Preparing Smallholder Farm Families
to Adapt to Climate Change

POCKET GUIDE 1
EXTENSION PRACTICE FOR AGRICULTURAL ADAPTATION

Brent M. Simpson

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Acronyms

°C	degrees Celsius
CGIAR	Consultative Group for International Agricultural Research
CH_4	methane
CO_2	carbon dioxide
CRS	Catholic Relief Services
°F	degrees Fahrenheit
F-gases	fluorinated gases
F2FE	farmer to farmer extension
FAO	Food and Agriculture Organization
FFS	farmer field school
IIED	International Institute for Environment and Development
IPCC	Intergovernmental Panel on Climate Change
MEAS	Modernizing Extension and Advisory Services (Project)
N_2O	nitrous oxide
NERICA	New Rice for Africa (rice cultivar group)
NGO	nongovernmental organization
NOAA	National Oceanic and Atmospheric Administration
ppm	parts per million
PRA	participatory rural apraisal
PVS	participatory variety selection
PVS-E	participatory variety selection - extension
UNDESA	United Nations Department of Economic and Social Affairs
USAID	United States Agency for International Development

The concepts and practical suggestions in this guide come from many sources and are based on the field experiences and research of farmers, agricultural extension agents and scientists. To keep the body of the guide uncomplicated, these information sources and citations are listed together in the *References* section at the end of this guide. Information and links to helpful guides and manuals are also included throughout the guide in sections entitled *Resources*.

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PART 1

Introduction

1.1 Purpose and content

This set of pocket guides, *Preparing smallholder farm families to adapt to climate change*, is written for you, the field agent working in agricultural extension. The concepts, information and practices in these guides are meant to support your work with farm families in helping them to reduce their risks from changes in the weather. Many of the families who farm small, non-irrigated plots in the tropics already struggle against poverty, degraded land, and rainfall that varies from year to year. This type of rainfed agriculture is especially vulnerable to climate change, although even irrigated agriculture can be vulnerable. The suggestions in these guides will help you work with farm families and rural communities to make changes in their farming systems that can withstand and are adapted to changing weather patterns.

These guides include practical methods that meet the objectives outlined by the Food and Agriculture Organization of the United Nations for climate-smart agriculture:

- Ways to increase agricultural productivity sustainably – practices that protect the environment and reduce poverty.
- Farming practices for individual farm families and communities to improve their resilience to climate change.
- Practices that can reduce some of the causes of climate change – decrease greenhouse gases to avoid contributing to further changes in the climate.

Preparing smallholder farm families to adapt to climate change is a set of five complementary guides:

- Extension practice for agricultural adaptation
- Managing crops
- Managing water resources
- Managing soils
- Managing livestock

The adaptation pocket guides follow a general four-step approach developed for designing and implementing responses to climate change to help reduce the vulnerability of small-scale farming systems.

These steps are:

- **Understanding** concepts: the effects of climate change on each guide's focus area
- **Assessing** climate change risks for each theme and appraise agricultural vulnerability
- **Recommending** practices for adaptation
- **Mobilizing** community planning and action for adaptation

See Ashby and Pachico (2012) for more information on this approach.

1.2 The language of climate change

These guides will use climate change terms that you will want to know. They can help identify how farm livelihoods are vulnerable to climate change and how you can support farmers to be less vulnerable by improving their ability to adapt to climate change.

Climate change terms

Exposure to climate change is related largely to geographic location. Inland communities in semi-arid regions may be exposed to drought, and coastal communities will have higher exposure to cyclones or hurricanes.

Sensitivity is the degree to which a system or community is affected by climate-related stresses. A cool-weather crop such as coffee will be more sensitive to increasing temperature than a heat-loving species such as banana.

Adaptive capacity is the ability of a system or household to adjust to climate change – including weather variability and extremes – to avoid or reduce potential damages, to cope with the consequences and to take advantage of opportunities.

Vulnerability is the degree to which a system is susceptible to or unable to cope with the adverse effects of climate change. Vulnerability depends on the type, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and adaptive capacity.

Source: IPCC, 2007

Three elements contribute to the vulnerability of farm livelihoods:

Livelihood vulnerability = (exposure x sensitivity) – adaptive capacity

In other words, the **vulnerability** of a family's farming system is the result of its **exposure** to climate change risks multiplied by its **sensitivity** to those risks minus its **capacity to adapt** to climate change.

For example, if a family grows rice in a valley bottom that is starting to have higher floods that submerge their rice plants every 3 to 4 years for the first time in memory, the farm's **exposure** to climate change damages is increasing, resulting in yields that in flood years are less than half of past yields. Most rice varieties will die if completely submerged for more than a few days, so they are **sensitive** to deep flooding. When you recommend that the family adopt a new rice variety that can tolerate being submerged, the family can reduce its **sensitivity** to the new pattern of flooding. Your knowledge and work with the family has increased its **adaptation** to the changing conditions.

The practices shared in this series of guides will provide suggestions for how you can help improve the **adaptive capacity** of farm families and their communities. The practices can help farmers producing under rainfed conditions to reduce the negative impacts of climate change and recover from them more quickly. It is important to understand, however, that they may not be able to overcome all of the vulnerabilities that climate change causes or makes worse. Farm families must also learn to *live with* the changes that climate change brings, and to make important decisions about their future.

"Climate" and "weather"

These are often used interchangeably, but this is not correct – each refers to conditions and behavior of the atmosphere over a different period of time. Weather is what is happening, now, today, yesterday, this season or over the past few years – the temperature, cloud cover, humidity, wind direction and speed, and rainfall. Climate refers to average weather conditions over a longer period of time, generally a period of 30 years or more, and how the atmosphere has behaved, on average, over this time period.

From coffee to chocolate

For a decade, a farmer has worked to increase shade on his small coffee plot, but the shade is no longer enough to reduce the impact of rising temperatures on this cool-weather plant, which prefers temperatures of 16° to 24°C. Now the farmer is gradually replacing his aging coffee plants with cacao, which prefers warmer weather (18° to 32°C). The farmer could not overcome his farm's **vulnerability** to higher temperatures because of its **exposure**, caused by its position at a lower elevation, and coffee's **sensitivity** to higher temperatures. By making a transition to a different cash crop, he is **adapting** his farming system and learning to live with the effects of climate change.

Exposure to the risk of climate change refers to the various **direct** and **indirect** effects of changes in temperature and rainfall. For example, drought and high temperatures can directly reduce crop yields or affect animal health. Climate change may also indirectly affect crop yields or livestock productivity by influencing the types and number of pests and diseases that can injure or kill crops and animals.

Sensitivity to the effects of climate change is the degree to which a farming activity or an entire agricultural system is affected. Take, for example, a 60-year-old farmer who plants maize. She has seen a drying trend in the weather over the past 25 years. Her yields have fallen even though she started planting a variety that is less sensitive to dry weather. Her neighbor had savings and was able to invest in a pond and irrigation equipment and can still grow maize even in the driest of years. But she can grow only sorghum now, which is less sensitive to dry spells than maize. Unlike her neighbor, she faces **economic scarcity** as well as water scarcity because she lacks the funds for the water storage and basic irrigation equipment that her neighbor has – so her production is lower, her **adaptive capacity** is less, and her **vulnerability** is greater. Smallholder farm families producing under rainfed conditions who are experiencing drying trends may be unable to adapt to the impacts of climate change through technical improvements alone.

Adaptive capacity depends on many factors other than technical practices, which are the focus of these guides. In addition to technologies and management practices, adaptation also depends on whether:

- The farmer is aware that patterns of weather – the climate – have changed and that she/he needs to adapt.
- The farm family has enough people to do the work (family labor) needed to make changes and adopt new farming practices.
- The farm family has money and other resources (their assets) to invest in making changes.
- The farm family or group has ownership or control over key resources (tenure) necessary to make changes.
- Their community is willing to work together to make the necessary changes that improve all of their lives (working together at different scales).
- Their community receives government support services, such as extension.
- They live in a country that has agricultural policies and strategies to increase national climate change resilience.
- Agricultural research and extension services support adaptation, especially for rainfed farming (national systems and structures).
- Social and economic systems support fair access to water and land, education, information, financial services and infrastructure.

In your work it will be important to identify whether these other conditions necessary for farm families to adapt to specific climate change risks are met.

Inequality is another consideration in adaptive capacity. Inequality has many faces in different places: different social classes or castes, different ethnic groups, even different livelihoods, such as pastoralists versus crop farmers. For example, although 43 percent of farm workers in developing countries are women, their average agricultural yields are 25 percent lower than men's. Their yields are lower not because they are less skilled farmers but because of their restricted access to fertile land, financial resources and productive inputs (appropriate tools, improved seeds or livestock). They also have less access to critical services of agricultural extension and credit. Women's time is also split between farming and household tasks such as water collection, fuel gathering, food preparation and childcare. Thus, women farmers may often have less adaptive capacity because of social gender inequality.

1.3 Adaptive capacity with new information and old practices

Scientists are improving their ability to predict how climate change will affect a certain area and certain crops or farming systems through the analysis of weather information and use of computer simulation models. This climate modeling research is beginning to predict changes in temperature and precipitation within the next 15 to 25 years and their effects on some crops. When this information is available, it will help you to make decisions about what to recommend to farm families to reduce their exposure or sensitivity to climate change and increase adaptive capacity.

With or without specific information on the effects of climate change for your local area, you will need to work with farm families, who are often struggling against poverty, to reduce their sensitivity and exposure to the risks of rising temperatures and changes in rainfall patterns. Being able to adapt successfully depends on knowledge and information. One of your tasks will be to look for new information and training opportunities all the time and everywhere. In this way you can continually learn from farmers, test new methods with them to discover what works locally, and also train them in practices and methods that will result in more resilient farms and communities. The changes that are occurring as a result of climate change will continue with time, so it will be important for you to continue to learn.

Many of the technologies and practices that extension programs already promote can contribute to climate change adaptation. In fact, other than breeding efforts to develop new crop varieties tolerant to some of the effects of climate change – such as drought- and heat-tolerant maize, heat-tolerant bean varieties and submersion-tolerant varieties of rice – all other agricultural practices we have were developed long ago. What is new is the use of these "old" technologies and practices to respond to today's climate-change-related stresses. By updating your knowledge, you will understand how various practices can be used to reduce vulnerability to specific weather risks and where to focus efforts for the greatest benefit. Should you reduce exposure first or work to reduce sensitivity? Or should you focus on increasing adaptive capacity? What are the costs and benefits of starting with one or the other or a combination?

One of your tasks is to look for new information and training opportunities all the time and everywhere.

For example, when you encourage farmers at lower, warmer elevations to transition from annual cropping to mixed agroforestry systems, farmers increase the number of trees that absorb the carbon dioxide that is contributing to global warming. At the same time, the trees add leaf litter to the soil as mulch, soil evaporation is slowed, the soil holds more water, and nearby crops withstand dry spells longer. Trees and annual crops are sensitive to different types and levels of climate risks, so the mixed system diversifies the farms' exposure and sources of income. These all increase the adaptation of the farming system. Returning to basic agronomy in extension practice and learning to combine new tools and techniques with the beneficial practices of the past has great potential for improving adaptation on millions of small-scale farms in the tropics.

1.4 Why do you need guides for climate change adaptation?

It will be very difficult for farm families to adapt to climate change without improving their management of resources, especially in rainfed systems. Crop, livestock, fish and tree production all depend on water. About 80 percent of the world's farmland is rainfed, and much of it is land with low soil fertility, which results in low yields, especially in water-scarce areas. Also, most of the food produced in the world is produced on small farms. These farmers are getting yields that are much lower than the yields they could get with improved practices and technologies. This is especially true in Sub-Saharan Africa, Central America and Central Asia, where current yields are at 76 percent, 65 percent and 64 percent below potential, respectively. To improve yields, farmers will need to adapt by improving water management, soil management, crop management, agroforestry and animal husbandry. In nearly all locations, increased diversity of agricultural activities will be important.

Farmers past and present are used to coping with variability in weather – for example, years when rain comes later or in greater amounts than in others. But climate change really does mean change; conditions will be different and will not return to the way they were in the past, and farming systems must adapt. To respond to these changes, farmers in most locations will need to begin making important adjustments to their farming systems within the next 10 to 15 years. Your job as an extension agent is to help them to understand what is happening to the environment and to make the necessary adjustments. Your role is more important today than ever before.

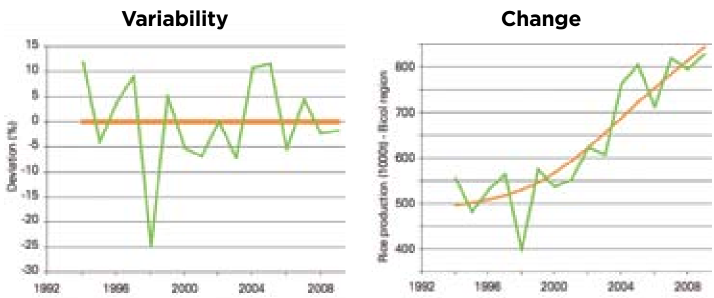
Variability and change

Both weather patterns and longer-term climate conditions are variable, and both can change.

Variability in weather is what we are used to – the natural difference between what normally happens (the average) and what actually happens. Some areas, particularly those in dry environments, have more variable weather conditions than others. Variation can be observed over different periods of time – between days, months or years. For example, the difference between the temperature today and the average temperature on this date over the past 30 years; the amount of rainfall received this month, and the amount of rainfall received on average during this month; when the rains begin, how long they last and the amount of rainfall received this season versus long-term average seasonal conditions.

Change is what we must become used to, the trend in average conditions over time in one direction or another – rising temperatures, increasing or decreasing rainfall, earlier or later start of the rains, shorter or longer rainy seasons, more or less total rainfall received. There will always be variability with changing conditions. With climate change, the amount of variability itself will increase.

Figure 1: Variability and change



Source: DuBois et al., 2012.

To adapt to increasing weather variability and climate change, farmers will have to change their management practices in a number of ways – for example, how they grow their crops, manage soils and manage water. To help you in assisting farmers to improve their management practices, several pocket field guides have been developed for your use.

Pocket Guide 1: Extension practice for agricultural adaptation provides an overview of climate change, how it is affecting agriculture, and some basic concepts, guiding principles and practices to assist you in evaluating vulnerabilities, testing responses, and working with farm families and rural communities to strengthen their adaptive capacities to respond to climate change stresses. This guide should be used in combination with *Pocket Guide 2: Crop management* to improve decisions about crop selection and care; *Pocket Guide 3: Water management* on ways to increase the capture and storage and improve drainage of water; *Pocket Guide 4: Soil management* to increase the soil's ability to retain water and provide nutrients; and *Pocket Guide 5: Livestock management.*

Most of the impacts of climate change on agriculture and rural livelihoods are expected to result from changes in the water cycle.

Climate-Smart Agriculture Sourcebook, Module 3: Water Management. United Nations Food and Agriculture Organization, 2014a

1.5 Who can use this guide?

This guide and the other guides in this series are written for you – government and non-governmental agronomists, extension field agents and program managers working with farm families and rural communities. They may also contain information that helps policymakers in setting government priorities. The authors understand that readers of these guides will have significant differences in training and field experience. Our hope is that all readers will find something of value to support their extension efforts in assisting farm families to adapt to climate change.

1.6 How can this guide be used?

You can use this guide with individual farmers, farmer groups or communities in analyzing, designing and planning ways to adapt their farming systems to changing temperatures, changes in the timing and amount of rainfall, and changes to insect pest and disease pressures. You can also use the guides in developing training workshops or in project planning. The pocket guide series provides a sample of practices for adaptation to climate change within a framework of basic concepts and principles. It also includes assessment tools, participatory approaches and activities that may help you in planning and prioritizing activities before taking action.

The challenge for adaptation is that temperature and precipitation will continue to change and will require a continuous process of introducing, testing and modifying practices to fit local conditions. The speed and severity of change in various types of weather stresses will vary from one location to another and will change over time. Each country and locality has its own unique combination of soils, crop and water resources, market opportunities, institutional services and social preferences. For that reason, much of the information provided here covers general extension approaches and practices with some examples from particular conditions, rather than a set of specific practices to be followed everywhere.

1.7 What is in this guide?

After this introduction, the guide contains four additional parts:

- Overview of why and how the climate is changing
- How climate change is affecting agriculture
- Assessing agricultural risks and vulnerability to climate change
- Working with farmers to adapt to climate change

You will want to use these guides together at various stages in the adaptation process. In the early stages, when you are assessing livelihood vulnerabilities and selecting priorities for adaptation practices, individual technical issues cannot be thought about alone. They must be considered as they interact with others – soil conservation, water management and crop selection, for example. Technical options will also need to be considered within the local context – the type and quantity of household assets, access to and control over important resources, location of markets and availability of support services, among others. You will need to do an assessment first so that you can set priorities and address the most serious risk exposures and sensitivities due to climate change in the locations where you work.

In addition, when setting priorities for improved farm management, you will need to compare individual practices with other priorities and consider any trade-offs. How do the various options for adapting to climate change affect other areas of farm management? For example, if crop residue is used to protect the soil surface to reduce evaporation, the residue cannot be used as livestock feed or cooking fuel or for making compost. When you set priorities with farmers for action and choose options for implementation, it is important to think broadly about all the effects.

Guides in this series include familiar practices that are beneficial even when future climate change impacts are uncertain. In cases where modeling studies predict specific local impacts, you will find it easier to focus on practices with the greatest potential to reduce local vulnerabilities to the identified threats, now and in the future. For example, if, 20 percent of the time (once in five years), the rainy season is currently shorter than average and models predict that this will increase to 50 percent of the time, local adaptation efforts can focus on adjusting to the earlier ending of the rainy season rather than preparing for some extreme weather event that has never occurred but might occur at some unknown time in the future. Focusing on changes in the weather that are most likely to occur will be the most effective strategy for helping farmers to adapt to climate change. To do this, it is important to include the preferences of the farmers and consider the resources available to local communities. In general, the practices selected offer "no regret" options – those that deliver benefits even if specific climate change threats do not happen. Most also deliver multiple benefits – increased productivity, reduced vulnerability and, often, reduced production of greenhouse gases.

Plants, soil and water interact closely with one another, and the adaptation guides are meant to be used together. You will find that some practices appear in more than one of the pocket guides. As an example, cover crops are mentioned in *Pocket Guide 2: Managing crops*, as a way to control weeds. They also appear in *Pocket Guide 3: Managing water*, as a way to conserve soil moisture, and in *Pocket Guide 4: Managing soils*, as a way to improve soil fertility, soil structure and overall soil health. In addition, some practices will be fully effective only if they are combined with others. Even when the most limiting factor to good yields is scarce water, the addition of irrigation can result in only modest yield increases if soils are degraded. To get larger yield increases, farmers must also improve soil fertility. Meanwhile, temperature changes may require growing new varieties or switching to different crops. Use the pocket guides together and you will multiply the benefits they provide in increasing resilience to climate change, whatever the source.

Additional resources

Ashby, J., and D. Pachico. 2012. *Climate change: From concepts to action. A guide for development practitioners*. Baltimore, Maryland, USA: Catholic Relief Services.

FAO. 2014a. *Climate-smart agriculture sourcebook*. Rome: Food and Agriculture Organization of the United Nations.

Dubois, K.M., Z. Chen, H. Kanamaru and C. Seeberg-Elverfeldt. 2012. *Incorporating climate change considerations into agricultural investment programmes: A guidance document*. Rome: Food and Agriculture Organization of the United Nations.

PART 2

An overview of climate change

2.1 What is causing the climate to change?

The short answer is that we are. Human beings. Through human activities – clearing forests for timber, fuel and agricultural land; burning fossil fuels (coal, gas, oil); and industrial processes – vast amounts of carbon dioxide (CO_2) and other important gases have been released into the atmosphere. Together, these are commonly referred to as "greenhouse gases." The name comes from their effect in the atmosphere, where they trap the sun's energy that radiates from the earth's surface, preventing it from escaping back into space, in much the same way that the glass roof of a greenhouse allows sunlight to enter but traps the sun's energy (heat) inside.

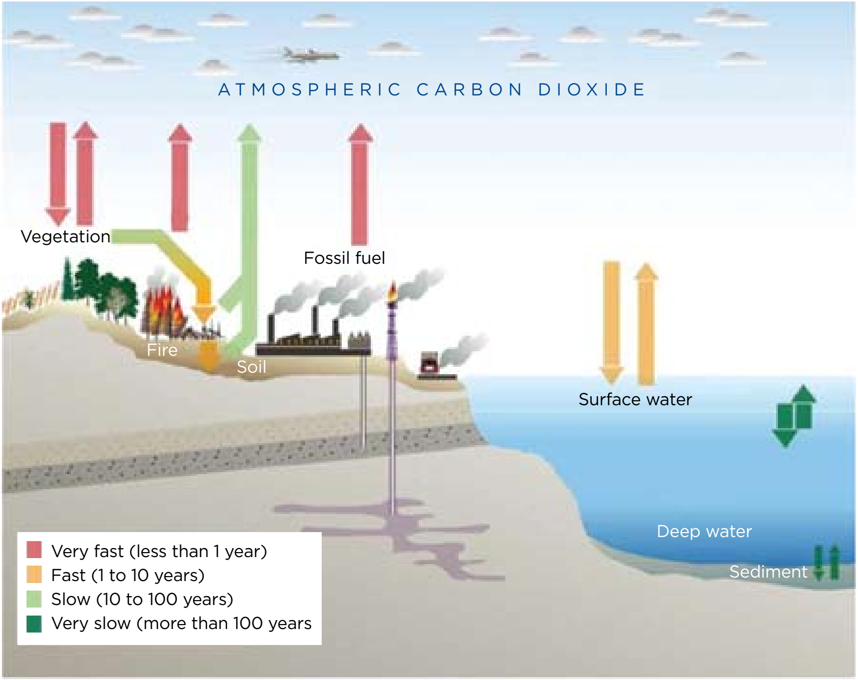
Greenhouse gases

There are six major greenhouse gases; three of them – carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) – are commonly emitted during agricultural practices.

- The burning of crop residues, forest and bush fires, and the natural decomposition of organic matter release carbon dioxide.
- Livestock and irrigated rice production are major sources of methane.
- Chemical fertilizers and nitrogen-fixing plants and trees release nitrous oxide.

We commonly talk about carbon dioxide because it is the most common and important greenhouse gas, but other gases are even more powerful in contributing to the greenhouse effect. Methane, for example, is about 34 times more potent than carbon dioxide; nitrous oxide is 298 times more powerful. More attention is paid to carbon dioxide because it is the most common greenhouse gas and is responsible for the majority of climate changes. See Figure 2: Carbon cycle.

Figure 2: Carbon cycle

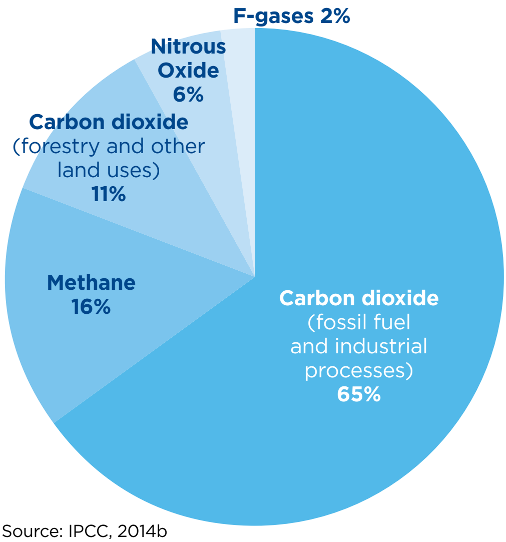


Source: IPCC, 2014a

The industrial revolution (1760-1840), named for the rapid development of steam-powered engines to power industries that previously relied on horse power, water power or manpower, marked the beginning of the rapid increase in CO_2 emissions. Initially, steam engines used wood fuel to produce steam, but increasingly they relied on coal. Today, over 40 percent of the world's electrical energy is produced by steam-powered technology fueled by coal.

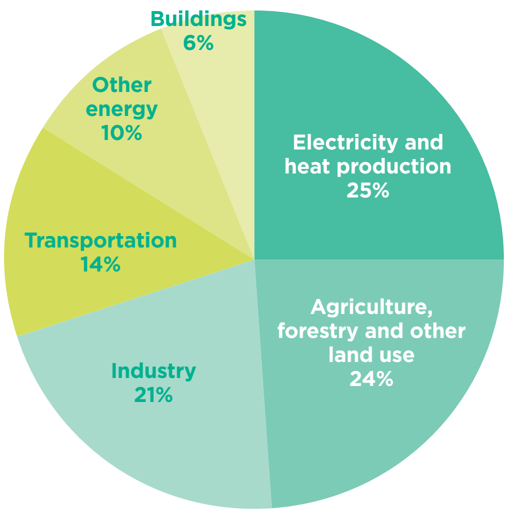
By the 1850s, the extraction and refinement of crude oil enabled development of internal combustion engines – those that power cars, trucks and tractors – and their widespread use. Together, the burning of these fossil fuels is responsible for nearly 60 percent of the total CO_2 emissions. Other sources of greenhouse gases are shown in Figure 3, and the sectors of the economy responsible in Figure 4.

Figure 3: Sources of greenhouse gases by type (CO_2 equivalent)



Source: IPCC, 2014b

Figure 4: Greenhouse gas emissions by economic sector (CO_2 equivalent)



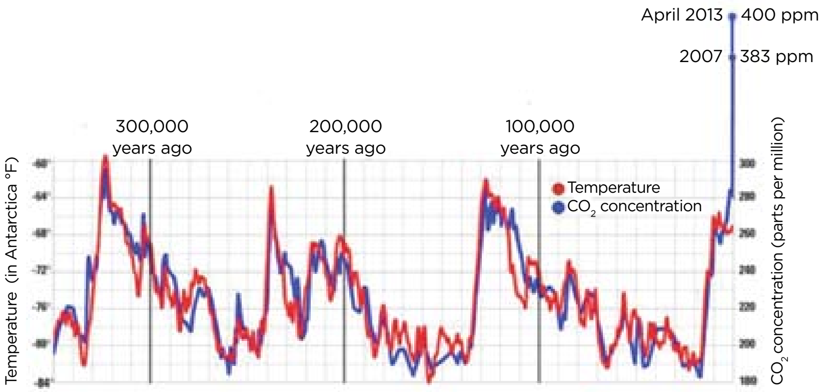
Source: IPCC, 2014b

Capturing carbon

Trees, plants and soil organic matter are important in the capturing and holding of carbon. Through the process of photosynthesis, plants absorb CO_2 from the atmosphere through their leaves and convert it into new plant tissue. This is known as sequestration – the removal of CO_2 from the atmosphere and its storage elsewhere. Globally, species such as trees and shrubs that produce woody plant material are especially important in the storing of vast quantities of CO_2. All plants contribute to the formation of soil organic matter through the loss and decomposition of their leaves, twigs and fine roots. This is another important means of sequestering carbon. In total, global forests annually absorb roughly twice as much CO_2 as is released through forest destruction. Protecting and increasing these global reserves of carbon through forest conservation and tree planting are vital to efforts in keeping the quantity of CO_2 in the atmosphere below a level that will lead to more global warming and trigger more severe changes to the climate.

Historically, the levels of CO_2 in the atmosphere have been far lower than they are today. Measured in parts per million (ppm) – the number of CO_2 molecules per million molecules in the atmosphere – the level of CO_2 in the atmosphere has been below 300 ppm for at least the past 800,000 years. The last time CO_2 levels were as high as they are today was possibly as long ago as 15 million years. During the past several hundred thousand years, because of the greenhouse effect, global temperatures have closely followed the change in the concentration of CO_2 in the atmosphere, rising when CO_2 levels rise, falling when CO_2 levels fall (see Figure 5).

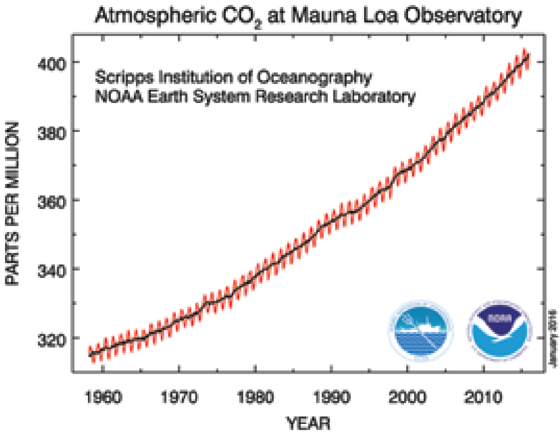
Figure 5: Relationship between atmospheric CO_2 and temperature



Source: Southwest Climate Change Network, The University of Arizona, modified from Marian Koshland Science Museum of the National Academy of Sciences. In Simpson and Burpee, 2014

In 2015, the CO_2 level in the atmosphere was about 400 ppm and is increasing at a rate of about 2 ppm per year. Some scientists believe that we need to reduce the amount of CO_2 in the atmosphere to below 350 ppm to prevent global warming from rising more than 2°C above preindustrial levels and causing very serious environmental impacts.

Figure 6: Atmospheric CO_2 concentrations

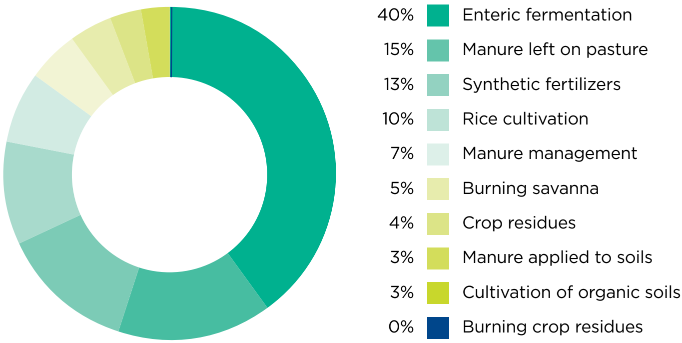


Source: NOAA, 2016a

As described in the next section, agriculture is very sensitive to changes in the environment. Agriculture is also a key contributor to the release of carbon dioxide, methane and nitrous oxide. Agricultural activities are responsible for roughly one-third of the total carbon dioxide emissions, over half of human-caused methane emissions and three quarters of nitrous oxide emissions. In other words, the very act of feeding ourselves is causing much of the climate change problem. And it will become worse as we prepare to feed and improve the nutrition of the world's growing population.

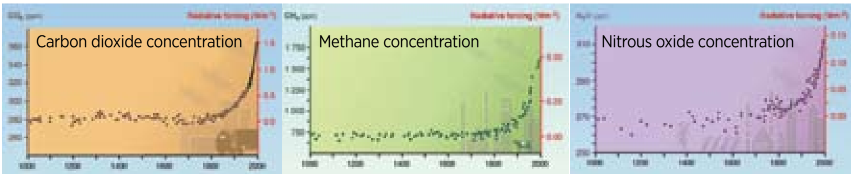
Agriculture is responsible for roughly one-third of the total carbon dioxide emissions.

Figure 7: Agricultural sources of greenhouse gases (CO_2 equivalent)



Source: Tubiello et al, 2014

Figure 8: Greenhouse gas timeline

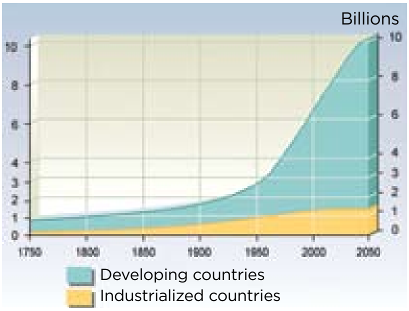


Source: IPCC, 2002

2.2 Climate change in context

In our focus on climate change adaptation, we must not lose sight of other important forces. Human **population growth** is expected to reach 9.7 billion people by 2050, from the current (2015) level of 7.3 billion. To feed this many people and support the changes to diet enabled by increased incomes, cereal production will need to increase by between 60 and 70 percent above that produced in 2010. A 60 percent increase is equivalent to what was produced globally in 1979; a 70 percent increase, equivalent to what was produced in 1985. These increases are in addition to what we are currently producing using the same land with the same water.

Figure 9: World population development

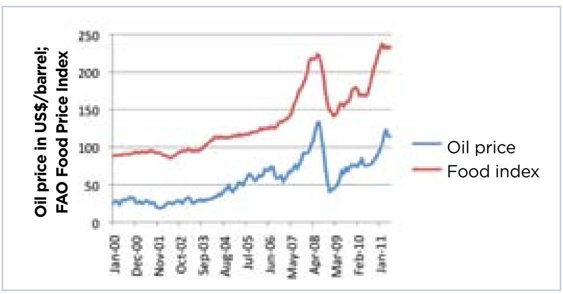


Source: Philippe Rekacewicz, UNEP/GRID-Arendal. 2005.

Producing this amount of additional food will greatly increase the pressure on **natural resource systems**. Already more than 60 percent of the earth's natural resource systems that we depend on are considered degraded or are being used unsustainably. We can no longer assume that these systems will be able to provide for the needs of future generations.

From the clothes we wear to the houses we live in and the transportation we use, virtually every part of our lives depends on **fossil fuels**. That is also true of the food we eat. Most cereals traded internationally are produced by industrial agriculture systems that use a lot of energy – depending on the crop, energy accounts for 40 to 60 percent of the total production costs. Additionally, transportation energy costs account for 40 to 50 percent of the final sale price. This means that the global food system is highly sensitive to energy prices. The spikes in food prices in 2008 and 2011 were caused largely by increases in oil prices. The majority of petroleum deposits have already been discovered and the most easily accessed brought into production. The reserves that remain are more difficult and expensive to reach. With growing energy demands will come the risk of rising food costs until other energy sources are developed.

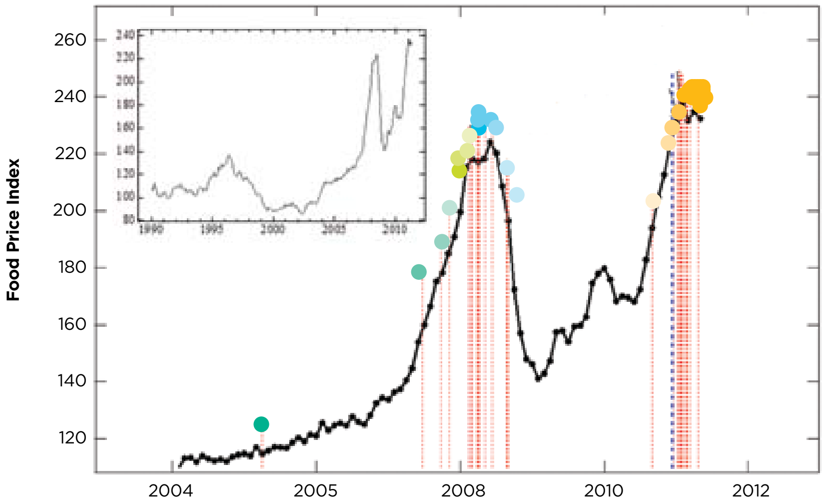
Figure 10: Global food and North Sea crude oil price rises



Source: Tverberg, 2011

As **food prices** rose dramatically in 2008 and 2011, violent protests broke out in more than 30 countries around the world. Lives were lost and several governments toppled (as shown in Figure 11 – red lines indicate protests with loss of lives). The reason is simple: the urban poor, who spend 50 to 70 percent of their income on food, were unable to feed themselves when food prices doubled. Maintaining a stable policy environment that supports agricultural research, extension and markets is critical to the functioning of food systems, and will be increasingly vulnerable to disruption in the future.

Figure 11: Food price protests



Numbers in brackets indicate number of deaths.

- Burundi (1)
- Somalia (5)
- India (4)
- Mauritania (2)
- Mozambique (6)
- Cameroon (40)
- Yemen (12)
- Sudan (3)
- Haiti (5)
- Egypt (3)
- Cote d'Ivoire (1)
- Somalia (5)
- Tunisia (1)
- India (1)
- Sudan (1)
- Mozambique (13)
- Tunisia (300+)
- Libya (10,000+)
- Egypt (800+)
- Algeria (4), Saudia Arabia (1), Mauritania (1), Sudan (1), Yemen (300+), Oman (2), Morocco (5), Iraq (29), Bahrain (31), Syria (900+), Uganda (5)

Source: Lagi et al., 2011

2.3 How is the climate changing?

Trapped by greenhouse gases, the sun's energy is slowly heating the earth's surface. Fortunately, oceans cover 71 percent of the earth's surface, and they absorb over 90 percent of the additional heat. The oceans are massive, so they warm slowly, thus protecting the planet from experiencing even more rapid rises in average temperatures. Once absorbed, however, this heat is not lost. It simply takes longer for the effects to be felt. Scientists have calculated that it takes about 40 years for the additional energy trapped by greenhouse gases, most of it stored in the oceans, to affect air temperatures. This means that the rise in average temperatures that we are now experiencing is due to greenhouse gas emissions that occurred in the 1970s and 1980s, when atmospheric levels of CO_2 were between 325 and 353 ppm. The full effect of warming that will come from the current CO_2 level of 400 ppm will not be felt until the 2040s and 2050s. These effects will continue into the future as long as we continue to release more greenhouse gases.

Once released, much of the CO_2 will remain in the atmosphere for a very long time and will continue to hold in the sun's energy. The process is complex, but scientists generally believe that 50 percent of the CO_2 leaves the atmosphere within 30 years of being released, 30 percent will stay in the atmosphere for 100 to 300 years, and 20 percent will linger for over 1,000 years. The combined effect of the length of time that CO_2 stays in the atmosphere and the warming of the massive volume of water in the world's oceans means that up to 40 percent of the global warming caused by greenhouse gases already released will continue for the next 1,000 years. In other words, global warming is very serious and is essentially permanent. We must do all that we can to prevent more greenhouse gases from being released and to promote carbon sequestration; and we will need to learn to live with and continue to adapt to the processes of change that have already been set in motion. The additional heat trapped in the atmosphere is causing several changes to our climate. These changes are commonly divided between what are called **slow-onset** and **extreme events**.

Global climate change has already begun. Every month of every year since February 1985, the average global temperature has been warmer than it was during the preceding climate period. As of 2015, 14 of the hottest 15 years ever recorded have all occurred since 2000, and the five hottest years have all occurred since 2004.

(NOAA, 2016b)

2.4 Slow-onset climate change

Slow-onset changes to the climate are those that occur gradually. The first and most important slow-onset change in the climate is the increase in average global temperatures over land and sea surfaces.

Figure 12a: Global land surface temperatures °C/°F (1880-2015)

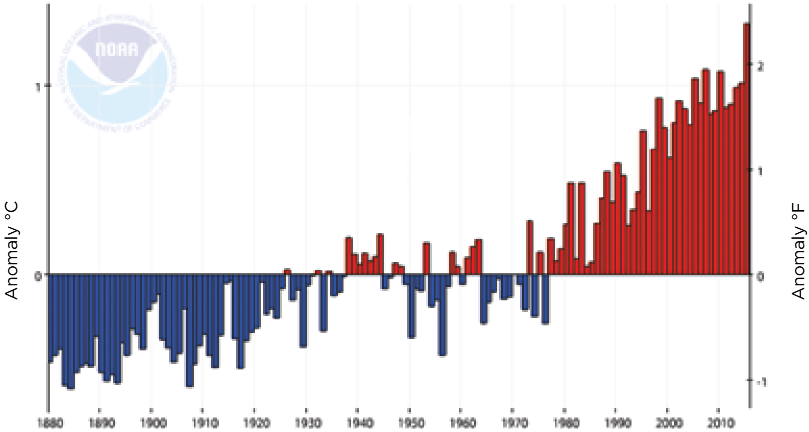
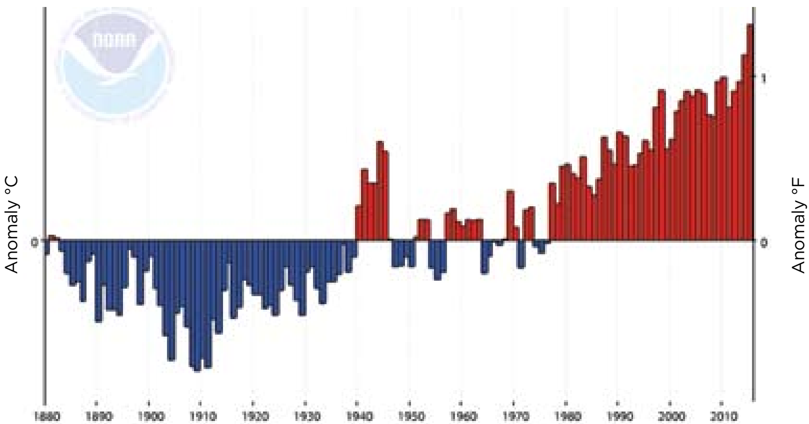


Figure 12b: Global sea surface temperatures °C/°F (1880-2015)

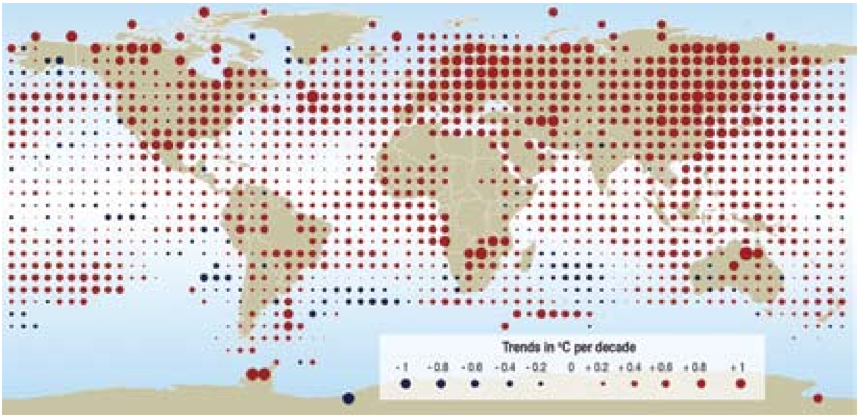


Source: www.ncdc.noaa.gov

Since 1880, average global temperatures have increased by 1°C. Most of this increase has occurred since 1980. The rise in temperatures, however, has not been the same everywhere:

- Average temperatures are increasing more rapidly over land areas than over oceans. As the ocean surface heats, some of the heat is removed through evaporation. The rest of the heat is absorbed at the ocean surface and mixed into the tremendous volume of water with little immediate warming. When land areas heat, the warmth remains at the surface.
- Average global temperatures north of the equator are increasing more rapidly than temperatures in areas to the south. Oceans cover more of the surface area in the southern hemisphere while the northern hemisphere has more land, which heats faster than the oceans.

Figure 13: Location of global temperature increases (1976-2000)



Source: IPPC, 2001

- Temperatures are increasing more rapidly at high latitudes (the Arctic) than nearer the equator. The immense areas of snow and ice covering the Arctic reflect much of the incoming sunlight back into the atmosphere, but these surfaces also heat up, causing the snow and ice to melt. As the snow cover is removed, the dark surface areas of land and water beneath are exposed. These dark surfaces absorb more heat, causing the already warmed surface to heat even more rapidly.
- Nighttime temperatures are increasing more rapidly than daytime temperatures. After sunset, nighttime is the period with the greatest potential for cooling. Clouds and increased moisture in the atmosphere, however, prevent heat from land surfaces that gradually warmed during the day from escaping into the atmosphere during the night. This trapping of daytime heat means less cooling is taking place and causes nighttime temperatures to increase faster than daytime high temperatures.

As air temperatures continue to rise, two important things happen. First, evaporation of moisture from soil and bodies of water (oceans, lakes and rivers) increases. Second, warmer air can hold more moisture than cooler air. Combined, these two forces – more evaporation and the air's capacity to hold more moisture – lead to increasing amounts of water moving through the global climate system. That means more rainfall. The increase in rainfall, however, is not evenly distributed – not where it falls nor when it falls. It is predicted that those areas that are already dry may become drier, and those with abundant rainfall may get more. When rain does fall, its distribution is beginning to change, with rainy seasons starting earlier or later, and ending earlier or later, with more of the rain falling in large storm events in some areas and longer dry spells between rainfalls in others.

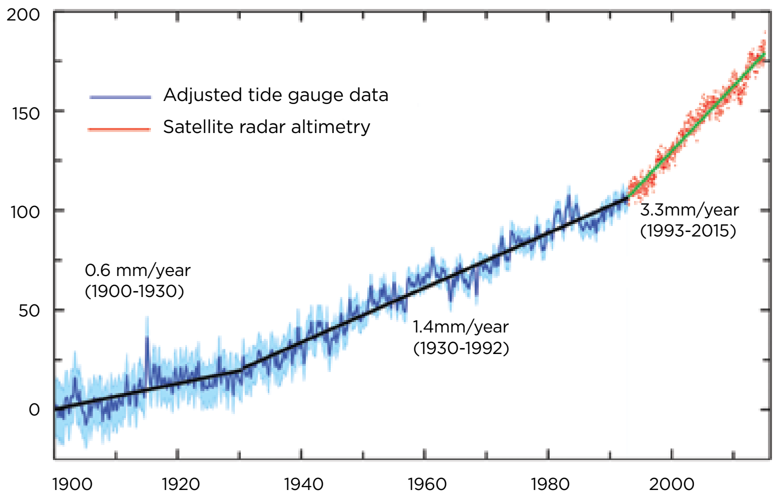
Rapid melting of sea ice in the Arctic and recent observations on the beginning of the collapse of important Greenland ice fields have the potential to increase sea levels by an additional half meter by 2050, and potentially several meters by the end of the century.

Depending on your location, you may also experience other slow-onset effects of global warming. Just as warmer air holds more moisture, warmer water increases in volume. Much of the initial rise in sea levels has been due to the warming of the oceans. Ocean levels have risen 20 cm over the past century, and they are expected to rise much more in the future as the effects of global warming increase.

The increase in air and ocean temperatures is also melting the world's glaciers, ice caps and sea ice. Future sea level rise will increasingly be the result of melting sea and land ice. Rapid melting of sea ice in the Arctic and the beginning of the collapse of important ice fields in Greenland have the potential to increase sea levels by an additional half meter by 2050, and potentially several meters by the end of the century. Nearly 1 billion people live within 10 meters of sea level around the world and are at risk from future sea level rises.

The addition of these huge volumes of water to the world's oceans will result in the gradual inundation of islands and increased flooding of coastal areas. That will mean seawater coming farther inland and contaminating coastal freshwater systems. Melting glaciers will also affect the timing and amount of runoff flowing into important river systems upon which some countries depend for their water supply.

Figure 14: Global average sea level rise



Source: Hanson et al., 2015

Melting permafrost

The rise in temperatures in the northern regions has another important, potentially catastrophic effect. Temperatures in the Arctic are rising twice as fast as those in other areas, melting glaciers and also melting permafrost. Permafrost is a subsurface layer of frozen rock, ice and organic matter that covers nearly 24 percent of the ice-free areas of the northern hemisphere. It holds roughly half of all the organic matter contained in the earth's soils – more carbon than has been released into the atmosphere since the end of the industrial revolution (1850). As the land surface warms and permafrost melts, bacteria become more active and begin to break down the organic matter contained in the permafrost, releasing carbon dioxide and methane into the atmosphere. The worry is that, as air temperatures continue to warm, more of this stored carbon will be released, leading to further warming of air temperatures, more melting of the permafrost, more release of carbon dioxide and methane – a positive feedback loop. There are also vast quantities of methane trapped in a frozen state on the ocean floor of the Arctic, and that is also at risk of being released through the warming of the oceans. If these additional stores of greenhouse gases escape into the atmosphere, the impact on the global climate system will be catastrophic.

In addition to absorbing most (90 percent) of the sun's energy trapped by greenhouse gases, the world's oceans also absorb about 25 percent of the CO_2 released into the atmosphere each year. Because CO_2 is an acidic gas, the oceans are becoming more acidic – a process known as ocean acidification. Ocean acidity has increased by 30 percent in the past 200 years, and it continues to rise. This increase in the acidity of seawater is causing problems with the health, normal body functions and even communication among various ocean species. Some species of plants and algae grow better with higher acidity and will flourish. High acidity levels, however, hurt other species, including key species of zooplankton – microscopic species at the bottom of the food chain – upon which other, larger species feed and are in turn eaten by others even higher up the food chain. The reduced production or even removal of these primary plankton species has important implications for the future of entire food chains. Also, in more acidic water, most shell-forming organisms – clams, mussels, oysters, urchins – find it more difficult to build shells, and thus construct weaker shells and, ultimately, may have their shells dissolved by high levels of acidity. Coral, which makes up reefs and entire ecosystems that provide food and shelter for complex communities of ocean species, is at risk of collapsing under the combined effects of ocean acidification and rising water temperatures.

2.5 Extreme events

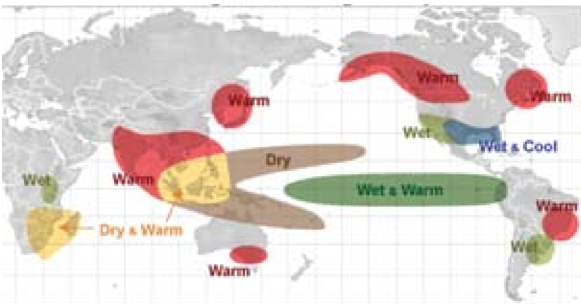
As the name suggests, extreme events have to do with excesses – too much or too little – in basic weather conditions that occur over short periods of time. Changes in the severity and frequency of extreme events are related to slow-onset changes in the climate. For example, in addition to the slow onset of rising global temperatures, the number of extremely hot days and heat waves is also increasing, and they are lasting longer and reaching higher temperatures. In parts of Africa, it is predicted that by 2100 average temperatures may be higher than the extreme temperatures of the past, and that heat waves that once occurred on average every 20 years may occur every two years.

As ocean temperatures increase and the air warms, holding more moisture, conditions are ripe for the formation of large cyclones and hurricanes, leading to flooding, and damaging winds when the storms hit land. Some of these extreme storms have almost unimaginable power. Take, for example, Hurricane Mitch, which hit Central America in 1998. Over a few days, the storm produced over 1.2 meters of rainfall in some areas, causing over 18,000 deaths and US$6 billion in damages. In 2015, Hurricane Patricia formed over the eastern Pacific, with wind speeds recorded at over 320 km/hr, the strongest storm ever measured. Depending on your location, you may already have experienced some of these extreme storm events. Since the 1970s, the power and duration of these tropical storms have increased, a trend that is expected to continue.

El Niño/La Niña

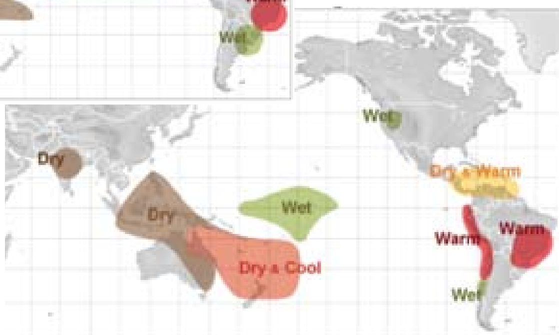
The world's oceans play an important role in controlling the climate of the planet. Ocean currents transport heat absorbed at the surface, moving it from the tropics to the northern regions, and bring cool water to the surface near the equator. Without these movements of water and associated airflows, much of the northern hemisphere would be a frozen wasteland, and areas of the tropics intolerably hot. These ocean and air currents, however, are not constant, and when they shift, we experience changes to the weather on land, sometimes resulting in extreme events. One of these important combinations of water and air movement is in the central and eastern Pacific, off the coast of South America. Under certain conditions, the ocean surface can become much warmer than normal because less cool water is rising to the surface. When these periods are strong, an El Niño (Spanish for "the boy") is said to occur and can last for several years. The opposite, La Niña (Spanish for "the girl"), results in a cooling of ocean surface temperatures below normal. During an El Niño event, some areas far away experience heavy rains and flooding, and others experience drought (see figure below). If the El Niño conditions are particularly strong, the additional warm water staying at the surface is thought to contribute to a more rapid increase in global temperature, as happened in 1997/98 and 2014/15, when there were particularly strong El Niños and global temperatures spiked. Intense warming of surface water is also thought to contribute to the formation of especially strong tropical storms, such as Hurricane Patricia.

Figure 15: El Niño rainfall impact



El Niño effect December through February

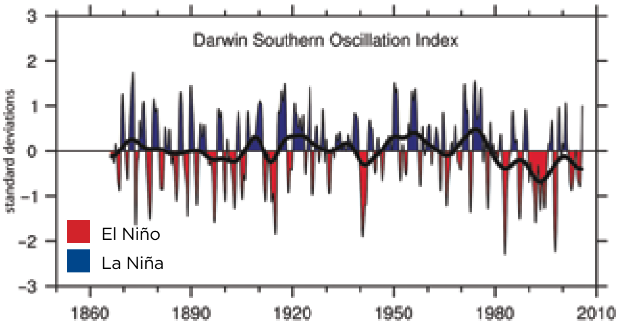
El Niño effect June through August



Source: NOAA

Conditions shift between El Niño and La Niña, with the ocean in a neutral phase about half of the time. An El Niño peaked in late 2015 that produced the warmest sea surface temperatures ever recorded. Overall, the frequency of El Niño years has been increasing since the 1970s (see Figure 16) and is expected to continue, with a decrease in La Niña phases. Other ocean and wind currents affect the weather in other regions of the world in a similar way, such as the seasonal monsoon patterns bringing rain to large parts of Asia and West Africa.

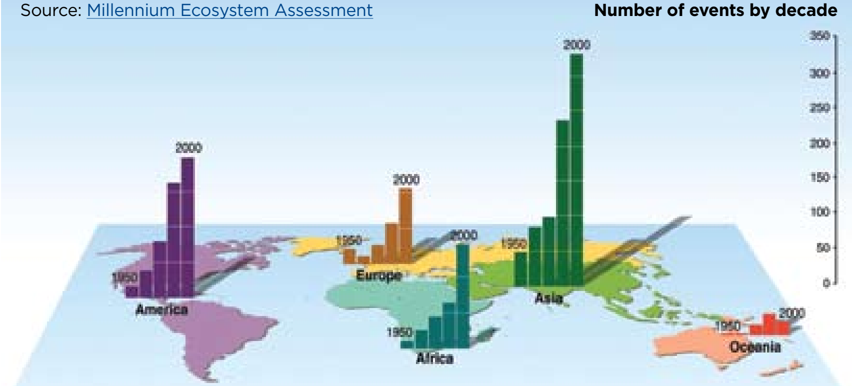
Figure 16: El Niño/La Niña timeline



Source: Archer and Rahmstorf, 2010.

In addition to the influence of El Niño events, the general ability of warmer air to hold more moisture is leading to storms that produce more rainfall. The frequency of flooding produced by these larger storms has increased significantly over the past 50 years (see Figure 17).

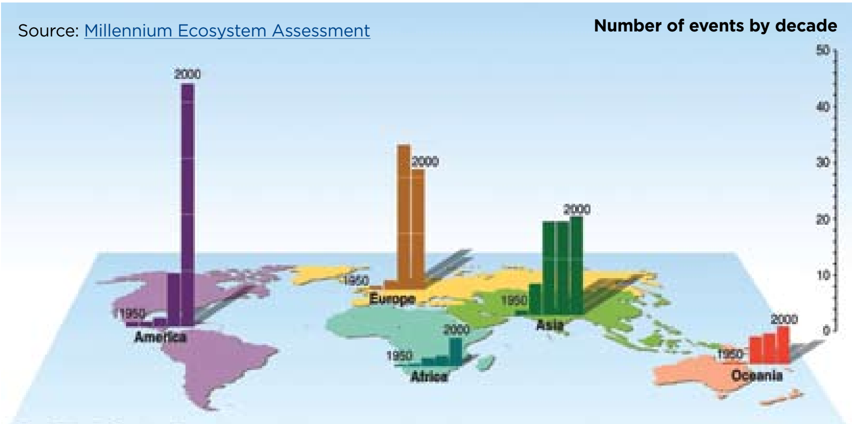
Figure 17: Flood events (1950-2000)



Source: Millennium Ecosystem Assessment

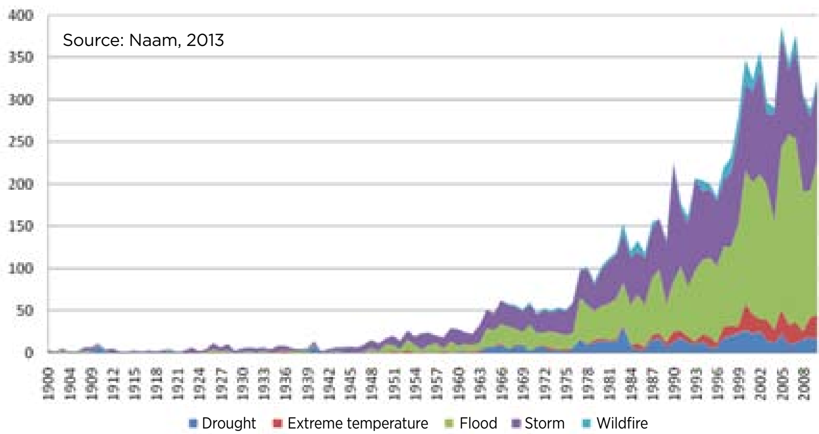
In other areas, increasing temperatures and changes to rainfall patterns over inland areas have led to more dry spells and droughts. Globally, the land area affected by drought has doubled since the 1970s. Higher temperatures, more evaporation, and more frequent dry spells and droughts also cause vegetation to dry. As a result, the number of brush and forest fires has also increased (see Figure 18).

Figure 18: Wild fires (1950-2000)



In total, the number of extreme events recorded globally each year is rising, making the world a more chaotic and difficult place to live, and creating a more challenging environment for agriculture (see Figure 19).

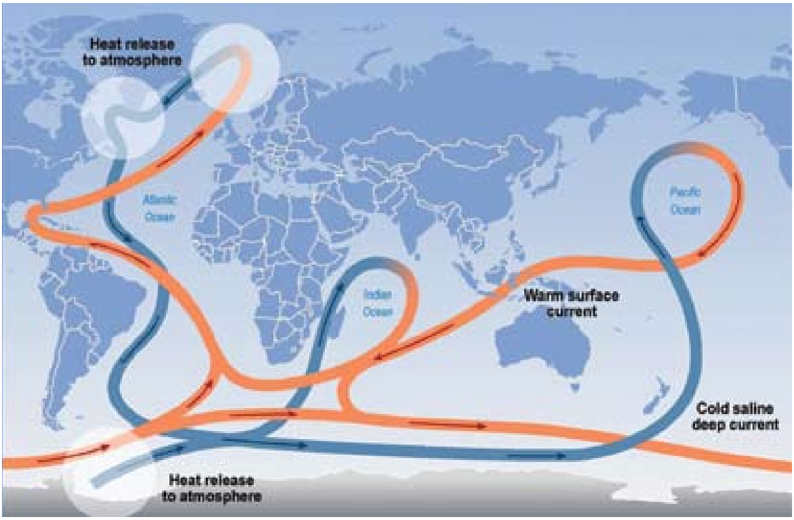
Figure 19: Number of extreme weather events globally



Vulnerable oceans

Oceans have important warm- and cold-water currents that are also vulnerable to climate change. Sea surface water that is warmed in the tropics flows northward, taking the absorbed heat with it. As the water cools, it sinks (extremely cold water is more dense than warm water), and deep-water currents flow back toward the equator.

Figure 20: Great ocean conveyor belt



Source: IPCC, 2001

The oceans are so large that these currents, carrying heated water to the polar regions and returning cold water to the tropics, stabilize the global climate system and make the planet habitable. These vital currents have been observed to be slowing, and as global warming continues they may even stop – warm water will stay in the tropics and cold water will stay in the northern regions. If this happens, the consequences will be catastrophic. This would be the most extreme event to occur in human history with the potential of triggering an ice age that would affect all life on the planet.

Key ideas

Our knowledge of climate change is growing rapidly as new information becomes available. Nevertheless, many basic facts are well-understood. The following are some key things that we know about climate change:

- Climate change is real. There is no disagreement that the climate is changing, and virtually no disagreement that human activities are the cause (97 percent of scientists working on climate change believe human actions are responsible).
- Climate change is already happening. There is also no disagreement that climate change is happening now. The evidence is well-documented by the latest report of the Intergovernmental Panel on Climate Change, the largest scientific review ever undertaken.
- Climate change is so long-lasting that it is essentially permanent, in terms of human lifetimes. The impacts will last well beyond our lifetimes, as well as those of our children's children's children. In fact, at least 40 generations will pass before the current effects of climate change will disappear, and that is only if we stop emitting all greenhouse gases now.
- Climate change includes both changes that are slow in appearing (slow-onset) and changes in the frequency and intensity of rapidly occurring extreme events. Individually and in combination, they will affect different locations at different times.
- Multiple changes are occurring at the same time. Because of the forces behind the various events – rising temperatures and changes to patterns of rainfall – some changes may seem incompatible with one another, such as more frequent floods occurring while the average annual rainfall is declining.

Additional resources

Archer, D., and S. Rahmstorf. 2010. *The climate crisis: An introductory guide to climate change*. Cambridge, United Kingdom: Cambridge University Press.

Intergovernmental Panel on Climate Change. 2014a: *Climate change 2014: Synthesis report.* Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. R.K. Pachauri and L.A. Meyer (eds.). Geneva, Switzerland: IPCC.

King, D., D. Schrag, Z. Dadi, Q. Ye and A. Ghosh. 2015. *Climate change: A risk assessment*. London: United Kingdom Foreign and Commonwealth Office.

World Bank. 2012. *Turn down the heat: Why a 4°C warmer world must be avoided.* A report for the World Bank by the Potsdam Institute for Climate Impact Research and Climate Analysis. Washington, D.C., USA: The World Bank.

PART 3

How climate change is affecting agriculture

The impacts of climate change discussed above – the slow onset of rising global temperatures and related changes to rainfall amounts and distribution, and the increased frequency and severity of extreme events – are affecting the basic environmental conditions upon which every living thing on the planet depends. Every species – plant and animal – prospers under certain environmental conditions, can tolerate others and will perish beyond some limit. Agricultural crops and animals are no different. Some of the impacts – temperature and rainfall – **directly** affect plant and animal growth, health and reproduction. Other impacts are **indirect** in their influence, leading to changes in the populations and distribution of weed species and crop and livestock pests, and the outbreak of diseases. Changes in the productivity, nutritional content and mixture of forage plant species that livestock feed on – caused by temperature and rainfall effects and increased carbon dioxide in the atmosphere – will affect animal health, making them more susceptible to diseases and parasites. The exact types of changes that you may see in the production system where you work may be very different from those occurring in other locations, and they will continue to change over time. If you work over large areas or in different ecologies, you may see some of these differences yourself.

In general, crops and animals are most sensitive to weather-related stresses when they are young, during their reproductive period, and when grain or fruit is forming or animals are lactating. For example, if, after germination, young seedlings experience a gap in rainfall for a week or more in hot environments, many will likely perish, even though most adult plants will be able to survive. Some crops and animals are more tolerant – or less susceptible – than others to certain types of stresses. There are, however, no super crops or animals that are unaffected by weather stresses.

Various types of stresses affect species in different ways. For example, well after maize plants have established themselves and are past the point of extreme vulnerability to early-season drought, the growing tip of the main portion of the plant is still below the soil surface, even when the plant is 20 cm tall. Heavy rains that cause standing water to form can kill plants at this stage of development in just a few days. As the plants approach their reproduction period – generally two weeks before and after silking – maize plants are very vulnerable to heat and moisture stress. During this time, plants can tolerate higher temperatures unless they are, at the same time, under moisture stress. Then high temperatures can cause devastating damage. Extreme temperatures at this time – above 40°C – even for a few hours, regardless of soil moisture levels, can cause pollen to become sterile, greatly reducing the amount of grain that is formed. Severe moisture stress after pollination, while grains are forming and maturing, can also greatly lower yields.

In similar fashion, livestock, poultry and fish species are also sensitive to weather and related environmental stresses. Heat stress caused by high air temperatures, especially when combined with high humidity, causes all species – cattle, small ruminants, pigs, poultry – to reduce their food intake, leading to reduced weight gain and lower milk and egg production. Depending on the heat levels and the duration of hot spells, the reduced feeding and other changes in body functioning can cause changes in the size and quality of eggs, thinning of egg shells, and reduced fat and sugar (lactose) content of milk. If the heat stress lasts long enough, the quality of both animal and poultry meat also changes, with more fat than muscle being formed. Heat-stressed animals also have less success reproducing, low-birthweight offspring, and increased susceptibility to diseases. Extreme heat waves can be especially lethal, such as that experienced in India in May 2015, when sustained temperatures above 40°C led to the death of more than 17 million birds.

Heat stress causes all species – cattle, small ruminants, pigs, poultry – to reduce their food intake, leading to reduced weight gain and lower milk and egg production.

Wild freshwater and saltwater fish populations, and species cultivated in aquaculture systems, are perhaps the most vulnerable to climate change stresses. Fish are cold-blooded, meaning that the temperature of the environment largely controls their body temperature. They cannot effectively cool themselves as water temperatures rise. Also, of critical importance as water warms, it holds less oxygen. Cold-water, cool-water and warm-water species all have their preferred range of water temperatures and oxygen levels. As water temperatures rise to near the maximum that each species can tolerate, fish become stressed – they grow more slowly, are more vulnerable to disease and parasites, and have less success reproducing. Depending on where they are – river, lake or ocean – fish have limited ability to migrate in search of new environments with conditions closer to those they prefer. Once temperatures exceed critical thresholds, species that cannot escape will die out.

Improving your knowledge of when in their stages of development various species are most sensitive to weather risks will help you to identify potential risks related to climate change and to work with farmers in selecting adaptive management practices that they might use to avoid or reduce risk exposure.

The following are some of the important direct and indirect effects that changes in the weather are having on agriculture (more detailed discussions of these impacts and other climate-change-related risks are included in the pocket guides on crops and livestock):

3.1 Direct effects

Rising average temperatures: Higher temperatures have many direct impacts on crop and animal species. In cool environments, heat-loving plants such as bananas and cassava can benefit as temperatures increase, whereas cool-climate plants such as Arabica coffee suffer. In most crops, yields begin to decline when daytime high temperatures exceed 30° to 34°C. Some fruit and nut species require cold periods during the year to produce well. For these species, rising temperatures will lead to declining yields and ultimately their disappearance from farming systems in some locations where they now prosper.

In cool environments, heat-loving plants such as bananas and cassava can benefit as temperatures increase, whereas cool-climate plants such as Arabica coffee suffer. Some fruit and nut species require cold periods during the year to produce well.

One of the most important general impacts of rising average temperature on plants is that they mature more quickly. The faster plants mature, the less time they spend in each stage of their development, including the reproduction stage. A shorter flowering period can result in less successful fertilization and lower yields. All plants have limits to the temperatures that they can tolerate (high and low). Ultimately, once these limits are passed, specific varieties and crops will no longer be able to be grown.

Livestock, poultry and fish are also directly affected by rising temperatures. Important differences exist between species, breeds and even individuals, but at some temperature level all species become stressed (heat stress), resulting in reduced feed intake, slower growth, less successful reproduction, less milk production or fewer, smaller eggs, and changes to meat quality.

Increasing nighttime temperatures: Because nighttime temperatures are rising faster than those in the daytime, the increase in average temperatures is due mainly to the more rapid increase in temperatures at night. Higher nighttime temperatures affect crop species in many ways. One of the most important is through increasing plant respiration. Plants create energy from sunlight and soil nutrients through the process of photosynthesis, and they use some of this energy along with oxygen to power growth and maintain plant health. This is called growth and maintenance respiration. It occurs day and night, and as temperatures rise, the rate of plant respiration also rises. At night, after the sun has set and while no photosynthesis occurs, high temperatures lead to the consumption of larger amounts of plants' energy created during the day. In rice, for example, the increase of nighttime temperatures from 27°C to 32°C increases respiration by 40 percent. Energy used in respiration is not available for producing grain, so crop yields decrease.

High nighttime temperatures can also interfere with plant respiration and reproduction.

High nighttime temperatures can also interfere with other processes of plant growth, including reproduction. Varieties of common beans, for example, need temperatures to fall below 18°C (generally at night) during flowering or they will not reproduce. In livestock and poultry, sustained high nighttime temperatures do not allow individuals to recover from the heat of the day, thus magnifying the impacts of heat stress on health, growth and reproduction.

Heat waves: Exceptionally high temperatures can be particularly damaging if they occur when plants and animals are reproducing. The pollen of important cereal crops such as rice and maize, for example, will become sterile if, during flowering, temperatures rise above 35° and 40°C respectively, even for a few hours. If, during heat waves, the core body temperature of livestock and poultry rise above tolerable limits – 41.5°C and 47°C (38.6°C and 42°C are normal) – animals begin to die.

General changes to rainfall: Rainfall that occurs out of season – too early or too late, or when crops are not being grown – or rain that falls in quantities greater than the soil can absorb, and is therefore lost to runoff or evaporation, is not useful for agriculture. Thus, even if the overall amount of annual rainfall remains nearly the same under climate change, changes to when the rainfall occurs may reduce the portion that is actually available to crops. In some areas, rainfall is becoming more variable and thus less dependable, resulting in more "false starts" to the rainy season, crop failure after germination and the need to replant.

Overall decreases in rainfall will also decrease the amount of forage that is available for livestock and can affect water systems (lakes and rivers) supporting wild fish populations and aquaculture systems.

Changing seasonality and monsoon patterns: Changes to overall rainfall patterns are changing the very nature of rainy seasons – when the rains begin, how long they last and the total amount that an area receives. A shortened rainy season – because of a later start or an earlier end or both – reduces the time that crops have to complete their growth cycle. The reproductive cycle of some plants (photosensitive species), such as varieties of sorghum, is triggered by day length. North of the equator, where the end of the rainy season occurs as days are growing shorter, an earlier end to the rainy season can mean that these species may not have sufficient soil moisture to produce good yields because the timing of the rainy season no longer matches their reproductive cycle, which is determined by day length.

The reproductive cycle of some plants, such as varieties of sorghum, is triggered by day length.

In areas of South and Southeast Asia and West Africa, the rainy season is triggered by subcontinental monsoons, the massive movement of moist air from nearby oceans onto land areas. Changes in these critical movements of air masses, which are driven by seasonal changes in ocean surface temperatures and continental trade winds, are affecting the cropping season over vast areas. Events such as strong El Niños can significantly affect rainfall patterns in one or more cropping seasons on a global scale.

Dry spells and droughts: Up to a point, periods without rain can be healthy for plants and animals – they reduce risks of rot, fungus and mold, and some diseases, and stimulate plants to send roots deep into the soil in search of moisture. This benefit, however, is not the same for all species, and there are limits beyond which the lack of water has damaging effects. In pastoral systems, for example, adult animals of indigenous cattle breeds can go 2 to 3 days or more without water if they must, whereas milking dairy cows must have water every day. Under higher temperatures, livestock and poultry significantly increase their water consumption to replenish moisture lost through sweating and respiration (panting). Heat-resistant livestock breeds are able to sweat more than non-resistant breeds. As temperatures rise above 30°C, dairy cows and poultry will increase their water consumption more than 50 percent above normal. If there is an absolute shortage of water, however, individuals die. It is estimated that during severe droughts in Africa, 20 to 60 percent of the livestock have perished in affected areas.

Fish species, of course, need water to survive. Wild freshwater fish populations and those raised in aquaculture systems are highly vulnerable to long periods of drought that affect the water systems (lakes and rivers) in which they live and reproduce. Significantly reduced water levels can decrease the number of wild fish that can successfully reproduce, leading to declines in populations. Very few species, especially those with commercial value, can tolerate being out of water for very long.

Floods and periods of inundation: Serious flood events can be devastating, literally washing soil, crops and livestock from hillsides and level plains, bursting the banks of fish ponds, and drowning animals trapped in cages or structures. In less severe cases, flooding that results in standing water that lasts for several days will drown most crops by filling the air spaces in the soil that crops need to breathe (waterlogging). Some locations in the landscape are more vulnerable to damage from floods and inundation than others, and these locations may change as rainfall patterns change.

In heavy, water-holding soils, an excess of rainfall that lasts for several days will damage or even kill sensitive crops.

Because of the relationships between crop tolerances, soil types and water availability, highly localized inundation that affects portions of fields can cause damage that is difficult to see. Maize and millet, for example, do not tolerate waterlogging. In heavy, water-holding soils, an excess of rainfall that lasts for several days will damage or even kill these crops. Other crops that are more tolerant to wet conditions, such as sorghum and rice, or all crops planted in light, freely draining soils will be little affected.

High winds: The impact of high winds along coastal areas from hurricanes, cyclones and typhoons, and those associated with severe storm events inland can be devastating for crops and trees. Cereal and horticultural crops in particular are susceptible to being knocked down (lodging), especially when they are heavy with mature or nearly mature grain or fruit.

Interactions between direct effects: Important interactions can occur between changes in weather conditions that directly affect all animal and crop species. Livestock, for example, are more vulnerable to the effects of rising temperatures when air humidity levels are also high. The combination of high temperatures and a shortage of water can be fatal to livestock and poultry. Likewise, in the effort to cool themselves, crops naturally lose more moisture through their leaves (transpiration) as the temperature increases. This can magnify the stress on plants if they are also suffering from lack of water due to inadequate rainfall.

Higher temperatures also result in greater evaporation of soil moisture, which increases the chance that crops will become moisture-stressed. This combination of heat and moisture stress is particularly damaging during crop reproduction. The effect of both heat and dry spells on crops and livestock is intensified by strong winds, which increase the rate of moisture evaporation from soil.

3.2 Indirect effects:

Pollinators: Worldwide, over 80 percent of all flowering plants are pollinated by another species. These species, known as pollinators, are essential in assisting crop reproduction that globally produces 35 percent of the food we eat. Birds, bats and small animals contribute, but the most important are insects – bees, wasps, flies, beetles and ants. Climate change impacts that directly affect these species will have a devastating effect on crops that require pollinators for their reproduction. In the tropics, most pollinators are nearing the upper limit of their temperature tolerance, so the effect of rising temperatures will be most severe here.

Climate change impacts may have devastating effects on crops that require pollinators for their reproduction.

Pests and pest predators: Worldwide, pests reduce crop yields by 10 percent to 16 percent. As temperature and rainfall conditions change, the locations where various insect pests are found and their populations will also change.

In cold-weather climates, milder winters and temperatures that rise earlier in the spring will also allow more pests to survive and to appear earlier in the year. Higher temperatures may allow some pests to reproduce more frequently, thus increasing the potential intensity (more pests per season) of crop damage.

The same changes that affect insect pests also affect other species that feed on these pests (pest predators). There may be situations where important pest predators are no longer able to cope with changes to the climate while pests are less affected. This could lead to a decline in predator populations and rising populations of pests.

Diseases: Some crop and livestock diseases are spread by insects. Others are spread through the environment by wind, water or infected soil, and still others by physical contact – animal to animal, or contact with infected tools or clothing. Those diseases that are spread by insects or environmental conditions are most likely to be affected by changing weather conditions. In some locations, changes in climate conditions can lead to the sudden appearance of diseases that were not present in the past, and increasing outbreaks and severity of diseases that had been present but not devastating. This is most easily seen in mountainous areas. As temperatures rise, pests and diseases can move higher up the slopes into areas that were previously too cold for them. In places where diseases are already present, local infection rates may explode in years when conditions are right. Heavy rainfall, for example, that leads to increased local humidity or flooding of pasture areas can create conditions in which populations of certain types of crop disease organisms (mold and fungi) and livestock pests (gastrointestinal parasites) can soar. In general, crops and animals that are already stressed by other changes in environmental conditions – heat, drought and poor nutrition – are more vulnerable to disease infections and parasites.

Livestock pests and diseases

Responding to climate change impacts on livestock pests and diseases will be particularly challenging. Globally, in developing countries, livestock diseases kill 20 percent of ruminants and over 50 percent of poultry each year. Different diseases are transmitted directly through the environment (water, wind, pasture), through insect pests (flies, mosquitoes, ticks) and through direct (animal-to-animal, animal-to-human) contact. As weather conditions change, the locations where insect pests carrying disease are found will also shift, resulting in the introduction of new disease risks into areas where they were not found or were less common. Conditions in particular years may favor specific disease-carrying pests and result in disease outbreaks. Weather events such as frequent heavy rains and flooding may create conditions that are ripe for increasing the transmission (through infected mosquitoes) of diseases such as Rift Valley fever in livestock.

Initial livestock management responses to changing weather conditions can also influence the level of exposure of animals to various pests and diseases. For example, during dry spells that limit the number of places where livestock can access water, herders may need to move their animals to new watering points where the animals will potentially be in more frequent close contact with other herds, thereby increasing the risk of animal-to-animal disease transmission. In more severe droughts, herds from one area may need to move long distances to new locations in search of forage and water, potentially carrying diseases with them.

Weeds: As with insect pests, weed species' populations and where they are found may change. Globally, weeds are believed to reduce potential crop yields by as much as 36 percent. Relying primarily on wind, water, birds and animals, weed seeds are constantly being moved to new locations. Often the conditions in areas where these seeds land are not suitable, and weed species do not become established. As temperature and moisture conditions change, however, weeds can quickly occupy new locations. Weeds have not been bred to put their energy into producing edible grain or fruits – instead, they use their energy to establish themselves quickly and develop extensive root systems that ensure their survival. As a result, once established, weeds are generally more resistant to weather stress than agricultural crops. Weed seeds can also survive in the soil for decades and longer. Even after severe weather events, such as droughts, they will return as soon as there is sufficient moisture.

As temperature and moisture conditions change, weeds can quickly occupy new locations.

Environmental effects: Changes in rainfall and temperature will affect entire ecosystems and food chains, starting with the smallest species. When there is sufficient soil moisture, higher temperatures stimulate soil organisms and microbes (bacteria and fungi) and speed up the breakdown of crop residues and the decomposition of soil organic matter, which makes nutrients available to plants. If plant roots do not take up these nutrients, they are at risk of being lost through soil erosion (which may increase as large storms become more common) or movement into deeper soil layers where crop roots may not be able to reach them. Changes in temperature, rainfall, soil fertility and rising carbon dioxide levels will also change the diversity and nutritional quality of plant species in grazing areas. The types of plants that will be favored may be less nutritious feed for livestock and thus affect their health and productivity.

Interactions of indirect and direct stresses: Just as changes to the climate that have direct effects on crop and livestock species can have greater impact when combined, these direct impacts also can combine with indirect effects to place even more stress on animals and plants. For example, when some crops, such as potatoes, are under moisture stress, damage from insect pests (green leafhoppers) can soar. The weakened plants become more attractive to pests when they are stressed. Livestock and poultry that are under heat stress or weakened by low quality forage (another potential indirect result of climate change) are more vulnerable to diseases and the impacts of pests and parasites.

Management responses can create new vulnerabilities: Sometimes human management responses to direct and indirect effects of climate change, such as decreased rainfall, can create new vulnerabilities. For example, in areas experiencing a decline in rainfall, farmers can take steps to capture more of the rain that does fall. Some of the available technologies are very effective. Depending on the soil types and crop sensitivities to waterlogging, the capture of more rainfall, especially that from large storm events (also increasingly common), can create localized inundation conditions that decrease growth in waterlogging-sensitive crops. The movement of livestock herds to new locations in search of water and better pasture can expose animals to new pest and disease pressures. Efforts to retain river water in reservoirs and dams in response to reduced rainfall can affect stream flow and survival of wild fish populations downstream. Some species have adapted their reproduction cycle to match seasonal flooding. Disruption of that cycle can greatly reduce their populations.

Key ideas

- Every species has unique tolerances as well as limits to the range of conditions that it can withstand.
- Increasing temperatures and changes to rainfall patterns and amounts directly affect crop and animal production systems. Climate change can also indirectly affect these same systems through changing pressures from diseases and weed and pest populations. These indirect impacts are sometimes less noticeable than direct impacts and less readily connected to changes in the climate.
- Climate change stresses can also act in combination with greatly increased effects. The potential combination of effects – heat and moisture stresses (direct-direct), moisture stress and vulnerability to insect damage (direct-indirect), increased pest populations and pest-transmitted disease (indirect-indirect) – makes the identification of appropriate management responses and rapid action especially important and challenging.
- Some management responses can create new risks. It is important to thoroughly think through the potential consequences of various management options before taking action.

Additional resources

FAO. 2016a. *Climate change and food security: Risks and responses*. Rome: Food and Agriculture Organization of the United Nations.

World Bank. 2015. *Agricultural risk management in the face of climate change*. Agriculture Global Practice Discussion Paper 09. Washington D.C., USA: The World Bank.

PART 4

Identifying climate change risks and assessing vulnerability

As described in the previous sections of this guide, climate change and its direct and indirect impacts on crop and animal production is not one thing but many related changes and types of stresses. Exactly what, when, where and how farm families will feel these changes in the areas where you work – individually, one after another and in combination – is unknown. To work with farm families to reduce their vulnerability to the various climate change risks, you will need to identify with them the:

- *Exposure* to various climate change risks
- *Sensitivity* of various species or activities to the risks identified
- *Adaptive responses* that they can make to avoid risks and reduce sensitivities

These are challenging tasks, but you are not alone! The number of potential partners and valuable resources available to assist you, including these pocket guides, is rapidly growing.

4.1 Identifying climate change risks

To start, your first and most important task will be to learn all you can about how the weather patterns have changed over the past several decades in the locations where you work, and how they are expected to change in the future. This information is essential in helping you to identify the types of climate risks to which crop and animal systems are exposed. One valuable source of information will be the national meteorological service. Its responsibility is to collect and analyze weather data. Many countries now have a specialized research unit within the agriculture, environment or natural resources ministry working on climate change impacts, and many donor-funded projects have carried out important climate vulnerability studies. Often researchers at national universities or research institutes are working on climate change issues. These units, individuals and studies will be important sources of information on climate and weather changes.

Details are important!

For example, you may learn from the meteorological service that the total amount of annual rainfall has not changed much in the past 20 years. But you need to go deeper to learn, for example, whether more of the rain that does fall now comes outside of the traditional growing season or falls in large storm events, with longer gaps between storms. Rain falling outside of the growing season – too late or too early – and rainfall lost as runoff in large storms is not available to growing crops. Changes in the amount of moisture actually available to crops – especially during critical stages of plant development such as germination, reproduction and grain development – may have important impacts on the ability of farmers in your area to produce certain crops.

The meteorological service may also tell you that daytime temperatures have risen around 1°C over the past several decades, still well within the limits for good crop production of the major crops in your areas. But you need to go deeper to learn whether nighttime temperatures are rising faster than daytime temperatures, and if the number of extremely hot days has been steadily rising. You will learn in *Adaptation Guide 2: Managing crops* that higher nighttime temperatures have a much more serious effect on crop production than daytime temperatures, and that extremely hot days during the critical periods of flowering and grain maturation are very damaging to yields, especially if crops are under moisture stress at the same time.

You may find information on *annual averages* – average annual temperature, average annual rainfall – useful, but more useful will be information on how these averages have changed over time, especially in the past few decades. Better still are details on changes to specific weather features that have important impacts on local crop and animal production systems. Looking for specific weather information and assessing crop and livestock risks (covered in the next section) will be an iterative process. In other words, the more specific information you have about crop and livestock sensitivities, the more you will need to look for specific weather information that tells you whether the weather risks affecting crops and livestock are occurring more frequently. Table 1 lists some important general weather features. If information on these is available, it will help you to better understand what changes are occurring in local weather patterns and to identify the risks that may affect agricultural activities.

Table 1. Climate change risks for rainfed cropping systems

Temperature		Rainfall	
Measure	**Insight**	**Measure**	**Insight**
Change in average annual temperature	Are temperatures increasing?	Change in average annual rainfall	Is rainfall increasing or decreasing?
Change in average monthly high temperature	Are days getting hotter and, if so, how quickly?	Change in average monthly rainfall	Is there a shift in when rainfall is occurring during the year?
Change in average monthly low temperature	Are nights warming and, if so, how quickly?	Change in timing of start of rainy season	Are rains starting sooner or later?
Change in number of days above high-temperature threshold	Is more of the growing season experiencing critically high temperatures that could affect crop yield?	Change in number of dry spells at the start of rainy season	Are false starts to the growing season increasing?
Change in number of days above low-temperature threshold	Are hot nights becoming more common?	Change in length of rainy season	Is the growing season getting longer or shorter?
Change in number of extremely-high-temperature days	Are hot days or heat waves becoming more frequent?	Change in amount of rainfall within rainy season	Is the amount of rainfall available during the rainy season changing?
		Change in number of days between rainfalls	Are dry spells becoming more frequent and/or longer?
		Change in number of rainfalls above threshold	Is more rainfall being lost to runoff?

Source: Simpson, B.M. 2015a.

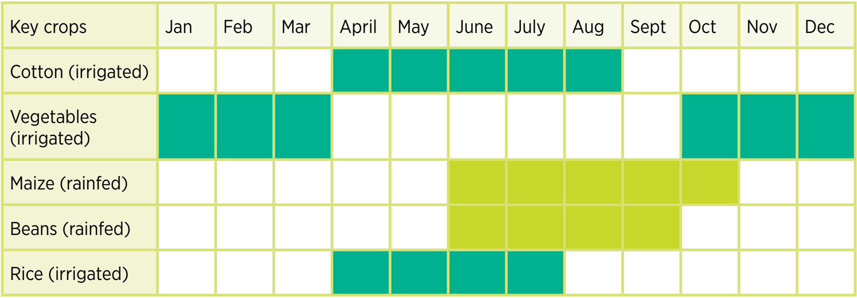
Another very important source of information will be farmers' observations. Farmers, through years of experience in the locations where they live, are often very aware of changes in local weather patterns. Farmers' observations on these changes – the frequency of inundation and dry spells occurring in local fields – are as important as weather data from the national meteorological service and are often more locally relevant. Because farmers rarely keep records of exactly when various events occurred, in which years and what months, it may be difficult to determine the changes in frequency or severity of certain events, or any shift in when they occur within the growing season over long periods of time. Some changes, such as an increased frequency of high nighttime temperatures during a particular point in the growing season, are difficult for farmers to notice. In these instances, you will need to rely on other sources of information in combination with farmers' observations.

As a general rule, you should always look for and compare multiple sources of information – for example, using farmers' observations to validate data analyzed by the national meteorological service or the information from vulnerability studies. The very act of getting farmers involved in discussions about the changes that they have observed in local weather patterns is valuable – it encourages them to be more alert to future changes that will be critical in making future adaptive decisions.

Equipping farmers with a simple rain gauge and maximum/minimum thermometer can allow them to begin to accurately measure and record the patterns in their local weather. This is one way of strengthening their adaptive capacity.

One useful tool to help organize the various types of information that you will need is to develop calendars with farmers of their cropping season and main agricultural activities, and indicate when certain types of damaging weather events are present. As shown in Figure 21, you can start by first making a calendar of the cropping season with columns for the months of the year or local ways of dividing up the calendar year. Next, create a new row for each major agricultural activity. Indicate the time period when the crop is being cultivated, beginning with planting and ending with harvest for crops. For livestock, indicate any regular sequence of events related to conception, gestation, lactation and harvest.

Figure 21: Cropping calendar



Figures, diagrams and models

The use of figures, diagrams and models is a good way to focus attention, demonstrate relationships, stimulate discussion and record information for use in planning. When you create any diagram, chart or graph with farmers, it is vital that they understand what is being represented. Depending on the education level of the farmers that you work with and their familiarity with charts and graphs as a way of representing information, you may need to experiment with different approaches to recording information and representing events. Do not be afraid to give farmers the pen so that they can create their own way of representing information in a way that makes sense to them. Just make sure that you also record what the various symbols or figures represent so that later on you can easily refer to and use the information that the group has recorded. At the end of this section are some resources that you can explore to help identify alternative approaches that you can adapt to work with farmers in recording critical information related to climate change.

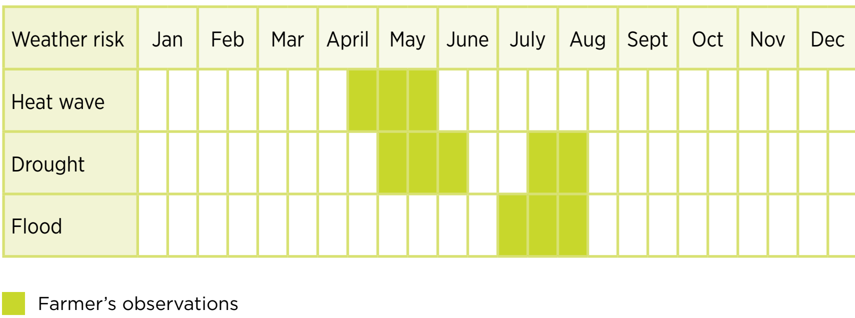
Development of the cropping season calendar (and the following one on weather threats) can be carried out with mixed groups – men and women, and farmers of various ages. You will need to be alert so that certain individuals or those representing any particular type of farming system do not dominate the discussions. If this begins to happen, use your good facilitation skills and thank the individual(s) for their contributions and ensure that others also have the opportunity to speak. It will be important to ensure that all of the major crop and livestock activities are identified. If a single group is too large – more than 25 – or it proves too difficult to enable everyone to equally participate, you can create smaller groups and repeat the exercise with individuals with similar social backgrounds. If you make smaller groups, it will be important to later bring the groups back together and share results and create a single cropping season calendar representing the combined input.

Next, identify the weather threats that farmers have observed (let farmers identify the threats themselves – do not give them the answers), and indicate when these weather events most commonly occur within the cropping season. These threats (such as dry spells) may occur more than once a year. The list of weather threats can be placed immediately below the crop/livestock rows on the same calendar, or you can create a separate calendar, as in the figure below.

Farmers' knowledge of weather is most closely associated with their primary activity – farming. Therefore, before talking about changes to weather patterns, it is important to put the discussion of weather in a context that makes most sense to farmers.

Farmers growing beans, for example, may be able to easily recall specific events such as flooding caused by heavy early rains or damaging dry spells that occurred while their crops were very young and sensitive to these types of stresses. In dryland areas, farmers raising sorghum and millet will have noticed rainy seasons that ended sooner, causing lower yields due to moisture stress during the crop's grain-filling stage. The intent is to have farmers think back over the past 10 to 20 years and indicate at what point in the growing season specific types of weather events most often occur in their area.

Figure 22: Farmer's observations of weather threat calendar

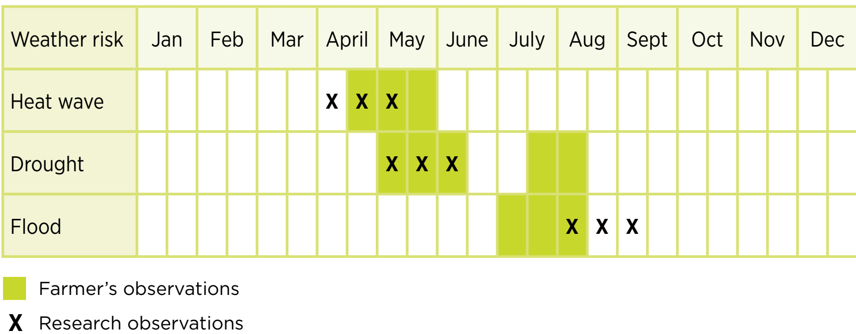


Optimum balance

Areas with two rainy seasons (bi-modal) will be more complicated to represent than areas that have only a single rainy season (mono-modal). Always seek an optimum balance between completeness and simplicity, so that diagrams do not become too complicated and unreadable.

Once you have indicated on the calendars what the farmers do (their agricultural activities) and what they have observed (weather threats or changes to weather patterns), you can add information that you have gained from other sources, such as researchers, the meteorological service or special studies. This can be added to the same calendar using different colors or symbols (see the example below). It is good then to discuss with farmers any differences between their observations and those from other sources, and to come to agreement on the best way to represent recent weather patterns. If you have information or predictions on future changes to the climate, this information can also be added to the calendar.

Figure 23: Farmer/researcher observations of weather threat calendar

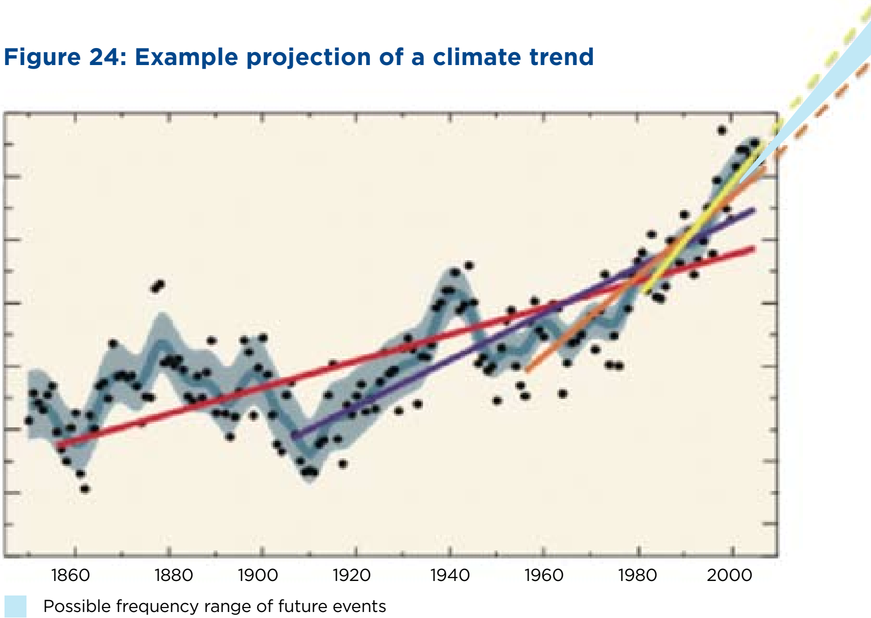


Predictions for the next 10 to 20 years are more useful than those that cover much longer periods of time (until the year 2050 or 2100, for example). If you do not have access to useful estimations of how the climate is expected to change, you can attempt to make your own estimations using the information that you have on how the weather has already changed. Simply extend the trends of any noted changes over the past few decades (increases, decreases, later, earlier) for another 10 to 20 years (see Figure 24).

For example, if you have information showing that the rainy season starts 10 days later than it did 20 years ago (an average change of a half day later per year), you can extend this trend over the next decade or two. In this case, the rainy season would be expected to start five to ten days later than it does now. Similarly, if over the past 20 years, the frequency of midseason dry spells lasting one week or more has increased from once to twice a year, you would extend that trend over the next decade or two and indicate that droughts might occur as often as three times a year.

The number of years that you include in determining past changes in the weather is very important. You may find, for example, a steep increase in the frequency of certain events – say, dry periods during the growing season – over the past decade. As shown in the figure below, taking a very long view – say, the past 100 years – could lead you to underestimate the likely increase in the number of dry periods per season in the future. Similarly, taking a very short-term view – over the past decade – may lead you to overestimate the frequency of future dry spells. In this situation, you can extend the trends of the past 20 and 40 years to create a range in the possible frequency of future events (as shown in the figure below).

Figure 24: Example projection of a climate trend



Source: Archer and Rahmstorf, 2010

Note: Estimations of climate change are often very general and not organized in a way that will allow you to place the information on a cropping calendar. For example, the results of a vulnerability study may simply state that dry spells are predicted to be more frequent by 2050. If this is the case for the information that you have access to, simply list the major climate changes that are anticipated. You can use this information along with information on the changes that farmers have observed when discussing what the future might look like. This additional information may confirm what farmers are already observing, or it may differ, indicating that more – or less – change may be anticipated.

Depending on the type of information that you have access to, you may be able to use the weather threat calendar to discuss with farmers what has occurred up until the present and modify the calendar to show what is anticipated to occur in the future. Comparing and discussing the two situations – the past and the future – will be helpful in understanding climate trends and what challenges may be coming (see Figure 25 below). Looking only at what happened in the past may lead to mistakes in anticipating what conditions will be like in the coming decades.

Figure 25: Example of observed and estimated future weather threat calendar

Weather risk	Jan		Feb		Mar		April		May		June		July		Aug		Sept		Oct		Nov		Dec	
Heat wave							X	■ X	■ X	■ X (red)														
Dry spell								■	■ X	■ X	■ X	X (red)		■	■									
Flood													■	■	■ X	X	X							

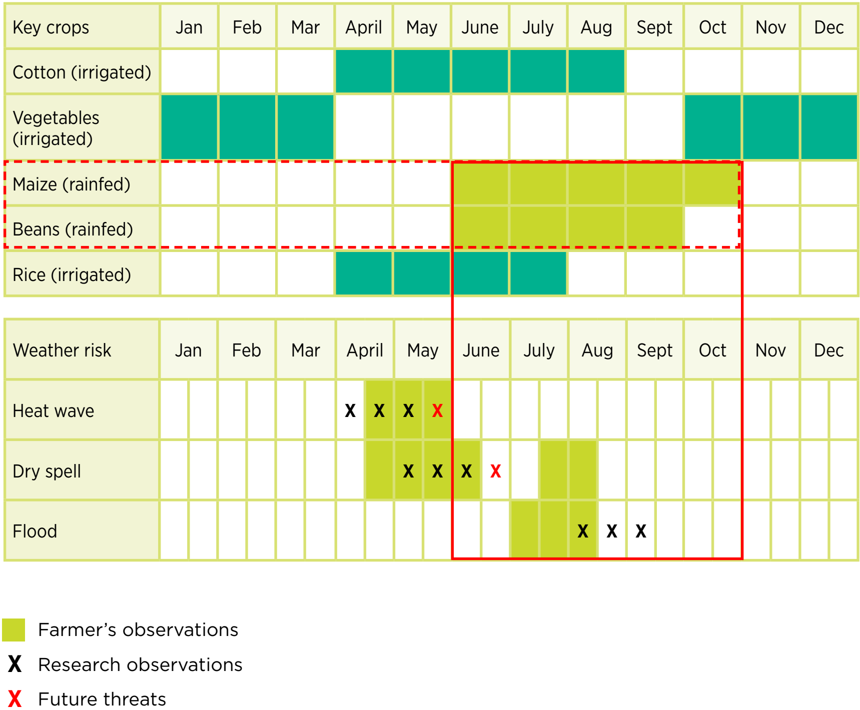
■ Farmer's observations

X Research observations

X (red) Future threats

Once you have developed the agricultural activities calendar and the observed/estimated weather threat calendar, you can compare the two and look for areas of overlap, as shown in Figure 26. Any areas of overlap indicate particular crops or activities that are potentially at risk to specific weather stresses. You will want to look in greater detail at these potential risks because they represent areas where adaptive actions may be needed.

Figure 26: Linking agricultural activities and weather threats



With what you learned in the previous section – how climate change is affecting agriculture – and the steps covered here on how you and the farmers that you work with can improve your knowledge of how the changes to local weather patterns may threaten various agricultural activities, you are ready to begin identifying potential climate change risks to specific agricultural activities.

4.2 Assessing crop and livestock vulnerability

The second most important thing that you can do in preparing to work with farm families to adapt to climate change is to learn all that you can about how crop and livestock species are sensitive to various types of weather stresses and at what point in their development. Some general information was provided in the previous section of this guide, and you will find much more detailed information in the pocket guides on crops and livestock in this series. You may find even better, more locally specific sources of information within your national research institutes and universities. These will be important resources for you, and you should get to know them well.

As discussed in the previous section, the same weather stresses can have very different impacts on growth and productivity depending on when they occur – at what stage of crop development, or gestation or lactation cycle of animals. You will also want to investigate possible combined effects – high temperatures occurring at the same time as moisture stress – and learn when crops or animals are most sensitive to these combined stresses.

Just as you used a variety of sources of information to determine how the climate has changed over recent decades, you can use this same approach to gain a better understanding of the climate change sensitivities of local farming systems – local crops and animals in local fields. The information available from the farmers that you work with and from researchers and other development partners will be equally important. From researchers you will likely get general information about the sensitivity of particular crops or species to various climate stresses, as well as very specific and important details of crop growth and reproduction. Farmers, on the other hand, will often have the most detailed knowledge about the sensitivities that they have observed in local varieties and breeds under local conditions. Both sources of information will be important for you.

A useful first step is to focus on those agricultural activities where you have identified a potential weather risk. To organize information on how sensitive the specific crops or animals are to various climate stresses, you will want to develop a timeline (the use of pictures is helpful) of the stages of growth, starting with seeding and germination for crops, and gestation and birth for animals (see the upper part of Figure 27). Farmers can lead this exercise, but be sure that the timeline includes the critical stages of reproduction, including flowering, yield formation and harvest for crops, and laying and lactation for animals. Also include in the timeline any important information that you learned from researchers related to important stages of growth and development where crops or animals are particularly vulnerable to specific weather stresses, such as heat or moisture stress.

As shown in the bottom part of Figure 27, beneath the picture of each stage of plant or animal growth, indicate those stages where particular weather threats are most harmful. Threats may appear in more than one stage of development. It is best to lead farmers through this exercise first, then add any additional information that you might have collected from researchers, using a different color or symbol. When you are done, you will have created an accurate diagram of the stages of development showing when each crop and animal species is most vulnerable to various weather threats.

Figure 27: Stages of plant growth and vulnerabilities to weather threats

	Germination/Emergence Early vegetative growth 25-30 days	Vegetative maturation 25-40 days	Flowering 15-20 days	Early grain filling / Grain maturation / Harvest 45-60 days
Frost				
Heat				
Drought	XXXXXX	XXXXXXXX	XXX	
Flood	XXX			

X Farmer's observations Research observations Most severe Less severe

Preparing these diagrams will be time-consuming, but they are critical to deciding what to do next. It is a good idea to start with the crops or livestock species that are most important in either household food security or income generation. Remember, however, that what is most important is not the same for everyone. The farming activities of men and women, as well as farmers with different types of farming systems (or farmers that are better off and poorer) are not the same. Farmers' knowledge of crops and activities will be most detailed for the management practices that they perform at various points in the cropping season. Determining who does what and when they do it will be an important step. In addition to gender considerations, if the communities where you work also include important differences in household resources (land, labor, money) that are linked to different farming systems, or include families that are primarily herders or fisherfolk in additional to agriculturalists, it is a good idea to organize separate meetings with these groups so that everyone has a chance to express her/his views.

If you work with separate groups and create different calendars, you will also need to bring the groups back together to share information and learn from one another. Individuals may have specialized knowledge about certain crops or activities, but they are also part of communities, and it is important to strengthen these community relations. Some adaptation measures will require community efforts. It will be easier to carry out these group actions if the identification of problems and potential solutions was also part of a group effort.

The more you learn about climate change and what this means in terms of potential risks and sensitivities for various crop and livestock systems, the better questions you will be able to ask to get the additional information that you may need. The more you learn, the more questions you may have. If you do not have immediate access to the type of information that you need, identify who may have it, and ask for it.

If you do not have immediate access to the type of information that you need, identify who may have it, and ask for it.

Work with farmers

Never before has it been so important to work with farmers than in helping them to adapt to climate change. Changes are beginning to occur so rapidly in so many areas that it will be difficult for research programs to keep up. Every farm that you see is the living record of past adaptive decisions made by the farm family. As climate conditions continue to change, individual agricultural activities and entire farm systems will also need to change. As illustrated in the diagram below, both farmers and researchers have valuable knowledge to share to help this adaptive process. Farmers and researchers may know some things in different ways. Other things may be known only to one group but not the other, and some things neither group understands. Only by working together can we reduce the gaps in our knowledge about the difficult challenges of climate change adaptation.

		Farmers: Known	Farmers: Unknown
Researchers	**Known**	Known to both, farmers and researchers	Known only to researchers
	Unknown	Known only to farmers	Known to neither

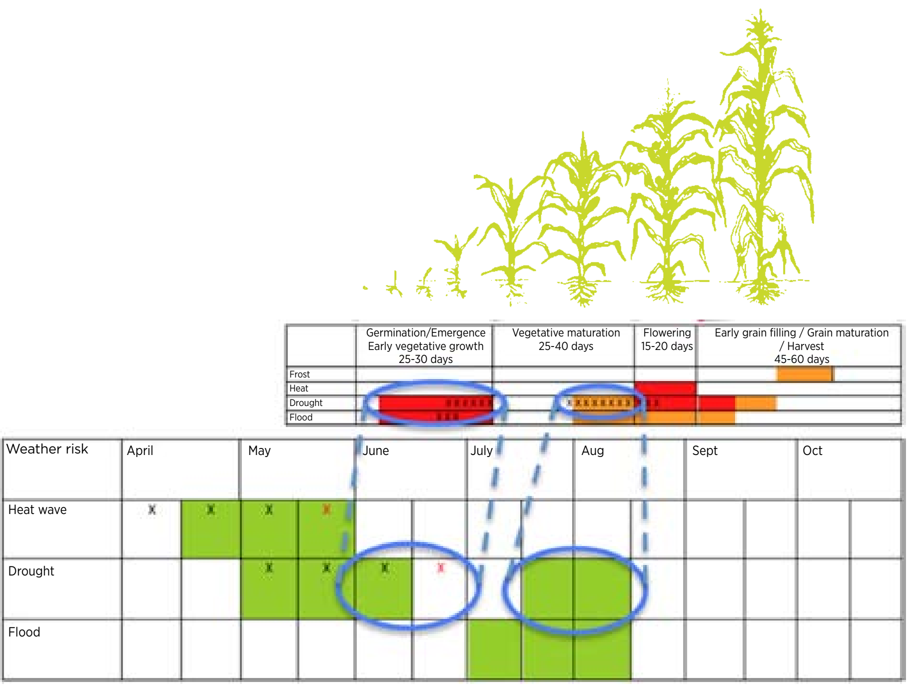
Source: Simpson, 1999

Farmers' knowledge – sometimes called traditional or indigenous knowledge – is most helpful over the range of environmental conditions under which it developed. This knowledge is a rich and tremendously valuable resource. Climate change, however, will result in weather conditions that farmers have little or no experience of, and it will require the introduction, testing and modification of entirely new practices. A resource even more valuable than farmers' existing knowledge is their ability to adapt and create new practices. In fact, most new practices that farmers adopt require some degree of adaptation before they can be put to use. You may already have had some experience in working with farmers in testing and adapting new practices. For others, it will be new. For all, it will be an important skill to become expert in as the needs for continued change increase. The next section of this guide and the pocket guide on crop management contain some examples of working with farmers in testing new technologies.

Next, you can use the calendars that you have prepared – observed/estimated weather threat calendar and crop/livestock sensitivity calendars – to identify areas of overlap, as shown in Figures 28. Looking closely at the observed/estimated weather threat calendar and the individual crop/livestock sensitivity calendars will show you when the particular crop or livestock is highly sensitive to specific weather stresses, and when (on average) those stresses occur now or may occur in the future. You will need to repeat this exercise for each of the crops/livestock species for which you developed sensitivity calendars.

Remember to pay particular attention to the estimated future climate changes if you have been able to include this information on the weather threat calendar. These estimations will help to reinforce areas of concern – things that may be getting more common with time – and also may help you to identify potential threats – those that are not currently a problem but may become problems in the future. The areas of overlap between crop/livestock sensitivities and the occurrence/estimation of weather stresses represent the areas where you should target your efforts with farmers in finding adaptation solutions. These are their main areas of greatest climate change vulnerability.

Figure 28: Linking crop sensitivity and weather threat calendars



In your work with farming communities, it will be important to keep the following key ideas in mind.

Key ideas

- Change is different from variability. You will need to help farmers to understand that what is happening to their farming systems is different from the stresses of weather variability that they have experienced in the past – where coping until conditions returned to normal was the best strategy. Under climate change, weather conditions are increasingly moving away from the way they were in the past and will not return to former levels. In response, farmers will need to change their farming practices to adapt to the new conditions.
- Climate change is a process without end, so adaptation will be continuous. Each new adaptation will offer a window of opportunity where it provides benefits until conditions pass a point where another adaptation is required. There are limits, however, to the adaptive options available for any activity. At some point, activities may simply need to be abandoned.
- Determining the best moment to switch between adaptive practices (the switching point) will be farmers' most difficult challenge. Depending on the practice, such as switching crops, changing too early may put the farmer at a disadvantage with a less productive or less valuable crop. Waiting too long can result in needless losses. Because of local conditions and household resources, households and communities will likely make adaptive changes at different times.

Determining the best moment to switch between adaptive practices (the switching point) will be farmers' most difficult challenge.

- Work at the scale that the climate change threat needs to be addressed – plot, hillside, watershed. The response to some risks is best taken at the field level by individual farm families, such as the decision to change varieties. Other risks require group actions, such as farmers up and down the hillside each protecting his/her own plot to reduce soil erosion and prevent landslides brought on by heavy storm events.
- Timing is everything. Individually and in combination, when specific weather events occur makes all the difference. Various species of crops and animals have different sensitivities to weather stresses at different stages of their development. For crops, dry spells of a week or more during the growing season can be fatal for seeds that have recently germinated,

whereas plants that are already well-established will generally survive. The combination of two or more stresses at the same time generally has much greater impact than one alone. For example, dairy cattle can tolerate high temperatures, but when high temperatures are combined with high humidity, milk production quickly drops. Similarly, many crops can tolerate high temperatures unless they are under moisture stress at the same time. Then high temperatures can have very severe impacts, especially if these stresses occur during critical times such as flowering.

Additional resources

FAO. 1999. *Conducting a PRA training and modifying tools to your needs: An example from a participatory food security and nutrition project in Ethiopia.* Rome: Food and Agriculture Organization of the United Nations.

Mwongera, C., J. Twyman, K.M. Shikuku, L. Winowiecki, W. Okolo, P. Laderach, E. Ampaire, P. Van Asten and S. Twomlow. 2014. *Climate Smart Agriculture Rapid Appraisal (CSA-RA): A prioritization tool for outscaling. Step-by-step guidelines*. Rome: International Fund for Agricultural Development.

Simelton, E., V.B. Dam, R. Finlayson and R. Lasco (eds.). 2014. *The talking toolkit: How smallholder farmers and local governments can together adapt to climate change*. Hanoi, Vietnam: World Agroforestry Center.

PART 5

Working with farmers to adapt to climate change

Once you and the farmers that you work with have identified the major climate change risks and the exposure and sensitivity that various agricultural activities have to those risks, it is time to prioritize what to focus on and to begin selecting and testing adaptive options. In the introduction to this guide, it was suggested that you might be able to determine whether you should first **reduce exposure** or work to **reduce sensitivity** or focus on **increasing adaptive capacity**.

These are very challenging questions and the answers will be different for different types of stresses, crops, communities and individual farm families. In other words, **there is no single answer that fits all situations**. When you start working with farm families, it is advisable to begin by looking for "easy wins," those things that can be done with little difficulty that generate positive results that are visible over the short term. Farmers are most aware of the impacts of weather variability, such as dry spells and floods – events that they have always struggled with that may be getting more common or severe with climate change. Addressing these immediate challenges may be a good place to start. For example, farmers growing maize, beans or rice may have identified a trend of increasingly frequent dry spells that are affecting their upland crops or severe flooding of valley bottoms where rice is grown, resulting in loss of their harvests. Once this issue is identified, introducing them to drought-tolerant varieties of maize or beans or varieties of rice that tolerate flooding (submergence) immediately improves farmers' adaptation to an identified major stress. This easy win contributes to farmers' adaptation to climate change, making their farms more productive and profitable and their families more food-secure. Successes like this can also help to strengthen farmers' confidence that they can identify and respond to the problems that they face. This confidence will be important as they attempt to address more difficult adaptation challenges in the future, particularly those where solutions might not be immediately visible.

It is advisable to start looking for "easy wins," those things that can be done with little difficulty that generate positive results that are visible over the short term.

5.1 Adaptive options

Adaptive responses fall into three general categories (the pocket guides on crops, soils, water and livestock will provide more detailed discussion of these):

- **Genetic** – Use biodiversity – the characteristics of different varieties, crops or breeds – to escape or reduce sensitivity to certain changes to the climate, such as planting earlier maturing varieties to avoid late-season drought stress or planting drought-tolerant varieties that are less sensitive to drought when it does occur.

- **Environmental** – Make changes in the productive environment to remove or reduce the impact of climate-change-related risks, such as adopting rainwater harvesting techniques to capture more of the rainfall that does come, and building up soil organic matter and using mulch to reduce moisture loss due to evaporation from the soil.

- **Management** – Make decisions, other than using biodiversity or altering the production environment, that reduce exposure to climate risks, such as feeding poultry or livestock during cool parts of the day. Feeding raises body temperature, so feeding in the hottest part of the day increases risk of heat stress associated with digestion. Another management change would be changing planting dates – planting later or earlier – to avoid more frequently occurring false starts to the rainy season or earlier ending to the rains.

Assessing the local exposure of farming systems to climate change risks (discussed in the previous section) will show you how each agricultural activity is exposed to different types of climate risks and has different sensitivities. As shown in the example in Table 2, farmers may be able to choose from among various types of adaptive responses. On the basis of what you will learn from the other pocket guides in this series and information you collect from the research institutions in your country, you will be able to propose several adaptive options for farmers to choose from and experiment with.

You will be able to propose several adaptive options for farmers to choose from and experiment with.

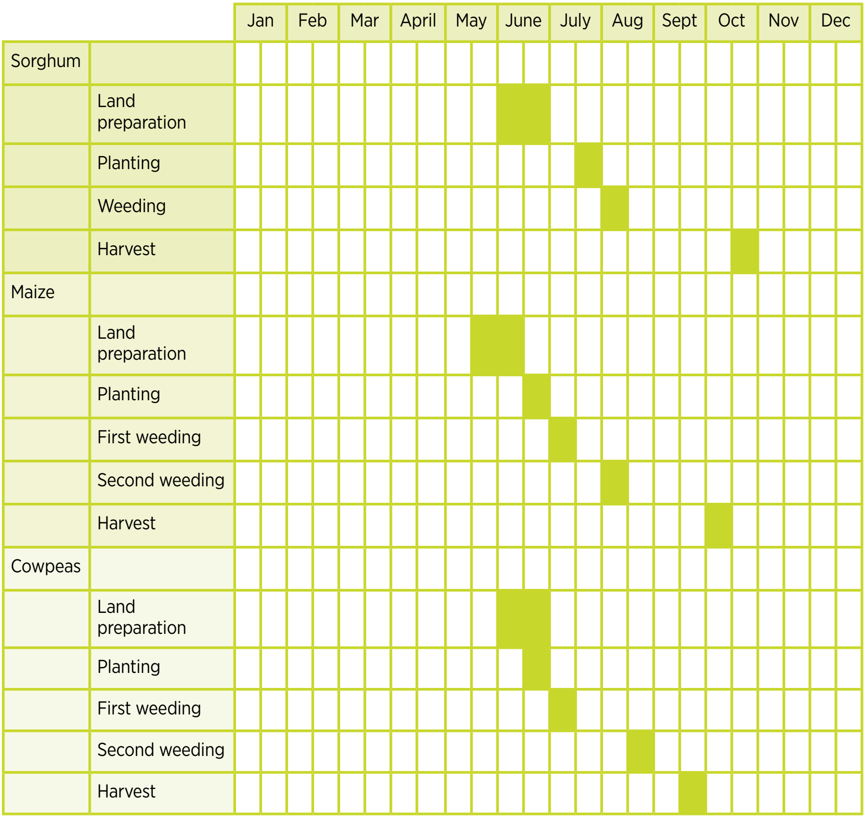
Table 2. Adaptation: Maize moisture stress risk

	Exposure		Sensitivity	
	Escape	Reduction	Reduction	Removal
Genetic		Faster maturing varieties	Drought-tolerant varieties	Abandon maize; switch to other crops
Environmental	Irrigation – secure groundwater source	Irrigation – insecure surface water source; rainfall water harvesting	Cover crops, mulch and windbreaks to conserve moisture and reduce evaporation	
Management	Change field type where crops are planted	Change planting dates		

Depending on the agricultural activity, the type of climate risk and the scale at which a response needs to be organized (for example, plot-level or entire hillside), as well as the availability of household and community resources, some options may be preferable over others. On the surface, changes to **management practices** may seem the easiest way to introduce adaptive practices because there may be no need to access new varieties, make physical changes to fields or invest in additional equipment. This may be true, but you may also find that there are complications in management changes relating to other activities in the farming system – such as changes in the overall amount or timing of labor demands. You will want to guide farmers in a detailed discussion on any proposed management changes, thinking through the possible implications of any changes before starting. One way to do this is by developing a whole-farm labor calendar, showing all of the activities throughout the season – land preparation, planting, fertilizer application, first and second weeding, harvesting, drying, threshing and livestock management tasks. Such calendars can help farmers to identify potential labor bottlenecks if they change certain management practices. Developing such a calendar offers an excellent opportunity to discuss gender roles in agriculture and which household members are responsible for what activities, whose labor may be most constrained, and who has access to various household and non-household resources.

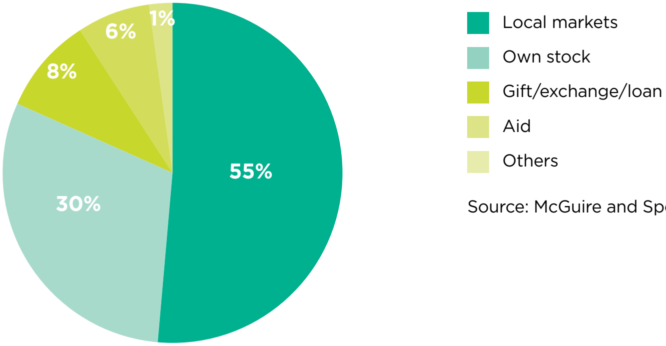
You will want to guide farmers in a detailed discussion on any proposed management changes.

Figure 29: Simplified cropping system labor calendar



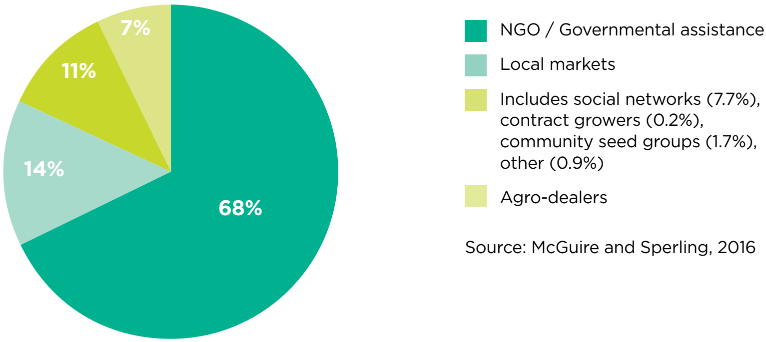
Making changes to **genetic material**, once the issue of access to new varieties is overcome, often presents fewer complications because the management of most varieties of the same crop is similar. Here also there may be complications related to changes to the timing of labor demands, especially at harvest if the new varieties have a shorter or longer maturity cycle. The vast majority of smallholder farmers save their own seeds or access them through informal exchanges with friends or neighbors, or buy seeds in local markets (see Figure 30). For new varieties, however, government and donor support is often an important source (see Figure 31). Support for farmers to locally produce their own seeds, and seeds to sell, has gained importance in many countries. The approach, sometimes called "community-based seed multiplication," trains farmers in producing their own seeds and may be a useful, even necessary, option for you in strengthening farmers' adaptive capacities to acquire and utilize new varieties.

Figure 30: Sources of all seeds (+10,000 observations)



Source: McGuire and Sperling, 2016

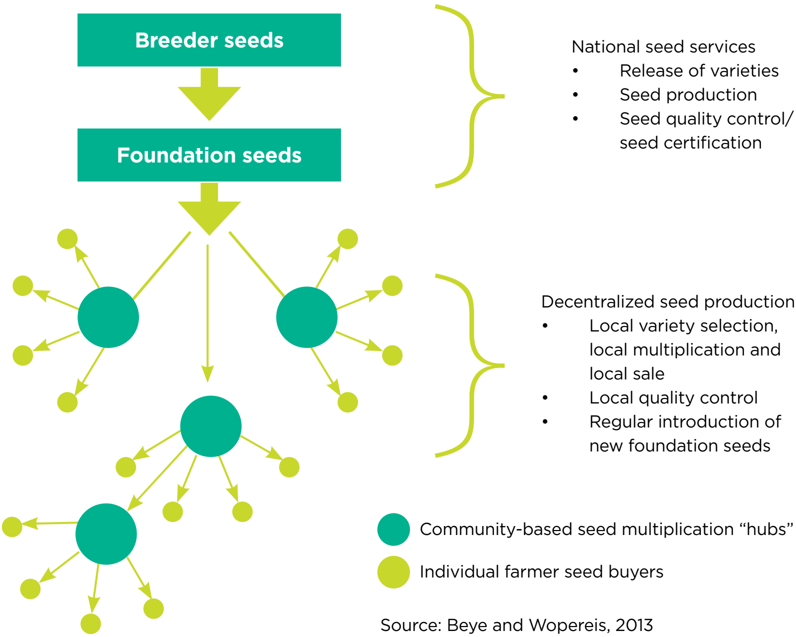
Figure 31: Sources of new seed varieties (683 observations)



Source: McGuire and Sperling, 2016

Community-based seed systems

Studies suggest that over 80 percent of the seeds used by resource-poor farmers are bought in local markets or saved from their own production. In other words, most of the seeds used by farmers are produced by farmers. Farmers have been doing this since the first crops were domesticated. In contrast, studies also suggest that government programs and development projects are the source of nearly 70 percent of seeds of new varieties. For many crops, there is not enough market demand from resource-poor farmers to support commercial seed companies.



Source: Beye and Wopereis, 2013

Combining external sources of new seeds with farmers' ability to produce and access seeds locally offers a way of making new varieties available to farmers. Strengthening farmers' capacity to produce high-quality seeds involves attention to improved field practices – appropriate field separation, removal of abnormal plants in the field (roguing), and good disease and pest control. Careful postharvest handling is also necessary – maintaining separation of seeds from other harvests, proper drying, threshing, winnowing and storage. The result can be the production of seeds of a very high quality. Such locally produced seeds can – and should – be sold at a higher price than grain produced for consumption. Technical support from research and the national seed service may be available to help you establish productive and profitable local seed-production systems. Once established, the capacity to produce seeds of new varieties locally will be a valuable asset for farmers in continuing to adapt to climate change.

Source: Beye, Jones and Simpson, 2011a,b,c

Investments in making **environmental changes** are often more demanding, but they can offer the advantage of improving crop and livestock productivity regardless of what happens with the climate. These are often called “no-regret” options because they can provide benefits, perhaps even multiple benefits, even if anticipated changes in the weather do not occur. A more secure water supply, more fertile soils, reduced erosion, more diverse agricultural systems and healthier animals all provide multiple benefits no matter what happens with the weather. If you are uncertain how severe various types of climate change impacts in the areas where you work will be, how soon they will occur – if at all – adaptive changes involving improvements to the productive environment are often the most secure and most beneficial. Some of these changes, however – such as building up soil organic matter in nutrient-depleted soils – will not show immediate benefits. It may take several years before their full benefits are visible. Some benefits may be fully visible only when more extreme weather events occur. For example, the benefits of investments in moisture conservation practices may be most visible in a drought year, while the benefits of hillside soil conservation may appear only during periods with extreme rainfall. If an extreme event should occur in an area where you work – a long dry spell or extreme storms – and one of the adaptive practices that you have helped to introduce performs well, make sure that you do all you can to allow as many farmers as possible to visit and observe how the practices performed. This type of visible evidence and the advice of farmers who have adopted the practices will do more to encourage other farmers to consider taking up new practices than anything that you can say or do.

The advice of farmers who have adopted the practices will encourage other farmers to consider new practices.

A hurricane's lesson

In 1998, Central America was hit by a hurricane with an intensity that occurs on average about once every two centuries. Hurricane Mitch had winds of 290 km/hour (180 mph), delivered 1,270 mm (50 inches) of rain and centered on the small, mountainous country of Honduras. It resulted in 22,000 deaths and the loss of 500,000 homes in that one country. One-third of Honduran farmers lost their entire crop, and 10,000 hectares of land were stripped of topsoil.

After the hurricane, a study team found that the farm plots where farmers had adopted soil and water conservation practices had 58 to 99 percent less damage (the differences varied by country). Conservation agriculture plots had 28 to 38 percent less topsoil washed away and suffered half to one-third less surface erosion than conventionally managed plots unless they were located downslope from either conventionally managed plots or degraded land. Below unprotected areas, conservation plots had the same levels of damage as the conventional plots. There was simply too much water flowing downslope from these unprotected areas for the conservation practices to withstand. Unless families work together to protect and restore an entire hillside, conservation practices on individual plots do not always offer protection from severe weather.

When farmers compared what had happened to their farms with those where farmers had adopted the conservation practices, many made strong, repeated requests for retraining in watershed and natural resources management. They intended to use the conservation practices from then on.

Source: World Neighbors, 2000

5.2 Principles and practice

The remainder of this section offers some basic suggestions on how to work with farmers in testing adaptive changes and how to help spread what is learned from these experiences to the larger community. Additional examples are provided in the other pocket guides in this series. As with the activities discussed in the previous section – Identifying climate change risks and assessing vulnerabilities – farmers' knowledge and skills will be your most valuable resource in assisting farm families to adapt to climate change. Your ability to work with farmers in testing and further modifying adaptive options will be critical, as will be getting farmers involved in sharing what they have learned and training other farmers. You cannot do everything yourself – you will need help!

To start, when testing new adaptive options, it is essential that you are clear on what adaptation challenge you are trying to address and why you are trying a specific new practice or technology. Following the steps discussed in the previous section will allow you to clearly identify what specific climate change challenge you are trying to address. For any challenge there may be alternative adaptive choices – genetic, environmental and management-focused – each requiring different resources to implement. It will be important to discuss the options with farmers and let them select those that they are interested in testing.

For any challenge there may be alternative adaptive choices; let farmers select those that they are interested in testing.

Second, it will be important for you to identify and work at the appropriate scale that the climate change challenge demands. Many challenges are best addressed within individual fields under the management of a single household, but not all. Some challenges, particularly those involving environmental management, require work at a larger scale – an entire hillside, valley bottom, forested area or grazing land – to be effective. It is critical that you correctly identify these situations and mobilize farmers to work at the scale necessary to achieve positive results.

Third, various challenges and purposes will require that you use different approaches. An experiment designed to test or validate something entirely new is different from a demonstration of a practice or technology that has already been proved to be effective, and each will require a different approach. The other guides in this series, especially the guide on crop management, provide examples of types of experimental designs that you may find useful with various technologies. You may also receive valuable support from scientists from your national research institute and other development partners in setting up experiments.

Fourth, have confidence in working with local farmers who volunteer or are selected by their communities or groups to conduct trials or manage demonstrations. These individuals are generally highly curious about new practices and willing to take risks to experiment. Farmers may also have good ideas of their own, and you should make every effort to include these when testing adaptive options.

Fifth, many adaptive responses will require other, non-technical inputs. For example, new varieties and equipment need to be locally available if farmers are to benefit. Credit may be necessary for farmers to invest in more expensive options. In the case of adaptive responses that require group action – such as the collective management of water resources or grazing lands or construction of watershed conservation measures – farmers may require assistance in establishing organizations to allow them to carry out these tasks. Make sure that you think through and identify with farmers all of the non-technical requirements for implementing an adaptive practice or technology. If some non-technical barrier prevents farmers from adopting a new practice or technology, they will not benefit no matter how well that practice would respond to the identified challenge.

Farmers' risk

In the same way that you screen the various agricultural activities with farmers for sensitivities to changes in the climate, you will also need to screen potential adaptive options for possible risks. In addition to direct and indirect climate change risks, farmers living in poverty also face other types of risk including: the difficulty in learning to use new practices effectively and the potential failure of adaptive practices to perform as expected; changes in markets and the availability of essential inputs and access to credit; and insecure access to and control over resources. It will be important that you not overlook these other types of risk when planning with farmers to adapt to important changes in local weather patterns.

At some point, after testing and adapting innovations to fit local conditions, you will want as many people as possible to have the opportunity to learn about particular new practices and the benefits that they offer. You and the program that you work in already use many communication methods in your normal work – individual and group visits, radio shows, leaflets, booklets and posters, farm tours, field days, demonstrations and others. To spread the word, it will be important to match these approaches with specific steps in the adoption process. Carefully select the most appropriate media (face-to-face, radio, print and video), message content and messenger (other farmers or trusted individuals) to:

- Raise awareness and stimulate interest in the new practices.
- Help farmers to evaluate whether the new technology or practice meets their needs and is something that they can use.
- Provide opportunities for farmers to try the new practice or technology.
- Encourage them to make adaptations necessary for them to integrate the practice into their farming system.

In helping farm families to adapt to changes in their climate, your most important job as an extension agent is to help farmers assess their situation and then go through the steps of raising awareness of new options, stimulating interest, evaluating usefulness, trying out new practices and technologies, and making necessary adaptations.

To adopt or not to adopt

All farmers go through a similar set of steps in deciding to adopt a new technology or new practices. First, they must become aware that a new practice or technology exists. Second, they need to be interested in what the innovation has to offer. Third, they need to evaluate whether the innovation fits their situation and whether they can make use of the technology or practice with the resources that are available. Fourth, they need to try out the innovation. This often leads to modifications of the technology or practice to better fit the resources available to them. If the technology performs well, delivering the desired benefits, farmers may decide to use it on a regular basis or at a larger scale.

Farmers learn about new innovations at different times and take different amounts of time to go through the steps of deciding to adopt or not to adopt. With any new technology, someone is always first to adopt, and someone is last. Some farmers, especially those with more resources, are often the first to learn of new opportunities and may make the adoption decision quickly. Others are more cautious and need to see how the new practices perform in their neighbors' fields for a season or more before they are willing to try it. Your efforts to introduce new technologies will therefore need to be carried out over several seasons to ensure that all farmers have the opportunity to learn about and see new practices perform under local conditions.

Each technology also has unique features that you will need to recognize and consider in adjusting your approach to help farmers assess whether the new practice is useful for them. Differences between technologies will require that you use different methods. New varieties, for example, are easy to showcase in a demonstration plot, and interested farmers can test the varieties on a small scale in a portion of a field with little expense or risk. Innovations that require environmental changes, such as constructing terraces or no-till farming, require greater investments by farmers and are difficult to try on a small scale – they may also demand coordinated group efforts. In such cases, using exchange visits or videos showing other farmers or groups who have already adopted the technology may be an effective way of stimulating interest in trying the new practices. You will need to carefully match your use of various extension practices to fit the characteristics of the innovations.

Source: Simpson, 2015b

It will be important for you to get farmers involved in sharing their experiences and directly working with you in encouraging and supporting other farmers and communities to experiment with new practices and technologies. In some places this is called farmer-to-farmer extension, and it involves lead farmers or volunteer farmer trainers. The names and responsibilities vary, but the essential practice involves training and supporting volunteer farmers to pass on new knowledge and skills to their fellow farmers through demonstrations, trainings and individual support.

Farmer-to-farmer extension

The fact that farmers trust the advice and experience of other farmers has long been recognized and used in extension practice. Farmers live and work in similar contexts, they grow the same crops, eat the same foods, and their children attend the same schools. In short, they are known to and trusted by other farmers. The formal involvement of farmers in helping to train and advise other farmers in extension programs – farmer-to-farmer extension (F2FE) – has been a growing trend in many countries. Research shows that farmer trainers or lead farmers who are well-trained and supported by extension programs are very effective in assisting other farmers in making changes to their farming systems.

In some technical areas, however, the use of F2FE may not be appropriate. These include when decisions need to be made that involve the fate of highly valuable assets, such as livestock health; those that are essentially permanent, such as the positioning of expensive infrastructure such as terraces and water control structures; and technologies with human health risks, such as pesticide and herbicide use. Putting volunteer farmer trainers in a position of being the sole source of advice on these critical activities is unfair and may lead to local conflicts if problems arise.

The use of the F2FE approach in donor-funded projects – separate from ongoing extension programs such as government extension services – risks lead farmers becoming isolated and irrelevant. Research shows that farmer trainers or lead farmers may often continue providing assistance to other farmers years after a project ends. However, if they no longer have access to technical support or new information because the project has ended, their efforts will become increasingly out-of-date. If you are working in such a project, make sure that you invest in establishing strong relations between the volunteer farmer trainers or lead farmers that you work with and more permanent sources of support and new technical information. As the climate continues to change, farmer trainers will also need to be able to change what they are teaching to other farmers.

Source: Simpson et al., 2015

As you will know from your own experience, farmers modify nearly every new practice that they adopt. Farmers are not doing anything wrong when they make these changes. In fact, this is a normal and necessary part of farming. With some practices, however, there may be elements that must be maintained unchanged if the practice is actually to provide the benefit(s) that it is meant to deliver. For example, it is not possible to benefit from no-till (conservation agriculture) without maintaining minimum soil disturbance – this is a **non-negotiable** requirement of practicing no-till farming. In such instances, it will be important when you work with farmers or groups in adapting agricultural practices to assist them in understanding how the new practice works, what needs to be maintained and how they can preserve the critical, non-negotiable feature(s) while making adjustments to those features that can be changed.

Some extension programs (perhaps the one in which you work) use the farmer field school, or FFS, approach. Farmer field schools offer an excellent opportunity to test and refine any type of adaptive practice, and they are already being used to support climate change adaptation efforts in some locations. Farmer field schools can and should be used as a valuable community resource. In fact, field schools lose much of their value if the only ones to benefit are the school members. If you are using the field school approach, you will need to ensure that other farmers in the community and those in other communities have opportunities to learn from the school's activities. Holding field days and farm tours gives field school members an opportunity to explain what they are doing, why and what they have learned. It is a good idea to mix the farmer field school approach with other extension methods to allow the lessons from the field school to reach as many others farmers as possible.

Farmer field schools

The FFS approach is built on principles of adult learning – learning by doing – with the field as the classroom. The main objectives of the approach are to enhance farmers' productivity and profitability, and strengthen their knowledge and skills in analyzing situations, formulating questions and finding their own solutions.

In using the approach, extension agents serve as facilitators, with farmers taking the lead in determining what to do. The field schools typically begin with an agroecosystem analysis to identify key production challenges. Farmers then design, carry out, observe and interpret results of experiments that address their main challenges, using their school's field as a laboratory. The process of carrying out experiments often leads to new questions and further experimentation. The field schools use a life-cycle approach – following the entire production cycle of the targeted crop or livestock activity from beginning to end. As a result, in the course of a single season, farmers are able to address a wide range of challenges at various points in the production cycle.

The FFS approach was developed to support integrated pest management in rice production in Southeast Asia. It has since been used in more than 90 countries and expanded to cover many other technical areas. Many good FFS manuals are available, focusing on various technical areas. The approach is also beginning to be used in parts of Asia and West Africa to help farmers adapt to climate change. You also may find the approach useful in your work. The need to continue introducing and testing new practices to adapt to changes in weather patterns makes the investment in establishing and working with field schools well worth the effort.

Even if your program does not formally use the farmer field school approach, you can make use of some of the core features used in field schools to complement your other work. One of the key concepts was described in the previous section – assessing the farming system for exposure to risks and sensitivities. Another is using the normal life cycle of the crop or activity to guide you in organizing regular opportunities for farmers to visit and observe the performance of any trial or demonstration. Visits should correspond with important management activities or key stages in crop growth so the farmers can see how the new adaptations perform in comparison with what they are currently doing.

Participatory variety selection for extension

One example of using a life cycle approach involves the testing of new varieties through what is known as participatory variety selection (PVS). This is an established approach used by researchers to determine farmers' preferences to assist breeding programs. "Variety gardens" are created, containing many varieties, planted in small plots (2 to 3 square meters). Farmers are invited to view the development of the varieties at multiple times in the year at key stages of crop growth, including a taste test after harvest, to provide feedback on their preferences. Plant breeders use this information to select and develop new varieties.

The same approach has been used in extension programs (PVS-E) to help expand the availability of new varieties. A limited number of varieties are used – usually no more than four to six – that have already been found to be preferred by farmers in similar locations. The demonstration plots are established on a larger scale, usually a minimum of 10 by 20 meters. Farmers are invited to visit the demonstration plots several times during the growing cycle. The seeds produced in these plots are generally sufficient to supply 30 to 40 farmers with the variety that they are interested in trying on their own farms. The key is that farmers, not researchers or others, select the varieties that they want. When combined with community-based seed multiplication efforts or used to supply local marketing channels, PVS-E can assist the rapid introduction of new varieties that are most desired by farmers.

Technology demonstrations are commonly used by extension programs to introduce farmers to new technologies and practices. Though demonstrations are widely used, they are often not implemented or managed to their full advantage. The following are some basic guidelines on using demonstrations to effectively showcase new adaptation practices:

Demonstrate only technologies that you are confident are better than current local practices. As intended, demonstrations are established to allow as many people as possible to see how the new technologies perform under local conditions. A poorly performing technology will never be adopted by farmers, nor should it.

Things to look for:

- Locations along roadways with good visibility and where many people pass.
- Locations near market points, schools and other areas with regular traffic.

Things to avoid:

- Sites in remote or obscure locations with little passing traffic.
- Sites not immediately visible from the road.
- Sites where shading from nearby trees will affect the performance of some or all of the subplots.

- Boundary areas near bush where wild animals/birds may damage fields.
- Fields in runoff-prone areas or areas subject to inundation that may be affected by heavy rainfall.
- Areas with atypical soils or soils that have been subject to a history of abusive practices – unless, of course, the technology being demonstrated is specifically targeting these types of conditions.

Things to do:

- Know the field's history. Depending on the technology, what happened in that field the year before can have a significant impact on how crops perform in your demonstration. Avoid fields where past practices may interfere with the performance of your technology.
- Always include a local check – this is not the same as a zero treatment plot. A local check should represent common or best local practice as determined by farmers in that area. Farmers need to see how the new technology performs in that location, in the current season, compared with what they are already doing.
- Establish permanent signs at each site for the length of the demonstration. Each subplot should be clearly marked so visitors know what they are looking at.
- Signs should include basic information on what is being demonstrated, why and the advantages that the new practice offers.
- Signs should be in the language most commonly spoken in that area. Diagrams or small illustrations are good for those who do not read. Avoid photos – these often fade and cannot be seen after a few months.
- Minimize logos on the signs (place them at the bottom of the sign), and include contact details so that anyone interested can get further information.
- Plan to maintain your demonstration sites for two to three seasons; longer for the demonstration of technologies that require several years to show results (e.g., conservation agriculture, use of rotations, etc).
- Make maximum use of your demonstration plots. Establishing and maintaining demonstrations is a time-consuming and expensive undertaking, so get the most out of your investments. Hold field days at critical periods in the production calendar, especially those where management operations related to the technologies are being performed so that farmers can see what is required in using the technology.

- Many demonstration plots featuring new varieties will also be used as sources of seeds for local farmers who are interested in trying out the new varieties. These plots may need to be established on a larger scale so that they produce a sufficient amount of seed. All demonstration plots serving as sites of seed multiplication will need additional attention (in the field and postharvest) to ensure that the seeds produced meet minimum standards and are of the best possible quality.

Things *not* to do:

- Avoid demonstrating multiple technologies in a single plot (e.g., new land preparation technique + planting technique + new variety + fertilizer application + herbicide use). This constitutes a "package" of inputs, and history shows that smallholder farmers rarely adopt packages all in one go. Individual subplots should feature individual technologies, or at most two-technology combinations, so that farmers can see the advantages that each technology offers.
- Do not neglect your demonstration sites. If you decide to use demonstration plots, keep them well-maintained.

Unpacking packages

Making any type of change to established management practices requires learning and making adjustments in the household labor and farming system. Change also involves risk. In locations where farmers already face high levels of uncertainty because of variable weather conditions, maintaining security of their basic production is their first priority. They will find it difficult to change or abandon practices that they know and trust. Farmers rarely, if ever, adopt more than one new practice at a time – it is simply too disruptive, too risky. Promoting "packages" of technologies that require the adoption of many new practices at once generally does not work. You will have better success by introducing new practices in sequence, starting with the most important – the practice that delivers the greatest benefit or is required before other changes can be used. Later, if the new practice is successful, and after farmers have mastered its use, you can begin to introduce other practices that are complementary and offer additional benefits.

As you have probably noticed, many of the extension practices discussed above can be used in combination – such as farmer field schools and farmer-to-farmer extension, or participatory variety selection and community seed multiplication. If your extension program allows, think about how you might use various practices alone and in combination to your greatest advantage. Feel free to discuss with your extension director new ways of organizing your fieldwork to allow you to have greater and longer lasting impact. Be sure to discuss and exchange ideas with your colleagues and make opportunities to interact with field staff from other programs. You will learn a lot from other people's experiences and you will also contribute to their knowledge.

The other pocket guides in this series (on crops, soils, water and livestock) will help you address specific technical problems. Each guide provides examples of technologies that may provide adaptation solutions to the specific problems faced by farmers in locations where you work. These guides also include examples of specific methodologies that you can use in testing, refining and spreading adaptive practices, as well as references where you can find other ideas or adaptive practices that might help you in your work with smallholder farm families to adapt to climate change and improve their livelihoods. Good luck!

Key ideas

- Work with farmers in assessing their situation and identifying and prioritizing key challenges. Wherever possible, look for easy wins that address these major challenges and deliver observable benefits quickly.
- For each agricultural activity and each type of weather stress, there will be a variety of adaptive options – genetic, environmental and management. Work with your research and development partners to identify the full range of options and let farmers choose those that they are most interested in testing.
- Make sure that you identify all of the technical and non-technical requirements of using an adaptive technology or practice, and ensure that these requirements are locally available. Farmers can benefit only from options that they can implement.
- Get farmers involved in testing and adapting new practices and technologies that meet their needs. Make sure that farmers understand any 'non-negotiable' features of the practices, and support them in making changes to the practices you introduce, as well as in testing their own ideas.
- Get farmers involved in spreading awareness and assisting other farmers to gain the knowledge and skills necessary to make changes in their farming systems.

- Match your use of various extension methods to specific objectives. Some methods are best for raising awareness and stimulating interest; others are more effective in helping farmers to evaluate whether they can use new practices; others are best suited for supporting farmers to test new technologies and make changes. Using the right practice at the right time for the right purpose will help you to increase the impact of your work.

Additional resources

FAO. 2011. *Farmer field school implementation guide.* Farm Forestry and Livelihood Development. Rome: Food and Agriculture Organization of the United Nations.

FAO. 2013. *Gender and climate change research in agriculture and food security for rural development. Training guide* (second edition). Rome: Food and Agriculture Organization of the United Nations, and the CGIAR Research Program on Climate Change, Agriculture and Food Security.

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PART 6

The role of policymakers, extension directors and program managers

We are moving towards a point in history where the continued neglect of agricultural extension will bring far more serious consequences than the lost opportunities of the past. Not everyone is a farmer, yet we all must eat – thus we all depend on those who produce our food. Because climate change is global, there will be no region of the world that is not affected. Over the near term, some areas may even benefit. Over the long term, however, all areas will suffer. Even countries with ample land and water resources for irrigation still must contend with rising temperatures and extreme weather events. Reliance on international trade for maintaining national food security may become an increasingly risky option, as the soaring food prices and violent demonstrations of 2008 and 2011 showed. Strengthening domestic food security through investment in agricultural research, extension and supporting institutions (training centers, universities, finance), and markets will be critical. Each of these investments in turn will need to become more climate-smart, building on biological principles and the judicious use of external inputs in responding to the direct physical stressors of climate change and the many indirect effects that these cause.

Not everyone is a farmer, yet we all must eat – thus we all depend on those who produce our food.

The required investments in extension have both quantitative and qualitative dimensions. Not only do most countries simply need more field agents, but these men and women need to receive better support in carrying out their work. Most importantly, they need to be better trained. Nearly all extension training programs will need to be extensively revised to include advanced training on the realities of climate change – what it is, its cause, how it affects agriculture and what can be done in response – so that field agents will be able to recognize and respond to these challenges in their work. Relations between extension and research programs also need strengthening, just as the importance of climate change adaptation within the research agenda needs to be enhanced. The future of farm family welfare and national food security rests on making these critical investments. Climate change is real, and it will require real adaptive responses at all levels. Our future depends on it.

A final note:

The purpose of the guides in this series is to share basic facts, concepts and principles relating to climate change and the impact that these changes are having on farm families. These guides provide examples of practices that illustrate important principles and adaptive options, but they are not intended to serve as comprehensive desk references – they are meant to be taken to the field and used by extension field agents. The authors of these guides strongly encourage others to use, update, modify and strengthen the material presented here in developing revised and more locally relevant publications to assist extension field agents where they work. To aid in this process, these guides are released under a Creative Commons Attribution License (see details on the copyright page) to allow others to make use of this material to the best effect.

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