nam and included in the package of the provincial extension agents (8). To improve the sustainability of rice-shrimp farming systems in the brackish area three options to increase the availability of fresh water were considered, of which two were evaluated theoretically. In theory, the option to store water in the canal system for rice irrigation during peaks of saline intrusion would provide enough water, but this could not be tested in the field given constraints, such as large area of rice field to be affected and high investment cost (48).

The option to store water in flood plains in provinces further upstream was also evaluated (Box 2). Instead of these communal adaptations, a household-scale model was tested (8, 9).

Box 2

Climate change adaptation in the Mekong Delta: giving room for water in upstream areas (12).

One of the strategies to increase the availability of fresh water of the coastal Mekong delta provinces in the dry season would be to extend/increase the water storage in the upstream floodplains in An Giang province, where the Mekong River first enters into Vietnam. This study explored this alternative through function analysis and a multi-criteria analysis (MCA) to evaluate the best adaptation option for water scarcity with data collected through desk studies, and structured interviews of stakeholders, including households and local experts. Using indicators for land-use, the researcher identified two study sites: 24 ha of crop land near Binh Thien Lake and 245 ha from the Tra Su forest.

Four alternatives for water storage were evaluated: expanded lakes, community ponds, natural wetlands and household ponds by using the following criteria: effectiveness, implementation cost, loss of annual yield, preserving biodiversity, benefits from aqua-products, capability for expansion, public access, and human health and safety. A function analysis was applied to both study sites to identify the current functions and services of ecosystem. The potential losses and gains of these functions and services for each measure were quantified. The interested participating stakeholders determined different weights for the criteria.

The MCA shows that expanding Binh Thien Lake is the best adaptation option for the first research area, and transforming in natural wetlands is the preferred option for Tra Su forest. In the Binh Thien area, the provincial government has policy instruments to support the implementation. However, in the forest area, the consequence of longer flooding for the biodiversity should be assessed.

The techniques to improve productivity and resilience of integrated mangrove-shrimp farming were successfully demonstrated. Cleaning and dredging the pond, post-larvae nursing and supplying additional shrimp seeds improved the yield of shrimp and other aquatic animals. Total production costs of the pilot farms were lower compared with both the control farms and before intervention in 2012, while gross and net incomes of pilot farms were higher (40).

tTo sustainably produce dryland crops in Soc Trang, local authorities and farmers need to design and use production systems that do not depend on the deep phreatic water. Though technically feasible, solutions, such as buying and/or constructing large storage tanks and installing drip irrigation systems are not economically feasible; thus, shifting to various other mixed systems was tested ((9) and (Box 3).

Water-sharing mechanism in Dai Loc

To elaborate the water-sharing mechanism, the Dai Loc team measured and mapped all waterways for two cases: hydropower vs. irrigation in the Suoi Mo basin (a conflict between Dai Quang and Dai Dong commune, and drinking vs. irrigation in Suoi Tho basin in Dai Quang commune. The team separately met with each stakeholder group of three communes, including the electricity and water companies. The team used PRA tools, such as power mapping matrix, Venn diagram, crop and irrigation calendars, and problem and solution trees ((22), and Table 4). During this process, the team was advised by a WUR expert on participatory water management. After several rounds of consultation, a water-sharing protocol was signed by leaders of the involved parties. The protocol included an autonomous funding mechanism for the monitoring.

Box 3

Improved fresh water storage at household level.

In My Xuyen district, three groups of farm households tested new techniques on water storage: (i) six piloted the storage of water in their pond area, (ii) eight were early adopters of storage ponds, and (iii) six continued their normal practice of shrimp farming without storage pond, but tested the culture of upland crops and grass for cattle on the dikes. Farmers stocked Nile tilapia with low density to improve the quality of the inlet water for the shrimp in the storage pond occupying 15 to 20% of the shrimp farming area. After harvesting the tiger shrimp, farmers raised white leg shrimp (*Litopenaeus vannamei*) in the storage pond.

The first group raised tiger shrimp (*Penaeus monodon*) with low stocking density. The second group tested the feasibility of raising freshwater prawn (*Macrobrachium rosenbergii*) in the rice field. Before the wet season, freshwater prawn juveniles were raised in a pond for 2 to 3 months, and when rice had reached an acceptable height, shrimps having 3-5 cm were released at low stocking density (0.5-1.0 shrimp/m^2 water surface).

The storage pond improved the water quality, shortened the shrimp farming cycle and reduced the feeding costs; the first two contributed to reducing the disease risk. Stocking white leg shrimp in the storage pond after harvest of the tiger shrimp gained high financial returns. Freshwater prawn farming in rice fields did not affect the rice yield. Stocking 1.0 shrimp/m^2 water surface had a higher yield than stocking at a density of 0.5 shrimp/m^2. Growing vegetables and grass for fodder on pond dikes made a high financial return (8, 9). Cultivating these 'upland' crops would provide a higher income if farmers would do two crops/year, or combine vegetables with sorghum to produce feed for livestock. Growing sorghum mulched with rice straw yielded about 30% more than that without mulch. Farmers integrating all three practices got higher economic returns than that from the traditional tiger shrimp-rice farming system.

Table 4

Overview of the data and methods used for the pilot in Dai Loc district (Source: 25).

Objective	Input data	Tools/Methodology	Expected Output
1. Analyse the trends of rainfall and temperature (min-max) from 1978 to 2013 and 2014 to 2050.	Rainfall, T (daily min-max) from 1978 to 2013 Rainfall, min-max T in future (period 2014-2050)	Primary data collection in Excel Analyse the outputs of the RCM model or MONRE 2012	The tendency of climatic factors from1978-2013 Explore the tendency of rain and T (2014-2050); Calculate SPI (Standardized Precipitation Index)
2. Assess drought index and identify future potential drought hazard areas.	Current land use map, soil map, topographical map. Satellite images: Landsat, NOAA/AVHRR Existing drought map (if available). Climate change scenarios of district. Information about drought hazard; including: frequency, intensity, time, area…	Secondary data collection. Interpret satellite images with ENVI and ArcGIS. Secondary data collection. Participatory Rapid Assessment (PRA).	+ Landsat to detect land use/cover change (1978 -2013) + NOAA/AVHRR to calculate Normalized Difference Vegetation Index (NDVI) from 1978 -2013 Scenarios of drought for Dai Loc at present and in future
3. Evaluating the predicted impacts of climate change (drought) on the present and future cropping calendar, focusing on rice production.	Land use planning map. Influence of climate change (drought) to rice production (seasonal yield, cultivated area, irrigated sources, gender…). Simulate the influences of climate change (drought) on rice production till 2050.	Secondary data collection. PRA and Stakeholder analysis. Observe and assess seasonal variations. GIS & SPI tool. GIS, SPI and PRA.	Assess the influence of climate change to rice production at present and in future
4. Inform stakeholders: local decision-makers & representatives of producers.	Presentations of the modelling results. Discussion guidelines.	Break-out group discussions. SWOT analysis.	Validation of the model results; Pilot sites for testing adaptation/mitigation measures.
5. Identify and design solutions to adapt with climate change.	Information of resource persons, literature and experts; Local people's experiences; A list of options for adaptation and mitigation in Dai Loc, Quang Nam.	Secondary data collection; Focus Group Discussions (FGDs) and expert/literature consultation.	A list of test to be carried out at farm / hamlet/ district level; list of hamlets were this can be done; planning.
6. Feedback to the district and decision on the adaptation tests to carry out.	District leaders (district people committee e.g. vice head of the district), DARD, DONRE, Irrigation company, Dyke protection unit. Representatives from communes where the agricultural land uses are vulnerable (commune leaders, farmers).	Presentations, round table and break-out groups to discuss and agree upon the suggested options.	

Recovering the sedge yields

In order to propose technologies to recover the sedge yield, the team carried out preliminary on-station trials near the stakeholder's residences. The first trial assessed the use of an organo-mineral fertiliser (46), and the second one demonstrated the effect of reducing urea and adding Silicium to correct the micro-nutrient balance (28).

The results were presented to and discussed with the stakeholders, agents of the extension services, interested local farmers and representatives of farmers from neighbouring communes. Discussions used open questions to analyse the results together, and were done in three FGDs: one group each for officers, female farmers and male farmers. Though the trials did not demonstrate a full recovery, these clearly showed that the farmers had been applying high dosage of N, low K and non or too little organic matter. Twelve farmers registered for an on-farm experiment with an adapted fertilizer regime.

Red River delta

In the Red River delta, two adaptation models were tested: the introduction of a technology package with a new Melon variety (37) and the polyculture of shrimp with red-tilapia (27). The design of an agronomic trial to test a new melon variety in Giao Thuy was simple for the responsible team. However, the farmers needed to be trained in composting and in culturing the new variety; this was done by the seed company. Moreover, to ensure that the participating farmers could avail of the correct inputs and a market for the new variety, the researchers embedded the value-chain concept in the minds of the farmers right at the start of the trial. The value-chain analysis allowed the farmers, who were willing to engage in the market, to benefit from the new melon variety (37).

Step 6: Evaluating the tests

In the Mekong Delta, the Alternate Wet/Dry rice farming and the options to improve water management for shrimp farming at household level were included in the package of the extension agents of Soc Trang province. Rules of the contracts for mixed mangrove–shrimp farming in the special use forests were adjusted. Although producing vegetables at large scale remains an option for the farmers, converting to growing sorghum for livestock farming seems the better one to consider. After the trial period, the teams of Dai Loc and Giao Thuy evaluated the implementation. In Giao Thuy, this evaluation consisted of two straightforward steps: i) listing the constraints and advantages experienced by the participants, and ii) counting the number (%) of farmers who continued to use the new melon variety in the next season (37). The Dai Loc team surveyed the stakeholders and held two plenary meetings to assess the satisfaction on the two equitable water-sharing mechanisms. Overall the stakeholders were very satisfied as no conflict had occurred; all had reached their goals and funding for implementation in the next season was ensured (22). Both cases that had completed the cycle could recommend to the authorities a broader implementation of the solutions.

However, when responses are insufficient to deal with the predicted impacts, the team would need to further analyse the evaluation, and then redesign the solution or propose to implement one of the other solutions that has more constraints, according to the initial assessment of step 4, but which might be more effective.

Step 7: Reporting to the authorities

The last step is to inform the requesting authorities on the results of the tests on the assessment and the development of CC responses. This meeting is also an opportunity to inform or remind these authorities about other challenges and options for follow-up when responses were insufficient. When relevant, the authorities can call upon the university to assist them in identifying responses to CC threats to other sectors. This would make the CCA research a double-edged sword: cutting through both research &training for university staff &students, while simultaneously responding to CC concerns at the local level.

Discussion

As the impact of climate change and resources utilization gets more intense so that the natural resources base, both in quantity (inundation and flood hazards, droughts and water shortages) and quality (salinity intrusion, waste management, sedimentation and fertilization) within agricultural systems and production come under duress, the call to redress these effects on the resources base increases.

The usual response is a quest for planned adaptation. The six described cases using the seven-step approach show conscious anticipatory actions to stimulate autonomous CC adaptation and contain three interwoven restorative themes:

(i) Putting up multi-functional natural resources (water and land) management arrangements, not only to provide specific natural resource functions, but also to combine with direct agricultural production practices.

(ii) Designing climate-smart agricultural production systems that embed technical and social empowerment, good market/profit offer within CC adaptation responses, and

(iii) Enhancing autonomous adaptation that requires human resources and training, as well as creativity and flexibility.

Multiple functions of water

A central feature of the agriculture-based CC adaptation approaches described above, lies in the establishment of multifunctional agricultural systems that provide for the CC adaptation based on water availability. The functions of water for ecology and food production are optimised in an integrated production system that is specifically tailored and nested within its landscape and natural resources base. Safeguarding existing production systems tends to resort in calls for infrastructural measures such as flood protection dykes.

These planned adaptations increase the regulation capacity of the water resources base that depends on government funding and community external interventions. But the more the pressures and impacts on the resources base increase, the more the technical options and cost-effectiveness of such measures become delimiting (32), while at the long term, the production might decrease (24).

With the proposed agriculture-based CC adaptation approach, the CC impacts and adaptation measures are internalised, rather than externalised, becoming central features of a multifunctional production system. In these specific CC-adaptation functions – e.g., flood protection, water retention for drought spells, water purification etc. – are purposely shaped within the landscape and natural resources management arrangements to not only provide specific water (or natural resources) regulation functions to the agricultural production system, but also to combine with direct production functions. Thus, (i) retention of fresh water for rice cultivation in canals or lakes is combined with fresh aquaculture and forestry biodiversity, whilst safeguarding the water supply for biodiversity; or (ii) polyculture-based brackish aquaculture systems with retentions/settling basins to enable the storage of fresh brackish water with good water quality (sanitary, salinity & waste), the production of seafood and waste treatment; or (iii) the provision of drinking water and electricity to complement to food production. In essence, the multi-functionality is given shape by purposely combining and exploiting the inherent multiple ecosystem services (6, 30, 50) and aligning these for multiple uses and services – within a natural resources system (fish & water retention) and across systems (water retention & irrigated rice).

Smart design of production systems

The historical alignment of apparently successful trials in Giao Thuy district, followed by no or weak adoption of the tested technologies, shows that developing adaptations that are effectively taken-up require a participatory approach.

In our case, establishing the water-sharing mechanism required more complex negotiation skills that were not yet available in the community. Once these negotiation skills were embedded at local level through series of trainings, the adaptation by respective stakeholders became more autonomous; but would still require some level of planning in the future.

In their decision for autonomous adaptations, farmers do consider factors relating to the market and economic profitability (1, 17, 18, 25, 33). Therefore, farmers having a good profit margin tended to adapt various methods more autonomously to counteract drought (39), as shown also through the adoption by some other farmers of the new melon variety with a technology package and with good market opportunities after the trial (37). The market element confirms the findings of Fujisawa *et al.* (16) who stated that adaptation policies deployed through sale channels tend to be more successful.

The reluctance of farmers in Dai Loc to shift away from rice, an important commodity for their household's food security, is supported by findings from other authors (42, 2). The six cases demonstrated that the solutions are not outlined from the start, but gradually develop from scratch in consensus between and among the stakeholders.

Stimulating autonomous adaptation

Climate change adaptation includes planned or autonomous actions to enhance the resilience against increasing influences of climate change (35). The implementation of the two fair water-sharing arrangements required many rounds of consultations and signing of contracts, but were successfully implemented in the first year. The rice crop did not fail, and although the electricity company had to accept a lower turn-over, all stakeholders were satisfied with the results and agreed on permanent funding mechanisms for the control. Thus, the water-sharing mechanism should be classified as planned adaptation.

While enhancing household's capacity to adapt to impacts of climate change, the positively tested farming systems required management skills and family labour resources. Promoting farming practices demanding new skills might require support from the government and new services either from public or private partner, particularly for training, credit, input supply and marketing. However, most of the adjusted agricultural practices can spread autonomously from farm to farm (group to group) without government support, if input supply and marketing is not regulated. These adaptations included: alternate wet/dry rice farming, increased on-farm water storage, melon cultivation, polyculture of tilapia and shrimp. The autonomous response usually happens when farmers perceive the benefits or observe the good experiences from others (16, 41).

In some cases, these responses might require (i) first a participatory technology development (20) as done in the proposed step 4, 5 and 6, and (ii) the assistance of a training program by the regular extension services (1). Then, preferably these services organise innovation platforms where farmers exchange know-how (26).

In general, the pilots learned that supporting conscious anticipatory interventions that stimulate autonomous climate change adaptation requires creative and flexible institutions and their respective staff. Nevertheless, increased output from improved integrated farming would also create opportunities for rural employment and market development, which would pay for the complementary public investments.

In most cases, the implementation of the seven steps required training and expert's guidance of the teams on several technical and social tools (Figure 2 and Table 4). Using PRA tools, such as the FGDs to engage the farmers seems easy, but we learned that some trainings are required to obtain good results. Moreover scientist and policymakers tend to neglect the importance of separating farmers from officers and men from women in different FGDs. Giving each person the opportunity to talk is crucial for obtaining all relevant information and support from all groups (4).

Conclusion

The design and establishment of an agriculture-based CC adaptation, as described above, place specific requirements on an integrated and interdisciplinary resources management approach. The first requirement is a multi- (or inter-) disciplinary assessment together with an understanding of the biophysical system. This type of assessment considers the dynamic behaviour of the natural resources base across the realms of climate, water management & hydrology, soils and ecology. The second requires a holistic identification of agricultural production systems that cuts across the broad spectre of crops, aquaculture, fisheries, animal husbandry, (agro)forestry, and ecology. The third considers the social & institutional realms of rethinking on natural resources management arrangements in the context of community stewardship (either private or community enterprise form) of management and exploitation of multiple services. The fourth emphasises the spatial planning and congruent alignment of multiple systems and functions (or ecosystem services) – both at community and river or delta scale. Specific demands in this case are on coordination and integration of plans, policies and regulations across institutional governance levels. These same elements were likewise highlighted in the recent established Mekong Delta Plan.

Using the seven-step approach, the two projects developed climate change responses for the most felt problems which all revolved around water in the districts of Nga Nam, My Xuyen and Vinh Chau in Soc Trang province, and in the districts Giao Thuy (Nam Dinh province) and Dai Loc (Quang Nam province). The experiment in Nga Son demonstrated that climate change can be a scapegoat for poor management and maintenance practices.

Most responses related to improving farming practices of one (rice, melon) or more crops (rice-shrimp, rice-grass or other dry-land crops, tilapia-shrimp), or to increasing on-farm water storage capacity combined with shrimp farming. Crucial for the adoption of a new variety (melon) was the integration of all value chain actors in the trial phase. The response regarding the mangrove-shrimp farming on land, with limited user rights, required changes in the contractual rules on dredging of canals; thus, the need to involve institutions in charge of forest management. Most of the autonomous adaptations were complex and could be developed only by multidisciplinary teams. To be successful even for the introduction of a single new crop variety, all interested value-chain actors needed to be associated to the trials. Except for the water-sharing mechanisms, these adaptations could be realized without engaging in political advocacy. Higher-scale planned adaptations, e.g., of increasing water storage in canals or in upstream flood-plains, are often cross-border issues, and even for district borders, these required negotiation at a higher hierarchical level by politicians or NGOs.

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