

WHAT CAN SMALLHOLDER FARMERS GROW IN A WARMER WORLD?

CLIMATE CHANGE AND FUTURE
CROP SUITABILITY IN EAST
AND SOUTHERN AFRICA



Investing in rural people



WHAT IS ASAP?

IFAD's flagship Adaptation for Smallholder Agriculture Programme (ASAP) is the largest global source of financing that supports poor smallholder farmers in their efforts to adapt to climate change. The programme was launched in 2012. The second phase of the programme, ASAP2, started work in 2017 and has a particular focus on providing technical assistance and capacity-building to IFAD's portfolio and partners, in cooperation with ministries, research institutes, farmers' organizations and civil society. Eight in-depth Climate Risk Analysis reports were produced by the University of Cape Town in 2020 with funding from ASAP2. The reports look at future crop suitability in selected countries of IFAD's East and Southern Africa region.

To download research highlights from the full reports:

www.ifad.org/en/web/knowledge/-/publication/climate-risk-analysis

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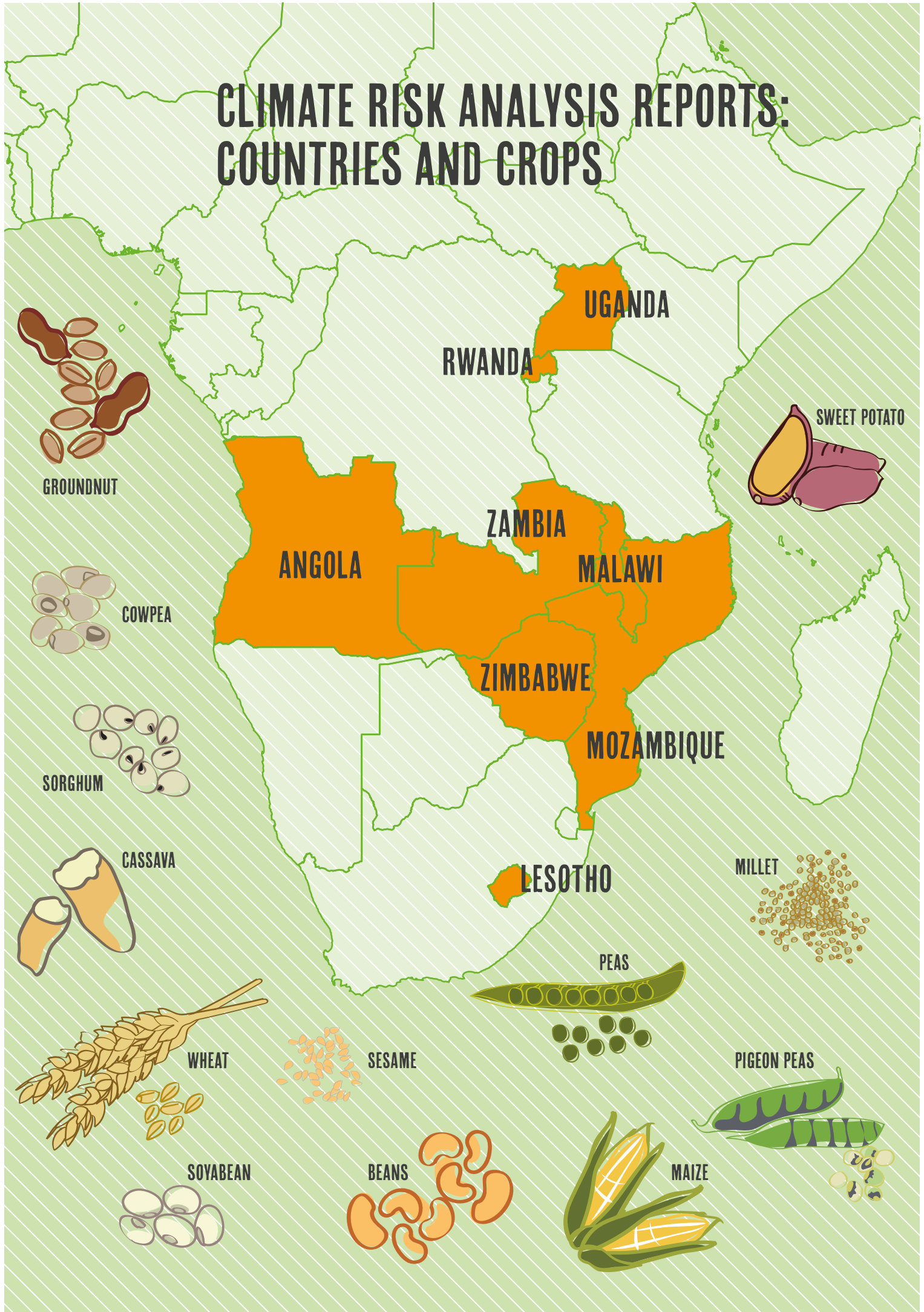
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CLIMATE RISK ANALYSIS REPORTS: COUNTRIES AND CROPS



UGANDA

RWANDA

SWEET POTATO

GROUNDNUT

COWPEA

ANGOLA

ZAMBIA

MALAWI

ZIMBABWE

MOZAMBIQUE

SORGHUM

CASSAVA

LESOTHO

MILLET

PEAS

WHEAT

SESAME

PIGEON PEAS

SOYABEAN

BEANS

MAIZE

MAIN MESSAGES

- The **WORLD IS HOTTER TODAY THAN IT HAS BEEN FOR 12,000 YEARS**; the last seven years have been the hottest on record.
- On every continent, people are already **FACING THE EFFECTS OF THE CLIMATE BREAKDOWN**. Storms are more devastating, floods are more frequent, heat waves kill thousands, even in affluent societies.
- A global mean temperature rise of just 1°C is estimated to **REDUCE CEREAL YIELDS BY ABOUT 5 PER CENT**.
- The costs of the climate crisis are enormous. Developing countries need around **US\$70-US\$100 BILLION A YEAR** for climate change adaptation.
- Out of the estimated US\$463 billion invested annually in global climate finance, only **US\$22 BILLION IS DIRECTED TOWARDS CLIMATE ADAPTATION**.
- To date, **JUST 1.7 PER CENT OF CLIMATE FINANCE** has been targeted at smallholder farmers.
- IFAD's flagship **ASAP PROGRAMME** works to channel the benefits of climate and environmental financing to smallholder farmers.
- Climate Risk Analysis reports produced by the University of Cape Town for eight countries in East and Southern Africa reached strikingly similar conclusions. By mid-century, **TEMPERATURE INCREASES IN THE HOTTEST MONTHS ARE PREDICTED TO BE A FULL 2°C OR MORE** and could reach as much as 2.6°C in some places.
- At the same time, **RAINFALL IS FORECAST TO DECREASE BY WELL OVER 20 MM** in the driest months, and by more than 100 mm per year in the worst hit nations.
- Climate change is predicted to have **MULTIPLE NEGATIVE EFFECTS** on a range of staple and cash crops grown by smallholder farmers for food and income.

- **FAMILIAR SEASONAL PATTERNS WILL BE DISRUPTED**; temperature rises will also include more frequent and severe heat waves and unusually hot days. Rainfall will be scarcer but also more erratic, particularly in southern Africa. Flash floods will threaten crops and soil stability.
- Reduced rainfall, changing patterns of precipitation and late onset of rains can also lead to the **DISASTER OF TOTAL CROP FAILURE**.
- Drier conditions will inevitably force **FUNDAMENTAL CHANGES TO LOCAL CROP CHOICES** and agricultural practices by the year 2050.
- **MONTHLY RAINFALL MAY INCREASE DURING RAINY SEASONS** in some areas, particularly in East Africa. This could give farmers the option to extend or stagger the timing of crop establishment. However, this is likely to vary from year to year, making it difficult to plan.
- **ADAPTATION** to the new emerging conditions is a complex undertaking and means making fundamental changes to choice of crops, growing techniques, use of inputs, technology and financial services, timing of agricultural activities, and more.
- **FOOD SYSTEMS** built on the bedrock of prosperous and productive smallholder farmers are more likely to contribute to resilient, equitable rural communities, and to feeding vulnerable people.
- Recommended **ACTIONS** include:
 - Planting alternative crops and crop diversification.
 - Planting different varieties, including locally adapted varieties, based on further research and development.
 - Using different planting techniques, with improved seeds and plant material.
 - Strengthening storage and processing capacities and infrastructure, and climate proofing value chains.
 - Improving access to and management of irrigation.

THE CLIMATE CRISIS: FAST AND SLOW

Research shows that the world is hotter today than it has been for 12,000 years, since the dawn of agriculture and human civilization.¹ Warnings about the climate crisis call for immediate radical action if we are to draw back from global catastrophe. On every continent and in every country, people are already facing the effects of the climate breakdown. Storms are more devastating, floods are more frequent, heat waves kill thousands even in affluent societies. Experts are even debating the relationship between climate and earthquakes.²

Alongside the disasters that hit the headlines, there are gradual and incremental shifts and disruptions to weather patterns and seasonal rhythms. And there are relatively slow but inexorable changes, such as increasing average temperatures and rising sea levels. There is no debate that the last seven years have been the hottest on record.³ A global mean temperature rise of just 1°C is estimated to reduce cereal yields by about 5 per cent.⁴

With the historic Paris Agreement signed by 196 countries at COP21 in 2015, the aim is to limit warming to well below 2°C. At the same time, there is a concerted drive to ramp up ambition and keep warming to within 1.5°C. Scientists say this is the safe space for humanity,⁵ and would give us the best chance of staying away from dangerous tipping points in the world's climate.

The costs of the climate crisis are enormous. Developing countries need around US\$70-US\$100 billion a year for climate change adaptation. Yet, according to the Climate Policy Initiative, out of the estimated US\$463 billion invested annually in global climate finance, only US\$22 billion is directed towards climate adaptation.

To date, just 1.7 per cent of climate finance has been targeted at smallholder farmers – the people whose labour produces half the world's food calories, and whose lives and livelihoods are among the most vulnerable to climate variability and change.

Enabling these women and men to adapt their agricultural practices to the emerging and challenging new conditions is vital to the eradication of poverty and hunger (Sustainable Development Goals 1 and 2) and to the UN Member States' pledge, when they adopted the 2030 Agenda, to ensure "no one will be left behind".

1. www.theguardian.com/environment/2021/jan/27/climate-crisis-world-now-at-its-hottest-for-12000-years

2. www.researchgate.net/post/Does_climate_change_have_any_effect_on_earthquakes or www.axa-research.org/en/project/rebekka-steffen

3. <https://climate.nasa.gov/news/3061/2020-tied-for-warmest-year-on-record-nasa-analysis-shows/>

4. www.pnas.org/content/114/35/9326

5. <https://climate.nasa.gov/news/2458/why-a-half-degree-temperature-rise-is-a-big-deal/>

The COVID-19 pandemic, which continues to devastate societies across the globe, is a threat multiplier, exposing the frailties and inequalities that exist on every continent.⁶ The socio-economic impacts of the virus have led to a reconsideration of what resilient food systems are and highlighted the crucial role of rural people – especially small-scale farmers, rural workers and small-scale entrepreneurs.

IFAD's flagship ASAP2 programme works to channel the benefits of climate and environmental financing to smallholder farmers. The programme also aims to improve and disseminate knowledge about climate-related risks to smallholder agriculture. It makes up-to-date analyses and information available as a public good – so that they can be integrated into rural development projects worldwide.

THE DRIVERS OF CLIMATE CHANGE

It is now abundantly clear that changes in patterns of land use contribute significantly to the emissions that are driving the climate breakdown. Deforestation, often on a massive scale, slash-and-burn agriculture, and poor management of water resources and soil fertility are all key drivers.

In addition to releasing huge quantities of carbon, over time deforestation leads to soil run-off, which is further exacerbated by inadequate or

overuse of fertilizer. Poor management of precious groundwater reserves and over-application of pesticides further impoverish Africa's natural capital and undermine farmers' capacity to produce food that meets minimum health requirements. Sustainable intensification of agriculture is now urgent; without it, hunger looms.

6. <https://news.un.org/en/story/2020/05/1063022>

CLIMATE RISK ANALYSIS REPORTS FOR EAST AND SOUTHERN AFRICA

With funding from ASAP2, eight Climate Risk Analysis reports were produced by the University of Cape Town, covering Angola, Lesotho, Malawi, Mozambique, Rwanda, Uganda, Zambia and Zimbabwe. The reports assessed the future suitability of selected crops in each country, particularly staples grown by subsistence farmers such as beans, cassava, cowpea, groundnuts, maize, millet, peas, pigeon peas, sesame, sorghum, sweet potato and wheat.

The reports analyse the likely effects of climate change by mid-century and reach strikingly similar conclusions. Far from staying within the safe space of 1.5°C, temperature increases in the hottest months in all eight countries are predicted to be a full 2°C or more, and could reach as much as 2.6°C in some places. At the same time, rainfall is forecast to decrease by well over 20 mm in the driest months, and by more than 100 mm per year in the worst hit nations.

THE MULTIPLE NEGATIVE EFFECTS ON CROPS

The reports looked at projected changes between a historical baseline (the average climate for 1980 to 2010) and “mid-century” – between 2040 and 2069.⁷ The eight countries analysed are very different, landlocked, coastal, mountainous or semi-arid, but the conclusions are repeated and grim. Climate change is predicted to have multiple negative effects on a range of staple and cash crops grown by smallholder farmers for food and income.

Compounding the hotter, drier conditions that are forecast, familiar seasonal patterns will be disrupted. Temperature rises will also include more frequent and severe heat waves and unusually hot days. Rainfall will be scarcer but also more erratic, with flash floods threatening crops and soil stability. The combined effects of the hotter, drier conditions will exacerbate water and heat stress on crops, and reduce the growing seasons.

In many countries, conditions in areas that were well suited for the cultivation of beans, for example, will become much less suitable, reducing both the hectares available for planting and the productivity of the remaining land. Drought-sensitive but important and popular crops, such as slow-maturing maize, are likely to become increasingly unreliable or poor in yield.

Smallholder farmers' crops are largely rainfed. As well as cutting yields, reduced rainfall, changing patterns of precipitation and late onset of rains can also lead to the disaster of total crop failure. Drier conditions will inevitably force fundamental changes to local crop choices and agricultural practices by the year 2050.

At the same time, monthly rainfall may increase during rainy seasons in some countries and areas (for example, in mountainous Rwanda) and rainy seasons may be a month or two longer. This could give farmers the option to extend or stagger the timing of crop establishment and training is vital to enable them to take advantage of this. However, these effects are likely to vary from year to year and across different geographic areas, making it difficult to predict or plan for the impact on agricultural activities, or to rely on the changes.

7. The studies used Representative Concentration Pathway 8.5, the high-emissions scenario.

WHAT DID THE STUDIES LOOK AT?

The full Climate Risk Analysis reports/Research Highlights looked at:

- The characteristics of countries' agricultural sectors.
- Countries' current and future climate characteristics.
- The potential change in the suitability of selected staple and cash crops under projected climate shifts, mapping areas of current and future suitability.
- Potential risks and economic impacts related to climate change.

- Potential adaptation options to increase climate resilience.
- Farmers' capacities to adapt and take advantage of opportunities.

The studies use EcoCrop analyses, which allow for map-based visualizations of crop suitability zones across the countries. These can be used to inform decision-making and further planning, including identification of areas that are particularly vulnerable to climate change, and value chains that could be prioritized for additional support.

WHAT DID THE STUDIES NOT LOOK AT?

It is important to note that the studies are based on a narrow range of modelled variables. They have not been further validated or calibrated and do not account for local-level factors, such as differences in crop performance, climatic suitability and yield potential between locally adapted land races and improved cultivars. Furthermore, the studies do

not analyse the potential indirect effects of climate change on crop production, including an increase in pests and diseases, soil degradation or flooding, and water-logging. The aim is to provide indicative guidelines to inform further research and decisions at the local level.

ADAPTATION: ENABLING FARMERS TO CHANGE CROPS AND CULTIVATION METHODS

In line with IFAD's focus on empowering poor rural people, the studies analysed the adaptive capacity of farmers across the different regions and provinces of the selected countries. Adaptation to the new emerging conditions is a complex undertaking and means making fundamental changes, not only to the choice of crops, but to growing techniques, use of inputs, technology and financial services, timing of agricultural activities, and more. Adaptation is vital if smallholder farmers are to protect and strengthen their livelihoods, feed their families and increase their productivity. Farmers' ability to make the necessary changes is determined by many factors.

To assess adaptive capacity, the studies looked at detailed socio-economic data for indicators, including:

- Education (literacy rates and primary school enrolment rates).
- Access to agricultural information (households with a mobile phone, receiving extension services, weather or market information).
- Access to alternative off-farm sources of income, not related to agriculture.
- Adoption rates of improved agricultural practices (use of manure, irrigation or improved seeds, use of chemical fertilizers, pesticides and herbicides).

The indicators were weighted and national statistics collected to assess and rank adaptive capacities in different areas. This will enable planners to focus particularly on areas where smallholder farmers are expected to be least able to respond and adapt to climate change-related impacts. Inclusive capacity-building will be vital and should include training on techniques to manage the challenges of delayed rainfall, conservation agriculture to improve the fertility and water-holding capacity of soils, and increased access to and ability to use seasonal weather forecasts.

SUPPORTING SMALLHOLDERS TO ADAPT, INTENSIFY AND PROTECT THE ENVIRONMENT

Through their work and culture, smallholder farmers are closely linked to the natural environment, making them important custodians of biodiversity and ecosystems. With the right support, smallholders can increase their productivity, provide a range of essential ecosystem services, and make a vital contribution to protecting the environment for future generations.

To enable Africa's farming families to intensify their production in a sustainable way, innovative technologies and approaches must be scaled up and made accessible. These include improved farming practices and seeds, and more efficient water management techniques. Access to finance, digital soil diagnosis, and climate information and education is also essential.

Investment in value chains is key to boosting poor producers' efficiency and competitiveness. Investment must be stepped up in critical infrastructure, including rural roads, storage and cold storage facilities, small-scale irrigation, and markets and abattoirs. Accessible, affordable digital services and renewable energy options are also crucial. Multi-stakeholder partnerships that leverage mutually beneficial investment from the private sector are also necessary.

Governments have an important role to play in supporting farmers to adapt sustainably, for example to adopt new crops, shift production or stop cattle ranching. Affordable finance is essential. Instruments and tools like climate insurance help smallholders manage risks, while contract farming enables them to bridge market failure. These options incentivize farmers to make climate-smart investments in their land and production.

Improved land tenure arrangements and security, together with better and fairer access to land markets, also play a critical part in giving women and men the assurances they need to invest in the lands that they farm and in their livelihoods.

Small-scale producers who are truly trapped in subsistence agriculture for whatever reason – environmental degradation or plot sizes that are too small to produce saleable surplus, for example – must be given options to transition to other rural livelihoods. Providing off-farm opportunities is about enabling rural women and men to make choices and leaving no one behind.

RECOMMENDED ACTIONS

In addition to providing the groundwork for more detailed localized analysis and agricultural planning, the reports give broad-brush recommendations and guidance on ways to increase climate resilience for smallholder farmers. These include:

- Planting alternative crops and crop diversification.
- Planting different varieties, including locally adapted varieties, based on further research and development.
- Using different planting techniques, with improved seeds and plant material.
- Strengthening storage and processing capacities, infrastructure and value chains.
- Improving access to and management of irrigation.

PLANTING ALTERNATIVE CROPS AND CROP DIVERSIFICATION

Some crops are more resilient to climate change, tolerating drier conditions for example, or having a shorter growing season. Species including cassava (see box), groundnuts, beans, sorghum and millet, are all expected to be comparatively less affected by climate change and may experience mild positive effects in some areas. Increased use of these crops is recommended in many countries, particularly for household food security.

In Zambia, for example, groundnuts have potential to safeguard food security at the household level and to increase cash income. In Angola, farmers would benefit from adopting crops including sorghum and beans. In Malawi, cowpeas, groundnuts, sorghum and millet are proposed as alternative staples.

Planting alternative crops is not a quick fix, however. Local cultures and gastronomic traditions may mean that subsistence farming families have strong preferences about the crops they plant. They may have negative perceptions of cereals such as sorghum and millet, for example, and these must be addressed through extension workers and other capacity-building channels. Inputs and processing facilities for alternative crops that are new and unfamiliar must also be made available.

PLANTING DIFFERENT VARIETIES

Some varieties of a particular crop are more resilient to climate change than others. Maize is an important staple crop in many of the countries under review and early-maturing varieties are strongly recommended to reduce future losses. In Zambia, for example, potential losses are significantly higher to late-maturing maize production than to early-maturing – approximately 300,000 tonnes greater, with additional replacement costs of up to US\$40 million. Increased investment in research and development will be necessary to identify locally appropriate cultivars, including locally adapted varieties, that will do better under the harsher conditions.

USING DIFFERENT PLANTING TECHNIQUES, WITH IMPROVED SEEDS AND PLANT MATERIAL

Different planting techniques that increase farmers' ability to cope with climate change include crop diversification using inter-cropping and multi-crop approaches, and conservation agriculture, which can be particularly useful in drier areas. Both crop diversification and conservation agriculture also improve soil fertility and stability. In Uganda, for example, the risk of reduced maize production can be partly offset by also planting diverse legumes and alternative cereals, including sorghum and millet. In Malawi and Rwanda, groundnuts should be promoted within inter-crop and multi-crop combinations.

Subsistence farmers traditionally plant farm-saved seeds, yet improved seeds can give a better chance of a good harvest. This is flagged for maize in Zimbabwe, for example, where access to certified high-quality seeds is unreliable and variable between districts. Seed production cooperatives managed by smallholders themselves can be part of the solution, producing high-quality, affordable seed and boosting farmers' income at the same time. Good-quality plant material is important for crops such as cassava (see box).

STRENGTHENING STORAGE AND PROCESSING CAPACITIES, INFRASTRUCTURE AND VALUE CHAINS

Improved post-harvest infrastructure, including all-weather roads and better storage facilities, is vital to boosting smallholder farmers' resilience to climate change. Access to efficient processing techniques and equipment allows farmers to cut waste and spoilage, add value to crops and increase their incomes.

The importance of being able to process fresh cassava into shelf-stable products is flagged in several country reports, including Mozambique, Uganda and Zambia. In Lesotho, improved processing capacity is recommended for wheat, which is grown as a subsistence crop across most districts.

Strengthening value chains is also important for cash crops, to enable farmers to get a fair, reliable price for their harvests and to add value. In Uganda, sesame, soyabean and sunflower are recommended climate-resilient oilseed crops, which can be used to boost household incomes by processing oils, or by marketing seeds to commercial oilseed processors.

IMPROVING ACCESS TO SUSTAINABLE IRRIGATION

Smallholder agriculture across the countries reviewed is largely rainfed, which makes decreasing and more erratic rainfall a huge threat to food security and agricultural incomes. Irrigation can be one part of the answer, but it brings its own challenges.

In many countries, infrastructure for irrigation is not in place or not accessible to smallholder farmers. Existing irrigation systems may also use water inefficiently, while more efficient systems, such as drip irrigation, may be too costly. In Mozambique,

improved access to irrigation is considered one of the few strategies to maintain the food security of subsistence farming households, and many districts urgently need to invest in infrastructure for water management. This is essential to supply fresh water for people, livestock and irrigation, but also to mitigate the impact of floods after heavy rainfall.

While water infrastructure is a key priority in Mozambique and other countries, there is also an urgent need for research and monitoring of surface and ground water sources to prevent unsustainable use. Training is also important to ensure that improved infrastructure is properly managed and maintained.

A similar situation exists in Zimbabwe. Here, devolution of irrigation schemes to community or farmer-based management structures requires sustained support and capacity-building. Furthermore, it is increasingly likely that irrigation schemes, in this country and others, will face periodic disruptions or constraints as a result of drought and reduced rainfall, which means that farmers cannot become over-reliant on irrigation.

Unirrigated crops will therefore remain significant sources of food and income in many contexts. Livestock will also continue to make an important contribution within mixed smallholder farming systems. Small livestock species, including poultry and goats, offer a climate-resilient alternative to cattle raising.



ROOTING FOR CASSAVA

Cassava (*Manihot esculenta*) is relatively climate-resilient. The root crop is a staple for smallholder farmers in many countries, playing a key role in food security and contributing to household incomes. It has a flexible growth habit, which means that the leaves or the tuber can be harvested when they are needed and this makes it a particularly useful option for climate-resilient subsistence farming systems.

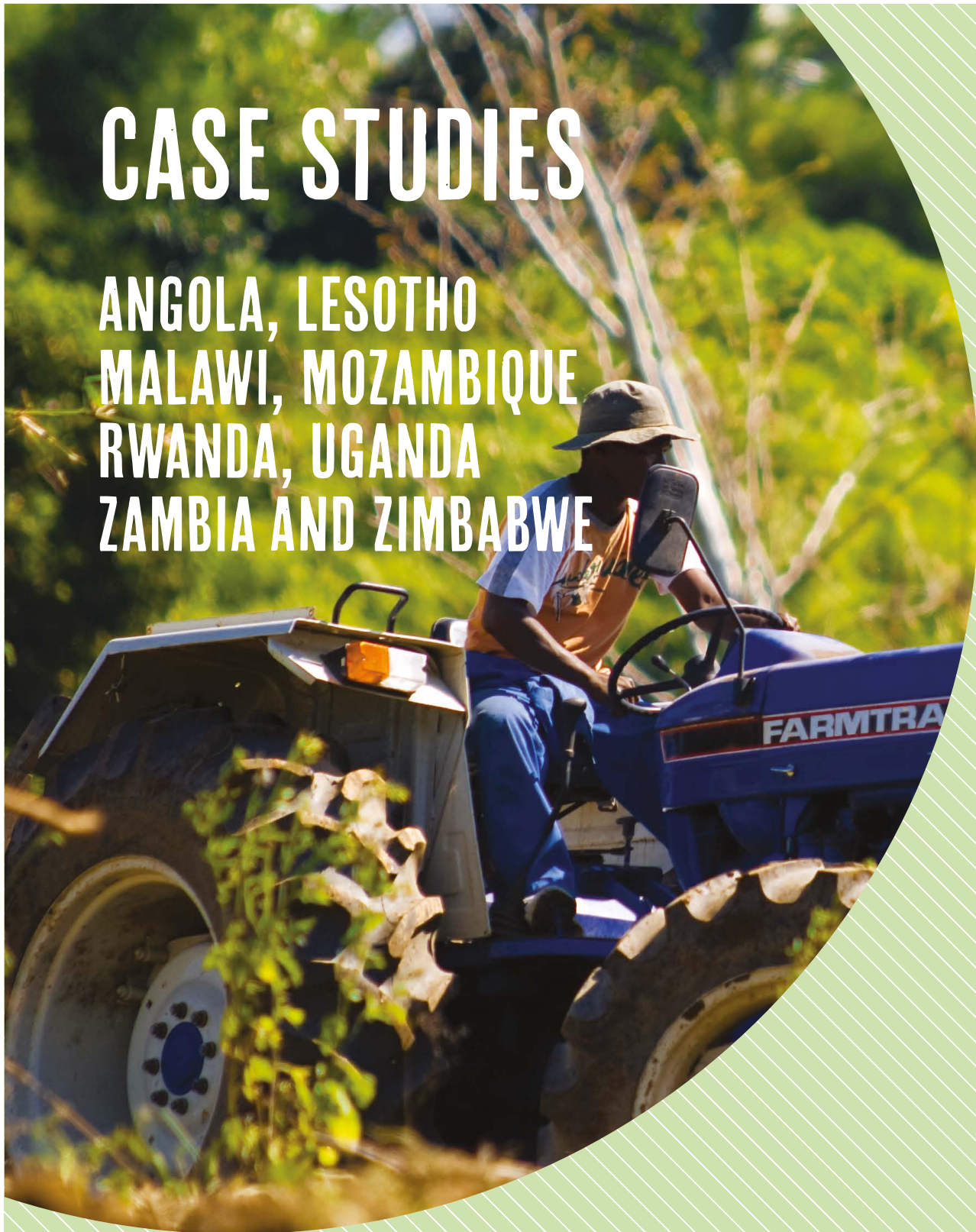
Although it is categorized as resilient, cassava will not be unaffected by climate change and several countries will see the crop decreasing in suitability. To offset this, the reports recommend that facilities be developed for post-harvest processing, together with supporting value chains. With the right

equipment, fresh cassava roots can be processed into flour, chips, starch and other shelf-stable marketable products, reducing waste and spoilage, adding value and boosting cash incomes.

The production of cassava in countries like Angola, Malawi, Mozambique, Rwanda, Uganda and Zambia can also be strengthened by promoting access to good-quality plant materials, focusing on virus-free clones of high-yielding and locally adapted varieties. In addition, farmers should be provided with capacity-building and training for ongoing management of pests and diseases, particularly to control the insect vectors of cassava mosaic virus, as well as to identify and remove infected plants.

CASE STUDIES

ANGOLA, LESOTHO
MALAWI, MOZAMBIQUE
RWANDA, UGANDA
ZAMBIA AND ZIMBABWE





ANGOLA

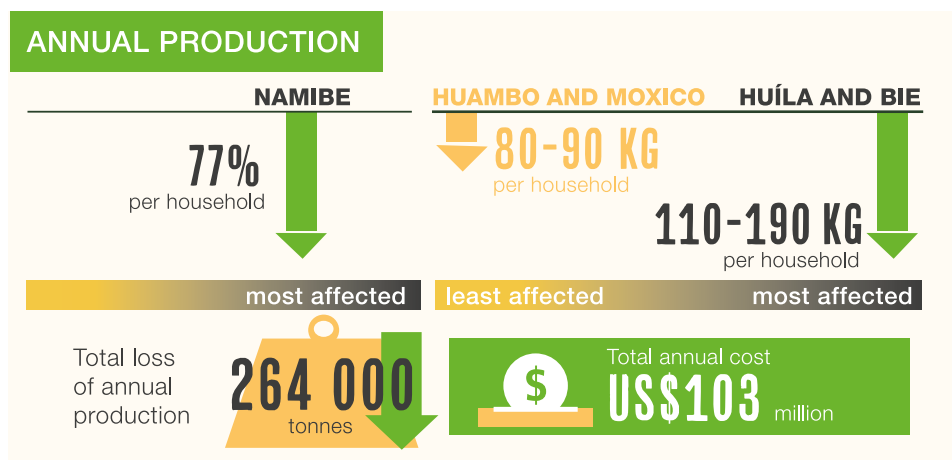
Maize (*Zea mays*) is a hugely important staple for smallholder families in Angola and is grown as a subsistence crop across all provinces. In the 2017-2018 growing season, 1.7 million tonnes was harvested from over 1.9 million hectares. By mid-century however, many provinces are expected to see a sharp reduction in areas that are suitable for maize. Households in the worst affected provinces will see their annual harvests cut by as much 190 kg. The total loss of annual production is forecast to be 264,000 tonnes, with a replacement cost of US\$103 million.

THE TOTAL LOSS OF ANNUAL PRODUCTION IS FORECAST TO BE 264,000 TONNES, WITH A REPLACEMENT COST OF US\$103 MILLION.

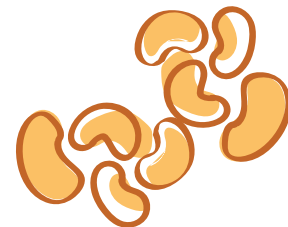
There is a marked difference, however, between long-maturing maize varieties and improved, short-maturing varieties. Looking ahead to the mid-century point, short-maturing varieties will have widespread areas of moderate to good suitability, particularly in the central and northern regions.

It is therefore important to support farmers in accessing locally adapted, short-maturing cultivars and to help them adopt climate-resilient cultivation practices. At the same time, alternative and complementary crops, such as sorghum, beans, cowpeas, groundnuts and pigeon peas, should be promoted.

HOUSEHOLD- AND PROVINCE-LEVEL IMPACTS ON MAIZE PRODUCTION



LESOTHO



In Lesotho, smallholder farmers grow a limited selection of staple crops using rainfed agriculture across most of the planted area. Alongside the staples, complex mixed farming practices include small stands of fruit trees, kitchen gardens, grazed cattle and small ruminants.

By mid-century, temperatures are predicted to rise across the country's ten districts by at least 1.9°C, and in the hottest months by as much as 2.3°C. At the same time, total seasonal rainfall between October and March will be reduced by 5.5 per cent and the onset of rains may be delayed, which can cause devastating crop failure.

Beans are widely grown as a staple subsistence crop across Lesotho and many areas are currently marginally or moderately suitable. Production for 2016-2017 was more than 6,600 tonnes across more than 27,000 hectares. Climate change is projected to reduce average suitability index scores, and productivity in the worst affected areas will be cut by as much as 17 per cent. Although some areas may benefit from slight increases in suitability, the total loss of annual production is forecast at 417 tonnes, with a total annual replacement cost of US\$962,000.

THE TOTAL LOSS OF ANNUAL PRODUCTION IS FORECAST AT 417 TONNES, WITH A TOTAL ANNUAL REPLACEMENT COST OF US\$962,000.

KEY FINDINGS AND RECOMMENDATIONS FOR BEAN CULTIVATION



Moderate decrease in area and productivity predicted for the southern and western districts.



Minor increases in suitable area predicted to occur in the mountainous zones of northeast districts. It is likely these new areas will be characterised by low suitability.



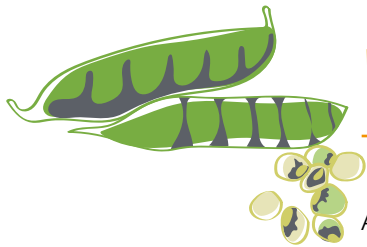
Mafeteng, Mohale's Hoek and Qacha's Nek are likely to be particularly vulnerable to decreases in production of beans, both from the perspective of household production, and from the perspective of total district production.



The total replacement costs incurred by households to replace lost bean production is estimated to be up to US\$962,000 per year.



Despite the predicted negative changes to production, it is likely that beans will be comparatively more resilient than crops such as maize. Beans, and other leguminous crops, will therefore remain a useful option for climate-resilient farming systems.



MALAWI

Although agricultural productivity is relatively low, smallholder farmers in Malawi grow a broad selection of staple crops, a wide variety of annual and perennial horticultural products, and cash crops – the most important of which is tobacco. Agriculture is rainfed across most of the planted area. Smallholders also have complex mixed farming practices, with fruit trees such as banana, avocado, mango, pawpaw and citrus growing near households, kitchen gardens for vegetables, and grazed production of cattle, goats and sheep.

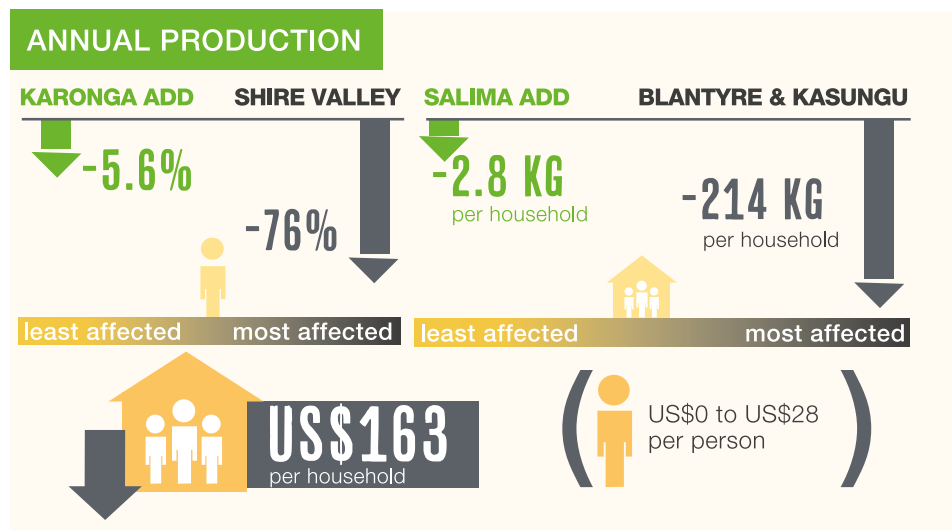
By mid-century, temperatures are predicted to rise by as much as 2.5°C in the hottest months and the higher average temperatures are expected to include more frequent and severe heat waves and unusually hot days, further exacerbating crop stress.

Total seasonal rainfall in the rainy season is expected to fall by more than 10 per cent. Monthly rainfall deficits are likely to force fundamental changes to local crop choices and farming practices by 2050.

THE HARVEST AT THE NATIONAL LEVEL IS FORECAST TO FALL BY 160,000 TONNES, WITH A REPLACEMENT COST OF US\$86.5 MILLION.

Pigeon peas are one of several legumes grown as subsistence crops across most districts in Malawi. In 2018, over 403,000 tonnes were harvested across 430,000 hectares. Climate change analyses indicate that most regions will see moderately or severely negative changes to suitability for pigeon pea. Annual household production in the worst affected areas is forecast to fall by as much as 214 kg, with a replacement cost of US\$163 per household. The harvest at the national level is forecast to fall by 160,000 tonnes, with a replacement cost of US\$86.5 million.

HOUSEHOLD LEVEL IMPACTS ON PIGEON PEA PRODUCTION



NATIONAL LEVEL IMPACT



MOZAMBIQUE



Smallholder farmers in Mozambique cultivate a wide variety of rainfed staple crops. They also grow fruit trees such as banana, avocado, mango, coconut and papaya adjacent to households, tend kitchen gardens for vegetables, and keep grazing cattle, and goats and sheep.

By mid-century, temperatures across the country are predicted to increase by at least 1.7°C, and by as much as 2.1°C in the hottest months. Rainfall is expected to decrease by about 12 per cent over the rainy season. The combination of drier conditions and higher temperatures is likely to reduce agricultural production, as a result of either lower yields or outright crop failure, and this is particularly true for heat- and drought-sensitive crops such as maize and wheat.

AT THE NATIONAL LEVEL, LOSS OF PRODUCTION WILL REACH 886,000 TONNES WITH A REPLACEMENT COST OF US\$37 MILLION.

Smallholder farmers grow cassava as a staple subsistence crop across all provinces in Mozambique. Production figures for 2015 show that 3.6 million tonnes of cassava were harvested over 621,000 hectares. Climate change is like to reduce the suitability of land for cassava across the country. In the worst affected region, Maputo, households will see their annual production fall by 850 kg, with a replacement cost of US\$35.50. At the national level, loss of production will reach 886,000 tonnes with a replacement cost of US\$37 million.

KEY FINDINGS AND RECOMMENDATIONS FOR CASSAVA PRODUCTION



Mozambique's potential production for cassava is likely to be reduced across all provinces as a result of climate change.



Most of the northern and central provinces are expected to remain suitable for production, while Inhambane, Gaza and Maputo may become increasingly marginal.



The total replacement cost for the predicted loss in production of cassava is estimated to be US\$37 million per year.



Despite the negative changes to the production potential of cassava, the flexible growth habit of the crop suggests that it is still likely to be a useful option for climate-resilient farming systems.



Recommended actions: increased access to quality, virus-free planting material of improved varieties; increased access to facilities and equipment for processing fresh cassava; improved capacity of farmers to monitor and respond to common pests and diseases.



RWANDA

Rwanda has a highly productive agricultural sector that benefits from two rainy seasons. Smallholder farmers grow rainfed crops across most of the planted area. Important subsistence crops include cassava, sweet potato, maize, beans, groundnuts and bananas. Coffee and tea are significant cash crops.

Temperatures are expected to rise across the country by at least 1.7°C and as much as 2.1°C in the hottest months of August and September. Rainfall will decrease by as much as 73 mm over the year and the onset of both rainy seasons may be delayed, threatening crop establishment. Predicted increase in rainfall in December and January may extend the first rainy season, giving farmers the option of staggering or extending the planting period. Drought-sensitive crops such as maize, and vegetables like tomatoes and peppers, are likely to be increasingly unreliable or poor in yield.

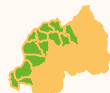
Smallholder farmers grow groundnuts as a subsistence crop across all of Rwanda's provinces. Widespread areas are likely to remain suitable for groundnut cultivation in the first rainy season, but production in the second rainy season is predicted to be severely affected, with productivity losses ranging from 0.7 to 100 per cent. Total loss of annual production across the country is forecast to reach 4,980 tonnes, with a replacement cost of US\$8.8 million.

**TOTAL LOSS OF ANNUAL PRODUCTION
ACROSS THE COUNTRY IS FORECAST
TO REACH 4,980 TONNES, WITH A
REPLACEMENT COST OF US\$8.8 MILLION.**

KEY FINDINGS AND RECOMMENDATIONS FOR GROUNDNUT PRODUCTION



Rwanda will likely experience minor or moderate decreases in production of groundnut during rainy season B (March), particularly in the Eastern, Kigali and Southern provinces.



The Western and Northern provinces are unlikely to experience severe negative impacts to production of groundnuts as a result of climate change.



All provinces continue to be characterised by widespread areas of suitability for groundnuts in season A.



The total loss of national production resulting from climate change is estimated to be 4,980 tonnes per annum, equivalent to a replacement cost of US\$8.8 million per year.

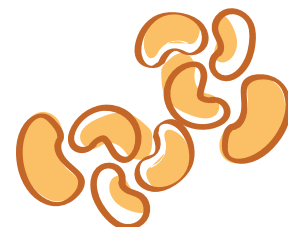


Despite the predicted negative impacts, the continued extensive distribution of suitable areas for groundnut production suggests that this crop is likely to remain a useful option for climate-resilient farming systems.



Recommended actions: promote within diversified, multi-crop and intercrop combinations; research, develop and promote locally-adapted and drought resilient varieties; invest in post-harvest processing facilities.

UGANDA



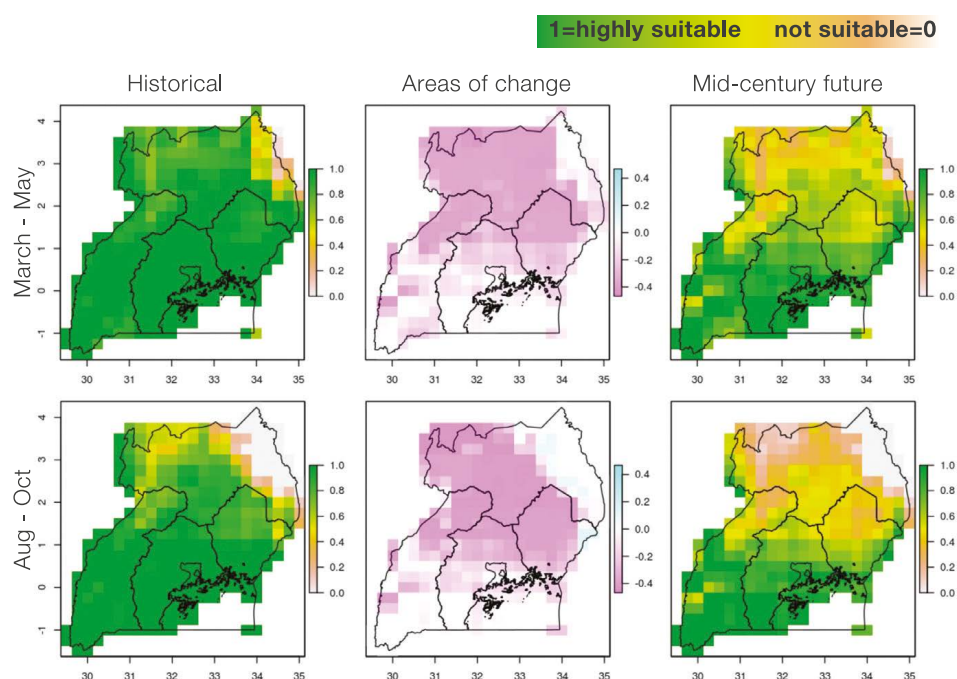
Uganda has a highly productive agricultural sector. It benefits from two rainy seasons in most districts and geographic variability means that a diverse range of subsistence and cash crops can be grown. Smallholder farmers cultivate rainfed crops across the vast majority of the planted area. Subsistence crops include maize and other cereals, plantains, legumes like beans and groundnuts, cassava, sweet potatoes and various vegetables and horticultural crops. Important cash crops include coffee, sesame, soyabean and other oilseed crops.

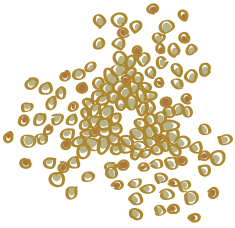
By mid-century, the hottest months of January, February and March are predicted to see temperatures rise by 1.7°C. Increases of between 1.6°C and 2.1°C are expected for the other months of the year. Rainfall is forecast to decrease by 31 mm in each of the two rainy seasons, and to increase slightly in the dry season months of November to February, potentially extending the second rainy season and giving farmers the option of staggering or extending the timing of crop establishment.

AT THE NATIONAL LEVEL, BEAN PRODUCTION IS FORECAST TO FALL BY 116,400 TONNES, WITH A REPLACEMENT COST OF US\$69.8 MILLION.

Beans are widely grown as a subsistence crop across the country in both rainy seasons. All regions are predicted to see negative changes in land suitability as a result of climate change. The Northern region is likely to be the worst affected, with productivity decreases of 20 and 29 per cent in the first and second rainy seasons respectively. Households in the Northern region are expected to see annual production fall by as much as 112 kg, with a replacement cost of US\$67. At the national level, bean production is forecast to fall by 116,400 tonnes, with a replacement cost of US\$69.8 million.

PROJECTED EFFECT OF CLIMATE CHANGE ON DISTRIBUTION OF SUITABILITY FOR BEANS IN UGANDA





ZAMBIA

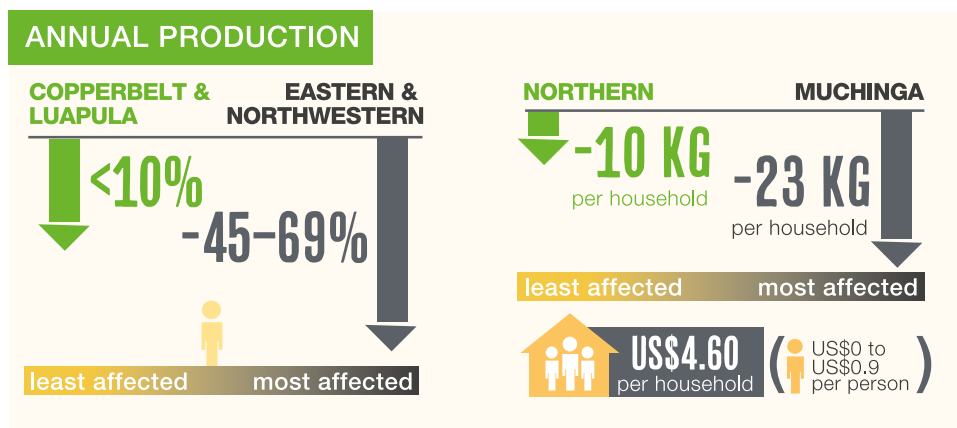
Agriculture in Zambia is relatively low-productivity. Smallholders cultivate most of the planted area with rainfed crops, including a wide range of staples, a variety of perennial and horticultural products, and cash crops – particularly tobacco. There are also mixed farming practices at the household level, with fruit trees such as banana, mango, cashew and citrus, kitchen gardens for vegetables, and grazing cattle, sheep and goats.

By mid-century, temperatures are predicted to rise by at least 1.8°C, with the hottest months seeing huge increases of up to 2.6°C. Higher average temperatures will also include heatwaves that are more frequent and more severe. Climate change is predicted to result in complex changes to rainfall across the country, although both mean monthly precipitation and total annual precipitation will be reduced in all provinces. Total rainfall in the rainy season is expected to reduce by 9 per cent. Delayed rains will force changes to the traditional agricultural calendar, including the timing of field preparation and sowing of seeds. The hotter, drier conditions will compel farmers to make fundamental changes to their crop choices and agricultural practices by 2050.

MILLET WILL NOT BE IMPACTED AS NEGATIVELY AS MAIZE, WHICH IS THE MAIN CEREAL CROP.

Millet and sorghum are relatively climate-resilient grains that are widely grown in Zambia. The country is expected to experience minor to moderate decreases in production of these grains, but substantial areas are predicted to remain suitable. Millet in particular will not be impacted as negatively as maize, which is the main cereal crop. Efforts must be made to encourage farmers and consumers to adopt these often less familiar cereals, including as a diverse feed for livestock. Research and development are required to identify cultivars suited to local conditions and to make improved seeds available.

HOUSEHOLD LEVEL IMPACTS FOR MILLET PRODUCTION



ZIMBABWE



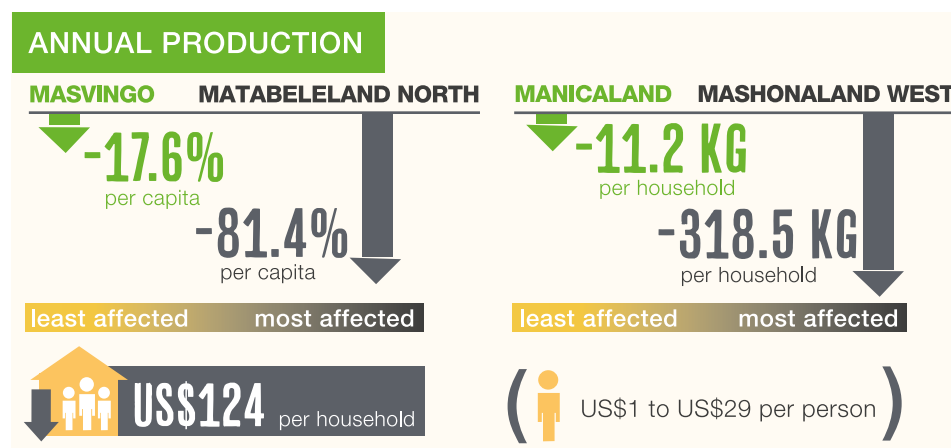
Smallholder farmers in Zimbabwe grow a limited selection of staple cereals and legumes – including maize, sorghum, millet, beans, groundnuts and soyabeans – across most of the country’s planted land. Crops are mostly rainfed and productivity is relatively low. Cash crops such as tobacco and cotton are also grown. In a few areas where rainfall is higher, high-value, sub-tropical plantation crops are cultivated, including citrus, avocado, tea and coffee.

Temperatures are predicted to rise by at least 1.8°C across the country, and by as much as 2.7°C in the hottest months of October, November and December. This will increase crop water demand, and increase the risk of crop failure, particularly for staples such as maize and wheat, which are sensitive to heat and drought. Rainfall will decrease both month by month, and in terms of total annual precipitation. Total seasonal rainfall for the rainy season is predicted to decrease by 14 per cent.

BY MID-CENTURY, FORECASTS INDICATE THAT PRODUCTION LOSS WILL AMOUNT TO 230,000 TONNES WITH A NATIONAL REPLACEMENT COST OF US\$88.8 MILLION.

The effect on maize production will be significant, with declining suitability across most of the current growing areas. According to figures for 2015, total annual production of maize was 582,000 tonnes. By mid-century, forecasts indicate that production loss will amount to 230,000 tonnes with a national replacement cost of US\$88.8 million, or US\$124 per household.

HOUSEHOLD- AND NATIONAL-LEVEL IMPACTS ON MAIZE PRODUCTION





International Fund for Agricultural Development
Via Paolo di Dono, 44 - 00142 Rome, Italy
Tel: +39 06 54591 - Fax: +39 06 5043463
Email: ifad@ifad.org
www.ifad.org

-  facebook.com/ifad
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