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Rural adaptation to climate change

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ACIAR TECHNICAL REPORTS

Rural adaptation to climate change

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Cover: Farmer in a 'safe vegetables' farm in Vietnam. Photo: Khan Long

Foreword

Millions of farmers in East and South-East Asia are responding to climate change, whether they know it or not. They risk poverty by not responding proactively. Adaptation to a changing climate will come about through practices and policies at household, farm, market and government levels.

The Australian Centre for International Agricultural Research (ACIAR) is mandated under the ACIAR Act (1982) to work with partners across the Indo-Pacific region to generate the knowledge and technologies that underpin improvements in agricultural productivity, sustainability and food systems resilience. We do this by funding, brokering and managing research partnerships for the benefit of partner countries and Australia.

This technical report presents the findings of an ACIAR project that examined the effects and potential benefits of responses to climate change in rice markets in China and Vietnam. The project provided a social sciences dimension to the study of climate change. Its primary objectives were to identify those farmers most at risk from climate change and then to identify policy responses to assist their adaptation and adjustment.

The research found that some farmers were responding to climate change mostly by adopting changes in farm management practices. However, adoption is dependent on the relative advantage to be realised from innovation. The research also found that the incentive for farmers to act was influenced by the policy environment, the institutional environment and investment by governments. Because planned and institutional measures are in the hands of various levels of government, the research reinforced the importance of coordination to develop a cohesive package of measures for farmers to address climate change at the farm level.

Understanding farmers' adaptation strategies and decision-making processes is important for designing future policy interventions to ameliorate and prevent the adverse effects of extreme weather events on farming systems. I look forward to the contribution that this research will make to understanding the interaction of farmers and government when responding and adapting to climate change.

Importantly, this work also contributes to a strategic objective of ACIAR, of building knowledge to support managing natural resources and producing food more sustainably, adapting to climate variability and mitigating climate change.

Andrew Campbell
Chief Executive Officer, ACIAR

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Acknowledgments

This technical report is a summary of other reports prepared from research conducted in the ACIAR project, 'Assessing farmer responses to climate change—adjustment policy options' (ADP/2011/039).

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Introduction

Climate change is a new source of pressure for adaptation in farming systems (Cooper et al. 2008; Thornton & Herrero 2015; Huang & Sim 2017). In particular, the number of extreme events such as droughts, floods and severe storms (Easterling et al. 2000) is increasing (Adger et al. 2003). Consequently, welfare effects are likely to be significant (Howden et al. 2007). Farmers in developing countries are likely to be more vulnerable (Adger et al. 2003). There are different channels for adaptation to these events, at the levels of markets and of households.

Trade can ameliorate the effects of extreme weather events on local markets, through access to farm produce from less affected regions. Extreme weather events elsewhere may create new market opportunities for local producers. Opening markets to trade is therefore an important means of adapting to climate change, so that inter-regional adjustments in production and consumption buffer the severity of the effects of climate change (Reilly & Hohmann 1993).

At the farm household level, adaptation is a key strategy that can alleviate the severity of climate change effects on agriculture and food production (Alam, Alam & Mushtaq 2017). The risks associated with extreme weather events are highly uncertain, and the adaptations farmers make to accommodate them are significantly different from the day-to-day adaptations of existing farming practices traditionally made in response to seasonal fluctuations in climate (Adger et al. 2003). Traditional adaptations are based on methods that have proven successful in the past. Those adaptations are continually being tested and refined. However, there is no store of knowledge and learned experience for coping with infrequent and extreme weather events. No two such events are likely to be the same. Understanding farmers' adaptation strategies and decision-making processes is therefore important in designing policy interventions to ameliorate and prevent the adverse effects of extreme weather events on farming.

In considering existing and new policy measures that might improve rural adaptation to climate change, it is also useful to consider the perceptions farmers have about the effects of climate change, the conditions governing their access to land and water, and the supporting infrastructure available to them, both physical and social.

Our research project was undertaken with support from the Australian Centre for International Agricultural Research (ACIAR). We focused on the economies of China and Vietnam, and we review our results here along with those of related literature. In the next section we outline changes over recent years in the structure of the agricultural sectors in China and Vietnam. Following that is a review of the recorded effects and potential benefits of adaptations to climate change, as revealed by the research results from the project to date. We give specific attention in the subsequent sections to:

- forms of adaptation
- farmers' information and perceptions
- other drivers of adaptation, such as household characteristics, land tenure, water allocation, labour markets and social capital
- market signals
- infrastructure.

We then discuss adaptation and policy options.

Structural change in China and Vietnam

China and Vietnam are countries in transition, where the agricultural economies have been growing with significant transformation (International Fund for Agricultural Development [IFAD] 2016). Agricultural gross domestic product growth rates in China and Vietnam were 4.2% and 3.4%, respectively, over the period 2000–2015. Productivity in agriculture has increased at a rate of 4% per year in China and 3% per year in Vietnam. Drivers of growth included the use of irrigation and farm chemicals, investments in infrastructure, policy reforms and technological changes. Agricultural production has also gradually shifted from grains to higher-value-added products such as horticulture, livestock and fisheries in response to changes in consumption. The ongoing changes are an important part of the context of designing policy to respond to the risks associated with climate change.

Another important change in rural areas is the growth of off-farm employment. In China, 70% of the rural population now has some form of off-farm employment (National Bureau of Statistics of China 2015, quoted by IFAD 2016). In Vietnam, the share of rural household income attributed to agriculture fell from 43% in 2002 to 32% in 2012. Over the same period, the proportion of the population living in urban areas increased dramatically, from 20% in 1980 in China to 54% in 2013, and from 15% to 33% in Vietnam.

The land area in both economies is small relative to the populations, and the area of cultivated land has been falling as urbanisation occurs. Arable land is now 0.09 ha/person in China and 0.11 ha/person in Vietnam. IFAD has highlighted the big increase in land equipped for irrigation in China (from 38% to 55% since 1990), but that the proportion of land equipped for irrigation in Vietnam has remained at around 45% (IFAD 2016, Table 2.3). Average farm size is less than 1 ha in both China and Vietnam, which is the smallest in Asia. The average farm size increased in China by 37% from 2003 to 2013 (Huang & Ding 2016).

Food consumption has been growing and changing. Despite the strong productivity growth discussed above, imports of food have been increasing in both economies, and labour and land inputs to agriculture have been declining. The cost of labour has been increasing and the production of some foods has declined as farm resources have been used to expand the production of other foods. This process has been happening more rapidly in China, which became a net food importer in 2004, mainly because of imports of oilseeds. While other commodities are traded, on balance, it has remained nearly self-sufficient in them. Until 2011, however, Vietnam remained a net food exporter.

The change in trade patterns has led to concerns about Vietnam's food supply self-sufficiency. The Vietnamese government issued a resolution mandating a minimum land area of 3.8 million ha devoted to rice production and that at least one rice crop per year be grown on that land (Resolution 63/2009/NQ-CP on food security). The World Bank (2016, p. 17) notes that, as a result of this policy, 'farmers have faced difficulties introducing rotation crops which otherwise might be more profitable, help to maintain soil fertility, and interrupt cycles of pest and disease'. Giesecke et al. (2013) concluded that the rice land designation policy reduced the social welfare and nutrition security of Vietnamese people. Rules on the land areas to be held for rice production are particularly significant in limiting the adjustment options available to farmers to adapt to climate change (Nguyen et al. 2020). However, since 2015, because of Decree 35/2015/ND-CP on rice land use and management, some transfers out of rice production have been allowed, up to a limit in some provinces, but only as long as the transfers are registered with the local People's Committee and associated fees are paid. The World Bank observed that the decree in 2015 providing this flexibility was 'likely just the beginning of a major reform to come with respect to the governance of agricultural land-use.' (2016, p. 17).

In China, there has been a focus on the supply of staple goods, despite their falling share of consumption. Since 1996, the target has been for 95% self-sufficiency in grain. The main policy instruments for this purpose have been the payment of subsidies to farmers and a price intervention program (Huang & Yang 2017). Domestic prices have exceeded international prices, and the gap between them increased from 2009 to 2014 (Huang & Yang 2017, Table 2). These subsidies are growing rapidly (doubling in the five years to 2012, for example) and overall, China has been shifting from taxing agriculture to subsidising it. There have also been efforts to separate support for farmer income from pricing policy. Huang and Yang (2017) outline several efforts to curb the extent of the subsidies. However, with the growth of the consumption of meats requiring feed grains to produce, the goal of self-sufficiency in grains has been impossible to attain[1].

Huang and Yang (2017) explain that, since 2004, the policy has distinguished between food and feed grain, with the goal of self-sufficiency in the former, but with a more open market expected for feed grain. The soybean and rapeseed markets are already open, but price intervention continues to apply to maize. Huang and Yang (2017) also report on other efforts to increase productivity, including land consolidation (requiring land rights reform) and investment in research and development.

1 In the short term, meat self-sufficiency has also been challenged by the outbreak of African swine fever, which is reducing demand for imported grain. See **https://www.agriculture.gov.au/abares/research-topics/agricultural-commodities/sep-2019/african-swine-fever** and **https://www.scmp.com/economy/china-economy/article/3029961/chinas-pork-imports-surged-almost-80-cent-august-cover-gap**.

Effects and potential benefits of adaptations

In this section, we review the effects of climate change and the potential to benefit from adaptation. The key result is that the scope for adaptation to offset the impact of climate change is significant.

Channels of effects

The literature relating to the effects of climate change on agriculture has grown significantly in the past several decades. Early studies generally assessed such effects with simulation techniques that were built on theories from the physical and social sciences (e.g. Adams et al. 1990; Kane, Reilly & Tobey 1992). A substantial body of research, as reviewed in Adams et al. (1990), has addressed possible physical effects of climate change on agriculture, focusing on crop and livestock yield changes and the associated economic consequences.

Among all agricultural subsectors, most literature focuses on crop production and the possible effects of climate change. Hulme (1996) identifies four ways that climate could physically affect crops:

- Temperature and precipitation changes will alter the distribution of agroecological zones. The resulting changes of multiple environmental factors that lie within each would further affect crop production.
- Higher carbon dioxide levels can positively affect crop production through increased water-use efficiency and rates of photosynthesis (although the extra food that is grown in this environment may be less nutritious [Zhu et al. 2018]).
- Water run-off is affected by climate conditions and this directly affects crop yields.
- Climate variability, especially the increased frequency of extreme events such as droughts and floods, can result in unpredictable damage to crops.

Lobell and Burke (2008) explain that the agricultural effects of climate change are uncertain because of the varying relative importance of temperature and precipitation, therefore the net impact of climate change on crop production can be mixed. This is confirmed in most studies concerning climate change effects in China (e.g. Smit & Cai 1996; You et al. 2009; Zhai, Lin & Byambadorj 2009; Yin et al. 2016).

National, regional and sectoral studies

Multiple climate impact assessments have been performed using data from China, usually at either national or regional levels. Tang et al. (2000) applied alternative general circulation models to evaluate the potential impacts of global climate change on China's agriculture. Liu et al. (2004) used county-level data on agricultural net revenue to assess the economic impacts of climate change, and found that the overall effect could be positive. Wang, Huang and Rozelle (2010) refer to scenarios in which rice yields in China fall by between 9% and 13% by the 2020s (without consideration of a CO_2 fertilisation effect).

Tao et al. (2003) specifically broke down the climate–agriculture linkage from a water-use perspective. They found that the water demands of south and north China face opposite changes—demand would decrease in the south but increase in the north, and would consequently result in differing crop yield impacts. Zhai, Lin and Byambadorj

Productivity in agriculture has increased at a rate of 4% per year in China. Drivers of growth included the use of irrigation and farm chemicals, investments in infrastructure, policy reforms and technological changes. Photo: ACIAR

(2009) estimated the effect of climate change on China's agriculture with a general equilibrium model, and concluded that the overall impact would be moderate at the macroeconomic level.

From a regional perspective, Chavas et al. (2009) investigated the long-term climate change effects on agricultural productivity in eastern China. With simulation techniques, they concluded that maize and winter wheat would benefit significantly in the North China Plain, while potato yields might suffer in southwest China. Yin et al. (2016) assessed the climate change impacts on cropping systems in northeast China, and concluded that there could be production benefits from the expansion of the crop-growing season, but that the effects of pests, diseases and weeds could also become more severe.

Other researchers have focused on the climate change effects on one or several specific types of crops. These include You et al. (2009) who studied wheat productivity in China, Yao et al. (2007) and Xiong et al. (2009) who studied rice yields, and Xiong et al. (2010) who studied cereals. The use of key crop production inputs such as water has also been investigated in conjunction with crop yield impact assessments, for example, Wu et al. (2010) and Xiong et al. (2010). As Hulme (1996) predicted, the mechanisms linking climate change and agriculture are numerous and can result in mixed findings, as is evident in these studies.

Wang, Huang and Yan (2013) used a comprehensive water-simulation model to analyse the effects on agriculture in 10 river basins of China in three different climate scenarios. They report that in some scenarios, water shortages in the north (in particular in the Liahe and Haibe river basins) would become more acute, but that in other basins in the south, water balances would improve. They found that, despite the greater influence on water balances in the north, the effects on total crop production would be moderate if farmers were able to relocate water among crops and adjust irrigated and rain-fed land use.

There is less literature on the impact of climate change in Vietnam than in China. Rutten et al. (2014) have examined scenarios of the impact of climate change on land use in Vietnam. They found that 47% of paddy land area is at risk of flooding, and the areas that are more flood-prone are concentrated in the Mekong River Delta. The World Bank (2010) review of the effects of climate change on agriculture in Vietnam included effects through changes in temperature, changes in rainfall and rising sea levels. They include hydroclimatic risks such as river flooding, storms, salinity intrusion and sea inundation (all of which are important in the Mekong River Delta), as well as flash floods and droughts (which are less important). In the scenarios the World Bank considered, it estimated that rice yields could fall by 6.3% to 12% in the Mekong River Delta (without consideration of a CO_2 fertilisation effect) by 2050. Another study considered the possible effects of climate change on forest species (Booth et al. 1999).

ACIAR farm-level studies

A key objective of the ACIAR project reviewed here was to supplement and complement the existing literature on the effects of climate change on agriculture in China and Vietnam from a macroeconomic perspective, with an understanding of their microeconomic effects. This has involved using surveys of individual and farm-level decision-making in response to climate change events (see Appendix).

An example of this work was the consideration of the impact of climate change on net crop revenue in north and south China by Wang, Huang, Zhang and Li (2014). They used data from 753 national meteorological stations and socioeconomic data from 8,405 farms across 28 provinces in China. They concluded that, on average, a rise in temperature would reduce farm crop revenue in both north and south China. Increasing temperatures, while beneficial to irrigated farms, would have adverse effects on rain-fed farms. With climate change, farms in the north were considered to be more vulnerable to temperature and precipitation variations than those in the south.

Huang, Wang and Wang (2015) used data from a survey of 1,653 rice farmers to examine the impact of climate change on farm practices that had been adopted to cope with extreme weather events, and their consequences. They found that floods and droughts significantly reduced yields and increased the risk of reduction of rice yields. They also found that farmers who had adapted their farming practices had significantly reduced those risks and increased yields. They concluded that there was scope for scaling up cost-effective adaptive farm practices and provision of public services related to natural disasters. Similarly, in examining the impacts of climate change on mean (average) yields of *indica* and *japonica* rice and the variance (variability) of them, Wang, Zhang and Huang (2016) analysed 30 years of data. They found that both the trend of climate change and change in its variability significantly influenced the yields and variability of yield of both rice types.

Huang et al. (2018), using a panel of household survey data from a large sample in rural China, estimated the potential benefits of long-run adaptation. They found that, for various model settings and climate change scenarios, long-run adaptations should mitigate one-third to one-half of the damages of climate warming on crop profits by the end of the 21st century. A similar result was found using the same method in the USA and Vietnam, where long-run adaptations were estimated to mitigate one-third and one-half of the damages, respectively.

Using panel data of rice farmers in Vietnam, Dang et al. (2020) examined the short-run impacts of farmers' adaptations on rice yield. They found that adopting adaptive measures could reduce yield loss due to disasters. They also found that farmers having direct access to early-warning information about climate and technical support were more likely to apply adaptation measures.

In the following sections, the different forms of adaptation used by farmers and drivers of their use are reviewed. The focus is on decision-making at the household level.

A survey of 340 households in Vietnam found that farmers with access to government services were more likely to adjust farm practices to offset weather hazards, and farmers participating in agricultural production training were more likely to apply offsetting measures. Photo: ACIAR

1 Forms of adaptation

In the face of climate extremes, numerous adaptation strategies in different agroecological conditions have been adopted by farmers. These include, but are not limited to, irrigation technology advancement (Wu, Jin & Zhao 2010; Xiong et al. 2010), variety choice (Tao & Zhang 2010), cultivation-timing changes, soil-tillage practices, crop protection (Yin et al. 2016), and input changes (You et al. 2009), including, for example, the use of plastic film for soil cover (Yin et al. 2016).

Forms of adaptation may be conveniently divided on the basis of the level of the decision-maker involved. The categories shown in Table 1.1 are farm household, rural community and government measures. Measures may be further categorised into those related to engineering, and non-engineering. Examples of engineering measures are investments in irrigation. Non-engineering categories include new methods of farm management.

Chen, Wang and Huang (2014) present results for six provinces in China relating to farmers' choice of adaptation methods to the experience of drought. The farmers predominantly used only non-engineering drought-adaptation measures (76%); 14% of households used no measures; only 10% used both types of measures; and none used only engineering measures. The most popular non-engineering measures were changing inputs to production or adjusting crop planting and/or harvesting times.

Other frequently observed responses were to irrigate more frequently, change crop varieties and to buy crop insurance. Of interest, however, was the low use of engineering measures. In the small proportion of farm households who used engineering measures, the most popular measure related to water management—investing in wells, building new dams, purchasing pumps, investing in surface pipes and sprinklers, and maintaining channels. Chen, Wang and Huang (2014) observed that when 'policy support' was available, farmers were more likely to adopt both engineering and non-engineering measures. Policy support included early-warning technology and technical, financial and physical supports. However, few farmers (5%) received this type of support. Farmers with indicators of higher levels of social connections were also found to be more likely to adopt both types of responses.

Climate change is widely recognised but the role of government support in adaptation is much less understood. Xu and Findlay (2019) modelled the adaptation decision as a three-stage process, with the stages dependent on whether:

1. the farmer needs adaptation
2. there are constraints that prevent adaptation
3. such constraints are able to be removed through government support.

They found that government support was associated with an increase

Table 1.1 Types of adaptations

Level of decision-maker	Category 1	Category 2	Activity
Farm household	Engineering	Investment	Well, pump, greenhouse, water cellar and pond
		Maintenance	Well, pump, greenhouse, water cellar and pond
	Non-engineering	Water-saving technology	Border irrigation, furrow irrigation, level field, surface pipe, sprinkler, drip, plastic film, less tillage, residual retention, intermittent irrigation, drought-resistant crop varieties
		Farm management	Change: variety, sowing and harvest date, reseeding, fixing and cleaning, irrigation time and volume, other inputs
		Risk management	Adjust planting structure, agricultural insurance
		Off-farm	Employment, migration, investment etc.
Rural community	Engineering	Investment	Reservoir, irrigation–drainage system, dam, pond, well, pump and underground pipe
		Maintenance	Reservoir, irrigation–drainage system, dam, pond, well, pump and underground pipe
	Non-engineering	Risk management	Disaster-resistant activity, agricultural insurance
		Capacity improvement	Disaster-prevention training, water-user association, other farmers' association
Government	Engineering	Investment	Reservoir, irrigation–drainage system, dam
		Maintenance	Reservoir, dam
	Non-engineering	Risk management	Provide: disaster-warning service, disaster-response knowledge, funding support, technical support, emergency-warning system, emergency-response plan, rules and regulations for disaster, amended water price policy
		Capacity improvement	Disaster-prevention training

of 24.4% in the probability of adaptation measures being adopted. This positive change is much larger than the estimates in other recent literature and suggests that government support is much more effective among farmers with adaptation constraints that they can address. Therefore, there is value in correctly identifying each subgroup to optimise expected policy impacts.

In Vietnam, the adoption of engineering measures has been more widespread (see Figure 1.1), and has mainly consisted of modifications to irrigation systems. The non-engineering measures used most by Vietnamese farmers included changing sowing and harvesting dates, rice varieties and crops. These adaptation measures were adopted in disaster years to cope with disasters and in normal years as a precautionary measure.

Dang et al. (2016a) studied farmers' responses to drought and to salinity intrusion in the Mekong Delta during the 2010–2016 period. Using data from a panel sample of 340 farm households in the Ben Tra and Tra Vinh provinces, they found that more adaptations to traditional practices were made in the more serious disaster years and that government support influenced those adaptations (along with other household characteristics). Dang et al. (2016b) found that the more serious the disaster was, the more likely the adaptations of farmers and local governments were to reinforce one another (based on data for 2011, 2015 and 2016 from a sample of 390 rice-producing households in the same provinces). However, they also found that policy changes tended to lag behind the quicker shifts in climate conditions and farmer adaptations.

Our main focus from this point on in this report is therefore on the adoption of non-engineering measures and the drivers of the decision to adapt. Our discussion begins with farmers' use of information about climate change and their perceptions of it.

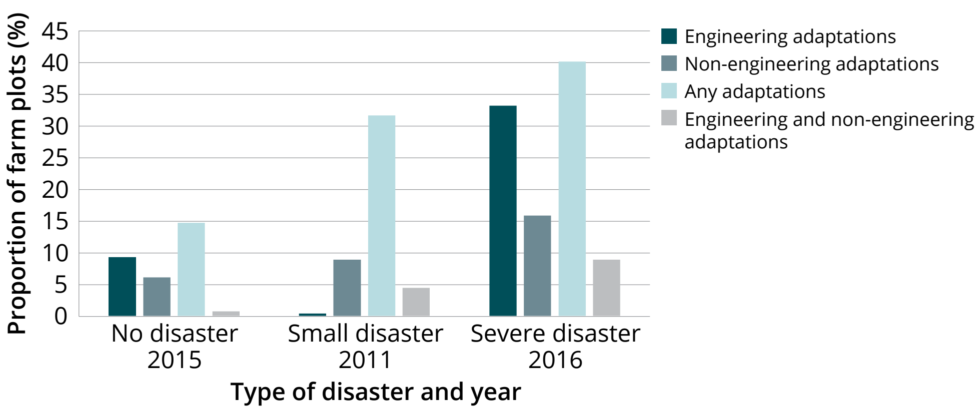

Figure 1.1 Adaptation measures, Vietnam, by disaster experience
Source: Institute of Policy and Strategy for Agriculture and Rural Development (2016)

2 Farmers' information and perceptions

The literature from many parts of the world has consistently shown that farmers' perceptions affect their choice of adaptation strategies (Juana, Kahaka & Okurut 2013; Asante et al. 2017; Ayanlade, Radeny & Morton 2017). A recent study in China has also confirmed that perceptions are a key factor affecting farmers' actual adaptation behaviour (e.g. Sjögersten et al. 2013). This follows from the reasoning that human actions are based on perceptions formed from the quality and relevance of available information, and the ability to access and assess that information. That ability is facilitated by social networks, education and experience. In particular, information about climate and early warnings about drought and floods are important in promoting better adaptive responses by farmers. Similarly, information about the availability of post-event services, assistance and support are important in alleviating hardship.

Empirically, overall perceptions have been shown to be affected by factors such as the farmers' age, education, and access to information (Debela et al. 2015). Moreover, risk perceptions have been shown to be affected by adaptive capacity at the farm level and sensitivity to climate change (Safi, Smith & Liu 2012).

In their study of early-warning information, and of farmer perceptions and adaptations to drought in China, Hou, Huang and Wang (2015) used household survey data from nine provinces and found that over half the farmers perceived that the severity of droughts had increased in the previous 10 years. Early warnings of drought had also altered their perceptions and affected their adaptation choices. Farmers perceiving an increased severity of drought were found to be more likely to adapt by adopting water-saving technologies. In looking specifically at the influence of social networks and farm assets on farmer perceptions of climate change, Hou, Huang and Wang (2017) found that only 18% of farmers accurately perceived the actual increases in annual mean temperatures over the past 10 years. However, they found that social networks improved perceptions, and those with larger land holdings had more accurate perceptions of climate change.

The China-based research on access to information stresses the value of early-warning systems. This is because, overall:

- Farmers are about 20% more likely to perceive an increasing drought severity when early-warning information is provided.
- About 8% more farmers are expected to adopt the use of surface pipes in particular to respond to drought if early-warning drought information is provided.

Weather information has the features of a public service, so its provision is unlikely to be adequately funded privately and there is a case for state funding. Dang & Nguyen (2016) found that the provision of formal

A study of information provision and policy supports in three provinces in Vietnam found significant improvement in the adaptive responses, because of early-warning information. Photo: ACIAR

information with government support played an important role in improving farmers' perceptions of local climate variability. As these authors pointed out, any consideration of a policy to raise awareness of climate change should consider its ability to be applied widely. Using household survey data from rice farmers in the Ben Tra and Tra Vinh provinces of the Mekong River Delta, Nguyen, Dang & Vu (2016) found that individual farmer perceptions of increases in drought and salinity intrusion during the 2010–2016 period had influenced their adaptation behaviours. They also found that the provision of early warnings of drought had altered those perceptions.

The North China Plain is an ecologically vulnerable region frequently hit by drought. In a study of farmer responses to drought in that region, using data from large-scale village and farm surveys in five provinces, Wang et al. (2015) found that wheat farmers adapted better to droughts when provided with early-warning information and policy support. The adaptations included adjusting seeding and harvesting dates and enhancing irrigation intensity. Similarly, in their study of the effect of information provision and policy supports on 2,157 plots of 695 households drawn from 66 villages in three provinces in Vietnam, Dang and Nguyen (2016) found a significant improvement in adaptive responses, because of early-warning information. In addition, the government support included financial, technical and in-kind measures.

3 Other drivers of adaptation

Household characteristics

Household characteristics have long been considered possible factors affecting adaptation to climate change. Commonly identified features include education level, sex, age and wealth status (e.g. Deressa et al. 2009), and the influences of these factors may be further manifested through perception formation (Juana, Kahaka & Okurut 2013; Asante et al. 2017; Ayanlade, Radeny & Morton 2017).

Huang et al. (2014) focused on farmers' use of crop diversification to adapt to the extreme weather events of flood and drought. They used data from a large-scale household survey in nine provinces of China, and found that crop diversification was used to adapt, and significantly so if they had experienced the event in the previous year. They also found that use of crop diversification varied by the age and sex of the farmer. Younger farmers were more likely to plant more types of crops. Female farmers were more likely to diversify than males. Interestingly, farmers with less education were more likely to manage risk in this way—the authors noted that these farmers may have had difficulty in responding using other measures. Farmers with larger farms were also found to be more likely to diversify. The authors concluded that the value of capacity-building to support adjustment varies between types of farmers, and they suggested that older farmers and those with smaller farms may benefit from more attention.

Results vary, however, with respect to the importance of various household characteristics. For example, Thennakoon et al. (2020) did not find statistically significant evidence that age, education or wealth affected the use of adaptation in the form of changes in a variety of management practices.

Wang, Huang, Wang and Findlay (2018) reviewed the determinants of changes in irrigation practices in response to extreme drought events. They found that a response was more likely when the household head was male. Their explanation was that changes in irrigation practices require more coordination among households and that heads are mostly male. The effects of age and, interestingly, education were negative in these results, but the effect of land holding per head and a location in a plains area was positive.

Capital intensity and farm size matter, according to the research results. Huang, Wang, Huang and Findlay (2018) examined the adaptive capacity of farmers, and identified factors influencing the ability to derive benefits from adapting to changed climate in the long run. They found that household-level capital intensity (production capital per hectare) had a significant positive effect on the adaptive capacity of farmers. They also found that beyond a certain level, increases in farm size led to increases in adaptive capacity.

Age had a significant negative effect in adaptive capacity.

These results reinforce the value of focusing on indicators of risk categories for farmers, such as:

- smaller farm size
- older age
- location other than a plains area
- lesser wealth.

In Vietnam, Vu et al. (2016), found that cultivated land size was a positive factor in adaptation, but that this could be offset by fragmentation of land holdings. Larger and more consolidated holdings helped farmers adapt. Other positive factors included ease of access to main roads, higher quality of cultivated soil, and irrigated land share at the village level. The authors referred to these features as matters of agricultural infrastructure. However, they found no effect of age or education level on adaptation. They speculated that farmers with higher education might be more likely to be involved in off-farm work, which would reduce the incentive to adapt on the farm.

Land tenure

Land tenure has widely been considered a factor affecting agricultural technology adoption, including climate change adaptation procedures (Soule, Tegene & Wiebe 2000; Place & Otsuka 2002; Gebremedhin & Swinton 2003; Deininger & Jin 2006; Abdulai, Owusu & Goetz 2011; Oostendorp & Zaal 2012). The nature of farmer rights to land and water has an important influence on farmer adaptation to climate change through their influence on farming practices. More sustainable and profitable practices depend on longer-term investments to maintain and improve the quality of soil and the manner in which it is used. Such longer-term investments are facilitated by land tenure arrangements that assure farmers who make such investments that they will be able to reap their longer-term benefits. Many of the successful adaptations to climate-change-related events depend on there being such longer-term investments.

In this project, we also found that better-defined property rights had an impact on the use of management practices as well. Thennakoon et al. (2020) found that in the Guangdong province of China, rice farmers with contracted land were more likely to implement successful adaptation measures to extreme weather events than farmers who rented land from the collective or from other farmers.

Water allocation regimens

Well-defined rights for water use encourage longer-term investment in conservation and efficient use of water. Rights to the available supplies of water and the ability to trade those rights are important for encouraging water flow to the most profitable uses. This is especially so at times when, or in areas where, water is scarce, and there are many uses for the available supplies.

Urbanisation in China has an effect on agricultural use of water and crop production. Yan, Wang and Huang (2015) estimated that a 1% increase in urbanisation would result in a 0.47% decline in the share of water used for agriculture. The decrease in use of water for irrigation of crops such as rice and wheat is associated with declines in yields and production, and an increase in reliance on rain-fed production. Adaptation measures they highlighted to minimise such declines included institutional and policy innovations, such as clarifying water rights and pricing mechanisms, to encourage use of water-saving techniques and technologies for both agricultural and urban uses of water.

Labour markets

Off-farm labour markets provide a means of adaptation for farmers to climate change. In response to the negative productivity shocks to agricultural output that climate change results in, farmers can mitigate the damage to their overall welfare by seeking off-farm employment. However, the mitigating effect of such labour reallocation depends on the property rights of farmland and the availability of off-farm work. This was illustrated in a study by Huang, Huang, Wang and Findlay (2016), who found that farmers with off-farm working opportunities who did not have property rights to farmland benefited most from the adaptation of labour reallocation.

Social capital

Social capital means the norms and networks that enable people to act collectively. Specifically, family, friends and associates represent an important collective asset which helps people deal with poverty and vulnerability, resolve disputes and take advantage of new opportunities (Woolcock & Narayan 2000).

An important area for discussion is the influence of policies and social capital on farmers' decisions to adopt adaptation measures against drought. Using a large-scale household and village survey in six provinces across China, Chen, Wang and Huang (2014) found that a higher level of social capital in a household was associated with better adaptation capacity against drought. They also found that the ability to adapt was influenced by characteristics of households and local communities. Dang (2016) found similar results relating to the influence of farm household characteristics, local infrastructure and government supports on adaptation capacity in Vietnam. These results were from a study of the adaptation behaviour of Vietnamese rice farmers based on a large-scale survey of 623 rice farmers affected by climate change in the Mekong River Delta and South–Central Coast regions.

4 Market signals

A major factor in influencing farmer behaviour is the prices of agricultural products. When the effect of climate change is to reduce supply, prices typically rise, inducing an increase in output in the new supply conditions. However, farmer response to price changes may also vary in the context of climate change. It is typically found that farmers' responses are not strong in the short-run because, as might be expected, periods of extreme weather limit their capacity to respond (Yang & Huang 2016; Huang & Yang 2016; Do & Dang 2016). In addition, elasticities of farmer responses will be underestimated by models which do not allow for the longer-run lagged adjustment in supply.

A further consideration with respect to the price signals is the extent of market integration. A weather event which shocks supply may have the initial effect of raising prices, but when local markets are integrated with the rest of the country or the rest of the world, the price impact will be reduced when goods are imported from other regions. The impact on consumers in that case is reduced, but a greater impact is borne by local producers. Incentives to increase local production are also reduced. This reduced-incentive effect is less significant when the weather events are more widespread.

The study by Huang, Xie, Ali and Yang (2017) examined these effects. They applied the empirically estimated price elasticities of major crops in both the normal and extreme weather event years from this project. They then simulated the impacts of extreme weather events using an integrated model of CAPSiM (a partial 'captive simulation' equilibrium model in agriculture for China) and a general equilibrium model (global trade analysis program). The results showed that, without considering the lower supply elasticities of many commodities in the crop sector when encountering extreme weather events, the impacts of climate variations on production, consumption and trade are underestimated. The impacts also varied with the degree of trade liberalisation assumed. A more open economy in the agricultural sector was shown to reduce the effects of extreme weather events on consumption and price through imports.

5 Infrastructure

Community infrastructure supporting agriculture includes roads and waterways that facilitate the transport of farm produce to markets; local community centres; schools and shops; and information about weather and market prices. The nature and quality of such physical and social infrastructure have important influences on farmers and on farming practices, especially during extreme weather events.

Household and community assets affect farmer adaptations to drought in China. Wang, Huang and Wang (2014), using data from a household survey in three provinces, found that both asset types affect adaptive behaviour. Household social capital and wealth, community networks and access to government anti-drought services facilitated farmer adoption of adaptation measures that resulted in higher crop yields. They also found there could be a degree of substitution between irrigation infrastructure and other adaptation measures.

In Vietnam, Dang et al. (2020) used data from a survey of 340 households undertaken in 2011, 2015 and 2016 to examine farmer adaptation to drought. They found that farmers having access to government services were more likely to adjust farm practices to offset weather hazards, and that farmers participating in agricultural production training were more likely to apply offsetting measures. The adaptations made had significantly increased rice yields and reduced yield variability.

Where suitable water resources are available, farm-specific infrastructure, such as irrigation systems, can be developed or enhanced to further facilitate the expansion of intensive water-dependent farming, such as rice paddies in drought-prone regions. For example, Wang, Huang, Wang and Findlay (2018) used a field survey to study the adaptive responses of rice farmers in their use of water, and found that in villages with irrigation infrastructure there was a significant increase in yields and reduction to the downside risks in rice production. Similarly, Wang, Yang, Huang and Adhikari (2018) report from a field survey of five provinces in the North China Plain that, when faced with a severe drought, farmers changed their management practices to mitigate its effects by increasing irrigation frequency and by increasing the efficiency of irrigation by using surface pipes. Again, they reported a significant increase in yields and a reduction in the downside risks in production with irrigation.

Adaptation and policy options

Options for adaptation are either those which are autonomous and can be undertaken by farmers individually, or those which are planned and require collective action and undertaken by local communities and governments. The latter include investments in infrastructure or other forms of social support. As noted earlier, adaptations can also be categorised into those which involve elements of engineering and the various other non-engineering types of adaptations, such as those listed in Table 1.1 under risk management and capacity improvement. Also, as illustrated in Table 1.1, most engineering adaptations are likely to require action by local communities or governments. Many of the non-engineering adaptations are in the hands of farmers and involve changes in farm management.

A focus of the project was on decision-making by farmers, and the belief that farmers are more likely to make decisions which can have a high impact on climate adaptation when those decisions are complemented by planned government measures. The importance of complementarities can be overlooked if undue emphasis is placed on individual measures.

Ease of implementation also matters. For each type of adaptation, implementation can be relatively easy or difficult. Similarly, the impact of implementation can be relatively low or high. Policy priority should be given to identifying and implementing adaptation measures that are easy to implement and have a high impact.

The ease of implementation will generally depend on local conditions. For example, the ease of implementation of various water-related measures will depend on the extent and quality of the irrigation infrastructure which farmers share, and this varies by catchment. Similarly, the ability to make investments will depend on the availability of credit, the financial viability of the particular measure and the credit-worthiness of the borrower. Also, in the results reported above, the security of property rights was found to affect not only longer-term investment in land improvement and on-farm irrigation works, but also even the willingness of farmers to adopt improved management measures.

The planning and institutional measures affect the impact of measures adopted. Specifically, there are synergies between planned adaptation activities at the community level, which can, through better incentives, stimulate adaptive responses. For example, good information systems will support more efficient choices by farmers. Likewise, water pricing provides incentives for farmers to make more efficient use of water, and also provides a benchmark for evaluating investments in local capture and storage of water. Removal of restrictions on labour mobility allows farmers to make efficient choices with respect to remaining in on-farm work or seeking work off the farm, or relocating to urban areas permanently.

A challenge is that these packages of planned and institutional measures are in the hands of various levels of government, so an important implication of this work is the degree of coordination required to implement them (Nguyen et al. 2020). Another challenge is that governments often have incentives to adopt particular types of measures. Visible initiatives such as large-scale engineering measures (e.g. sea walls) may be more visible to their constituencies, despite a lack of return on investment, compared to others which are less visible in those terms (e.g. water markets).

Conclusion

Climate change influences farming not only through changes to temperature and precipitation, but also, importantly, through increases in the frequency of adverse events such as droughts, floods and severe storms.

The traditional adaptations farmers make to their practices to respond to variations in seasonal conditions, such as changing the use of farm inputs and altering seeding and harvesting times, will continue to be applicable to coping with climate change. Facilitating the adoption and improving the efficiency of such adaptations is part of any policy response to climate change. This facilitation and improvement includes reviews of:

- farmers' property rights to land and water to encourage longer-term investments and to facilitate profitable adjustments to their use in farming
- physical infrastructure, such as roads and waterways, to ensure their continued relevance and maintenance
- social infrastructure, such as systems for the extension of knowledge about weather, and farming techniques and technologies.

The capacity of farmers to adapt varies considerably. Farmers who are older, less wealthy, with smaller farms, and living in mountainous areas are more likely to be adversely affected by climate change. They are less likely to adapt autonomously and more likely to have their incomes reduced, so a focus on the welfare of these farmers is important. Greater access to social capital and early-warning and other information systems is appropriate for these farmers.

A strategy which applies across all levels of government is valuable. A greater frequency of extreme events such as droughts, floods and severe storms will increase the incidence of episodic poverty among farmers and farm-dependent communities. Responses include policies to increase the resilience of farming systems and the adaptive capacities of farmers. These policies must be developed in the context of structural changes to the use of land that have occurred with urbanisation and diversion of water supplies from agricultural to urban uses. Local, regional and national governments should all be involved in these strategies.

Appendix: sampling methodology

The research undertaken in this ACIAR project was driven by interest in farmer adaptation to climate change, which involves long-run changes in temperature and rainfall. These changes are difficult to assess and predictions may be erroneous. More immediate changes involve weather variability, which is also associated with climate change. The research therefore focused on farmer decision-making in the context of weather-related shocks, in particular floods of various types and droughts.

This interest also drove the design of the sampling methods (explained in more detail in the studies cited).

A typical example of a sampling method is the following:

1. Define the years of the most severe events during a three-year period as disaster years, and the years of moderate or lesser weather events as normal years. Thus, a disaster year is defined as having had more adverse events (in frequency and magnitude) than a normal year.
2. Select counties and/or provinces in each country that had a disaster year.
3. Select counties and/or provinces that had normal years.
4. Out of the counties and/or provinces selected in this way, randomly select four counties in China and three provinces in Vietnam as the study areas.
5. Randomly select townships, districts and communes in those counties and/or provinces from three main groups divided on the basis of the quality of their agricultural production infrastructure (above average, average, and below average). Select one township from each category.
6. Randomly select villages using the same method as in (5), and randomly select 10 households in each village.

In China, our sample was comprised of three townships per county and three villages per township. In Vietnam, our sample was comprised of two to three districts per province, three communes per district and four villages per commune. In both China and Vietnam, we selected 10 households per village and two plots for each household to survey.

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