GCRF-AFRICAP Agricultural and food system resilience: Increasing capacity and advising policy

A Global Challenges Research Fund programme to help agriculture and food production in sub-Saharan Africa become more productive, sustainable and resilient to climate change.

GCRFAFRICAP
CLIMATE SMART AGRICULTURAL DEVELOPMENT

Final Report: March 2022

Our partners

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Foreword

A Global North South collaboration

The Global Challenges Research Fund programme, “Agricultural and Food System Resilience: Increasing Capacity and Advising Policy” (GCRF-AFRICAP) was co-designed, co-owned and jointly run between institutions in the Global North and Global South. GCRF-AFRICAP aimed to build capacity in prospective, systems-level, decision making for resilient agricultural development in sub-Saharan Africa to meet the complex challenges of climate change, the need for equitable economic growth, and the need to feed growing populations nutritiously and sustainably.

To address these challenges, we designed and implemented a collaborative programme involving over 80 team members, across nine institutions in five countries. We engaged a significant range of decision makers in the four focal countries (Malawi, South Africa, Tanzania and Zambia) in the African Union and in Europe, both to scope out the questions to address, and to consider the implications of the programme’s findings. These emerged from both our field research and an assessment framework we developed, called iFEED – the integrated Future Estimator of Emissions and Diets. iFEED integrates land use, agricultural, climate and socio-economic models under scenarios of change set by local stakeholders. It also incorporates results from other policy and applied research strands to provide an evidence base for decision makers. As the consequences of decisions made today will play out over the decades to come, iFEED provides a basis to explore how contemporary decisions, and the trade-offs they entail, will help or hinder countries’ progress in meeting aspirations for agricultural development, climate action, economic growth, food and nutrition security and reducing inequalities.

GCRF-AFRICAP – like the rest of the world – has had to deal with the impacts of COVID-19. Despite this, the programme has successfully delivered its major aims of integrating policy-relevant interdisciplinary research and building capacity, both among programme partners, and among a wider constituency of stakeholders. This has only been possible due to the huge and dedicated efforts of the whole team, their enthusiasm, professionalism and hard work.

Professor Tim Benton
GCRF-AFRICAP co-Principal Investigator; Research Director – Emerging Risks, and Director – Environment and Society Programme, Royal Institute of International Affairs (Chatham House); Professor of Population Ecology, University of Leeds.

Dr Tshilidzi Madzivhandila
GCRF-AFRICAP co-Principal Investigator; Chief Executive Officer, Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN).

A significant legacy

As members of GCRF-AFRICAP's Strategic Advisory Board, we have watched the programme go from strength to strength, despite the COVID-19 pandemic preventing travel during the second half of the implementation period. The final outputs are to be celebrated, particularly in the light of these challenges.

Capacity-strengthening activities have seen team members, especially from the African partners, gain skills in conducting and sharing their research, while their organisations are in a better position to advance future research and put knowledge into use.

Networks of agriculture and food stakeholders have used the results of GCRF-AFRICAP research to help build climate-resilient food and agriculture systems. This evidence is encapsulated in iFEED, which helps policymakers in choosing pathways that can lead to a climate-resilient future.

Given these achievements – as presented in the following pages – we are proud to have been involved with GCRF-AFRICAP and have no doubt that the programme's legacy will be significant.

David Howlett
Race to Resilience co-Lead at Climate Champions Team; Chair of the GCRF-AFRICAP Strategic Advisory Board.

Dr Nalishebo Meebelo
Executive Director at the Regional Network of Agricultural Policy Research Institutes (ReNAPRI) Secretariat; GCRF-AFRICAP Strategic Advisory Board member & iFEED Regional Champion.

Executive summary

GCRF-AFRICAP's vision is for agriculture and food systems in southern Africa to be resilient to climate change and contribute towards meeting the UN Sustainable Development Goals. Working in Malawi, South Africa, Tanzania, and Zambia, we have made progress towards this vision through building actionable evidence around climate-resilient pathways and transformations, and building capacities for the translation of this evidence into both policy and practice.

We have developed an evidence base for climate-smart food systems through three related strands – scenario planning workshops, cross-disciplinary research and our integrated assessment framework, **iFEED**.

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Scenario planning

The four national-level scenario planning exercises brought together stakeholders to collectively decide on the two most influential critical uncertainties facing their countries. These two selections were then used to create four possible future scenarios.

Climate risks and how they materialise was chosen by stakeholders in all four countries as one of the two critical uncertainties. The second varied by country:

- Effective policy implementation aligned to deliver food systems outcomes (versus poorly aligned, siloed, policy) - **Malawi**
- Land tenure and reform (little change versus radical reforms) - **South Africa**
- Technology innovation and adoption (weak versus strong) - **Tanzania**
- Global and local market integration and functionality (weak versus strong) - **Zambia**

Food system research

GCRF-AFRICAP's cross-disciplinary research has built a comprehensive picture of present-day agriculture and food systems in Malawi, South Africa, Tanzania and Zambia. Our work on agricultural innovation, seed systems, pests and diseases, food safety and nutrition within and across the focal countries has fed in to our interpretations of future food system pathways. It has also helped us to develop critical reflections on, and recommendations about, context-appropriate, sustainable innovations and interventions.

Integrated assessment

We took the possible agricultural futures as defined by the scenario workshops - looking forward to the year 2050 - and assessed how climate-smart and nutrition-secure they might be, using our integrated Future Estimator for Emissions and Diets (iFEED). iFEED is an assessment framework that incorporates models and in-country expertise with analysis from across the natural and social sciences in each country.

iFEED used integrated modelling of the agricultural system to represent each scenario, including agricultural land use allocation, climate-food-emissions modelling, and trade and nutrition security analysis. It then expanded the modelled outputs by incorporating findings from our farm system research.

Our analysis showed:

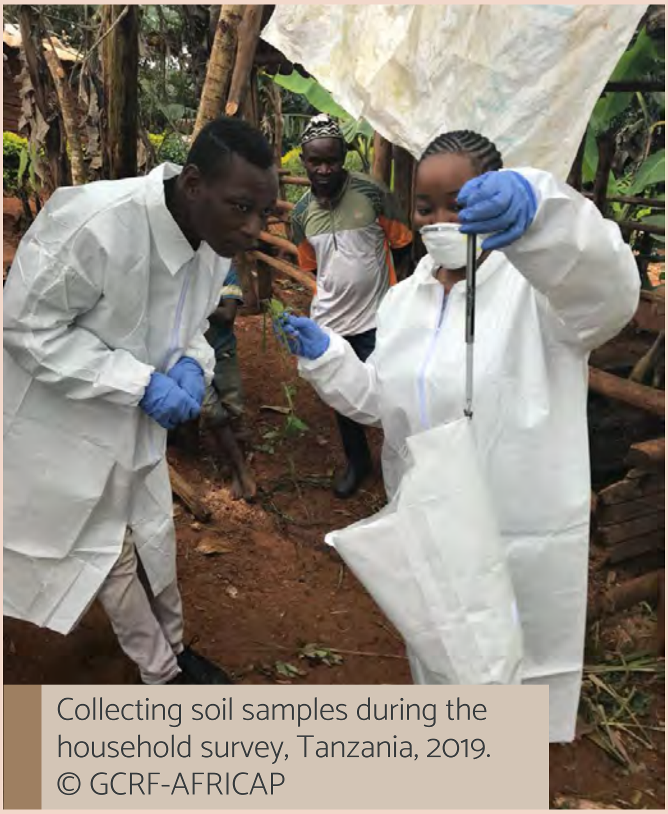
- Nutritional deficiencies can be reduced by 2050, although this requires substantial increases to crop yields. Without these increases, nutritional improvements will require agricultural areas to expand and / or increased food imports.
- Maize crop failure rates could increase by more than 50% by 2050 under the most optimistic future climate scenarios (RCP 2.6) and more than double under the worse-case scenarios (RCP 8.5). Average maize yields could fall by as much as a quarter under some scenarios.
- Farmers are already seeing increasing impacts on crop production due to pests and diseases, in places accounting for nearly a third of annual yield losses.
- Increases in precipitation intensities will likely increase soil erosion in Tanzania and Malawi, negatively impacting agricultural yields.
- Drought and high temperatures in Malawi, Tanzania, and Zambia will increase the cyanide toxicity of cassava, making it harder to process into safe, edible forms.
- Although the impacts of climatic changes will be felt differently by different communities, owing to differing exposures, vulnerabilities, and capacities to adapt, female smallholders will be disproportionately affected.

Policy engagement

These assessments and the insights from our research and iFEED have formed the basis for much of GCRF-AFRICAP's engagements with policymakers. This has included sharing our findings with key institutions across the wider region, such as the Common Market for Eastern and Southern Africa (COMESA), the Southern African Development Community (SADC) and the African Union Commission. Through our in-country lead partners, we have also engaged with national governments and local organisations to support policy development and implementation. Our work has helped to highlight where national policies do not integrate well with each other and identify areas where policy coherence can be strengthened.

Capacity-building

Growing research capability has been a vital and consistent component of our work throughout the GCRF-AFRICAP programme. We have improved individual research skills among early career researchers and our lead partners in each country by providing training, fellowships and opportunities to collaborate with more experienced colleagues. All organisations involved in the consortium have also identified areas for improvement at an institutional level. Our aim was to ensure GCRF-AFRICAP enhanced the ability of our partners in the four countries to translate evidence into policy and to design and implement multi-disciplinary research programmes.



Collecting soil samples during the household survey, Tanzania, 2019. © GCRF-AFRICAP

Recommendations

Achieving food systems that are resilient and sustainable under a range of plausible futures requires them to be 'climate-smart': able to adapt to climate change, reduce emissions and increase production; and to support nutrition and livelihood security. This necessitates holistic and integrated policymaking and implementation at many scales. Our work in Malawi, South Africa, Tanzania and Zambia shows that this requires:

- Investing in climate services; supporting climate-smart agriculture (CSA) practices; improving water management; and aligning and coordinating nutrition, agricultural, and economic development objectives. If policy processes are not integrated, incoherence will exacerbate land-use conflicts, environmental degradation, and climate change.

- Supporting long-term capacity-building interventions at sub-national levels, including targeted support for the most vulnerable groups. Such measures can improve adoption of CSA practices and technologies.

- Linking seed systems to long-term climate information to make them more resilient. Identifying future conditions can inform trade-offs in crop breeding, such as between shortening growing seasons and increasing temperatures.

- Diversifying crop production and increasing imports of nutrient-dense foods. This will enable more diverse diets and achieve nutrition security in the face of increasing demographic and environmental pressures in the coming decades.

- Proactive efforts to strengthen tools, networks and capacities, across a broad spectrum of stakeholders, to share knowledge and develop integrated solutions.

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Introduction

GCRF-AFRICAP's vision is for agriculture and food systems in southern Africa to be resilient to climate change and contribute towards meeting the UN Sustainable Development Goals. Working in Malawi, South Africa, Tanzania, and Zambia, we have made progress towards this vision through building actionable evidence around climate-resilient pathways and transformations, and building capacities for the translation of this evidence into both policy and practice.

Central to the GCRF-AFRICAP approach, described in this report, has been:

- The integration of interdisciplinary, on-the-ground research with policy engagement.
- The development of scenarios of future food system change, using a multi-stakeholder and participatory approach.
- The application of integrated modelling approaches to analysing future changes in agriculture and food systems in southern Africa.

Focus group discussions with farmers in Mwansambo, Malawi. October 2018. © GCRF-AFRICAP

Building 'climate-smartness' and SDG-compliance is a systemic challenge. It is not simply about the identification and transfer of promising technologies and strategies, although these can contribute to improved agro-ecological health, diversity and livelihoods. More fundamentally, resilient and sustainable systems are underpinned by diverse and enduring communities of knowledge exchange and information sharing, ongoing dialogue across policy and different levels of governance, and proactive envisaging and planning for future change.

GCRF-AFRICAP's multi-scale, transdisciplinary framing of African food system resilience to climate change and identification of policy and practice interventions offers a model and an evidence base that future research programmes can build upon. This is already happening in the '**Food System Research Network for Africa**', set up by the University of Leeds, FANRPAN and the University of Pretoria's ARUA Centre for Excellence in Sustainable Food Systems. The network works with stakeholders across six countries to design and implement research into sustainable change in African food systems, building directly on GCRF-AFRICAP's insights and networks.

AFRICAP - Agricultural and Food System Resilience: Increasing Capacity and Advising Policy

Aim: To build capacities for the identification and implementation of evidence-based policy pathways towards SDG-compliant and climate smart agrifood systems.

Growing capability

Activities and initiatives to build research capability at the individual, organisational and institutional levels.

Building policy and practice capacity for translating evidence into resilient pathways of change.

Future food system scenarios
Workshops where in-country experts outlined key challenges for a sustainable nutrition-secure future:

How can nutrition and food security be ensured?

How quickly is the climate changing and what policies are needed to adapt?

How does agricultural land use need to change?

Establishing best practice in climate resilience
Evidence base created in the areas of:

Crop health eg. aflatoxins

Water use

Crop and livestock diversification

Seed systems

Households and livelihoods

Soil health

iFEED: Integrated assessment of transformational pathways
Analysis of the above evidence base integrated with modelling summarised with systematic confidence assessments in the areas of:

Irrigation

Pests and diseases

Climate shocks and extremes

Food production and land use

Emissions, soils, erosion

Trade and nutrition security

Climate-crop impacts and adaptation

Policy engagement and de-risking
In-country policy expertise, giving guidance on targeting of results into important policy areas through scenarios workshops, engaging with stakeholders on transformational pathways.

Section 1: Transformational pathways to climate-smart agrifood systems

The GCRF-AFRICAP programme developed an evidence base for climate-smart food systems through three related strands:

1. **Scenario planning workshops** to determine possible food system development based on four scenarios of change identified in each country. These scenarios are used to identify the long-term consequences of today's policy decisions (see section 1.1)

2. **Cross-disciplinary research** to build a comprehensive picture of present day agriculture and food systems in Malawi, South Africa, Tanzania and Zambia (see section 1.2)

3. **Development of an integrated framework (iFEED)** to assess the degree to which future scenarios are climate-smart and nutrition-secure, using both a range of models and findings from the agriculture and food system research (see section 1.3)

Measuring soil moisture in a conservation agriculture farm in Malawi, October 2018. © GCRF-AFRICAP

1.1. Scenario planning workshops

Food systems in Africa and the factors that shape them will undoubtedly evolve considerably over the next 30 years, but exactly how is hard to predict. Accordingly, plans to develop sustainable, productive, climate-smart agricultural systems to meet food security and economic development aspirations need to account for a wide range of plausible futures, and decision makers need to identify strategies that are resilient to these indeterminant outcomes.

To enable stakeholders to develop shared visions and articulations of potential futures, we ran four participatory GCRF-AFRICAP scenario exercises at the outset of the programme, examining the future of food systems in Malawi, South Africa, Tanzania and Zambia. These scenarios provided the framework for much of the programme's subsequent research, looking at transformational pathways to climate-smart agrifood systems and engaging decision makers to consider these pathways.

Scenarios are a route to aid decision making under uncertainty, when past trends cannot necessarily be extrapolated into the future with confidence, and where the future is likely to be shaped by drivers or events which may plausibly lead to very different outcomes. Rather than forecasting the future, they examine a range of plausible futures, and provide a systematic mechanism for thinking through the challenges that might be encountered and opportunities that might arise. Strategies and alternatives can be 'future tested' for robustness against different scenarios to determine whether decisions made today would remain fit for purpose if the future diverges from existing trends.

The four national-level exercises brought together stakeholders (approximately 200 across the four countries) for day-long workshops to discuss the drivers shaping the future of agrifood systems. Participants included national and regional government officials and policy stakeholders, academics and civil society representatives, many of whom have remained engaged with the GCRF-AFRICAP programme since.

We used the narrative-based futures they collectively agreed and articulated as the basis for GCRF-AFRICAP's integrated assessment framework, iFEED, to quantitatively model and qualitatively explore various agrifood development pathways. These assessments and the insights they provided have formed the basis for much of GCRF-AFRICAP's engagements with policymakers.

Methodology

Each workshop listed the broad social, technological, economic, environmental, and political factors that are expected to shape each country's food system by mid-century, and then separated them into 'known knowns' and 'known unknowns'. The 'known knowns' are drivers about which there is low predictive uncertainty into the future; for example, the demographic distribution of a country's population can be projected into the future with relative certainty. 'Known unknowns', in contrast, are drivers that will certainly play a role in shaping the future, but which will have very different impacts depending on the form in which they materialise and their magnitude. For example, whether the world is more globalised or less globalised makes a radical difference to the drivers of agriculture. Through an iterative series of discussions and anonymous voting, participants collectively arrived at the two most influential and mutually exclusive 'known unknowns'. These two selections were then used to create a set of orthogonal axes defining four scenarios (Figure 1).

We ran four participatory scenario exercises which provided the framework for much of the programme's subsequent research, looking at transformational pathways to climate-smart agrifood systems and engaging decision makers to consider these pathways.

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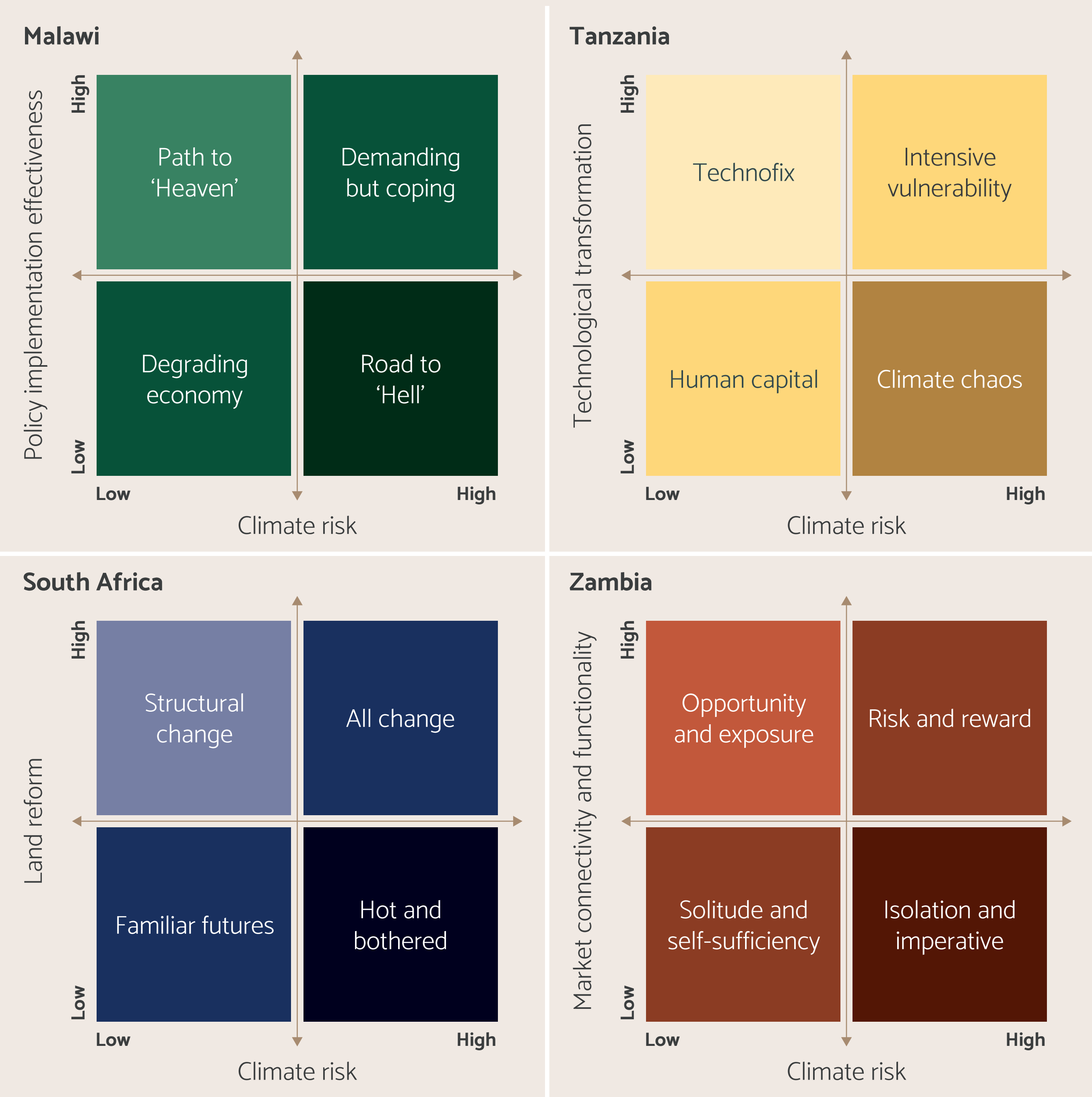
Figure 1: Four GCRF-AFRICAP scenarios per country



With each scenario defined by its two axes, workshop participants then collectively considered each one in turn. They looked at these in the light of other critical uncertainties to paint a narrative picture of the plausible characteristics of each scenario and how these conditions might interact to shape each country's food system.

Over the course of the programme, GCRF-AFRICAP drew on these scenarios to engage decision makers and stakeholders throughout each country's food system. The scenarios helped stakeholders to consider the policy decisions that can be taken to increase resilience of the system irrespective of which version of the future materialises. This in turn will help to increase the probability of outcomes that are aligned with the more aspirational visions of the future, reducing the chances of undesirable outcomes materialising.

1.2. Cross-disciplinary research

Our work on agricultural innovation, seed systems, pests and diseases, food safety and nutrition within and across the focal countries has fed in to our interpretations of future food system pathways. It has also helped us to develop critical reflections on, and recommendations about, context-appropriate, sustainable innovations and interventions. This research is summarised below.

Future pathways of agriculture and food system change are based on policy and implementation decisions being taken today. It is essential that these are grounded in understandings of local and contemporary system dynamics. The narratives we develop about the future must not be divorced from the experiences and realities of the past and present.

1.2.1. Climate-smart agricultural intervention and innovation

Agriculture in eastern and southern Africa is largely rain-fed, and there is significant uncertainty when it comes to projecting future rainfall regimes and soil water availability.

In the context of agro-climate uncertainty and risk, there is a clear push within national policies to promote the accelerated uptake of climate-smart agriculture. For example, Malawi's National Planning Commission focuses on intensification of agriculture, through irrigation and commercialisation, as a key pillar of its Vision 2063. The participatory scenarios exercise in Tanzania highlighted technological development and adoption as one of the most critical factors influencing future agriculture and food systems.

GCRF-AFRICAP carried out field trial experimentation and observation of climate-smart practices at three sites in central and southern Malawi and in the Usambara mountains of Tanzania. This work showed that conservation agriculture and other technologies such as terracing could improve soil health, particularly soil structure, which can increase water availability and the resilience of crops during increasingly prevalent dry spells.

However, such evidence should not be translated uncritically into a singular 'technological fix' narrative. Other GCRF-AFRICAP field-based research has shown that the nature of agricultural technologies, and the way in which development projects are governed, can either help to address or further exacerbate social (including gendered) inequalities. Our research highlighted that innovation has complex social and political dimensions, as it is experienced differently by different people. Innovation is a not a linear process of technology transfer or the inevitable outcome of a short programme of

Our work on agricultural innovation, seed systems, pests and diseases, food safety and nutrition has fed in to our interpretations of future food system pathways and helped us to develop context-appropriate, sustainable innovations and interventions.

intervention, to be measured through technology adoption metrics or equally narrow criteria.

This research helped us to add context and caution to the broader-scale evaluation of food system pathways and futures within the iFEED process. Building sustainable and resilient agricultural systems requires more than investment in technological solutions. It also requires investment in individual and local capacities, good governance and knowledge networks, and inclusive approaches to evaluation.

1.2.2. Seed systems

Crop model projections show that without adaptation to climate change, yields will reduce substantially – for example Crop model projections show that without adaptation to climate change, yields will reduce substantially – for example greater than 20% yield losses for maize by 2050 with RCP8.5. Even with incremental adaptation to climate change (allowing planting dates and crop varieties to vary) and lower climate risk (RCP2.6) yield losses are still projected. Yield shocks are also projected to approximately double by 2050. New crop varieties need to be developed that can cope with warming and increasing extremes of temperature and precipitation.

The crop breeding, delivery and adoption cycle can take up to 30 years to complete. Therefore, the initial conditions under which crop developers identify priority traits, select germplasm and test new varieties are not the same conditions under which seeds will eventually be planted by farmers.

We found that there was significant effort going into the breeding of early maturity, or short duration, maize varieties. However, long term climate models project an expansion of areas across southern Africa suited to longer duration varieties.

In our survey of 238 African seed system professionals, we found no concrete examples of long-term climate projections being used to influence the choice of breeding materials or target traits.

For example, we found that there was significant effort going into the breeding of early maturity, or short duration, maize varieties. However, long-term climate models project an expansion of areas across southern Africa suited to longer duration varieties. This shows that equal effort should potentially be going into the breeding of longer duration varieties.

Our survey also showed there has been increased crop breeding investment in cassava over the past 10-15 years. Our climate models predict that drought and high temperature stress will become more common and severe in many regions. For cassava, this means that future climatic conditions may trigger higher concentrations of cyanide toxicity within the plant. Based on climate information, breeding lower toxicity varieties of cassava may be a priority.

These examples illustrate the value of bringing together climate science and crop breeding insights to proactively plan for future conditions. Of course, climate risk is not the only, or even the most important, priority for seed systems. But this kind of knowledge exchange is equally important to enable seed systems to address other challenges and opportunities, be that reducing nutritional deficiencies, providing for new markets, or meeting the demands of new consumer preferences.

A resilient African seed system needs crop breeding and innovation to be informed by information and knowledge exchange. It needs to include long-term foresight and proactive planning for future challenges and opportunities. There needs to be sustained and collaborative engagement across research disciplines and between research and policy, to ensure that seed system investments and priorities are responsive to a cross-disciplinary evidence base.

1.2.3 Crop pests and diseases, and biodiversity food production trade-offs

GCRF-AFRICAP's agricultural ecology research evaluated the ecological implications of climate-smart agriculture (CSA) in the Tanga region of Tanzania, and conservation agriculture (CA) in the Free State province of South Africa. CSA in Tanzania mainly involved improved varieties of maize, inter-row spacing, live mulches in Fanya juu terracing, and agroforestry. CA in South Africa included cover crops, low tillage, and compost mulching in small-scale and commercial farms. In Tanzania, terracing and trenching with live and compost mulches provided the greatest crop production, pest suppression and agricultural income. However, we found a greater diversity of pests in fields where neighbours planted improved crop varieties. This suggests that the use of improved varieties by one group of farmers may increase vulnerability to pest damage among neighbours using local varieties.

In South Africa, commercial farms produced more food per unit area due to greater access to labour and chemical inputs, but were more vulnerable to value chain shocks like COVID-19 than the diversified and heterogenous small-scale farms. However, small-scale farms had higher invertebrate diversity than commercial farms. Fields with cover crops had a higher diversity of beneficial insects, such as pollinators, predators, and decomposers, in both small-scale and commercial farms. Commercial farms with deep tillage had a greater abundance of pests than farms with low tillage and mulches.

Our survey of farmers in Tanzania found they considered pests and diseases to have a significant negative impact on food production, accounting for over 30% of annual yield losses. Most farmers also believed that pests and diseases have substantially increased in the last two years. The older and more experienced the farmer, the greater their understanding of the impact of crop pests and the importance of natural enemies. Knowledgeable farmers deployed a more comprehensive range of management practices to reduce pests and maintain natural enemies.

1.2.4. Food safety, nutrition and health

GCRF-AFRICAP's food safety, nutrition and health research was carried out in the Tanga Region of Tanzania, and in Nkhotakota and Balaka Districts of Malawi. Our field survey identified high levels of aflatoxin contamination of maize, milk and bran, with some samples measuring 30-50 times the regulatory limits. Through household surveys, we assessed how agroecology, postharvest practice and storage conditions could influence aflatoxin levels in maize. Most of the surveyed households in Malawi, but fewer in Tanzania, are aware of aflatoxins. Nevertheless, in both countries, a considerable number of households consume contaminated maize. Improving education and awareness and the use of green processing technologies could reduce aflatoxin contamination.

Gathering data during the household survey in Tanga Region, Tanzania, August 2019. © GCRF-AFRICAP

Most of the households in our survey experienced a moderate level of food insecurity. Preharvest losses of maize were high, in the main caused by insects, flooding, drought and fungal spoilage. These factors are all predicted to worsen with climate change, which will drastically increase food insecurity. We found the key determinants of maize losses include household gender and age, land size, crop management and agroecology practices, and postharvest activities. Understanding these determinants can help governments and organisations to design tailored intervention strategies for reducing maize losses.

We analysed maize grown under various conservation agriculture (CA) regimes in Malawi and found that CA did affect grain and nutrient yields. For example, CA could reduce the risk of selenium deficiency in Malawian women and children, but could exacerbate the risk of iron deficiency.

We also looked at household diet records and found that diet diversity scores (DDS) in the two countries were medium, with only a small proportion of the households achieving high scores. We therefore recommend that a more diverse diet combined with nutrient improvement through agricultural and postharvest practices (CA, biofortification, fortification) can improve diet quality and health outcomes.

1.3. Development of an integrated framework (iFEED)

The integrated Future Estimator for Emissions and Diets (iFEED) is an assessment framework that incorporates models and in-country expertise with analysis from across the natural and social sciences in each country. iFEED took the possible agricultural futures defined by the scenario workshops outlined in Section 1.1 and assessed how climate-smart and nutrition-secure they are. We compared a baseline period, centered on the year 2000, to a future period centered on the year 2050. Each stage of the iFEED workflow involved in-country expertise (see box below).

iFEED used integrated modelling of the agricultural system to represent each scenario, including agricultural land use allocation, climate-food-emissions modelling, and trade and nutrition security analysis. We then summarised the model results using 'calibrated statements' - a systematic process that translates the numerical results into a written description and assesses the confidence experts have in the projections.

iFEED then expanded the modelled outputs by incorporating the farm system research described in Section 1.2. This is used to form 'implication statements' that provide additional

Stakeholder engagement
Each stage of the iFEED process involved in-country expertise:

- In-country stakeholders took part in scenario workshops, to identify two key drivers of change in the food system, and define four possible future scenarios.
- A taskforce of in-country experts (including food system practitioners and academics) then provided guidance on the modelling of each scenario – such as how agricultural land area could expand or contract; whether crop diversity and irrigation will change; and possible changes to agricultural imports and exports.
- Lastly, iFEED champions within the wider taskforce helped in writing final summaries ('calibrated' and 'implication' statements) and in disseminating the results to influence policy.

details beyond modelled outcomes to enrich the overall conclusions. We then summarised the results for each scenario, before forming country-level recommendations.

1.3.1. Climate risks, shocks, extremes

Weather and climate extremes have significant adverse impacts on food, energy and water systems, and other vital infrastructure. Maize harvests in Africa are heavily reliant on rainfed agriculture and so highly vulnerable to extreme weather events such as heatwaves, droughts, and floods. Trade networks cause the impacts of these extreme events to be felt at a domestic, regional, and global scale.

To manage the impact of climate extremes both now and in the future, we need better understanding of present-day climate risks due to natural climate variability. We can then explore how these extremes may evolve in the future as result of climate change.

Our climate model simulations show that record-breaking hot and dry extremes are possible in the present day, and would result in severe heat stress and drought conditions. In all four countries, hot extremes during the summer are strongly associated with El Niño events, as are dry summer extremes in South Africa, Zambia, and Malawi. This offers the potential for effective early warning systems.

The chance of record-breaking hot conditions has increased since the 1980s, and this trend will continue as the climate continues to warm. Although rainfall trends are less clear, climate models show a trend towards severe droughts, droughts combined with high temperatures, and more intense rainfall, which will result in increased flood risk and soil erosion.

Without sufficient adaptation to changing climate extremes, crop failure rates are likely to increase. Significant investment is therefore needed in heat, drought and flood-tolerant crops, effective irrigation and drainage systems, and coordinated regional action to distribute food, such as during the severe droughts associated with the El Niño events of 1992 and 2016.

1.3.2. Food production and land-use modelling

We modelled changes in food production and land use under each of the four possible futures identified for each country through the scenario workshops. The results described below hold true whether the degree of climate risk is high or low, unless otherwise stated.

Malawi – Effective policy implementation vs. poorly aligned policy

If policy is poorly aligned, there are no significant changes to land use and production compared to the baseline.

If policy is implemented effectively and aligned to deliver food systems outcomes, Malawi sees an expansion in agricultural area, irrigation, and crop diversification. Crops return the highest yields, maximising production. Crop varieties improve, and yields increase at a similar rate to that seen between 1960 and 2010. Crop production therefore increases by over 700% and livestock production by over 150%.

South Africa – little change vs. radical reforms in land tenure

In all scenarios, South Africa sees crop diversification and yields increasing at around half the rate of increases seen between 1960 and 2010, as technological yield improvements were not clearly associated with land reform.

Under high climate risk, irrespective of land reform, irrigation and pasture areas increase. Where there are radical reforms, arable areas decrease but crop varieties improve.

Irrespective of land reform, crop production approximately doubles under low climate risk and increases by approximately 150% in the high climate risk scenarios. Livestock production approximately doubles in all scenarios.

Tanzania – weak vs. strong technology innovation and adoption

Where technology innovation and adoption is weak, food production increases by approximately 50% due to agricultural area expansion.

Where innovation is strong, agricultural area and irrigation expand. Crops are grown where they return the highest yields, maximising production. Crop varieties improve, and yields increase at a similar rate to that seen between 1960 and 2010. This sees crop production increasing by 685% (low climate risk) and 1676% (high climate risk), and livestock production more than doubling.

Zambia – weak vs. strong local and global market integration and functionality

Under weak market integration, Zambia sees no significant changes to land use and production compared to the baseline.

Under strong market integration, agricultural area and irrigation expand. Crops are grown where they return the highest yields, maximising production. Crop varieties improve, and yields increase at around half the rate of increases seen between 1960 and 2010. This sees crop production increasing by 252% (low climate risk) and 564% (high climate risk), and livestock production more than doubling. The strong market integration and high climate risk scenario features the highest production as agriculture becomes homogenised and intensified.

1.3.3. Climate smart agriculture

For each of the four scenarios in each country, we assessed whether agriculture would be climate-smart, based on the following criteria:

- The sustainability of increased production
- The resilience of the agricultural system
- The balance of greenhouse gas (GHG) emissions and increases in soil organic carbon (SOC)
- Food and nutrition security in 2050

Scenarios that increase productivity through higher inputs of fertiliser and irrigation or the expansion of agricultural land will increase GHG emissions but this is partially balanced by a potential increase in SOC. Emission intensities (emissions per unit of food produced) also tend to decrease with increased productivity.

In Malawi, Tanzania and Zambia, in both high and low climate risk scenarios, lower increases in production might favour lower GHG emissions but risk food security.

In the higher production scenarios specific to each country (effective policy implementation in Malawi, technology innovation in Tanzania and market integration in Zambia) agricultural systems will be more resilient and production can be sustainably increased, depending on the technologies and methods used.

In Malawi, Tanzania and Zambia, our models showed policy actions can mitigate the impacts of climate change, and create a more resilient food system. Policy actions can enable Malawi, Tanzania and Zambia to improve food and nutrition security in 2050. However, under the higher risk climate scenarios, stronger action is required to achieve climate-smart agriculture. If only weak action is taken, or none at all, food systems will be unsustainable and will not provide enough food and nutrition.

In South Africa, our modelling gave similar results in both climate scenarios and under radical or minimal land reform. They show an increase in GHG emissions and loss in SOC, and mixed results for adaptation and productivity. In all four scenarios, South Africa achieved food, but not nutrition, security.

1.3.4. Trade and nutrition

Our trade and nutrition analysis explored how future food production and trade affect supplies of energy, macro- and micronutrients, under the different scenarios for each country. We used two approaches to examine future nutrition security given changes in domestic food production. The first explored population-level nutrition outcomes under different international trade vignettes (selfsufficiency; business as usual; stakeholder expectations). The second approach examined the food imports required to satisfy population-level nutrition security, and the exports that are possible without compromising these outcomes. We used data from the FAO Food Balance Sheets as the baseline for domestic food supply and international trade.

Under the first approach, nutrient supply improves relative to the baseline in several scenarios, but not enough to meet population requirements. In Malawi and Tanzania, the stronger policy and technology scenarios are associated with increased per capita nutrient supplies. In South Africa, marginal improvements are seen in the per capita supply of most nutrients for all scenarios, under different levels of land reform and climate risk. In Zambia, the per capita nutrient supply only improves under the high climate risk and strong market integration scenario, provided there is some degree of international trade.

Under the second approach, Malawi, Tanzania and Zambia are significantly more dependent on imports of nutrient-dense foods under weaker policy, technology and market integration scenarios, and there is little potential for surpluses to be exported. This is due to inadequate in-country production of nutrient-dense foods to achieve nutrition security, expanded populations and low baseline trade. Conversely, export potential increases with stronger policies, technologies and market integration. However, the volume of imports required tends to be nearly as high as under the weaker scenarios, suggesting there is scope to better align production with nutritional requirements. The increasing South African trade surplus is largely consistent across all scenarios.

Both analytical approaches illustrate the need for a more integrated food system approach. Increasing yields, diversifying production, and pursuing different trade relationships all need to be consistent with the objective of achieving nutrition security.

Planting maize in conservation agriculture field trial site at Chitedze, Malawi. © GCRF-AFRICAP

1.3.5. iFEED results summary and overview

Our iFEED analysis shows that policies need to take multiple factors into account – climate change, agriculture, trade and nutrition – to achieve sustainable, climate-smart and nutrition-secure food systems.

Food production and resulting nutritional outcomes are more favourable under agricultural land expansion and intensification. However, these can increase land conflict between water, food, energy and tourism and put environmental sustainability at risk (for example, through increased fertiliser and pesticide use).

In Malawi, Tanzania and Zambia, crop productivity and adaptive capacity improve under strong policy, technology and market integration scenarios. Nutrition security also generally improves, although adequate nutrient supply is not completely achieved in any scenario without increases in agricultural imports. Productivity, adaptive capacity and nutrient supply improve in all the scenarios for South Africa, although improvements are larger in high climate risk scenarios, where increased crop diversification and irrigation mitigate against increasing climatic risks.

Greenhouse gas emissions increase as agricultural land and productivity grow. Increased soil organic carbon and reduced emission intensities can compensate for this to some extent.

Record-breaking high temperatures, droughts and floods are expected to increase, particularly under high climate risk scenarios. Although average production increases with agricultural intensification and expansion, relatively poor production years caused by climate extremes could also become more common.

Our iFEED analysis shows that policies need to take multiple factors into account – climate change, agriculture, trade and nutrition – to achieve sustainable, climate-smart and nutrition-secure food systems.

Gathering data during the household survey, Tanzania, August 2019. © GCRF-AFRICAP

Section 2: Policy engagement and de-risking

Throughout the GCRF-AFRICAP programme, we have engaged with networks of local, national, regional and international organisations with a stake in sustainable agriculture and food production in east and southern Africa. By sharing evidence developed in our research and modelling with policy and decision makers, we aim to de-risk their decision making and enable climate-smart and sustainable agricultural development.

Researchers, farmers, extension officers and government officials share knowledge during the GCRF-AFRICAP study tour in Tanzania, March 2020 © GCRF-AFRICAP.

The future of agriculture and food systems across southern Africa is uncertain. Technological, social and environmental changes, both in the region and beyond, will create unprecedented situations. Confluences of events could lead to impacts that escalate in unpredictable ways. Interconnections between different drivers of change could result in problems that are very complex and difficult to solve.

This makes policy and decision making fraught with risk. Typical approaches have tended to look to the past, to what has worked before, but this cannot necessarily ensure resilience in the face of an uncertain future. Our scenario development exercise, which worked with stakeholders to envisage a number of plausible futures, provides an approach to de-risk decision making.

The scenarios helped stakeholders to consider the policy decisions that can be taken now to increase resilience of the system irrespective of which version of the future materialises. This is turn will help to increase the probability of outcomes that are aligned with the more aspirational visions of the future, reducing the chances of undesirable outcomes materialising.

The evidence base created by iFEED, drawing from a wide range of research and modelling based on these scenarios, can help stakeholders ensure that policies are coherent across the different domains that impact food systems and agricultural production.

Over the course of the programme, GCRF-AFRICAP drew on the scenarios to engage decision makers and stakeholders throughout each country's food system. We also took steps to ensure that the results of our work – and iFEED in particular – was and continues to be used by policy and decision makers across the wider region.

2.1. Policy engagement

2.1.1 Regional engagement

FANRPAN has led engagement of policymakers at a regional level, holding briefing sessions to share GCRF-AFRICAP research results and scenario planning reports with key policy officers from the Common Market for Eastern and Southern Africa (COMESA), the Southern African Development Community (SADC) and the African Union Commission.

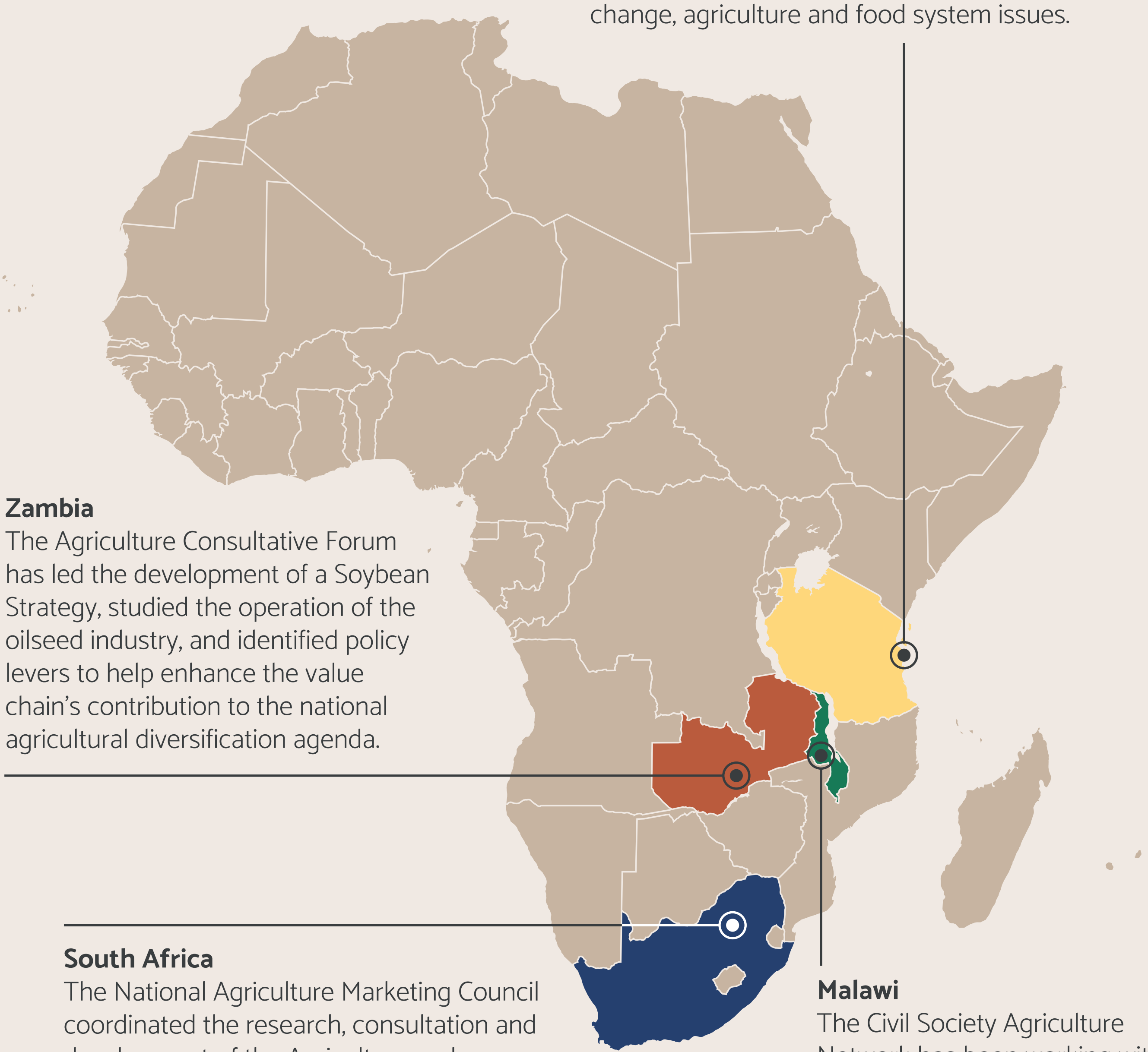
FANRPAN collaborated with COMESA, SADC and other partners, including the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Centre for Agriculture and Bioscience International (CABI), CARE International, the Initiative for the Adaptation of African Agriculture (AAA) and the World Bank, to convene side events at the 2021 United Nations Climate Change Conference of Parties (COP) to highlight the need to develop climate resilient food systems. These strategic engagements ensured that GCRF-AFRICAP outputs fed into policy discussions and processes at a national, regional and global level.

FANRPAN also drew on GCRF-AFRICAP results to inform its annual regional multi-stakeholder policy dialogues which aim to catalyse action to transform Africa's food systems to deliver sustainable and healthy food for all.

The evidence base created by iFEED, can help stakeholders ensure that policies are coherent across the different domains that impact food systems and agricultural production.

2.1.2. National and local engagement

Tanzania
The Economic and Social Research Foundation has been working with the Tanzania Climate Smart Agriculture Alliance to set up the Muheza Climate Smart Agriculture Learning Alliance - a learning platform that brings stakeholders together to exchange experiences and knowledge on climate change, agriculture and food system issues.



Zambia
The Agriculture Consultative Forum has led the development of a Soybean Strategy, studied the operation of the oilseed industry, and identified policy levers to help enhance the value chain's contribution to the national agricultural diversification agenda.

South Africa
The National Agriculture Marketing Council coordinated the research, consultation and development of the Agriculture and Agro-processing Master Plan, which provides practical actions and reforms to address structural constraints that limit inclusive growth and development in the agriculture and agro-processing sectors.

Malawi
The Civil Society Agriculture Network has been working with the Government of Malawi Department of Disaster Management to implement the National Resilience Strategy.

Implementing national policies through local institutions – Malawi

GCRF-AFRICAP's lead partner in Malawi, the Civil Society Agriculture Network (CISANET), has been working with the Government of Malawi Department of Disaster Management (DODMA) to implement the National Resilience Strategy (NRS) through local institutions in Balaka District. CISANET has facilitated a number of stakeholder meetings at national level and at district level in Balaka to promote institutional arrangements for NRS implementation. Achievements include the alignment of national level NRS indicators with District Development Plan (DDP) indicators. CISANET has also agreed, with key policy stakeholders, the timelines, resources, role and responsibilities for data collection, quality control, reporting and use of data for the district NRS monitoring and evaluation plans. CISANET is supporting both national and district level policy discussion on NRS institutional set-up at district level and the capacity strengthening efforts for NRS implementation in Balaka. CISANET's engagement strategy, developed for use in Balaka, is now being used for the implementation of the NRS by local institutions in the other districts of Malawi.

Providing an evidence base for climate proofing key national policies - South Africa

GCRF-AFRICAP's lead partner in South Africa, the National Agriculture Marketing Council (NAMC), coordinated the research, consultation and development of the Agriculture and Agro-processing Master Plan on behalf of the Department of Agriculture, Land Reform and Rural Development, in consultation with industry stakeholders and communities. The Master Plan provides practical actions and reforms to address structural constraints that limit inclusive growth and development in the agriculture and agro-processing sectors. GCRF-AFRICAP's research into the impact of changing climate on strategic food commodities in South Africa has helped those drafting the Master Plan to consider the changing climate in identifying strategic commodities and regions that can increase food security. The research also helped stakeholders identify production corridors for implementation of the Master Plan in line with commodity value chains, including grains and oilseeds (maize, soybean, wheat, cotton), animals and products (cattle, poultry, wool, mohair) and horticulture (citrus, deciduous, viticulture, potato, tomato).

Building capacities for implementation of evidence-based policy pathways towards SDG-compliant and climate-smart agrifood systems - Tanzania

GCRF-AFRICAP's lead partner in Tanzania, the Economic and Social Research Foundation (ESRF) has been working with the Tanzania Climate Smart Agriculture Alliance (TACSAA). They have jointly run workshops at a local level to stimulate shared learning on the opportunities for, and critical challenges or constraints to, achieving food system resilience in the Tanga Region of Tanzania in the context of climate change. ESRF and TACSAA have also helped to set up the Muheza Climate Smart Agriculture Learning Alliance. This is a learning platform that brings stakeholders together to exchange experiences and knowledge on climate change, agriculture and food system issues. The Alliance also provides an opportunity for stakeholders to work with research and agricultural development programmes to build local capacities for the identification and implementation of evidence-based policy pathways towards SDG-compliant and climate-smart local agrifood systems.

Supporting the development and implementation of national development policies and programmes - Zambia

In Zambia, GCRF-AFRICAP has supported the development and implementation of key national policies and programmes. GCRF-AFRICAP's lead partner in Zambia, the Agriculture Consultative Forum (ACF), has led the development of a Soybean Strategy, which has been accepted by the Ministry of Agriculture and is awaiting full cabinet approval. This strategy looks at climate resilience and the food and nutrition security implications of soybeans, the different supply chains that soybeans feed into and the crop's potential to contribute to the country's agricultural diversification agenda. The development of the Soybean Strategy is one of a number of commodity-based action plans or strategies planned by the Zambian government.

ACF also studied the operation of the oilseed industry and identified policy levers to help enhance the value chain's contribution to the national agricultural diversification agenda, to support a sustainable and climate-resilient agriculture sector. ACF also carried out a consolidated assessment of the five-year performance of the country's first National Agriculture Investment Plan (NAIP) and recommended areas of improvement in the design and implementation of NAIP II.

2.2 Policy coherence

Each of the four GCRF-AFRICAP focal countries have strategic long term visions, which are in line with **eight principles outlined by the Organisation for Economic Co-operation and Development** on policy coherence for sustainable development. The eight principles are: (1) political leadership; (2) strategic long-term vision; (3) policy integration; (4) government coordination; (5) subnational and (6) stakeholder engagement; (7) financing, and (8) monitoring and evaluation.

Agriculture is seen as integral to the achievement of development goals in each country. However, there is often a lack of policy integration. The strategies within sectoral policy often fail to show how they will achieve the long-term vision. Different national policies do not always integrate well with each other and so are not mutually reinforcing. For example, agricultural policies often support the expansion of agricultural land, even though this can exacerbate land-use conflicts, and be in direct opposition to conservation policies.

The participatory scenario exercises undertaken at the outset of GCRF-AFRICAP, and the integrated assessments these informed, helped us to join the dots between different policy domains and objectives, and assist policymakers to better understand the broader dependencies and consequences of their decisions.

Coordination across sectors (for example agriculture, land, planning, forestry, conservation) still presents a major challenge, although this is improving. However, a critical lack of capacity in and communication at sub-national levels significantly weakens policy implementation, an area that GCRF-AFRICAP has sought to address through its work building a district learning alliance with TACSAA in Tanzania, and by developing processes for NRS implementation at district level in Malawi. Financing of action plans, and monitoring and evaluation at the local level by national governments will be critical to the longer term success of policy coordination and implementation.

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Section 3: Growing capability

Growing research capability has been a vital and consistent component of our work throughout the GCRF-AFRICAP programme, from launching individual fellowships, to increasing policymakers' capacity to interpret and integrate academic evidence into their decision making.

This is not purely because our funding through the UK Research and Innovation Global Challenges Research Fund expected it, but because designing and implementing policy and practice for sustainable climate-smart food systems requires a wide range of individual and institutional skills and capabilities.

GCRF-AFRICAP has improved individual research skills among early career researchers and our lead partners in each country by providing opportunities to engage in data collection and analyses and collaborate with more experienced researchers. We have provided training on project design, proposal writing and other key research skills.

All organisations involved in the consortium have also identified areas for improvement at an institutional level. The University of Leeds as lead partner has improved how it manages financial and contractual processes with overseas partners and developed new online education and training resources. This will pave the way for smoother international collaboration in the future.

We also wanted to ensure that GCRF-AFRICAP enhanced the ability of our partner organisations in the four countries to design and implement multi-disciplinary research and advocacy programmes with large budgets.

A brainstorming session during the scoping trip in Tanzania, March 2019. © GCRF-AFRICAP

FANRPAN PIVA

Our organisational capacity building work centred on the Partner Institutional Viability Assessment tool (PIVA).

Colleagues from GCRF-AFRICAP's lead partner organisations (CISANET, NAMC, ESRF and ACF), worked with the FANRPAN secretariat to train as **PIVA assessors and conduct capacity reviews** during exchange visits. Based on reports, individual and group interviews, each organisation was assigned a capacity score in areas such as governance, finance, human resources, programme delivery and advocacy. This allowed us to identify areas for improvement and implement targeted country-specific and programme-wide capacity strengthening activities.

Chatham House fellowships

Four GCRF-AFRICAP team members from Malawi, South Africa, Tanzania and Zambia were offered the opportunity to join Chatham House as fellows for three months.

Two fellowships took place in London in 2019 and **two were remote placements in 2021** (due to COVID-19 travel restrictions). The GCRF-AFRICAP fellows developed policy leadership skills, through training and capacity building from Chatham House's established Queen Elizabeth II Academy for Leadership in International Affairs, where fellows joined peers from across the world. The placements also gave fellows and Chatham House colleagues the opportunity to work together more closely on GCRF-AFRICAP policy research and other related activities.

Tanzania study tour and learning alliance

In Tanzania, GCRF-AFRICAP supported training among District Agricultural Officers through a **study tour** across the Tanga Region of Tanzania. Held in March 2020, the tour brought together international researchers, national facilitators, government representatives and local farmers to develop shared knowledge on resilient food and agricultural systems.

As well as supporting the implementation of climate-smart agricultural policy at a local level, **the new CSA Learning Alliance in the Muheza District of Tanga (MCSAA)**, which GCRF-AFRICAP's lead partner in Tanzania helped to establish, will strengthen individual and institutional capacities amongst smallholder farmers and organisations. It will also ensure that the legacy of GCRF-AFRICAP's capacity building work continues beyond the life of the programme.


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Conclusions and recommendations

Climate change is already harming agriculture and food systems in sub-Saharan Africa. Without action to create resilient and sustainable food systems, crop failures and post-harvest losses will only increase.

To make agriculture sustainable, resilient and productive, effective policies and practices require robust evidence in the face of uncertainty. Working with local organisations and governments in Malawi, South Africa, Tanzania and Zambia, GCRF-AFRICAP has created an evidence base, to underpin country-specific policies in agriculture and food production and to inform food system policy and practice across the region.

Summary of evidence

Climate model simulations show that the chance of record-breaking hot conditions in sub-Saharan Africa has increased and this trend will continue as the climate continues to warm. Climate models also show a trend towards both severe droughts and more intense rainfall, and this will result in increased flood risk and soil erosion. Extreme temperatures and precipitation will increase the damage and disruption caused by pests and diseases. Without sufficient adaptation to these kinds of climatic changes, crop failure rates are likely to increase and average yields to decrease.

Our analysis shows:

- Nutritional deficiencies can be reduced by 2050, although this requires substantial increases to crop yields. Without these increases, nutritional improvements will require agricultural areas to expand and / or increased food imports.
- Maize crop failure rates could increase by more than 50% by 2050 under the most optimistic future climate scenarios (RCP 2.6) and more than double under the worse-case scenarios (RCP 8.5). Average maize yields could fall by as much as a quarter under some scenarios.
- Farmers are already seeing increasing impacts on crop production due to pests and diseases, in places accounting for nearly a third of annual yield losses.
- Increases in precipitation intensities will likely increase soil erosion in Tanzania and Malawi, negatively impacting agricultural yields.
- Drought and high temperatures in Malawi, Tanzania, and Zambia will increase the cyanide toxicity of cassava, making it harder to process into safe, edible forms.
- Although the impacts of climatic changes will be felt differently by different communities, owing to differing exposures, vulnerabilities, and capacities to adapt, female smallholders will be disproportionately affected.

Policy and practice recommendations

Achieving food systems that are resilient and sustainable under a range of plausible futures requires them to be 'climate-smart': able to adapt to climate change, reduce emissions and increase production; and to support nutrition and livelihood security. This necessitates holistic and integrated policymaking and implementation at many scales.

Our work in Malawi, South Africa, Tanzania and Zambia shows that this requires:

- Investing in climate services; supporting climate-smart agriculture (CSA) practices; improving water management; and aligning and coordinating nutrition, agricultural, and economic development objectives. If policy processes are not integrated, incoherence will exacerbate land-use conflicts, environmental degradation, and climate change.
- Supporting long-term capacity building interventions at sub-national levels, including targeted support for the most vulnerable groups. Such measures can improve adoption of CSA practices and technologies.
- Linking seed systems to long-term climate information to make them more resilient. Identifying future conditions can inform trade-offs in crop breeding, such as between shortening growing seasons and increasing temperatures.
- Diversifying crop production and increasing imports of nutrient-dense foods. This will enable more diverse diets and achieve nutrition security in the face of increasing demographic and environmental pressures in the coming decades.
- Proactive efforts to strengthen tools, networks and capacities, across a broad spectrum of stakeholders, to share knowledge and develop integrated solutions.

Further information

Briefing notes covering the results of the iFEED process for each country and the findings from research projects can be found on the GCRF-AFRICAP website at: **https://africap.info/policy-briefs**

To learn more about iFEED visit: **https://ifeed.leeds.ac.uk**

Full details of academic papers published by the GCRF-AFRICAP programme team can be found at: **https://africap.info/research-papers**

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