Assessment of potential CSA options for future agriculture production in the South Central Coast region of Vietnam

CGIAR Research Centers in Southeast Asia

1-5 April 2017
Khanh Hoa, Ninh Thuan and Binh Thuan Provinces
Vietnam

CGIAR Research Program on Climate Change, Agriculture and Food Security- Southeast Asia (CCAFS-SEA) (2017). Assessment of potential CSA options for future agriculture production in the South Central region of Vietnam. Hanoi, Vietnam.

The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is a strategic partnership of CGIAR and Future Earth, led by the International Center for Tropical Agriculture (CIAT). The Program is carried out with funding by CGIAR Fund Donors, the Danish International Development Agency (DANIDA), Australian Government (ACIAR), Irish Aid, Environment Canada, Ministry of Foreign Affairs for the Netherlands, Swiss Agency for Development and Cooperation (SDC), Instituto de Investigação Científica Tropical (IICT), UK Aid, Government of Russia, the European Union (EU), New Zealand Ministry of Foreign Affairs and Trade, with technical support from the International Fund for Agricultural Development (IFAD).

The CCAFS Southeast Asia Regional Program is led by the International Rice Research Institute (IRRI) and is based in the IRRI Vietnam office in Hanoi, Vietnam.

Acknowledgement

The Assessment Team would like to thank Dr. Le Quoc Doanh, Vice Minister, Ministry of Agriculture and Rural Development (MARD), who suggested that CCAFS conduct an assessment for the South Central Coast, to contribute to the future transformation of the region. The Team acknowledges the support given by Department of Crop Production(DCP)-MARD, through Dr. Nguyen Hong Son, Director General, whose staff provided guidance and inputs to the Team. The Team is also thankful to the People's Committees (PC) and Department of Agriculture and Rural Development (DARD) of Khanh Hoa, Ninh Thuan, Binh Thuan for approving the Team's visit and arranging the site visits. Special appreciation and thanks also goes to CGIAR colleagues and local experts for their invaluable contributions during the site visits and their constructive inputs that improved this report considerably. Many thanks to the farmers in the sites visited for their openness in sharing with us their experiences and insights.

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Acronyms

ACIAR	Australian Centre for International Agricultural Research
ASISOV	Agricultural Science Institute for Southern Central Region of Vietnam
CCAFS	CGIAR Research Program on Climate Change, Agriculture & Food Security
CSA	Climate-smart agriculture
CSV	Climate-Smart Village
DARD	Department of Agriculture and Rural Development
DCP	Department of Crop Production
ENSO	El Niño Southern Oscillation
FOT	Fertilizer Optimization TOol
ICRAF	World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IMC	Irrigation management companies
INGO	International non-government organization
INM	Integrated nutrient management
IRRI	International Rice Research Institute
IWMI	International Water Management Institute
MAR	Managed aquifer recharge
MARD	Ministry of Agriculture & Rural Development
OFRA	Optimising Fertilizer Recommendations for Africa
R4D	Research for development
SEA	Southeast Asia
SCC	South Central Coast
SWUP	Surface water use plan
UN	United Nations
UTFI	Underground taming of floods for irrigation

Executive Summary

As a follow-up to discussions with the Ministry of Agriculture and Rural Development (MARD) about the effects of drought in the South Central Coast (SCC) region, and particularly in light of the impact of the 2014-16 ENSO, CCAFS organized a team to contribute to the development of climate-smart agriculture (CSA) plans for the region. The assembled team conducted a rapid assessment of the biophysical conditions in the SCC region by conducting a site visit, expert interviews, and analyses of available literature. The aims of the assessment were to identify CSA options that could be integrated in ongoing and future climate-adaptation interventions, and to provide science-based recommendations to MARD and local authorities to support future planning and action strategies aimed at coping with unfavorable climate conditions and climate change problems in the region.

The rapid assessment team visited the provinces of Khanh Hoa, Ninh Thuan, and Binh Thuan. These provinces are impacted by drought every year and experienced particularly severe conditions during the 2015-2016 dry season. All three provinces are affected by either heavy rainfall/flooding or severe drought during peak crop growth stages with the result that there is a 30-40% probability of crop failure annually. Furthermore, the three provinces are affected by soil erosion and runoff; low soil fertility; inappropriate soil, water and nutrient management practices; improper land use planning; lack of strategy for drought mitigation; and degradation of the natural resource base.

Based on the members' overall assessment, the team identified opportunities for innovative CSA solutions in seven broad areas, as follows:

1. **Agricultural drought mapping** to identify hotspots of higher climatic risk and aid planning;
2. **Implementation of a more effective water-resource infrastructure** through the systematic construction of infrastructure for surface irrigation and aquifer replenishment;
3. **Increased nutrient and water productivity** through improved agronomic practices;
4. **Strengthening water users groups** to promote more effective farmer management of resources through farmer to farmer water sharing;
5. **Promotion of agricultural diversification** with market-oriented crops that are suitable for the different drought risk conditions;
6. **Improvement in the management of watershed areas and agroforestry areas;**
7. Development of an **integrated systems master plan** for coping with the water-related problems in each of the provinces and in the region as a whole.

The situation in the SCC region provides both a challenge and an opportunity for Vietnam. The prevailing climatic conditions and the scenario projections point to an uncertain future on many fronts. This should drive the implementation of water-saving technologies and recommended CSA solutions. Given the region's exposure to natural hazards, a piecemeal approach is unlikely

to have the desired effect. In fact, the introduction and adoption of innovative CSA solutions at scale is crucially important to achieve region-wide sustainability and resilience.

It is recommended that the potential positive actions identified by the team be considered in the region's policies and regulations in the future; in the incentives adopted to promote new technologies and practices; in investment priorities; and in capacity development initiatives.

Finally, it is notable that Vietnamese agricultural research institutions have a strong history of collaboration with the CGIAR and other research organizations. Many outputs from previous collaborations can be harnessed and mobilized to respond to the present needs of the South Central Coast region, even as investments in R4D are made to find suitable new practices and technologies.

Introduction

The South Central Coast (SCC) is considered the driest area of Vietnam. Agricultural production faces serious problems in the provinces of the region and is vulnerable to the impacts of El Nino (ENSO) and other unpredictable climatic hazards. Seasonally arid, drought-prone conditions particularly affect certain localities in the 3 southern provinces of Khanh Hoa, Ninh Thuan, and Binh Thuan. In lowland and coastal areas of these provinces, drought likely occurs yearly with frequent severe events (UNITAR 2015). Since 2000, severe drought impacts have been recorded in 2002, 2005, 2010, and especially 2016.

Beginning at the end of December (2015), the 2016 dry season in the South Central Coast region started earlier than normal and was also more prolonged, lasting through until August 2016. Water for agricultural and domestic use is drawn mainly from reservoirs, and these saw significant depletion. According to a report from the Central steering committee for Natural Disaster Prevention and Control (CNDPC 2016), March 2016 saw water levels in reservoirs far below the designed capacity. Water volume in reservoirs reduced approximately 50% in Khanh Hoa, 75% in Ninh Thuan, and 60% in Binh Thuan. Drought impacts were recognized in 43% of the natural area of Ninh Thuan, 39% of Binh Thuan, and 13% of Khanh Hoa (Bui Quang Huy et al 2016). This severe drought also resulted in the fallowing of 23,000 ha of rice (15,400 ha in Binh Thuan, 5,770 ha in Ninh Thuan and 1,800 ha in Khanh Hoa). Scarcity of water for domestic use was a big issue and had significant impact on the livelihoods of nearly 32,000 households in Ninh Thuan (5,500 households) and Binh Thuan (25,000 households).

To cope with future droughts, the government has identified various long-term actions and plans. These include adjusting cropping systems and the cropping calendar to adapt to drought and better match irrigation capacity; extending water supply coverage to reach drought-affected areas; drilling deep boreholes to exploit groundwater; strengthening weather forecast and communication capacity; developing plans for using and sharing water sources effectively; completing irrigation structures in high drought risk areas more quickly; and applying water saving technologies and practices.

In partnership with the United Nations (UN), development partners, international non-government organizations (INGOs), and technical experts, the government has also organized a joint team to assess drought response and recovery (MARD et al 2016). This team has provided recommendations for water and crop management, regulatory measures, emergency preparedness and livelihood support, and capacity building.

However, the agricultural services sector in the provinces has not yet been provided with detailed technical guidelines with recommended adaptation practices for specific agro-ecological areas, or with a prioritization framework. In light of the increasing negative impacts of climate change, identifying appropriate solutions for agricultural production of the region is an urgent

requirement. The Department of Crop Production (DCP) of the Ministry of Agriculture and Rural Development (MARD) is planning to organize a consultation workshop to gather promising and practical climate-smart agriculture (CSA) options for sustainable agricultural development, and formulate the short-, medium-, and long-term action plan needed for the region.

Objectives

To analyze the challenges and opportunities, and provide technical recommendations to MARD, the DCP and CCAFS have recently organized a rapid, joint site assessment in the SCC region. The objectives of the assessment were:

1. Rapidly assess bio-physical conditions in the SCC region through an actual site visit, expert interviews, and analyses of available literature.
2. Identify potential CSA options that can be integrated in ongoing and future climate-adaptation interventions.
3. Provide science-based recommendations to MARD and local authorities that can support future planning and actions to cope with unfavorable climate conditions and climate change problems.
4. Identify feasible research for development (R4D) activities of CGIAR centers in the region.

The assessment will also help CGIAR research centers to identify entry-points for contributions to coping with the impacts of climate change in the SCC.

Methodology

Site Selection

The sites visited for the rapid assessment were selected based on the literature review and suggestions from the Department of Crop Production (DCP) and the Provincial Department of Agriculture and Rural Development (DARD). First, Khanh Hoa, Ninh Thuan, and Binh Thuan provinces were selected as appropriate locations due to the annual impacts of drought in these provinces and particularly during the 2015-2016 dry season (Figure 1). Land use maps (2010) and drought index maps (2016) were then used as references to identify the most affected areas and districts in each of the three provinces. The districts that had the largest drought areas in each province (Table 1) were then selected for the site assessment. The travel itinerary and program of the assessment team are listed in Appendix 2.

The Assessment Team

The assessment team was composed of experts in crop production management (DCP, MARD), rice cultivation (International Rice Research Institute, or IRRI), tree-integration/agroforestry in farming systems and landscapes (World Agroforestry Centre, or ICRAF), watershed management and cropping systems for dryland (International Crops Research Institute for the Semi-Arid Tropics, or ICRISAT), water management (International Water Management Institute, or IWMI), crop health management (Center for Agriculture and Biosciences International or CABI), and local experts in industrial crop production (Agricultural Science Institute for Southern Central Region of Vietnam, or ASISOV). The members of the team are listed in Appendix 3.

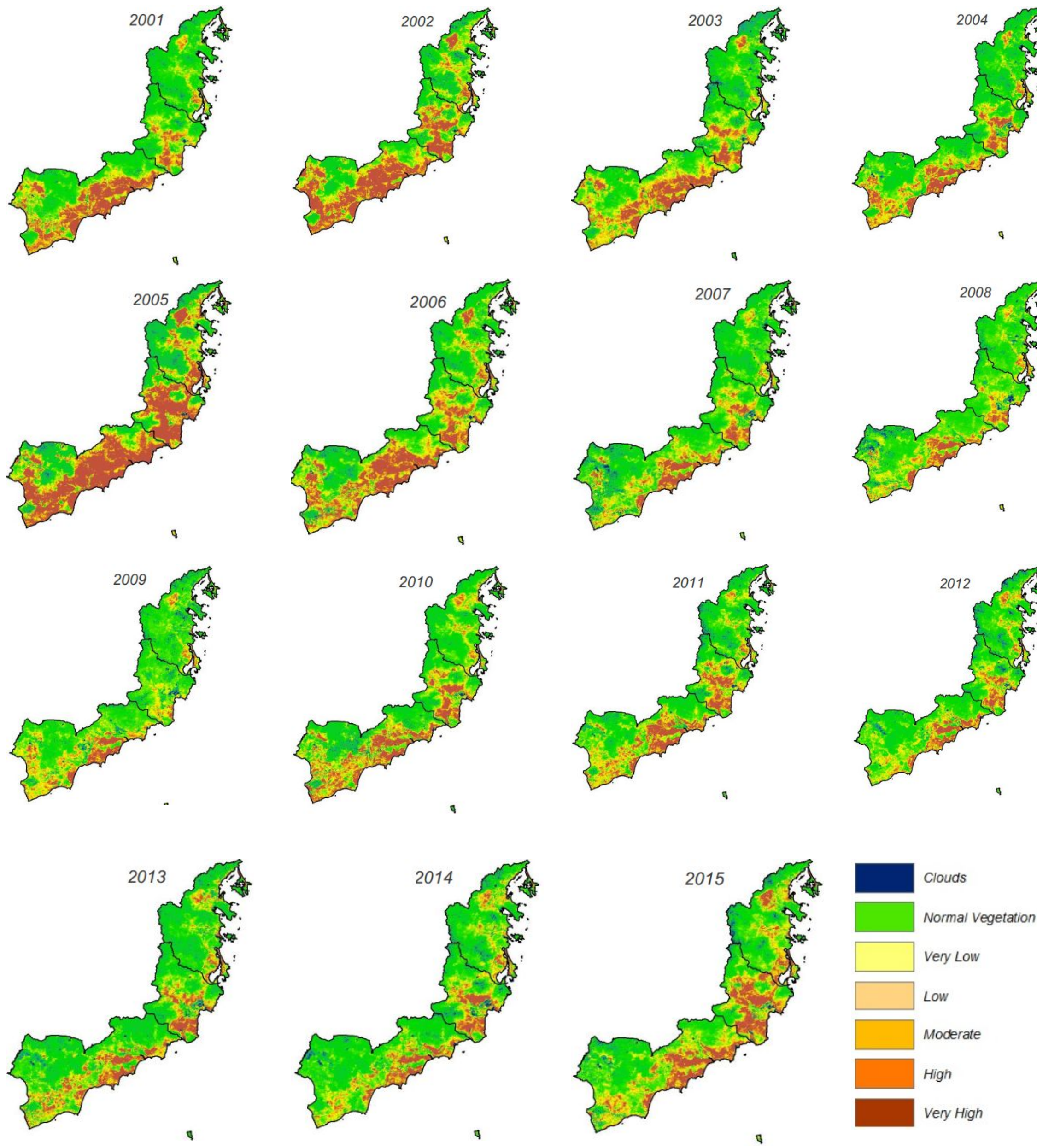

Figure 1. The variation of drought index from 2001 to 2015 of Khanh Hoa, Ninh Thuan and Binh Thuan provinces (UNITAR 2015).

Table 1. Drought affected area by district in Khanh Hoa, Ninh Thuan and Binh Thuan provinces (updated on 24/3/2016)

Districts	Actual area (km^2)	Drought impact area	
		Area (Km^2)	Proportion (%)
Ninh Thuan			
Phan Rang	80.1	37	46.8
Bac Ai	1,032.0	386	37.4
Ninh Hai	253.3	32	13.6
Ninh Phuoc	344.1	181	53.1
Ninh Son	774.0	422	54.5
Thuan Bac	318.6	98	30.8
Thuan Nam	560.5	312	59.1
Binh Thuan			
Bac Binh	1,873.2	1105	59.4
Duc Linh	546.0	182	33
Ham Tan	735.9	230	47.6
Ham Thuan Bac	1,346.8	616	45.9
Ham Thuan Nam	1,060.8	352	43.5
Tanh Linh	1,201.3	210	17.5
Tuy Phong	774.5	257	36.2
Phan Thiet	210.8	135	71.8
La Gi town	183.4	36	25.2
Khanh Hoa			
Cam Lam	676.5	135	22.1
Dien Khanh	344.6	51	14.8
Khanh Son	340.6	11	3.2
Khanh Vinh	1,170.4	63	5.4
Ninh Hoa	1,202.0	278	24.6
Van Ninh	510.7	13	2.8
Cam Ranh	297.9	76	36.9
Nha Trang	216.7	3	1.7

Information Collection Methods

Following a review of literature, the assessment team collected information from field observations and key informant interviews with the provincial and district level officials of the DARD, the provincial level of the Department of Water Resources and its line offices, and face-to-face interviews with farming households and local government representatives.

Key guide questions asked during the field visits

- What are the bio-physical challenges for agricultural production in the region?
- What are the possible relationships between climate-related hazards and the bio-physical characteristics of the region?
- Which agricultural products (crops, livestock) are most deeply affected by the current conditions?
- Are there existing techniques/practices being applied by farmers and/or local organizations to cope with unfavorable conditions? What has been the effect of the practice/technique?
- What are the potential areas where unfavorable conditions could be effectively addressed in the province/region? What would be required to make this happen?
- What plans do farmers/agencies intend to implement in order to cope with climate-related hazards in the future? What support/contribution will be needed from other stakeholders (government, private sector, research community)?
- What CSA options can be recommended for evaluation in the region to ensure sustainability?
- What can be foreseen as the future direction of agriculture in the region considering the challenges and development trajectories of the region?

Climate Analysis of South Central Region (by ICRISAT)

For this report, ICRISAT analyzed the long term trends for observed seasonal precipitation and temperature over south central coastal Vietnam using AgMERRA gridded daily rainfall and temperature at 0.25 degree spatial resolution for the time period 1980-2009 (30 years) (Ruane et al 2016). The range of indicators is presented in Appendix 1.

Key Observations and Findings

All three provinces are affected by either heavy rainfall/flooding or severe drought during peak crop growth stages, ultimately affecting crop productivity. In general, probability of crop failure is 30-40 per cent and even when failure does not occur, a wide yield gap exists. The overall situation can be categorized as being affected by soil erosion and runoff; low soil fertility; inappropriate soil, water and nutrient management practices; improper land use planning; lack of strategy for drought mitigation; and natural resource base degradation.

More specifically, the following observations were made:

1. A recurring phenomenon, drought in the SCC varies from year to year in terms of quantity of rainfall and its intra-year distribution, exacerbated most severely during ENSO years (especially those years with prolonged occurrence or in which rainfall is reduced significantly).
2. Land degradation due to aberrant rainfall events is increasing, resulting in a decrease in factor productivity.
3. Surface water flow is very limited as there are no major rivers or their tributaries in the region. There is limited/seasonally constrained surface and groundwater storage, leading to shortfalls in water availability for supplementary and/or dry season irrigation. This condition also varies the effects of drought in different areas within and among the provinces.
4. The water table in many areas is deep, and in some places it is within thick rock layers. Poor groundwater availability can also be due to limited thickness of sedimentary sequence and/or heterogeneous basement rock properties.
5. Unchecked deep drilling potentially threatens the groundwater resource. This is compounded by an absence of monitoring of groundwater use.
6. High dissolved iron (i.e. $Fe2+$) content in groundwater in some areas (e.g Ham Thuan) leads to lower nutrient bioavailability and reduced yields, as surface water low in iron is preferred in agricultural production.
7. Changes in cropping patterns are observed, but cropping system diversification based on land capability is still required in many areas.
8. Water-saving technologies are being utilised for certain crops, for example, grapes, mangoes, citrus, dragon fruit, and vegetable production.
9. Crop damage and yield losses due to frequent flooding or high air humidity during wet season (e.g rice in Ninh Hoa District or grape in Ninh Son district) are observed.
10. The issue of conflict over water use is expected to become more serious in the future, for example between upstream and downstream farmers in a river basin or irrigation system; and between water for agriculture and water for other uses. High water costs are also due to water imports from neighboring districts.

Lowland Areas

1. This area is predominantly designated as a rice area and hence mostly planted to rice.
2. The current policy support is focused on rice production, which is a disincentive to diversification to crops that require less water.
3. Crop diversification (vegetables, dragon fruits, grapes and mango orchards) is occurring in designated rice areas. This deviates from existing policies, but in practice recognizes the constrained water and high risk associated with rice farming in these areas.
4. The irrigation system was constructed to support the rice production thrust of Vietnam in the 1980s and 1990s, and displays a poor drainage element. This makes it difficult to diversify in some areas.
5. The lowland areas have mostly sandy soils with very low organic matter content.
6. Many farmers use good farming principles and practices, like VietGAP. However, many still use too much water, poorly balanced fertilizer inputs, and improper pesticide application. The implementation of VietGAP principles and practices appears inconsistent also, as farmers continue to use substantial amounts of pesticides on their crops (e.g. grapes).

Coastal Areas

1. The area is planted with vegetables (garlic, onion, chili, asparagus, lettuce, ground nut), along with mangoes, dragon fruit and grapes.
2. The area has good potential for improved crop diversification and the introduction of new crops into existing cropping systems (e.g. sweet sorghum, short duration chickpea, cowpea, etc). The current cropping systems are highly affected by drought conditions.
3. Current farmer-managed irrigation systems are dependent on a limited groundwater source. Over-extraction of both groundwater and surface water is leading to ingress of seawater and the salinization of coastal waterways and groundwater.
4. Light soil texture (e.g. loamy sand or sandy loam) leads to poor water retention, highl infiltration and low soil nutrient content. The soil nutrient base has been highly mined or eroded.

Hilly Areas

1. Vegetation cover is generally low in the region. The hills surrounding the flat to undulating croplands are severely denuded with almost no tree. In areas where vegetation cover is higher, low monetary value trees, shrubs and bushes are dominated vegetation. These exacerbate soil erosion and flooding. Water flow-induced erosion is a major problem during the rainy season and wind is the primary agent of erosion during the dry season.
2. The area for natural forest shows a declining trend, whereas acacia plantation is expanding rapidly in some provinces. The expansion of shallow-rooted tree species such as *Acacia mangium* may not help much in improving water recharge in the landscape. Growing Acacia is also not as profitable as expected.

3. The area is basically rainfed with limited water storage capacity or irrigation infrastructure.
4. Crops found in the hilly areas include rubber, cassava, sugarcane and fruit trees.

   Additional observations are described in Appendix 4 and 5.

Opportunities for Innovative CSA Solutions

The SCC region is characterized by its dry weather and it is evident that the effects of climate change are primarily felt in terms of water-related constraints (drought, salinity intrusion, and water shortage during the dry season). For this reason, solutions to the current effects of climate change must focus on agricultural water management. Below are some suggested actions:

1. **Agricultural drought mapping** to identify hotspots of higher climatic risk, for planning land use and farming systems that are more resilient to high climate variability;
2. **Implementation of a more effective water-resource infrastructure** through the systematic construction of infrastructure for surface irrigation and aquifer replenishment;
3. **Increased nutrient and water productivity** through improved agronomic practices;
4. **Strengthening water users groups** to promote more effective farmer management of resources through farmer to farmer water sharing;
5. **Promotion of agricultural diversification** with market-oriented crops that are suitable for the different drought risk conditions (based on drought risk maps);
6. **Improvement in the management of watershed areas and agroforestry areas.** In a dry area like the SCC region, the use of perennial and annual systems, along with incorporation of livestock enterprises will bring higher levels of resilience to the farming systems; and
7. Development of an **integrated systems master plan** for coping with the water-related problems in each of the provinces and in the region as a whole.

Description of the proposed actions

1. Agricultural drought mapping to identify hotspots of water shortage for land use planning.

Leaders of DARD in Ninh Thuan and Binh Thuan made the strong point that even though the province has been facing serious drought for many years, a map (1:50,000) to show agricultural drought hotspots has not been prepared. They agree that such a map would be useful for land use and irrigation planning. In particular, if the map could be incorporated with a drought early warning system, coordination for water allocation would be much more efficient. To prepare such a map, a process similar to the preparation of salinity and flood maps for the Mekong River Delta provinces organized by CCAFS since December 2016 could be applied. However, in this case the indigenous knowledge will be contributed by local officers from districts in the SCC provinces rather than by provincial officers as in the Mekong Delta mapping project.

The map should combine meteorological and hydrological data from normal years and severe

drought years (i.e. ENSO years). Areas that are affected by drought every year should be marked as high risk (red). Other water deficit areas should be marked as moderate risk (yellow), and low risk (green). Likewise, areas usually affected during severe drought periods should be identified. Corresponding with the risk areas (red, yellow, green areas), land-use options will be recommended based on available knowledge and research and development studies. These recommendations should include reference to suitable crop species and varieties, and their water requirements (Nor Adawiyah Abdullah et al, 2014); crop-specific management practices (e.g. crop selection and establishment, cost effective water and nutrient management, pests and general crop health management, post-harvest management); and cropping calendars (taking into account seasonal forecast and water availability).

2. Effective management of water resources.

Managed Aquifer Recharge (MAR) is a well-established method of enhancing groundwater recharge by harvesting surface water to achieve a variety of water management objectives. It has been applied in a great many countries for decades, but experience is limited in Vietnam. MAR trials are due to commence in Dak Lak province in areas where intensive groundwater pumping for coffee production has led to declining groundwater availability. A new means of implementing MAR referred to as '*underground taming of floods for irrigation*' (UTFI) has been proposed by IWMI and is being tested in the Ganges Basin. UTFI is a form of MAR that is implemented at the catchment scale to increase groundwater volume for irrigation and other purposes and to reduce the damage caused by floods downstream during heavy rains (http://utfi.iwmi.org/). Global assessments of UTFI reveal that this may also have value in the Vietnam context.

MAR/UTFI must be implemented in a staged approach to minimize risks and influence policies and investment strategies of potential donor/implementing agencies. The first stage typically commences with site selection, design of MAR intervention according to the setting, and baseline assessments. This is followed by pilot testing for demonstration and learning, and ultimately scaling-out to larger areas.

Lack of reliable of water supplies at the household and community level is a major concern in areas where there are no major surface water or groundwater storage facilities. In such areas, harvesting of rainwater from residential dwellings and other significant areas of untapped roof space for local domestic use may be implemented. Studies in the Mekong Delta show that rainwater is often the most common water source for domestic supplies, and that a total storage capacity of about five cubic-metres is sufficient to last through the dry season (Özdemir et al., 2011). In the case of Laos, an area of five cubic-metres is also sufficient for domestic and small garden, with an acceptably low probability of emptying the tank (Jacq et al n.d.). For large household sizes or where supplies are needed to also support gardening, the economic feasibility of providing larger storage may be a serious consideration, even where surfaces to collect water for the required volume are present.

3. Increased soil nutrient and water productivity

Changing to direct dry seeding with the use of available irrigation facilities, using drought tolerant rice varieties and applying alternate wetting drying (AWD) method can help optimize water use during the dry season. For direct dry seeding, the introduction of suitable machinery for land levelling (laser), seeding, weeding, and harvesting should be supported.

Because pumped groundwater comes at a direct (input) cost to the farmer, farmer-managed groundwater use seeks to be efficient. However, despite the efforts of farmers not to overwater, high leaching losses may be incurred due to the light textured, permeable soil. Opportunities to reduce demand and increase water productivity may be achieved through improved organic matter management, bringing about crop productivity improvement by increasing the water holding capacity and fertility of the root zone soil, and minimizing leaching of water and nitrate to the groundwater.

As indicated in an Australian Centre for International Agricultural Research (ACIAR) project report (Keen et al 2013), the main constraints in South Central Coast sands have been identified as low organic matter/soil carbon; acidity; alkalinity; low water and nutrient holding capacity; high infiltration and nutrient leaching; hardpan formation (depending on land use history); N, P, K, S, Cu, B, Zn and Mo deficiencies. Nutrient omission experiments with soil-applied K and S and soil- or foliar-applied micronutrients demonstrated that correction of nutrient deficiencies can result in significant productivity gains (20-30%) in annual crops, such as peanut, and in tree crops including cashew and mango grown in South Central Coast sand.

A balanced nutrient management strategy based on soil testing is essential to this region. At present, farmers are blindly applying only the major nutrients, and this is one of the stumbling blocks for higher crop productivity. Fertilizer manufacturers in Vietnam currently lack the technology to produce slow release, complete, and micro-nutrient fertilizers, so availability of these types of fertilizers is very limited. Collaborating with fertilizer manufacturers in Vietnam to develop technologies to produce high quality, slow release, complete, and micro-nutrient fertilizer products will increase their availability. However, it will require sustained co-investment in the longer term to demonstrate proven fertilizer combinations and application rates, and to facilitate the development of a supply chain.

Utilization of organic soil amendments and mulching can increase soil water holding capacity, improve soil physical parameters, and ameliorate soil nutrient deficiencies. Previous ACIAR projects (Keen et al., 2013) demonstrated the potential for rice husk biochar to be an economically effective soil amendment to improve cashew, mango, and peanut productivity in sand. The rice husk biochar effect was greatest when combined with manure and NPK. This may have occurred due to the rice husk biochar increasing soil carbon, soil water (marginally), nutrient retention, and by slow release of P and K. Improved storage and composting methods for preparing cattle manure soil amendments also improved peanut productivity. Manure adds limited N and P to the soil unless application rates are high, but K supply may be significant and manure can also be a source of Cu.

Farmers are currently relying on high doses of inorganic fertilizers with little or no application of

organic fertilizers. Good scope exists for introduction of appropriate integrated nutrient management (INM) practices. In this context, CABI's Fertilizer Optimization Tool (FOT) could be considered. The tool is based on the principle of fertilizer optimization for use in a range of agro-ecological zones and was developed under the auspices of the Optimising Fertilizer Recommendations for Africa (OFRA) project.

4. Strengthening water user groups

High spatial variability in water availability necessitates linking farmers with a water surplus to those with a water deficit. The objective here is to avoid the need for high cost imported water by linking water suppliers with water users at the local level. In the South Central Coast, the water users group can be linked to farmers/growers associations using groundwater for irrigating their crops (mango growers, dragon fruit growers, vegetable growers). At present, such arrangements are informally agreed among individual farmers and show little coordination in harmonizing crop types or irrigation calendars. If water user groups are organized, it is envisaged that the use of water resources, in particular groundwater and surface water, will be improved and water use efficiency will be higher. Water users groups can also make distribution of water more equitable among farmers (in different location, type, or size of farm), provide a more reliable water supply that is responsive to crop needs, and facilitate quicker dispute resolution at the local level (Kazbekov et al 2007).

It is noted that some water users groups already exist in surface irrigation systems managed by the government or irrigation management companies (IMC). In such cases, these water users groups should be strengthened to make them effective partners in the management, operation, and maintenance of the system. Related to this, water pricing has to be reviewed so as to promote use of water-saving techniques and ensure maintenance of systems' infrastructure and operations (no free irrigation).

5. Promoting agricultural diversification

The limited and limiting availability of water in the region requires rotation or moving away from rice production and instead promoting crop diversification to market-oriented crops that are suitable for the different drought risk conditions (based on drought risk maps). Moving to market-oriented crops (domestic or international markets) is feasible considering the suitability of high value crops such as grapes, dragon fruits, vegetables (onion, garlic, bell pepper, etc), legume crops (peanut, green bean, mungbean), and fruit trees (mango, cashew, orange, pomelo etc).

In order to support diversification, a level playing field in terms of policy support is needed and should include efforts toward remunerative prices for the crop, assured marketing of alternative crops, value addition and processing (cassava in Ninh Hoa is an example). Supportive policies could also include the removal of subsidies for rice, a review of land-use zoning to open it up for crop diversification, and the introduction of tax incentives for crop diversification and the use of water saving technologies. The expansion of planting areas for these crops can be increased with better market access. There is, however, a need to redesign the irrigation system to

facilitate crop diversification, for more efficient distribution of water, and for better drainage (e.g. use of pipe irrigation and provision for drainage). This will also allow the more effective use of other water-saving technologies for diverse crops (in line with Decision No. 1788/QD-BNN-TCTL of 2015 by MARD promoting advanced water-saving irrigation for upland crops).[1] Large scale crop diversification will also need new guidelines for water-use in alternative crops, and the application of water saving technologies e.g. irrigation and fertigation. These guidelines only exist in rice, maize and grapes but are not yet formulated for other crops.

Currently, commercial planting of *Sterculia foetida sp.* can be observed in the region. A study on the biophysical suitability and markets for high-value multi-purpose tree species such as *Sterculia foetida sp.* should be supported to explore different options, especially since farmers are open to shifting their land use and/or crops to respond to climate change related challenges. Options suitable for consideration may include crop intensification in rice fallows (i.e. depending on water availability in the non-rice season, short duration pulse or cereal crops may provide additional income and inputs to the system); short duration, drought-avoiding pulses (chickpea, cowpea); oil seed crops (peanuts); or combinations of drought-resilient longer duration crops such as pigeon pea, intercropped with shorter duration pulses and cereals. If a bioenergy industry emerges, biomass crops such as sweet sorghum (grown as a complementary biofuel feedstock to sugarcane) has shown great promise in India, China, and other regions.

To increase the resilience of the poor in the region, who may have more limited capacity to diversify into commercial crops or who may be located in less productive (barren and degraded) areas, an integrated systems approach with inclusion of small ruminants can be promoted. Small livestock (pigs and chickens) can also be included for smallholders who have limited land to help buffer the shocks from extreme weather-related events. These animals provide immediate sources of income (from the sale of the animals) during crop failure, and provide access to food (eggs and meat) to smoothen consumption when there are not enough staples produced from the farm.

Development of larger-scale diversified landscapes that support and improve ecological resilience in agricultural systems requires a more in-depth analysis of farm business, and landscape-level scenario modelling for on-farm diversification possibilities. Stakeholder involvement and participatory research are useful tools in developing adaptation options that have a higher likelihood of uptake by the local community (Central Highland Report 2016).

6. Integrated watershed management and agroforestry.

Considering the dry conditions in the region, there is a need to develop a paradigm tailored to the special conditions of the sloping land ecoregions. A diverse land use mosaic with trees helps maintain the landscape's water balance (Myers 1988). Trees modify water balance in a watershed through their morphology and phenological processes, both above and below ground. Above ground, the tree canopy intercepts rainfall and reduces its erosive power on the ground

[1] MARD decision No. 1788/QD-BNN-TCTL dated 19th May 2015, Action plan for the development of advanced water saving irrigation for upland crops to assist the Water Resources Sector Restructuring Plan.

surface. To improve management of watersheds in the area, the following points can be considered for implementation:

- Benchmark sites should adopt an integrated watershed approach with emphasis on addressing the issues of runoff, drought, and soil erosion.
- Farmer-managed natural regeneration could be promoted to allow for native tree species to regenerate on farmlands. This is a low-cost approach to bringing back useful trees in the landscape. Such tree regeneration has multiple benefits; it improves microclimates, adds biomass to the soil from tree litter, and develops soil macropores that improve water infiltration. Otherwise, intercropping with high-value tree species for timber, fruits, or fodder is also an option in addition to the ecosystem services they provide. Assisted natural regeneration in the denuded hills can/should also be supported. As well as improving overall tree cover, it brings multiple additional benefits including control of soil and wind erosion, climate amelioration, and improved water recharge.
- Diversification of acacia plantations with deep-rooted exotic or native tree species should be promoted not only to enhance ecosystem provisioning of tree plantations, but also to spread economic risks when the market for acacia pulp becomes saturated. In addition, a transition to long-rotation acacia plantations should be promoted and supported for farmers to produce high-quality timber and take advantage of the rapidly growing demand for timber in Vietnam.
- Tree planting around farmplots should be also promoted to serve as windbreaks, thus protecting crop damage from strong winds, and mitigating wind erosion. Suitable boundary tree species can be identified through analysis of tree-biophysical suitability.
- Identification and/or introduction of appropriate technologies with a focus on soil, water and nutrient management at the micro-level in a watershed context will help optimize food production and arrest further erosion of the natural resource base.

The ultimate aim of every watershed management strategy is to stabilize groundwater storage and steady river flow. This plays a significant role not only in enhancing water balance, but also for climate amelioration, improving soil infiltration, influencing rainfall amount and pattern, and watershed protection in general. In addition, good watershed management also prevents soil erosion and reduces sediment deposition in reservoirs.

7. Integrated systems master plan

The water deficit condition in the region affects not only agriculture but also non-agriculture activities. The demand for water for non-agricultural use, especially for urban areas is expected to increase with the growth of urban areas and the development and expansion of other sectors (e.g. tourism). The issue of water use, therefore, needs to be addressed beyond its impact on agriculture. Agricultural requirements have to be considered in relation to the demands from other sectors (White et al 2014). Considering that political exigencies often prioritize the demand for water in urban areas or for household use over the needs of agriculture during water shortage in the region. An integrated system's master plan will put the future direction of agriculture in the region in a clear perspective. An example is Binh Thuan's Surface Water Use Plan (SWUP), which is enforceable until 2020.

Conclusions

The South Central Coast provides both a challenge and opportunity for Vietnam. Both the prevailing climatic conditions in the region and the scenario projections point to a dire situation in terms of drought, flooding, water supply, conditions for rice production, and availability of natural resources. Conditions are also being aggravated by continuing soil erosion and runoff; inappropriate soil, water and nutrient management practices; outdated land use plans; fragmented drought mitigation; and degradation of the natural resource base.

The situation, however, is not hopeless. Managed correctly, it can provide an opportunity to apply integrated solutions that will not only enable agriculture to cope with current and future conditions but will also transform the region's agriculture to be productive and sustainable. The situation should drive the implementation of water saving technologies and other recommended CSA solutions described in this report. Piecemeal solutions should be avoided given the magnitude of the region's exposure to natural hazards. Furthermore, the introduction and adoption of innovative CSA solutions, at scale, is thus, crucially important to achieve region-wide sustainability and resilience.

It is recommended that such solutions be considered in policies and regulations (focus on rice relative to other crops, land use plans, irrigation policies, loans); incentives for new technologies and practices (water-saving technologies, crop diversification, water-shed management); investment priorities (MAR/UTFI, pipe irrigation, early warning systems, new crops/varieties); and capacity development for the region.

It is notable that Vietnamese agricultural research institutions have ongoing and historic collaborations with the CGIAR and other organizations. These collaborations have already generated outputs that can be mobilized (repackaged and adapted where necessary) to provide numerous technologies, practices, and knowledge products relevant to the situation of the drought-affected areas. These outputs can be harnessed and mobilized to respond to the needs of the South Central Coast region, even as new investments in R4D are made to find new solutions.

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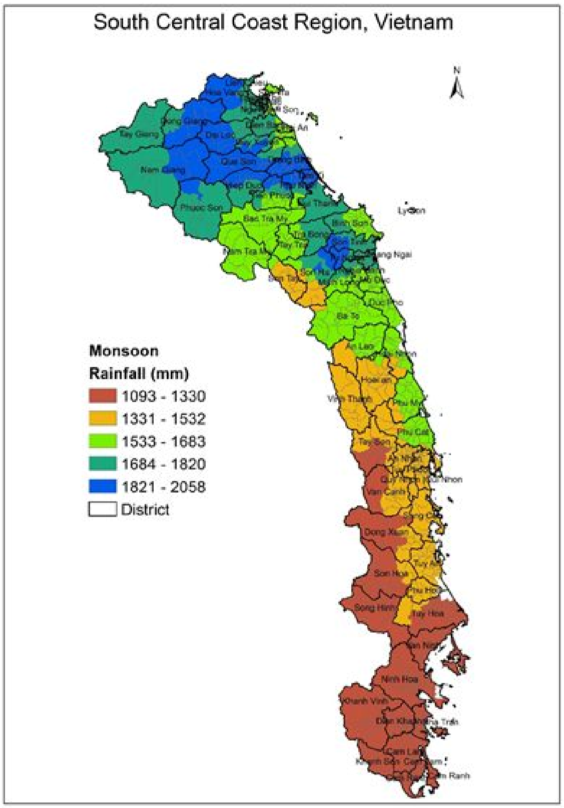
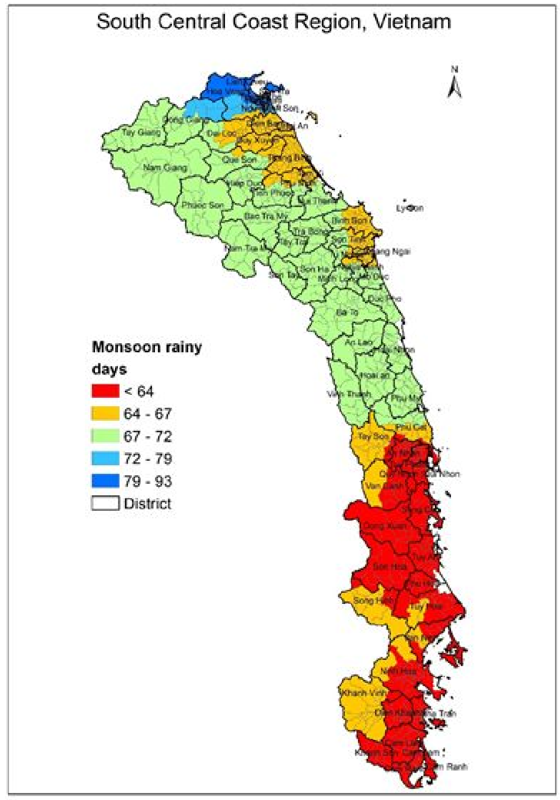
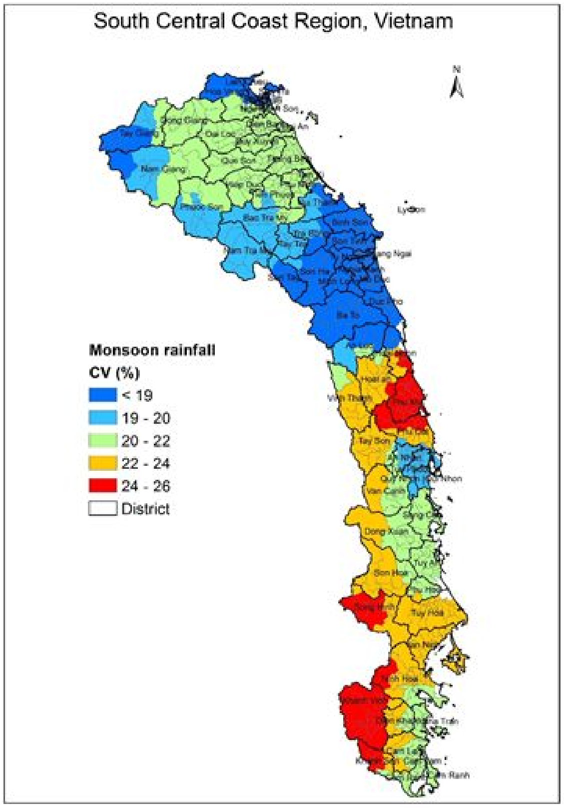
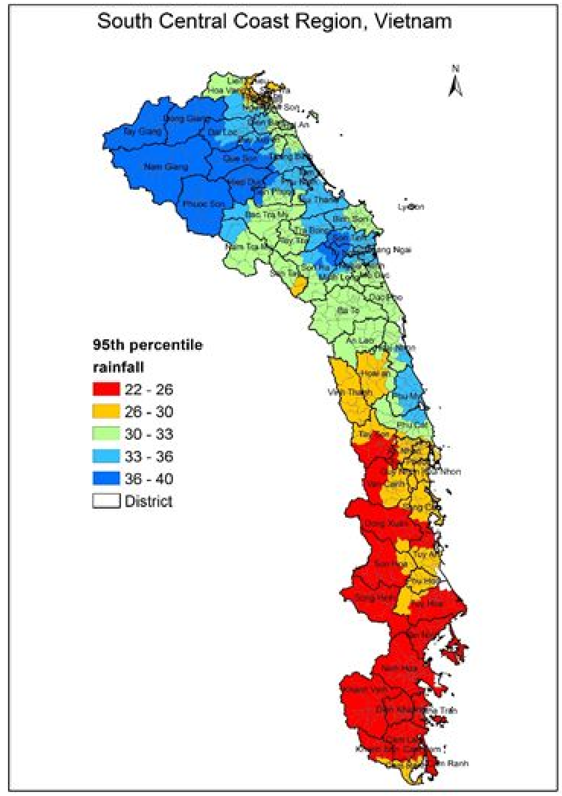
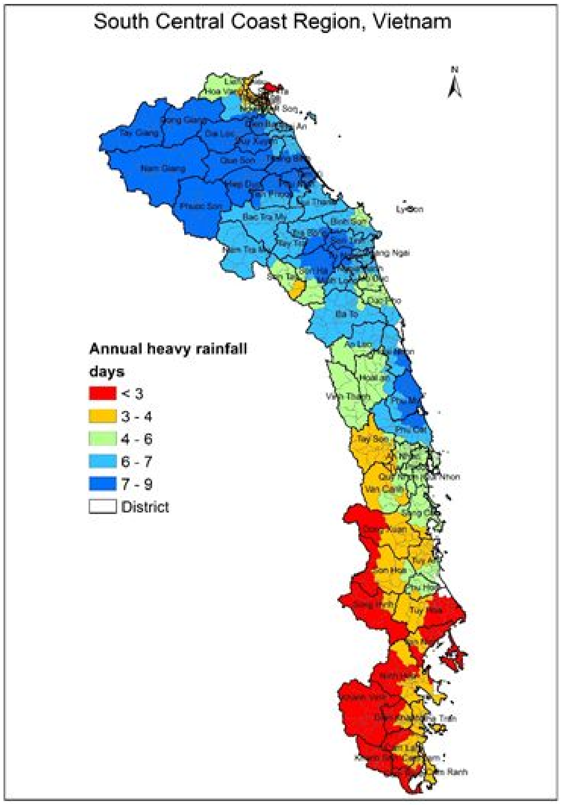
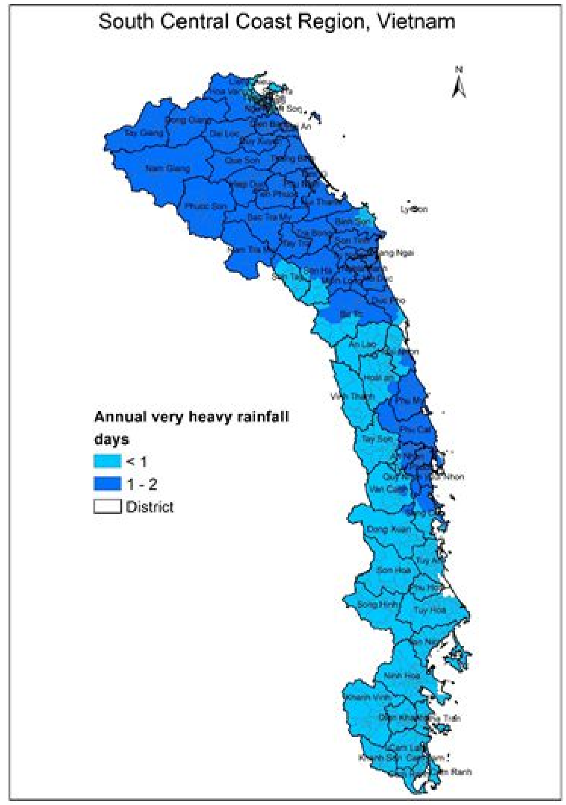
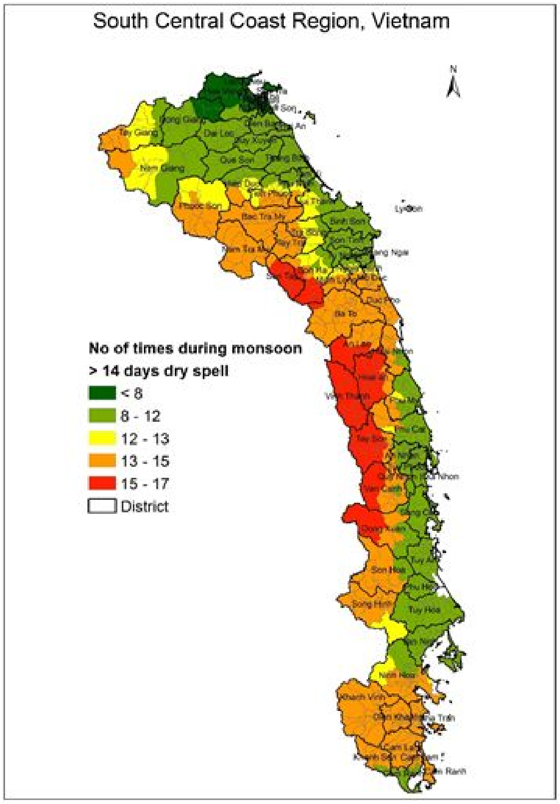
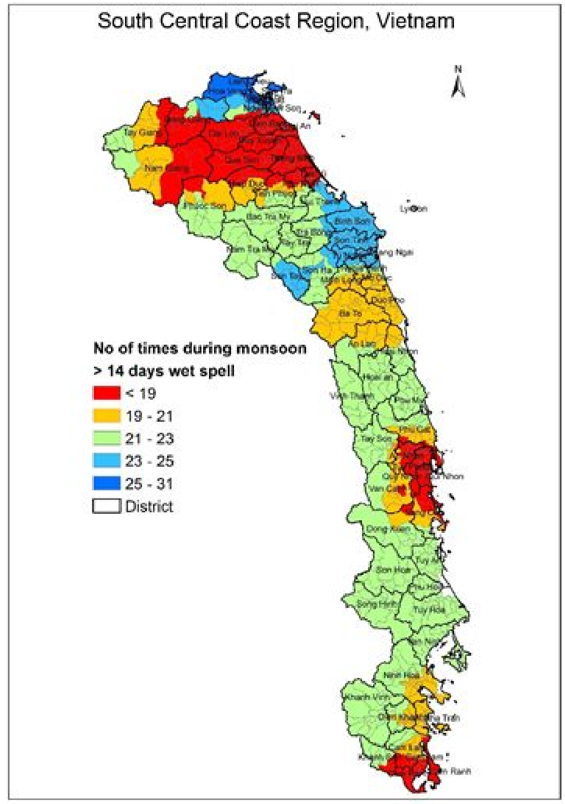
Appendix 1. Indicators used for climate analysis

Indicator	Description
Annual Maximum Temperature	Mean 30 year annual maximum temperature in °C
Annual Minimum Temperature	Mean 30 year annual minimum temperature in °C
Heat wave occurrence (days)	No of days when maximum temperature is > 45° C
Cold wave occurrence (days)	No of days when minimum temperature is < 10° C
Severe Heat wave occurrences (days)	No of days when maximum temperature is > 47° C
Severe Cold wave occurrence (days)	No of days when minimum temperature is < 8° C
CV of annual precipitation (%)	Coefficient variation of total rainfall for 30 year slice
Annual Precipitation	Total amount of rainfall (mm) received during a year
Monsoon rainfall	Total amount of rainfall (mm) received during June to September
CV Monsoon rainfall (%)	Coefficient variation of monsoon rainfall for 30 year slice
Simple daily Intensity Index (Mm/day)	Annual total precipitation divided by number of number of wet days (defined as RF>=1.0 mm)
Heavy rainfall (days)	No of days of daily rainfall events >64.5
Very heavy rainfall (days)	No of days of daily rainfall events >124.5
No of times more than 14 days of dry days in monsoon (no/time slice)	Number of consecutive two weeks of dry days in monsoon period over 30 year slice in monsoon period during a year
No of times more than 14 days of wet in monsoon (no/time slice)	Number of consecutive two weeks of wet days in monsoon period over 30 year slice in monsoon period during a year
Number of annual rainy days	Annual count of days when RF>=2.5 mm

	
Mean total amount of rainfall (mm) received during monsoon season	Mean total number of rainy days received during monsoon period

	
Coefficient of variation (%) of monsoon rainfall during	95th percentile rainfall during monsoon period

	
Average number of annual heavy rainfall days during 1980-2009	Average number of annual very heavy rainfall days during 1980-2009

	
Number of times more than 14 days of dry spell during monsoon period in 1980-2009	Number of times more than 14 days of wet spell during monsoon period in 1980-2009

Appendix 2. The itinerary of the assessment team

1st April, Saturday	
Morning	Arrival of the assessment team
Afternoon	Group meeting at the hotel to go through the working plan
Evening	Stay in Nha Trang city
2nd April, Sunday	
Morning	Site assessment in Khanh Hoa province
Afternoon	Travel from Khanh Hoa to Ninh Thuan province
Evening	Stay in Phan Rang city (Ninh Thuan province)
3rd April, Monday	
Morning	Site assessment in Ninh Thuan province
Afternoon	Travel from Ninh Thuan to Binh Thuan province
Evening	Stay in Phan Thiet city (Binh Thuan province)
4th April, Tuesday	
Morning	Site assessment in Binh Thuan province
Afternoon	Group debriefing
Evening	Travel from Binh Thuan to Vung Tau
5st April, Wednesday	
Morning	Departure of the assessment team

Appendix 3. The members of the assessment team

Name	Position/Organization
1. Dr. Leocadio Sebastian	Regional Program leader, CCAFS-SEA Country representative, International Rice Research Institute (IRRI) office in Vietnam
2. Dr. Bui Tan Yen	Science officer, CCAFS-SEA
3. Dr. Chu Thai Hoanh	Principal scientist, International Water Management Institute (IWMI)
4. Dr. Paul Pavelic	Country Representative, International Water Management Institute (IWMI) office in Laos
5. Dr. Annamalai Sivapragasam	Regional Director, CABI
6. Dr. Delia Catacutan	Country Representative, World Agroforestry Center (ICRAF) office in Vietnam
7. Dr. Sawargaonkar, Gajanan	The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
8. Pham Vu Bao	Department of Science Management and International Cooperation, Agricultural Science Institute for Southern Central Region of Vietnam (ASISOV)
9. Mrs. Tran Thi My Hanh	Officer, Department of Crop Production (DCP), Ministry of Agriculture and Rural Development (MARD)

Technical Inputs:
Dr. Anthony Whitbread, Dr Murali Gumma and Dr Dakshina Murthy, ICRISAT-India

Technical Editing:
1) Mr. John Cleary, NUIG/CCAFS
2) Ms. Amy Cruz, ICRAF/CCAFS

Appendix 4. Field notes

Khanh Hoa province:

Local staff:

- Ms. Luong Kim Ngan, Deputy Head of the Crop Production and Plant Protection office
- Mr. Le Quang Vinh, official of the Department of Crop Production and Plant Protection
- Mr. Tran Quoc Khanh, official of the Plant Protection Station of Cam Lam commune

The Department of Crop Production and Plant Protection of Khanh Hoa province reported a total of 45,000ha planted with rice in Ninh Hoa district, including 19,000ha of Winter-Spring rice, 18,500ha of Summer-Autumn rice, 6,000ha of Summer rice and 500ha of rainfed rice. About 17,000ha were irrigated during the rainy season (September-November). Agricultural lands buffered by a mountain range and crops were grown on the plains below. The main vegetation covers are sugarcane, rice, rubber and other annual crops.

Figure 1. Concrete irrigation canal in Ninh Hung commune, Ninh Hoa district

Rice lands are located in lowland parts of the province, where irrigation systems have been well developed. For example, concrete irrigation canals (Figure 1) transfer rainwater stored in the Suoi Trau reservoir to irrigate 300-400 ha of rice land in Ninh Hung commune, Ninh Hoa district. During normal years, this water source is enough to cultivate two rice crops per year (Winter-Spring and Summer-Autumn). During dry years, however, actual coverage area of the reservoir reduces significantly. This strongly influences rice production in downstream areas.

Farmers have to skip the Summer-Autumn rice (from May to July) due to water shortage during severe drought years. On the other hand, excess rain during the wet years often causes floods between November and December. Local officials reported five to six flood events in last 10 years.

Sugarcane is an important crop of Khanh Hoa province. In Ninh Hoa district, sugarcane is planted on elevated lands. In some fields, farmers create small water storage (Figure 2) to supplement irrigation water for sugarcane during the dry season. A key problem in sugarcane production is weeds, which farmers handle with a range of herbicides, including glyphosate sprayed on a regular basis. The crop yields vary from 40-70 tons/ha/year, depending on the phase of the 4-year planting cycle.

Figure 2. A farmer is re-planting sugarcane in Tay Ninh commune, Ninh Hoa district

Sugarcane is often planted in April and harvested in March of the next year. Good Agricultural Practices (GAP) (e.g. herbicide use and disposal of herbicide containers) should be practiced as this may affect sugar quality. Greater knowledge of the yield potentials of the varieties and related CSA interventions (e.g. drought and disease tolerant variety) are needed to elevate current yields and increase farmer incomes. According to Mr. Le Quang Vinh, official of the Department of Crop Production and Plant Protection, most of households in Ninh Hoa district are planting sugarcane under contract with the Khanh Hoa sugar company. Therefore, sugarcane price is generally stable.

The land planted for sugarcane is however also suitable for maize. In this area, farmers can grow three seasons of maize per year, thus giving farmers higher annual incomes. However,

maize is more sensitive to drought than sugarcane and its market price is unpredictable. Due to these reasons, farmers prefer to shift from maize and other annual crops to sugarcane.

Mango is the main fruit tree of Cam Lam district, which is planted with more than 5000 ha. In Cam Hoa commune, mango has been planted since more than 60 years ago (Figure 3). Mango farms often include various domestic and imported varieties (e.g. from Australia and Thailand). Each year has two mango seasons per year. On average, a 40-year-old tree can produce 5 tons of fruit per season. During flowering period, mango should be supplemented with irrigation water to maintain high yields; however, water shortage is the major problem during the dry season. Tanked water and groundwater are thus the main sources for irrigation. Farmers often drill 100m deep boreholes within mango fields to exploit groundwater. Each borehole cost about 100 million VND (4,300 USD). Water use efficiency needs to be improved in this area.

Figure 3. A mango farm with 60 year old trees in Cam Hoa commune, Cam Lam district

Ninh Thuan province:

Local staff:

- Ms. Nguyen Thi Minh, Planning Office, DARD of Ninh Thuan
- Mr. Nguyen Le, Deputy Head of the Crop Production and Plant Protection office
- Mr. Nguyen Dinh Quang, Thai Thuan Agriculture Production Ltd.

Ninh Son district was reported as a drought-prone area. However, the cropping system in Ninh Son district is very diverse with different annual crops (e.g. maize, rice, melon, cucumber, vegetables, etc.) and perennial crops (e.g. grape, mango, pomelo and dragon fruit). The highest value crop is grape, which is mainly planted in irrigated areas (Figure 4). The main sources of irrigation water are reservoirs and groundwater. In general, the water table is around 2-10m deep, and it is therefore easy to exploit groundwater for irrigation. According to farmers, grape crops are resistant to drought.

The main climate-related problem in this region is unusual heavy rain in harvesting season, which causes a production loss of 20-30% due to cracking of the fruit. Therefore, post-harvest technologies are the main interest of grape farmers. Serious pest and disease problems are associated with unexpected high rainfall and humidity, such as botrytis, anthracnose and downy mildew, mites fruit-flies. Farmers usually use a mixture of fungicides and insecticides, and spray 15-20 times during the three or four months of growing season. Pesticide efficacy is low as it is easily washed off by rain.

Smallholder farmers growing grapes and vegetables (i.e. chilli, onion and garlic) are also found in Ninh Phuoc district. Availability of water for irrigation is also the chronic problem in this area. To improve soil moisture, farmers are using mulching techniques and organic fertilizers.

Figure 4. A grape farm during harvesting season in Nhon So commune, Ninh Son district

The recent drought occurred in Ninh Thuan from August 2014 and prolonged till September 2016. It seriously affected districts were Thuan Bac, Thuan Nam and Bac Ai. To cope with future droughts, Ninh Thuan plans to shift from intensive rice cultivation to rice-based systems and cash crops. The Department of Agriculture and Rural Development of Ninh Thuan expressed the need for studies on irrigation water-saving technologies for different crops. These will provide the scientific basis for developing farming guidelines for farmers.

Binh Thuan province

Local staff:

- Mr. Nguyen Huu Phuoc, Vice Director of DARD of Binh Thuan
- Mr. Nguyen Van Thu, Head of the Planning Office, DARD
- Ms. Nguyen Thị Kim Huong, official of the Planning Office, DARD
- Ms. Ngo Minh Trang, Deputy Head of the Irrigation Management Office

Tuy Phong district is the most drought-prone area of Binh Thuan province. The district has 2,600ha of rice. Frequent drought impacts strongly influence rice production of the district. Currently, 50ha of rice have been converted to *Sterculia foetida* (Trôm, in Vietnamese), a perennial crop (Figure 5) that is highly resistant to drought and has high economic value. Income from this crop is about 150 million VND per ha, which is a much higher than the income from rice. Therefore, the district plans to increase area planted with *Sterculia foetida* from current 100ha to 1,000ha in the future.

Figure 5. Rice fields are being converted to Sterculia foetida, a drought resistant crop in Tuy Phong district

Ham Thuan Nam district, which has shallow groundwater table, is also prone to drought. Before 2000, the district had 4000ha of rice. Rice yields had significantly declined recently due to increasing drought impacts. Starting from the 2000s, dragon fruit was introduced to the area (Figure 6). This crop is resistant to drought and provides higher incomes than rice, and is therefore considered a sustainable crop. More than 2,000ha of rice plantations have been converted to dragon fruit. Currently, the district has a total of 28,000 ha of dragon fruit, which

exceeds the 20,000 ha projected by the local government. Irrigation water is from Phan River and/or from open wells or boreholes.

Figure 6. Rice has been replaced with dragon fruit in Ham Thuan Nam district

Unlike Tuy Phong and Ham Thuan Nam districts, the Ham Tan district fully relies on rainwater for water for irrigation and domestic use, as it does not have any irrigation canals or reservoirs. It is considered as a dry area of Binh Thuan province. Land cover has changed to adapt with this climatic condition. In Tan Phuc commune, land use is dominated by fruit trees (e.g. citrus, mango and dragon fruit), planted forest, shrubs and pastures. Nearly half (800ha) of the total area (1,997ha) of the commune has been used for citrus production (Figure 7a). In 2016, the severe drought caused significant reduction (10-60%) of area planted with citrus. A popular practice to cope with insufficient irrigation water in this region is to store rainwater during rainy season (Figure 7b). In general, each household has one or two small reservoirs with a storage capacity of 500-600 m^3. The groundwater table is very deep, as some households drilled boreholes of more than 100m in depth but they still could not reach the aquifer.

a *b*

Figure 7. (a) Citrus farm of Mr. Tran Van Loc in Tan Phuc commune, Ham Tan district, and (b) his water storage

For the medium- and long-term climate change adaptation strategy, the DARD of Binh Thuan province plans to build more reservoirs for water storage. They also expect to receive technical support for: (1) recharging and exploiting groundwater; (2) improving water holding capacity of forest lands; (3) identifying measures to address drought for alternative crops; (4) establishing water management groups; (5) developing a drought risk map for whole province; and (6) developing policies to improve access to fresh water for domestic use.

Appendix 5. Pest-related observations and proposed interventions

1. **Ninh Hoa district, Khan Hoa Province:** The major crop cultivated by the farmer is sugarcane with a range of other crops, such as rice, rubber and others. Farmers have dug out ponds to tap both ground and surface water for irrigation.

   Key problems: Weed infestation, which farmers manage with a range of herbicides (including glyphosate) regularly sprayed using water from the pond. Improper waste management where used herbicide containers were found all over the area (see picture below).

   Solution: Good Agricultural Practices (GAP) (e.g. herbicide use, water use; and disposal of herbicide containers) should be practiced as this may affect sugar quality. Other CSA interventions could include the use of drought- and disease-tolerant varieties, and training on proper and efficient pesticide use and disposal.

2. **Ninh Sơn district, Ninh Thuan:** A dry region with a mean temperature of 24-28°C, the district has a low relative humidity of 72-85%, 130-287 sunshine hours per month, an annual average rainfall of 750-900mm, and fewer rainy days per year. These climatic conditions are fairly favourable for the production of grapes. The area visited had been growing two types of grapes (red and green) for local consumption. The district also produces shrimp, although an ADB-funded program only provides support until pre-processing. The area has experienced a prolonged drought and shortage of water for irrigation. Furthermore, although the farmers grow grapes under the rain shelter, unpredictable weather conditions result in the cracking of the fruits.

   Key problems: Heavy rains often occur at the end of the year (August to November) together with high temperature, thus some diseases develop very quickly. Large quantities of fungicides have to be used during this period. Serious diseases include bunch rot caused by *Diplodia natalensis*, rust, anthracnose and downy mildew (caused by *Plasmopara viticola*),

while pests include mites fruit-flies, mealy bug (*Ferrisiana virgata*), thrips (*Thrips* sp.), red spider mites and yellow spider mites etc. These pests usually exist on the vines and cause great damage during the dry seasons. The main kind of chewing pest is the army worm (*Spodoptera exigua*). It eats young leaves, buds and flowers, and causes serious damage mostly during the dry seasons.

Post-harvest loss of grapes is also up to 30% due to high temperatures. Prolonged drought may be overcome through weekly controlled flooding irrigation when required and drip irrigation. Fruits are pruned during the rainy season to reduce losses. Farmers usually spray a fungicide-insecticide mixture 15-20 times per season, which lasts 3-4 months. Pesticide efficacy is uncertain due to rain wash-off, etc.

Solution: Farmers need to reduce pesticides they use on grapes. A holistic, environment-friendly cost-effective spray program, which takes into consideration the seasonal changes, should therefore be developed. A number of new fungicides and pesticides can be used to control diseases and insects of grapes. Some of the fungicides include Ridomil, Score, Antracol, Copper hydroxide, Tilt, Baycor, Curzate and Bayfidan. Researchers in Vietnam found it easy to control army worm with a biological product, Nuclear Polyhedrosis Virus (NPVSe), which is made at the Cotton Research Centre. Both efficacy and toxicity tests should be continually done to help promote the best products against pests. Post-harvest processing facilities and protocols need to be set up to further reduce losses.

3. **Ham Thuan Nam and visit to Tan Thanh irrigation canal (ADB project):** This is a drought-prone area cultivated mainly with rice. Some areas are encroached by dragon fruit. The ground water not suitable for immediate use due to the high iron content and thus needs to be filtered first.

Key problem: Golden apple snail (GAS) is prevalent.

Solution: Integrated GAS management can be advocated with the farmers' active participation. At the start of each rice cropping season, they need to handpick the GAS and collect egg masses along canals, irrigation systems and in rice fields after land preparation. GAS can also be used as biocontrol agents to feed duck and fish.

Appendix 6. Pictures of the site visits

Members of the Team interviewing a farmer planting sugar cane (missing hills) in a ratoon fields.

Golden fields of rice in Khanh Hoa. On the background is a mountain planted with trees in the upper slopes and sugar cane in the lower slopes.


A woman picking grapes for the market in Ninh Thuan.


Interviewing a farmer planting *Sterculia foetida sp* in Ninh Thuan

The team discussing with an old woman how she is filtering the high iron content of the groundwater used for irrigation and home in Binh Thuan.

Almost empty farmer managed water impounding in Binh Thuan.

The Team under the mango tree in Khanh Hoa province