ABCG project documenting human responses to changes in weather and climate in Africa

Kyarumba town, Kasese district, Uganda: In the foreground, a newly constructed temporary bridge following floods, with a permanent bridge in the background (*source:* Nikhil Advani)

AFRICA BIODIVERSITY COLLABORATIVE GROUP

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1. Introduction

The Africa Biodiversity Collaborative Group (ABCG) comprises seven international conservation NGOs (African Wildlife Foundation, Conservation International, the Jane Goodall Institute, The Nature Conservancy, Wildlife Conservation Society, World Resources Institute, and World Wildlife Fund) with the goal of working collaboratively and efficiently and effectively to further a sustainable future for the African continent. The four organisations that comprise the Climate Change Working Group (namely Conservation International, The Nature Conservancy, Wildlife Conservation Society and World Wildlife Fund) was interested to investigate the effects of climate change in four countries: Gabon, Madagascar, Tanzania and Uganda. This report documents the findings of qualitative research undertaken through interviews and focus groups in selected communities in which Group members work. These primary findings are complemented with evidence from the literature, and placed within the context of anticipated future climate change with the intention of identifying sustainable adaptations that can be actively supported.

Section two provides a background to the primary data collection. Section three gives an overview of the anticipated nature of climate change in Africa, and the impacts on various sectors. Section four looks at observed changes and impacts, informed by the field data collection. Section five examines responses reported in the communities, and divides them into coping strategies, reactive adaptation and anticipatory adaptation. Section six looks at barriers to adaptation, and ways of overcoming these barriers to support local adaptation. Section seven provides a conclusion.

2. Background to primary data collection

Primary data collection took place between May 2014 and March 2015, and was led by researchers from four of the seven ABCG members. In total 28 interviews were undertaken in Gabon (10 interviews), Madagascar (7 interviews; 3 in the southwest and 4 in the south), Tanzania (9 interviews) and Uganda (2 interviews). Interviewees are engaged in various natural resource-based livelihoods, mainly farming (crop and livestock) and fishing. In addition two focus groups were facilitated – one in Uganda and one in Madagascar. In Uganda there was one agricultural supervisor, approximately 10 officers and one banana and coffee producer present. In Madagascar there were 8 male and 4 female farmers. Table 1 summarises the locations, characteristics and timing of this primary research. In addition the villages where interviews took place in Gabon, Madagascar, Tanzania and Uganda are represented on maps in Appendices A, B, C and D respectively.

Table 1: Summary of locations, characteristics and timing of primary research

Country	*ABCG Organisation*	*Quantity and location*	*Characteristics*	*Timing*
Interviews				
Gabon	Wildlife Conservation Society	10 interviews on the border of Loango National Park, or its periphery zone, on the coast of Gabon (2 in Rabi village-Rive droite; 1 in Rabi village-Rive gauche; 1 in Ignoungou; 1 in Bonne Terre, 1 in Ghendanaghoulou; 1 in Obiro II Idjembo; 1 in Iguela and 1 in Ekondet	4 farmers, 4 fishermen, and 4 people that engage in both farming and fishing	July 2014
Madagascar	Conservation International and WWF	7 interviews: 2 in the Ifanadiana District and 2 in Ambositra District (south central); 2 in Beheloke and 1 in Marofijery (southwest)	4 farmers, of which one is also a religious leader and one also sometimes practices carpentry; 3 fishermen who also farm	September 2014 (south central) and March 2015 (southwest)
Tanzania	The Nature Conservancy	9 interviews in Simanjiro district (3 in Loborsoit, 3 in Terrat and 3 in Sokoro)	Livestock keepers and farmers	30 August 2014
Uganda	WWF	2 interviews (1 in Mabira forest, near Jinja, eastern Uganda; 1 in Kyarumba, near Kasese, western Uganda)	Farmers selected on experience and length of time in the area (Kyarumba farmer is a "model farmer"	May 2014
Focus groups				
Uganda	World Wildlife Fund	Focus group in Kyarumba town, Kasese district	Bukonzo Joint Co-operative Union (grows coffee as cash crop, cotton in the lowlands) – 1 agriculture supervisor, approximately 10 officers and 1 coffee and banana farmer	May 2014
Madagascar	World Wildlife Fund	Focus group in Marofijery, southwest Madagascar	Farmers	12 March 2015

3. Brief of overview of climate change in Africa – projected trends and impacts

An authoritative source of information on the science of climate change, its likely impacts, and options for adaptation and mitigation is the Assessment Reports produced by the Intergovernmental Panel on Climate Change (IPCC). The recently–released Fifth Assessment Report (AR5) of the IPCC states that "warming of the climate system is unequivocal and, since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased" (Christiansen et al, 2013). This section first reviews the science of climate change and what Global Climate Models (GCMs) project for the future before looking briefly at the vulnerability of different sectors relevant to this study.

3.1 Projected climate change in Africa

Global Climate Models are run by supercomputers housed in a variety of specialist centres around the world, for example the National Oceanic and Atmospheric Administration (NOAA) (USA) and the Hadley Centre (UK). Given that the future emissions trajectories are also unknown, and will depend on a variety of factors (e.g. population growth, level of urbanisation, degree of dependence on fossil fuels, or the role of policies which influence any of these), GCMs are run under a variety of scenarios, each representing plausible futures. Until recently the most commonly used scenarios were from the Special Report on Emissions Scenarios (SRES). AR5, on the other hand, presents the results of different scenarios, known as Representative Concentration Pathways (RCPs). Instead of trying to predict highly variable futures, RCPs show the concentrations of greenhouse gases in the atmosphere, and thus the models project how different concentrations will lead to different temperatures and rainfall regimes. This provides more for policy-makers to work with, as they can determine the impact of policies on the overall concentration levels, and make choices that are in-keeping with their global commitments and priorities. In the literature it is likely that task managers may come across reference to both SRES and RCPs; and it is important to note, when assessing any data on projections, which model and scenario they used. The most robust projections come from ensembles – when multiple models have been used together. This is the case for AR5, where the models used were part of the 5th Climate Model Intercomparison Project (CMIP-5).

Temperature is easier to project using models than rainfall. There are various reasons for this: systems that affect rainfall are more localized than those which affect temperature (e.g. presence of mountains; major forest basins such as the Congo). In Africa, some areas are projected to become wetter and others drier. Broadly speaking, eastern Africa is projected to become wetter and southern Africa drier. The extent to which models agree, even on the direction of change (e.g. increase vs. decrease) does, however, vary. The models for western Africa, for example disagree on the direction of change – some project an increase, some project a decrease.

AR5 divides Africa into 3 different regions: Mediterranean and Sahara; Central and Eastern; and Southern. For each region projections are provided to three different timescales: 2016-2035; 2046-2065; and 2081-2100, compared to a baseline situation of 1986-2005, based under the RCP4.5 scenario. Two sets of temperature projections are available; covering December to February and then June to August (i.e. the major winter and summer months in each of the northern and southern hemispheres); together with two sets of rainfall projections, which cover the same range (2081-2100 relative to a baseline of 1986-2005), but different months (October to March and April to September).

For each projection and timeframe (e.g. temperature from July to August in 2046-2065) there are also three diagrams – available in Appendix E - each representing the 25th, 50th (mean) and 75th percentile of the distribution of models. This is because it provides a more robust output to run a variety of models under the same scenarios to compare their outputs. How this can be interpreted is that, for the 25th percentile, 75% of models agree that rainfall change will exceed that denoted in that diagram. For the 75th percentile; 75% of models agree that rainfall change will be less than that denoted in that diagram. The mean (50%) can sometimes be misleading, hence it is often preferable to cite the 25th-75th percentile range; i.e. by the period 2046-2065, temperature in the Sahara is likely to be 1-3^{0}C warmer than the period 1986-2005 (1^o is shown for most of the desert, excluding the coast, in the 25th percentile diagram, and 3^o is shown for most of the desert, excluding the coast, in the 75th percentile diagram)(figure 2, Appendix A). As with previous models, rainfall projections are subject to greater uncertainties than temperatures, and the presence of hatching over the block colours indicates that the degree of difference is not more than one standard deviation from current variability.

Given the size of the continent, African climate varies. In tropical latitudes rainfall follows insolation (although this simple picture is complicated by the presence of mountains, particularly in the horn of Africa; and also the significant influence of the oceans). The eastern side of the continent is exposed to tropical cyclones, and monsoons (the sub-Saharan Sahelian zone), the El Niño Southern Oscillation (ENSO) (southern and eastern Africa), and sea surface temperatures (bringing about general variability) affect climates. CMIP-5 models show less certainty than the earlier CMIP-3 results, which projected both significant wetting and significant drying, as well as change in the character of the rainy season meaning later onset of rains, but more intense rainfall events towards the end of the season. In terms of general robust conclusions using the latest available science, the continent is very likely to warm and very dry areas (e.g. the Sahara) are likely to remain very dry. The controversy over whether West Africa will become wetter or drier remains. With rainfall projections there is medium confidence for several regions: around the rainy season beginning later but experiencing greater intensity of rainfall events towards the end in monsoonal areas; around reduced rainfall in the winter rainfall region of South Africa's Western Cape; and little change in mean precipitation in east Africa (although it is likely that there will be increasing rainfall in the short rainy season (Christensen et al, 2013).

3.2 Vulnerability of different sectors to climate change

Terrestrial Ecosystems

According to AR5 continuing changes in precipitation, temperature, and carbon dioxide (CO2) associated with climate change have resulted in changes in the distribution and dynamics of all types of terrestrial ecosystems in Africa, including deserts, grasslands and shrublands, savannas and woodlands, and forests (Niang, et al, 2014). In recent years, three main trends have been observed at the continental scale. The first is a small overall expansion of desert and contraction of the total vegetated area. The second is a large increase in the extent of human influence within the vegetated area, accompanied by a decrease in the extent of natural vegetation. The third is a complex set of shifts in the spatial distribution of the remaining natural vegetation types, with net decreases in woody vegetation in western Africa and net increases in woody vegetation in central, eastern, and southern Africa.

Freshwater ecosystems

Climate change is also beginning to affect freshwater ecosystems (as can be seen by the higher water temperatures reported in surface waters of Lakes Kariba, Kivu, Tanganyika, Victoria, and Malawi). Along with warming of the water itself, atmospheric temperature increases and associated increases in evaporation may be contributing to reduced lake water inflows and therefore nutrients, which subsequently upsets plankton dynamics and thereby adversely affects food resources for fish. However, it is important to remember that climate is not the only driver of change – freshwater ecosystems are also at risk from anthropogenic land use change, over-extraction of water and diversions from rivers and lakes, and increased pollution and sedimentation loading in water bodies (Niang, et al, 2014).

Coastal and Ocean Systems

In Africa, ocean fisheries mainly depend on either coral reefs (on the eastern coast) or coastal upwelling (on the western coast). These two ecosystems will be affected by climate change through ocean acidification, a rise in sea surface temperatures, and changes in upwelling. Other impacts of climate change on coastal systems include sea level rise (SLR) which will be even further exacerbated by increased storm swells and the flooding of river deltas. Migration toward coastal towns is also expected to increase due to increased drought induced by climate change and this will increase already-existing challenges such as overexploitation of resources, habitat degradation, loss of biodiversity, salinization, pollution, and coastal erosion (Niang, et al, 2014).

Water resources

Several studies from Africa point to a future decrease in water abundance due to a range of drivers and stresses, including climate change in southern and northern Africa. In eastern Africa, potential climate change impacts on the Nile Basin are of particular concern given the basin's geopolitical and socio-economic importance. Reduced flows in the Blue Nile are estimated by the late century due to a combination of climate change (higher temperatures and declining precipitation) and upstream water development for irrigation and hydropower. Estimating the influence of climate change on water resources in West Africa is limited by the significant climate model uncertainties with regard to the region's future precipitation. As with other sectors, it is important to remember that climate change is just one of many stressors affecting the water sector in Africa - a growing body of literature in recent years in fact suggests that it will have an overall modest effect on future water scarcity relative to other drivers, such as population growth, urbanization, agricultural growth, and land use change (Niang, et al, 2014).

Agriculture

Climate change is very likely to have an overall negative effect on yields of major cereal crops across Africa, with strong regional variability in the degree of yield reduction. Maize-based systems, particularly in southern Africa, are among the most vulnerable to climate change but in eastern Africa maize production could benefit from warming at high elevation locations (Niang, et al, 2014).

Livestock systems in Africa face multiple stressors that can interact with climate change and variability to amplify the vulnerability of livestock keeping communities. These stressors include rangeland degradation; increased variability in access to water; fragmentation of grazing areas; sedentarization; changes in land tenure from communal toward private ownership; in-migration of non-pastoralists into grazing areas; lack of opportunities to diversify livelihoods; conflict and political crisis; weak social safety nets; and insecure access to land, markets, and other resources. Loss of livestock under prolonged drought conditions is a critical risk given the extensive rangeland in Africa that is prone to drought. Adequate provision of water for livestock production (especially for feed production but also drinking water) could become more difficult under climate change (Niang, et al, 2014)

Health

Africa currently experiences high burdens of health outcomes whose incidence and geographic range could be affected by changing temperature and precipitation patterns, including malnutrition (resulting in stunted growth), diarrheal diseases, malaria and other vector-borne diseases, with most of the impact on women and children. Cholera is primarily associated with poor sanitation, poor governance, and poverty, with associations with weather and climate variability suggesting possible changes in incidence and geographic range with climate change. The frequency and duration of cholera outbreaks are associated with heavy rainfall in Ghana, Senegal, other coastal West African countries, and South Africa. Projected increases in precipitation in areas in Africa, for example West Africa where cholera is already endemic, may result in more frequent cholera outbreaks in the sub-regions affected (Niang, et al, 2014).

Weather and climate are among the environmental, social, and economic determinants of the geographic range and incidence of malaria. Climate change is expected to affect the geographic range and incidence of malaria, particularly along the current edges of its distribution, with contractions and expansions, and increasing and decreasing incidence depending on other drivers, such as public health interventions, factors influencing the geographic range and reproductive potential of malaria vectors, land use change (e.g., deforestation), and drug resistance, as well as the interactions of these drivers with weather and climate patterns (Niang, et al, 2014).

Other diseases which have a strong link with weather and climate and are therefore likely to be affected by climate change include leishmaniasis, Rift Valley fever (RVF), schistosomiasis and meningococcal meningitis. Heat waves and heat-related health effects are also beginning to attract attention in Africa (Niang, et al, 2014).

4. Nature of observed changes and impacts

The previous section gave an overview of the projected future climate trends over Africa as well as anticipated impacts. However, climate change is not something that will happen sometime in the future – it is already happening now. The report now turns to reviewing the current climate changes that have been experienced and outlines the impacts as observed by the respondents of interviews in Gabon, Madagascar, Tanzania and Uganda. First hand observations are supported by information gathered from secondary sources.

4.1 Observed temperature changes and impacts

In Gabon, nine of the ten key informants (KIs) interviewed contributed observations on temperature changes. Only one said that there had been no change in the temperature while the remaining eight maintained that temperatures were increasing, especially during the wet season. The increase in temperatures was seen as a possible reason for a decline in big fish, although the respondents did admit that this was probably also due to the increase in illegal fishing. The literature does indicate that the fisher people of Gabon are correct in believing that temperature increases play an important role. Coastal countries of West Africa are expected to experience a significant negative impact from climate change - the annual landed value of fish for that region is estimated to decline by 21%, resulting in a nearly 50% decline in fisheries-related employment and a total annual loss of US$311 million to the region's economy (Niang, et al, 2014).

Amongst the key informants interviewed in Madagascar there seemed little agreement concerning a change in temperature – two people said that the winter (dry) season had got colder and increased in length, while two others argued that it had got hotter. The continued existence of frost ("*fanala*") much later into the year was also mentioned. One of the respondents blamed the increase in temperature and the "irregularity of winter time" for an increase in human diseases such as influenza and fever. Cattle diseases were also noted to have increased, as was the occurrence of pests such as crickets, both of which are likely to be affected by changing temperature regimes.

Amongst the eight (out of a total of nine) KIs from Tanzania who provided information about any observed changes in temperature, there was also some disagreement. The majority (7) agreed that the dry season was getting warmer and two of these KIs believed that the rainy season was also getting warmer. The Tanzanian respondents also gave some information on the observed length of hot and cold period but the answers were also not unanimous. However, the majority believed that the cold periods were getting shorter and the hot periods longer (with one respondent stating that the cold period was now only three months long and the hot period nine months long). The minority who believed the contrary argued that there had been an increase in human disease occurrences with more cold and chest infections from dust and prolonged cold seasons.

In Uganda, with regards to observed changes in the climate, one of the respondents stated that it is cooler nowadays than in the past while one KI thought the opposite – that it was much colder in the past. This KI observed that banana yields have been negatively affected by some kind of pest which he attributed to increased temperature. This observation was supported by the literature: It is believed that temperature increases in highland banana-producing areas of eastern Africa enhance the risk of altitudinal range expansion of the highly destructive burrowing nematode, *Radopholus similis*, although no detailed studies have assessed this risk (Niang, et al, 2014). Furthermore, a decrease in other crop yield and quality was also blamed by the respondent on increased temperature.

Although there were differences in the respondents answers, on the whole, the majority across all four countries, observed an increase in temperature. This concurs with the literature - according to the most recent IPCC Assessment Report (AR5), near surface temperatures have increased by 0.5°C or more during the last 50 to 100 years over most parts of Africa, with minimum temperatures warming more rapidly than maximum temperatures (Niang, et al, 2014).

4.2 Observed rainfall changes and impacts

All ten respondents in the Gabon interviews provided observations about how rainfall has changed. Most (9) agreed that the timing of the seasons had changed with a decrease in rainfall and a shortening of the wet season (with one KI stating that the dry season had increased from three to five months). Only one person thought that rainfall had increased and that the dry season had gotten shorter.

All the Madagascan KIs agreed that there are now delays in the onset of the first rains. Furthermore, two respondents specifically mentioned an increase in intense downpours while another observed that there was now less rain during the dry season. Examples of the impacts of less rainfall included a reduced crop yield since 2002 (for instance, rice used to be harvested twice a year but now only once). Possibly also related to the reduction in rainfall is an observed decrease of drinking water sources (since 2009) and water for watering for crops. Increased competition between livestock and crops results from the smaller availability of suitable land. Two farmers also noted how reductions in agricultural production have led to many people turning to fishing, which places increased pressure on fish stocks and has also led to a decline in average annual catch.

There was complete agreement (amongst those who answered the question) concerning how climate change had affected the timing of the seasons (dry and wet) in Tanzania. All agreed that season start and end dates had changed with some providing the further detail that this change meant an increase in the length of the dry season and delays in the start of the rainy season. Furthermore, seven of the nine key informants agreed that there had been less overall rainfall within a shorter rainy season. The length of the dry season ranged from four to nine months between different KIs. In contrast, a small minority (2) stated that, although they agreed that the rainy season had decreased in length, there was an increase in the amount of rain because the magnitude of the rainfall events was much greater.

A significant discrepancy in the responses from the Ugandan informants with regards to rainfall was also apparent. Two KIs believed there was less rain today and a shorter rainy season than in the past while the focus group said there was more rain nowadays and a longer rainy season. The two KIs also argued that the rainfall is much more unpredictable than it was in the past.

According to the secondary literature, most areas of the African continent lack sufficient observational data to draw conclusions about trends in annual precipitation over the past century. In addition, in many regions of the continent discrepancies exist between different observed precipitation data sets. However, areas where there are sufficient data include very likely decreases in annual precipitation over the past century over parts of the western and eastern Sahel region in northern Africa, along with very likely increases over parts of eastern and southern Africa (Niang, et al, 2014).

Precipitation in eastern Africa shows a high degree of temporal and spatial variability due to a variety of localised physical processes. Studies indicate that over the last three decades rainfall has decreased over eastern Africa between March and May/June. The suggested physical link to the decrease in rainfall is rapid warming of the Indian Ocean, which causes an increase in convection and precipitation over the tropical Indian Ocean and thus contributes to increased subsidence over eastern Africa and a decrease in rainfall during March to May/June (Niang, et al, 2014).

4.3 Observed changes in extreme events and impacts

Extreme events do not seem to be very common in the Gabon. However, more than half of the KIs (6) did mention more intense wind and stronger storms (with one of the six being more specific and claiming that these stronger winds occurred in the dry season). Extreme heat was mentioned by four of the respondents as being the only extreme event they had experienced.

In Madagascar, all of the KIs mentioned strong winds during the flowering period of the crops which disrupts the reproductive cycle of the crop. Unpredictability of the winds was also observed. Other extreme events mentioned included droughts (2), landslides (2), hailstorms (3), cyclones (3), frost (2) and thunder (1). The frequency of cyclones was also noted to have increased (one farmer said from twice a year to monthly during the season), which brings heavy rain at a critical time in the growing season and can destroy crops.

In Tanzania, an equal number of respondents (5) stated that they had experienced droughts and floods. Heatwaves were also mentioned by two of the respondents. Also included as an observed change were increased wind speeds with the majority of KIs claiming that winds had increased in intensity all year round. Only a few (2) said that the increased wind was observable only during the dry season while another claimed the opposite – that stronger winds were apparent in the wet season.

One Ugandan KI stated that heatwave type events with weeks of "too much sun and no rain" were the most significant extreme events impacting him and that there had been no floods. On the other hand, the focus group and other KI interviewed listed floods (and associated landslides) as the major extreme event affecting them. According to this KI, days of heavy rains in the Ruwenzori Mountains had resulted in flooding on May 1 2013. Rivers burst their banks and houses, hospitals, schools and a bridge had been swept away. There had also been an increase in typhoid because of the floods. The river washed away trees and crops (fruit, beans, potatoes) during the flood, including 1000 eucalyptus trees which she had taken a loan to plant seven months before the flood. Also washed away was the soil and humus thus negatively impacting on the growth of future crops. The difference in identifying the most important extreme event can be explained by the fact that floods can be relatively localised and only significantly affect those living close to rivers or in low-lying areas. In addition to heatwaves and floods, one of the Ugandan KIs also mentioned damage to coffee crops from hailstones (as well as too much sun during the dry season) - berries drop before they are ripe due to hail.

AR5 provides an overview of the literature on the occurrence of extreme events up until the present (Niang, et al, 2014). Extreme precipitation changes over eastern Africa such as droughts and heavy rainfall have been experienced more frequently during the last 30 to 60 years. Over southern Africa an increase in extreme warm ETCCDI indices (hot days, hot nights, hottest days) and a decrease in extreme cold indices (cold days and cold nights) in recent decades is consistent with the general warming trend. The probability of summer heat waves over South Africa increased over the last two decades of the 20th century compared to 1961 to 1980.

5. Responses

5.1 Reactive responses to observed changes: Coping strategies

Amongst the response to the climate changes identified by the respondents (described above), two of the strategies can be classed as coping – in other words, they are short term survival strategies that do not alter the underlying vulnerability and/or are economically and/or environmentally unsustainable in the long-term (Vincent et al, 2013). The first of these strategies is hunting animals or seeking wild foods which was mentioned by respondents in Gabon, Tanzania and Madagascar. In Gabon people said "we have to eat" and only hunt animals when their usual fishing yields are low. In Madagascar, moky (a wild plant similar to cassava) cactus fruit and tamarind are sought from forests, sea cucumbers are collected from the sea flats, and tenrec and hedgehogs are hunted as a food source. In Madagascar reliance on external agencies, such as the World Food Program, was also mentioned.

A second strategy which can be considered coping - selling any existing assets inside the household - was identified by a Madagascan respondent. Like the hunting of bush meat, this is an unsustainable practice and while it may enable respondents to deal with the immediate problem by making money available, it is likely to result in households being worse off in the long run.

5.2 Reactive responses to observed changes: Adaptation strategies

Adaptation refers to "the process of adjustment to actual or expected climate and its effects" (IPCC, AR5 glossary, 2014). On the other hand, maladaptation is defined as "actions that may lead to increased risk of adverse climate related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future" (IPCC, AR5 glossary, 2014). It is difficult to definitively claim a particular activity is a maladaptation as it is often a question of scale. For example, an activity which may be beneficial to one person, or community, and reduce their vulnerability in the face of climate change (i.e. be considered an example of adaptation) – such as diverting river water for irrigation - may have negative consequences on the wider scale (i.e. be a maladaptation) – for example by reducing water availability for those people downstream. The following section outlines the activities which respondents identified as adaptation strategies (mostly actual cases occurring in their communities but also some desired strategies which they would like to do) and discusses the wider consequences (both positive and negative) on the environment, explaining how some of these activities may be considered possible maladaptations. These are examples of community-based adaptation (CBA) i.e. adaptations that operate at the community level and are based on community priorities, needs, knowledge and capabilities. CBA is "autonomous" adaptation in that local communities and individuals are using self-initiated strategies (often traditional) in response to climate change.

Conservation agriculture and land management

The first of the adaptation strategies may be classified as conservation agriculture which includes a variety of different practices. Mulching (leaving organic material on the ground) results in much higher soil moisture retention and increased soil nutrient levels and was specifically mentioned as an adaptation strategy in Uganda. One of the Ugandan respondents explained how she now grows grass to sell to other farmers as mulching material. Also occurring in Uganda was the growing of cover crops to reduce evaporation of soil moisture. In Tanzania, tilling to allow (the reduced) rainfall to penetrate the soil further is now practiced.

All conservation agriculture strategies have the double benefit of, on the one hand, increasing (or at least maintaining) agricultural yields in terms of quantity and quality and, on the other hand, in improving the wider environment. Mulching has a positive impact on the environment as soil moisture is retained and the decaying plant material which is left on the surface of the soil will decompose and thereby add to the nutrients in the soil. Farmers can therefore reduce the amount of fertiliser they use which is also a positive outcome for the wider environment. Tilling is much less disruptive to the soil (and the organisms which live in the soil) than ploughing and the planting of trees is also highly advantageous from an ecosystem point of view – along with the benefits outlined above, a Ugandan respondent claimed that the planting of multiple tree species (including along river) had attracted birds and snakes back to the area.

Planting trees is another land management practice which improves the wider environment and was found in more than one of the countries. In Uganda, one of the KIs plants trees primarily to provide shade for his coffee bushes but claims there are other benefits including soil conservation (added humus through leaf fall) ; an increase in soil nutrient and moisture levels and reduced erosion through acting as a wind break. Planting trees is also listed as an adaptation strategy in Tanzania and Gabon. Another Ugandan KI said that they had been advised by the Bukonzo Joint Cooperative to plant five trees for every one they cut down. Reforestation and maintenance of land cover not only improves soil fertility but also helps to regulate the hydrological cycle and reduce the likelihood of flooding, as well as creating more humid microenvironments to enable cultivation during dry periods. Planting trees as a barrier to the river, and requires that settlements be shifted further away from the river, thereby reducing their exposure to flooding.

Changing farming practices

One of the observed impacts of climate change in all of the countries in which interviews were conducted was that rainfall patterns are changing and often the onset of the rainy season is delayed. In order to adapt to this aspect of climate change, farmers in Tanzania and Gabon explained that they have changed their planting dates in order to follow the rainfall shifts. Shifting the timing of planting is a common adaptation practice that has been widely observed in African countries (Niang et al, 2014).

As well as changing the timing of planting, another adaptation strategy is to change the location of fields, or to expand the area under cultivation. However to do so, particularly in a context of population increase, runs the risk of increased human-wildlife conflict. This has already happened in Gabon where the changing of livestock and crop farming locations has resulted in the encroachment on previously natural environments – "Animals like elephants eat our plantations" while "Threats from wildlife in our agricultural areas and conflicts with conservationists that block the communities activities" was another issue raised by the interviewees. Similarly, increasing fields for crop farming often encroaches on protected land. This is especially the case in Madagascar where slash and burn (known locally as *"tavy"*) is regularly practiced in order to enlarge the area under cultivation.

Changing the crops grown or using different varieties of the same crop is a strategy employed by many of the respondents in order to adapt to climate change. A move to using "observed heat resistant crop varieties" was mentioned and, by way of an example, one of the Ugandan KI interviewed explained that he has shifted from growing Arabica to Robusta coffee as the latter is more tolerant of the changed climate (and diseases). In Madagascar, a respondent pointed out that they use new seeds as an adaptation strategy but the downside is that they need expensive "crop medicine". The introduction of new crop types and varieties and livestock species (presumably better adapted to the changed environment) was also identified by a respondent from Tanzania. Early maturing crops are also a popular adaptation strategy that, at a minimum, ensure maintenance of yield and, at best, can allow for two crops to be grown per season.

Diversification

Diversification of income generating activities is a common adaptation to climate change strategy. In Tanzania, respondents said that they have diversified their livelihoods by hunting and harvesting forest and wild plants. In Gabon, citrus plantations and hunting - "Some people hunt wild pigs to compensate for losses in fishing" - were mentioned as specific diversification activities while the interviewees from Madagascar listed a number of potential activities which they could, and do, diversify into: handicrafts such as basketry; small scale gold and stone mining; temporary jobs (for instance labour on rich farmers in the other villages); beekeeping and farming rabbits; brick making and masonry/ building; and carpentry and joinery.

While livelihood diversification is an important adaptation strategy, it may replace formerly sustainable practices with livelihood activities that have negative environmental impacts. For instance, the use of forest resources and hunting has the potential to impact negatively on the environment if not controlled. Some diversification strategies, such as charcoal production and artisanal mining, may increase risk and thereby reduce vulnerability through promoting ecological change and the loss of ecosystem services to fall back on (Niang, et al, 2014). According to one respondent in Gabon “We have always done this, without changing” but, under conditions of climate change, this activity may increase beyond sustainable levels. Small scale gold and stone mining in Madagascar can also have a negative impact on the environment if not controlled. According to one of the respondents, small scale gold exploitation has increased land degradation while another said it lead to the impoverishment of rice fields [but did not provide further explanation]. Similarly the increasing reliance on fishing, due to the unpredictability of farming, was observed to cause destruction to coral reefs and loss in species diversity of fish and octopi. One KI noted that there used to be many juvenile sharks near the coast in October and November, but now they only see adults far from the coastline; and that he doesn’t see as many marine turtles nesting on the beach as in the past.

5.3 Planned adaptation to observed changes

In comparison to grassroots emerging responses, with “planned” strategies typically require external support. That is the case for improved technology and subsidies and social protection, which require functioning markets and/or government support to be in place. In Madagascar it was suggested that the numerous studies conducted in the area should start to bear fruit and that projects based on the results of these studies be implemented with external support. Migration is often considered a planned adaptation because, even if it is an option to act upon when other responses have become unviable, it still requires planning on the part of the migrant.

Improved technology

Improved technology can apply to a variety of natural resource-based livelihoods. In Gabon better equipment to increase fish catches was listed as a possible or desired adaptation strategy – “We need help if we want to increase the catch”. This better equipment included outboard motors and fishing nets to increase fishing yield. While this strategy may have an immediate benefit on the recipients of the better and more modern equipment, it also has the strong potential to be a maladaptation as, in this case, improved equipment will likely lead to overfishing and ultimately the reduction in fish stocks and thus diminish people’s welfare and increase their vulnerability to climate change.

Irrigation was mentioned as a possible adaptation strategy by farmers in both Tanzania and Madagascar. By managing water availability and flow and matching this to crop needs, irrigation can support production in dry periods. However, if not implemented in a sustainable manner, can result in maladaptation. Whilst it may reduce vulnerability in the short term, if the scheme is not designed to take into consideration future water availability, it may increase vulnerability in the long term by promoting reliance on a resource which may not be available to the same extent. In addition availability of irrigation can discourage demand management and resource conservation and undermine more sustainable traditional methods of water allocation. Suitable approaches to expand irrigation in Africa include using low-pressure drip irrigation technologies and construction of small reservoirs, both of which can help to foster diversification toward irrigated high-value horticultural crops.

Improved technology often requires enabling by financial resources. Irrigation, for example, requires energy. Limited access to energy was listed as a barrier to adaptation by respondents in Tanzania and

Gabon. Other technologies, such as improved fishing gear and farming inputs are typically more expensive than traditional equipment and practices.

Subsidies and social protection

Reliance on subsidies was included in the list of adaptation strategies of one of the Tanzanian respondents. If reliable, predictable and long term (for instance, included as a line in national budgets), subsidies (such as social grants or agricultural input subsidies) can be a very valuable adaptation strategy. However, if the opposite is true – if subsidies are provided only over an unpredictable short term – then this strategy could lead to maladaptation.

The literature points out that social protection is being increasingly used in Ethiopia, Rwanda, Malawi, Mozambique, South Africa, and other countries to buffer against shocks by building assets and increasing resilience of chronically and transiently poor households; in some cases this surpasses repeated relief interventions to address slower onset climate shocks, as in Ethiopia's Productive Safety Net Program. However, while social protection is helping with pre and post – disaster risk reduction initiatives and will be increasingly important for securing livelihoods should climate variability increase, less evidence exists for its effectiveness against the most extreme climatic shocks associated with higher emissions scenarios, which would require reducing dependence on climate-sensitive livelihood activities (Niang, et al, 2014).

Migration

Linked to diversifying activities is migration which was included as an adaptation strategy by respondents from both Tanzania and Gabon. In the latter, respondents explained that "We leave the village to look for work elsewhere in the cities" and "Many young people leave because the elephants devastate everything". According to Niang (et al, 2014), remittances are a longstanding and important means of reducing risk to climate variability and other household stressors, and of contributing to recovery from climatic shocks.

The literature indicates that, although migration has long been seen as a fundamental process for most African families to incorporate choice into their risk profile and adapt to climate variability, there is evidence in some areas of the increased importance of migration and trade for livelihood strategies, as opposed to subsistence agriculture (Niang, et al, 2014)

A negative impact of migration is that the influx of people to areas which may already be facing numerous stressors, including but not limited to, climate change, over-stretched infrastructure; poor governance; lack of resources; etc. may exacerbate existing problems in those areas.

5.4 Anticipatory adaptations

The use of weather forecasts and early warning systems (EWS) could be considered anticipatory actions to adapt to potential changes but it does depend on how they are used (i.e. the information gained from these sources is then used to change or modify what otherwise might have happened). With regards to weather forecasts: in Uganda, two of the three respondents said that this technology was used and one added that climate data gained through weather forecasts had influenced their crop growing season. In Madagascar, respondents agreed that weather forecasts are useful. These forecasts are given over the radio (so, as one respondent pointed out, they are only accessible to those with a radio) – there are four district broadcasters (in Imady, Mada, Viva and Ambositra) as well as a national broadcaster (although the respondent did complain that they did not receive a warning about the cyclone and their village was hit by winds and rain and the crops destroyed).

Only one respondent in Tanzania and all (4) the respondents in Madagascar said that early warning systems were used. The Tanzanian said that the EWS "had helped" but there was no explanation of in what way. In Madagascar the EWS seems to be mostly by word of mouth and one respondent therefore questioned the accuracy and said that it often comes too late to be useful.

The literature shows that, elsewhere in Africa, early warning systems are gaining prominence as multiple stakeholders strengthen capabilities to assess and monitor risks and warn communities of a potential crisis, through regional systems as well as national, local, and community-based EWS on for example food and agriculture. Some of the recent EWSs emphasize a gendered approach, and may incorporate local knowledge systems used for making short-, medium-, and long-term decisions about farming and livestock-keeping. The health sector has employed EWS used to predict disease for adaptation planning and implementation (Niang, et al, 2014).

Although not mentioned by any of the respondents in the interviews, the literature indicates that community-led DRR initiatives are another important anticipatory adaptation response. These initiatives include activities that link food security, household resilience, environmental conservation, asset creation, and infrastructure development objectives and co-benefits. Food security and nutrition-related safety nets and social protection mechanisms can mutually reinforce each other for DRR that promotes adaptation, as in Uganda's Karamoja Productive Assets Program. Initiatives in Kenya, South Africa, Swaziland, and Tanzania have also sought to deploy local and traditional knowledge for the purposes of disaster preparedness and risk management (Niang, et al, 2014).

6. Enabling environment and conditions for transferability of adaptations

6.1 Barriers to local level adaptation

The primary research conducted as well as the secondary literature consulted indicates that there are numerous barriers to adaptation – obstacles that inhibit a desired state (Spires, et al, 2014). The KIs from the four countries identified a number of common barriers to adaptation: lack of access to finance and credit; lack of access to technical information and know-how; and inadequate land tenure systems. The extent to which barriers to adaptation exist will also depend on the magnitude and rate of climate change (Klein et al, 2014).

Lack of access to finance and credit

One of the most significant barriers was the lack of funding and access to credit. A KI from Madagascar explained that they could not meet the requirement for loans by a microfinance institution. This lack of funding meant that respondents could not, for instance, buy seeds that were more adapted to a shorter growing season; invest in machinery necessary for adapting their farming practices (for example, tractors for conservation farming) or in equipment needed to diversify their livelihoods. In Madagascar, a KI raised the associated issue of corruption, explaining that donations are often "mismanaged" with only the relatives and friends of the leader receiving support through donations. A Tanzanian respondent explained that access to loans would enhance livestock breeding as farmers would be able to invest in livestock which was better suited to changed climatic conditions. A farmer in Tanzania mentioned the provision of increased quality and quantity of maize seeds [including hybrids adapted to climate change] as a desirable adaptation strategy while one of the Madagascan respondents also recommended the "provision of selected seeds" as an important adaptation strategy – but such technology requires financial capital.

The lack of access to funding and credit is not restricted to just the communities from which the KIs were drawn. According to Klein (et al, 2014, 915) "the implementation of specific adaptation strategies and options can be constrained by access to financial capital". The potential for finance to constrain adaptation is evident in a number broad range of recent case studies exploring adaptive capacity in different sector and regional contexts. Investigations of farming communities in Africa have identified finance as a key determinant of vulnerability and adaptive capacity of farmers to climate variability and change. Access to credit is a key constraint on adaptation among fishing communities in Bangladesh, and financial constraints have also been documented in municipal governments in South Africa.

Lack of access to information and technical know-how

The second most significant barrier to adaptation identified by the respondents from all four countries was a lack of access to information and technical know-how, including help from the government in the form of extension services, which a KI from Uganda complained was lacking. Geography has an impact with a respondent from Gabon stating "We are isolated, there is no clear information." A Madagascan KI added that there are also no other non-government supporting organisations to help them to adapt. Even those communities that were selected for studies on rural development have not received any support or feedback. Even when technical support to villages was provided by outside donors, a respondent noted that it was not accompanied by effective communication and training, and thus its potential to support adaptation is limited. In Tanzania, one respondent said that what was needed by the communities was education and sensitization on climate change adaptation. In Madagascar the responses were more specific: improve crop production with technical support on agriculture (especially on the use of fertiliser and selected seeds) and improve communication around rural support and donations. The lack of follow-through has also been observed in other circumstances. In Uganda, for example, farmers receive seasonal climate forecasts, but they are unlikely to have the knowledge and resources to utilize that information by adopting alternative strategies (Spires, et al, 2014).

The wider literature provides some examples to show that the lack of access to information and technical know-how is a common barrier across Africa and the rest of the world (Klein, et al, 2014). Access implies not only being able to get hold of the information but also being able to understand it and the ability to transform the information into knowledge which can then be put into practice. The lack of communication between scientists and community members can lead to climate information not being tailored to the local context and producers of information disseminating what they know as opposed to what communities need. Another problem highlighted in the literature is that of inappropriate scale of the information – seasonal climate information is prepared for a broad geographic area and for time periods that do not match the communities decision making horizons, resulting in information has very limited relevance to community level concerns (Spires, et al, 2014). There is also the potential of community misconceptions due to translation challenges – for example, the word used for 'climate' in some local languages is the same word used for 'weather' and in Fijian there is no word for vulnerability, the closest word means weakness.

Although not mentioned by the respondents themselves but which may yet be relevant to this study are the barriers caused by culture and tradition. Social and cultural factors can influence perceptions of risk, what adaptation options are considered useful and by whom, as well as the distribution of vulnerability and adaptive capacity among different elements of society. In Brazilian and Cambodian communities, for example, culture and tradition played a role in fuelling scepticism and inflexibility to new agricultural information and technologies. This scepticism was underpinned by the significant risk to poor communities if new agricultural practices fail. This risk is illustrated by the experience of farmers in Bangladesh, who have had to mortgage their assets and borrow money to re-sow seeds, replace or irrigate crops in order to change agricultural practices. Unsurprisingly, these communities tend to adopt risk averse strategies by continuing to do what they know and trust (Klein, et al, 2014; Spires, et al, 2014).

Land tenure systems

Another barrier to adaptation, less often referred to by the interviewees but still significant, was the land tenure system in many of the research countries which discourages investment in new adaptation methods. According to the literature cited in the AR5 (Niang, et al, 2014), tenure security over land and vital assets is widely accepted as being crucial for enabling people to make longer-term and forward-looking decisions in the face of uncertainty, such as changing farming practices, farming systems, or even transforming livelihoods altogether. In addition to insecure property rights, legislation forbidding ecosystem use is one of the issues strengthening underlying conflicts over resources in Africa. Resolving this would enable ecosystems to contribute to adaptation in a sustainable manner (ecosystem-based adaptation).

The literature supports all of the observations of barriers to adaptation made by the interviewees. In AR5 (Niang, et al, 2014), it is argued that few small-scale farmers across Africa are able to adapt to climatic changes, while others are restricted by a suite of overlapping barriers. Constraints identified in Kenya, South Africa, Ethiopia, Malawi, Mozambique, Zimbabwe, Zambia, and Ghana included poverty and a lack of cash or credit (financial barriers); limited access to water and land, poor soil quality, land fragmentation, poor roads, and pests and diseases (biophysical and infrastructural barriers); lack of access to inputs, shortage of labour, poor quality of seed and inputs attributed to a lack of quality controls by government and corrupt business practices by traders, insecure tenure, and poor market access (institutional, technological, and political barriers); and finally a lack of information on agroforestry/afforestation, different crop varieties, climate change predictions and weather, and adaptation strategies (informational barriers).

6.2 Recommendations to support local level adaptation

The primary research conducted in Tanzania and Madagascar resulted in recommendations to support local-level adaptation from the communities themselves. These have then been complemented with information drawn from the literature. Also included below are recommendations arising from the “wish lists” of adaptation strategies outlined by some of the respondents – i.e. suggestions of how to implement these desired adaptation practices in a way that is sustainable and will not result in maladaptation.

Klein (et al, 2014) highlight the difference between adaptation opportunities (i.e. enabling factors that enhance the adaptation objective(s) or facilitate adaptive responses by natural systems to climate risk) which are distinct from adaptation option, which is a specific means of achieving an adaptation objective (such as an early warning system as a means of reducing vulnerability to tropical cyclones) or a strategy for the conservation of an ecological system. The sub-sections below comprise both possible opportunities and options.

While not mentioned by the respondents themselves, recent literature outlined in AR5 (Niang, et al, 2014) has outlined the positive role of local and traditional knowledge in building resilience and adaptive capacity, and shaping responses to climatic variability and change in Africa. This is particularly so at the community scale, where there may be limited access to, quality of, or ability to use scientific information. As described in section 5.1 on barriers to adaptation, culture and tradition may make people sceptical of new information and technologies – the inclusion of indigenous knowledge systems could go a long way in allaying this scepticism. In support of this, Klein (et al, 2014) argues that recent literature suggests the extent to which knowledge acts to constrain or enable adaptation is dependent on how that knowledge is generated, shared, and used to achieve desired adaptation objectives.

Building on local institutions is also important to create an enabling environment for adaptation. CBA in developing countries is most often implemented and funded by numerous stakeholders, from diverse sectors (international funders, government, non-government organisations (NGOs), research institutions and/or civil society). Most of the implementation is done via partnerships between stakeholders operating at different scales, where government and NGOs implement projects with communities using international funding (Spires, et al, 2014). In order to play a leading role amongst all these stakeholders it is important that communities have strong groups or associations to represent them. In many cases this requires climate change capacity building.

Nevertheless, numerous recent studies caution that addressing knowledge deficits may not necessarily lead to adaptive responses. Recent research indicates that multiple factors influence how knowledge is perceived including political, educational attainment, and the confidence placed on different information sources (Klein, et al, 2014). Innovative methods used to communicate climate change include participatory video, photo stories, oral history videos, vernacular drama, radio, television, and festivals, with an emphasis on the important role of the media. Better evidence-based communication processes will enhance awareness raising of the diverse range of stakeholders at all levels on the different aspects of climate change (Niang, et al, 2014).

A suggestion from a tangible adaptation strategy is weather based insurance which is available in other parts of Africa. Malawi's initial experience of dealing with drought risk through index-based weather insurance directly to smallholders appears positive: 892 farmers purchased the insurance in the first trial period, which was bundled with a loan for groundnut production inputs. In the next year, the pilot expanded, with the addition of maize, taking numbers up to 1710 farmers and stimulating interest among banks, financiers, and supply chain participants such as processing and trading companies and input suppliers.

7. Conclusion

The report provides an analysis of the results of primary research conducted at the community level in four African countries (Gabon, Madagascar, Tanzania and Uganda) documenting observed changes in climate and their responses. Some observed responses were examples of short-term coping designed to ensure survival without altering underlying vulnerability to hazard exposure. Reactive community-based adaptation strategies include conservation agriculture and land management, changing farming practices and diversification. Planned adaptations, which require actions from outside communities themselves, include improved technology and subsidies and social protection.

Migration was also cited as an adaptation to a changed climate. A number of barriers to adaptation were identified, and financial, technical and regulatory/legal support would enable these to be overcome. The report concludes with some examples from outside the case studies of creating an appropriate enabling environment for successful adaptation, such as using traditional knowledge, raising awareness of climate change, and building on existing local institutions. Weather based insurance is an example of a tangible adaptation that is being scaled up in a variety of African contexts.

8. References

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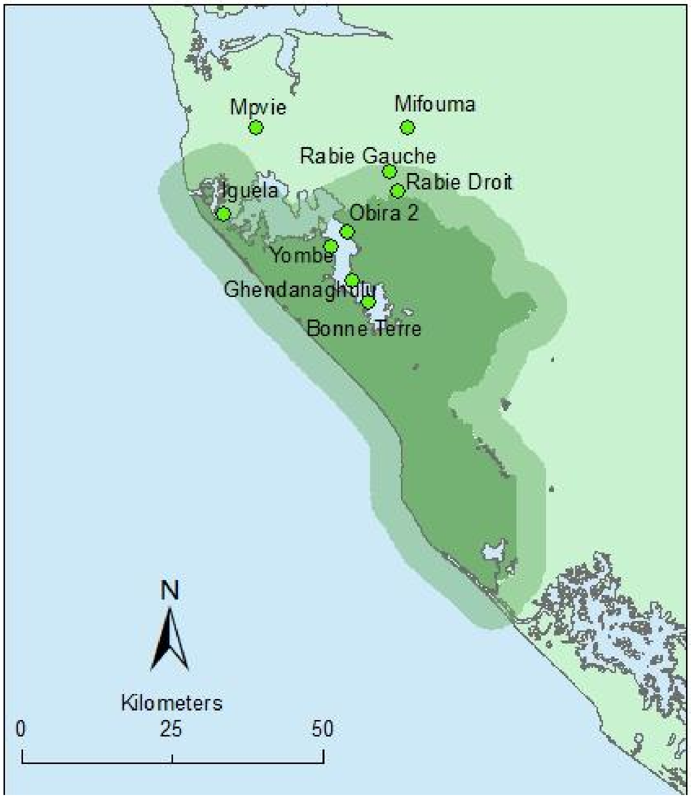
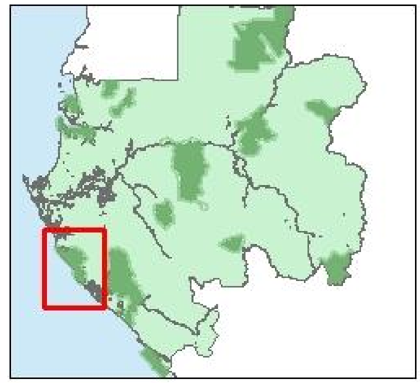
Appendix A: Location map of study sites in Gabon



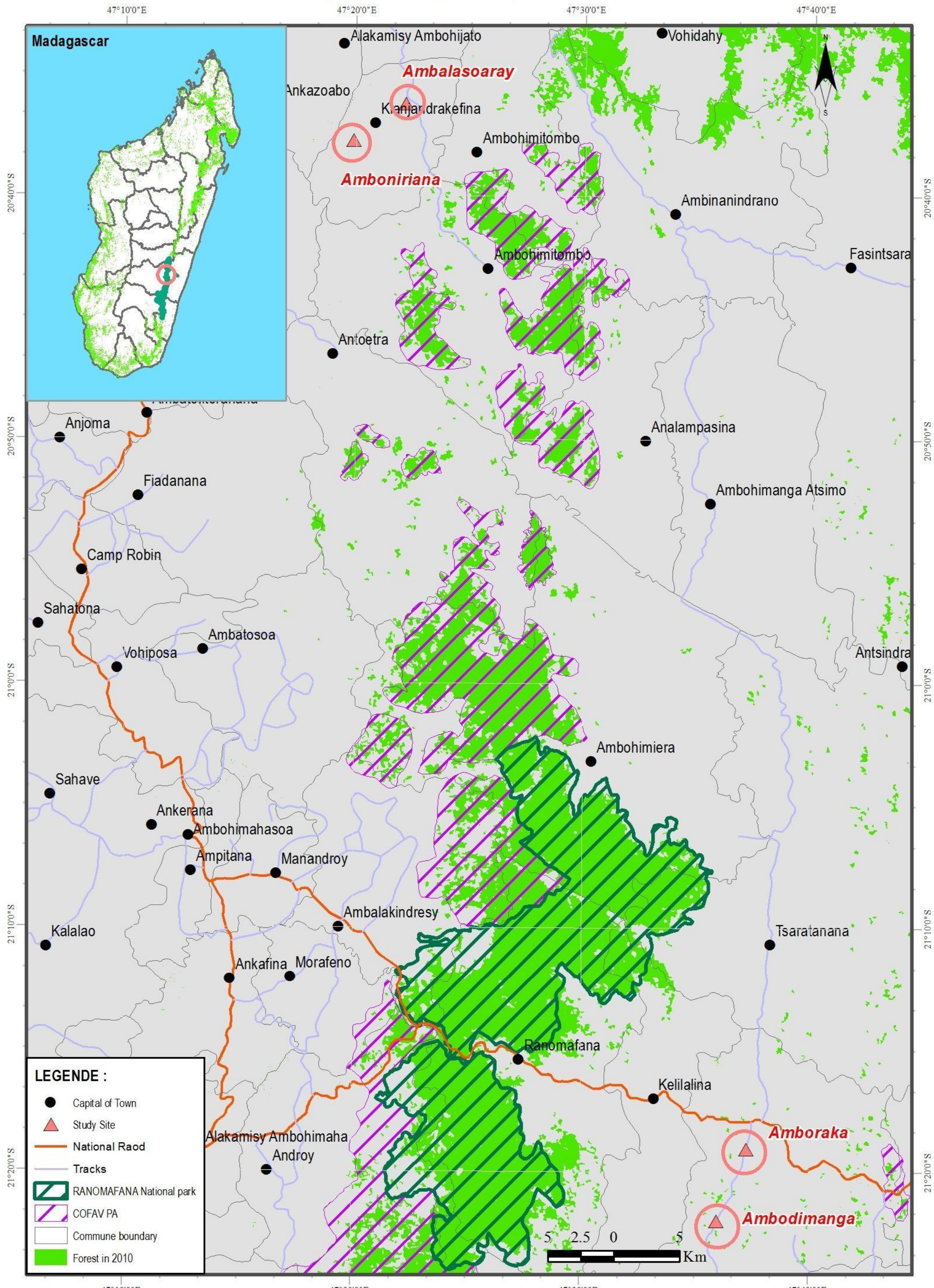


Villages in northern Loango National Park included in Climate Change survey
July 2014 - WCS

Data sources:
WRI, WCS

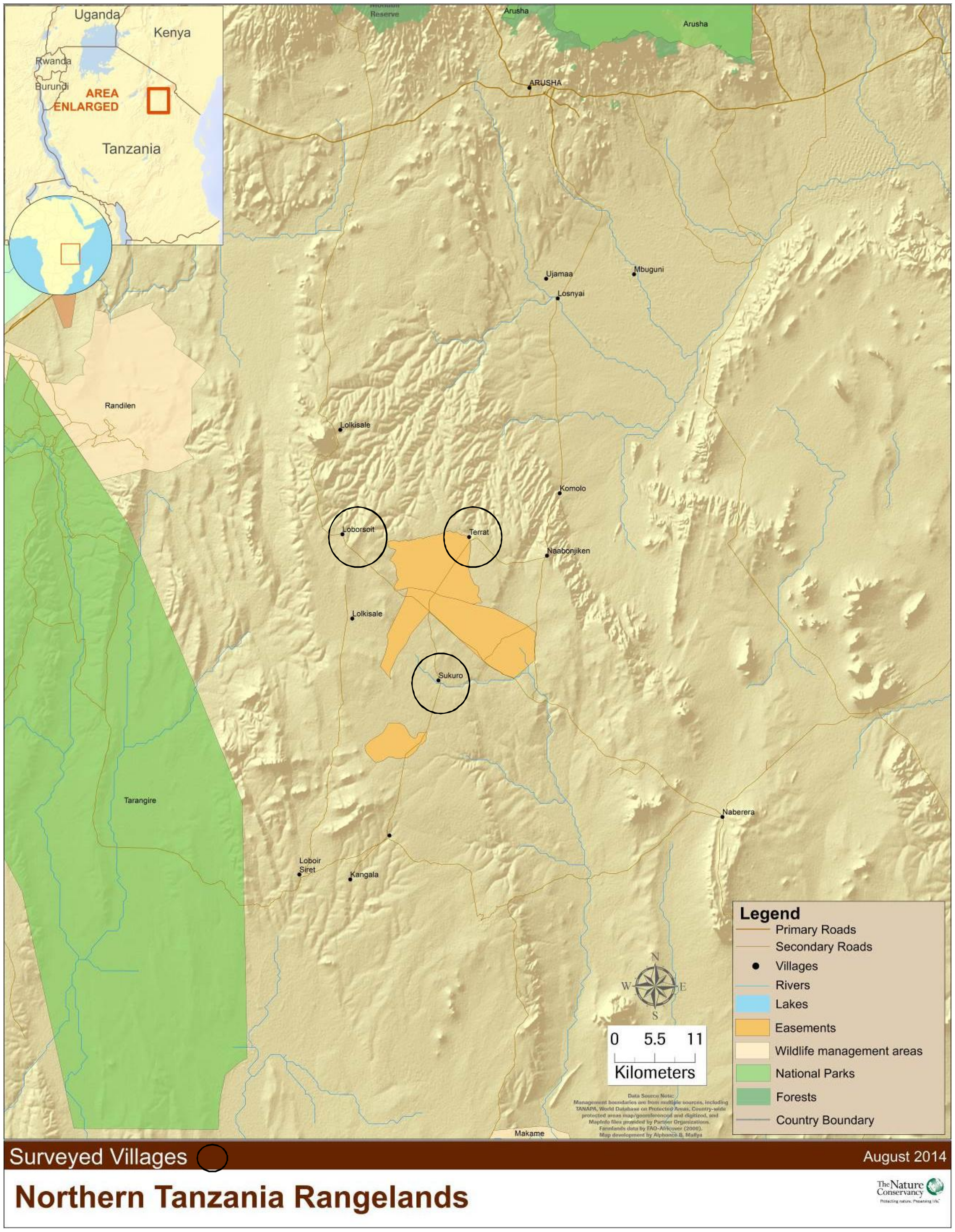
Appendix B: Location map of study sites in south central Madagascar

Study sites for documenting unplanned human responses to changes in weather and climate, and subsequent impacts on biodiversity

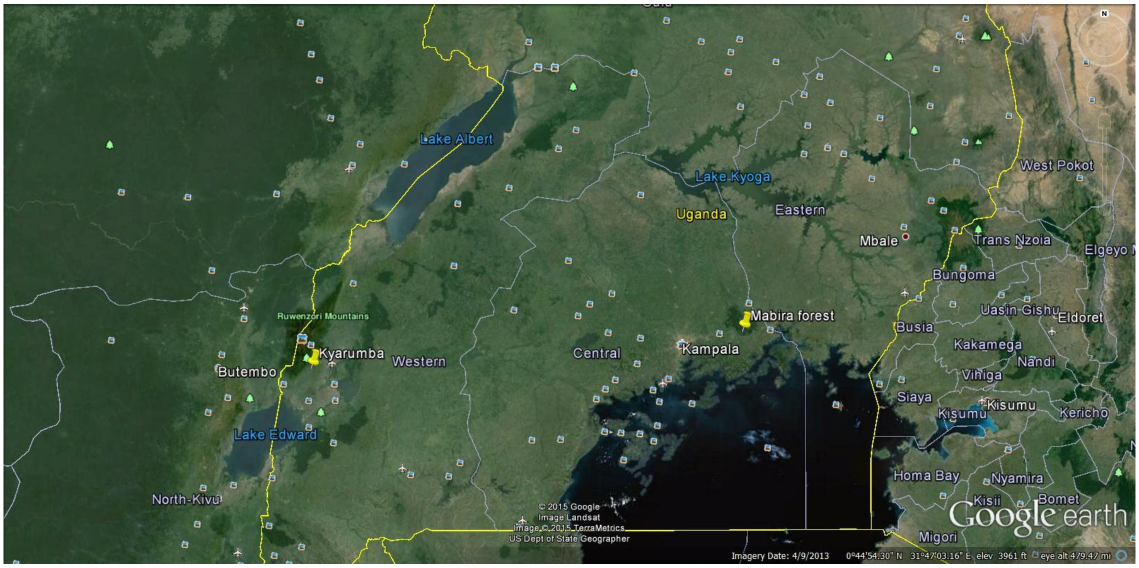


Appendix B: Location map of study site in southwest Madagascar

Appendix C: Location map of study sites in Tanzania



Appendix D: Location map of study sites in Uganda



Appendix E: Climate projections (temperature and rainfall) for Africa

Figure 1: Temperature change December-February in the Mediterranean and Sahara

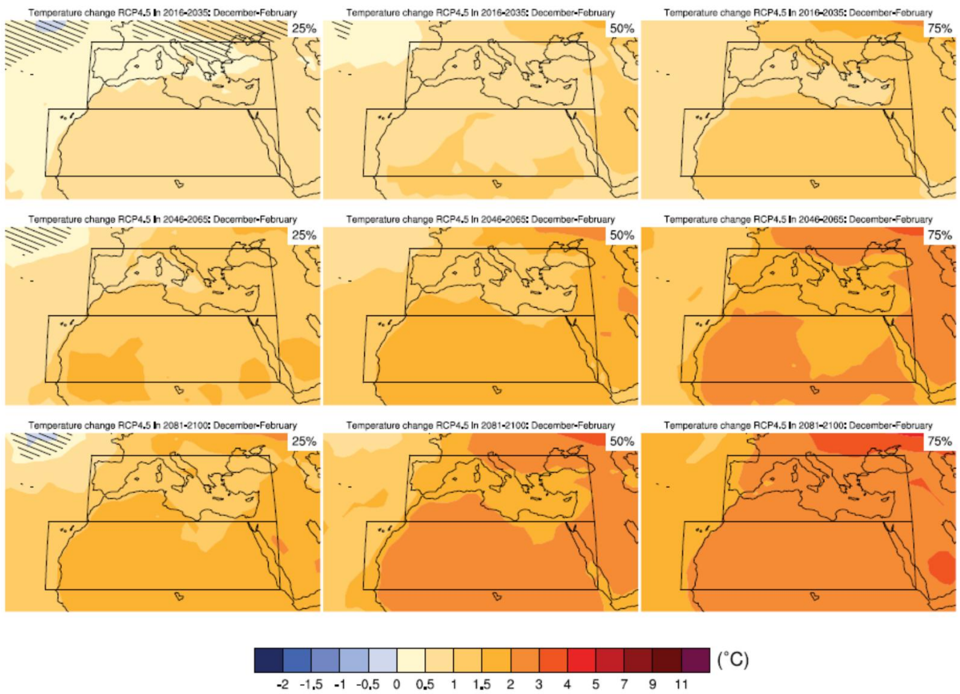


Figure 2: Temperature change in June-August in the Mediterranean and Sahara

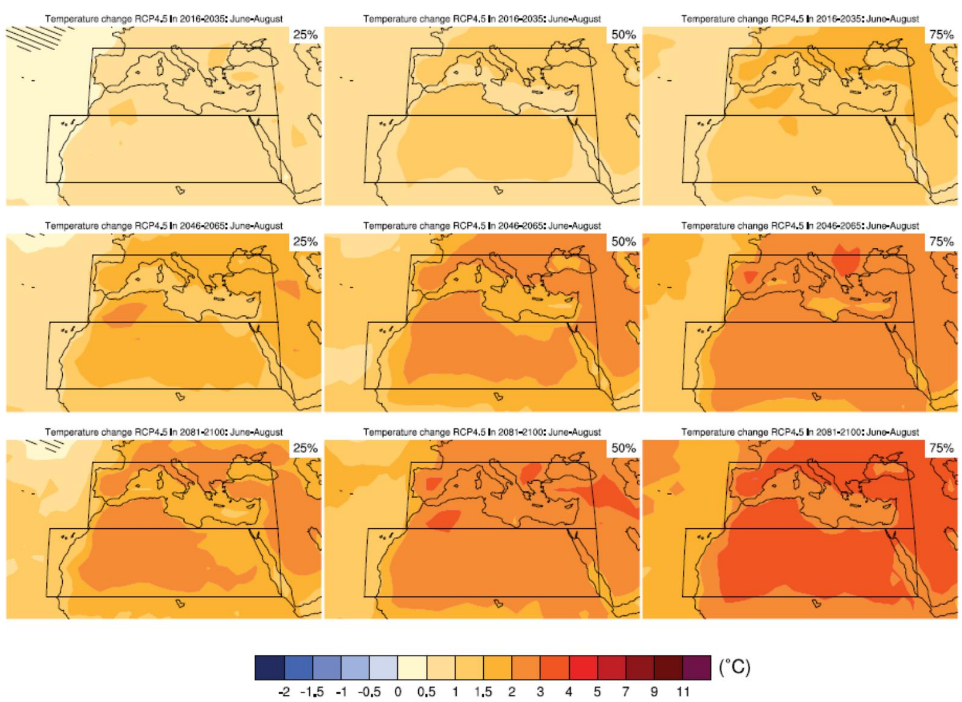


Figure 3: Precipitation change October-March in the Mediterranean and Sahara

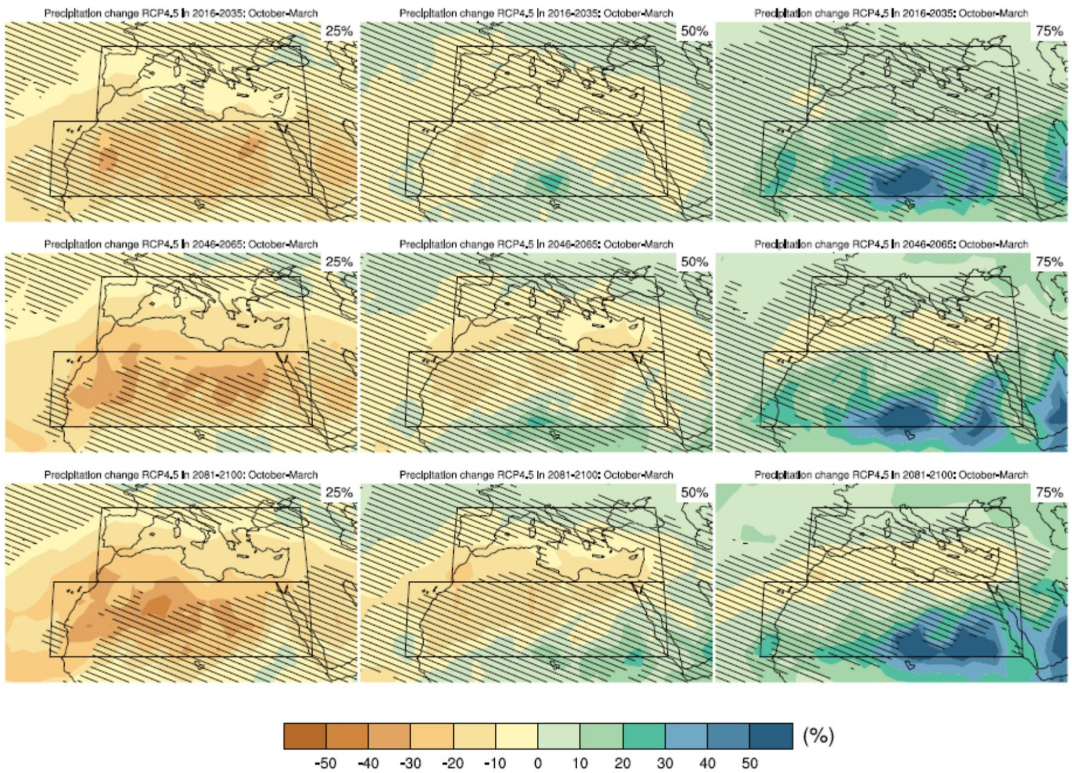


Figure 4: Precipitation change April-September in the Mediterannean and Sahara

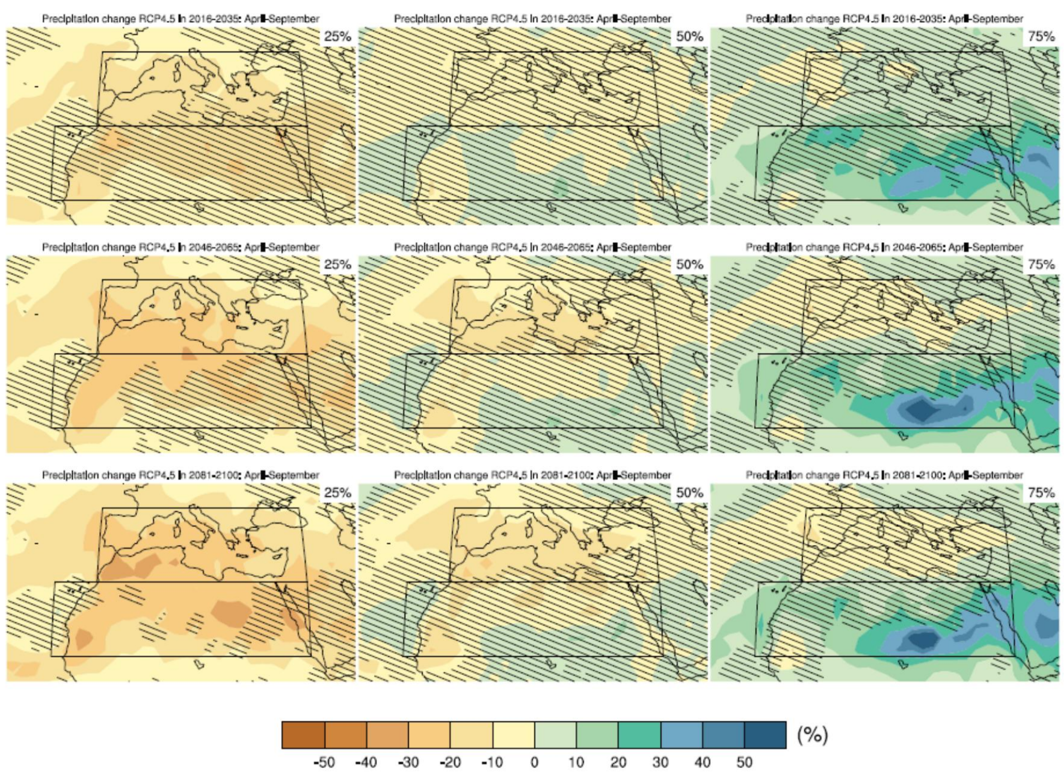


Figure 5: Temperature change December-February in Central Africa

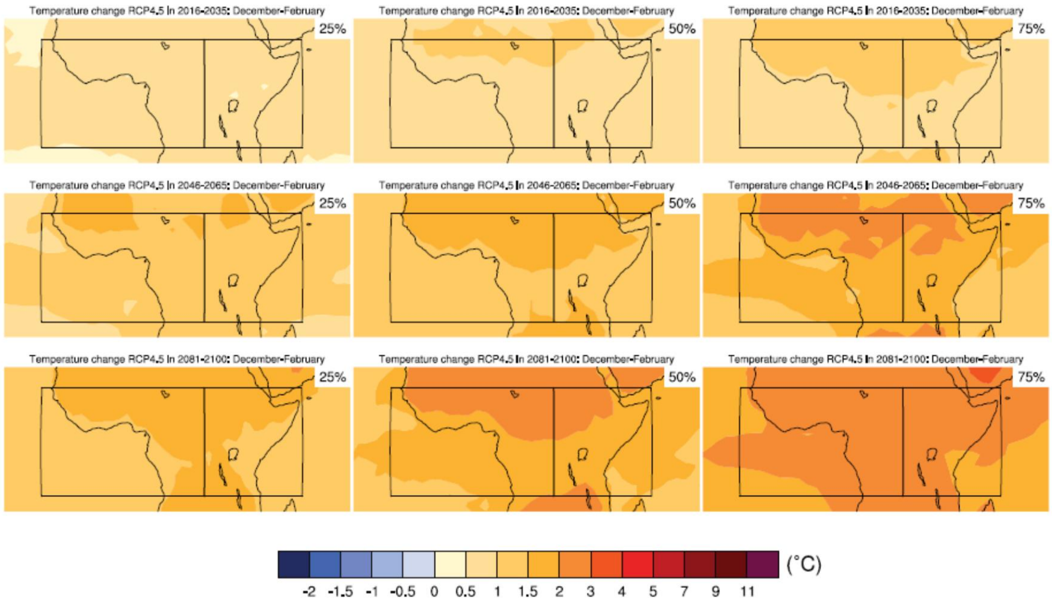


Figure 6: Temperature change June-August in Central Africa

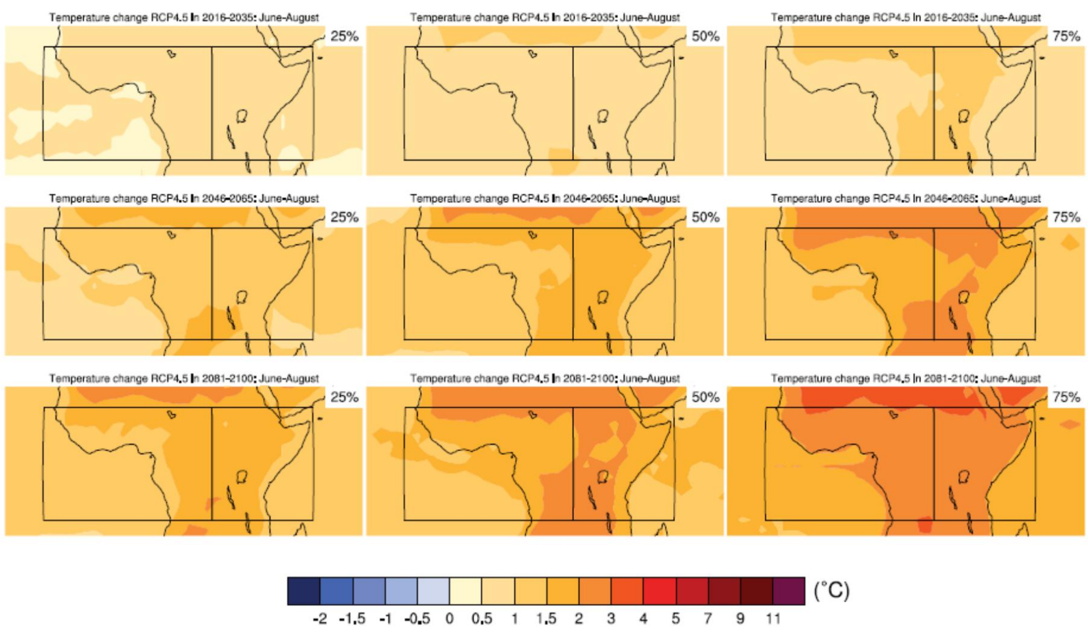


Figure 7: Precipitation change October-March in Central Africa

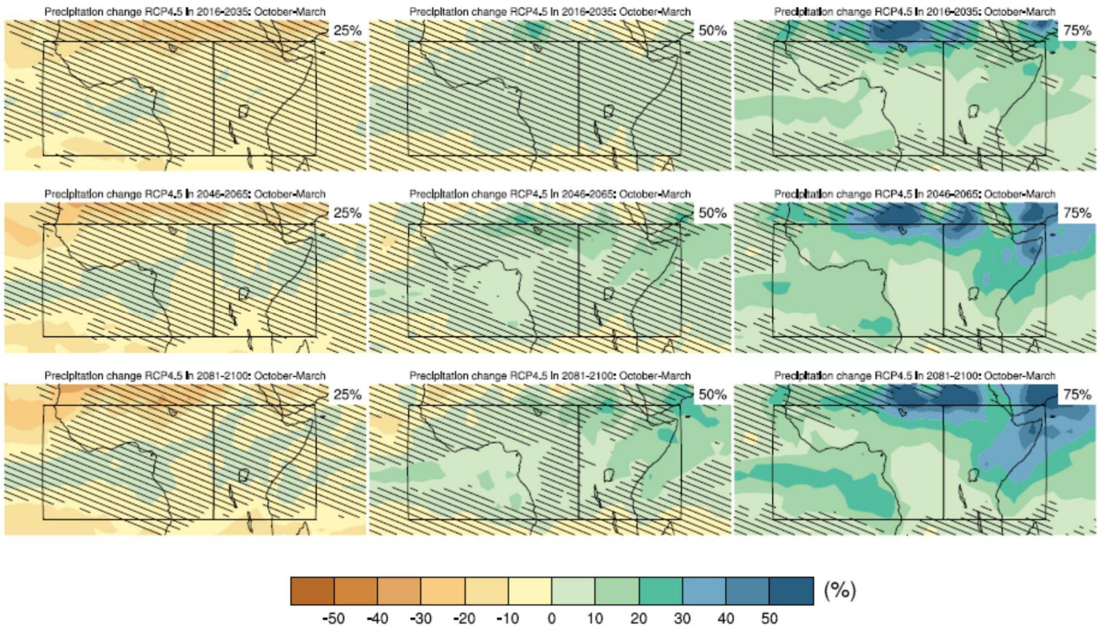


Figure 8: Precipitation change April-September in Central Africa

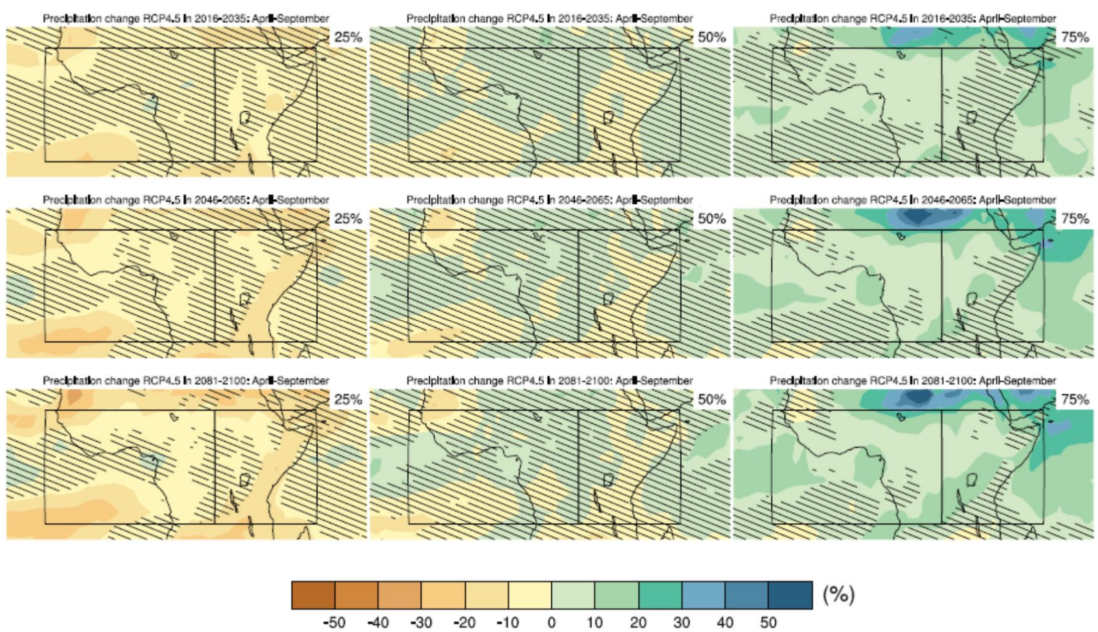


Figure 9: Temperature change December-February in southern Africa

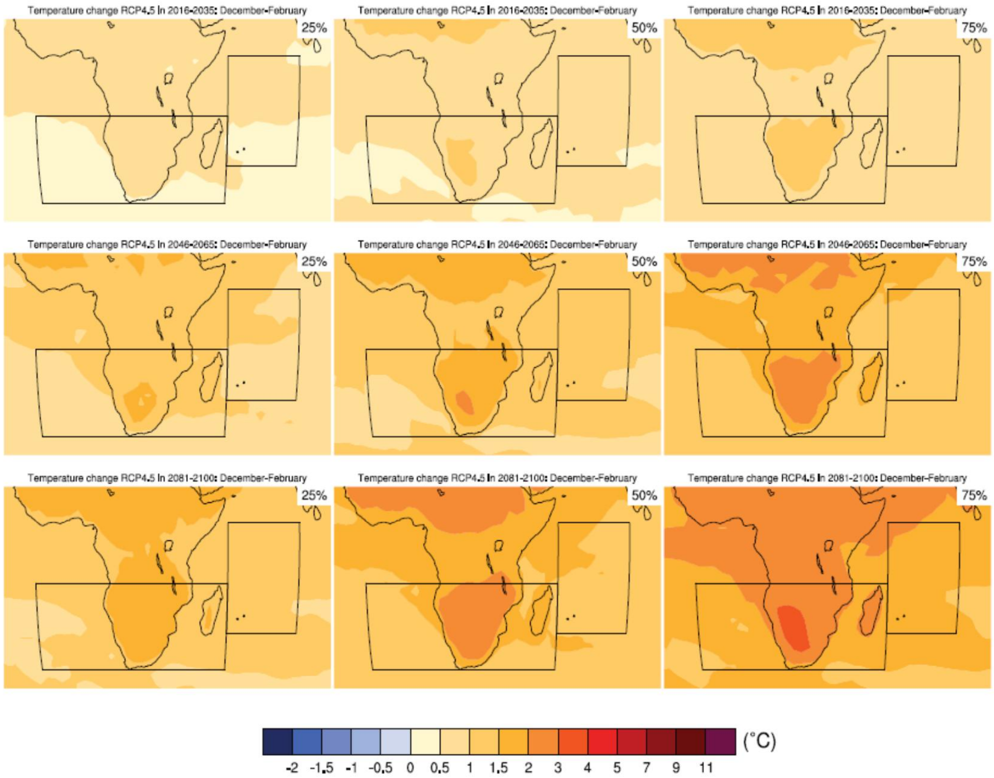


Figure 10: Temperature change June-August in Southern Africa

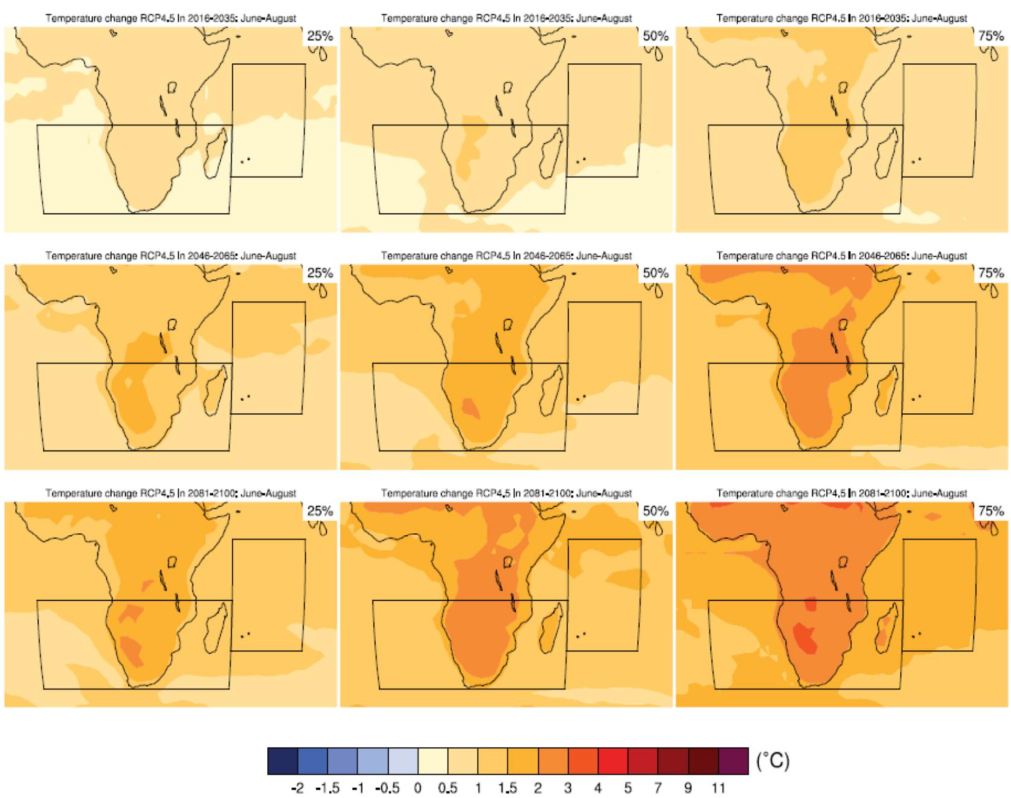


Figure 11: Precipitation change October-March in southern Africa

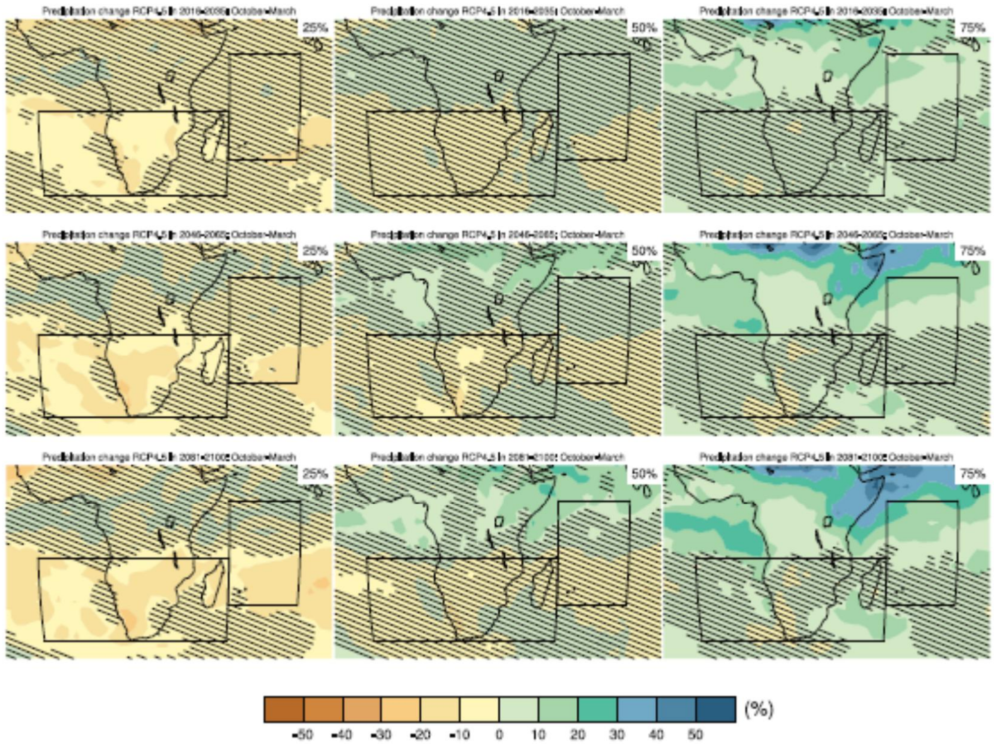


Figure 12: Rainfall projections April-September for southern Africa