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Agricultural adaptation: Six categories of good practices and technologies in Africa

Project Report

Adaptation of agricultural practices and technologies to climate change in Sub-Saharan Africa

Imprint

Published by: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Support to the Comprehensive Africa Agriculture Development Programme (CAADP)

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Published in South Africa - September 2017

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Adaptation of agricultural practices and technologies to climate change in Sub-Saharan Africa

Contents

List of figures

List of tables

List of acronyms

AGRHYMET	*Centre Regional de Formation et d'Application en Agrométéorologie et Hydrologie Opérationnelle* (Agriculture, Hydrology, Meteorology Research Centre)
ARC	Agricultural Research Council
AU	African Union
CAADP	Comprehensive Africa Agriculture Development Programme
CASU	Conservation Agriculture Scaling Up
CDC	Catholic Development Centre
CIMMYT	International Maize and Wheat Improvement Centre
ECRDA	Eastern Cape Rural Development Agency
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agricultural Organisation
FISP	Farmer Input Support Programme
GDP	Gross Domestic Product
GIZ	*Gesellschaft für Internationale Zusammenarbeit*
GM	Genetically modified
INERA	*Institut de l'Environnement et Recherches Agricoles*
IPCC	Intergovernmental Panel on Climate Change
NEPAD	New Partnership for Africa's Development
NAIP	National Agricultural Investment Plan
NGO	Non-governmental organisation
PADAT	*Projet d'Appui au Développement de l'Agriculture au Togo* (Agricultural Development Project)
PASA	*Projet d'Appui au secteur agricole* (Agricultural Sector project)
PNIASA	*Programme national d'investissement agricole et de sécurité alimentaire* (National Agricultural Investment Programme)
PPAO	*Programme de Productivité agricole de l'Afrique de l'Ouest* (West African Agricultural Productivity Project)
REDD+	Reducing Emissions from Deforestation and Land Degradation +
SOC	Soil Organic Carbon
SODECOTON	La Société de développement du coton
UN	United Nations
ZNFU	Zambia National Farmers Union

EXECUTIVE SUMMARY

The threats posed by climate change to agriculture are now well known. Climate change has already resulted in a negative trend in mean crop yield per decade, and this is likely to continue as the century unfolds. In Africa, 650 million people are currently dependent on rain-fed agriculture and, despite progress in the Millennium Development Goals, food and nutrition insecurity remain unacceptably high. In the 2014 Malabo Declaration, African leaders reiterated their commitment to the Comprehensive Africa Agriculture Development Programme (CAADP) and the target of 6% annual growth in the agricultural sector. They also committed themselves to ending hunger and halving poverty in Africa by 2025. To achieve this it will be essential to take into account the risks posed by climate change, and be active in supporting adaptation.

Adaptation refers to "the process of adjustment to actual or expected climate and its effect, which seeks to moderate harm or exploit beneficial opportunities"[1]. Although progress has been made in managing the risks of climate variability and near-term climate change, the adaptations undertaken so far are insufficient to address the long-term impacts[2]. The CAADP is committed to catalysing agricultural transformation and encouraging the growth of sustainable agricultural systems. The GIZ (*Gesellschaft für Internationale Zusammenarbeit*) is providing support to CAADP to ensure the systematic inclusion of climate change adaptation into National Agricultural Investment Plans (NAIPs).

Rather than duplicating extensive existing literature on agricultural adaptation, the purpose of this study was to undertake an empirical investigation of adaptation "good practices" and define six categories of actions that can be practically considered by governments for scaling-up in order to reduce the risks of climate change. The focus is on what needs to be in place, in terms of the enabling environment, in order for the good practices and technologies to be effectively transferred to other contexts. The report is not intended as a prescriptive policy recommendation document but rather as a research report which provides governments with practical options on how to undertake agricultural adaptation to climate change, based on tangible and proven practices.

A rigorous evaluation process was followed to identify the six categories of good practices and technologies. Six case study countries were chosen for empirical investigation of adaptation. Within Burkina Faso, Cameroon, Ethiopia,

Boundaries and limitations of the research

The research is NOT:

- based on large-scale quantitative research and is thus not intended to be fully representative of the agricultural sectors in Africa, or even of the agricultural sectors in the six case study countries
- a definitive list of all good agricultural adaptation practices and technologies in Africa, or even of the agricultural sectors in the six case study countries
- a set of policy recommendations but rather it highlights empirical evidence on observed adaptation good practices and is thus a knowledge product
- prescriptive
- concerned with fishing (the third category – along with crops and livestock – included in the AU definition of agriculture)

[1] IPCC AR5 WG2 Glossary

[2] Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham and P. Urquhart (2014). Africa. In Climate Change 2014: Impacts, Adaptation and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White (eds)]. Cambridge University Press, Cambridge, UK and NY, USA, pp. 1199-1265. Available online at http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap22_FINAL.pdf

South Africa, Togo and Zambia, agricultural sub-sectors were chosen to represent various crops and livestock grown under different production systems (**Annex A**). "Sub-sector" is defined in this report as referring to a commodity type and scale of farming. The purpose was to ensure that sub-sectors were investigated in more than one country so that there would be scope to compare different contexts. Observed adaptations were investigated in partnership with farmers themselves, farmers' organisations, Non-Government Organisations (NGOs), government staff, and other relevant experts.

Using information from the research (**Table 1**), the national expert for each country completed a qualitative scorecard for each observed adaptation practice and technology in each sub-sector. The scorecard captures the multiple elements / features / characteristics of adaptation that require evaluation in order to define a good practice and / or technology, each grouped in a number of overarching categories (**Annex B**). The categories considered for each practice and/ or technology were: proof of concept; robustness under projected climate change; environmental and social externalities; acceptability to farmers; accessibility to farmers; productivity; access to markets; support of appropriate institutions; level of government support; effects on women; and then a criteria to capture co-benefits, such as mitigation, biodiversity conservation, or multiple production objectives.

The scores of the good adaptations and technologies observed in each country were then compared in order to distil a final list of six categories of good agricultural adaptation practices and technologies (**Annex C**). The final six categories of practices and technologies have been observed to be successful in more than one country and in more than one agricultural sub-sector, and scored the highest against the evaluation criteria in the scorecard. In some places, the particular activities that were observed as being good examples of adaptation differ, but they fall under the broad categories mentioned here. However, it is important to highlight that mention of a category in its own right does not mean that every possible option / activity that falls under that category (in the traditional sense of agricultural activities) is a good adaptation practice

Table 1: Qualitative methods used in the six countries

Methods	Burkina Faso	Cameroon	Ethiopia	South Africa	Togo	Zambia
Interviews with individual farmers			✓	✓	✓	
Interviews with farmers' organisations and co-operatives		✓	✓	✓	✓	✓
Interviews with local leaders and elders	✓					
Interviews with members of local technical services	✓					
Interviews with agricultural experts (researchers; climate change experts; relevant government officials)	✓		✓	✓	✓	✓
Interviews with representatives of civil society and religious organisations	✓					
Interviews with members of the private sector	✓			✓		
Interviews with representatives from international institutions	✓				✓	✓
Interviews with NGOs					✓	
Focus group discussions with farmers			✓			✓
Participatory field observations		✓	✓		✓	
Collection of secondary data and information (including published and unpublished reports; government policies and strategies)	✓	✓	✓		✓	

or technology. Hence, although use of improved seeds is one of the good practice and technology categories, this does not mean that every improved seed is an agricultural adaptation. Instead, there is empirical evidence that improved varieties (genetically-modified (GM) and non-GM); use of pest and disease tolerant varieties; use of certified varieties; planting different maturity varieties; and use of early maturing varieties (GM and non-GM) are examples of seed-related agricultural adaptations based on the evidence from the six case study countries. The six good practice categories are: use of improved seeds; soil and water management; changing timing of farming practice; changing crop/livestock distribution and density; tillage and associated practices; and crop and livestock diversification (**Table 2**).

Whilst many of the identified good practices and technologies are not new, the elements identified have been observed to, at a minimum, sustain and ideally improve agricultural production in the context of a changing climate. Since the exact nature of change will vary from place to

Table 2: Summary of six main categories of adaptation practices and technologies and examples thereof

Good practice	Components	Proven examples
Use of improved seeds		Use of improved varieties (GM and non-GM)
		Use of pest and disease tolerant varieties
		Use of certified varieties
		Planting different maturity varieties
		Use of early maturity varieties (GM and non-GM)
Soil and water management	Input for soil and water management	Manure/ composting/ vermicast/ biofertiliser
		Fertiliser use
		Zaï/ planting circle
	Practices and technologies for soil and water management	Crop rotation
		Leaving fields fallow
		Mulching
	Erosion control measures	Contour soil/ stone bunds/ bounds/ filter bounds
		Vegetation bands/ grass strips
Timing of farming practice		Planting of early, medium and long duration varieties
		Dry sowing/ early sowing/ dry planting/ early dry planting
		Change in feeding quantities and times
		Mechanisation
Changing crop/livestock distribution and densities		Reducing stock density
		Intercropping
		Distribution (row planting/ spaces between rows)
Tillage and associated practices		Reduced/no tillage
		Repeated tillage
Farm crop and livestock diversification		Crop diversification
		Diversifying to livestock farming
		Diversifying farming activities/ income

Ugandan Farmer watering his tomato field. **© GIZ**

place, it is critical to assess the likely appropriateness of each practice based on the particular socio-economic and biophysical environment and climate context. There are also particular conditions that need to be in place to enable their effectiveness, the precise nature of which depends on the practice itself (**Table 3**). Thus, should any government wish to support any of these activities as agricultural adaptations, it is necessary to be aware of the enabling criteria that must also exist for these to be robust and effective.

Government has a vital role to play in regulating and/or supporting several key factors which will determine the success, or otherwise, of these practices and technologies in supporting adaptation to climate change. This is particularly important to ensure affordability for small-scale farmers, and may require smart subsidies and/or distribution of free (initial) inputs and/or availability of expensive farming equipment; as well as investments in infrastructure (e.g. roads and markets). The continuing success of the technology-related practices – for example use of improved seeds – is highly contingent on ongoing research and testing, for example to breed seeds that are suitable for evolving local conditions. It is important that government supports this research because when it is driven by the private sector the benefits tend to be skewed towards farmers who can afford their products. Ensuring that effective markets exist is also critical to ensure the availability of appropriate inputs, including seeds and farming chemicals such as herbicides. This is particularly important in remote rural areas. It is important that governments support value chains and encourage entry of new farmers into the market. Awareness raising and ongoing support through partnerships between government and farmers' organisations underpin the effective implementation and sustainability of any of the good practices.

Weather and climate information has a crucial role to play in all six of the good adaptation practices and technologies – farmers need to know what the future will hold with regards to weather and climate before they can be expected to invest both time and money into new practices and technologies. While there are a number of sources of weather and climate information, a number of barriers have been identified to their use, including accessibility; timing of dissemination and credibility of information.

Table 3: Summary of key requirements to introduce/scale up the categories of good practices

Good practice	Enabling environment	Environmental consequences	Ensuring accessibility to women farmers
Use of improved seeds	• Research to develop seeds appropriate for the soil and climate conditions • Markets to supply seeds • Demonstration plots • Technical assistance relating to seed existence and how to farm	Local breeding of seeds should ensure no negative environmental externalities	• Security of land tenure • Subsidies to enable affordability • Provision of varieties requiring minimal tending during the growing season
Soil and water management	• Research to determine most appropriate methods for different biophysical environments • Availability of land and security of tenure • Availability of residues for mulching • Technical assistance to select most appropriate mechanism and how to apply it	Actively aims to protect the soil, and thus have positive environmental benefits	• Security of land tenure • Labour availability • Technical assistance on most appropriate method accessible to women
Changing timing of farming practice	• Communication of weather information • Accessibility of necessary machinery for planting • Combine with other practices, such as appropriate seeds (e.g. early maturing) or fertility-enhancing inputs • Technical assistance to provide advice on options from season to season	Aims to link seed growth needs with weather-related resource availability, and thus minimise risk of degradation	• Labour availability
Changing crop/livestock distribution and densities	• Availability of required inputs (e.g. seeds, manure) • Technical assistance to make appropriate selection for biophysical environment	Technical assistance should ensure that new distributions and densities are compatible with environmental resource availability	• Technical assistance to make appropriate selection, avoiding options with additional labour requirements
Tillage and associated practices	• Demonstration of effectiveness • Availability and affordability of herbicides • Accessibility of planting machinery	Positive impacts on soil moisture content	• Subsidies for affordability • Technical assistance in options that do not have additional labour requirements
Crop and livestock diversification	• Availability of land and security of tenure • Technical assistance to raise awareness on options appropriate for the biophysical environment • Access to markets for inputs and products	Technical assistance should ensure options are compatible with environmental resource availability	• Security of land tenure • Gender-sensitive technical assistance on appropriate options

Farmers' organisations and extension services are also critical to ensure that implementation of practices and technologies has a neutral or positive effect on the environment. The essence of agricultural adaptation is to undertake sound farming management practices and technologies, but also to ensure that those will be robust in the context of a changing climate. Sound farming management practices and technologies involve sustainable utilisation of natural resources in order to optimise production now and in the future. Climate variables, such as temperature and rainfall, are critical in affecting natural resource availability meaning that good practices and technologies are based on linking farming with resource availability. When the soil is effectively managed there is also scope for the co-benefit of mitigation.

Women farmers are largely marginalised relative to men, and addressing this situation requires a number of transformations as well as an explicitly gender-sensitive approach in agricultural policy and support programmes. The major disadvantage that women face relates to security of land tenure and access to land. Whilst many countries are addressing their land laws, proactive approaches to improve access of women to communal land are critical. At the same time, recommended adaptations for men and women farmers, even within the same locality, may need to be different. Adaptations that are contingent on significant inputs of physical labour are likely to disadvantage women relative to men, and thus in places where these are appropriate and encouraged, corresponding support should be made available to women. In areas of high soil erosion, for example, whilst men farmers may be able to create bunds, women farmers could be supported to introduce vegetation bands, both through technical assistance and, potentially, provision of seedlings to plant.

The agricultural adaptations and technologies within the six categories, and the enabling environment to support adaptation, are consistent with the strategic action areas as outlined in the New Partnership for Africa's Development's (NEPAD) Implementation Strategy and Roadmap to achieve the 2025 vision on CAADP[3]. Supporting agricultural adaptation will be an essential element in effectively addressing these strategic areas and ensuring that the CAADP target of 6% annual growth in the agriculture sector is met, even within the context of a changing climate.

A woman in her homestead garden. **© GIZ**

[3] http://www.nepad.org/system/files/Implementation%20Strategy%20Report%20English.pdf

1 INTRODUCTION

1.1 Background to the study

The threats posed by climate change to agriculture are now well known. Climate change has already resulted in a negative trend in mean yield per decade. There is variability in the nature of the projected impacts on crop yield, reflecting different models, scenarios and assumptions. In the short term, approximately equal numbers of models predict an increase and a decrease in yields. However, there is more agreement that from the mid-century onwards there will be a decrease in yields, and the amount of reduction in yield is also likely to be greater (**Figure 1**)[4].

The threat to crop yields is of particular concern in Africa, where 650 million people are currently dependent on rain-fed agriculture. In Sub-Saharan Africa, the agricultural sector provides employment to 60% of the population and adds 30% to the Gross Domestic product (GDP)[5]. In 2010, 30% of the population (239 million) were undernourished[6]; and Africa is the only continent where the number of undernourished people has risen since 1990.[7] The Intergovernmental Panel on Climate Change (IPCC) ranks food security as one of the greatest risks posed to the continent by climate change[8]. With an expected doubling of the African population to over 2 billion people by 2050, this will be an even greater challenge[9]. In the 2014 Malabo Declaration, African leaders reiterated their commitment to the Comprehensive Africa Agriculture Development Programme (CAADP) and the target of annual growth of 6% in the agricultural sector but also committed themselves to end hunger and half poverty in Africa by 2025. To achieve this, it will be essential to take into account the risks posed by climate change, and be active in supporting adaptation.

In order that food production and food security are not adversely affected by climate change, adaptation is imperative. Adaptation refers to "the process of adjustment to actual or expected climate and its effect, which seeks to moderate harm or exploit beneficial opportunities"[10]. Although progress has been made in managing the risks of climate variability and near-term climate change, the adaptations undertaken so far are insufficient to address the long-term impacts[11]. A proactive approach to building adaptive capacity is thus necessary, embedded in more robust food production and distribution systems that are designed to be sustainable in the context of a changing climate. This will require effective partnerships between farmers and government.

Catalysing agricultural transformation and encouraging the growth of sustainable agricultural systems is a key focus of the CAADP. Initiated following the African Union (AU) heads of state and government summit declaration (Assembly/AU/Decl.7(II) in 2003 in Maputo, Mozambique, as an integral part of the NEPAD, the main support provided by CAADP to governments is embedded in evidence. It is in this context that GIZ (*Gesellschaft für Internationale Zusammenarbeit*) is providing support to CAADP to identify the risks and opportunities associated with climate change, to ensure that agricultural transformation is based on appropriate adaptation.

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4 Porter, J.R., L. Xie, A.J. Challinor, K. Cochrane, S.M. Howden, M.M. Iqbal, D.B. Lobell, and M.I. Travasso (2014) Food security and food production systems. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 485-533.

5 Weltbank (2011): Policy Brief: Opportunities and Challenges for Climate-Smart Agriculture in Africa

6 FAO (2010): State of Food Insecurity 2010

7 FAO (2015) The State of Food Insecurity in the World 2015

8 Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham and P. Urquhart (2014). Africa. In Climate Change 2014: Impacts, Adaptation and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White (eds)]. Cambridge University Press, Cambridge, UK and NY, USA, pp. 1199-1265. Available online at http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap22_FINAL.pdf

9 UNFPA (2010): State of world population 2010

10 IPCC AR5 WG2 Glossary

11 Niang et al, ibid.

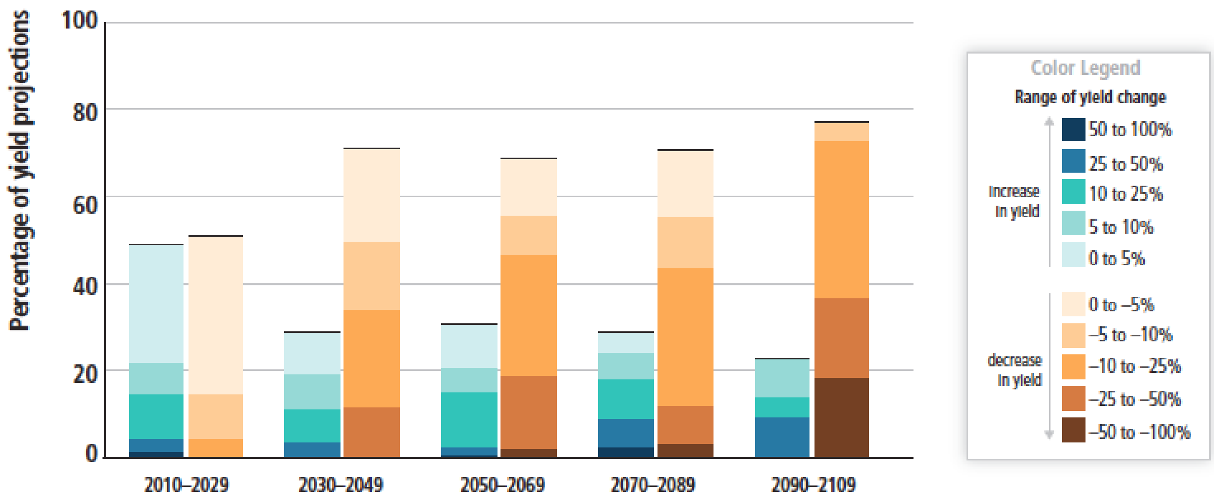


Figure 7-5 | Summary of projected changes in crop yields, due to climate change over the 21st century. The figure includes projections for different emission scenarios, for tropical and temperate regions, and for adaptation and no-adaptation cases combined. Relatively few studies have considered impacts on cropping systems for scenarios where global mean temperatures increase by 4°C or more. For five timeframes in the near-term and long-term, data (n=1090) are plotted in the 20-year period on the horizontal axis that includes the midpoint of each future projection period. Changes in crop yields are relative to late-20th-century levels. Data for each timeframe sum to 100%. Projections taken from Abraha and Savage, 2006; Alexandrov and Hoogenboom, 2000; Arndt et al., 2011; Berg et al., 2013; Brassard and Singh, 2008; Brassard and Singh, 2007; Butt et al., 2005; Calzadilla et al., 2009; Chhetri et al., 2010; Ciscar et al., 2011; Deryng et al., 2011; Giannakopoulos et al., 2009; Hermans et al., 2010; Iqbal et al., 2011; Izaurralde et al, 2005; Kim et al., 2010; Lal, 2011; Li et al., 2011; Lobell et al., 2008; Moriondo et al., 2010; Müller et al., 2010; Osborne et al., 2013; Peltonen-Sainio et al., 2011; Piao et al., 2010; Ringler et al., 2010; Rowhanji et al., 2011; Schlenker and Roberts, 2009; Shuang-He et al., 2011; Southworth et al., 2000; Tan et al., 2010; Tao & Zhang, 2010; Tao and Zhang, 2011; Tao et al., 2009; Thornton et al., 2009; Thornton et al., 2010; Thornton et al., 2011; Tingem and Rivington, 2009; Tingem et al., 2008; Walker and Schulze, 2008; Wang et al., 2011; Xiong et al., 2007; Xiong et al., 2009.

Figure 1: Projected changes in crop yields over the 21st century based on multiple studies

1.2 Aim of the report

Much has been reported about agricultural adaptation in Africa. Studies exist at the macro-scale, investigating the aggregate effects of climate change on production levels, and also at the micro-scale, using livelihoods-based approaches to look at actual and potential interventions by farmers themselves. Rather than duplicating extensive existing literature, the purpose of this study was to undertake an empirical investigation of adaptation good practices and technologies in order to provide insights into observed good practices from a selection of case studies in six countries. The research was qualitative in nature and, as such, it was not designed to be fully representative of the agriculture sectors in the six countries, nor of the sub-sectors within those countries. In this report the term “sub-sector” refers to a commodity type and scale of farming.

Six categories of options that can be practically considered by governments for implementation in order to reduce the risks of climate change were identified. The focus is on what needs to be in place, in terms of the enabling environment, in order for the good practices and technologies to be effectively transferred to other contexts. The report is thus not intended as a prescriptive policy recommendation document but rather as a research report which provides governments with practical options on how to undertake agricultural adaptation to climate change, based on tangible and proven practices.

In addition to not being prescriptive, it is important to note that the list of six categories of good practices and technologies is not definitive and there are many other practices and technologies which are not included. The AU definition of agriculture includes crops, livestock and fisheries while **this research only covers crops and livestock**.

Boundaries and limitations of the research

The research is NOT:

- based on large-scale quantitative research and is thus not intended to be fully representative of the agricultural sectors in Africa, or even of the agricultural sectors in the six case study countries
- a definitive list of all good agricultural adaptation practices and technologies in Africa, or even of the agricultural sectors in the six case study countries
- a set of policy recommendations but rather it highlights empirical evidence on observed adaptation good practices and is thus a knowledge product
- prescriptive
- concerned with fishing (the third category – along with crops and livestock – included in the (definition of agriculture)

2 METHODS AND DATA COLLECTION

2.1 Initial scoping reports on adaptation in each country

Six scoping studies were conducted in 2013 by national experts from the selected countries (Burkina Faso, Cameroon, Ethiopia, South Africa, Togo and Zambia). These summarised observed adaptations and also garnered opinions on the characteristics that define a good practice. This was variously based on interviews with farmers themselves, extension officers, farmers' organisations, Non-Governmental Organisations (NGOs), donors, multilateral agencies and government staff. They were asked what they considered to be successful adaptation interventions, and the (often implicit) criteria they used to make their judgements were noted.

2.2 Selection of agricultural sub-sectors

The scoping studies conducted in each of the countries explored existing agricultural adaptations across the whole variety of agricultural sub-sectors. In order to identify sub-sectors for further investigation, a stepped process of selection and/or elimination was followed in order to ensure that the ultimate shortlist was not only feasible for further investigation within each country, but would yield additional cross-country results of relevance to CAADP.

An initial meeting of the project team was held to discuss and decide upon the process of how to achieve the collective goal of coming up with the overall six good practices. In line with this goal, the initial meeting produced two main outputs: the identification of priority sub-sectors for further in-depth fieldwork in each of the six countries; and an evaluation framework to use in order to identify adaptation good practices. **Figure 2** is a schematic representation of the steps followed.

Step 1
Creation of matrix of countries and the most important agricultural subsectors.

Step 2
Refinement of matrix to include top 10 subsectors in each country.

Step 3
Removal of subsectors that were not important in at least 3 of the 6 countries.

Step 4
Identification of whether examples of agricultural adaptations exist in the subsectors.

Step 5
Identification of subsectors where it is feasible to work with farmers organisations.

Figure 2: Schematic representation of steps followed to identify priority sub-sectors for further in-country investigation

In the following tables, abbreviations are used as follows:

- BF = Burkina Faso
- Cam = Cameroon
- Eth = Ethiopia
- SA = South Africa
- Zam = Zambia

Step 1

The first step in the process was the identification of the most important agricultural sub-sectors in each of the six countries (up to a maximum of 15). In order to be included in the initial amalgamated list, the sub-sector had to be regarded as important in at least two of the six countries (see **Table A.1** in **Annex A**). This key criterion was introduced in order to ensure that comparisons between countries could be made and that any good practices and technologies were derived from evidence from more than one country context. However, this meant that certain important sub-sectors (such as coffee and teff in Ethiopia) did not progress past the first step.

Step 2

Given that the output of Step 1 was still a substantial list (27 sub-sectors), the second criteria for shortening was to identify the top 10 most important sub-sectors in each of the six countries (as identified by the national experts) and disregard the others. See **Table A.2** in **Annex A** for the results of this step. Since in some cases sub-sectors are farmed together, this ultimately yielded 15 sub-sectors.

Step 3

From the 15 sub-sectors resulting from Step 2, any sub-sectors that were not important in at least three countries were removed – once again, in order to ensure comparability of results. In some cases, less common sub-sectors were retained if their importance within at least one of the countries was deemed critical.

Step 4

Step 4 involved looking through the shortened list produced in Steps 1 to 3 in order to determine whether or not adaptation practices and technologies exist within the sub-sectors in each of the six countries. **Table A.3** in **Annex A** shows the resulting matrix of where adaptation practices and technologies exist.

Step 5

From the list of the top 11 sub-sectors with adaptation practices and technologies (Step 4), Step 5 involved also assessing the existence of active farmers' associations relating to these sub-sectors and the perceived accessibility of these based on the initial scoping work undertaken by national experts. The final list (**Table 1**) resulted in identification of up to five sub-sectors in each country (with the number based on the size and perceived feasibility of investigation, given the size of the country and the time and budget available). The national experts would undertake fieldwork in these sub-sectors, using a qualitative methodology, in order to understand what practices and technologies work, for whom, and why, as well as what practices and technologies do not work and why.

2.3 Evaluation framework for good practices

Based on the criteria for good practices and technologies identified as part of the scoping studies, additional discussion addressed the criteria that constitute good practices and technologies with regards to adaptation. Ultimately, these agreed-upon criteria were classified into a "scorecard". This scorecard was to be completed by each national expert for each good practice observed within the respective agricultural sub-sectors in their countries.

Table 1: Matrix of the final sub-sectors chosen for investigation by country

Commodity	Burkina Faso	Cameroon	Ethiopia	South Africa	Togo	Zambia
Sorghum	C				Y	Y
Maize	C	Y	Y	Y	Y	Y
Cotton	Y	Y			Y	Y
Rice	Y					
Beans (haricot in Ethiopia; soya in Burkina Faso)			Y			
Vegetable (incl. tomatoes in Cameroon)	Y	Y		Y		
Cocoa		Y			Y	
Fowls				Y		
Cattle-beef	Y	Y				
Wheat			Y	Y		

(Note: "C" means combined: in Burkina Faso, sorghum and maize are always grown in combination so can be assessed together)

The criteria in the evaluation framework for good practices and technologies are:

Practice

- Proof of concept (proof of track record at a local level)
- Sustainability (lack of negative externalities, and appropriate longevity)
- Build on existing practices/structures (cultural compatibility, inclusivity, demand-led, adoption rates, applicable to different scales)
- Accessibility (cost efficiency ratio, availability, ease of use)
- Improved outputs (production and quality)

Enabling environment

- Support of appropriate institutions (private sector, research organisations including extension services, markets, meteorological services)
- Government support (extension services, policy environment, national strategies)
- Positive impact on women

Additional "bonus" criterion

- Co-benefits (mitigation, biodiversity, multiple production objectives)

The full scorecard, including guiding questions, appears in **Annex B.** All scoring was positive except impact on women, which could be negative if use of the practice reinforced gender inequality.

2.4 Fieldwork to observe good adaptation practices and technologies

Each national expert conducted primary and secondary data collection through in-country fieldwork in order to collect the data necessary to identify good practices and technologies (**Table 2**). Completing the scorecards required interviews with farmers themselves, as well as with other stakeholders, such as extension officers, farmers' organisations, NGOs, donors, multilateral agencies and government staff. On the scorecard (**Annex B**), **themes in bold** were intended to be elaborated through interviews with farmers, whilst *themes in italics* were intended to be elaborated through interviews with relevant stakeholders. A scorecard was completed for each good practice in the respective agricultural sub-sectors. Each national expert assigned a numeric score for each evaluation criterion, which was informed by more extensive qualitative research around each good practice with the variety of stakeholders. Thus, at the end of the process, based on extensive qualitative research, each country had a number of scorecards for each of the good practices and technologies in each of the agricultural sub-sectors.

Table 2: Qualitative methods used in the six countries

Methods	Burkina Faso	Cameroon	Ethiopia	South Africa	Togo	Zambia
Interviews with individual farmers			✓	✓	✓	
Interviews with farmers' organisations and co-operatives		✓	✓	✓	✓	✓
Interviews with local leaders and elders	✓					
Interviews with members of local technical services	✓					
Interviews with agricultural experts (researchers; climate change experts; relevant government officials)	✓		✓	✓	✓	✓
Interviews with representatives of civil society and religious organisations	✓					
Interviews with members of the private sector	✓			✓		
Interviews with representatives from international institutions	✓				✓	✓
Interviews with NGOs					✓	
Focus group discussions with farmers			✓			✓
Participatory field observations		✓	✓		✓	
Collection of secondary data and information (including published and unpublished reports; government policies and strategies)	✓	✓	✓		✓	

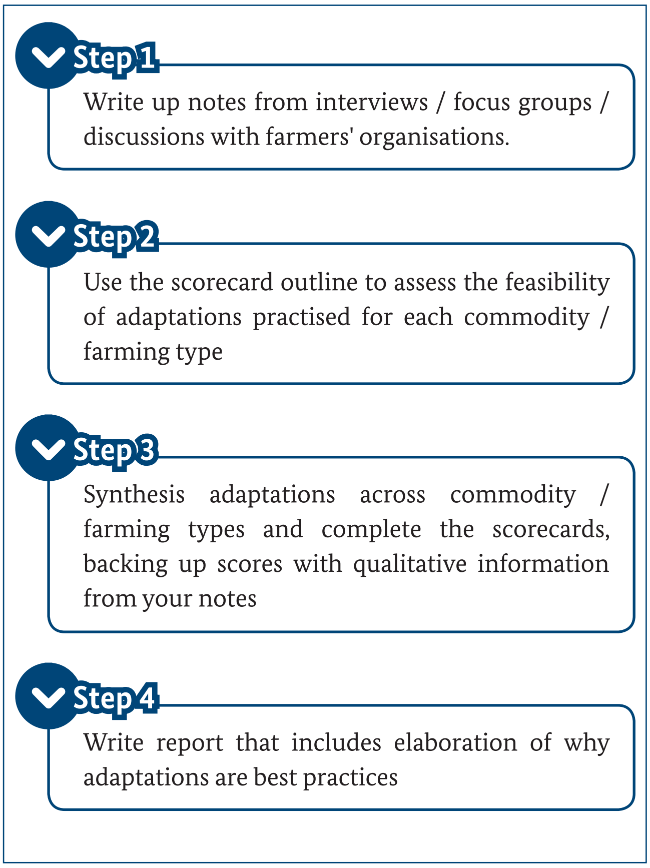


Figure 3: Process diagram to record and analyse fieldwork findings

Figure 3 outlines the process national experts were required to follow in order to document the results of their primary, qualitative, research in the field. It was deemed important that all national experts follow the same process and produce country-specific reports of a similar structure so as to facilitate the writing up of this report of continent-wide good practices and technologies that draws on information from all six countries.

2.5 Identification of overall categories of good practices

A second workshop took place in Addis Ababa, Ethiopia, in January 2015. The purpose of this meeting was to discuss and decide upon the six categories of good practices and technologies across all six countries included in the project. National experts submitted a country-specific report outlining the results of their fieldwork, as well as a table identifying the top scoring adaptation practices and technologies observed in their country.

Similar to the initial workshop, the second workshop followed a stepped process to amalgamate and narrow down the results from all six countries to result in a final list of six categories of good adaptation practices. Tables resulting from each step of the identification process are to be found in **Annex C**.

Step 1

A table of the categories of good practices and technologies and their scores (converted to a percentage in order to aid comparison) across all six countries was constructed – see **Table C.1** in **Annex C**. It was recognised that national experts scored differently (i.e. some scored constantly lower than others) so the highest score in each country was identified as a reference point, and to allow comparison with other scores in that country.

Step 2

In the second step of the process of identifying the six categories of good practices and technologies from across all six countries, certain practices and technologies were removed from the table. These included those that were only considered good practices and technologies in limited sub-sectors, in only a few countries, and those which scored low compared to the rest of the scores within one country. During this step, practices and technologies in different countries which were essentially the same but named differently were consolidated and finally, practices and technologies were grouped into six larger categories of good practices and technologies – See **Table C.2** in **Annex C**.

Step 3

In Step 3, the larger categories of good practices and technologies were then considered and those that were only considered good practices and technologies in limited sub-sectors, in only a few countries, and which scored low in those countries compared to the rest of the country scores were removed from the table (shown in blue in **Table C.2** in **Annex C**). In addition, erosion control measures were moved to the "Soil and water management" category which resulted in six good practice categories – see Table 3 (and **Table C.3** in **Annex C** for full information, including scores).

The six categories of good practices and technologies are thus: use of improved seeds; soil and water management; timing of farming practice; changing crop/livestock distribution and densities; tillage and associated practices; and farm crop and livestock diversification. It is worth reiterating that the observed practices and technologies are those in the column labelled "proven examples" – and they have been grouped into the six categories of associated good practices. This does not mean, for instance, that every example of farm crop and livestock diversification is a good adaptation practice – but that several of the observed adaptations are within the realm of crop and livestock diversification.

Table 3: Summary of six main categories of adaptation practices and technologies and examples of these

Good practice	Components	Proven examples
Use of improved seeds		Use of improved varieties (GM and non-GM)
		Use of pest and disease tolerant varieties
		Use of certified varieties
		Planting different maturity varieties
		Use of early maturity varieties (GM and non-GM)
Soil and water management	Input for soil and water management	Manure/ composting/ vermicast/ biofertiliser
		Fertiliser use
		Zaï/ planting circle
	Practices and technologies for soil and water management	Crop rotation
		Leaving fields fallow
		Mulching
	Erosion control measures	Contour soil/ stone bunds/ bounds/ filter bounds
		Vegetation bands/ grass strips
Timing of farming practice		Planting of early, medium and long duration varieties
		Dry sowing/ early sowing/ dry planting/ early dry planting
		Change in feeding quantities and times
		Mechanisation
Changing crop/livestock distribution and densities		Reducing stock density
		Intercropping
		Distribution (row planting/ spaces between rows)
Tillage and associated practices		Reduced/no tillage
		Repeated tillage
Farm crop and livestock diversification		Crop diversification
		Diversifying to livestock farming
		Diversifying farming activities/ income

3 CATEGORIES OF GOOD PRACTICES AND TECHNOLOGIES

The entire process of identifying good practices and technologies began with the initial country-based inventories of observed agricultural adaptations that were judged to be successful by a variety of agricultural stakeholders: farmers; farmers' organisations; extension agents; government staff; and donor, NGO and academic researchers working in these fields. Whilst many of these practices and technologies are not new, they have been observed to, at a minimum, sustain and ideally improve agricultural production in the context of a changing climate. The future climate across different parts of Africa is likely to be variable. Temperatures are universally expected to increase, whilst levels of agreement and confidence in rainfall projections vary. Although the identified practices and technologies have been distilled from a variety of farming contexts to ensure that they are likely to be feasible adaptations, **determining the promotion, scaling up or introduction of any options requires that the likely future climate be considered, and that the practice be appropriate as an adaptation in that context**.

As well as feasibility based on climate conditions, there are other elements that determine which of the good practices and technologies would be most appropriate – or what other factors would need to be changed to provide a supportive environment in which they could function as a good adaptation practice. These considerations include **what needs to be in place in terms of an enabling environment** – referring to such factors as policy support, existence of markets, and technical capacity. The **potential for environmental externalities of a particular practice is also crucial**. In many cases, whether or not a practice has positive or negative environmental externalities depends on how it is implemented and this, in turn, often reflects the availability and accessibility of technical knowledge. Similarly, **different practices and technologies have different levels of appropriateness for women farmers**. In some cases, ensuring accessibility for women requires structural change – for example land reform that secures tenure. In other cases, it can be achieved by gender-sensitive approaches ensuring that practices and technologies are appropriate to culturally-specific gender roles, and that gender sensitivity is applied in government support, for example through input access, research and transfer of knowledge.

The current section takes each category of good practice in turn, identifying the aspects/characteristics/features of the observed examples that make them good adaptation practices and technologies, and then highlighting the enabling environment that must be in place in order for the various practices and technologies to be successful. Environmental consequences and ensuring opportunities for women farmers are also identified. In many cases, the way in which each agricultural adaptation is practised varies between large-scale and small-scale farmers, and these differences are also addressed. Examples from the case study countries are also included.

The importance of water availability and water conservation

Water conservation was not identified as one of the six categories of good adaptation practices and technologies. However, this is not to say that it is not important. A theme which is implicit in all the categories outlined below is that of water availability and the need to conserve water. In many parts of the continent, changes in the availability of water is the most critical impact of climate change facing farmers. This is especially important for rain-fed agriculture which makes up the vast majority of agriculture in Africa.

Seeds are being improved in order to become more drought resistant or to mature at a different time so as to match the change in rainfall patterns that is being experienced or is expected. The practices and techniques detailed under the soil and water management category (for example, building stone bunds and mulching, to name but two) are largely concerned with water conservation. Changing the timing of many farming practices (such as planting and harvesting) and the distribution and density of crops and livestock are made necessary by the change in rainfall patterns and thus the availability of water. Tillage and associated practices are, in large part, driven by the need to conserve soil moisture while crop and livestock diversification is made necessary by changes in the availability of water.

3.1 Improved seeds

The good practices and technologies making up the improved seeds category and the countries in which they were found to be effective adaptations are:

Use of improved varieties: Burkina Faso; Cameroon; Ethiopia; South Africa; Zambia

Use of pest and disease tolerant seed varieties: Zambia

Use of certified varieties: Zambia

Planting of different maturity varieties: Zambia

Use of early maturing varieties: Cameroon; South Africa; Togo; Zambia

Summary of how use of improved seeds can be a category of agricultural adaptation good practice:

- Improved seeds (certified, drought-tolerant, early-maturing or genetically-modified) can increase crop yield and quality
- Combining improved seeds throughout the season can maximise production and/or reduce risk of loss from changing weather conditions
- New seed varieties must be tested and adapted to local circumstances (either by research institutes or private companies)
- Markets need to exist to make improved seeds available to large- and small-scale farmers of different commodities – and government interventions may be needed to enable this
- Awareness of, and training in, farming practices and technologies is necessary to make optimal use of improved seeds
- There are minimal negative environmental externalities of using improved seed technologies (with the exception of genetically-modified (GM) seed – which is addressed separately)
- Improved seeds can enable adaptation by women provided a gender-equitable approach is taken to availability and training.

3.1.1 Benefits of improved seed varieties

Improved seed technology and more strategic use of different types of seeds as suited to evolving conditions is a key mechanism through which agriculture can adapt to climate change. Different types of improved seed varieties exist. Whilst the overarching goal is to maintain or improve yield (and ideally quality), the mechanisms through which this can be achieved differ. **Improved seeds can be certified, drought-tolerant (or appropriate to other environmental and climate conditions), early-maturing, or GM (the latter is banned in some countries)**. Drought-tolerant varieties are better suited to changing rainfall conditions, particularly where a drying trend has been observed. Early maturing varieties are also important, especially given the widespread tendency for delayed onset of the rainy season, and mid-season dry spells. They can be planted later but still harvested at the optimal time. However, early maturing seeds with shorter growing periods do tend to be lower yielding than longer duration maturity. GM seeds are particularly popular in South Africa, although they are controversial and banned in many countries.

Examples of improved seeds used in African countries

Among other examples, improved seeds are used for vegetables (Burkina Faso), haricot beans (Ethiopia), soybeans (Togo); and for cereals, including wheat (Ethiopia, South Africa), maize (Burkina Faso, Ethiopia, Cameroon, South Africa, Togo), millet (Togo), sorghum (Togo, Zambia), cassava (Cameroon), peanuts (Togo) and cotton (Burkina Faso, Cameroon, Togo and Zambia).

Use of improved seed varieties was noted to be a *good agricultural adaptation among wheat farmers in Ethiopia* in terms of maintaining (and improving) yields in the context of a changing climate. *Yields from improved varieties in Togo are significantly higher than those from traditional seeds* – over ten times more in some cases; and the crop is of high quality. “This practice is preferred to other traditional practices because we want what improves the conditions of our producers," said a farmer.

3.1.2 Combining seed technologies for risk diversification

Since there are different types of improved seed technologies, it is possible to use them in combination. **Some varieties have been bred to embody more than one improvement: for example drought-tolerant GM; or drought-tolerant early maturing varieties**. The choice of which varieties can also vary on both an inter- and intra-seasonal basis in order to support the most effective adaptation to climate change. One method of applying improved varieties of seeds is to take advantage of the fact that different cultivars have different growing periods. Depending on how early or late in the season they plant, farmers can purchase the most appropriate seeds to maximise production. Planting a range of seeds that require different lengths of time to reach maturity, at different points within the season, is an important agricultural adaptation as it minimises the risk of crop loss through catering for different seasonal conditions/ potential adverse conditions. In Zambia, many farmers reported that they would plant a mix of early, medium and late maturity maize and sorghum varieties due to the recurring unpredictable weather conditions, which include short rainy seasons, delayed onset of rains and frequent seasonal dry spells. On the other hand, they will choose only one maturity of crop if they have strong confidence in the likely weather conditions. Typically, this prediction of forthcoming rainfall patterns is based on expected weather patterns and existing indicators which they have developed over the years. However, it also highlights a role for more robust and higher resolution seasonal weather forecasts to inform choices and ensure optimal levels of adaptation.

Combining different seed varieties has the benefit of overcoming risks associated with of an overreliance on one. It also addresses the particular weaknesses of different types of improved seeds. Improving varieties to have higher production and pest/disease resistance has typically been problematic. This is exacerbated by the fact that when a new “super” seed enters the market many farmers want to plant it, which increases the risk of macro-level crop loss in the case of disease or other unpredictable adverse conditions. Traditional seed varieties better tolerate rust disease in Ethiopia. In Zambia, the risk minimisation strategy is to plant a mix of early and late maturing sorghum varieties. Armoured cricket infestations are a key pest to sorghum crops and set in the fields at a critical period late in the season when early maturing varieties are almost ready to harvest. Similarly, the improved varieties of sorghum are said to be more vulnerable to bird invasion. Although traditional varieties may have been more resilient in the face of these pests, farmers in focus group discussions pointed out that traditional seed is rarely found due to the impact of drought on germplasm preservation. Maintaining diversity in seed availability is therefore also important to ensure adaptation to climate change while avoiding concurrent problems from pest and disease.

The practice therefore needs to be applied in combination with other adaptations in order to be effective. These other adaptation activities include the use of fertiliser and mechanisation, and changing timing of farming practices and technologies (see section 3.3).

3.1.3 Requirements of an enabling environment

Accessibility of improved seeds is dependent on a number of different factors, including availability, cost, awareness, and scale of farming. There is also a need to ensure quality of seeds, which includes ensuring ongoing genetic viability after many years of use. In many cases, a key enabling factor that affects accessibility to different seeds is the extent to which farmers’ organisations and other agricultural bodies are promoting them – and the extent to which they influence the aforementioned factors.

3.1.3.1 Local seed breeding and testing

The production of improved seed varieties is highly research-intensive. **It is essential that improved varieties are bred, according to international research standards and procedures, to be appropriate to the local conditions**. Ethiopia has long researched improved varieties of seeds, through the Ethiopian Institute of Agricultural Research (EIAR). There are also specialist research agencies for different crop types, for example haricot bean researchers at the EIAR Research Centre at Melkasa and the National Wheat Research Centre at Kulumsa. Development requires long-term trials with different climatic and environmental conditions – with the result that improved varieties are available for different moisture regimes (both high and low rainfall areas) for cereals (maize and wheat) and vegetables (haricot bean). In South Africa, the Department of Agriculture (DoA) is investigating a triticale (wheat/rye hybrid) as a potential alternative crop because it can be grown in marginal areas that are not suitable for wheat. In Zambia, the Zambia Agriculture Research Institute, in collaboration with the International Maize and Wheat Improvement Centre (CIMMYT), has a fully-fledged research programme on drought-tolerant and early maturity maize and sorghum varieties which are being promoted for adaptation in drought-prone areas.

Ensuring that improved seed varieties remain sustainable adaptation options also requires ongoing scientific research to maintain genetic viability and to ensure **ongoing suitability for changing environmental conditions**. In Cameroon, for example, improved maize and cassava seeds have a long history but declining productivity suggests that there is a need for reassessment and additional seed breeding. Whilst improved seeds may have increased yields, they are often susceptible to diseases, and thus there is an ongoing need for research to address this.

As well as state entities, **private seed companies are also developing new varieties**. These are typically targeted at, or at least are only affordable to, large-scale commercially-oriented farmers. Most research done by private companies is problematic because it is used to promote their own products. However, in certain cases the development by private companies is the only means through which improved varieties can be produced. Wheat farmers in South Africa highlighted the differential progress made between researching and developing improved wheat varieties and improved maize varieties. The former lags behind because, relatively speaking, it is too small an industry – and as yet there are no GM wheat seeds available (although they noted that drought-tolerant seeds have been developed in other contexts – in this case by Monsanto in Australia – and that there is scope to genetically modify these and adapt them to South African conditions).

A farmer winnowing seeds. **© GIZ**

3.1.3.2 Effective awareness-raising and promotion of improved seeds

Use of improved seeds is dependent on awareness of improved varieties themselves, and knowledge about how best to farm them. **Farmers need to know what improved seed varieties exist before they can, or will, consider switching from traditional varieties**. Small-scale maize farmers in South Africa have recently switched from replanting traditional seeds to using high-yielding certified varieties. They were introduced to these new seeds by the farmers' organisation GrainSA, which ran farmers' days in various areas where small-scale farming predominates in order to raise awareness and provide training. Small-scale farmers tend to be concerned with risk minimisation as opposed to yield optimisation, and are thus reluctant to apply new technologies until they have witnessed their successes. In the Eastern Cape, small-scale maize farmers have witnessed the substantial increase in yields from certified varieties, and thus are convinced of the potential returns from buying the seeds. Thus, whilst the initial investment for demonstration purposes was external, the practice continues because its value has been observed. However, only small numbers are using GM seeds because the technology is newer and its effects have not yet been observed. In Togo, early maturing and drought-tolerant maize and sorghum varieties have become normal over the last two decades as yields from traditional varieties declined due to a combination of recycling and inappropriateness to changing climate conditions.

As well as awareness of the existing of improved varieties of seeds, **farmers must also have appropriate knowledge on how to farm them in order to gain maximum benefits**. Achieving optimal yield increases from improved varieties requires an enabling environment in which knowledge transfer can take place. This can be accomplished in various ways: providing an active extension service to provide advice on farming techniques and optimisation of production; field days; farmer exchange visits and on-farm demonstrations. In Cameroon, for example, extension is provided by SODECOTON (*La Société de développement du coton*), the private company which provides improved varieties, and to which small-scale producers sell. In Ethiopia, there is a strong extension service and policy support to promote improved seeds to farmers, which is well linked with the national and regional seed enterprises that were established to cater for the provision of improved variety seeds for cereals and vegetable crops. In Zambia, extension agents indicated that farmers are regularly made aware of the existing varieties that are suitable to the different environmental and weather conditions and, as a result, there is significant evidence for the use of maize that is appropriate to the changing temperature conditions.

Behavioural change is most likely when farmers have directly experienced the benefits of improved seed varieties. One key barrier which needs to be overcome in order to augment the regular use of improved seeds is a behavioural one that exists particularly among small-scale farmers. In many cases, the farming practice for generations has been to continually recycle traditional seed, even when production levels decline and/or are variable because the seeds are not well adapted to changing conditions. Farmers may plant improved seeds if they are provided with them at no cost, for example through a government or donor/NGO programme. However, even direct experience of higher yields, better quality and greater likelihood of yields in seasons of adverse weather conditions is not always sufficient to encourage them to purchase seeds. This was observed in Togo and Zambia and is the case even when the greater returns from higher production levels more than compensate for the cost of doing so. This is not always a barrier – as shown above, small-scale maize farmers in South Africa are buying improved variety seeds having been convinced of their utility after they were provided for one season. However, it is an important element that needs to be addressed in any programmes that aim to increase usage of improved varieties. This can be aided by a continuing programme of extension-based field support.

Without appropriate knowledge on how to farm improved seed varieties, their benefits will be sub-optimal and there is a danger of dis-adoption. In Burkina Faso, for example, theoretical improvements in yields from improved seeds should be in the order of 40-60% higher production. However, yields among small-scale farmers often barely exceed the norm, reinforcing their confidence in, and use of, traditional seed varieties. In 2011, only 17% of small-scale farmers in Burkina Faso were using improved varieties; whilst in Cameroon it was around 40%.

3.1.3.3 Buoyant seed markets that ensure availability

Availability of seeds is typically dependent on markets. Although distortions to the process are possible, **markets usually emerge where there is a demand at scale**. Increased demand only arises when the new seed technologies are affordable, both for large-scale and small-scale farmers. At national and sub-national level, demand for availability of improved seed varieties can be skewed depending on who purchases seeds and where they are located. At the local scale, improved varieties of seeds are typically not available. Even when markets are well developed, physical infrastructure and remoteness may impede accessibility. In Burkina Faso, markets for cereal seeds do not exist other than private shops in urban areas. In the southern part of Zambia, the poorer road network meant that Chirundu farmers were less able to access seeds than similar farmers in Chibombo, in the centre of the country. This impedes the effective use of the Kuyuma variety of sorghum, which is very early maturing, short, well adapted under drought conditions, and widely adopted by farmers. Where it is not available, farmers are forced to recycle improved varieties but their yields decline sharply after a couple of seasons. Similarly in Ethiopia, with the help of the Melkasa Research Centre, some haricot bean farmers had diversified their livelihoods and were now involved in the production of seeds for sale (not just for feed or food). However, the seeds sat in a warehouse and the Research Centre staff acknowledged that there is a breakdown in the marketing and dissemination of seeds – a "missing link" between suppliers and users of seeds. The research centres have a mandate to provide new seed varieties to government and private enterprises who then mass produce the seeds and distribute them to farmers. Additionally, they now also give initial seeds to local seed businesses (co-operatives and private-public partnerships) at kebele level.

3.1.3.4 Public sector support to ensure accessibility

Accessibility of improved seeds is contingent on both availability and affordability. In many cases, government and development partners (including NGOs) are actively involved in supporting the use of improved varieties of seeds. **Public support for accessibility of improved seeds can come from government policies and/or subsidies that ensure affordability and effective distribution of seed technologies (i.e. accessibility)**. This can happen through a variety of mechanisms: dedicated public programmes that are based on availability through the extension service; rotating farmers' days; or voucher systems in partnership with networks of commercial suppliers.

Examples of public support for seed accessibility in selected African countries

Governments can:

- **Purchase large quantities of improved seeds and then distribute them among small-scale farmers.**

  The national agricultural research board, INERA (Institut de l'Environnement et Recherches Agricoles) in Burkina Faso holds an annual meeting where seeds are sold to farmers. Various projects are underway by the Ministry of Agriculture and Food Security (Ministère de l'Agriculture, et Ressources Hydrauliques, de l'Assainissement et de la Sécurité Alimentaire) to test the viability of improved cattle breeds. The South African government also distributed certified varieties of seeds that are higher yielding than traditional varieties to many maize farmers in parts of the country where people are particularly dependent on small-scale farming, such as the Eastern Cape.

- **Recommend use of improved seed varieties**

  Togo's government policy recommends the use of improved seeds under the National Agricultural Investment Programme, PNIASA (Programme national d'investissement agricole et de sécurité alimentaire); which it actively implements through a number of projects, such as Togo's Agricultural Development Project, PADAT (Projet d'Appui au Développement de l'Agriculture au Togo), Agricultural Sector project, PASA (Projet d'Appui au secteur agricole) and the West African Agricultural Productivity Project, PPAO (Programme de Productivité agricole de l'Afrique de l'Ouest).

- **Subsidise improved seed varieties**

  In Ethiopia, government policy is for all farmers to use improved maize varieties, and thus they are available and affordable for all. Such government support can also act to bolster the market for seeds and other inputs. The country-wide Farmer Input Support Programme (FISP) in Zambia has a subsidised loan scheme where farmers pay upfront 50% of the cost of fertiliser and maize seed. This system has further encouraged growth in the number of seed companies and created an incentive for agro-dealers to expand their geographical coverage even to the remote parts of the country.

- **Government can build on private sector distribution networks to improve national availability**

  In Zambia, for example, making seed available through the existing agro-dealers locally and through an active private sector distribution network means that improved seeds are more readily available for purchase than in the past. The existence of viable farmer cooperatives creates the scale required to facilitate farmer access to improved seeds as well as fertilisers.

Onions from improved seeds. © GIZ

Improved seeds and effective farming practices and technologies alone are not enough: to improve yields there is typically a need for additional inputs, such as fertiliser and pesticides, herbicides (particularly for early planting) and labour-saving technologies (equipment and machinery). This leads to extra cost and the need for additional technical knowledge. In Burkina Faso, where cotton farming is typically done on a contract basis, the cotton companies provide the associated inputs (e.g. fertiliser as well as improved seeds) to their members. In Ethiopia, improved varieties of wheat do not have the same levels of resistance to diseases such as rust attack. If farmers cannot afford the pesticides then they tend to reject the improved varieties and continue to farm with the traditional seeds.

Whilst government support is often required to support the greater use of improved seed varieties, at least in the beginning, care also needs to be taken so that government and NGO involvement does not distort markets. There are cases where markets are not always able to keep up with demand, resulting in a shortage of improved seeds. Where seeds are distributed by larger bodies, timeliness of delivery is critical to ensure they are available for the planting season.

Genetically-modified seeds: improved yields and weed and pest resistance in South Africa

GM crops are a controversial technology, but still an example of improved seeds. GM seeds are very popular and widely used in South African maize farming on the basis of their increased yields and improved weed and pest control. GM maize is widely used amongst large-scale commercial growers, for example those in the Free State, where there is preference for those that are modified to be resistant to herbicide (Roundup ready maize), resistant to insects (BT maize), or a combination of both. Small-scale maize farmers are also beginning to buy GM seeds, mainly on the advice of GrainSA. Most of those who have tried GM seeds have only done so for one or two seasons and it remains to be seen whether they will continue to purchase them annually at prices higher than those of other seeds. In the last few years, Monsanto – a leading GM seed producer – has developed a drought-resistant maize seed, which could be an extremely important factor in the ability of farmers to adapt in the future. Some large-scale maize farmers believe that the only way to farm maize in the future will be through using GM crops.

Consumer and government perspectives on GM may, however, limit the extent to which it can be counted as a good practice of agricultural adaptation. Opposition to GM food crops is related to concerns over human and environmental health, food sovereignty, and because of the commercial nature of GM seed development and sales. There are a small number of South African farmers that produce non-GM maize because it is sold at a higher price. Non-GM grain is sold to the international market or used for specialised small-scale food production within South Africa. GM seeds are illegal in several African countries and some African leaders have gone as far as to reject GM food aid. In this context, the potential for use of GM seeds as a climate change adaptation is uncertain.

3.1.4 Environmental externalities

Improved seed varieties are also an agricultural adaptation good practice because they have no negative environmental impacts and, with appropriate support, need not have social dis-benefits. The length of time that improved varieties of seeds have been in use has demonstrated that there are no environmental externalities from their use. From a socio-economic perspective the affordability element of accessibility is the biggest potential problem. Without appropriate government support, there is a risk that small-scale farmers will be unable to acquire improved varieties – but evidence from the case study countries shows that many governments are aware of this and have put in place pro-poor measures to overcome this barrier. The greater yields from improved seeds contribute to food security. Use of improved seeds also enables the generation of cash income, whether by increasing production of export crops, such as haricot beans in Ethiopia, or by enabling excess production which can be sold to generate additional cash income.

3.1.5 Accessibility to women farmers

Improved varieties can also support the agricultural adaptation of women farmers. Providing that government programmes that support both availability of improved seeds and knowledge transfer for their effective use (e.g. through agricultural extension) are gender-sensitive and target both men and women farmers, higher yields increase food availability and often also nutritional quality for households. Since women are typically responsible for producing/procuring food to eat, this could reduce a potential burden on them if the adverse impacts of climate change reduce production levels and make it necessary to seek alternative food sources. Another key enabling factor at government level to ensure that improved seed varieties benefit women farmers, as well as men, is providing security of land tenure. Improved seeds are expensive and are a regular expense in that they need to be replaced more frequently than traditional seeds. Farmers may thus be reluctant to make this investment unless their control over land (where their investment is made) is guaranteed. In many countries, women's rights to land are dependent on men. Until they have control over land, in addition to mere access to it, there is the potential that men farmers may be better able to use this technique of agricultural adaptation, leaving women farmers in a situation of greater relative vulnerability to climate change.

Figure 4: Drought-resistant sorghum in Togo

3.2 Soil and water management

The good practices and technologies making up the soil and water management category and the countries in which they were found to be effective adaptations are:

Input for soil and water management:

Manure / composting / vermicast / bio-fertiliser: Burkina Faso; Cameroon; South Africa; Togo; Zambia

Fertiliser use: South Africa

Zaï / planting circle: Burkina Faso; South Africa

Practices and technologies for soil and water management:

Crop rotation: Ethiopia; South Africa; Zambia

Leaving fields fallow: South Africa

Mulching: Ethiopia; South Africa; Togo; Zambia

Erosion control measures:

Contour soil / stone bunds / bounds / filter bounds: Burkina Faso; Cameroon; Togo

Vegetation bands / grass strips: Cameroon; Togo

Summary of how soil and water management can be a category of agricultural adaptation good practice:

- Maintained and/or improved yields
- Support to ecosystem integrity and functioning of ecosystem services
- Low-cost options are available
- Various techniques of erosion prevention and soil quality protection and enhancement exist, meaning that there are techniques available to support the particular risks posed by climate change to soils in different agro-ecological zones
- When effectively selected for the circumstances, soil and water management should have no negative environmental externalities
- Women farmers can benefit from soil and water management, provided they have equitable access to necessary resources (including land and technical know-how).

3.2.1 Benefits of soil and water management

Maintaining soil quality is essential to ensure optimal production. Soil quality can decline as a result of farming practices and technologies and types that deplete nutrients and have adverse effects on soil structure. However, soil quality is also affected by natural processes, such as geochemical cycling and wind and water erosion. Changes in the climate can affect the nature and rate of these natural processes. As a result, the need to ensure soil and water management is even greater under climate change. Soil and water management is thus a sound example of an agricultural adaptation. Soil and water management takes on various forms, and the particular type of soil and water management that is required is highly dependent on the agro-ecological context.

One way of categorising these examples is prevention of soil erosion, protection of soil quality, and enhancement of soil quality. These categories are not mutually exclusive.

Prevention of soil erosion is particularly important where the geomorphology of the land creates a particular vulnerability to water and wind erosion: for example steep gradients and areas that experience flash flooding. Prevention of soil erosion can take place through planting circles (zaï), contour farming, and the use of bunds. These farming practices and technologies require no or little financial investment (materials for the creation of bunds can usually be locally gathered) – although awareness and technical know-how are important to ensure their maximum effectiveness. Stone bunds comprise rubble that is aligned along contours. These bunds reduce erosion and improve water infiltration. An alternative which is appropriate in areas of lesser gradients is grass strips.

Examples of prevention of soil erosion from around Africa

Zaï in west Africa

Zaï means "getting up early and hurrying out to prepare the soil". It is a traditional practice which consists of digging holes for fertilisation by manure or composting. It improves water infiltration levels and thereby increases soil moisture as well as improving soil fertility. As a result, zaï typically lead to improved yields – or enables crop production in particularly dry conditions, such as those anticipated under climate change. Dry cereals, cotton and vegetables are among the crops that are planted in zaï. As a low cost measure, availability of labour is the only required input. This has proved to be such a successful climate adaptation that many research institutes are now investigating options to mechanise it in order to facilitate scaling up.

Planting circles in South Africa

Whilst zaï are common in west Africa, similar practices and technologies are also emerging elsewhere on the continent, such as among small-scale farmers in South Africa. Planting circles entail digging a circular, knee-deep hole in the path of naturally occurring drainage. This hole is then filled with empty cans and old animal bones before being covered with maize stalks, manure and, finally, soil (see **figure 5**). The intention is to retain water and moisture and thereby enable production even in drying conditions; or to enable crops to survive longer without rain. A raised edge is built with soil around the down-slope side of the hole and vegetables are planted on the raised edge. Water drains into the hole and is then stored by the bones, cans and maize stalks, where plants on the edge can access it through their roots.

Figure 5: Animal bones collected to make a planting circle, Eastern Cape

Stone bunds and grass strips in Togo

Protection of degraded soils by stone bunds and grass strips has a long history in the savannah region of Togo (e.g. in Tone, Tandjoaré and Kpendjal districts). By protecting against erosion and land degradation, stone bunds and grass strips have enabled recovery of many hectares of land that was formerly unsuitable for crop production. Bunds and strips are produced by the farmers themselves, largely using local materials – although there is also need for some tools for the construction process (e.g. hoe, dabas, pickaxe, shovel, wheelbarrow, spirit level, crowbar, masses, gangs, boots).

Protection of soil quality can also take place through farming practices, such as rotating crops, leaving fields fallow, and mulching. Rotating crops (typically over a single to multi-year timeframe) enables regeneration of soil quality, since different crops require different micronutrients. It can also provide the ancillary benefit of disrupting disease cycles, which otherwise have adverse effects on crop production. Crop rotation with legumes is particularly common, since legumes are nitrogen-fixing and thus actively contribute to soil fertility through replenishment of soil nutrients. Planting deep rooting crops in a rotation system is also popular, as they aerate the soil. Crop rotation is also an important diversification/risk spreading mechanism for small-scale farmers, increasing the likelihood of crop production within the system, even under adverse climate conditions. It can also be used as a mechanism for maximising income if two crops are rotated within a year – particularly if drought resistant and/or early maturing seeds are planted. Leaving fields fallow allows groundwater reserves to be replenished. Mulching involves leaving some crop residue in the fields. It therefore ensures that soil is not exposed, protecting against wind and water erosion, and conserving moisture availability. The breakdown of organic matter also serves to maintain soil fertility. However, declining rainfall patterns can reduce the popularity of mulching. Rainfall is often required to enable decomposition, without which planting is also more difficult the following season, especially for large-scale farmers. Large-scale wheat farmers in South Africa's Western Cape reported that they partially break down the material by mechanical means such as dragging tyres behind tractors.

Enhancing soil quality through application of fertilisers has a long history. Fertiliser use will not directly enable farmers to adapt to climate change, but the increase in yields could help them to better cope with threats from climate change. Chemical fertilisers, however, have typically been unaffordable for many small-scale farmers. They can also have potentially adverse environmental consequences – such as leaching, eutrophication, and pollution of water courses – unless effectively managed.

There are now also many bio-fertiliser options, such as manure, composting, vermicast, and the use of complementary plants. This is increasing the accessibility of soil enhancement as a mechanism of soil and water management. In particular, manure and composting are suitable adaptations to drying conditions. They can improve soil fertility to the extent that dry season crops can also be planted without prejudicing production levels of staples – thereby increasing overall land productivity. Composting is a biological process of conversion and valorisation of organic materials (biomass by-products, biological organic waste, etc.) in the presence of oxygen into a stable and hygienic product similar to a mould or compost. Movement to bio-fertilisers is also increasingly being embraced by large-scale commercial farmers who recognise the importance of maintaining ecosystem integrity and services; as well as to respond to the growing demand among middle class consumers for organic products.

3.2.2 Requirements of an enabling environment

The wide range of options for preventing soil erosion and protecting and/or enhancing soil quality are variously appropriate to different agro-ecological zones and farming systems. In particular, they require different levels of resources, in terms of financial inputs, material inputs, availability of natural resources (including land and water) and human capital. Thus the most appropriate options for adaptation will vary from place to place, and this should be supported by appropriate research and promotion by governments and non-government partners.

3.2.2.1 Availability of inputs/materials

The accessibility and appropriateness of the mechanisms of soil and water management are dependent on the availability of inputs and materials. These can include land, competition for crop residues, water, and labour capacity and time.

Availability of land affects whether farmers can adopt practices and technologies to protect soil quality. Rotating crops and leaving fields fallow is only an option for farmers who have access to sufficient land for their needs. In many cases, lack of land availability means that all land must be continuously cultivated in order to ensure food production and security. This need to ensure maximal land use can, in turn, further increase vulnerability to climate change because the soil quality is diminished from planting under inappropriate conditions.

Soil fertility mechanisms that require residues are also impeded by competing needs for the resource. Mulching may reduce the availability of feed for livestock as it is left in the farm fields. The input for mulch is primarily crop residue and some farmers do not have sufficient feed for livestock and they may use the mulch for animal feed. In the maize growing areas of Ethiopia, almost all farmers use conservation agriculture. However, the practice is limited to reduced tillage and residue management. On average, only about 25% of the mulch or crop residue is left in the fields (in maize fields). The rest of the residue is used as forage or fuel. Similarly, manure and composting are contingent on the availability of inputs. As well as the availability of residues as inputs, prioritising grass and crop residues for animal feed also reduces the availability of inputs to produce compost. It also often means the quality of inputs for mulching and compost is reduced, which in turn reduces the extent of the benefit to soil fertility. Climate change will likely further exacerbate this competition – and thus mulching

Examples of enhancing soil quality from around Africa

Composting in Togo

Making compost from animal or vegetable waste through traditional methods is a nationally widespread practice in Togo. It is used by both maize and sorghum farmers in many districts, especially in the dry northern part of the country (for example in the districts of Kozah, Assoli, Bassar, Doufelgou, Kéran, Oti, Tandjoaré, Kpendjal, Tône, Cinkassé, Agou, Haho, Est-Mono, Kloto, and Amou). Both men and women farmers use composting. Compost is made in large pits, as shown in **Figure 6**.

Figure 6: Making compost from vegetable waste in Togo

Vermicast in South Africa

Vermicast – produced by worms – is an organic fertiliser that is used to enhance crop production and has the potential to greatly increase yields. The high cost of production of vermicast means that it is typically applied to high value and intensively farmed crops. However, it has also been applied to maize that is commercially farmed at large scale. A small group of farmers in the eastern Free State have started farming worms for the production of vermicast.

and composting should only be promoted where there will feasibly be suitable inputs available.

As well as requiring inputs, **some processes of soil and water management place constraints on labour**. Compost is produced during the rainy season, which is also typically the main planting season, and thus places additional demands on farmers' time. Other activities are physically intense. Zaï and planting circles require significant effort and, whilst the returns on labour input are worth it in the case of drought/dry conditions, their benefits are negated in the case of floods. Creating stone bunds also requires significant manual labour to transport stones.

Example of ensuring manure availability in Burkina Faso

In some villages in Burkina Faso farmers are engaging in trading of manure and compost. Some livestock farmers sell their manure, or exchange it for local seeds and food. Local farmers usually have a contract with cattle breeders. Cattle are parked in a farmer's field for three to four years so that it can benefit from direct deposition of manure. However, these contracts have di-minished over time because of the many constraints caused by transhumance.

3.2.2.2 Affordability of inputs

Enhancing soil quality through the application of fertilisers has a cost implication. **Accessibility of chemical fertilisers is dependent on farmers' access to financial resources**. Cash crops and commodities have typically relied upon the application of chemical fertilisers. Commercial farmers have long used fertilisers. Small-scale contract farmers, for example those producing cotton, typically receive fertiliser as part of their contracts. Under conditions of a changing climate there is often increasing interest from farmers to apply chemical fertilisers. However, as with other farming inputs (for example improved seeds, **section 3.1**), for fertilisers to be promoted they need to be made available through the market, affordable, and accompanied by transfer of technical knowledge to ensure that they do not inadvertently contribute to soil degradation and long-term unsustainability of the agro-ecological system.

3.2.2.3 Technical knowledge on soil and water management options

The various options for preventing soil erosion, and protecting and enhancing soil quality, require selection of the most appropriate method(s) for the context, and then knowledge transfer and the development of skills in their use. **Providing technical knowledge on the most appropriate soil and water management options, and how best to practice them, is essential to ensuring their optimal use**. There is growing interest in bio-fertilisers because of their ecological sustainability relative to chemical counterparts, and because of their greater accessibility to farmers of different scales and means. Awareness-raising of these options, some of which are highly experimental and recently emerging, is a prerequisite for gaining interest. Technical knowledge in how to use them is also essential to ensure they are effectively applied. In Burkina Faso and Togo, for example, compost quality and quantity is impeded by farmers not being aware of how to produce it (in terms of how to dig the pits and how best to layer materials within them). In South Africa, vermicast is an emerging technology and, as a result, there are very few organisations that have the skill to transfer knowledge or provide training.

3.2.2.4 Support to improve levels of soil and water management

Given that the appropriateness of different soil and water management options is contingent on local conditions, **there is a role for research institutes to determine the most appropriate methods**. Vermicast, for example, is a new bio-fertiliser and because its production is effectively another commodity to farm (worms), there will be particular scales and value chains for which it will be most appropriate. In Cameroon, a number of intercropping pilots are taking place, together with the addition of certain crop leaves to different crops to support pest control and maintain soil fertility. Research institutes in Ethiopia and South Africa have promoted crop rotation on the basis of positive findings from studies. Research institutes could also play a role in assessing soil samples (for fertiliser use, etc.): this is often typically done in private laboratories which means it is unaffordable for many farmers and there is no opportunity to undertake research on the soil samples.

Government support for improving awareness about, and use of, soil and water management is typically provided through the extension service. **The extension service has a key role to play in promoting appropriate soil and water management techniques**. In the Eastern Cape of South Africa, for example, the Catholic Development Centre (CDC) promotes mulching among vegetable farmers. In order to overcome the challenges of competition for crop residues, the training highlights that – in the absence of sufficient dry grass and maize stalks – alternative materials can be used, including cardboard, paper, sticks, foam and even corrugated roofing metal. These have varying degrees of effectiveness. In addition to keeping the soil moist, farmers reported that mulching helped to control weeds. Mulching will be a successful adaptation practice in the future because it requires otherwise unused resources and it can greatly enhance the potential for farming in dry conditions. In Ethiopia, the extension service plays a key role in highlighting good practices and technologies for crop rotation.

As well as the extension service, **government has the opportunity to incentivise particular soil and water management techniques and practices through policies and programmes**. Research in the six case study countries did not identify any explicit government policies that promote soil and water management as an agricultural adaptation. NGOs are often working on a small-scale to provide training and support to the use of various methods for prevention of erosion, and protection and enhancement of soil quality, often as a component of improving crop production levels. Policies and programmes could also ensure availability of inputs. The challenge of producing appropriate quantities and qualities of compost has been noted. When farmers cannot produce their own compost there is the option to purchase it; although it is often prohibitively expensive for small-scale farmers due to the transportation costs. For comparison, a parcel of land that would require 400kgs of chemical fertiliser would require seven tonnes of compost or manure to achieve the same nutritive benefit. Incentivising availability through markets could overcome this – and perhaps be used in place of many existing nationally supported chemical fertiliser subsidy programmes.

Soil management. **© GIZ**

3.2.3 Environmental externalities

With the exception of chemical fertilisers, the techniques for prevention of soil erosion and protection and enhancement of soil quality are all designed to have positive environmental impacts - when implemented correctly. This is based on the recognition that an agro-ecological system of sound integrity is more likely to support adaptation to climate change. When used correctly, chemical fertilisers do not necessarily have adverse environmental impacts – but correct use is dependent on appropriate knowledge. It is important that promotion of soil fertility techniques is based on principles of environmental sustainability. Training and knowledge transfer in the use of soil and water management techniques should take into account particular local circumstances, and modify choice and design of techniques accordingly. For example, in the construction of stone barriers, stones must be removed from elsewhere. If the terrain is rocky and stones are freely available, there need not be any negative environmental consequences. If, however, obtaining the inputs to create such stone bunds requires that they are removed from locations where they are serving other roles (for example in a river/stream where they modulate the flow of water), there is a danger of negative environmental externalities.

3.2.4 Accessibility to women farmers

One key role that government policies and programmes could support is making soil and water management gender equitable. Ensuring that policies and programmes are gender-sensitive is important because some soil and water management techniques – particularly those geared at prevention of erosion – may be inaccessible to women given the requirements for land availability and physical labour (for example to transport stones to farms). In addition, it is important to make explicit attempts to make training and knowledge transfer activities available and accessible to both men and women.

3.3 Timing of farming practice

The good practices and technologies making up the timing of farming practice category and the countries in which they were found to be good adaptations are:

Early planting for early, medium and long duration varieties: Cameroon; Zambia

Dry sowing/ early sowing/ dry planting/ early died planting/ modern planter: Cameroon; Ethiopia; South Africa; Zambia

More efficient/ faster harvesters: South Africa

Change in feeding times and quantities: South Africa

Summary of how altering the timing of farming practice can be a category of agricultural adaptation good practice:

- Early/dry planting, staggered planting, and altered feeding times make use of the shift in availability of natural resources occurring due to climate change
- Changing the timing of farming practice is typically optimised when used in conjunction with other practices, e.g. different seed types and cultivars, and production-enhancing inputs such as fertiliser
- Information on likely weather conditions throughout the season is required in order for early/dry planting, staggered planting and changing feeding times to be successful
- Access to inputs, including seeds/feed, labour and machinery determine the likelihood of/extent of success from changing the timing of farming practice
- Changing the timing of farming practices and technologies is likely to have positive environmental benefits because it is done with the intention of linking the crop production cycle with the availability and quality of environmental resources to support the growth cycle
- If women farmers have access to land, labour and technical know-how, changing the timing of farming practices and technologies can be accessible to them.

3.2.1 Benefits of changing the timing of farming practices

The importance of climate change for agriculture is not just about changes in the magnitude of climate parameters – for example annual average rainfall – but also in the distribution throughout the season. Changing rainfall distribution patterns have been widely observed across different agro-ecological zones in Africa, and responses are also already visible. In order to adapt to a different rainfall distribution and increased temperatures, farmers from some of the sample countries are changing the timing of when they plant and harvest crops or feed livestock. Practices and technologies for crops include: planting early (before the rains arrive); staggering the planting of different crops; and harvesting quickly (before the rains begin). Practices and technologies for livestock (poultry) include feeding chickens at night when it is cooler in order to increase the amount they consume.

Early/dry planting

Farmers, particularly small-scale ones, traditionally waited until the onset of the rains before planting their crops. However, since the timing of onset has become so variable, and is often accompanied by irregular subsequent rainfall, many farmers are now sowing their seeds when it is still dry (dry planting). This is intended to compensate for any growing time lost due to the delayed onset of rains and dry sowing facilitates early germination. This practice can also be adopted as part of a conservation agriculture system. In Zambia, tillage of the fields takes place early in the season before the rain starts, mainly from September to November, using hand hoes, animal-drawn rippers or chaka hoes. Ripping can then take place just before or with the first rains depending on their arrival.

Early/dry planting is also practiced by large-scale commercial farmers. In South Africa, commercial wheat farmers have invested in modern planters. This technology which allows for rapid planting is ideal for dry soil, enabling early planting and thus ensuring optimal use of the rain. In addition to being required for minimum and no-tillage systems, modern planters also plant the seeds deeper in the soil, enabling them access to greater quantities of soil moisture.

In the process of planting, they also leave little furrows on the either side of the seed so that when the rain does fall it is naturally funnelled towards the seed (rainwater harvesting).

Staggered Planting

Staggered planting is also a response to unpredictable and erratic weather conditions which are typically characterised by very wet or dry spells coupled with mid-season prolonged dry spells, especially at critical crop growth stages. Major crops are staggered in their planting times, ensuring that at least one of the crops planted within the season escapes potential losses due to unpredictability of rainfall distribution. In southern Africa, one of the crops may be dry planted, or planted with the initial rains (even before effective rains for planting have commenced). Some crops are planted once rains have stabilised and potentially the last crop towards the end of December or early January of each year in anticipation of a longer rainy season which could extend into the month of April. Both early and medium maturity crop varieties are staggered to ensure an early harvest in a good season. In Zambia's dry agro-ecological region (agro-ecological region one), farmers reported that maize is planted first and then followed by cotton and sorghum. Maize is planted earlier because the crop is the most important staple food and cash crop and more vulnerable to adverse weather conditions, especially dry spells, compared to sorghum and cotton which withstand harsh drought conditions in reasonable condition.

Changing feeding times

Failure to effectively link farming practices and technologies with weather conditions can also limit production levels of small livestock. In poultry farming, prolonged warm weather lowers the productivity of laying hens because they do not like to eat when they are too hot meaning that they produce fewer eggs. Eating also causes a rise in metabolism, which generates body heat from the chickens. In response to this challenge, some farmers choose to feed their chickens at night (when they would otherwise not normally have access to food). This ensures that the hens consume adequate feed to ensure optimal production, and prevents additional heat stress. Diets are also more or less dense depending on the season, and the stage in the lifecycle of the chicken. For poultry farmers, changing when they feed their birds and how much they feed them can ensure that their outputs remain high during hot periods and that heat mortalities are reduced.

Feeding of chickens. **© GIZ**

Example: Harvesting winter wheat when it is suitably dry in South Africa

The changing rain patterns play a fundamental role in timing of planting, but in other cases it is important for harvesting. In South Africa, winter wheat needs to be harvested when it is dry in the spring, after the bulk of the winter rainfall. To manage the threat of rainfall during harvesting, wheat farmers have increased their harvesting capacity by buying bigger combine harvesters so that they can harvest faster. One farmer's wife stated that it used to take six weeks to harvest but they now do it in two weeks. This reduces the risk of late season rain during harvesting and can prevent farmers from losing money due to lost crops. It also contributes to efficiency gains. This adaptation option is largely enabled by the ability to afford to increase harvesting capacity – in this case by buying bigger combine harvesters.

3.3.2 Combine changing the timing of farming activities with other adaptation practices and technologies in order to reduce risk

On its own, changing the timing of farming practices is more a strategy to maintain yield in the face of risk, as opposed to increasing yield (although in a good year it has the potential to increase yields, particularly for farmers who can capitalise by planting more than one crop). However, it is a risky strategy and, as a result, not one in which all farmers are willing to engage.

Early/dry planting can fail in the case of extremely delayed rains, or significantly reduced total rainfall throughout the season/conditions of drought – because seeds will dry out and lose viability. In such cases, farmers lose the value of the inputs and risk their immediate food security, as well as the availability of seed for planting in the following season. For this reason, in Burkina Faso early/dry planting is only common in the Sudan zone and the southern part of the Sudan-Sahelian zone, where rainfall variability is fairly low. In Ethiopia, haricot bean growing areas are naturally arid or semi-arid and thus characterised by high rainfall variability, which means that early/dry planting is not the most appropriate adaptation option. In Zambia, it is recommended by extension agents with caution – and ideally with some understanding of the seasonal forecasts. Some improved seeds may be appropriate for dry planting.

Staggered planting is most likely to be effective if the seeds used have different characteristics. **Section 3.1** highlighted how planting a range of seeds that require different lengths of time to reach maturity, at different points within the season, is an important agricultural adaptation practice. Similarly, combining different seed varieties in staggering has the benefit of overcoming the risks associated with overreliance on one. It also addresses the particular weaknesses of different types. In South Africa, early maturing seeds were deemed essential to enable quicker planting and thus to gain optimal benefit from rain conditions.

Changing the timing of farming practices and technologies is more likely to be successful if combined with other inputs aimed at enhancing production. In order to conserve moisture under early planting, farmers can apply kraal manure to improve the soil structure and soil water holding capacity in maize-livestock and sorghum-livestock based farming systems in the rip lines and planting basins. This practice is consistent with conservation farming systems and is regularly used in Zambia. Focus group discussions with both male and female farmers revealed that once sorghum germinates in such systems, the crop is significantly more resilient to normal dry spells compared to maize. This is, however, dependent on the timing and severity of extreme weather events. Likewise, for large-scale commercial farmers in South Africa modern planters are necessary, along with early-maturing seeds, to facilitate change in the farming practice in order to adapt to changing rainfall characteristics.

3.3.3 Requirements of an enabling environment

3.3.3.1 Access to information

The biggest predictor of success in changing the timing of farming practice is **the availability of timely and targeted weather information which farmers can use to inform their planting**. Seasonal forecasts are variously issued by National Meteorological and Hydrological Offices and regional bodies and fora, including the regional Climate Outlook Fora and the Agriculture, Hydrology, Meteorology Research Centre (AGRHYMET) Regional Office. These forecasts are probabilistic in nature, and give the likelihood of rainfall exceeding, being equivalent to, or being less than the average. The high inter-annual variability in rainfall in many African countries limits the utility of these forecasts, and they do not provide any insights into the potential distribution of rainfall within the season. Small-scale farmers are typically dependent on receiving information through extension agents. Large-scale commercial farmers, on the other hand, have the technical and financial resources to access a variety of prediction tools, including those with high levels of precision, to know what seeds they should plant and when.

Extension agents, NGOs and private sector companies play a key role in providing advice to farmers on early/dry planting and staggering planting, although the extent to which this happens varies from country to country. In Zambia, the government is supporting early planting through various avenues, including providing information on available agronomic practices and technologies that enable early planting and through advocacy by extension services for early planting and staggered planting. In Ethiopia, on the other hand, extension services do not officially recommend early planting. Private sector companies also play a role. In South Africa, feed suppliers provide knowledge and techniques to poultry farmers on how to best respond to changing temperature and rainfall conditions – and provide options for them to purchase suitable feed. In Zambia, cotton companies, such as Dunavant, have been working in collaboration with the Conservation Farming Unity, Department of Agriculture and Zambia National Farmers Union (ZNFU) in supporting early planting through the promotion of minimum tillage based innovations that include tillage methods of ripping and planting basins.

3.3.3.2 Access to inputs

Since early/dry planting and staggered planting are most effective when used in conjunction with other adaptation practices, access to agricultural inputs often play a key role. When improved seeds are used, it is necessary that the seeds are available for procurement through the market (see **section 3.1.3.3**). **Government, NGOs and the private sector play a role in facilitating timely seed availability** before the onset of the rains; and this is typically linked with active dissemination of information pertaining to the nature of recommendations based on the weather forecast and early warning systems. In Zambia, farmers indicated that there are good chances of achieving higher crop yield under early planting if they plant improved and early maturity varieties which are able to escape the short rain seasons – but these are expensive for farmers who are more accustomed to recycling traditional seed. In Ethiopia, experts cited the inability of farmers to purchase additional seed should their first attempt at planting fail as a barrier to changing the timing of farming practice as an adaptation. **Affordability is thus an important consideration**.

Access to the right amount of labour at the right time determines whether or not farmers are able to practice

Examples of support for mechanisation in Africa

Conservation farming equipment for small-scale cereal farmers in Zambia

ZNFU is supporting the “Lima Credit Scheme” as well as another loan package called “Bunjimi Assetplus Loan” that enables farmers to access agricultural implements that include rippers, knapsack sprayers, chaka hoes as well as improved crop seeds and fertilisers – all of which support changing the timing of farming practices and technologies to adapt to climate change.

Farmers‘ organisations supporting small-scale farmers to mechanise in South Africa

GrainSA assists small-scale farmers in putting together the business plans that allow them to apply for funding from government sources (e.g. the Eastern Cape Rural Development Agency (ECRDA)). ECRDA has supported applications to the recapitalisation programme in the Eastern Cape, although available funds are always subject to political reprioritisation prior to allocation.

GrainSA has also supported the brokering of private sector support for small-scale farmers in the Eastern Cape. In one case, it has asked John Deere to loan farmers in the Eastern Cape a complete package of equipment and implements for six months. They will receive a 50kW tractor, a ripper, a planter, a boom sprayer and a disc. The farmers will have to pay John Deere R1250 (approximately US$90 at the current exchange rate) per hectare, per month, for the use of the equipment, which is a much smaller amount than what they would need to rent each of those implements. Individual farmers will use the equipment for their own land and also contract out to other farmers. After six months, John Deere will take back the implements. Then GrainSA will help farmers to get loans from the Land Bank to buy all of the equipment back again. This in on the condition that farmers have performed well during the six-month trial. These loans would be at a low interest rate of 4% and the farmers could pay them back over six or so years. GrainSA is in the process of choosing those farmers who have the land and labour inputs to benefit most from the scheme, which is intended to be profitable for both John Deere and the farmers.

Mechanisation: advantages and disadvantages

Mechanisation increases the efficiency of agricultural processes, from land preparation to harvesting. Farmers with access to machinery are able to increase their productivity and increase the area on which they cultivate (presuming land is available). Machinery that supports the farming process includes tractors as well as rippers, discs and planters. It is an important adaptation to climate change as it enables greater returns from physical environments that are changing in terms of temperature and rainfall, which affect the growing season. However, there are also a number of disadvantages, some of which can be managed with appropriate policies and government support.

- **Cost:** Machinery is expensive and can only be afforded by large-scale commercial farmers. Smaller-scale farmers may share and/or hire equipment, but in this situation the effectiveness is impeded by the timing of use.
- **Land requirements:** The efficiency of mechanisation depends on land availability and the size of farms. In the Eastern Cape of South Africa, small-scale farmers have access to 1ha of communal land but ideally require 5ha for mechanisation to be economically viable.
- **Inequality between farmers:** Access to machinery contributes to inequality between farmers. Additionally, as a result of the need for larger land areas for mechanisation to be viable, better-off farmers tend to expand by buying up/ amalgamating smaller farms which can disadvantage farmers with insecure land tenure.
- **Unemployment of farm labour:** Mechanisation requires better educated and trained workers to operate machinery and, at the same time, makes the entire farming process less labour-intensive. As a result, less educated workers (who are also often those without access to land) are left without employment.
- **Concurrent need for associated facilities:** As a result of improved land efficiency, mechanisation typically supports harvesting of greater yields. Appropriate storage facilities are therefore required and often must be constructed and/or expanded.

Female Farmer using a mechanical plough for soil preparation. **© GIZ**

early/dry planting and staggered planting. Early/dry planting requires an intensive effort, often within a short time period, in order to minimise the time the seeds are in the ground prior to rainfall occurring. Similarly, staggered planting requires more than one intense planting (and tending and harvesting) effort. This practice is thus only applicable if appropriate labour is available at the right time. In some cases, finances permitting, mechanisation is able to substitute for labour effort.

Availability of, and access to, equipment and machinery determines the success of changing the timing of planting practices. When early/dry planting and/or staggered planting are encouraged as part of a (minimum tillage) conservation agriculture system, as is the case in Zambia, it is not only labour requirements that are important, but also draught animals. This is because ripping needs to take place immediately prior to planting. Similarly, in Ethiopia, wheat farmers are resorting to the use of tractors for tillage because this typically shortens the time required for land preparation. Given that the rental cost of these is more expensive, it is not an option accessible to everyone.

3.3.4 Environmental externalities

Changing the timing of farming practices and technologies is undertaken with the intention of linking the crop production cycle with the availability and quality of environmental resources to support the growth cycle. As a result, early/dry planting, staggered planting and changing feeding times do not have negative environmental externalities. In fact, since this adaptation practice is typically utilised in combination with conservation farming, there can be environmental benefits. Minimum tillage encourages water infiltration and replenishment of soil moisture, which is not only good for crop growth, but also improves soil quality. Early planting may also extend the time during which land has crop cover, which can reduce the likelihood of soil degradation and erosion.

3.3.5 Accessibility to women farmers

Both male and female farmers participate in, and remarked on the benefits of, changing the timing of farming practices. However, labour availability can be a barrier for women farmers. Early planting requires significant labour input at one time, and may conflict with women's other roles. The socio-cultural constructions of gender roles, which mean that men typically own the livestock, can limit the access of women to draught animals. As a result, they are dependent on male family members to assist, or required to rent such services, which requires that they have access to the necessary financial resources. Staggered planting, on the other hand, enables even labour-constrained households to participate and better distributes the labour input requirements. Changing feeding times can also adversely affect women, who make up the majority of the workforce in poultry farms in South Africa. Feeding the chickens at night can either extend their hours of work, or potentially create the need for split shifts, both of which can interfere with other obligations, such as child care (despite the additional financial compensation). Travelling to and from work late at night may also pose personal safety risks.

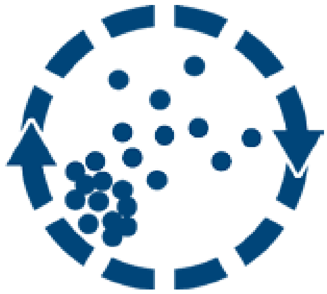
3.4 Changing the distribution and density of crops and livestock

The good practices and technologies making up the changing crop/livestock distribution and density category and the countries in which they were found to be good adaptations are:

Intercropping: Ethiopia; South Africa

Crop distribution (including row planting and spaces between rows): Cameroon; Ethiopia; South Africa

Reducing stock density: South Africa



Summary of how changing crop/livestock distribution and density can be a category of agricultural adaptation good practice:

- Intercropping, row planting, and increasing or decreasing the density of crops and livestock (depending on the resource availability) can improve yields and environmental sustainability
- In order for changing crop/livestock distribution and density to be successful, access to inputs, such as seeds and fertiliser, is important
- Having the technical knowledge on the most appropriate crop/livestock distribution and density is also important – and this knowledge may vary on the basis of information about the forthcoming weather and climate conditions
- Changing crop/livestock distribution and density has beneficial, or at least neutral, impacts on the environment.
- Providing they have land and the technical know-how, women farmers can benefit from these practices and technologies as they do not require additional inputs.

3.4.1 Benefits of changing the distribution and density of crops and livestock

Intercropping

Intercropping is widely practised by farmers around Africa. In its most basic form, it involves planting alternate rows of different seeds, so that each field has two planted crops. In the Eastern Cape of South Africa, intercropping entails planting up to around six to seven rows of different crops. In Burkina Faso, for example, it is common to intercrop dry cereals, such as millet and sorghum, with beans. Vegetables are also frequently intercropped with maize. In Ethiopia, haricot bean and maize are also produced by intercropping.

Intercropping maximises the effective utilisation of space and can lead to at least two crop outputs. Additional production is augmented by the diversification of crops produced, which also serves to spread risk. Plants with complementary water and nutrient requirements may be planted together thus ensuring better use of resources and therefore higher yields. The production outputs are partly enabled by the way in which intercropping provides protection for soil cover. This reduces the risk of soil degradation and erosion and also acts as shade, increasing the availability of soil moisture for production. The two crops are also often chosen to be mutually beneficial through, at a minimum, having different levels of relative dependence on soil nutrients. In some cases, as in Burkina Faso, nitrogen-fixing legumes are used in intercropping systems. They actively replenish nitrogen, thereby enabling greater production by the other crop. Intercropping can also be used as an adaptation to the late onset of expected rains. In Ethiopia, for example, when rainfall is late for haricot beans, intercropping is applied to utilise the residual moisture in the maize fields. There are also reported benefits of intercropping for pest management, with a reduced need for pest control methods. Intercropping also reduces the number of weeds as farmers can use a wider variety of herbicides (and pesticides) and this is very important as weeds consume much more water than crops.

Row planting

An alternative mechanism for changing density and distribution of crops is to plant in rows, and leave spaces between those rows. This adaptation mechanism is only an option where space and land availability is not a constraint. However, it does improve efficiency in other ways. Firstly, fewer seeds are required and the likelihood of each seed successfully growing to maturity is higher, as each has access to necessary soil nutrients and moisture. Yield increases of more than 200% were reported in some instances in Ethiopia, particularly for maize. Row planting reduces the

Example: Harvesting winter wheat when it is suitably dry in South Africa

Intercropping cereals and leguminous plants is very common across Togo. Leguminous plants commonly used are *Mucuna* sp (i.e. in Tchamba) and *Cajanus cajan* (i.e. in Vo Koutimé). According to the farmers, when grown in association with maize or sorghum these legumes have the ability to cover the soil and prevent the growth of weeds, especially *Imperata cilyndrica*. This is of particular benefit to the productivity of maize and sorghum because it improves soil fertility through the falling leaves and the decomposition of roots and branches. It also aids in the fight against weeds including *Imperata cylindrica*.

labour demand for weeding because the line furrows make removal easier.

Density of planting

Planting in rows does not necessarily require a reduction in the density of planting. As well as making the row layout more efficient, it is also possible to increase the density of rows. Many small-scale farmers in South Africa reported this strategy as a mechanism to adapt their maize crop to local conditions. Some farmers reported that they have started planting maize in narrower rows than in the past, which results in denser crops (the row width now planted by commercial maize farmers is 76cm, instead of 91cm). This was undertaken so that the closely packed maize plants would create dense shade on the top soil and thus reduce evaporation. In one case, the conservation agriculture applied by a farmer had resulted in fields that were too wet for optimal maize production and by increasing his plant population he was able to utilise all available water. That said, in other instances, large-scale commercial maize farmers were increasing the space between their rows in planting to respond to drier conditions, so that fewer plants had to compete for the available water. One farmer stated that he decides on the row width seasonally based on the expected rainfall – if it is expected to be dry he plants in wider rows. So the density of planting is one adaptation mechanism that maintains yields but can easily be modified on a seasonal basis to suit weather and environmental conditions.

Changing the density of livestock

The same principles for changing density and distribution of crops also apply to small livestock. The body temperature of chickens is 42°C and part of the reason that they are vulnerable to heat stress is that they are densely packed in multi-level cages with no airflow around individual birds. Chicken cages are a standard size and the allowable stocking density in South Africa is five birds per cage. Reducing stocking density to four birds per cage can help to reduce incidences of heat stress because airflow around the birds is encouraged and there are fewer birds generating heat inside the shed.

3.4.2 Requirements of an enabling environment

Unlike some of the other adaptation good practices, limits to the utility and appropriateness of this particular mechanism are already becoming apparent in different circumstances. This underlines the critical need to promote adaptation practices and technologies that are appropriate to the local context. In Ethiopia, for example, intercropping is only possible during normal rainfall years. In this case, maize is planted at the end of April, and haricot bean will be intercropped within the maize plants in early June. Given that nowadays rainfall rarely beings in April as was the case in the past, maize will be replaced with other crops meaning that intercropping will not be utilised. Also in Ethiopia, intercropping may not be suitable in extreme drought cases for maize and haricot beans. That is not to say that it could not be used with other crops – but reiterates how local context matters. In the same way, whilst farmers can reduce poultry stocking density now, if temperatures continue to increase then this will likely become economically unviable, and alternative adaptations will need to be sought.

3.4.2.1 Availability of inputs

As with many of the adaptation good practices and technologies outlined here, the greatest efficiency of changing the distribution and density of crops and livestock arises when additional inputs are available. In Burkina Faso, for example, despite the fact that many farmers have begun intercropping, the yields are not maximised because fertiliser use is sub-optimal. Intercropping without application of manure, composting or fertiliser can give rise to land degradation; and thus ultimately reduce productivity. Row planting is also made more efficient with the use of planting machines, which were particularly mentioned in Ethiopia.

A farmer with his livestock in Namibia. **© GIZ**

Inability to access these machines can reduce the efficiency of the process, and has to be offset by physical labour.

3.4.2.2 Technical knowledge and know-how

Intercropping, row planting and changing the density of livestock are only likely to be adopted by farmers who understand how the practices and technologies work and the benefits that they are likely to yield. Government and farmers' organisations have a key role to play in disseminating knowledge. In Ethiopia, both the research and extension services strongly support and promote intercropping in their extension package for both maize and haricot beans (despite the limitations observed above). Likewise, row planting is promoted for wheat, maize and haricot bean. Their justification for doing so is that it is a simple, cost-effective adaptation technique that works with all crops to increase yield, manage fields and reduce resource wastage in the production process.

The role of farmers' organisations in providing training and technical know-how to farmers is also a critical means of disseminating information. GrainSA plays a key role in training and skills development in South Africa, with funding from the Maize Trust, Agri-seed, and Agricultural Research Council (ARC). Small-scale maize farmers say that they are very accessible: that they get all their information from them and "call them day and night" for advice. According to the farmers, advisors from GrainSA are very accessible.

3.4.3 Environmental externalities

The practice of changing the distribution and density of crops and livestock has beneficial, or at least neutral, impacts on the environment. Intercropping is designed to improve soil quality, both in terms of nutrients and moisture availability. Weed control is also easier, which reduces the need for use of herbicides. In terms of livestock, an additional benefit of lowering the stocking density is that it is more humane. Controlled environment sheds for poultry will usually be kept at a higher stocking density than simple open-sided sheds, and small-scale farmers have an even lower stocking density than simple commercial sheds.

3.4.4 Accessibility to women farmers

The fact that intercropping, row planting and changing the density of livestock can be practised with knowledge, and do not necessarily require other inputs, means that they are typically accessible to female farmers as well as male farmers. Indeed, any practices and technologies that sustainably increase the density of production can benefit women farmers by enabling higher productivity from smaller plots of land. Reduced need for weeding under row planting also typically benefits women, who tend to take responsibility for this farming task, whether in their own fields or those under the control of men. The need for additional labour to undertake the row planting, as opposed to broadcast sowing, would largely be offset by the savings due to reduced need for weeding.

3.5 Tillage and associated practices

The good practices and technologies making up the tillage and associated practices category and the countries in which they were found to be good adaptations are:

Ripping: Zambia

Reduced/ no tillage: Ethiopia; South Africa; Togo

Repeated tillage: Ethiopia

Chaka hoes/ basin preparation: Zambia

Direct planting: Cameroon

Herbicide application for weed control: Zambia

Summary of how improved tillage and associated practices and technologies can be a category of agricultural adaptation good practice:

- Minimum tillage (and zero tillage) improves soil moisture quality for increased outputs
- Practising minimum tillage requires machinery and an increased need for herbicides, which may affect affordability
- Technical knowledge, and often demonstration of positive effects, is required to introduce this practise
- Like other conservation agriculture techniques, minimum tillage has significantly positive outcomes for the environment by reducing soil degradation and erosion, and suppressing the growth of weeds
- Limited accessibility of inputs (machinery and herbicides) can impede the use of this prac-tice by women farmers.

3.5.1 Benefits of minimum tillage

Minimum tillage

The downside of conventional ploughing is that it results in the soil drying out and disturbs the beneficial organisms that live in the soil, like earthworms. It also destroys the structure in the soil that naturally forms from plant roots and it removes organic matter. Minimum tillage methods allow more carbon to stay in the soil, which aids water retention, and they leave root structure in the soil that acts as a conduit for surface water to penetrate deeply. **Minimum tillage is a key mechanism for moisture conservation, which makes it a robust practice for drying conditions**. It will remain robust under increasing temperatures and changing rainfall regimes. Use of minimum tillage was widely reported by farmers in Ethiopia, South Africa and Zambia; and in Zambia was the most widely applied practice for adapting to the lower moisture conditions that are being observed.

Repeated tillage – still a common practice in Ethiopia

Although minimum tillage has gained momentum in line with the increased popularity of conservation agriculture, repeated tillage is still widely used in Ethiopia, particularly in high rainfall areas.

Ploughing is undertaken to aerate the soil and to kill weeds and is believed to improve water and air movement, increase root growth, facilitate germination and reduce the risk of crop failure during early cessation of rains.

Repeated tillage is currently most practiced by wheat farmers, but in areas where there is higher rainfall projected under climate change it will continue to be a sound adaptation practice for both maize and wheat farmers. On the other hand, it may not be an effective practice in areas experiencing increasing temperature conditions, especially for haricot bean farmers. It also has higher labour costs and, in the case of wheat, financial costs (because tractors are typically used, as opposed to traditional ploughs for maize).

Minimum tillage has additional economic benefits by reducing the costs of preparing land. As well as reducing the time and costs (labour and/or financial) associated with ploughing, minimum tillage reduces labour inputs required during seed germination and enables early planting (and thus a potential extension to the crop growth period). Minimum tillage is mostly associated with herbicide application for weed control and this helps reduce the weed pressure. Farmers reported that they are able to plant much earlier in the season due to the reduced need for weed removal, and because soil moisture is conserved under minimum tillage (see **section 3.3.1**). Sorghum and maize farmers and extension agents in Zambia reported improved efficiency in input and labour utilisation in production under minimum tillage and associated practices.

3.5.2 Requirements of an enabling environment

3.5.2.1 Additional inputs required

Minimum tillage requires the use of herbicides to control weeds, creating additional expense and issues of supply. The emergence of effective herbicides to control weeds is one of the factors that makes minimum tillage possible as farmers no longer have to mechanically control weeds with ploughing. Weed control is very important in the context of climate change because weeds have a higher water requirement and can outcompete crops for moisture. In Ethiopia, farmers reported a shortage of supply of herbicides. In Zambia, farmers are concerned with the exclusion of herbicides from the government-subsidised “Fertiliser Input Support Programme” that is mainly supporting maize production.

Expensive heavy equipment is necessary to practice minimum tillage. Since the soil has not been ploughed, the planting of seeds is more difficult. Heavy planters with large tractors are thus re-quired, which can create a barrier to adoption among small-scale farmers. In South Africa, the De-partment of Agriculture has conducted research and trials the results of which suggest that it is economically feasible to switch to minimum tillage and that it is cheaper and more sustainable in the long-run because it requires less diesel for machinery. However, perceptions in South Africa among small-scale farmers are that it is too expensive to switch. In Zambia, small-scale farmers expressed a desire for a scheme to facilitate access to the implements necessary to effectively practise minimum tillage. The Conservation Agriculture Scaling-Up programme is one such major initiative that is promoting minimum tillage in Zambia to support climate change adaptation and soil conservation.

Availability of heavy equipment impedes the uptake of minimum tillage. Whether farmers expect to use mechanised or draught-powered equipment, availability is often an issue due to high demand. In Zambia, small-scale farmers commonly use Fitarelli planters, chaka hoes and rippers. In addition to their application as ripping implements, the Fitarelli and ripper also enable farmers to plant early with the first rains thereby allowing the maize, cotton and sorghum crops to mature and escape dry spells (see **section 3.3.1**). The use of animal-driven Fitarelli planters and rippers is constrained by low rates of cattle ownership. Cattle diseases have contributed to this problem in the livestock-maize systems of the Southern and Central provinces of Zambia. In the Eastern Cape of South Africa, farmers have to hire and share equipment. The few tractors that are actually owned by farmers in the study area are in very poor condition and have a small horsepower of only about 50 kilowatts, meaning that minimum tillage – which requires big powerful implements – is not possible. Exacerbating the situation is the fact that small-scale farmers do not qualify for loans because of the land tenure system – very few black farmers in the Eastern Cape actually own their own land, so they are not able to demonstrate security for a loan.

3.5.2.2 Technical knowledge

Even when minimum tillage is recognised as a good practice, farmers do not always have the technical capacity to implement it themselves. Government support is essential in providing technical knowledge transfer. In Zambia, the government has adopted conservation agriculture as a strategic framework for improved crop production since 2009, and it is currently the most widely supported innovation countrywide. Extension officers perform training and conduct on-farm demonstrations of minimum tillage with a focus on this practice’s role in climate change adaptation (see **Figure 7**). Farmers highlighted that ongoing support is required in terms of demonstrations on the technicalities of handing the implements and agronomic practices, particularly the use of herbicides since this is so key in the success of minimum tillage.

Technical knowledge can also be supported by donors and farmers’ organisations. In Zambia, the Ministry of Agriculture is supported by the Food and Agriculture Organisation (FAO) of the United Nations (UN) in promoting conservation agriculture country-wide through a programme called Conservation Agriculture Scaling Up (CASU). In South Africa, small-scale farmers in particular have received training and support from various institutions, most notably GrainSA and the CDC.

Demonstration of the practice and its success is also important to encourage adoption. In the Eastern Cape of South Africa, a few of the small-scale farmers had heard of minimum tillage but stated that they were unwilling to try it out until they knew more about it and had seen its success on their neighbours’ farms. Although most farmers had not heard of minimum tillage, when it came up in the course of interviews they expressed interest in it and requested that the GrainSA development officer inform them about it. In Zambia, farmers' perceptions are that it is labour-intensive, especially for the hand hoe-based innovation components. They also subscribe to the myth that herbicides destroy the soils.

Awareness of how to use inputs to optimise the effectiveness of minimum tillage is also important. Availability and appropriate application of herbicides is essential knowledge for farmers. In Zambia, such agrochemicals are available countrywide. However, farmers there and in Ethiopia identified a desire for support to manage the application of herbicide.

3.5.3 Environmental externalities

Like other conservation agriculture techniques, minimum tillage is significantly positive in terms of its environmental impact. It requires less fertiliser, results in reduced rates of soil degradation and erosion, and tends to suppress the formation of weeds.

3.5.4 Accessibility to women farmers

Minimum tillage requires a lesser input of labour compared to ploughing. As a result, women farmers have to spend less time weeding, which they may do in their own fields and/or in those of male relatives. However, the requirement for heavy equipment, draught animals and herbicides as inputs may act as a barrier to resource-constrained farmers. It is recommended that extension officers make a concerted effort to ensure that their trainings are accessible to women (i.e. held at appropriate times and in appropriate places) and that they are prioritised for the loan of equipment where possible in order to address this potential gap.

Examples of the involvement of women farmers in minimum tillage in Zambia

In Zambia, minimum tillage is currently the most widely supported system. Principally, there are two forms of minimum tillage systems that have been adapted at farm level: hand hoe basins and ripping using draught power. Women are the major source of farm labour and are actively involved in these tillage systems. The increased labour demand under minimum tillage can offer them opportunities to increase their income through informal employment (**Figure 7**).

Figure 7: Women learn minimum tillage and ripping techniques in Chibombo, Zambia

Conservation Agriculture

Conservation agriculture is based on several key facets: crop residue retention, crop rotation, leaving fields fallow, and minimum or no tillage. Conservation farming methods are in widespread use by both small- and large-scale farmers.

For large-scale farmers it makes sound economic sense: inputs are typically reduced (particularly in the long-run) and outputs increase. If small-scale farmers have access to the required technical knowledge and inputs (e.g. rippers, planters, hand and chaka hoes – and in some cases mechanised equipment and herbicides) they are also able to capitalise on their labour availability and increase outputs.

Through its focus on soil moisture conservation, conservation agriculture methods are well recognised as providing some of the best options for farmers to continue farming productively under changed climatic conditions, especially with regards to reduced water availability and increased incidence of extreme events.

Since the different methods of conservation agriculture variously arose as important in different contexts and under different enabling environments, they have here been designated as different examples of good practices. Mulching and fallow are both addressed in **section 3.2** (as part of soil and water management), and minimum tillage is addressed in **section 3.5** (as part of tillage and associated management practices).

Crop rotation does not feature as a good practice in its own right, taking into account the different country contexts and farming scales. However, it was highlighted as important in some contexts. In South Africa, it is not only practiced by small-scale farmers in order to provide variety in their diet, but it is also an essential part of commercial wheat farming where wheat is rotated with commercial crops or other food crops. A common crop for wheat farmers to rotate with is canola as it is nitrogen fixing and because planting canola one year leads to noticeable improvements in the wheat yield the following year as a result of soil improvements (a crop rotation of wheat-canola-wheat-canola gives a 20% higher yield than a wheat monoculture). Canola is also susceptible to entirely different diseases than wheat; alternating the two crops can break disease cycles. In addition, different herbicides are available for use with the two different crops, so weeds are more easily controlled.

3.6 Crop and livestock diversification

The good practices and technologies making up the farm crop and livestock diversification category and the countries in which they were found to be good adaptations are:

Crop diversification/ shifting to more drought-resistant crops: Ethiopia; South Africa; Togo; Zambia

Diversifying to livestock farming: South Africa; Zambia

Summary of advantages and disadvantages of crop and livestock diversification as a category of agricultural adaptation good practice:

- Crop and livestock diversification can be temporary or permanent, and spatial or temporal in nature – but ultimately its aim is to spread risk and reduce potential losses/maximise gains as a result of variations in the production environment
- The type of crop and livestock diversification that can be practised varies with land availability, access to inputs (such as seeds) and technical knowledge
- Crop and livestock diversification can have positive environmental impacts: conversion to alternate crops can increase biomass, assist pest and disease management, and enhance biodiversity and carbon sequestration potential
- Land availability and security of tenure and technical knowledge are a key determinant of whether crop and livestock diversification can be practiced by women farmers.

3.6.1 Benefits of farm crop and livestock diversification

Crop and livestock diversification is widely practiced by farmers in different agricultural sub-sectors at different scales across the continent. Changing weather and climate is one of the key reasons cited for crop and livestock diversification. As an adaptation practice, it is likely to be robust under changing climate conditions and therefore become even more widely accepted. Increased temperatures, changing water availability and more extreme weather events will make some farming areas less suitable for the crops that are grown there now, thereby necessitating the change to growing different types of crops. Planting a wider variety of crops is another adaptation to climate change as it will ensure that farmers' income and livelihoods are stable (and may even improve).

Of the observed diversification, there is a particular emphasis on improved drought-tolerance. In some cases, diversification involves **planting a different cultivar or variety of the same crop, and in other cases a different crop altogether**. In Zambia, all farmers interviewed grow more than one maize variety, and more than one crop. Diversification within varieties is mainly centred around early and medium maturity varieties. The motivation for doing so is that should conditions impede production of one crop, the other(s) will survive, thus allowing maintenance of food security and/or income.

Diversification can be a temporary or permanent strategy, and is often driven by changes in climate. In some cases, diversification is temporary – resulting in a different crop being grown for one or a couple of seasons. In Ethiopia, for example, when rainfall variation differs significantly from the norm farmers might shift from haricot beans, wheat and maize to teff. In other cases, it is more permanent. In Ethiopia, the projected increase in temperature is likely to affect the wheat and maize growing areas in the long term, and thus farmers may have to shift to more drought-resistant cultivars or more drought-resistant crops. In South Africa, several small-scale vegetable farmers in the Eastern Cape reported that they are now planting more potatoes than previously, largely because potatoes "do well during droughts". In addition to potatoes, butternut squashes "do very well in dry soil" and are sometimes planted in preference to previously popular crops. Switching to more drought-resistant crops will be an important adaptation in the future because it will allow food security to be maintained in a changing climate.

Diversification can take place over space or time. In spatial diversification, farmers allocate their available land to different crops. In temporal diversification they grow some crops in the winter and some crops in the summer. In Zambia, for example, green maize and horticultural crops (leafy vegetables and tomatoes) are grown in winter (often requiring small-scale irrigation), and then others (e.g. yellow maize) are grown in the summer, under rain fed conditions.

Agroforestry: an example of diversification in Togo

In Togo, farmers are capitalising on both spatial and temporal diversification through the introduction of agroforestry systems. Agroforestry refers to all the systems and techniques of land use where crops/livestock and trees are deliberately combined as a spatial arrangement or temporal sequence taking place on a same plot. It has become popular among both men and women farmers in a variety of contexts and regions, including the districts of Kloto, Vo, Yoto, Moyen-Mono and in the savannah region. This practice involves linking an annual agricultural crop to hardwood in a short cycle. Agrosilviculture retains the status of agricultural land: it consists of large cultivated plots from 8 to 24m or more, allowing mechanisation and the use of fertilizers and pesticides, thus ensuring a satisfactory level of production for several years. This option requires the choice of intensive silviculture or "true tree culture". Parklands refers to associations of various annual crops with a sparse cover of various trees, as Albida, shea (*Vitellaria paradoxa*) and locust bean (*Parkia biglobosa*), which are protected by farmers because of their multiple uses.

In South Africa, large-scale commercial farmers in the Western Cape alternate between different cash crops on a multi-annual cycle. The four cash crops grown in rotation in the Southern Cape and the Swartland are wheat, oats, barley and canola.

Diversification with livestock

In an attempt to spread risk and maintain or enhance productivity and incomes, farmers are also diversifying into other farming systems. For crop farmers this may mean introducing livestock; for livestock farmers it may mean selling by-products; or it may involve diversifying into a new farming system that gives rise to at least two products. Both small- and large-scale crop farmers have begun introducing livestock. In Zambia, for example, small-scale farmers in the dry agro-ecological zone are engaging in sorghum-livestock based farming systems. They grow sorghum, cotton, maize, bulrush millet, cowpea and sesame. In addition to the field crops, off-season crop production for vegetables and green maize is commonly practiced. The major livestock types reared include cattle, goats and chickens. These enterprises are integrated. Livestock are a source of manure which plays a critical role in moisture conservation and soil fertility in field crop and vegetable production. In South Africa, poultry farmers are able to use waste from their birds as an input for vegetable production, or pastures for cattle. One poultry farmer sells the bird waste as organic sterile fertiliser to neighbouring farms to raise additional revenue.

Commercial wheat farmers in South Africa explained that such diversification is popular because **crops are higher risk but can yield a high return whereas livestock are lower risk but also result in lower returns**. They keep either cattle or sheep, or both, along with farming wheat. Farmers stated that crop farming is more risky because input costs are high and it is possible that bad weather will destroy most of the yield, but that the potential gains with crop farming are very high. When the weather is favourable, as in the last three years, farmers can obtain better yields and make a large profit. Livestock, on the other hand, offer a more steady income. The potential profits are not as high but if the weather is bad or any other factor is negatively influencing the livestock, it is possi-ble to sell them and recoup the input costs. Farmers rely on the income from their livestock during bad cropping years. The balance between land under cropping and land under improved silage for livestock differs between farmers in relation to their farm size, preferences, and how much risk they are prepared to expose themselves to.

For small-scale farmers in the Eastern Cape of South Africa, livestock are easier to farm because fences are not required and communal land can be used with no extra effort, cost or risk to the farmer. There is abundant grassland in the region and cattle and sheep can utilise this area. In regions of South Africa where rainfall is inadequate for crop cultivation, livestock are a good agricultural option, so this adaptation could increase farmers' resilience to climate change. In the Eastern Cape and western Free State, raising livestock was a popular option for farmers to diversify their income, and it was noted that cattle could always be sold if the weather was unfavourable as opposed to a crop, which will not generate any profit if it fails. One farmer suggested that he would start farming poultry if his maize stopped being profitable.

3.6.2 Requirements of an enabling environment

3.6.2.1 Inputs

As with many of the other adaptation practices, access to sufficient land is a prerequisite of crop and livestock diversification. One small-scale farmer in the Eastern Cape,

Crop and livestock diversification is likely to continue into the future

As changing temperatures and rainfall patterns continue to be reflected in changing characteristics of the biophysical environment, crop and livestock diversification is likely to continue into the future. In southern Africa, for example, the changing temperature belt is likely to reduce the viability of maize, encouraging farmers to switch to more drought-tolerant cereal crops. Commercial farmers in the Free State of South Africa indicated that they will switch to farming sunflowers when maize becomes infeasible. Sorghum is a more drought-tolerant staple than maize and its use is often advocated as an adaptation among small-scale farmers. In Ethiopia, increase in temperatures will affect moisture availability in the highlands and it is expected that the emerging trend to shift from growing haricot beans to teff will continue.

South Africa, who only grows one type of vegetable, was very aware of the risk that poses. He would like to diversify but at the moment he does not have the land or resources to do so. Lack of available land can also be a barrier to engaging in agroforestry in Togo. The practice, though beneficial to the environment and crop production, also exacerbates issues of land availability. By its very nature, agroforestry functions by growing trees that act to improve soil fertility. The trees may increase maize productivity for several years, as it is well shaded and benefits from a soil in which the trees are regularly depositing organic matter. However, when the trees become too large and do not leave enough space for crop cultivation the field is abandoned and left as a reforested area. Clearly this has implications in terms of land availability in the long term and is only likely to be sustainable where there is enough land to do this.

For crop diversification, it is also important that farmers have access to appropriate seeds. With temporary diversification, seed availability is often the biggest constraint. In Ethiopia, for example, maize and haricot bean farmers make a last-minute decision to grow a different crop if the rain onset is late. In these cases, maize and haricot beans are normally replaced with teff. In addition to the expense of replacing seeds, supply shortage on the market is often experienced. Haricot bean seeds are often unavailable. The supply of maize and wheat seeds is relatively better and wheat seeds in particular are obtained through farmer-to-farmer exchange. With permanent diversification the affordability of seeds is important, particularly if farmers are diversifying from traditional seeds into hybrids, early maturing, or drought-tolerant varieties.

For temporal diversification, when more than one crop is grown in a year, water often needs to be available to support the dry season crop. In Zambia, for example, horticultural crops grown in the winter require watering for optimal production. When small-scale irrigation is not available, it can be grown under a traditional practice using residual moisture known as “Ncelela”, which takes place following the water recession along the Zambezi River/Lake Kariba in southern Zambia.

3.6.2.2 Demand for new products

The sustainability of crop and livestock diversification is clearly dependent on there being a demand for the new products. Among small-scale subsistence farmers there can be reluctance to switch from one staple food crop to another, even with the evidence of decreasing yields and growing risks of crop failure under evolving climate conditions. This is because the existing crops are appropriate for taste and cultural preferences. Ensuring that new products are culturally appropriate is thus essential. In some areas of southern Africa, for example, where cassava and sorghum are being promoted as alternatives to maize, adoption can be low due to the cultural preference for maize. By contrast, if crop and livestock diversification is to involve the inclusion of commercially-oriented crops or livestock, there must be evidence of an effective market to sell those products.

3.6.2.3 Farmers require training and know-how

Farming practices and technologies vary depending on the crop and livestock type. As a result, changing to or adding a different crop or livestock to the farming system requires understanding of how to effectively farm it. Raising awareness of alternative seeds or different cultivars, or different crops, is thus essential. This can be undertaken by extension services, farmers’ days, field days and awareness campaigns.

3.6.3 Environmental externalities

Adaptation practices and technologies categorised as crop and livestock diversification have both positive and negative impacts on the wider environment, depending on what the crop and livestock diversification entails and how it is carried out. Conversion to alternate crops can increase biomass, biodiversity and carbon sequestration potential. Agroforestry also serves this function. Crops such as legumes, which are nitrogen-fixing, can also improve soil quality, in turn increasing the likelihood of other crops being successfully planted. In South Africa, the temporal diversification of farmers rotating crops from season to season showed environmental benefits in this manner: canola is nitrogen-fixing and thus soil replenishing. As a result, it can lead to noticeable improvements in wheat yield in the following year.

3.6.4 Accessibility to women farmers

The wide variety of crop and livestock diversification options means that these can both benefit or disadvantage women, depending on the circumstances. Insecurity of land tenure and lack of land availability may impede women's ability to diversify crops. This is typically the case for agroforestry farming systems, which require additional land to be used in the long-term. Affordability of crop and livestock diversification may limit women's options relative to men's – for example, in terms of access to different cultivars. Similarly, extension work addressing a lack of technical knowledge and know-how may have to be targeted to women and their crop and livestock diversification preferences.

Women may also be affected by crop and livestock diversification undertaken by their husbands, even if they do not farm directly themselves. They should generally benefit from production that is more secure in the context of a changing climate, in terms of having greater food availability and/or income from sales. On the other hand, shifting to other crops may change the dietary habits of households and may also reduce availability of staple foods for the household. In Ethiopia, when farmers substitute teff for haricot bean and maize, there are potential implications for food security. Haricot bean is often a major source of protein to the household. Teff, on the other hand, is often a cash crop and is not used for household food (in the rural areas).

Mitigation co-benefits ("Climate-smart agriculture")

Many sound agricultural adaptation practices and technologies also have mitigation co-benefits, and thus can be classified as "climate-smart agriculture". Coined by the FAO of the UN, climate-smart agriculture increases food security through sustainable intensification that will be robust in the face of a changing climate and does so in a way that maximises the ability of the soil to sequester carbon.

Soil contains organic matter and thus can act as a carbon source or sink, depending on how it is used. The quantity of soil organic carbon (SOC) reduces when soil is cultivated – partly brought about by the turning of soil in preparation for planting. This carbon is released into the atmosphere, contributing to greenhouse gas emissions (and thus the soil under these circumstances is acting as a carbon source). Depleted SOC can be restored through the adoption of sound land management practices, which increase the soil's capacity for enrichment by atmospheric carbon dioxide. Reduced emissions from existing SOC, and active enhancement through carbon sequestration from the atmosphere represent a "win-win" benefit. Taking carbon out of the atmosphere and acting as a carbon sink means that agriculture has a large potential role to play in mitigation of climate change (hence the policy debates about Reducing Emissions from Deforestation and Land Degradation +, or REDD+).

As outlined above, three of the good practices and technologies are various components of the overall approach known as conservation agriculture. Tillage and associated practices and technologies and elements of soil and water management are part of the land management techniques that enable carbon sequestration by the soil. These practices and technologies thus have co-benefits of mitigation, in addition to enabling adaptation to climate change.

Large scale farming system. **© GIZ**

Small scale farming. **© GIZ**

3.7 Differences between large-scale and small-scale farmers

Both large- and small-scale farmers use the categories of good practices and technologies identified above. However, the way in which they are applied varies with the scale and the ultimate purpose of the farming. Whilst optimal production is arguably the key aim at both scales, commercial orientation is typically focused on maximizing production even if this requires taking some risks. In contrast, farming that is primarily intended for the farmer's own use and informal selling tends to engender a risk reduction approach. As a result, it is important to note that many commercially-oriented large-scale farmers did not identify their practices and technologies as agricultural adaptations. Instead, they are seen as good farming practices and technologies to maintain and improve yields in the changing environment (and of course the changing climate is a key component of that changing environment).

The availability of technical and financial resources to large-scale versus small-scale farmers is the major difference. The two are typically closely related and mutually reinforcing, because having financial resources enables the purchase of technical know-how (through access to education and information); whilst applying sound technical resources enables accumulation of further financial resources. Successful commercial farmers are typically supported by farmers' organisations that can access the latest international knowledge developments, including advancements in practices and technologies and equipment. This affects accessibility of improved seed varieties and conservation agriculture-related practices and technologies (including soil and water management and minimum tillage). In addition, access to improved climate services enables more accurate changing of timing of farming practices, changing crop/livestock distributions and density, and crop and livestock diversification. In comparison, many small-scale farmers are contingent on government extension services for their information or on the application of traditional methods.

In South Africa, one of the farmers' organisations, GrainSA, undertakes training and skills development for small-scale farmers with funding from the Maize Trust, Agri-seed, and ARC.

As well as having greater financial resources, large-scale farmers have high rates of return which means that they are more aware of technological developments. The scale of returns also means that they are typically able to overcome any barriers of availability by utilising global markets, and not just local ones. They are able to afford seed varieties that have been privately produced and thus are only available at high cost. In Burkina Faso, for example, the modified seed variety "cotton BT" is produced by private cotton companies, and is inaccessible to small-scale producers due to its high cost. Similarly, GM seeds in South Africa are typically twice as expensive as non-GM seeds, which largely restricts their use to commercial farmers. Small-scale farmers, in contrast, are more dependent on publicly-produced seed technology, or those varieties that have been tested for local conditions by government-run research institutes and parastatals.

Environmental externalities can be determined by the scale of farming – and the particular context may thus require regulations to ensure a positive balance. That said, it cannot be assumed that negative (or positive) environmental externalities are directly correlated with scale. The greatest potential negative environmental externality of the good practices and technologies identified here (as well as more widely) is the application of chemical fertiliser. Chemical fertiliser is widely used in commercial farming. With the use of chemical fertiliser, soil is tested for levels of soil nutrients and suitable fertiliser recipes are then used where required. In South Africa, the farmers send samples of their soil to laboratories throughout South Africa for testing and some send soil to international laboratories. Small-scale farmers in the Mthatha region of the Eastern Cape are assisted in their soil testing by GrainSA who notify them when it is required and then send the samples to appropriate South African laboratories – although this is not necessarily available in other countries.

Negative environmental effects of fertiliser are not necessarily directly related to scale, but are also dependent on the precision and timing of application. Commercial farmers apply fertiliser over large land areas. However, in general, they employ precision systems whereby the nutrient composition of each field is mapped and specific cocktails of fertiliser are applied to the exact areas required. This precise application of fertiliser can reduce the total amount used, cut down on costs to the farmer, and cause less environmental degradation than conventional fertiliser application. Small-scale farmers, on the other hand, with less technical knowledge may not apply the chemical so precisely and thus risk soil degradation and leaching followed by eutrophication of nearby water sources. This is a very real risk given the number of governments that provide subsidised fertiliser to small-scale farmers.

Large scale Maize production. **© GIZ**

3.8 The importance of weather and climate information

While not identified as a good practice in its own right – although, in Togo, the use of rain gauges did emerge as a top practice – availability of, and access to, weather and climate information is vital to the success of the six overall good adaptation practices and technologies. In order for farmers to know whether or not it is worth adopting a new practice or technology they must know what the future conditions will be. As has already been shown, many of the practices and technologies identified above require costly inputs, both in terms of time and money, and farmers cannot be expected to make these investments if they are uncertain of what the future holds with regards to weather and climate.

Weather and climate information is available but there are a number of barriers to its effective use by farmers. Accessibility is the first barrier – often the best information is available via the internet but this avenue may only be an option for wealthier commercial farmers. Even when small-scale and subsistence farmers can physically access the information, it is usually written in a scientific language which is inaccessible to farmers with low levels of formal education. In South Africa farmers wanted forecasts which were written in a way they could understand and which contained some level of "interpretation" – for example, advice on what they should do given a particular forecast. Agricultural extension services have an important role to play in making weather and climate information more accessible.

Water and Climate information being provided. © GIZ

A second barrier is that of the timing of the dissemination of information – oftentimes information reaches the farmer too late for them to act upon it. Communication networks need to be improved so as to ensure that farmers – especially those who do not have access to their own sources of information such as the internet – receive information in time and regularly. In parts of southern and eastern Africa there have been successful examples of this process taking place via cell phones[12]. The way in which information is disseminated is also important and there may be gender considerations to take into account with men and women farmers preferring to receive the information in a different format – for example, over the radio or in face-to-face meetings with extensions officers.

Finally, the levels of confidence in weather information are a significant barrier to effective use. Concerns exist over the accuracy of the information and credibility can be negatively affected if several forecasts prove to be incorrect. This relates to the limitations of probabilistic forecasts and their level of skill – and the lack of understanding of the scientific process underlying their generation.. More accurate forecasts and awareness raising amongst farmers about the limitations of forecasts would go some way to addressing this concern.

12 Vincent, K., Cull, T., Dalin, C., Deryng, D., Fallon, A, Archer van Garderen, E., Conway, D., Dorling, S. And Landman, W., submitted, Seasonal forecasts; perennial problems? User perspectives on the 2014-15 season in South Africa, Climate Risk Management

4 CONCLUSION

The report has outlined six categories of adaptation good practices and technologies that have been identified from empirical research in six case study countries. It is important to reiterate that mention of a category in its own right does not mean that every possible option/activity that falls under that category (in the traditional sense of agricultural activities) is a good adaptation practice. However, evaluation and scoring of observations of adaptations and technologies in Burkina Faso, Cameroon, Ethiopia, South Africa, Togo and Zambia led to identification of various good agricultural adaptation practices and technologies that fall under these broad six categories. The good agricultural practices and technologies, then grouped into the six final categories, have been observed to be successful in more than one country and in more than one agricultural sub-sector. The six categories under which the good practices and technologies fall are: use of improved seeds; soil and water management; changing timing of farming practice; changing crop/livestock distribution and density; tillage and associated practices; and crop and livestock diversification.

Whilst many of these practices and technologies are not new, they have been observed to – at a minimum – sustain and ideally improve agricultural production in the context of a changing climate. Climatic changes are already being observed in Africa and are projected to increase into the future. The six categories of practices and technologies have been effective adaptations thus far and a criterion of evaluation was anticipated effectiveness in the context of further change. Since the exact nature of change will vary from place to place, assessing the likely appropriateness of each practice based on the particular biophysical environment and climate context is critical.

The enabling environment that is required in order for these categories of practices to be classified as adaptations varies, and its precise nature depends on the practice itself. Table 4 summarises the key requirements for introducing/scaling up the good practices. Government has a vital role to play in regulating and/or supporting several key factors which will determine the success or otherwise of these practices and technologies in supporting adaptation to climate change. This is particularly important to ensure affordability for small-scale farmers, and may require smart subsidies and/or distribution of free inputs in order to stimulate demand. Strategies to ensure availability of expensive machinery and equipment are also critical, as these determine the viability and efficiency of many of the practices.

The continuing success of the technology-related categories of practices and technologies – for example use of improved seeds – is highly contingent on ongoing research and testing, for example to breed seeds that are suitable for evolving local conditions. It is important that government supports this research because when it is driven by the private sector the benefits tend to be skewed towards farmers who can afford their products. Ensuring that effective markets exist is also critical to ensure the availability of appropriate inputs, including seeds and farming chemicals such as herbicides. This is particularly important in remote rural areas. It is also important when governments want to develop value chains and encourage the entry of new farmers into the market.

When improved seeds and appropriate markets exist, it is also important to raise awareness of these new technologies and market availability to ensure that adaptations are accessible to all farmers. Demonstration of the effectiveness of practices and technologies was deemed particularly critical where additional financial resources are required. This is the case for minimum or no tillage, where equipment and machinery is required prior to planting and where herbicides are necessary throughout the growing period; and for improved seeds (e.g. hybrids and early maturing varieties). Farmers' organisations can play a key role in supporting this, by holding farmers' days and running demonstration plots. Farmers' organisations can also support extension services in providing ongoing technical assistance and training in how to successfully implement the practices and technologies as appropriate to the local contexts in order to enable adaptation.

The environmental effects of the categories of good practices and technologies will be at worst neutral and at best positive provided that the practices and technologies are appropriately implemented and managed. The essence of agricultural adaptation is to undertake sound farming management practices and technologies but also to ensure that those practices and technologies will be robust in the context of a changing climate. Sound farming management practices and technologies involve sustainable utilisation of natural resources in order to optimise production now and in the future. Climate variables, such as temperature and rainfall, are critical in affecting natural resource availability. For this reason, the good practices and technologies are based on linking farming with resource availability. Farmers' organisations and extension services are also critical in this regard to ensure that and technologies are implemented effectively in order to have neutral or positive impacts on the environment. There is the scope for the co-benefit of mitigation when soil is effectively managed.

Women farmers are largely marginalised relative to men, and addressing this situation requires a number of transformations as well as an explicitly gender-sensitive approach in agricultural policy and support programmes. The major disadvantage that women face relates to security of land tenure and access to land. Whilst many countries are addressing their land laws, active approaches to improve women's access to communal land is critical. At the same time, recommended adaptation practices and technologies for men and women farmers, even within the same locality, may need to be different. Adaptations that are contingent on significant inputs of physical labour are likely to disadvantage women relative to men, and thus in places where these are appropriate and encouraged, corresponding practices and technologies should be made available to women. For example, in areas of high soil erosion, men farmers may be able to create bunds whereas women farmers could be supported to introduce vegetation bands, through both technical assistance and, potentially, provision of seedlings to plant.

The agricultural adaptations within the six categories of good practices, and the enabling environment to support adaptation, are consistent with the strategic action areas as outlined in NEPAD's Implementation Strategy and Roadmap to achieve the 2025 vision on CAADP[13]. Supporting agricultural adaptation will be an essential element in effectively addressing these strategic areas and ensuring that the CAADP target of 6% annual growth in the agriculture sector is met, even within the context of a changing climate.

Mulching as a good agricultural practices. **© GIZ**

[13] http://www.nepad.org/system/files/Implementation%20Strategy%20Report%20English.pdf

Table 4: Summary of key requirements for introducing/scaling up the categories of good practices

Good practice	Enabling environment	Environmental consequences	Ensuring accessibility to women farmers
Use of improved seeds	• Research to develop seeds appropriate for the soil and climate conditions • Markets to supply seeds • Demonstration plots • Technical assistance relating to seed existence and how to farm	Local breeding of seeds should ensure no negative environmental externalities	• Security of land tenure • Subsidies to enable affordability • Provision of varieties requiring minimal tending during the growing season
Soil and water management	• Research to determine most appropriate methods for different biophysical environments • Availability of land and security of tenure • Availability of residues for mulching • Technical assistance to select most appropriate mechanism and how to apply it	Actively aims to protect the soil, and thus have positive environmental benefits	• Security of land tenure • Labour availability • Technical assistance on most appropriate method accessible to women
Changing timing of farming practice	• Communication of weather information • Accessibility of necessary machinery for planting • Combine with other practices, such as appropriate seeds (e.g. early maturing) or fertility-enhancing inputs • Technical assistance to provide advice on options from season to season	Aims to link seed growth needs with weather-related resource availability, and thus minimise risk of degradation	• Labour availability
Changing crop/livestock distribution and densities	• Availability of required inputs (e.g. seeds, manure) • Technical assistance to make appropriate selection for biophysical environment	Technical assistance should ensure that new distributions and densities are compatible with environmental resource availability	• Technical assistance to make appropriate selection, avoiding options with additional labour requirements
Tillage and associated practices	• Demonstration of effectiveness • Availability and affordability of herbicides • Accessibility of planting machinery	Positive impacts on soil moisture content	• Subsidies for affordability • Technical assistance in options that do not have additional labour requirements
Crop and livestock diversification	• Availability of land and security of tenure • Technical assistance to raise awareness on options appropriate for the biophysical environment • Access to markets for inputs and products	Technical assistance should ensure options are compatible with environmental resource availability	• Security of land tenure • Gender-sensitive technical assistance on appropriate options

ANNEXES

ANNEX A: Steps to finalising sub-sectors

Table A.1: Step 1 - Matrix of most important sub-sectors in each of the six countries:

Commodity	Burkina Faso	Cameroon	Ethiopia	South Africa	Togo	Zambia
Sorghum	Y	Y	Y	Y	Y	Y
Millet	Y	Y	Y	Y	Y	Y
Maize	Y	Y	Y	Y	Y	Y
Cotton	Y	Y	Y		Y	Y
Rice	Y	Y			Y	Y
Beans (haricot in Ethiopia; soya in Burkina Faso)	Y	Y	Y	Y	Y	Y
Yam	Y	Y			Y	
Potato	Y	Y	Y	Y		Y
Cassava		Y			Y	Y
Sweet potato	Y	Y	Y	Y	Y	Y
Vegetable (incl. tomatoes in Cameroon)	Y	Y	Y	Y	Y	Y
Cocoa		Y			Y	
Fowls	Y	Y		Y	Y	Y
Pigs	Y	Y		Y		Y
Cattle-beef	Y	Y	Y	Y	Y	Y
Coffee		Y	Y		Y	
Sesame	Y		Y			
Wheat	Y		Y	Y		Y
Sugar cane			Y	Y	Y	Y
Tea			Y	Y		
Bees		Y	Y	Y		Y
Groundnuts	Y	Y			Y	Y
Dairy				Y		Y
Goat	Y	Y			Y	Y
Plantain/banana		Y	Y	Y	Y	
Sheep	Y	Y	Y	Y	Y	
Apples			Y	Y		

Table A.2: Step 2 - Matrix of top 10 agricultural sub-sectors in each of the six countries.

Commodity	Burkina Faso	Cameroon	Ethiopia	South Africa	Togo	Zambia
Sorghum	Y	Y	Y		Y	Y
Millet	Y		Y			
Maize	Y	Y	Y	Y	Y	Y
Cotton	Y	Y	Y		Y	Y
Rice	Y				Y	Y
Beans (haricot in Ethiopia; soya in Burkina Faso)	Y		Y		Y	Y
Vegetable (incl. tomatoes in Cameroon)	Y	Y		Y	Y	Y
Cocoa		Y			Y	
Fowls	Y	Y		Y		
Cattle-beef	Y	Y	Y	Y		Y
Wheat			Y	Y		
Groundnuts		Y			Y	
Diary			Y	Y		Y
Goats	Y					Y
Sheep	Y			Y	Y	

Table A.3: Step 4 - Matrix of the existence of observed adaptation practices and technologies in the 11 sub-sectors in each country

Commodity	Burkina Faso	Cameroon	Ethiopia	South Africa	Togo	Zambia
Sorghum	Y	Y	Y		Y	Y
Maize	Y	Y	Y	Y	Y	Y
Cotton	Y	Y			Y	Y
Rice	Y				Y	Y
Beans (haricot in Ethiopia; soya in Burkina Faso)	Y		Y		Y	Y
Cassava		Y			Y	Y
Vegetable (incl. tomatoes in Cameroon)	Y	Y		Y	Y	Y
Fowls	Y	Y		Y		
Cattle-beef	Y	Y	Y	Y		Y
Wheat			Y	Y		
Groundnuts		Y			Y	

ANNEX B: Scorecard to be applied to observed adaptations in each sub-sector to identify good practices

Key:

Bold themes are those for farmers

Italics themes are those for other stakeholders (extension staff, government officers, private sector partners, agricultural researchers, NGOs with agricultural adaptation experience, etc.)

Bold italics are themes relevant for both farmers and other stakeholders

Practice

Proof of concept (local level, proven track record)			
To what extent has this practice been successfully used (i.e. to the satisfaction of the farmers) in at least one community (i.e. a group of farmers of the same commodity), or by multiple farmers of the same commodity in different communities, for at least one season? *Examples of probing questions/ themes to explore:* ***Is the practice widely adopted by local farmers/or in other ecologically similar areas?*** ***Do farmers have the required knowledge and understanding to implement the practice?*** ***What is the evidence or proof that the practice is a better one at the local level?*** *With which crops is this practice used?* **When did you start implementing this practice as a means to adapt to climate change?** **Is this practice used by many producers in your area?** **What lessons have you learnt about this practice since you adopted it?**	**7 to 10 points** Widespread proof of concept	**4 to 6 points** Less widespread proof of concept	**1 to 3 points** Some indication
Will this practice be robust under the projected temperature conditions in the next 10 20 50 years? *Examples of probing questions/themes to explore* *According to best available scientific knowledge and projections for the area in question, will this practice be robust under the projected temperature conditions? If not, why not?*	**7 to 10 points** Yes, completely and safely within the uncertainties of climate projections	**4 to 6 points** Yes, but with some uncertainty due to uncertainty in climate projections	**1 to 3 points** No
Will this practice be robust under the projected water availability conditions (rainfall and groundwater) in the next 10 20 50 years? *Examples of probing questions/themes to explore* *According to best available scientific knowledge and projections for the area in question, will this practice be robust under the projected water availability conditions? If not, why not?*	**7 to 10 points** Yes, completely and safely within the uncertainties of climate projections	**4 to 6 points** Yes, but with some uncertainty due to uncertainty in climate projections	**1 to 3 points** No

Will this practice be robust under the projected extreme events (droughts, floods, etc.) in the next 10 20 50 years? *Examples of probing questions/themes to explore* *According to best available scientific knowledge and projections for the area in question, will this practice be robust considering the likelihood of extreme weather events? If not, why not?*	**7 to 10 points** Yes, completely and safely within the uncertainties of climate projections	**4 to 6 points** Yes, but with some uncertainty due to uncertainty in climate projections	**1 to 3 points** No
To what extent does this practice entail adverse environmental consequences (e.g. pollution from fertiliser, disruption to biodiversity and natural resources, including soil and water)? *Examples of probing questions/ themes to explore:* ***Does the technique have any unknown negative environmental, social and economic impacts?*** ***What proof do we have that the practice applied will not affect the prevailing environmental balance?*** **Have you observed any environmental consequences relating to this practice?**	**7 to 10 points** Minimal/ acceptable consequences, e.g. those that are reversible or manageable	**4 to 6 points** Some environmental consequences but not significant enough to affect environmental integrity	**1 to 3 points** Unacceptable consequences
To what extent does the use of this adaptation by farmers have adverse social consequences? *Examples of probing questions/ themes to explore:* *Is the use of this practice only available to certain farmers (thereby reinforcing inequality)?* *Does this practice impinge on other rights of community members (e.g. does it affect their access to water resources, or make their lives more difficult in any way)?* **What are the side effects of using this practice in this community?**	**7 to 10 points** Minimal/ acceptable consequences, e.g. those that can be effectively managed	**4 to 6 points** Some consequences but possibility to manage with the required will and resources	**1 to 3 points** Unacceptable consequences, either in terms of magnitude or number of people who will be adversely affected
Is this practice deemed socially acceptable by farmers, i.e. is this a practice that they find suitable to their culture and daily routines, does it lead to outcomes which they find desirable (e.g. quality and quantity of product that has a use for them?) (all of which may be shown by how many farmers have adopted it, which is dependent on timescale) *Examples of probing questions/ themes to explore:* ***Is the practice compatible with and/or culturally accepted by communities?*** ***Are there any traditional and cultural barriers to the dissemination of the technique?*** ***What types of producers adopt this practice?*** ***Is there any difference between men, women and young people in terms of its implementation?*** ***Is this practice isolated from, or compatible with, other practices?*** *Under what conditions can it be applicable in other areas?* *By what criteria can we ascertain that the practice will be widespread or adopted even after the project support ends?* *Do you consider that the demand for the practice is: increasing, decreasing or steady?* *How can we ascertain that the actual practice will not negatively affect the existing farming system?*	**7 to 10 points** Highly acceptable as shown by high/ rapid rates of adoption and/ or high levels of interest expressed in adoption	**4 to 6 points** Of medium acceptability	**1 to 3 points** Low acceptability

Are farmers able to obtain the required inputs (in terms of seeds/ breeds, fertilisers, technical knowledge, etc.) to successfully engage in this practice? *Examples of probing questions/ themes to explore:* ***Is the technology accessible to and affordable for all farmers including the poor?*** ***What inputs/ resources (human, material, financial) do you need to implement this practice?*** ***Are these resources available locally?*** ***Are there any constraints when implementing the practice?*** ***What are the conditions or factors of success that have helped to overcome the constraints?*** ***Does this practice entail a change in usual practice?*** ***Do you need external support to implement this practice?*** ***Do you think that without this support you can continue to using this practice?***	**7 to 10 points** Completely; the full range of required technical and physical inputs are both available and accessible, i.e. affordable	**4 to 6 points** To a certain extent, i.e. the majority of required technical and physical inputs are available and/or they are both affordable and accessible to all farmers	**1 to 3 points** Low level of availability of the required technical and physical inputs and/or poor affordability
To what extent does this practice change existing (or previous) levels of production and quality of output? *Examples of probing questions/ themes to explore:* ***What are the benefits of the practice in terms of performance / production compared with other practices?*** ***What are the benefits of the practice in terms of cost compared with traditional practices and technologies used?*** ***Is the end product of the same standard? How can this be measured?*** *What do farmers gain by adopting this adaptation practice?* ***Why do you prefer this practice to other traditional practices?*** ***What have been the key benefits of this practice in terms of your crop production?***	**7 to 10 points** Both production and quality of outputs are higher than previously	**4 to 6 points** Either both production and quality of outputs are higher than previously, but to a lesser extent; or one of the two is higher	**1 to 3 points** Production and quality of outputs are similar to before

Enabling Environment

Support of appropriate institutions (private sector, research organisations including extension services, markets, meteorological services)				
To what extent is the effective implementation of this adaptation practice supported by appropriate institutions? *Examples of probing questions/ themes to explore:* *Define the relationship between the institution and the sector* *Have you planned or implemented activities on climate change, or do you have an interest in this area?* *What services is your organisation providing to the farming community in relation to climate change adaptation?* *Do you have a structure on the ground to facilitate your programming and activity implementation?* *How do you link up with farmers (modes of communication)?* *Re: research organisations* *What kind of research has been done on this particular practice and what are the findings?* *How are academic institutions contributing to the promotion of this adaptation practice?* *Is this adaptation practice promoted by research and academics?* *Re: meteorological services* *What climate related information is available with regard to this practice (e.g., rainfall and temperature requirements or needs)?*	**7 to 10 points** A wide range of appropriate institutional support is available to all farmers requiring it	**4 to 6 points** A lesser range of appropriate institutional support is available, or it is not available to all farmers	**1 to 3 points** Some, but incomplete, appropriate institutional support is available, or it is only available to a minority of farmers	**-1 to -5 points** There is total absence of required institutional support OR the institutional support is such that it impedes the effective implemen-tation of the adaptation practice)
Government support (extension services, policy environment, national strategies)				
To what extent does government support exist to enable the effective implementation of this adaptation practice? *Examples of probing questions/ themes to explore:* *Does the practice fit into or complement the existing practices and technologies in the extension system?* *Have you planned or do you have ongoing activities relating to climate changes?* *What policies/programmes are in place to support climate change adaptation practices and technologies for farmers?*	**7 to 10 points** Almost complete government support in terms of widespread availability of trained extension, appropriate policy support and recognition in existing national strategies, or those currently under draft	**4 to 6 points** Positive government support through partial extension services, policies and national strategies	**1 to 3 points** Minimal government support through scarce or unreliable extension services, incomplete or conflicting policies, and incomplete or missing national strategies	**-1 to -5 points** No support, or policies and strategies that are completely at odds with the effective implemen-tation of the adaptation practice

Positive impact on women

What effect does this adaptation practice have on the livelihoods of women? *Examples of probing questions/ themes to explore:* ***What proportion of women and youth farmers are involved in this particular adaptation practice?*** ***What are the positive impacts of this practice on women and youth farmers?*** ***Are there any negative effects on women and youth farmers?*** *In what way does the practice bring positive impacts or contributions to women and youth farmers?* *If there are any barriers to women or youth farmers' participation, how could these be overcome?*	**7 to 10 points** Significant positive impacts; it is available, accessible and culturally appropriate – i.e. leads to a qualitative improvement in the lives of women	**4 to 6 points** It has positive impacts on some women, or leads to some improvement but to a lesser extent than practices and technologies which receive the highest score	**1 to 3 points** It has minimal positive effects on women, or benefits only very few women	**-1 to -5 points** This practice reinforces gen-der inequality by being inac-cessible and unavailable (e.g. unafford-able or requir-ing inappro-priate inputs) or it increases women's work-loads

Co-benefits

Are there additional co-benefits that result from the adoption of this adaptation practice? *Examples of probing questions/ themes to explore:* ***What other benefits arise from adopting the practice?***	**7 to 10 points** Significant co-benefits that have substantial qualitative and quantitative impacts on farmers	**4 to 6 points** Medium co-benefits that are either not as widespread, nor as quantitatively positive as those that fall into the highest category	**1 to 3 points** Minimal current co-benefits, but potential for future opportunities (e.g. carbon credits, etc.)

ANNEX C: Identification of six categories of good practices

Table C.1: Step 1 - Good agricultural practices and technologies per country and per sub-sector

All numbers are percentages
No score denoted by *
Numbers in red are the highest score in the country (for the sake of comparison)

	Burkina Faso [14]	Cameroon [15]	Ethiopia [16]	South Africa [17]	Togo [18]	Zambia [19]
Improved varieties (non-GM)	53/ */ */ 48 (51)	62/ 65/ 56/ *	74/ 74/ 75			54/ 64/ *
Altered planting & harvesting dates/ early maturing varieties		62/ */ */ *		59/ */ 49/ *	77/ 77/ 0	
Alternative seeds/ different cultivars (including GM)				60/ */ */ 4		
Manure/ composting/ vermicast	49/ 60/ 49/ * (57)	48/ */*/*		63/ */ 3/ *	68/ 68/ 0	54/ 64/*
Fertiliser use				59/ */ */ *		
Biofertilisers with Titonia diverifolio ssp		*/ */ 51/ *				
Planting methods at 45^0		*/ */ 50/ *				
Agro-forestry			*/ */ 71		46 (all)	
Early planting for early, medium and long duration varieties						*/ 71/ *
Planting of early maturity varieties late in the season						*/ 43/ *
Planting field crop under off-season irrigation						*/ 38/ *
Dry sowing/ early sowing/ dry planting/ early dried planting		*/39*/ */ *	50/ 3/ *			57/ 68/ 38
Cultural practices and technologies (Early planting....)		53/ */ */ *				
Direct planting		*/ 45/ */ *				

14 Dry cereals/ Cotton/ Vegetables + Rice/ Cattle (Technical services – all commodities)

15 Maize/ Cotton/ Cassava/ Cattle

16 Haricot beans/ Wheat/ Maize

17 Maize/ Poultry/ Maize + Vegetables/ Wheat

18 Maize/ Sorghum/ Cotton

19 Sorghum/ Maize/ Cotton

	Burkina Faso	Cameroon	Ethiopia	South Africa	Togo	Zambia
Ripping/ chaka hoes						50/ 64/ 57
Change in feeding quantities and times				*/ 61/ */ *		
Leaving fields fallow				54/ */ */ *		
Mulching			*/ 3/ 70[20]	*/ */ 59/ *	59/ 59/ 0	61/ 61/ *
Crop rotation			63/ 68/ 71	65/ */ 64/ 70		68 (all)
Intercropping			57/ 3/ 59	*/ */ 64 / *		
Ripping						50/ 64/ 57
Basin preparation						50/ 64/ 57
Herbicide application for weed control						50/ 64/ 64
Mechanisation			*/ 59/ *	60/ */ 59/ *		
Modern planter				*/ */ */ 64		
Increasing harvesting capacity				*/ */ */ 58		
Controlled environment sheds				*/ 54/ */ *		
Circulation fans and tunnel ventilation				*/ 66/ */ *		
Evaporative cooling wall pads				*/ 68/ */ *		
Solar reflective roof paint				*/ 63/ */ *		
Climate sensitive shed design				*/ 68/ */ *		
Irrigating roofs				*/ 61/ */ *		
Relay cropping			*/ 58/ 58			
Off-season crop production						
Reduced/ no tillage			*/ 3/ 70[21]	68/*/ */73		

20 In the Ethiopian research, mulching and reduced tillage was grouped togther under "conservation farming" – they are separated out here and the same score is listed separately under "mulching" and "reduced/ no tillage

21 In the Ethiopian research, mulching and reduced tillage was grouped togther under "conservation farming" – they are separated out here and the same score is listed separately under "mulching" and "reduced/ no tillage

	Burkina Faso	Cameroon	Ethiopia	South Africa	Togo	Zambia
Utilisation of livestock in minimum tillage methods						57 (all)
Repeated tillage			61/ 66/ 62			
Row planting			74/ 78/ 77			
Changing plant population/ distribution				61/ */ */ *		
Pasturing		*/ */ */ 49				
Cattle feeding	*/ */ */ 59 (*)					
Complementation		*/ */ */ 52				
Supplements in feed				*/ 56/ */ *		
Zai / planting circle	57/ */ */ * (58)			*/ */ 59/ *		
Seed renewal			61/ */ *			
Use of pest and disease tolerant seed varieties						57/ 50/ *
Use of certified varieties						38/ 68/ 71
Planting different maturity varieties						50/ 61/ *
Shifting to other/ more drought resistant crops/ crop diversification			66/ 69/ 69	*/ */ 51/ *	77/ 77/ 0	64/ 68/ *
Contour stone bunds/ bounds	53/ */ */ * (*)				71 (all)	
Filter bounds					71 (all)	
Stone walls		*/ 48/ */ *				
Ridging 1m apart		*/ */ 48/ *				
Heap mounting (ados)		*/ 48/ */ *				
Vegetation bands		*/ 32/ */ *				
Grass strips					71 (all)	
Fodder / forage cropping	*/ */ */ 62 (54)	*/ */ */ 46				
Diversifying farming activities/ income				56/ 54/ */ *		
Diversifying to alternative cash crops				*/ */ */ 64		
Farming insurance	*/ */ */ * (63)					

	Burkina Faso	Cameroon	Ethiopia	South Africa	Togo	Zambia
Diversifying to livestock farming/ livestock diversification				*/ */ 3/ 66		54 (all)
Sale of livestock producers to purchase crop inputs						29/ 64/ 38
Early warning systems/ information sharing	*/ */ */ * (56)					
Reducing stock density				*/ 64/ */ *		
Installing and using rain gauges on farm					69 (all)	

Table C.2: Step 2 - Good agricultural practices and technologies per country and per sub-sector

			Burkina Faso [22]	Cameroon [23]	Ethiopia [24]	South Africa [25]	Togo [26]	Zambia [27]
	IMPROVED SEEDS	Improved varieties (GM and non-GM)	53/ */ */ 48 (51)	62/ 65/ 56/ *	74/ 74/ 75	60/ */ */ 4		54/ 64/ *
		Use of pest and disease tolerant seed varieties						57/ 50/ *
		Use of certified varieties						38/ 68/ 71
		Planting different maturity varieties						50/ 61/ *
		Use of early maturing varieties (GM and non-GM)		62/ */ */ *		59/ */ 49/ *	77/ 77/ 0	*/ 71/ *
SOIL AND WATER MANAGEMENT	INPUT FOR SOIL AND WATER MANAGEMENT	Manure/ composting/ vermicast/ biofertiliser	49/ 60/ 49/ * (57)	48/ */51/*		63/ */ 3/ *	68/ 68/ 0	54/ 64/*
		Fertiliser use				59/ */ */ *		
		Zai / planting circle	57/ */ */ * (58)			*/ */ 59/ *		
	PRACTICES AND TECHNOLOGIES FOR SOIL AND WATER	Crop rotation			63/ 68/ 71	65/ */ 64/ 70		68 (all)
		Leaving fields fallow				54/ */ */ *		
		Mulching			*/ 3/ 70[28]	*/ */ 59/ *	59/ 59/ 0	61/ 61/ *

[22] Dry cereals/ Cotton/ Vegetables + Rice/ Cattle (Technical services – all commodities)

[23] Maize/ Cotton/ Cassava/ Cattle

[24] Haricot beans/ Wheat/ Maize

[25] Maize/ Poultry/ Maize + Vegetables/ Wheat

[26] Maize/ Sorghum/ Cotton

[27] Sorghum/ Maize/ Cotton

[28] In the Ethiopian research, mulching and reduced tillage was grouped togther under “conservation farming” – have separated them out here and put the same score separately under “mulching” and “reduced/ no tillage

			Burkina Faso	Cameroon	Ethiopia	South Africa	Togo	Zambia
	AGROFORESTRY	Agro-forestry			*/ */ 71		46 (all)	
	TIMING OF FARMING PRACTICE	Early planting for early, medium and long duration varieties		53/ */ */ *				*/ 71/ *
		Dry sowing/ early sowing/ dry planting/ early dried planting		*/39*/ */ *	50/ 3/ *			57/ 68/ 38
		Change in feeding quantities and times				*/ 61/ */ *		
		Modern planter				*/ */ */ 64		
		More efficient/ faster harvesters				*/ */ */ 58		
	EXTENDING CROPPING SEASON	Planting field crop under off-season irrigation						*/ 38/ *
		Relay cropping			*/ 58/ 58			
	CHANGING CROP/ LIVESTOCK DISTRIBUTION AND DENSITIES	Intercropping			57/ 3/ 59	*/ */ 64 / *		
		Distribution (including row planting and spaces between rows)		*/ */ 48/ *	74/ 78/ 77	61/ */ */ *		
		Reducing stock density				*/ 64/ */ *		
	TILLAGE AND REQUIRED ASSOCIATED PRACTICES	Ripping (by hand)						50/ 64/ 57
		Ripping (by livestock)	57 (all)					
		Reduced/ no tillage			*/ 3/ 70[29]	68/ */ */ 73		
		Repeated tillage			61/ 66/ 62			
		Chaka hoes						50/ 64/ 57
		Direct planting		*/ 45/ */ *				
		Basin preparation						50/ 64/ 57
		Herbicide application for weed control						50/ 64/ 64

	MECHANISATION	Mechanisation			*/ 59/ *	60/ */ 59/ *		
		Controlled environment sheds				*/ 54/ */ *		
		Circulation fans and tunnel ventilation				*/ 66/ */ *		
		Evaporative cooling wall pads				*/ 68/ */ *		
		Solar reflective roof paint				*/ 63/ */ *		
		Climate sensitive shed design				*/ 68/ */ *		
		Irrigating roofs				*/ 61/ */ *		
	LIVESTOCK PRACTICES	Cattle feeding/ pasturing	*/ */ */ 59 (*)	*/ */ */ 49				
		Fodder/ forage cropping	*/ */ */ 62 (54)	*/ */ */ 46				
		Complementation/ supplements		*/ */ */ 52		*/ 56/ */ *		
	FARM CROP AND LIVESTOCK DIVERSIFICATION	Diversification (shifting to more drought resistant crops/ crop diversification)			66/ 69/ 69	*/ */ 51/ 64	77/ 77/ 0	64/ 68/ *
		Diversifying to livestock farming/ livestock diversification				*/ */ 3/ 66		54 (all) (29/ 64/ 38)
		Diversifying farming activities/ income				56/ 54/ */ *		
	EROSION CONTROL MEASURES	Contour soil/ stone bunds/ bounds/ filter bounds	53/ */ */ * (*)	*/ 48/ */ *			71 (all)	
		Vegetation bands/ grass strips		*/ 32/ */ *			71 (all)	
	INFORMATION USES	Early warning systems/ information sharing	*/ */ */ * (56)					
		Installing/using rain gauges					69 (all)	

[29] In the Ethiopian research, mulching and reduced tillage was grouped togther under “conservation farming” – they are separated out here and the same score is listed separately under “mulching” and “reduced/ no tillage

Table C.3: Step 3 - Six categories of good agricultural practices and technologies per country and per sub-sector

			Burkina Faso [30]	Cameroon [31]	Ethiopia [32]	South Africa [33]	Togo [34]	Zambia [35]
	IMPROVED SEEDS	Improved varieties (GM and non-GM)	53/ */ */ 48 (51)	62/ 65/ 56/ *	74/ 74/ 75	60/ */ */ 4		54/ 64/ *
		Use of pest and disease tolerant seed varieties						57/ 50/ *
		Use of certified varieties						38/ 68/ 71
		Planting different maturity varieties						50/ 61/ *
		Use of early maturing varieties (GM and non-GM)		62/ */ */ *		59/ */ 49/ *	77/ 77/ 0	*/ 71/ *
SOIL AND WATER MAN-AGEMENT	INPUT FOR SOIL AND WATER MANAGEMENT	Manure/ composting/ vermicast/ biofertiliser	49/ 60/ 49/ * (57)	48/ */51/*		63/ */ 3/ *	68/ 68/ 0	54/ 64/*
		Fertiliser use				59/ */ */ *		
		Zai / planting circle	57/ */ */ * (58)			*/ */ 59/ *		
	PRACTICES AND TECHNOLOGIES FOR SOIL AND WATER MANAGEMENT	Crop rotation			63/ 68/ 71	65/ */ 64/ 70		68 (all)
		Leaving fields fallow				54/ */ */ *		
		Mulching			*/ 3/ 70	*/ */ 59/ *	59/ 59/ 0	61/ 61/ *
	EROSION CONTROL MEASURES	Contour soil/ stone bunds/ bounds/ filter bounds	53/ */ */ * (*)	*/ 48/ */ *			71 (all)	
		Vegetation bands/ grass strips		*/ 32/ */ *			71 (all)	
	TIMING OF FARMING	Early planting for early, medium and long duration varieties		53/ */ */ *				*/ 71/ *
		Dry sowing/ early sowing/ dry planting/ early dried planting		*/39*/ */ *	50/ 3/ *			57/ 68/ 38
		Change in feeding quantities and times				*/ 61/ */ *		
		Modern planter				*/ */ */ 64		
		More efficient/ faster harvesters				*/ */ */ 58		

	CHANGING CROP/ LIVESTOCK DISTRIBUTION AND DENSITY	Intercropping			57/ 3/ 59	*/ */ 64 / *		
		Distribution (including row planting and spaces between rows)		*/ */ 48/ *	74/ 78/ 77	61/ */ */ *		
		Reducing stock density				*/ 64/ */ *		
	TILLAGE AND REQUIRED ASSOCIATED PRACTICES	Ripping (by hand) Ripping (by livestock)						50/ 64/ 57 57 (all)
		Reduced/ no tillage			*/ 3/ 70[37]	68/ */ */ 73		
		Repeated tillage			61/ 66/ 62			
		Chaka hoes						50/ 64/ 57
		Direct planting		*/ 45/ */ *				
		Basin preparation						50/ 64/ 57
		Herbicide application for weed control						50/ 64/ 64
	FARM CROP AND LIVESTOCK DIVERSIFICATION	Diversification (shifting to more drought resistant crops/ crop diversification)			66/ 69/ 69	*/ */ 51/ 64	77/ 77/ 0	64/ 68/ *
		Diversifying to livestock farming/ livestock diversification				*/ */ 3/ 66		54 (all) (29/ 64/38)
		Diversifying farming activities/ income				56/ 54/ */ *		

30 Dry cereals/ Cotton/ Vegetables + Rice/ Cattle (Technical services – all commodities)

31 Maize/ Cotton/ Cassava/ Cattle

32 Haricot beans/ Wheat/ Maize

33 Maize/ Poultry/ Maize + Vegetables/ Wheat

34 Maize/ Sorghum/ Cotton

35 Sorghum/ Maize/ Cotton

36 In the Ethiopian research, mulching and reduced tillage was grouped togther under “conservation farming” – they are separated out here and the same score is listed separately under “mulching” and “reduced/ no tillage

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