TOPIC GUIDE:

Climate Change, Food Security and Agriculture

Natasha Grist

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The Adaptation Knowledge and Tools programme is a DFID-funded programme intended to maximise the effectiveness of UK and international investment in climate change adaptation and resilience. The knowledge and tools generated through this programme are expected to promote greater understanding of what constitutes best practice in adaptation, as well as better international cohesion and coordination around adaptation. Through these entry points the programme expects to increase the quality of international and UK adaptation programming and reduce its risk.

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Contents

List of Figures

List of Tables

List of Case Studies

List of Boxes

About Topic Guides

Welcome to the Evidence on Demand series of Topic Guides. The guides are being produced for Climate, Environment, Infrastructure and Livelihoods Advisers in the UK Department for International Development (DFID). There will be up to 40 Topic Guides produced in 2013–2016. The purpose of the Topic Guides is to provide resources to support professional development. Each Topic Guide is written by an expert in the field. Topic Guides:

- Provide an overview of a topic
- Present the issues and arguments relating to a topic
- Are illustrated with examples and case studies
- Stimulate thinking and questioning
- Provide links to current best 'reads' in an annotated reading list
- Provide signposts to detailed evidence and further information
- Provide a glossary of terms for a topic.

Topic Guides are intended to get you started on a subject you are not familiar with. If you already know about a topic then you may still find it useful to take a look. Authors and editors of the guides have put together the best of current thinking and the main issues of debate.

Topic Guides are, above all, designed to be useful to development professionals. You may want to get up to speed on a particular topic in preparation for taking up a new position, or you may want to learn about a topic that has cropped up in your work. Whether you are a DFID Climate, Environment, Infrastructure or Livelihoods Adviser, an adviser in another professional group, a member of a development agency or non-governmental organisation, a student or researcher we hope that you will find Topic Guides useful.

Acknowledgements

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About the Author

The author, Dr Natasha Grist, is a Research Fellow in the Agricultural Development and Policy team at the Overseas Development Institute (ODI). She has worked in international development for 17 years, specialising in climate change and agriculture, currently advising the Climate and Development Knowledge Network on Climate Smart Agriculture. In her role as technical specialist at ODI she has advised and assisted: multilaterals including IFAD, FAO, and UNDP; DFID; Governments in developing countries; and a number of Non-Governmental Organisations.

About this Topic Guide

This Topic Guide, 'Climate Change, Food Security and Agriculture', focuses on two major issues:

- how climate change affects food security and agricultural growth ; and
- how programming around climate-smart agriculture can help adapt, build resilience and decrease greenhouse gas emissions while stimulating economic growth and poverty reduction in the agricultural sector.

Written for DFID staff, the Guide is suitable for non-experts and experts on food, farming and climate change. It is not a comprehensive manual, but aims to provide sufficient information to enable development professionals to take some practical steps in their day-to-day work, as well as to know where to look for more information.

The Topic Guide builds on an earlier Evidence on Demand analysis '*Climate-smart Agriculture: Mapping Guidance on Climate Change*' (Downing, 2013), which highlighted the need for this more in-depth review. It is also closely linked to Nicola Ranger's 2013 Topic Guide, '*Adaptation Decision Making Under Uncertainty*', which deals with the impacts of climate change on development interventions internationally.

This Topic Guide addresses the threat that current and future climate change poses to the food security and poverty reduction achievements of the last two decades. It responds to DFID's concerns to maintain and build on hard-won development gains with a focus on increasing inclusive growth.

The main message from this Topic Guide is that climate change is already affecting food security and agricultural growth under all types of agriculture, and is expected to continue to have an increasingly serious impact on smallholders and large scale agriculture.

A well-considered approach that tackles both technical and structural issues in agriculture is essential, and can create a prosperous climate-resilient agricultural sector that enables inclusive growth.

Well-tailored packages of interventions can support dynamic farmers to take advantage of new markets and opportunities. Other interventions can support those whose poverty constrains them significantly. But in many countries, significant structural issues constrain smallholder agriculture and need to be resolved for agriculture to prosper. These include a complex range of context-specific issues such as favourable national policies, better access to knowledge, credit and investment for women and the poor or marginalised.

They also include 'hard' physical or technological issues of adequate infrastructure, access to farm inputs, improved technologies and markets.

Within a world affected by climate change, it becomes ever more important that current science and early warning information are gathered and shared faster and better with farmers to improve their resilience and prosperity as farming conditions change.

What's in this Topic Guide

Sections 1-4 contain the main reading material

Two country case studies for Malawi and Nepal accompany the guide. Summaries are included in the text.

Section 1: provides an overview of the challenge of climate change, food security and agriculture. **We recommend that everyone reads this section**.

Sections 2 and 3: focus on "hot topics" on climate smart agriculture (CSA) including: CSA practices, gender, the economics of climate change and agriculture, the debate around multiple benefits and financing CSA approaches. You can dip in and out of this sections.

Section 4: looks at programming and draws out key messages for advisers and policy makers.

Each section provides:

- some theoretical background or assumptions.
- evidence and examples to illustrate main points.

Key messages. These are included at the end of each sub-topic or section for a quick recap of the main points covered.

Key readings or resources. One to two key readings or resources are included at the end of each sub-section and at the end is a fuller set of relevant readings for each section if you want to follow up further. Useful video material and blogs are also listed at the end. **A full set of references** is included at the end of the Guide. Web links to further useful materials on a topic are also included through the guide where relevant: these are indicative and readers are encouraged to add their own and read further on particular topics of interest.

How long should I set aside for reading this Topic Guide?

If you have time we recommend that you allow up to three hours to get to grips with the main points. Allow additional time to follow links and read some of the resources. Whilst readers are encouraged to read the whole piece we do not recommend reading this Guide in one sitting given the breadth of material covered. Here are some suggestions, depending on the time you have available.

If you only have time for a quick glance at this Topic Guide (5-10 minutes), we suggest you go to:

- **The overview and key messages**
- then go to the **Table of Contents** to guide you a relevant section, to pick up on any key messages or further reading.

If you have 15 to 30 minutes to spare, we suggest you read **Section 1** and then come back later to go to the most relevant sub-section for your purpose.

If you have half an hour or more to spare, we suggest you read **Section 1**, then go to the Section that is most relevant to you. For example go to **Section 2.2** on Building adaptation and resilience to climate change in agriculture or go to **Section 3.3** on Gender. At the end of each section there is at least one key reading on the topic, which you can open for more depth. Most of the key readings are short and accessible.

What's not included

This Topic Guide is a summary. It is intended to be an authoritative introduction for advisers. It is not exhaustive on all topics relating to climate change and agriculture. Key readings that provide in-depth information include:

- FAO Source Book on Climate Change and Agriculture (2013) is a 300+ page comprehensive report comprising separate modules and a reference tool discussing benefits and limitations of this approach to agriculture, forestry and fisheries at national and subnational levels.
- Lipper, L. et al., (2014) *Climate-smart Agriculture for Food Security* is a four page introduction to the latest understandings on climate smart agriculture in the journal Nature Climate Change.
- *FAO Success Stories on Climate Smart Agriculture (2013)* are compiled from the FAO Source book into a readable, accessible format for the non-specialist.
- Climate-smart agriculture: Success stories from farming communities around the world is a booklet produced by the CGIAR Research Programme on Climate Change, Agriculture and Food Security (CCAFS) and the Technical Centre for Agricultural and Rural Cooperation (CTA). It is based on research of large-scale implementation of adaptation and mitigation actions in agriculture conducted by Cooper PJM, Cappiello S, Vermeulen SJ, Campbell BM, Zougmoré R, Kinyangi J., Copenhagen and published in 2013.
- *Food Security And Climate Change* (2012). A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome, HLPE Report 3, June 2012.
- Beddington, J., et al. (2012) *Achieving Food Security in the Face of Climate Change: Final Report from the Commission on Sustainable Agriculture and Climate Change*. A set of policy recommendations based on best current knowledge of impacts of climate change on food security.
- Wheeler, T. and von Braun, J. (2013) Climate change impacts on global food security, Science 341 no. 6145 pp. 508 – 513 (not currently on open access journal) http://www.sciencemag.org/content/341/6145/508

The Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report contains summaries of the academic and published literature on related topics. Relevant readings include:

- The Working Group II *executive summary on impacts, adaptation and vulnerability (2014)* covers key understandings of climate change and provides a general overview of impacts worldwide.
- The sub-chapter from the Working Group II report on *food security and food production systems* covers the sensitivity of food production to weather and climate, integrated impacts and adaptation and risks.
- The IPCC's Working Group III report on Mitigation of climate change has a chapter on *Agriculture Forestry and other Land Use (AFOLU)* which covers trends in emissions, emerging technologies, mitigation options feedbacks, costing and co-benefits.

This Guide primarily focuses on land-based agriculture. It does not address the issues of fisheries and impacts of climate change. Summaries on these can be found in:

- Shelton, C. (2014) *Climate Change Adaptation in Fisheries and Aquaculture,* FAO Fisheries and Aquaculture Circular No. 1088. Rome, Italy: FAO
- Cochrane, K. et al. (eds.) (2009) *Climate Change Implications for Fisheries and Aquaculture: Overview of Current Scientific Knowledge*. FAO Fisheries and Aquaculture Technical Paper No. 530. Rome, Italy: FAO
- Brander, K.M. Global fish production and climate change. *Proceedings of the National Academy of Sciences of the United States of America* 104, 50, pp. 19709–19714. http://www.pnas.org/content/104/50/19709.full

Overview and key messages

The world produces enough food to feed the current population, but more than 842 million people are currently hungry. With more people to feed in the future there will be increased pressure on farming and agricultural systems. Climate change threatens food and agricultural production significantly and, with it, the assumption that farming can bring people out of poverty and into prosperity.

This Topic Guide seeks to help development professionals consider the implications of climate change and consider how to develop interventions in farming that are climate-smart. Interventions that integrate improved food security with better adaptation to climate change and, where appropriate, lower emissions of greenhouse gases.

Key messages

Farming faces the huge challenge of feeding the world's growing population, which is demanding more meat-intensive diets. Crop yields have grown impressively in the last few decades, but production still needs to increase by another 60-70% by 2050 to meet demand. Agriculture is intimately bound with global environmental systems, biodiversity and how effectively the natural environment can be shaped to the needs of human farming. In the industrial era huge changes have brought about increases in modernised farm yields. However, in many rainfed systems land areas have been degraded through human population increases, poor land husbandry or overuse of specific resources.

The impacts of climate change on agricultural systems vary by region, but most agriculture worldwide is rainfed and highly vulnerable to changes in temperature (especially extremes) and increased variability in precipitation. Modelling climate change and its impacts is complex and, with incomplete data sets in many developing countries, uncertainties are significant. By 2100 global average temperature will have risen between 2.6 and 4.8°C, but some parts of the world may experience temperature increases of up to 11°C[1]. While some cold regions will benefit as new areas open up for crops and growing seasons lengthen, overall, the impacts expected from climate change are negative and will lead to lower crop yields, especially in regions where most of the poorest and most vulnerable people live. The impacts include crop damage and lower yields, animal ill health and mortality, and erosion and degradation of soils.

Agriculture is a significant and increasing source of global greenhouse gas emissions – 13.5% of the global total – primarily through livestock gut fermentation processes, the use of manure and synthetic fertiliser, and wet rice cultivation in intensive and extensive agriculture. If no mitigation action is taken, agricultural emissions might increase by another 30% in the next 35 years because of the focus on increasing agricultural production. Deforestation for agriculture is a further cause of significant emissions, around 12% (Lipper et al 2014).

Integrating climate change through adaptation and by building resilience in both smallholder and commercial agribusiness food production systems is essential. Climate smart agriculture (CSA) is a significant new approach to increasing food security and yields. CSA seeks to contribute to adaptation to climate change, disaster risk reduction and/or reducing emissions through improved agricultural techniques and system changes. Many CSA approaches to date have focused on improvements at smallholder farm level,

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1 According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) report (IPCC, 2014a).

rather than further system changes. This includes: incorporating seasonal forecasting; modifying existing sustainable land management and conservation practices; introducing sustainable agricultural techniques; bringing further information about climate change and insurance as a risk reducing mechanism. Pilot projects and some larger scale initiatives, such as sustainable rice intensification and smaller doses of fertiliser applied to individual plants (see Section 2.3), show significant uptake and success.

In integrating climate change into development, planners and policy makers need to know that:

1. What we know already about long term climate change means that environments will change, much more than they have in memorable history. Many people's livelihoods and food sources are at risk, so **farming needs to be a priority for investment, and driven by understanding of changes that might occur**. Both risks and opportunities exist.

2. **It will get harder and harder for the rural poor to get out of the poverty cycle as a result of climate change**. Deeper issues that hinder rural development (e.g. land tenure, access to education, gender inequality) therefore need to be tackled robustly and fast.

A climate-smart approach to programming should include a critical consideration of the current and potential future roles of agriculture at regional, national and international levels. Finance available for agriculture and climate change internationally and at government level to date has been low. It needs to increase significantly if adaptation and mitigation potentials are to be understood and reached. The climate-smart approach offers some early and relatively easy wins. Suggestions include: measures with early 'robust' benefits that avoid locking in long-term risks; measures that focus on building capacity for long-term decision making; and low regrets measures with long lead-in times. Climate-smart actions consider effectiveness, feasibility, financial sustainability and sequencing/co-dependence of actions.

A range of climate smart agricultural technologies specifically developed for certain contexts can be scaled up to reach hundreds of thousands of farmers. In addition, development professionals can foster wider support for issues that curtail progress in agricultural development. This would include influencing national and international policy frameworks, leveraging existing private investment, improved information systems, developing risk insurance mechanisms, promoting gender equity, developing infrastructure, improving smallholders' access to markets and introducing alternative livelihoods that may increase resilience to climate change.

SECTION 1

Food security, agriculture and climate change: The challenge

Feeding the world: facts

We have enough food, but it is not getting to the right people and places. The world produces enough food to feed the current population, but it is not distributed equitably or efficiently (Hazell and Wood, 2008). Resolving this imbalance and reducing overconsumption would alleviate current malnourishment and reduce future food requirements (The Royal Society, 2012).

We will need more food in the future. Population growth, rising consumer demand for meat-rich diets and increasing affluence mean food systems will need to produce 60-70% more by 2050 to feed a projected world population of nine billion (Selvaraju et al., 2011; Lipper et al 2014).

But climate trends have reduced food production already. The negative impacts of climate change on crop yields have been more common than the positive ones (IPCC, 2014). Since 1980, global maize and wheat production have declined by 3.8% and 5.5%, respectively, in relation to a 'non-warmed' world scenario (Lobell et al., 2011).

Food production will decline further and faster with climate change. Food production is highly vulnerable to even a 2°C rise in temperature, and extremely vulnerable to a 4°C rise. A decline in food production will have major impacts on rural poverty, livelihoods and food security (Challinor et al., 2014; Battisti and Naylor, 2009). Models project that the direct climate impacts on maize, soybean, wheat and rice production will result in an 8 to 24% loss in total global caloric production by the 2090s (Elliott et al., 2014).

Where food production declines most will vary. The most vulnerable region will be sub-Saharan Africa, where mean negative changes in crop yields are projected to be between 5% (maize) and 17% (wheat) by the 2050s (Knox et al., 2012; Muller et al., 2011). Maize, sorghum, millet and groundnut are extremely likely to suffer yield losses of more than 7%, with a slim chance (5%) that this may be more than 27% (Schlenker and Lobell, 2010).

Farm systems also create emissions. Food production contributes between 19–29% of global anthropogenic greenhouse gas emissions.

We need to make decisions. Although a great deal of uncertainty persists about some aspects of regional and local climate impacts on agriculture, policy makers need to make informed decisions about investments in food security (Porter et al., 2014; Ranger, 2013).

1.1 Food security

Making sure that there is enough food for the world's growing human population is one of the most important humanitarian challenges of our time (Godfray et al., 2010).[2] Food production has grown in recent decades. World grain harvests have doubled from 1.2 billion to 2.5 billion tonnes per year as a result of more inputs, including land, improved technologies and better farming practices (IPCC, 2014b; FAOSTAT, 2013). Global per capita daily food availability has increased from 2,391 to 2,831 calories per day. There is enough food to feed current world populations but the food supply is unevenly distributed (FAOSTAT, 2013). While the richer populations have access to excess food[3], the poorest do not have enough (Hazell and Wood, 2008). Despite being close to meeting[4] the 1990 Millennium Development Goal target of halving world hunger by 2015, about one in eight people (some 842 million worldwide) are still suffering from chronic hunger[5] (UN 2014).

Looking to food supplies and the survival of the human population in the future, these challenges increase. The global population is expected to grow from the current 7.2 billion to 9 billion people by 2050, possibly reaching 11 billion by 2100 (Gerland et al., 2014; UN, 2013). Population growth has serious implications for resource use and consumption of materials: many forested areas have already been converted to agriculture; fish stocks have declined; access to fuel wood is increasingly difficult; and biodiversity has declined (The Royal Society, 2012). Agriculture faces the challenge of increasing food production by 70% by 2050 (FAO, 2013).

Many people suggest that food production needs to increase, and the hungry need to be able to access affordable food when they need it. If people do not have enough food 'to meet their nutritional requirements for a healthy and active life' they are said to be 'food insecure'. Proportionally, the largest group of food insecure is in sub-Saharan Africa (24% of the population), while the largest number live in South Asia (about 300 million people) (FAO, 2014a). Food security is influenced by several factors: whether enough food is available, if people have access to it, how secure that food supply is, and how they process and use that food. Recently, research into wider issues of food consumption and waste show that 30% of food produced is wasted at different points from harvest to plate. Table 1 shows how these four aspects of food security face distinct, but sometimes overlapping, challenges relating to land productivity, food availability and distribution.

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2 Many development agencies and national governments have prioritised this issue alongside the Millennium Development Goals. The United Nations launched the Zero Hunger challenge in 2012 to spur action towards eradicating hunger and malnutrition worldwide. The second goal of the draft 'post MDG' Sustainable Development Goals is to 'end hunger, achieve food security and improved nutrition and promote sustainable agriculture'.

3 Recent evidence from the World Health Organisation suggests that there are 500 billion obese adults in developing and developed countries; this number is expected to reach 1 billion by 2030. http://www.who.int/mediacentre/factsheets/fs311/en/

4 The MDG 1c '*Halve, between 1990 and 2015, the proportion of people who suffer from hunger*' (i.e. from 24% to 12%) is close to being met. Global proportions of undernourishment fell from 24% in 1990–1992 to 14% in 2011–2013, a decrease of 173 million people. However, progress on undernourishment slowed in the 2000s and some areas, notably sub-Saharan Africa, have shown much less progress (undernourishment only dropped from 33% to 25% during this period) (UNDP, 2014).

5 Chronic hunger, or undernourishment, is 'not having a sufficient food intake to meet dietary energy requirements for at least one year' (FAO, 2014a).

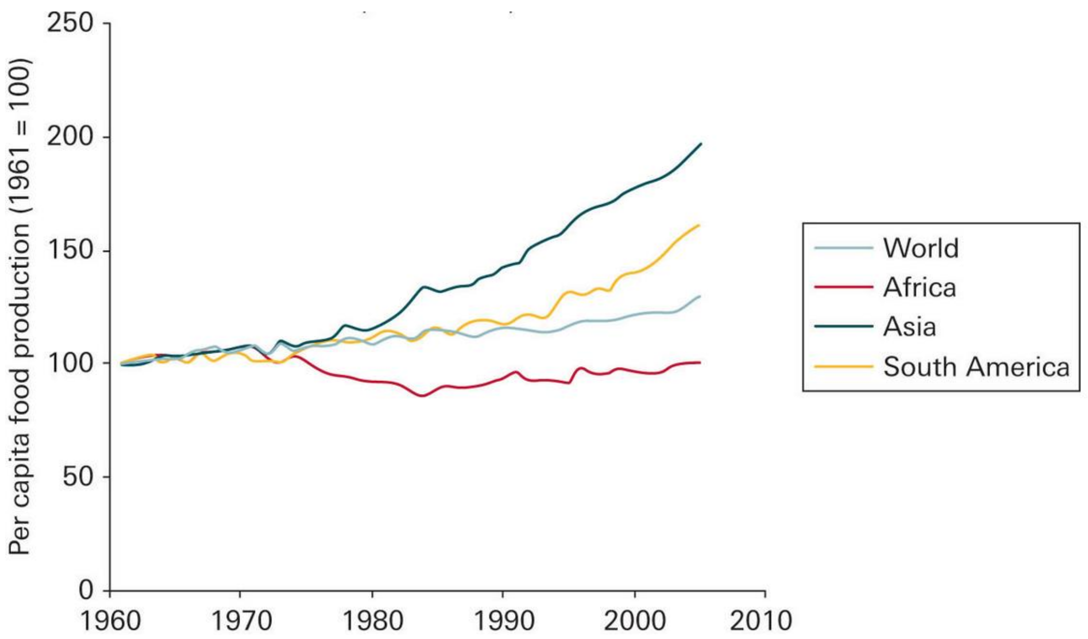
Aspects of food security	Challenges
AVAILABILTY. Ensuring food availability (production)	Limits to fertile agricultural land Limits to productivity Shocks and long-term climate change reduce yields
ACCESS. Ensuring that people have access to food (purchasing power)	Infrastructure Market and trade functioning; economic stability Humanitarian agency access (if emergency) Price spikes due to extreme weather events reduce access to food
STABILITY. Ensuring that the food sources are stable	Market functioning Political stability Climate change affects stability of local food supplies through crop yield variability
USE. Ensuring that food use in households and communities maintains nutrition and health	Household infrastructure Education on nutrition Water and sanitation Climate change may increase water-borne diseases, or cause or compound hunger, increasing morbidity

Table 1 Challenges to food security, including from the impacts of climate change

1.2 Agricultural production, growth and food security

The role of agricultural production in food security receives more emphasis than other aspects. The Green Revolution of the 1960s increased the total amount of food produced by applying technologies to improve yields per hectare and by expanding the area under production. This approach increased the availability of food globally – both total agricultural production and per capita food availability have risen since the 1960s – but the availability of food differed between regions. Per capita food availability in Africa barely changed during this time, while in Asia and Latin America food availability per capita increased dramatically (see Figure 1).

Figure 1 Changes in per capita agricultural production, 1961–2005



Source: Global Food Security, 2013.

Although other sectors are increasing in importance in many developing countries agricultural growth has helped deliver poverty reduction and economic growth in the recent past in many countries including: China, India and Vietnam. Higher productivity creates an agricultural surplus, kick-starting overall growth with its links to other domestic industry and services, agro-processing and food marketing (World Bank, 2007). The Topic Guide on *Agricultural Productivity* focuses on this in much more detail (Hazell, 2014). But three key points are worth reiterating:

- First, growth across other sectors of nations' economies does not necessarily lead to poverty reduction. Agricultural growth can be effective in reducing extreme poverty and hunger, if pro-poor policies are in place to support it (FAO, 2012).

- Second, given the role that agriculture plays in the economic growth of many developing countries, it is very important that this agricultural growth is sustainable over time in order to maintain the positive impacts on food security and the economy as a whole. Sustained agricultural growth needs investment in agriculture, infrastructure, health and education (Shepherd and Prowse, 2009).

- Third, serious questions have been raised about how environmentally sustainable growth in agricultural productivity has been in the past. Intensive farming systems have led to pollution, loss of biodiversity and increased greenhouse gas emissions. Extensive farming systems have changed land use, depleting natural resources (Hazell, 2014).

1.3 Climate change, and how it affects farming and agriculture

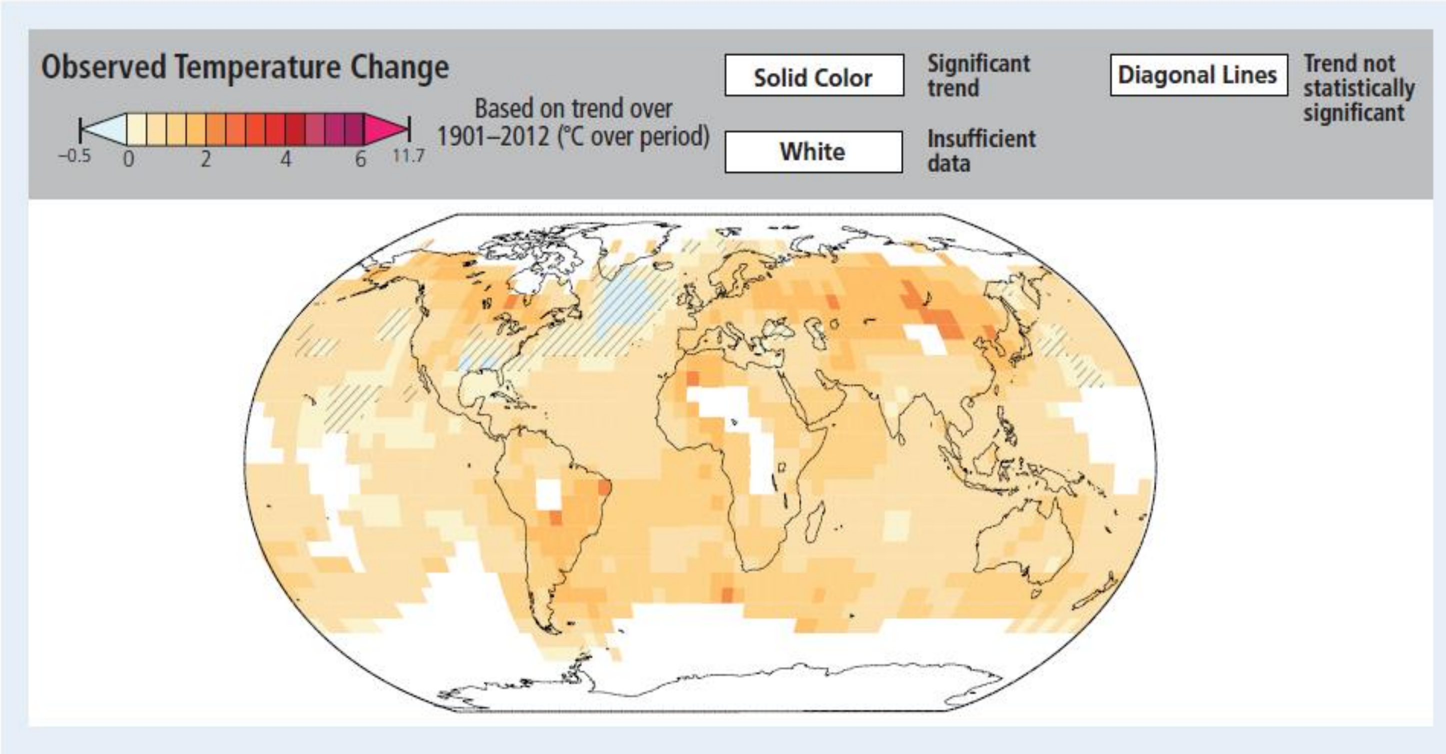
1.3.1 Physical changes in climate to 2100

Human-influenced climate change increases both the short-term variability in rainfall and temperature and long-term global average climate temperatures.

'A changing climate leads to changes in the frequency, intensity, spatial extent and duration of weather and climate events, and can result in unprecedented extremes, both through slow onset disasters (e.g. consecutive years of drought) and extreme events (e.g. heavy flooding)' (CDKN, 2013 p. 2)

Average increases in temperature of around 1ºC have already been observed over the last century (see Figure 2). There is now no doubt that the climate has already changed because of human influences in the last 100 years and will continue to change significantly in the future.

Figure 2 Observed changes in global temperature, 1901–2012



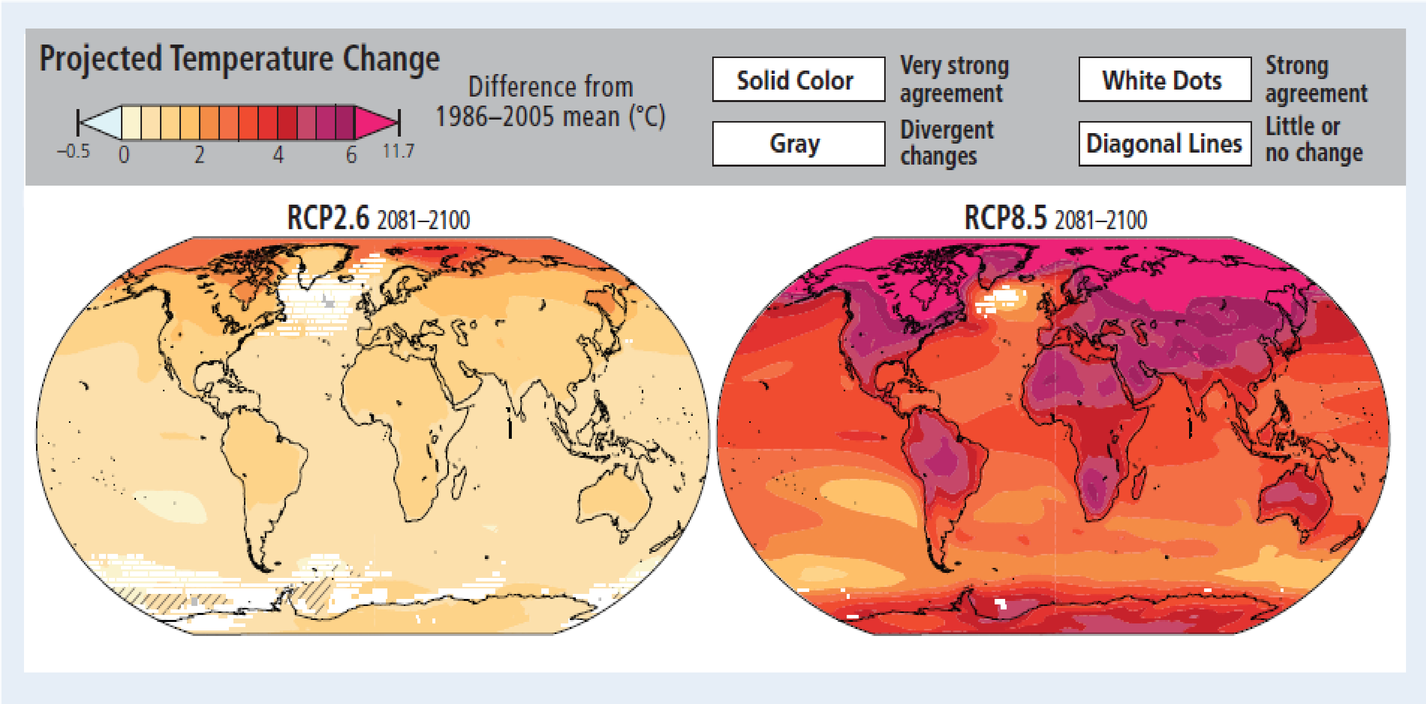
Source: IPCC, 2014a

Despite uncertainties[6], the models predict an increasingly human-warmed world (see Figure 3). Of these, even a 'best case' scenario (in the left hand image) demonstrates an average temperature increase of around 2ºC over much of the world by 2100. The 'business as usual model' shows a change of between 1º and 11ºC, with very high increases of 4–6°C over the main food producing regions of the world, China, the United States and India.

6 See Ranger (2013) for a fuller discussion of uncertainties in modelling and adaptation to climate change.

Figure 3 Projected potential average temperature changes from previous conditions to those expected in the late 21st century (2081–2100)

Regional concentration pathway 2.6[7] RCP2.6 shows a future with global emissions very strongly limited (0–4ºC change). RCP 8.6 shows a 'business as usual' future (1–11ºC change)



Source: IPCC, 2014a
RCP – Representative concentration pathway

7 Representative Concentration Pathways (RCPs) are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report (AR5) in 2014. The four RCPs, RCP2.6, RCP4.5, RCP6, and RCP8.5, are named after a possible range of increased radiative forcing values in the year 2100 relative to pre-industrial values. The level of average and likely warming of 1 degree centigrade by the end of the C21st is 1 degree centigrade under the lowest RCP 2.6; and 3.7 degrees centigrade under the highest RCP 8.5. See http://en.wikipedia.org/wiki/Representative_Concentration_Pathways for more detail.

1.3.2 Climate change effects on agriculture – overview and regional levels

As agriculture depends on water availability and specific ranges of temperature for plant growth, the farming sector is very vulnerable to climate change. Climate change and its associated impacts will affect agricultural systems in both the short and long term through:

- Increased frequency and/or severity of extreme events and increasing climate variability.
- Increases in global average temperatures and temperature extremes, and long-term changes in rainfall (regionally-dependent increases and decreases) and related sea level rise.
- Emissions-related impacts (increased atmospheric concentrations of ozone levels and CO_2).
- Increasing incidence and shifting range of plant pests and diseases and their negative impact on crops and yields.

Details of the types of agriculture and farming impacts resulting from these climate changes are summarised in Table 3. These include yield decline, crop damage and loss, land degradation and animal loss. Lower rainfall may prove a limiting factor for crops in many marginal environments. More frequent temperature spikes may damage plants, and crops may die in prolonged drought. Slight changes in temperature at critical growth stages can radically reduce yields (FAO, 2013). Climate change is also expected to increase the inter-annual variability of crop yields in many regions (Porter et al., 2014).

The effect of these changes on farmers' livelihoods, poverty and family food security is significant. A gradual decline in yields affects the viability of agriculture as a dependable base for subsistence and income. An increase in extreme events causes yields to fall abruptly or total loss of crops (IFAD, 2013).

Change type	Climate change impact	Potential positive impacts on agriculture and farming	Potential negative impacts on agriculture and farming
1. Extreme events and climate variability	Increasing length and frequency/intensity of extreme heat events and heat waves	None known	Wilting and death of plants Animal stress Decreasing productivity and ill health of farm workers
	Increasing frequency and changing patterns of intense precipitation (rainfall, hailstorms, snow)	None known	Crop damage through waterlogging and hail Soil erosion and degradation Crop yield lower
	Changing flood patterns	Few – potentially some areas silted/fertilised which are normally not reached by water flows	Crop damage and loss; salinisation from seawater estuary incursion Animal and human loss Infrastructure damage
2. Increase in global average temperature	Increasing global annual maximum daytime temperatures	Increase in growing season and crop yields in colder areas Affects crop growth and development	Over 30ºC daytime temperatures mean much lower yields Affects crop growth and development
	Intensifying droughts in some areas with water deficit; increase in multi-year droughts (compounded with overexploitation of and demand for water resources)		Crop water stress, reduced yield and crop death Animal stress Possible conflict over water supply Increase in wildfires in dry forest and savannah
	Lower frost occurrence	Less frost damage to crops	Higher incidence of pest and plant disease
	Increasing frequency of hot nights		Damages rice yield and quality
	Pests and diseases change in amount and range	Some diseases will decline depending on their geographic range	Greater disease impacts – accessing new populations previously unaffected/not immune Negative effects on yields and animal health
	Sea level rise		Salinisation of low lying areas Decrease in yields Decrease in available land

Change type	Climate change impact	Potential positive impacts on agriculture and farming	Potential negative impacts on agriculture and farming
3. Direct emission-related impacts	Increasing surface ozone (from air pollutant reactions)		Causes damage to capacity of crop plants to photosynthesise Globally, yield loss estimated at USD 14–26 billion
	Increased CO_2 concentrations in atmosphere	Stimulation of plant growth Increased water-use efficiency Soil moisture levels may increase Run off may increase. Effects not uniform across plants; interact with ozone levels	Increased weeds Reduced nutritional quality of food (protein and mineral concentration decline) Plants need more N and minerals
4. Human responses to climate change	Mitigation Responses to contain emissions include carbon sequestration through carbon capture and storage (CCS) underground, forest and soil sequestration Adaptation	Forest and soil conservation; improvements to biodiversity Well-designed adaptations to climate change may stabilise and enhance crop yields and pastoral livelihoods	CCS techniques are a high carbon option; ocean acidification is a threat if under seas Potential maladaptations to short or long term climate change (e.g. unsustainable management of irrigation water resource) may cause additional issues for farming such as salinisation

Sources: Porter et al., 2014; SREX, 2013; McGrath and Lobell, 2013; Selvareju, 2011

Table 2 Impacts of climate change on agriculture

1.3.3 Regional impacts of climate change

The Small Island Developing States are the most vulnerable to climate change because of the rise in sea level which threatens the entire land area of some of these countries. The 'Human Dimensions of Climate Change' project of the Met Office summarised the regional impacts of climate change in the major regions of the world described in the IPCC Fifth Assessment Report (Table 4). Sub-Saharan Africa and South and East Asia are particularly vulnerable to climate change as higher temperatures will affect food security and the vulnerability of coastal zones, exacerbating existing development issues, including population growth (Met Office, 2014).

Box 1 Projected regional impacts of climate change according to the IPCC Fifth Assessment Report

Middle East and North Africa. Parts of North Africa are already water stressed and projections indicate that the Mediterranean region will see some of the largest increases in the number of drought days and decreases in average annual water run-off. In addition the warmest days are projected to become warmer in the already hot climate. The Middle East and North Africa are major importing regions for wheat, maize and rice, and thus will be affected by the effects of climate change in the main regions where these crops are produced – mostly North America, but also South America, Russia, Australia and northern Europe.

Sub-Saharan Africa. The temperatures of the warmest days, the number of days of drought, and the frequency of flood events are all projected to increase across the region. Continued high birth rates will increase demand for food and water further, when **most of the region already suffers from high levels of food insecurity and water stress**. Coastal zones are threatened by salinization of farmland and damage to coastal settlements. Increased conflict and migration from less habitable areas may be a direct or indirect result.

South Asia. South Asia has a very high population density. **Continued population growth will increase the demand for food and water resources in an already water stressed and food insecure region**. Positive and negative changes in different crop average yields due to climate change range from a 16% decrease to a 19% increase. The frequency of inland flood events is projected to increase and, as the region is exposed to tropical cyclones, these floods, along with rising sea levels, could mean millions more people are subject to flooding every year along coasts.

East Asia. The East Asia region imports a high proportion of wheat, maize and soybeans. China imports over 40% of the world's soybean production to meet a growing demand for animal feed. Imports of food link the region to the climate impacts in the major production and export regions of these crops, primarily the Americas. **The frequency of flood events in East Asia is projected to increase**. The region is exposed to tropical cyclones and has densely populated coastal zones which mean that rising sea levels have the potential to affect millions of people. Increasing sea temperatures and ocean acidification may also threaten the important fishing industry in the region.

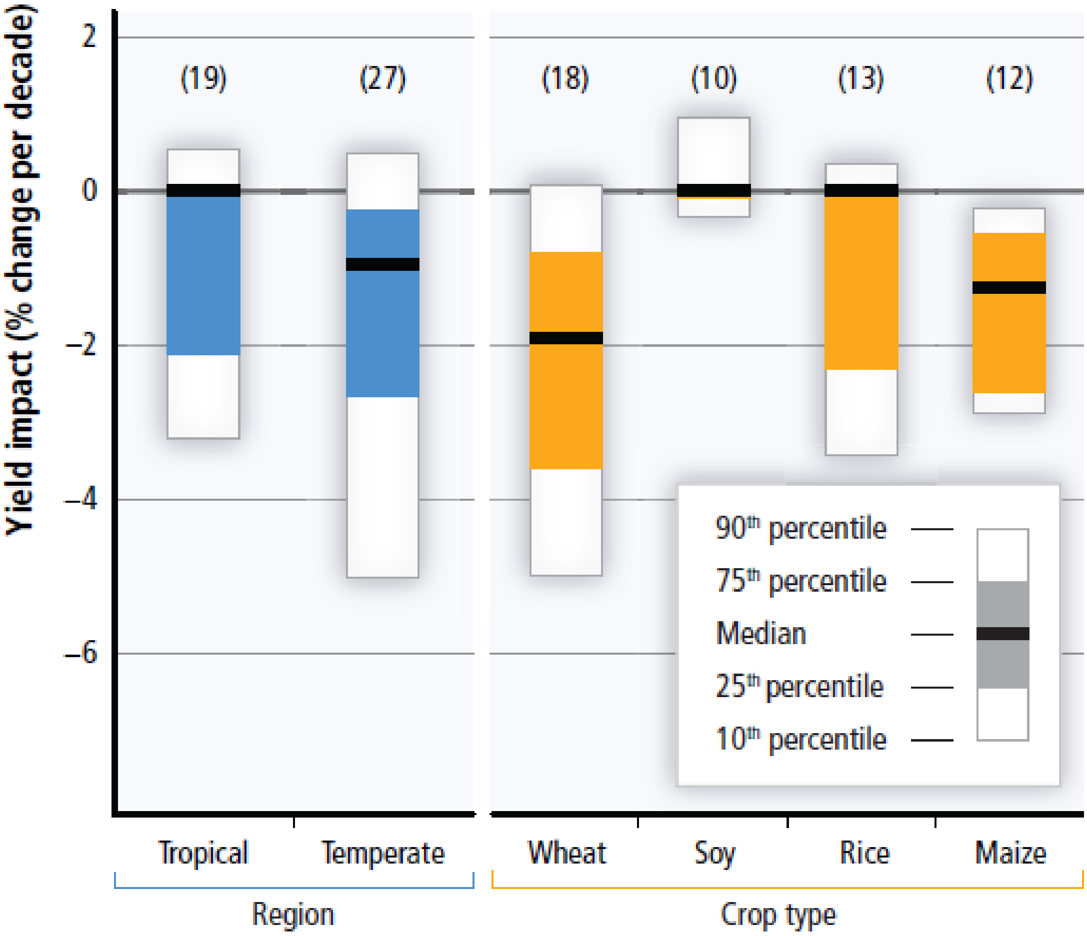
Southeast Asia. Southeast Asia is a densely populated region already exposed to coastal flooding and storms. **With projected population increases and rising sea levels, the exposure of coastal populations is projected to increase considerably.** The frequency of inland flooding events is also projected to increase. Warmer sea surface temperatures and ocean acidification may threaten fish stocks in this major fishing region. The region is important for rice exports and is a major producer of maize. While projections indicate a slight increase in the average rice yield, the maize yield is projected to decrease. Projections do not take into account an increasing demand for water for irrigation, decreasing water run-off, increases in drought days and the effect of storms.

Source: Met Office, 2014

1.3.4 Climate impacts on yields at the global and regional levels

Climate change affects crop yields quite differently in different regions of the world (IPCC, 2014a). Overall, yields of the four major crops of the world (wheat, soy, rice and maize) have already declined over the last 50 years as a result of climate change – the median decrease for maize is between 1 and 2% (see Figure 4) (Porter et al., 2014).

Figure 4 Estimated impacts of observed climate changes 1960–2013 for the major crops of the world

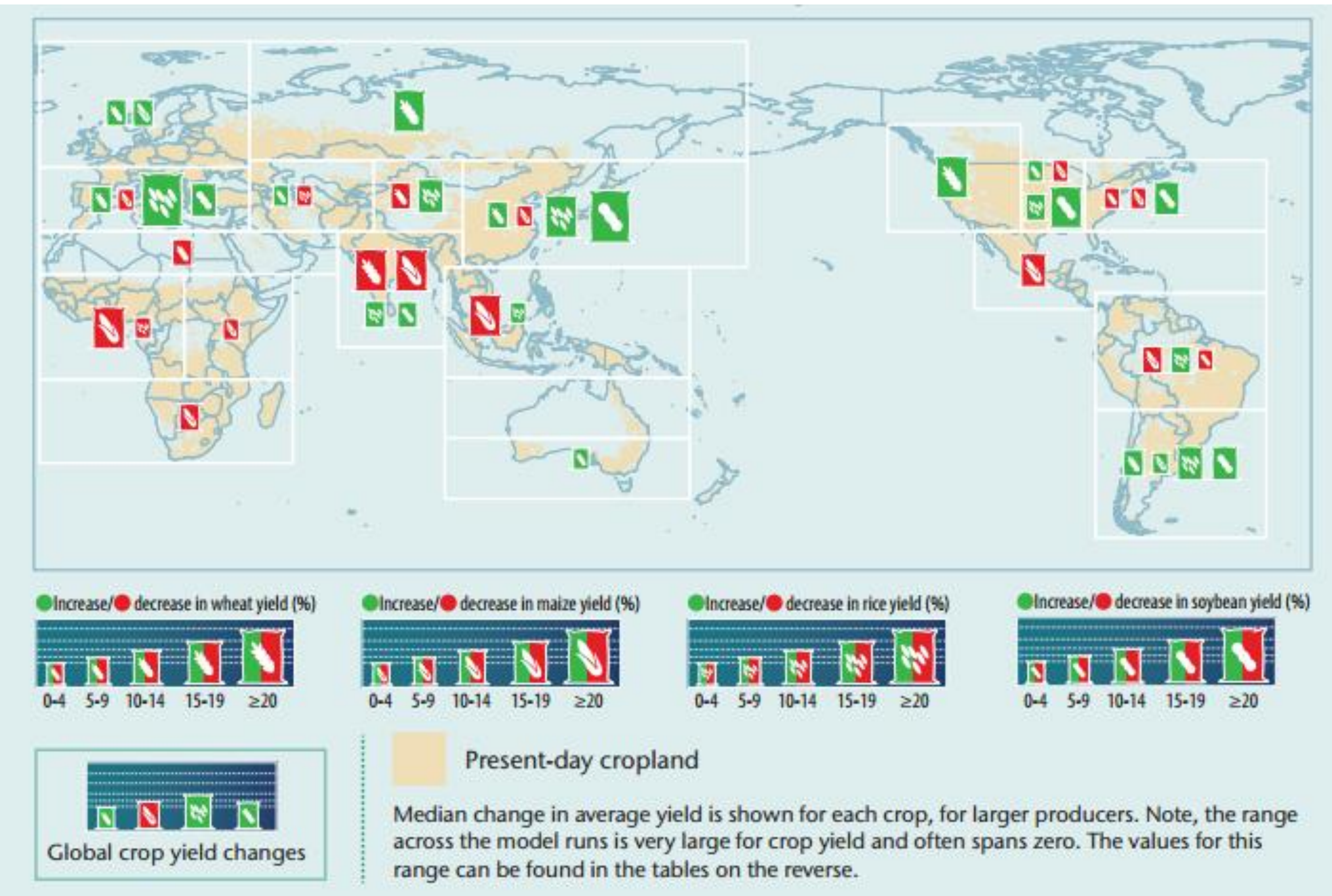


Source: IPCC 2014b, p.7

The expected future regional impacts on the four major staple global food crops vary. In general the lower latitudes will experience lower crop and livestock productivity. Short term impacts are less well understood due to modelling uncertainties and inability to isolate direct causality, but evidence to date shows that extreme events are increasing in frequency and are significantly damaging to food crops. Sub-Saharan Africa will have the biggest decreases in yields by 2100, according to the Met Office (2014) (see Figure 5). Wheat and maize yields will decline in the Indian subcontinent, but rice and soybean production will increase. The higher latitudes (Russia, northern Europe and southern Latin America) are likely to experience increased yields as higher temperatures lengthen the growing seasons.

Increased shocks and stresses from extreme events will affect all systems; but stronger impacts are expected on rainfed agriculture (Verhagen et al., 2014; Grainger-Jones, 2011; Dinar 2007). The poorest subsistence farmers and pastoralists in tropical regions are likely to suffer the most direct impacts of climate change, with complex local impacts.

Figure 5 Future changes (to 2100) in average crop yield by region, under the 'business as usual' concentration pathway (RCP 8.5)



Crop yield projections show both increases and decreases in different regions for different crops. However, viewed in the context of other changes, it is apparent that the climate projections shown here represent a threat to global food security. The changes in average yield above assume that irrigated crops will continue to be supplied with sufficient water. While demand for water is projected to increase due to the greater water requirements of crops at higher temperatures and also the growing global population; the availability of water will vary, with an increase in run-off in some areas and decreases in others. A larger population also means an increase in demand for food. Finally, average changes in yield mask the increase in year-to-year variability as a result of the projected increases in drought, high temperatures, and in many places, flooding.

	% change expected (see explanation below)			
	Wheat	Maize	Rice	Soybean
Eastern Africa		-3		
Southern Africa		-5		
Western Africa		-19	-1	
Sahara	-6			
Amazon Basin		-8	5	-3
Southern South America	9	0	13	12
Eastern Asia	5	-4	18	25
Southern Asia	-15	-19	5	8
Southeast Asia		-15	4	

Table 3 Future median crop yield impact projections of major crops, in percentage terms

Including CO_2 fertilisation over rainfed and irrigated lands for regions of Africa, South America and Asia (comparison shown as percentage change from period 1981-2010 to 2071-2100 under Business as Usual CO_2 emission scenario)

Source: Met Office, 2014.

Key messages

- Existing uneven food distribution, high levels of food waste from farm to fork, and increases in demand over the next 90 years mean that food security is a critical issue. Food security is further challenged by climate change as an additional stressor to existing contexts.
- Agricultural growth in recent decades has been higher in Asia and Latin America than elsewhere; sub-Saharan Africa has experienced agricultural growth, but not consistently, and there is significant potential to increase productivity in this region.
- Climate change impacts on agriculture and food security are already being observed across a number of the world's cropping systems in lower overall yields.
- Yields are expected to drop for the major food crops globally overall as a result of impacts of climate change, although uncertainty in modelling and biophysical system complexity hinder precision in predicting outcomes.
- Despite some positive impacts from increased plant growth due to higher CO_2 availability, negative effects are skewed towards tropical regions where food security and poverty are a significant issue.

Further reading

Overview

Module 1 of the FAO's (2013) Sourcebook on Climate Smart Agriculture *discusses* the intertwined challenges of food security, agriculture and climate change and outlines the case for Climate Smart Agriculture.

The *Fifth Assessment Report of the Intergovernmental Panel on Climate Change on Impacts, Adaptation and Vulnerability* (2014) summarises the best available published science on climate change.

A High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security produced a concise, clear report on Climate Change and Food Security in June 2012.

Food security and agricultural production

Food security: the challenge of feeding 9 *billion people*. Charles Godfray and other experts on food security discuss the challenge of population and consumption growth for food production and food security, and how the effects of climate change further threaten this. They claim that the world needs to not only produce more food, but also to use it more efficiently and equitably – and propose a global strategy that would help achieve this.

State of Food Insecurity Reports A comprehensive review of estimates of hunger and progress towards the Millennium Development Goal (MDG) and World Food Summit (WFS) hunger targets is produced annually in the FAO State of Food Insecurity in the World (SOFI) reports.

Peter Hazell's (2014) *Topic guide on Agricultural Productivity* provides an excellent overview of agricultural productivity, including growth in global agricultural production, regional variation, and concerns over sustainability of production. Future agriculture needs to focus on the role of women and the poorest.

Regional impacts of climate change on agriculture

CDKN summaries for South Asia, Africa and Small Island Development States are a good starting point.

The IPCC individual regional chapter reports providing more detail for specific areas are accessible at http://www.ipcc.ch/report/ar5/wg2/ under Part B: Regional Aspects.

SECTION 2

Climate change: mitigation and adaptation

2.1 Mitigating greenhouse gas emissions from agriculture

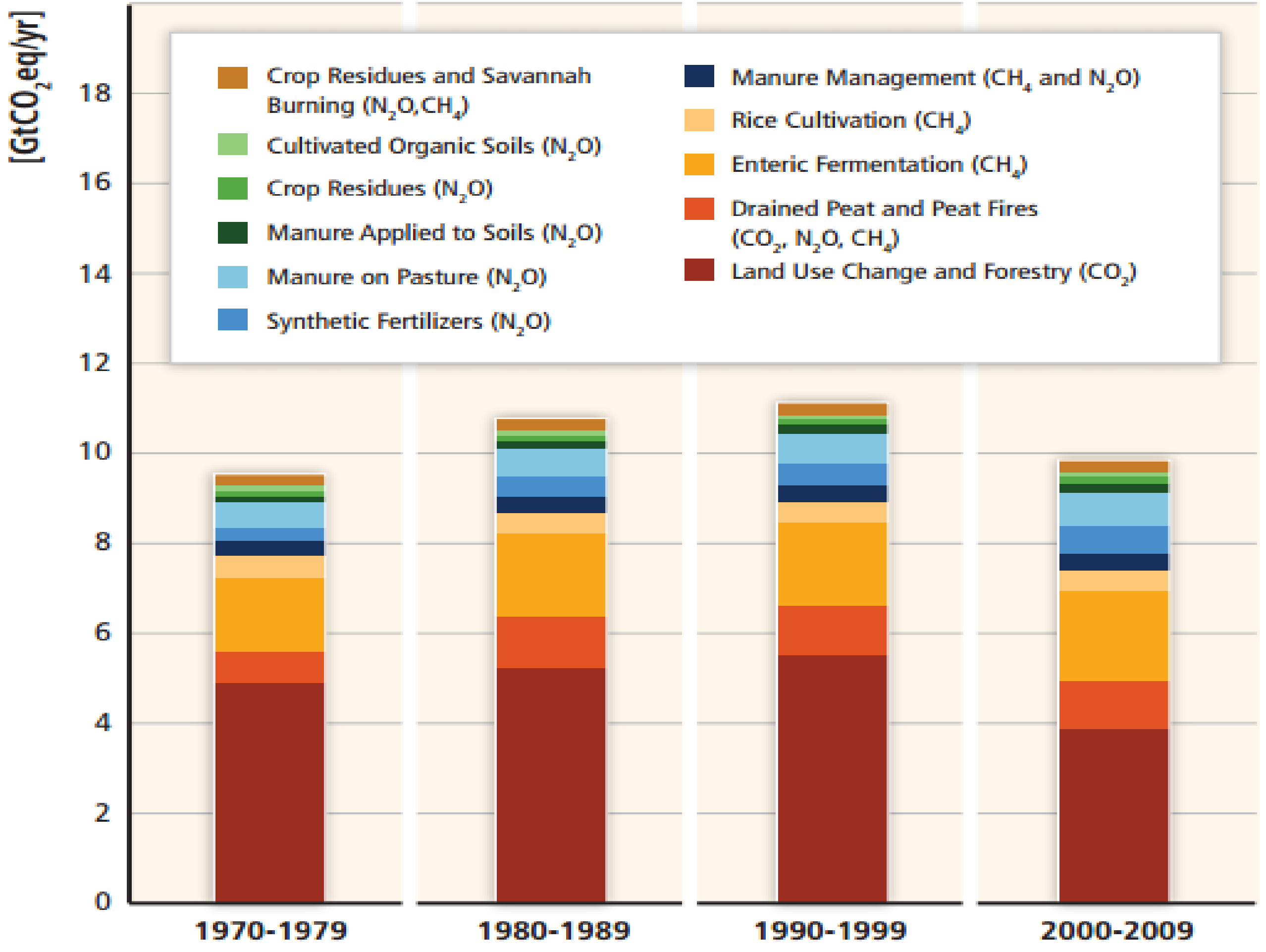
While agriculture is clearly vulnerable to climate change its contribution towards increased emissions is significant. About 13.5% of total current global emissions are from agriculture: emissions of greenhouse gases from agriculture were on average 5.0–5.8 gigatonne CO_2 equivalent/year from 2000–2010 (IPCC, 2014b). These include all anthropogenic emissions from the sector including animal production, manure management, rice cultivation, agricultural soil emissions, and land and residue burning for grazing / soil fertility[8]. Not included are emissions from fuel combustion (including manure for fuel) and sewage on-farm, and wider agriculture-related emissions including those from post-harvest food processing, distribution, retail and waste management: these emissions are counted elsewhere under IPCC inventories. But there is significant uncertainty in many nations underlying figures for the UNFCCC National Inventories due to assumptions made to cover significant data gaps and the difficulty to distinguish between man-made natural emissions and carbon sinks. The largest proportion of emissions from agriculture comes from livestock gut processes (enteric fermentation). Manure and synthetic fertilisers are responsible for much of the rest of the emissions from agriculture (e.g. fertiliser related emissions have increased 37% in the last 10 years).

Agriculture is considered alongside forestry, land use and land use change increasingly due the need for integrated policy and planning across land use systems, as reflected in the current IPCC Fifth Assessment Report. Taken together with forestry and other land use emissions involved in land use change, the entire agriculture, forestry and other land use (AFOLU) sector accounts for nearly a quarter of all (human-caused) global greenhouse gas emissions (IPCC, 2014b). The AFOLU sector is therefore receiving significant attention in attempts to reduce global emissions.

Land use change is a driver of emissions. In the last 40 years, half of total emissions have been the result of land use change (primarily deforestation). Recent decreases in emissions from agriculture, forestry and other land use are a consequence of declines in deforestation (see Figure 6).

8 See IPCC (2006) Guidelines for National Greenhouse Gas Inventories for full description of processes involved in greenhouse gas emissions and storage in agriculture http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_01_Ch1_Introduction.pdf

Figure 6 Agriculture, forestry and other land use emissions (in Gigatonnes CO_2 equivalent / year)



Source: IPCC, 2014b

Given the need to increase productivity and yields to meet increasing food demands, it is very likely that emissions from the agricultural sector will increase substantially in years to come. If no action is taken to reduce emissions from the sector, FAO estimates that emissions from agriculture could increase by 30% by 2050 (FAO, 2014b). The question is how food systems and agriculture could contribute to reducing greenhouse gas emissions without compromising agriculture and food security (FAO, 2013).

Emissions reduction in agriculture

In addition to being a source of greenhouse gases, agriculture and farming systems are important as potential sinks to absorb carbon dioxide. The potential for mitigation of climate change lies primarily in reducing emissions by changing practices at the farm level, including avoiding deforestation (75% of deforestation worldwide is a consequence of clearing forest for agriculture, according to FAO, 2014a). Mitigation also focuses on sustainable intensification of livestock and cropping systems, use of animal wastes for biofuels and better use of both synthetic and animal manures. Research has recently begun to explore the mitigation potential along agriculture value chains, for example reducing food waste and post-harvest losses, and increasing the energy efficiency of fossil-fuel-dependent farm vehicles (IPCC, 2014b; FAO, 2013).

Various agricultural techniques relating to sustainable agriculture, conservation agriculture and sustainable production address both adaptation and mitigation.

Options to reduce emissions include:

- Improving the efficiency of production per emission output.
- Increasing soil carbon 'sinks' – removing carbon dioxide from the atmosphere into the soil - (potentially through reducing tillage, improving grazing management, restoring organic soils and restoring degraded lands).
- Avoiding deforestation for agricultural production,
- Improving efficiency in food chains, including reducing on farm and post-harvest losses.

Increasing soil carbon sinks over the long term, through sustainable agro-ecological production methods, such as intercropping with leguminous crops, agroforestry and minimum tillage approaches, have long been thought to potentially decrease agricultural carbon emissions considerably (FAO, 2013). Studies model this potential with a huge range from 1.4 – 6 Gt CO_2 equivalents per year. However, a number of studies cast doubt on this, demonstrating areas where no-till approaches have had little or no effect on carbon sinks (Stockman et al. 2013; Powlson et al 2014). More broadly, others question this approach because sequestration potential is finite, reversible and the complexities involved in the process mean that increases in nitrogen dioxide emissions elsewhere may negate carbon dioxide storage. Powlson et al. (2011) show that this is a complex process, and where carbon may be taken out of the atmosphere by converting annual cropped land to land uses with more cover, if land is converted elsewhere to agriculture, this negates positive benefits.

Sustainable intensification (producing more food with less negative impact) could be efficient in very low productivity systems, especially in livestock systems where improvements in animal health and nutrition, and the productivity and quality of pastures could significantly decrease emissions (Lipper et al 2014). However, improved practices are generally not adopted for a series of reasons: perhaps increases in yield resulting from the investment of funds or labour are not sufficiently attractive, lack of land tenure security can decrease ability or desire to invest long term in the land; there may be too long a timelag before gaining financial benefits or smallholders may be unwilling to take on any further perceived risk of new practices (FAO, 2013).

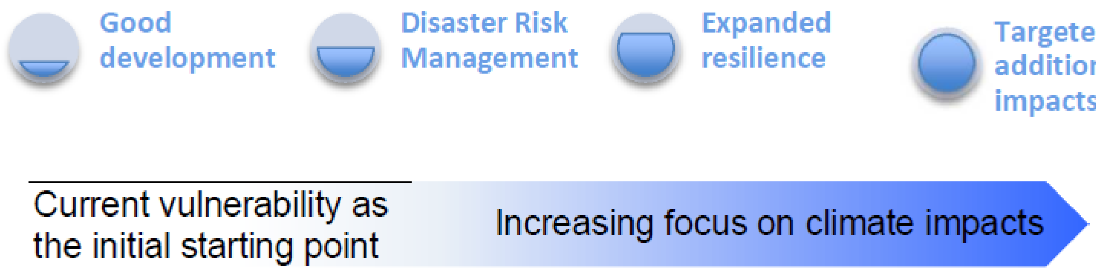
2.2 Building adaptation and resilience to climate change in agriculture

Given the growing evidence of the effects of climate change, farmers are now addressing the impacts of extreme weather events and have begun to address long term climate change adaptation. Emergency and longer-term development approaches to food security combine measures to reduce vulnerability and, more recently, improve resilience to climate change.

Approaches to adaptation to climate change, previously focused on biophysical vulnerability, are now including wider social and economic drivers of vulnerability, and people's ability to respond (IPCC, 2014a). An understanding of the various aspects of vulnerability and abilities to respond is especially important in agriculture. Direct climate impact scenarios are starting to incorporate the more complex socio-economic feedbacks of crop production, markets and global trade patterns (IPCC, 2014a).

Adaptation to climate change is now seen as a continuum starting from 'good development' to address current vulnerability (climate proofing existing investments), through disaster risk management (preventative action to reduce the impacts of extreme events) to expanding resilience and targeting additional impacts in the longer term (see Figure 7).

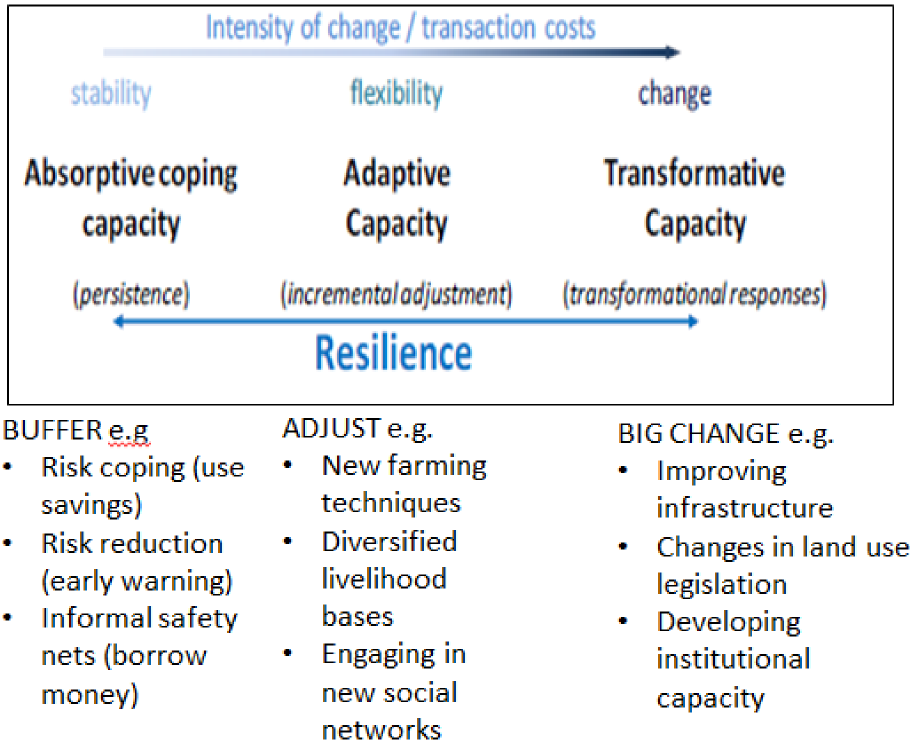
Figure 7 Continuum of adaptation actions



Source: Downing, 2013

Related to the continuum of adaptation is the continuum of people's resilience to climate change (see Figure 8). Resilience is measured in terms of short-term 'coping capacity', medium-term 'adaptive capacity' and longer-term 'ability to transform' in the face of climate change and extreme events. While most investment is currently linked to the first two 'incremental' areas, transformative and structural changes to agriculture are needed in order to deal with the impacts of climate change. For example, some parts of the world will become critically water-stressed during the next 40 years. These areas will need to plan to maintain food security and accommodate large movements in population. (Ranger, 2013). See Section 4.2 Climate-smart approach to programming for further detail on how this is being taken through into planning for climate investments.

Figure 8 A continuum of resilience



Source: Béné et al., 2012

2.3 Climate-smart agriculture: integrating adaptation and mitigation

Of the approaches developed to take account of climate change in agriculture, climate-smart agriculture has rapidly taken precedence. The term ‘climate smart agriculture’ (CSA) was first coined by the FAO in 2010 at The Hague Conference on Agriculture, Food Security and Climate Change. CSA recognises, first and foremost, the impacts of climate change on agriculture and food security. The CSA approach also integrates opportunities to mitigate carbon emissions from agriculture that contribute to climate change and are sustainable. CSA does not prescribe any particular type or scale of agriculture and can include agro-ecological approaches alongside the use of new technologies and innovative approaches.

While CSA has slightly different definitions across organisations, definitions generally involve:

- Increasing agricultural productivity and incomes in an environmentally and socially sustainable manner.
- Adapting and/or building resilience to climate change.
- Reducing and/or removing (storing) greenhouse gas emissions, wherever possible.

(World Bank, 2013; FAO, 2013; Lipper et al 2014)

Whilst initially posed as 'triple wins' that could be achieved in agriculture, a recent and more nuanced approach demonstrates that in different locations and at different scales, these elements need to be emphasised differently to find locally acceptable and effective solutions (Lipper et al 2014). Mitigation of greenhouse gas emissions may involve additional costs. Derived from this understanding, **climate resilient agriculture** combines a focus on agricultural productivity and resilience to climate change but does not include mitigation as a primary aim.

2.4 Development of CSA

Conceptual approaches to CSA have matured and developed with several important improvements.

First, CSA approaches originally focussed almost exclusively on farm level food production, climate risk reduction, and the availability of food. However as described in Section 1.1, the accessibility of food, food waste, stability (i.e. variability) and how food is used are beginning to be seen as areas where a climate smart approach could be applied to address food security challenges. It emphasises the wider food value chain, including patterns of consumption and food waste, and the politics and economics of food access and supply as well as food consumption.

Second, the FAO has proposed a 'landscape approach' to CSA. This approach integrates ecosystem services, forestry, biodiversity, water resources and other sources of alternative rural livelihoods (FAO, 2013). Climate Smart Villages, a concept piloted by the Climate Change Agriculture and Food Security (CCAFS) programme, take all aspects of a settlement's food security, development, adaptation and mitigation into consideration in planning how best to respond to climate change at the local level.

Finally, there is recognition that CSA is context specific – it is unwise to apply equal weighting to needs for food security, mitigation and adaptation (Lipper et al., 2014). A CSA approach might include building climate resilience, reducing poverty, enhancing biodiversity, increasing yields and/or lowering greenhouse gas emissions (FAO, 2013; Grainger-Jones, 2011; Nelson et al., 2009). In Africa, for example, agricultural emissions are very low, so mitigation is not needed although carbon sequestration through better land management is a potential opportunity for mitigation as is more sustainable intensification to reduce pressure to convert forests to agriculture lands. New technologies and agricultural inputs could, however, be screened for their potential to reduce greenhouse gas emissions. A context specific gender approach to CSA is important, as is increasingly noted in the literature (see Section 3.4). The context of certain regions that are particularly vulnerable to climate change is a central focus for DFID such as semi-arid agricultural and pastoral farming systems (see Section 3.3).

CSA caveats

A number of concerns about CSA are emerging:

1. **A focus on CSA may overemphasise the importance of agriculture to an economy or people in a region**. Approaches to respond to climate change need to retain a focus on the main areas of the economy of the region that are likely to be most highly affected by climate change. There may be a contrast between the interests of the most vulnerable rural dwellers dependent on rainfed agriculture, and the economic growth focus of a nation (e.g. Angola, which makes 95% of export revenue from oil, but 2/3 of population are farmers or farm workers).

2. **A focus on CSA may overemphasise the importance of climate change relative to other critical environmental limiting factors in rural areas**, such as loss of biodiversity, water availability, or ecosystem and land degradation, independent of climate change.

3. **The CSA 'badge' is both a strength and a drawback**. The practices, underlying paradigms and value systems involved are not specified. The CSA approach is broad, covering a range of efforts at various scales to increase agricultural productivity. Efforts range from: bunds to conserve rainwater on the poorest smallholder farms to sophisticated technology, downscaled seasonal forecasting, risk insurance mechanisms to research on drought tolerant crops and marketing through global multinationals. Some of these approaches have very different financial and political interests, which can cause problems if all approaches are housed under one 'umbrella'. For example, proponents of organic, conservation agriculture community level CSA approaches may disagree with CSA approaches focussed on high tech innovations and biological crop research advances due to different underlying value systems and goals.

4. To date, donor investment in CSA has mostly been focussed on the poorest and most vulnerable in developing countries and has not considered large scale agricultural practices and food systems in those countries. While this is not a limitation as such, it means that, while some are keen to expand the idea to large scale agriculture, others are less interested.

5. As agriculture is such a significant source as well as sink of greenhouse gases, a **strong global carbon market** could stimulate significant increased investment in the sector towards sustainable agricultural practices aimed at lowering emissions. However, the carbon market has been highly variable in recent years, and there remain significant current issues on the monitoring, reporting and verification of carbon emissions from the agriculture sector at many scales. These currently hinder the set up of appropriate effective mechanisms for investment.

2.5 Organisations working on climate change and agriculture

Consideration of the impacts of climate change on agriculture is still in its infancy. Policies on climate change and agriculture are not well integrated, and are slow to shift at national and international levels. Modelling the impacts of climate change on agriculture is improving, but significant uncertainties remain (Ranger, 2013; Met Office 2014). There is little robust evidence and empirical data from farm-level case studies on impacts and emissions. That said, evidence is currently emerging, the policy focus has sharpened among global and national leaders and, over the next five to10 years there will be progress in terms of research and action.

A number of international institutions are currently engaged in research and in developing policy, pilots and practices on climate change and agriculture in developing countries. Modelling the impacts of climate change on agriculture is improving, but significant uncertainties remain (Ranger, 2013; Met Office 2014). There is some evidence and empirical data from farm-level case studies on impacts and emissions, but much more to be done (Lipper et al. 2014).

Initiatives include:

- The International Fund for Agricultural Development's (IFAD's) 40-country programme 'Adaptation for smallholder agriculture' (ASAP). This involves implementing tried-and-trusted adaptation approaches, such as drought and flood risk management, new crop varieties, mixed crop-livestock systems, integrated water resources management, agroforestry and post-harvest storage. The programme also includes novel and technical approaches, such as climate models, community-based vulnerability analyses, empowerment mechanisms and evidence-based monitoring systems.

- FAO's 'Economic and policy innovations for CSA' (EPIC) programme, based in three countries, is developing CSA practices, analysing and mainstreaming policy, and developing CSA investment proposals.

- FAO's 'Mitigation of climate change in agriculture' (MICCA) programme is analysing global and farm level mitigation potentials and costs and building site specific evaluations and practices. Pilot projects are underway in Tanzania and Kenya.

- The CCAFS programme is researching long-term adaptation, climate risk management, low emissions agriculture, future scenarios, gender, sharing knowledge, and analysing data and policy. Work has included pioneering climate-smart villages, building adaptation strategies, improving insurance against crop failure, getting better meteorological data to smallholder farmers, empowering women to manage climate risks and providing climate data to agricultural development agencies.

- The World Bank supports and promotes CSA activities, including forest restoration, nitrogen fixing trees, evergreen agriculture and intensified rice growing.

- The Climate and Development Knowledge Network (CDKN) works directly with requests from the governments of developing countries to increase knowledge and practices on CSA and compiles research and case studies on climate smart agriculture.

- Global Environment Facility projects on mitigation and adaptation, particularly around land use change and forestry in mitigation and immediate and long term adaptation plans into action through National Adaptation Plans of Action.

Key messages

- Climate Smart Agriculture approaches address two or more elements of improving food security, adaptation and mitigation of climate change, with different context-specific priorities.

- CSA brings existing and new approaches to conservation agriculture, sustainable intensification and sustainable growth together with new technologies, science and policy mechanisms including seasonal forecasting, climate-linked advisories, and risk-based insurance. Recent nuances in CSA include landscape/village approaches and a focus on the wider food system beyond the farm gate 'from farm to fork'. There are many overlaps, but also some significant differences in approaches under the CSA banner, based on different underlying values and end goals.

- CSA's initial limitations included side-lining wider environmental issues and paying insufficient attention to identifying underlying political and institutional constraints for agriculture and vulnerability to climate change. These wider issues are now being drawn in as more central to CSA approaches and practices, though more needs to be done.

Further reading

The CCAFS website has a number of resources including videos, reports, papers and conference write-ups.

CDKN produced infographics and summaries from the IPCC's Fifth Assessment Report and a summary of lessons for agriculture from the chapter on agriculture in the IPCC's Special Report on Extreme Events.

World Bank. (2011*) Policy Brief: Opportunities and Challenges for Climate-smart Agriculture in Africa*, Washington, DC, USA: World Bank. Available at http://climatechange.worldbank.org/sites/default/files/documents/CSA_Policy_Brief_web.pdf

FAO Source Book on Climate Change and Agriculture (2013) is a 300+ page comprehensive report of separate modules, a reference tool discussing benefits and limitations of this approach to agriculture, forestry and fisheries at national and subnational levels.

FAO Success Stories on Climate Smart Agriculture (2013) are compiled from the Source book into readable, accessible format for the non-specialist.

Lipper, L. et al., (2014) *Climate-smart Agriculture for Food Security* is a brief four page introduction to the latest understandings on climate smart agriculture in the journal Nature Climate Change (not currently on open access journal).

SECTION 3

Climate-smart agriculture

3.1 Climate-smart agricultural practices

"Climate-Smart Agriculture is not a single specific agricultural technology or practice that can be universally applied. It is an approach that requires site-specific assessments to identify suitable agricultural production techniques and practices." (FAO, 2013).

Climate smart agriculture (CSA) to date has mostly addressed food availability and food production. Less attention has been paid to the other dimensions of food security (accessibility, use and stability) or the many opportunities for improvements in sustainability and efficiency in the food value chain (aggregation, processing and distribution) (FAO, 2013). IFAD's Adaptation for Smallholder Agriculture Programme is starting to work on these, amongst others.

CSA is a move away from the dominant focus in conventional agriculture on yields and productivity towards a holistic approach that links climate hazards and risk with ecological and economic sustainability and rural livelihoods. To ensure long-term sustainability and equity, particularly at the smallholder level, CSA practices combine simple, traditional techniques with innovative practices and technological advances. Many CSA practices are also 'low-regrets' measures, which are simple and low cost and can easily integrate climate issues into livelihood security, poverty and rural development goals (Conway and Schipper, 2011).

Table 4 indicates some of the most common traditional practices, innovative approaches and practices for CSA currently undertaken at the farm level, and the potential benefits.

Farm level Climate smart agricultural practices	Potential benefits
Traditional practices Mulching Intercropping Smarter use of chemicals and biological pest control Natural regeneration Crop rotation Integrated crop-livestock management systems Minimum soil disturbance (no till agriculture) Agroforestry and evergreen agriculture Improving grazing Improving water management Minimising the conversion of natural land to arable land, rehabilitating degraded land	Reduce greenhouse gas emissions Improve nitrogen cycles Improve hydrological cycles Improve soil carbon storage ***Improve livelihoods and provide economic benefits***
Innovative approaches and practices Conservation agriculture Climate-resilient crop varieties and hybrids Index-based weather insurance Early warning systems for extreme events Biotechnology Biochar (addition of charcoal to soil as soil improver and soil carbon storage) Crop and livestock breeding Carbon sequestration and carbon capture	Increase yields Better soil management Promote biodiversity increase Increase resilience Use of traditional knowledge and practice

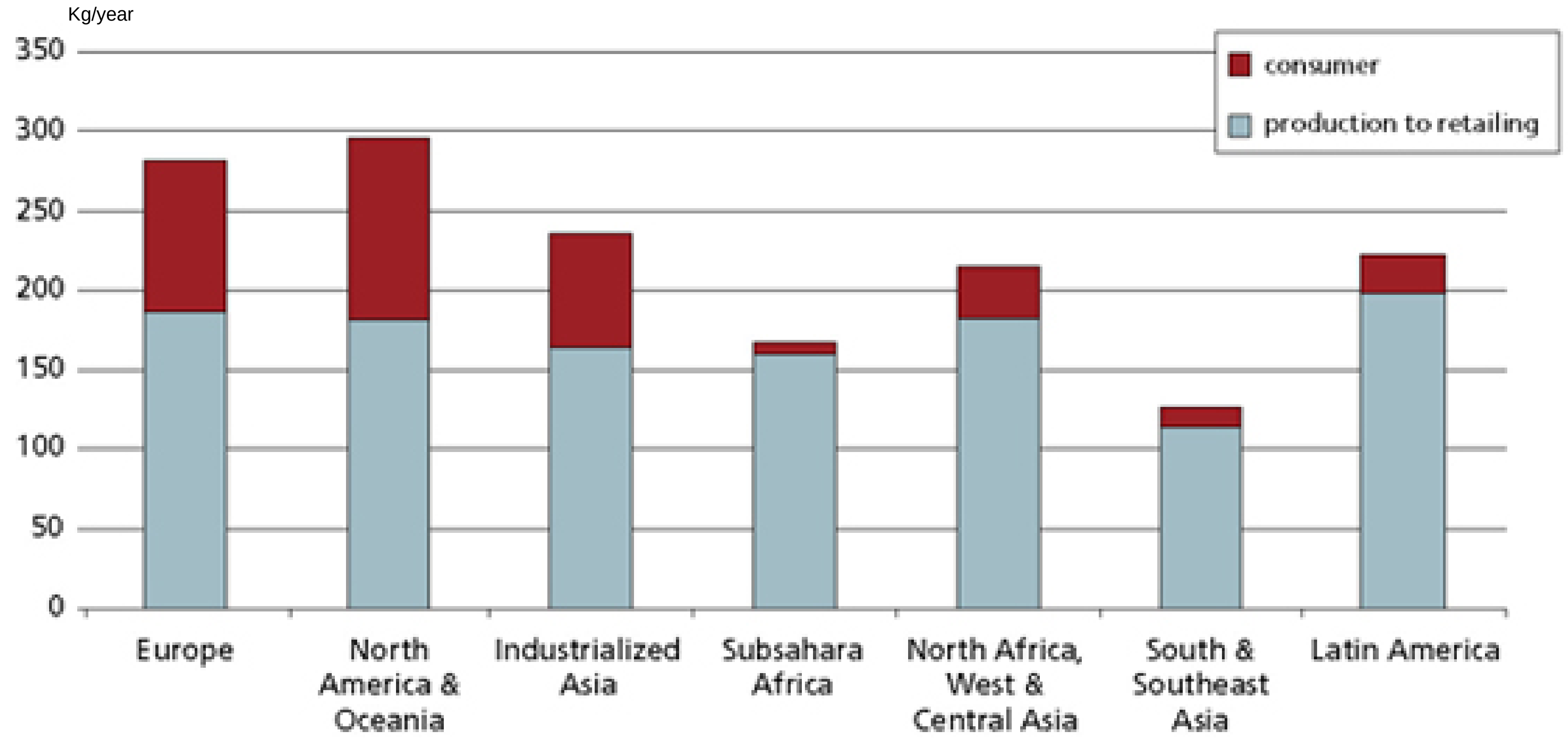
Sources: McCarthy et al., 2011; Derpsch and Friedrich, 2009; Verchot, 2007

Table 4 Climate smart agricultural practices – traditional and new

3.1.1 Food chains, supply and waste

Food chains link production, transport, conservation, processing, cooking and consumption. As global food losses and waste amount to 30% of all food produced (1.3 billion tonnes), reducing these is important for food security (FAO, 2013). The amount of food wasted by consumers in rich countries is nearly as much as the net food production of the whole of sub-Saharan Africa (FAO, 2013). In developing countries, food losses occur during production and post-harvest because of poor harvesting techniques, and limited storage and cooling facilities. In developed countries, food losses are mostly at the consumption stage. Measures to reduce food loss and waste in developed countries can involve making consumers aware, for example. Energy efficiency can be improved at all stages in the food chain (FAO, 2013). Preventing food waste at the consumption level reduces over-purchasing, labour and energy costs, and waste disposal costs (see Figure 9).

Figure 9 Per capita food losses and waste at consumption and pre-consumption stages by region



Source: FAO, 2014a. Available at http://www.fao.org/save-food/resources/keyfindings/en/

Many robust case studies are becoming available that demonstrate either climate-smart or climate resilient practices. These include on-farm practices, such as integrated crop-livestock systems (Case Study 1 case studies A to D), and wider food system practices.

Case Study 1 Case studies of climate-smart practices on-farm and in the wider food system

A. The globally important agricultural heritage systems initiative

The FAO provides a case study of an agroforestry system covering 120,000 ha on the southern slopes of Mount Kilimanjaro. The system is 800 years old and is one of the most sustainable examples of upland farming. The FAO have built on this existing system through the '*Globally important agricultural heritage systems'* initiative, which focuses on 660 households and seeks to enhance incomes and preserve ecological and social values. The steps FAO took included:

- Creating a source of cash income, such as by farming certified organic coffee.
- Rehabilitating irrigation systems to reduce water loss in dry seasons.
- Training in sustainable land management.

The outcomes are expected to increase farm incomes by 25% in just three years, to facilitate participation and decision making in the community, and to engage the government across sectors and scales (FAO, 2013).

B. 'Farmer-managed natural regeneration', CGIAR

Five million hectares of degraded, deforested land in the Sahel have been restored through 'farmer-managed natural regeneration', a process introduced by the 'Maradi Integrated Development Project' (MIDP). This project encourages farmers in the Maradi region of Niger to let tree stumps regenerate as part of a 'food for work' programme. Farmers who retained trees after the 'food for work' programme ended had the benefit of more firewood, fewer pests and diseases, less soil erosion, rising water tables, higher crop yields and better soil fertility. This good practice has now spread to Burkina Faso, Mali and Senegal. Over 200 million trees have been re-established.
The overall impacts include:

- Improved food security for 2.5 million people through increased fodder availability and an additional 500,000 tonne of grain production per annum.
- Economic returns of approximately USD 1,000 per year per household.
- Resilience to extreme weather events.
- Diversification of food, income and water resources (CGIAR, 2013).

C. Livestock system transitions

Havlik et al. (2014) estimate that livestock production, which currently accounts for 12% of anthropogenic greenhouse gas emissions, could be significantly improved through intensification of existing extensive pasture systems. This would reduce emissions by 736 million tonnes CO_2 equivalent/year, mainly by avoiding conversion of natural land to pasture. Intensification could increase incomes directly (and food security indirectly) through higher productivity. Whilst there are issues of potential increased land being turned to successfully intensified production systems, this approach demonstrates that policies that consider livestock, land use and climate can achieve efficient, triple win outcomes.

D. Three rivers sustainable grazing project

The 'Three rivers sustainable grazing' project in China's Qinghai province is positioning itself to tap carbon markets to support local livelihoods. Yak and sheep-herding households select a combination of sustainable management practices related to grazing intensity, grass cultivation and animal husbandry. The mitigation potential of the project is estimated at 63,000–66,000 tonne of CO_2 equivalent/year. The project will also restore degraded land, increase soil carbon, increase yields and build resilience in smallholder herder communities. To monitor the mitigation potential and allow access to carbon markets, FAO has developed carbon accounting methodologies under the verified carbon standard.

3.2 Trade-offs and localising CSA approaches

In running their farms and farming businesses, land users create positive co-benefits or calculated trade-offs between income, yield and environmental benefits or impacts. Many farmers choose short term yields and income from land over long term environmental sustainability and soil quality.

Trade-offs and impacts on resilience to climate change are complex to assess, and currently generalisations are made about the positive nature of CSA approaches that may prove not to be beneficial in the long term. For example, a typical 'resilience' based approach using CSA would be to encourage diversified cropping, with a range of food and fodder crops that could withstand heat, or drought, or flood, respectively, thus ensuring a farming family a secure food source in the event of a natural disaster. However, for some farmers who have non-farm livelihood options or access to crop insurance, it may be that a higher risk initial 'quick win' on a monocrop may prove a quicker or more effective way out of poverty. A deep understanding of local context is essential.

At the farm level, many CSA practices are promoted that are well known to proponents of sustainable agriculture. Uptake has been limited of these practices in general. But several factors have been shown to improve interest and adoption of new practices: short time frames for action to positive impact; localised specific benefit clear to the individual farmer or farming household; low risk/initial investment involved, or clearly reduced exposure to existing risk, through the changed practice. For example, some conservation agriculture practices that reduce local water insecurity may have rapid positive impact, but others, such as improvements to soil fertility through nitrogen fixing plants, may take years to be fully realised, and therefore be less well adopted . (Giller et al., 2009; McCarthy et al 2011).

Measures to minimise these trade-offs, provide incentives for smallholders to adopt CSA and to increase the role of CSA in international and national climate policy could include:

- Understanding the livelihood context, direction and focus of the economy, markets, interests and mobility of the rural population, especially youth, and the role of the farmstead and farming within that context.
- Working at the landscape level, creating synergies between land, agriculture, forests, water, fisheries and livestock.
- Investing in human and social capital in order to sustain natural capital and enhance adaptive capacity.
- Shaping CSA approaches in the country context and taking into account interactions between stakeholders, so as to help achieve multiple objectives and make decisions on trade-offs.
- Improving land tenure security.
- Establishing public and private financial support.
- Creating learning hubs and platforms for collaboration for further innovation and adaptation.
- Scaling up practices that already exist, but are tailored to specific contexts. This will require research into local trade-offs, contexts and the links between different actors and knowledge.

3.3 Vulnerable environments: Semi-arid and rainfed lands

DFID's CARIAA programme recently identified a number of hotspot areas vulnerable to climate change in Africa and Asia, including delta zones, glacial river basins and dryland areas[9]. Dryland and semi-arid areas in Africa whether farmed as rainfed agriculture or used for pastoral livelihoods, are especially vulnerable. Rising temperatures, increased drought periods and lower overall rainfall is causing significant impact on both of these farming systems in Africa and other regions of the world (Hesse and Cotula 2006). Pastoralists suffer from inadequate number and poor distribution of watering points for cattle, exclusion from decision making processes, constraints on mobility due to government policy and/or farmers' encroachment on livestock corridors. Droughts affect the nutritional quality of rangeland grasses, livestock quality and susceptible to disease. As a result conflicts can be expected to increase, environments can rapidly degrade and livestock productivity is lowered. Drought mitigation systems, government policy sensitisation and institutional conflict resolution are essential in these environments.

Smallholders face similar issues with declining yields from degraded farmland exacerbated by climate change – in the Sahel what has now become long term, chronic food insecurity is now worsened by climate change for both pastoral and smallholder communities (Gubbels, 2011). Small perturbations can causes crisis in these settings of fragile states with weak institutions.

Resilience building to climate change in these environments needs to focus on a suite of activities and wider diversification efforts. Within agriculture these actions should include:

- Robust technological innovations promoting agro ecological sustainable intensification, such as dissemination of appropriate soil and water conservation practices, rainwater harvesting, natural forest regeneration processes (such as that in Case Study 1 B Farmer Managed Natural Regeneration), and in pastoralist communities a focus on animal health, productivity and marketing.
- Soft information-related innovation including appropriate early warning and forecasting systems, aimed at reducing disaster risk and improving disaster preparedness.
- Innovations such as appropriate credit, insurance and social protection packages.
- Sustained government investment to promote access to markets and services.
- Access to basic services for the most marginalised. Access is a politicised issue in conflict and post conflict zones, such as South Sudan.

3.4 Gender in CSA

> *"Climate-smart agriculture is smarter when it is able to help meet food security, adapt to and mitigate climate change, and promote equality between men and women in a changing climate." (El-Fattal, 2012)*

Gender inequalities account for significant differences in income, wellbeing and standards of living worldwide and, in particular, in rural communities where women make up most of the rural poor[10]. The 2011 DFID Strategic Vision for Girls and Women focussed on helping girls and women to improve their opportunities and give them more control over their lives: voice, choice and control by addressing underlying structural issues.[11].

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9 See Collaborative Adaptation Research Initiative in Africa and Asia (here) for more detail.

10 A new Topic Guide on Women's empowerment in a changing agricultural and rural context, published in February 2015, explores this in greater depth.

11 See DFID's Strategic Vision For Women and Girls 2011, policy commitments and subsequent revisions on https://www.gov.uk/government/policies/improving-the-lives-of-girls-and-women-in-the-worlds-poorest-countries/

Early research addressed gendered vulnerability to climate change and disaster risk. Recent research on how men and women respond to climate change identifies issues for the development community to address (FAO, 2013):

- Women's and men's perceptions of climate change and weather are different.
- Women suffer greater loss of assets and nutritional impacts during and after a disaster.
- Men tend to have greater access to natural resources, extension services and credit for adapting to climate change.
- Broadly, women in rural areas experience the effects of climate change more acutely than men as a consequence of gender inequalities and structural disadvantages.
- Women perceive access to certain rural resources differently from men – e.g. they prioritise drinking water for their families over drinking water for the family's livestock.
- Women are particularly sensitive to changes in food security and food use as they are primarily responsible for feeding the family.
- In conflict situations (potentially exacerbated by climate change), women are much more vulnerable than men to gender-based violence and mistreatment.

Gender is the most obvious difference between people in a community. The relative powerlessness of women has, for the last 20 years, led to the creation of projects and programmes to help women generate assets and become empowered. However, as the Topic Guide *Women's empowerment in a changing agricultural and rural context* demonstrates, there are nuances of power: older, established married women in communities may have significant social status and some women take on leadership roles by virtue of their family background, education, wealth, personal effort or intelligence.

Other factors besides gender, like age, disability, ethnic group, education and health, also influence access to and control of resources. These other factors are even less well understood than gender in tailoring development solutions.

Technology is not gender-neutral. New technologies developed to help deal with the effects of climate change, or to help reduce emissions from agriculture, can marginalise women, the poor and vulnerable further. CSA requires 'better' ways of farming (scaling up traditional practices and innovations), but these require changes in behaviour, traditions, access to resources and investment. In general, gender issues are not an important consideration when developing agricultural policy and practice, and climate-smart approaches. A study by Beuchelt and Badstue (2013) examined the consequences of introducing conservation agriculture in Mexico and Zambia. They found that CSA approaches and impacts were contrary to women's needs and abilities in that:

- They increase the number of routine tasks in the household.
- Women do not want to cover and protect soils by leaving crop residues in place (conservation agriculture) because they use residues for fuel and roofing houses.
- People need assets to invest in conservation agriculture (women have far less access to these).
- Farmers need to mechanise and improve their farming practices to increase nutrition and food security in households, which is something women are less able to do.

Elsewhere in mitigation projects, such as projects for sequestering and offsetting carbon, women have less access to carbon markets than men.

3.4.1 Mainstreaming gender in climate-smart approaches

A number of initiatives addressing gender and climate change have been developed. But there is little robust data currently available. Agricultural programmes as a whole are inadequate in approaching the difficult political issues involved in tackling gender, despite evidence that demonstrates how important gender issues are for food security. It is not easy. The cultural aspects of gender directly and indirectly influence a range of mechanisms for coping with the impacts of climate change – women are less able to swim in cases of flooding, less confident in participating in manual labour for food (e.g. road building food for work initiatives) and less mobile, so migrate less in search of work (Nelson et al., 2002). Meaningfully tackling the issue of gender in agriculture is no less problematic. Tackling gender can be approached by improving women's rights and supporting their empowerment, access to assets and physical wellbeing.

Gender-sensitive projects under way currently either prioritise women specifically, or include gender-sensitivity as part of their approach. A gender focus in CSA approaches covers four main areas:

- **Absorbing the impacts of climate change**. For example, gender differentiation in disaster risk reduction activities such as training on climate change or providing access to early warning systems, or setting up grain banks owned and managed by women to help the community's poorest in seasons when food is scarce.
- **Training in adaptation to climate change**. For example, establishing women's village saving and loan schemes, and gender-differentiated extension services tailored to women and the poorer sections of the community.
- **Responding transformatively to climate change.** For example, reforming land rights, empowering women through education, capacity building and political influence.
- **Mitigation activities and related finance.** Mitigation actions related to the carbon market impose "special burdens on poor women and others marginalised by global market infrastructure and networks" (Edmunds et al 2013). Science driving mitigation analysis is often gender blind in dissemination, and works within existing patriarchal institutions, making it more difficult for women to be involved. Special measures need to be introduced to overcome these issues.

3.4.2 Understanding and adapting to climate change and enhancing women's participation in CSA

Approaches to providing women with access to information

Women's access to information is related to cultural norms that influence decision making and education. Women need gender-specific information flows to access information on climate change and incorporate it into daily life (IFAD 2014).

- In Nepal, the leaders of women's cooperatives use folk songs, dance and radio, alongside training manuals in local languages to train women to train other women. Tapping into existing knowledge, social and trust networks, extends CSA practices much further (CCAFS, 2013).
- Financing women who produce shea butter[12] helps prevent shea trees from being cleared for farming or firewood, thus maintaining soils, absorbing carbon emissions and providing shade (Root Capital, 2012).

[12] Shea butter a fat extracted from the nut of the African shea tree (Vitellaria paradoxa).

Access to carbon markets integrating gender issues
The 'flexible learning approach', part of the Sustainable Agriculture in Changing Climate (SACC) project, is designed to give smallholders greater access to carbon markets[13]. The primary focus is agroforestry, income generation, and carbon storage. However, the project recognises the need for women to participate and build their capacity. To do this, SACC establishes village savings and loans schemes, and provides drought resistant, early maturing crops. The new crops diversify direct income sources for the household, rather than relying simply on the potential of carbon markets for income. In addition, saving and loan schemes focussed on women encourage more equitable participation in financial decision making for the family.

Gendered transformative approaches to climate change: strengthening women's land rights[14]
Women's ownership of land and power to make decisions on managing assets in farming households is limited (Rakib and Matz, 2014). Land use and land tenure are generally not seen as important for effective climate change adaptation and mitigation. But inequitable land rights are a significant barrier to long-term investment in land. Without ownership of land, women cannot benefit from carbon markets, or credit and financial incentives for changing land practices. The requirements for measuring and reporting can actively discourage women (Brody et al., 2008). Without ownership of land, women have less incentive to adopt CSA practices in crop rotation, planting or the use of household products, which might provide benefits in the long term but reduce yields in the short term. Several projects, such as the '*Women and land rights'* projects in some southern African countries, deal with this issue. In South Africa, post-apartheid land reforms, such as the settlement/land acquisition grant, now allow women farmers to establish their rights and live on and cultivate their own land.

Wider issues for gender and CSA
There has been little analysis of gender issues in the agricultural value chain beyond the farm level in relation to climate smart approaches. Approaches designed to improve gender equity and introduce climate smart initiatives are often completely distinct in current development initiatives. Closer research and analysis could produce approaches that are well tailored for positive impacts and opportunities to both.

We need to know more about:

- How access to technologies for farming and food processing is differentiated between men and women.
- Gendered impacts of the current increases in 'vertical integration' in the global agricultural value chains (this is ownership of several stages in process of food production to processing and finished product).
- How agro-processing industries are gendered, and impacts of how climate smart practices and crops might alter these.
- Gendered access to markets and access to public and private financial services; and how climate smart approaches might influence these.

A number of training manuals and capacity building activities are being designed on gender in in climate smart agriculture that will be useful to those planning to integrate gender equity and social exclusion (GESI) into climate adaptation and CSA programmes. See here for a

[13] See Section 3.7 Financing CSA for broader discussion on carbon markets and financing climate change
[14] See the Evidence on Demand Topic Guide *Land* for more information on gender impacts of land reform and the Evidence on Demand Topic Guide *Women's empowerment in a changing rural and agricultural context*.

good introductory e-learning module on gender, climate change and agriculture from the Gender in Agriculture Sourcebook here:

3.5 Nutrition and climate change

3.5.1 Climate impacts on global nutrition

The UK Met Office and WFP (2013) reviewed the evidence on the impact of climate change on nutrition[15] and concluded that climate change will exacerbates the risks of hunger and undernutrition through two main mechanisms:

- **Extreme weather events** - Under climate change, the frequency and intensity of some extreme events such as droughts, floods and storms could increase, with an adverse impact on livelihoods and food security. Climate-related extreme events have the potential to destroy crops, critical infrastructure, and key community assets, therefore directly destroying food available, limiting access to food, weakening livelihoods and exacerbating poverty.

- **Long-term and gradual climate risks.** In order to reduce the numbers of hungry and undernourished while feeding the world in 2050 action is needed now, and it needs to start where the hungry people are. It is important that for some countries, in good locations for engagement into manufacturing exports, or resource-rich economies, agriculture is not the crucial constraint to growth.

The long term impacts of a changed climate (higher temperatures, changes in total precipitation and rainfall patterns) are likely to reduce crop yields unless adaptation measures are implemented (Lobell et al. 2011). This will lead to loss of incomes and a worsening of food security and increase in hunger and malnutrition.

The International Food Policy Research Institute (IFPRI) has investigated the costs of investing in agriculture to reduce the impact on malnutrition in children. They estimate that about $7.3 billion will need to be invested in agricultural public goods to avoid an extra 25 million children being malnourished by 2050 due to the impact of climate change. Within that, needs in Sub-Saharan Africa make up about 40% of the total (Nelson et al. 2009). Evidence from regions affected by climate extremes clearly demonstrates their impacts on nutrition and long term resilience. Studies from the Gambia reveal that women who are pregnant during a hunger gap give birth to smaller babies (Rayco-Solon et al. 2002). Longitudinal studies from Malawi have shown a seasonal variation, linked to the annual hunger season, in height gain among young children (Maleta et al 2003). In Ethiopia and Niger, children born during a drought are more likely to be chronically malnourished later in childhood than those who are not (Fuentes and Seck 2007). The prevalence of chronic undernutrition has been found to increase among Bangladeshi children following flooding (Del Ninno et al. 2003). In fact, it has been estimated that more than 20% of adult height variation in developing countries (the physical sign of having experienced chronic undernutrition in childhood) is determined by environmental factors, in particular drought (Silventionen, 2003).

Ensuring that development and adaptation investments support improvements in the nutritional status of communities will help to build their resilience. However, these investments might not go far enough to protect nutrition outcomes when shocks arise. It is

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15 Nutritional status includes not only the amounts of calorie intake available for a population but also the quality of nutrition in the food in terms of macronutrients (carbs, fats, protein, water) and vitamins and minerals needed for good overall human growth and function.

already recognised that nutrition-sensitive interventions that are crucial for ensuring optimal nutrition outcomes are not sufficiently disaster proofed to maintain effectiveness in the face of crisis[16].

A study of disaster resilience in the Sahel noted that "*there is no better single indicator of resilience…than the level of child malnutrition"*. The report went on to propose that "'nutrition security' be placed at the apex of the pathways to resilience" (Gubbels 2011). People who are well-nourished and who have been well-nourished from birth are less sick less often, achieve more at school and go on to earn more during adulthood. Meanwhile, chronically undernourished children are disadvantaged throughout life and are more likely to have children of their own who are trapped in a cycle of poverty and undernutrition (Black et al 2008). Research shows that children who periodically become acutely underweight during the first 2 to 3 years of life grow less well than children who do not (Richard et al 2012). Deficiencies of nutrients such as zinc, iron and iodine have significant implications for growth and cognitive development(Black et al 2008).

3.5.2 Nutrition sensitive agriculture

Nutrition sensitive agriculture is agriculture which is deliberately focused on improving nutrition outcomes. There are multiple pathways through which agriculture can improve nutrition. Agriculture can improve nutrition directly as a source of food, for example when farming households increase the production of nutritious foods, or more indirectly when household purchasing power increases through lower food prices or increased income resulting from greater agricultural productivity. Either route ultimately requires increased consumption of nutritious foods by those at greatest risk of undernutrition. These foods are either:

- **Staple foods.** Agricultural production of staple foods can increase nutrition when more nutritious varieties are used (such as biofortified crops), nutritionally enhanced fertilisers are used, toxins in crops are reduced by better production and storage techniques, or when programmes are designed to maximise the benefits for women (whether by reducing their labour demands or increasing their income).
- **Non-staple foods.** Non-staple foods provide the main source of nutritional quality in the diet thereby helping to meet the body's requirements of essential protein, fat and micronutrients. Increased availability of and access to pulses, animal source foods and fruit and vegetables can also contribute to improved nutrition.

DFID's (2014) Evidence Paper '*Can agriculture interventions promote nutrition?'* sets out the latest knowledge. This found robust evidence of a positive impact of biofortified crops on child micronutrient status, and more limited and mixed evidence of impact of home gardening, aquaculture, livestock production and cash crops.

3.5.3 Linking nutrition sensitive agriculture and climate smart agriculture

While nutrition sensitive agriculture and climate smart agriculture have different goals there outcomes do overlap and taking action together has the potential to deliver on nutrition and climate goals. To date there is limited evidence on how this is changing including within DFID and other development agencies. It is also expected the Global Panel on Agriculture and Food Systems for Nutrition will consider work in this area.

16 One example is the Ethiopian Productive Safety Net Programme which now incorporates a risk financing mechanism to provide additional support during bad years.

3.6 Achieving climate resilience in agriculture: context specificity is critical to scaling up

Good examples of CSA are emerging from pilot studies and some are starting to scale out and be taken up more widely. As the examples below show, approaches that are 'climate smart' in landscapes and farming practices range from the broadest strategies of 'traditional' approaches to land regeneration, such as in Niger and Ethiopia under two very differently managed schemes, to sustainable (gender aware) intensification of farm plots with rice, and specific microdosing of fertiliser applications, to a wide uptake of climate information and related insurance services, and improved knowledge of climate events prior to them happening. There are still many obstacles that hinder the uptake of CSA approaches, including the need for context specific solutions financing, awareness raising, proof of improved livelihood/yield for the farmer population and the length of time taken for benefits to become clear. However, **the cases below demonstrate that, where these factors are incorporated into the design of the approach, demand and uptake will be high**.

Case Study 2 Good examples of CSA emerging from pilots to scale

A. Landscape approaches to CSA - Integrated food-energy systems of Farmer Managed Natural Regeneration

Integrated approaches to farm management include growing fuel wood on-farm, evergreen agriculture and developing bioenergy alternatives to fuel wood. One of the most effective examples to date is from the Sahel.

The practice of Farmer Managed Natural Regeneration (FMNR) in the West African Sahel has restored more than 5 million hectares of degraded land and improved the food security of around 2.5 million people. FMNR involves farmers allowing the roots of trees still present in their fields to regenerate and then managing these trees to provide timber, fuelwood, fodder, fruits and nuts. The trees help to stabilise the soil and reduce erosion, while at the same time sequestering carbon to help mitigate climate change.

Studies by the World Agroforestry Centre show that FMNR has more than tripled yields of millet in Niger. Expansion of the practice across the Sahel has seen 200 million trees re-established or planted, resulting in an additional half a million tonnes of grain every year and enough fodder to support many more livestock (World Agroforestry Centre 2013) http://www.worldagroforestry.org/newsroom/highlights/climate-smart-agriculture-making-difference

B. Managing environmental resources to enable transitions (MERET) to more sustainable livelihoods, Ethiopia

The MERET programme increases incomes and community resilience to climate change by:

- Supplying 3 kg of cereal per workday to each participant.
- Providing equipment and technical guidance for sustainable agriculture projects (e.g. tree planting, terracing and rainwater harvesting).
- Supporting income generation activities (e.g. beekeeping and livestock production).
- Emphasising appropriate technology and community ownership.

Since 2003, this project has expanded to rehabilitate more than 300,000 ha of land. Environmental services and the natural resource base have improved, livelihoods and agricultural/food products are now more diversified and food security has increased 50% in participating communities. For more information see: http://documents.wfp.org/stellent/groups/public/documents/newsroom/wfp225961.pdf

C. Sustainable rice intensification with gender aspects in Vietnam, CGIAR
The project has scaled up effectively, helping over 1 million smallholder farmers increase rice yields, reduce water demand and mitigate climate change. CSA practices include alternately wetting and drying the soil during grain filling. This prevents the build-up of methane-producing anaerobic bacteria and allows application of organic (rather than inorganic) fertiliser. Methane emissions have dropped by 20–62%, water demand has fallen by 33%, yields have increased by 9–15% and farmers use 20–25% less nitrogen fertiliser. The incomes of smallholder farmers reportedly have risen by USD 95–260 per ha each season. The project encourages adoption through extension services, such as farmers' field schools and farmer-to-farmer training across 185,000 ha. Perhaps most important is the proportion of women involved; 70% percent of the farmers are women. By sharing what they have learned, each woman has helped, on average, five to eight other farmers, compared to one to three for men. However, it is important to note that there are trade-offs, especially if farmers do not manage fertiliser use carefully. For more information see: https://cgspace.cgiar.org/bitstream/handle/10568/34042/Climate_smart_farming_successes WEB.pdf

D. Urea deep placement (UDP) in climate smart rice systems, Bangladesh
The technology for urea deep placement (UDP) in rice systems has been developed and disseminated by the International Rice Research Institute and the International Fertilizer Development Center. Urea is a nitrogen fertiliser. Farmers generally apply urea inefficiently, losing up to 70% at each application. The UDP technology involves burying small 'briquettes' of urea in the soil after the paddy rice is transplanted. The UDP method requires an additional 6–8 days labour per hectare to place the briquettes manually. However, proponents claim this creates rural jobs and improves incomes, the labour cost being compensated by higher yields (of about 25%), and lower input costs (about 25% less urea is needed). Jobs have also been created locally in small enterprises, often owned by women, for briquette-making. At the local level, the rural economy is stimulated, and positive impacts saving to the economy at national level are significant: approximately USD 22 million in reduced import costs and USD 14 million in reduced government subsidies. At the same time, carbon emissions per unit of production are lowered through UDP (FAO, 2013: Box 1.1 http://www.fao.org/docrep/018/i3325e/i3325e.pdf)

E. Fertiliser microdosing
Microdosing is a conservation agriculture practice whereby farmers apply fertiliser at one-third of the usual rate but very specifically to each plant at certain times in the growing season when most needed. Small amounts of fertiliser have increased yield of sorghum and millet by 50–120%. http://www.icrisat.org/impacts/impact-stories/icrisat-is-fertilizer-microdosing.pdf

F. Climate services working with smallholder farmers
Rainfed agriculture is risky because it depends on the weather. Weather-based insurance allows farmers to pay a small premium and receive a pay-out if their crops are damaged by adverse weather. The ability to insure against bad weather makes farmers more resilient. To date, most weather index insurance schemes have insured farmers in developing countries against the risk of drought (more complex mechanisms in developed countries provide multi-risk insurance for commercial crops).

In Senegal, mobile phones and radios give weather forecast and market price information to smallholders. Climate information helps raise confidence in investors about harvests, helps farmers use seeds better, protect crops from extreme events and assists farmers with knowing when to sell or store crops. Related to this, climate information enables development of services such as climate-related 'index' insurance against extreme events that may damage a farmer's crops. In India, national index insurance programmes have reached over 30 million farmers, and in East Africa have scaled to reach 200,000 farmers.

Ethiopia and Senegal initiative is 20,000 farmers, and in Mongolia this has reached 15,000 nomadic herders. This increases farmers' resilience. Projects have been state-subsidised, farmer-led, and represent public-private partnership in development. For more see: https://cgspace.cgiar.org/bitstream/handle/10568/53101/CCAFS_Report14.pdf?sequence=1

The Horn of Africa Risk Transfer for Adaptation (HARITA) project strengthens food and income security among smallholder farmers by reducing risk, and providing drought insurance, credit and savings schemes. Since inception the project has reached up to 19,000 households. Promising though this scheme is, insurance is best targeted to emergent ('stepping up') and commercial ('stepping out') farmers, rather than to the most marginalised farmers who find it hard to afford premiums and are financially illiterate (RRI 2013).

3.7 Financing CSA

Investment in agriculture climate change projects covers a broad range of activities including energy production from biomass, agroforestry, emissions reduction from fertiliser production, and improvements in food security.

The financing currently available to address climate change and food security challenges in the agricultural sector is insufficient. The IPCC's Fifth Assessment (2014) report places more emphasis on adaptation than previous reports as mitigation efforts have not been successful. The IPCC (2014a) reports that recent estimates of the cost of global adaptation suggest that between USD 70 billion and USD 100 billion per year will be needed globally by 2050.

Private domestic investors account for most investment in agriculture in developing countries. Remittances from abroad, contributions from international donors and the public sector in developing countries account for the rest (FAO 2010) The agriculture sector has experienced a decline in funding in recent decades despite the increasing urgency to establish food security. In developing countries public sector spending on agriculture is low, at 4% of gross domestic product (GDP), compared to the 29% of GDP generated by the sector, and considering that agriculture involves 65% of the labour force (FAO 2010). Most of the spending on agriculture is for subsidies or credits to farmers that provide short-term food security. However, some spending, such as on fertiliser subsidies, does not consider the long-term environmental implications. The FAO has estimated that the annual cumulative gross investment needed for agriculture to 2050 in developing countries to meet the food security needs of the growing global population are about USD 210 billion (FAO, 2009 cited in The Hague paper).

As climate variability and climate change will affect farm yields both the in short and long term, more investment is needed to ensure food security. In 2010, FAO estimated a financing gap in adaptation of USD 2.5–2.6 billion per year for the period 2010–2050, and by 2030 an additional investment of USD12–14 billion per year will be needed in developing countries for mitigation. This might be provided by the public or private sectors, or a combination of the two.

Recent analysis of funding for CSA (Shames et al 2012) found that:

- International public funding sources are uncertain.
- Climate finance is fragmented.
- Private agriculture investments are the main drivers of land use decisions.
- Public funding supporting climate action and public funding supporting agriculture remain largely separate.

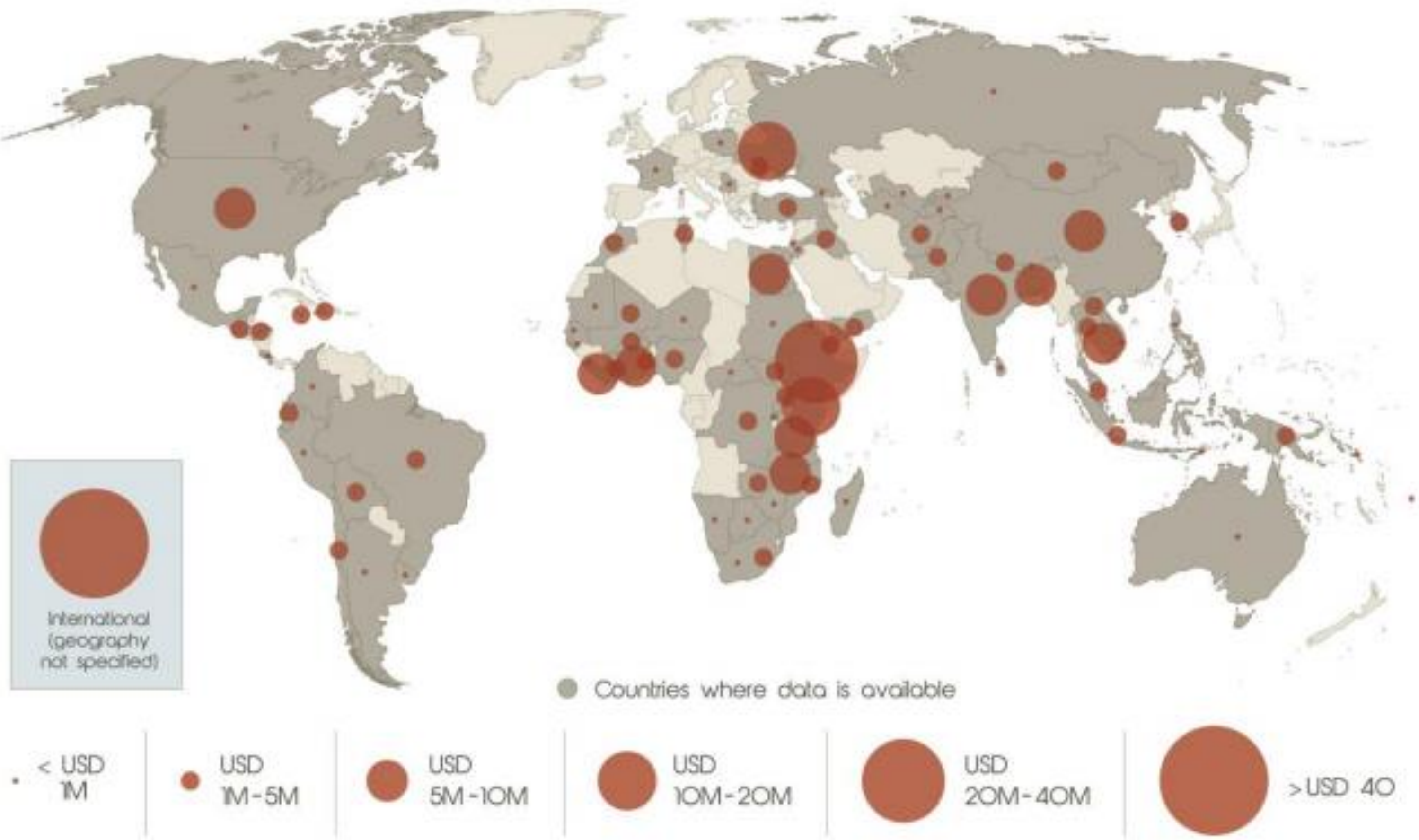
The latest figures, meticulously pieced together on the climate finance in public and private sectors, show two important things. Firstly, current investment levels are very low overall. Secondly, high volatility in focus of the investment reinforces ongoing uncertainties around investments in climate change and agriculture. In 2010-12, public funds for adaptation increased from USD 155-314m with the fast-start climate finance, whilst private funds for mitigation decreased from USD 289m to 48m due to declining carbon prices (Hoogzaad et al. 2014) (see Table 5). Funding has refocused from Asia more towards Africa in recent years (see Figure 10).

	Mitigation				Adaptation			
Financing Source	**2010**	**2011**	**2012**	**Total**	**2010**	**2011**	**2012**	**Total**
Bilateral funds & Fast Start Finance	31	38	20	**88**	155	143	314	**613**
CDM & JI	298	264	36	**598**				
Voluntary Carbon Markets	10	25	12	**47**				
	338	***326***	***68***	*733*				

Source: Hoogzaad et al. 2014

Table 5 Agriculture climate finance sources in 2010, 2011 and 2012 (USD Million)

Figure 10 Countries receiving agriculture climate finance in 2012 (Hoogzaad et al 2014)



3.7.1 Public investment

Investment in agriculture climate change projects covers a broad range of activities including energy production from biomass, agroforestry, emissions reduction from fertiliser production, and improvements in food security.

Agriculture climate finance from public sources is limited, and has experienced significant changes over the last few years. From years of semi-stagnation where funding through the UNFCCC's Clean Development Mechanism excluded agriculture due to uncertainties over measurements, recent years have seen an increase in fast-start climate finance pledged towards agriculture (see Table 5). Fast start finance was pledged at the UNFCCC COP15 in 2009, valued around USD 30billion. Of this, just 2% (USD 0.75bn) has been pledged to climate finance for agriculture (compare this to USD 6.4bn in 2011 of Official Development Assistance for agriculture). Decline in the carbon markets decreased availability of climate finances for the sector, and shifted the focus towards adaptation. Under the Adaptation Fund, little funding has become available downstream for the agriculture plans that are part of National Adaptation Plans of Action. However, funding is becoming more available. Although access to funds can be a little complex still, the Global Environment Facility supports climate change initiatives, and historically focussed towards mitigation and energy supply and forestry but also supports climate change adaptation in developing countries through the Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (CSSF) The GEF expects to program up to US$ 1.4bn on resilience, adaptation and disaster risk reduction (GEF 2015). In the next four years the GEF will be providing US$110m to improve food security, strengthen resilience and enhance carbon sequestration in sub-Saharan Africa, and will provide US$430m towards reducing land degradation. A new strategy for the Adaptation Fund, LDCF and SCCF highlights agriculture and food security, and water resources management, as two of ten key vulnerable sectors to receive a share of the US$1.18bn to be allocated (GEF 2014)

In addition, some countries are setting up national funds to address the deficit in climate funding for agriculture, such as the Amazon Fund in Brazil and the Climate Change Trust Fund in Indonesia. Recently, 14 African countries have developed national agriculture and food security investment plans in order to identify and access funds for adapting to and mitigating climate change. These plans are a first step. Cost-benefit and profitability analyses of climate-smart activities, and clear monitoring and accounting procedures will assist policy makers in making investment decisions (FAO, 2012).

3.7.2 Private investment

Currently, most investment in agriculture is made by farmers themselves. The voluntary carbon market is small, and has crashed since carbon prices declined in the last two years (Hoogzaad et al 2014). Farmers favour low risk, high return investments. In the relatively high risk, rainfed farming sector, there is little incentive for the farmers to invest in their farms. The challenges in the smallholder sector mean that private lenders are reluctant to provide loans (Sahin et al., 2014). These challenges include land tenure, high transaction costs, poor information flows, fluctuations in prices for agricultural produce and poor infrastructure in many rural areas. However, one area where private investment has been successful with innovative financing is in weather index insurance as outlined earlier in Case Study 2.

3.7.3 Combination of public and private funding

A recent analysis of climate-smart funding for agriculture and forestry suggests that public sector finance is needed to bridge the funding gaps and attract private investment in sustainable agriculture (Shames et al. 2012). This is because the poorest are often cash constrained and have few resources to invest in climate risk-reduction. To encourage combined public and private sector investment, clear roles, demonstrable due diligence and integration of climate finance with other overseas development assistance finance are needed (CCAFS, 2013).

FAO considers that combining funding for climate change and food security from public and private sources will help boost the funds available for CSA. Public-private partnerships are one way forward. Another is carbon financing to support environmental projects. There is some evidence that voluntary carbon finance schemes working with public sector organisations have had a positive impact on mitigation and sustainable livelihoods. But carbon offset markets have high transaction and coordination costs and widespread uptake is unlikely given the resources available.

There are gaps in the pre-requisites for climate financing: robust metrics for adaptation and adaptive capacity, measurement, reporting and verification of carbon stocks in landscapes and adaptation insurance mechanisms. These are being addressed through institutional research funded by CCAFS, IFAD and FAO.

Further work on public and private investment into climate smart agriculture is planned under the new Alliance on Climate Smart Agriculture.

Key messages

- Farmers assess short and long term benefits and trade-offs of CSA's new techniques on farm, and evidence suggests that spontaneous uptake is frequently limited unless any, or most, significant short-term disadvantages are overcome.
- Incorporating an understanding of gender issues into climate smart agriculture is essential given the different farm tasks, knowledge bases, access to decisions and social structures existing between men and women. This provides both a challenge and opportunity for supporting further gender-based equity, capacity building and empowerment initiatives.
- Scaling up successful pilot projects provides opportunities and challenges. Frequently, however, project success cannot be upscaled due to lack of development infrastructure like access to market, access to banks and credit, education and extension and access to inputs and seedbanks.
- Disaggregating smallholders by their ability to scale up and step out is important; some smallholders are able to expand production and take out risk-based insurance while others are limited to subsistence farming and would be better served by social protection schemes.
- Nutritional impacts of climate change are linked to food security, but are more nuanced as they focus on the quality of macro and micronutrients and impacts on human growth and function. Biofortification of crops and nutrition-sensitive agriculture, if linked with climate vulnerability analysis, may provide an important boost to the food security of many people worldwide.
- The focus of CSA to date has been primarily on food availability and food production, neglecting other parts of the food chain (such as reducing food waste at the farm gate and 'farm to fork', which account for 30% food loss), and other aspects of food security such as the more political side of nutrition issues around access to food
- Public finance on climate and agriculture initiatives from international multilateral and national sources has been poor to date –The International Climate Fund and the Global Environment Facility's two funds are examples of major funds that have been used to develop significant programmes. Lack of easy access to public sector finance means adoption of longer-term climate-positive initiatives is poor.
- Private finance has traditionally been through personal investment and family investment into smallholder agriculture, or through commercial large scale investment in farms. Climate sensitive approaches might introduce finance and credit to insure against climate risk.

Further reading

Gender and agriculture

On-line e-learning module on Gender, Agriculture and Climate Change from WB and IFPRI, with overview, key issues, M&E, guidelines and recommendations for planners and innovative activities – Module 17 - hosted by the Gender in Agriculture website here: http://www.genderinag.org/sites/genderinag.org/files/E-Learning_Course/module%2017/story.html

Women's Empowerment in a Changing Agricultural and Rural Context is an overview of literature and experiences produced by this series as a Topic Guide in 2015.

CCAFS theme on Gender and Equity http://ccafs.cgiar.org/gender, including A gender strategy for pro-poor climate change mitigation 2013

Platform for gender and climate change: Gender CC – Women for Climate Justice is a network for issues on gender and climate change, with a detailed database of recent publications, tools and case studieshttp://www.gendercc.net/metanavigation/home.html
UN's website Women Watch on Women, Gender Equality and Climate change, with a detailed list of relevant UN publications

FAO and CGIAR. (2013) Rome, Italy: FAO. This defines gender in agriculture, food security and outlines climate change impacts for non-specialists, and provides a set of field research tools to investigate gendered approaches to farming and risk management

United Nations Development Programme (UNDP). (2012) *Gender, Agriculture and Food Security*. Gender and climate change capacity development series, Africa. Training Module 4. New York, NY, USA: UNDP.

Finance

Shames, S., Friedman, R. and Havemann, T. (2012) Coordinating Finance for Climate Smart Agriculture, EcoAgriculture Discussion Paper No. 9. Washington, DC, USA: EcoAgriculture Partners. Available at http://ecoagriculture.org/documents/files/doc_431.pdf.

Scaling up climate smart resilient agriculture and mitigation
World Bank. (2011) *Climate-Smart Agriculture: Helping the World Produce More Food*. Washington, DC, USA: World Bank. Available at: https://www.youtube.com/watch?v=i0V2xzEw44Y

World Bank. (n.d.) *Climate-smart Agriculture: Triple Wins*. Washington, DC, USA: World Bank. Available at: http://wbi.worldbank.org/wbi/multimedia/climate-smart-agriculture-video
CGIAR and CCAFS. (2013)

Climate-smart Village Project: Farmer Testimonial on Minimum Tillage. Montpelier, France: CGIAR. Available at: https://www.youtube.com/watch?v=Q_34uNznW1Y&list=PLmATng7lKk6Uj1NFWZh2JQvUrDL5w2Bma

Nutrition, climate and agriculture

Met Office and WFP (2013) Climate Impacts on Food Security and Nutrition: a Review of Existing Knowledge. UK Meteorological Office and World Food Programme Office for Climate Change, Environment and Disaster Risk Reduction. Available at: http://www.metoffice.gov.uk/media/pdf/k/5/Climate_impacts_on_food_security_and_nutrition.pdf

SECTION 4

A way forward

4.1 Current investments in climate smart agriculture

DFID has launched the £3.83 billion International Climate Fund (ICF) to help developing countries reduce poverty, adapt to the impacts of climate change and pursue low carbon growth. This has invested in climate smart agriculture initiatives including:

- The £150 million *Adaptation for Smallholder Agriculture Programme* (ASAP) channels climate finance to smallholder farmers so they can access the information, tools and technologies that help them build their resilience to climate change. Launched by IFAD in 2012, ASAP has become the largest climate change adaptation programme and is expected to help at least 8 million smallholder farmers to build their resilience to the impacts of climate change while delivering economic impacts and mitigation benefits.
- The *Collaborative Adaptation Research in Africa and Asia* (CARIAA) programme to 2019. This initiative looks at increasing the resilience of vulnerable populations in three hotspots of vulnerability – semi-arid, delta and river basin areas.
- The *Building Resilience and Adapting to Climate Extremes and Disasters* (BRACED) programme has received up to £140 million from the ICF since 2013. This has been invested in up to ten countries for implementing community resilience and disaster risk reduction among those most at risk of climate extremes, and for making related policy and institutional changes.
- The Climate and Development Knowledge Network (CDKN) which promotes climate compatible development worldwide, and incorporates climate change into development policies and actions by governments through applied research and technical assistance. Internationally, CDKN's *Legal Response* initiative assists poor and climate vulnerable countries to negotiate within the United Nations Framework Convention on Climate Change (UNFCCC). Climate-smart agriculture (CSA) is a significant investment component within this at country and international levels.

4.2 Climate-smart approach to programming

We have seen that uncertainties around the impacts of climate change cause serious problems for policy makers and development professionals. The Topic Guide *Adaptation Decision Making Under Uncertainty* outlines four priorities for adaptation and climate resilient development (Ranger, 2013):

- Measures with early and 'robust' benefits (currently most interventions focus on these e.g. on early warning systems and climate resilient development).
- Acting to avoid locking in long-term risks (currently few do this).
- Capacity building in forward-looking decision making.
- Low regrets measures with long lead-in times (e.g. agricultural research).

The most common practical approach to early initiatives in CSA has been to identify 'low regrets' or 'no regrets' strategies. Essentially these are strategies for 'better' development that are climate-proofed to ensure that climate change does not negatively impact the effectiveness of development investments. In many cases, adaptation planning for agriculture in developing countries has been piecemeal. National adaptation planning processes involve little economic analysis of the costs, effectiveness and efficiency of agricultural adaptation priorities.

However, research has improved significantly, and value for money and aid effectiveness priorities are now applied stringently across international donor communities, including DFID. Robust analysis of the benefits of investments, from concept through to review, is required. Given the potentially huge deficit in available funding for adaptation in developing countries ('orders of magnitude' difference, according to IPCC, 2014), robust econometric analyses of potential investments are even more important.

Ranger outlines a number of tools to deal with the uncertainties involved in decision making around climate change, including analyses of cost benefit, expected utility, 'real options' analysis and multi-criteria (Ranger 2013).

Watkiss et al. (2014) classify approaches to climate programming for adaptation to climate change into a set of options to help deliver value for money for early adaptation investment:

- Low/no regret options that bring in the 'low hanging fruit' of addressing current climate variability, capacity building and 'good' practice development.
- Risk screening, resilience building including low cost options and improving information and capacity for future resilience.
- Addressing future climate challenges through longer term iterative adaptation pathways and transformative change that avoids major irreversibility or 'lock-in' of mal-adapted infrastructure in the face of climate uncertainties (see related Early Value for Money Adaptation report by Paul Watkiss et al., 2014 for more detail).

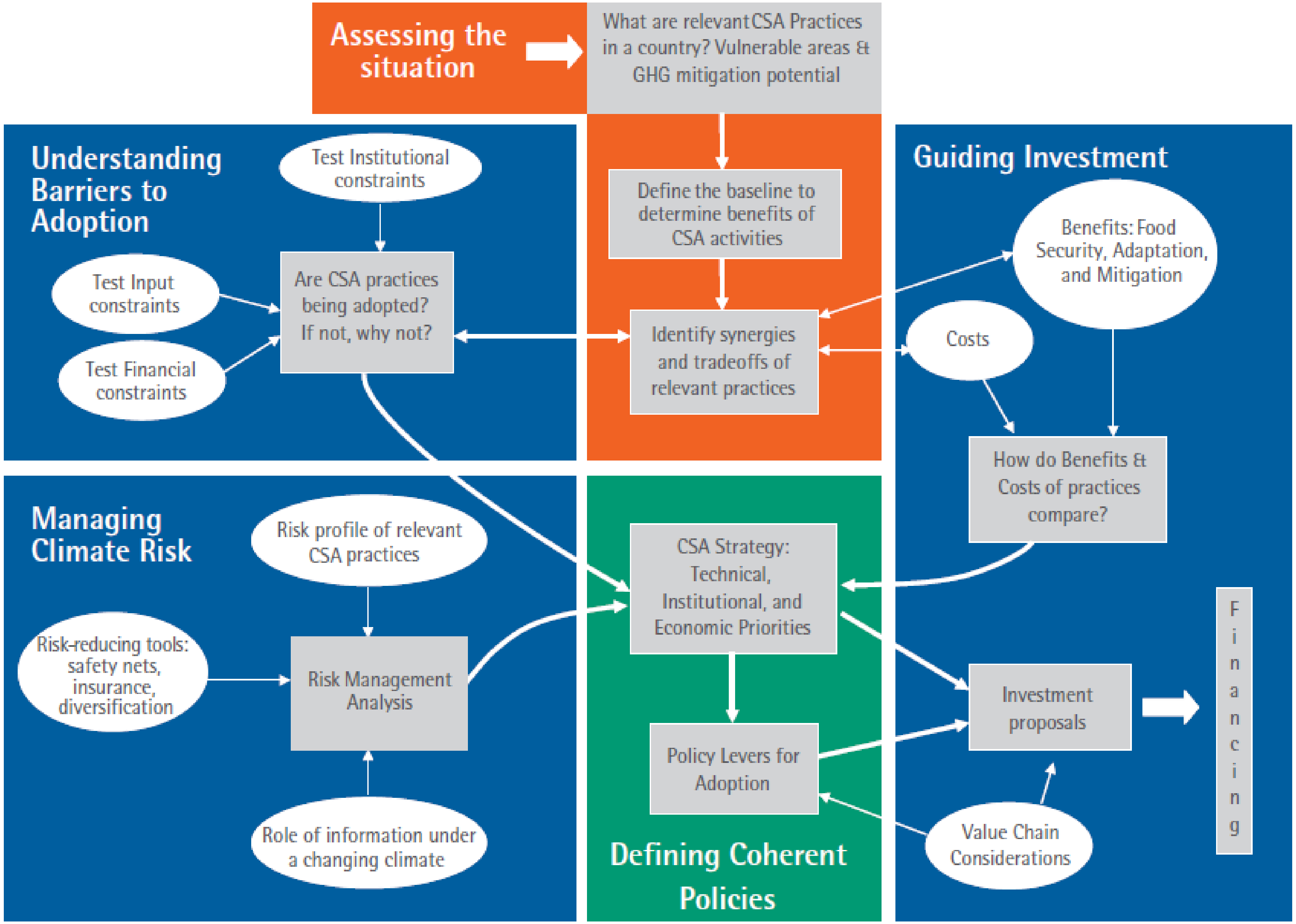
Downing's (2013) review of climate-smart approaches, suggests that the key criteria for choosing CSA actions should include:

- Effectiveness (agro-ecological systems and livelihood impacts).
- Feasibility (institutional and stakeholder requirements).
- Financial sustainability (costs and nature of benefits).
- Appreciation of sequencing and co-dependence of actions.

FAO has developed a framework for developing a CSA strategy and investment proposals (see Figure 11) (FAO 2012). The framework evaluates potential options through a number of filters, including relevant climate risk, barriers, policies and investment decision processes of costs and benefits. A number of additional aspects come out of this in-depth analysis:

- The need for clear baseline and indicators in assessing adaptation (resilience), mitigation and food security.
- The need for micro level CSA activities to be evaluated and priorities set.
- The need to understand climate risk.
- The need to coordinate activities, including between the private sector (farmer adaptation), financial sector (credit for investment), government (policies), research and extension (appropriate information on climate change), and information flows.
- The need for more investment in financial incentives at the farm level to cover transitions.
- The need for policy instruments – rural credit, input and output pricing, tenure, extension and safety net programmes – to improve livelihoods and provide farmers with incentives to adapt to climate change.

Figure 11 CSA options framework



Source: Cattaneo et al., 2012.

4.3 Prioritising interventions in sector, regional and national policies – minimum standards and best practice

While Rio+20 highlighted the need to integrate climate change and agricultural development, there has been more limited progress under the UNFCCC negotiations though four workshops on agriculture were agreed to take place under the Subsidiary Body for Scientific and Technological Advice (SBSTA). While at the national level, many countries have a strong interest in agricultural adaptation, and to some extent, in mitigation (particularly in the Clean Development Mechanism outside the agricultural sector).

Investment plans can be assessed according to:

- How climate-smart they are (contribution to resilience building – to resistance to shocks and long-term stresses; mitigation and food security and wider environmental systems and ecosystem services).
- The focus in the food production chain and how this relates to wider national development plans.
- The country policy environment for CSA investment (private sector readiness, country policy environment, agricultural programmes and institutional capacity).

A case study of Malawi's agriculture sector-wide adaptation plan (ASWAp) demonstrates the development of a set of activities relating to climate benefits, including food security and risk management, technology generation and dissemination (improved varieties, crop and livestock production techniques and post-harvest management), and commercial agriculture and market development (Branca et al., 2010). The ASWAp also focuses on increasing agricultural productivity through sustainable land and water management, improving soil fertility and expanding irrigation and improved water management.

Box 2 CSA screening of planned investments under the Malawi agriculture sector-wide approach (ASWAp)

Most investments planned under the ASWAp relate to increasing agricultural production (improving land and water management, improving seed production, enhancing the fishery sector and research support). Only 11% of the investments plan to improve the physical infrastructure required for productive agriculture (mainly irrigation). A significant proportion of resources (10%) is devoted to research, capacity building and institutional support, as these are considered to be key elements in supporting the activities that focus on increasing production.

Application of the screening methodology to the Malawi national agriculture investment plan for 2009–2013 showed that while few components of the plan enhance the ability to cope with adaptation to extreme events (e.g. actions to reduce storage losses, promotion of village grain bank schemes, establishment of a maize market insurance system and strengthening the weather forecasting capability for agriculture) most activities support enhancement of resilience to climate variability and gradual climate change (slow onset) and show potential mitigation benefits.

Activities	Summary climate benefits		
	Adaptation		Mitigation
	Slow onset	Extreme events	
1. Food Security and Risk Management	6	1	2
2. Commercial Agriculture and Market Development	7	0	1
3. Sustainable Land and Water Management	3	2	1
4. Technology Generation and Dissemination	6	0	2
5. Institutional Strenghtening and Capacity Building	3	1	0
6. Cross-cutting issues	1	0	0
Total	26	4	6

Table 6 Climate-smart screening matrix of the Malawi ASWAp (number of sub-programmes and activities)

4.4 Opportunities

DFID's and other donors investment in climate smart agriculture has grown significantly since 2012. Global, regional and local programmes that support adaptation, mitigation and growth in agriculture are all up and running and new programmes are being designed. However, the majority of agriculture programmes are not funded using climate finance but it is likely that they will have important co-benefits, especially in terms of climate change adaptation and building resilience. There is therefore an opportunity to use climate finance to strengthen these components of "traditional" agriculture and nutrition programmes. There are also significant opportunities to finance larger scale CSA interventions that focus on smallholders, commercialisation and agri-business. Key entry points include:

- Given the evidence gaps presented in this Topic Guide there is considerable scope to support research into the effectiveness of CSA approaches in commercial and large scale operations as well as at smallholder and in subsistence agriculture.
- Support for agribusiness and market development as a means of supporting agriculture, dedicated climate change expertise should be brought to bear on integrating CSA approaches into these programmes.
- The Topic Guide and associated case studies have demonstrated the structural political, economic and regulatory barriers to promoting wider adoption of CSA. There is an opportunity to provide support for integrating policy and practice on adaptation and mitigation in climate change and agriculture at the national level.
- Engage with international political processes. Several events 2010–2014 have moved the climate change, agriculture and food security agenda forward. The aim of these has been to bring together those at the forefront of knowledge and to outline programmes for further research and policy work. These current relevant international political processes include:

    1. The Global Alliance for Climate Smart Agriculture, launched September 2014 at the UN Climate Summit, sets out to enable 500 million farmers by 2030 to practice CSA. through the implementation of climate smart agriculture approaches that help:

- Achieve sustainable increases in the productivity of food systems in the face of climate change;
- Adapt people's livelihoods that are threatened by climate change; and,
- Sequester carbon, and help reduce emissions and deforestation as a result of agriculture.

Over 80 including 19 governments have joined and more expected. A governance structure and work plan has been agreed. Norway and NEPAD are the new co-chairs of Alliance for Climate Smart Agriculture (ACSA) and FAO is hosting its Facilitation Unit. A strategic committee helps direct ACSA and three action groups have been set up: investment; knowledge; and, enabling environment.

2. **United Nations Convention on Climate Change (UNFCCC).** At the December 2014 Conference, negotiations on agriculture stalled (Fuller et al., 2014). However, workshops on agriculture have been agreed under SBSTA and these could potentially lead to a work programme on agriculture and climate change. However, there are differences of opinion about how a work programme would integrate the expectations of emissions reductions or simply focus on adaptation (and resilience building) (Bickersteth, 2013).

3. **Sustainable Development Goals Open Working Groups on Food, Water, Land and Agriculture and Climate Change and Disaster Risk Reduction** are addressing issues related to this topic guide, including nutrition, raising agricultural productivity, and reducing risks of climate-related extreme events to agriculture.

Glossary of terms

Adaptation. The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to the expected change in climate and its effects. Recently, the definition of adaptation has differentiated between 'incremental' and 'transformative' – relating to whether it aims to keep existing structures in place or to make significant fundamental changes to these.

Adaptation deficit. The gap between the current state and one which minimises adverse climate impacts.

Agriculture. The science or practice of farming, including cultivation of the soil for the growing of crops and the rearing of animals to provide food, wool and other products. For the purposes of this Topic Guide, agriculture does not include fisheries.

Climate change. A change in global or regional climate patterns. In particular a change apparent from the mid to late 20th century onwards and attributed largely to the increase in atmospheric carbon dioxide produced by the use of fossil fuels.

Climate-smart agriculture (CSA). Agricultural practices that sustainably increase productivity and system resilience while reducing, wherever possible, greenhouse gas emissions.

Climate variability. The variations in climate over time and space beyond individual weather events. It can be caused by natural internal processes in the climate system or external processes (natural or human 'forcing').

Food insecurity. Insufficient supply of food that may cause hunger (food deprivation), malnutrition (deficiencies, imbalances or excesses of nutrients) and famine.

Food security. A state or condition where all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.

Food system. All the processes and infrastructure involved in feeding the population – growing, harvesting, processing, packaging, transporting, marketing, consumption and food waste disposal.

Hazard. The potential occurrence of a natural or human-induced physical event or trend, or the physical impact that may cause loss of life, injury, or other health effects, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.

Impacts. Effects on natural and human systems. In this Topic Guide, the term *impacts* is used primarily to refer to the effects on natural and human systems of extreme weather and climate events, and of climate change. Impacts generally refer to the effects on the lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure resulting from the interaction of climate changes or hazardous climate events occurring within a specific period and the vulnerability of an exposed society or system.

Livelihood. A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base.

Resilience. Resilience is the capacity that ensures adverse stresses and shocks do not have long term adverse development consequences.

Risk. The likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure and hazard. In this Topic Guide, the term *risk* is used primarily to refer to the risks of climate-change impacts.

Transformation. A change in the fundamental attributes of natural and human systems. Transformation could reflect strengthened, altered or aligned paradigms, goals or values towards promoting adaptation for sustainable development, including poverty reduction.

Vulnerability. This is the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm, and lack of capacity to cope and adapt.

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