

# SUSTAINABLE DEVELOPMENT FOR HIV HEALTH (SD4H) FELLOWSHIP PROGRAM

## CLIMATE CHANGE, AGRICULTURE & FOOD SECURITY

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# Definitions

According to the FAO, food security exists when **all people at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences** for an active and health life.”

Acute food insecurity is any manifestation of food insecurity at a specific point in time of a severity that threatens lives, livelihoods or both, regardless of the causes, context or duration. These acute states are highly susceptible to change and can manifest in a population within a short amount of time, as a result of sudden changes or shocks that negatively impact on the determinants of food insecurity and malnutrition (IPC, 2019).

Climate change is the long-term trend in weather, generally over decades or centuries. This includes long-term trends in the average climate (such as annual average temperature or precipitation) or trends in climate extremes (such as the frequency of intense rainfall events. (cf. IPCC, 2007).

# Definitions

“Resilience” is the ability of a system and its component parts to anticipate, absorb, accommodate or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration or improvement of its essential basic structures and functions (IPCC, 2012).

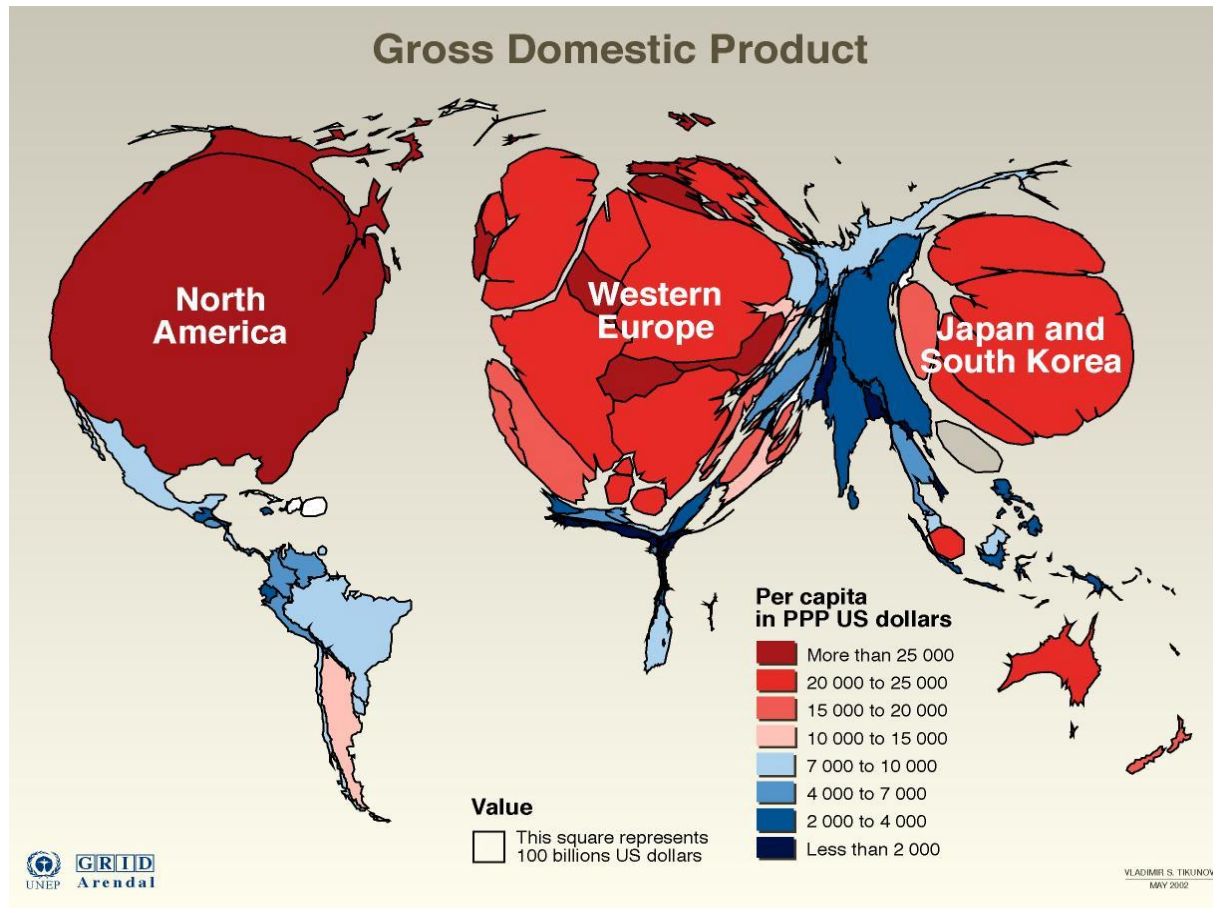
“Adaptive capacity”, the capacity of a system to adapt in order to be less vulnerable, is a dynamic notion. It is shaped by the interaction of environmental, social, cultural, political and economic forces that determine vulnerability through exposures and sensitivities, and the way the system’s components are internally reacting to shocks. In fact, it has two dimensions: adaptive capacity to shocks (coping ability) and adaptive capacity to change. The first dimension is related to the coping ability (absorption of the shock), the second dimension is related to time (adaptability, management capacity). Adaptations are manifestations of adaptive capacity (Smit and Wandel, 2006).

“Vulnerability” is the propensity or predisposition to be adversely affected (IPCC, 2012). It is a dynamic concept, varying across temporal and spatial scales and depends on economic, social, geographic, demographic, cultural, institutional, governance and environmental factors. Measuring vulnerability is complex as it needs to be considered across various dimensions.

# WHY SHOULD WE BE CONCERNED ABOUT CLIMATE CHANGE , AGRICULTURE AND FOOD SECURITY?

- Multiple severe impacts are likely to result from climate change.
- Agriculture is highly sensitive to variability and change in climate and markets/price.
- A large percentage of the population depends directly on rain fed agriculture and natural resources.
- There are already high rates of land degradation (erosion and declining soil fertility, increasing water scarcity and loss of biodiversity) and sensitivity to climate variability.
- There are already low yields and high post-harvest losses due to poor land management practices.
- Natural resources and ecosystems including drylands, mountains, rainforests, and wetlands are already fragile.

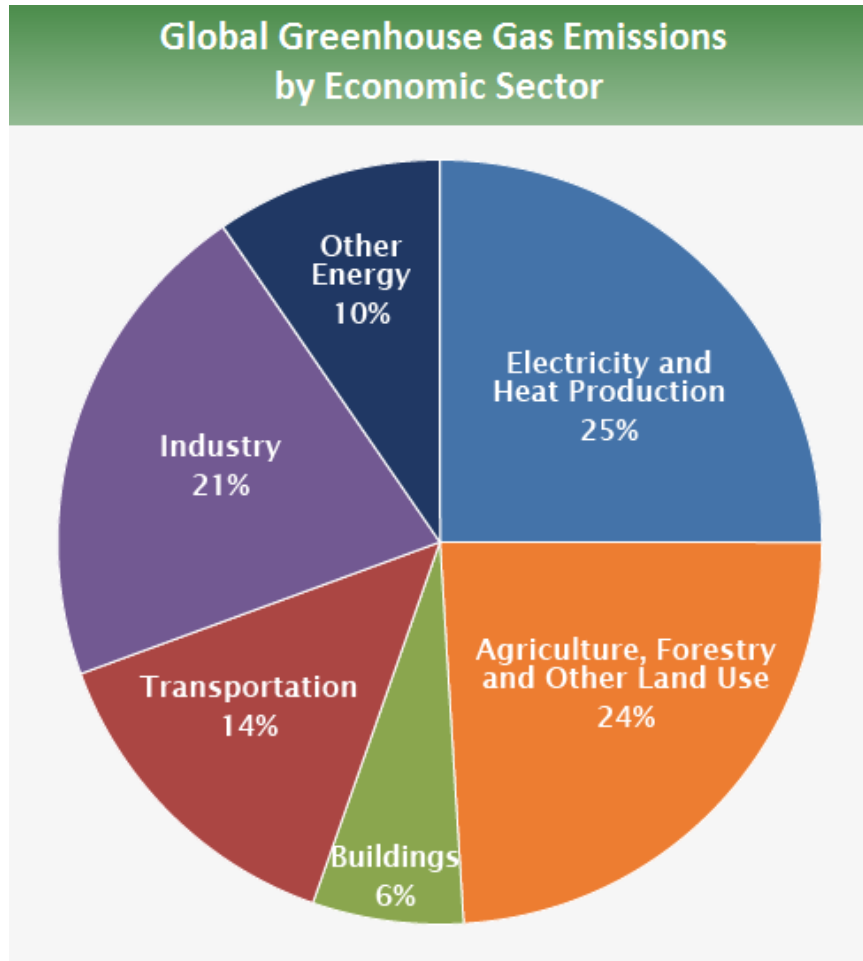
# CLIMATE AFFECTS LAND USE (AGRICULTURE) EVENTUALLY ECONOMIC GROWTH



## OVERVIEW: CLIMATE CHANGE AND AGRICULTURE

- ▶ Agriculture, climate change, food security and poverty reduction are inextricably linked.
- ▶ As the world population grows to a projected 9 billion by 2050, agricultural production must also increase by an estimated 70 percent according to FAO.
- ▶ Climate volatility, more frequent extreme weather events and temperature changes increasingly threaten the viability of agriculture sector and rural infrastructure throughout the world.
- ▶ Globally, agriculture directly accounts for 13.5 % of greenhouse gas emissions and indirectly for another 17% due to deforestation and land-use change.
- ▶ The sector holds a large mitigation potential, mainly through reduced deforestation, soil management and increased productivity.
- ▶ **Agriculture is therefore part of the problem and part of the solution to Climate Change.**

# Global Agricultural Contribution to GHG



Source: [IPCC \(2014\)](#); [Exit](#) based on global emissions from 2010. Details about the sources included in these estimates can be found in the [Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change](#)



# OVERVIEW: SUB SAHARAN AFRICA

- African countries are particularly vulnerable to climate change because of their dependence on rainfed agriculture, high levels of poverty, low levels of human and physical capital, and poor infrastructure.
- The negative effects of climate change on crop production are especially pronounced in Sub-Saharan Africa, as the agriculture sector accounts for a large share of GDP, export earnings, and employment in most African countries. Furthermore, the vast majority of the poor reside in rural areas and depend on agriculture for their livelihoods.
- Crop model outputs indicates that in 2050, average rice, wheat, and maize yields will decline by up to 14 percent, 22 percent, and 5 percent, respectively, as a result of climate change.

# OVERVIEW: SUB SAHARAN AFRICA (contd)

- Irrigation water supply reliability, the ratio of water consumption to requirements, is expected to worsen in Sub-Saharan Africa due to climate change.
- Without climate change, calorie availability is expected to increase in Sub-Saharan Africa between 2000 and 2050. With climate change, however, food availability in the region will average 500 calories less per person in 2050, a 21 percent decline.
- In a no-climate change scenario, only Sub-Saharan Africa will experience an increase in the number of malnourished children between 2000 and 2050, from 33 to 42 million. Climate change will further increase this number by over 10 million, resulting in 52 million malnourished children in 2050

# OVERVIEW OF SELECTED POSSIBLE IMPACTS OF CLIMATE CHANGE FOR AFRICA

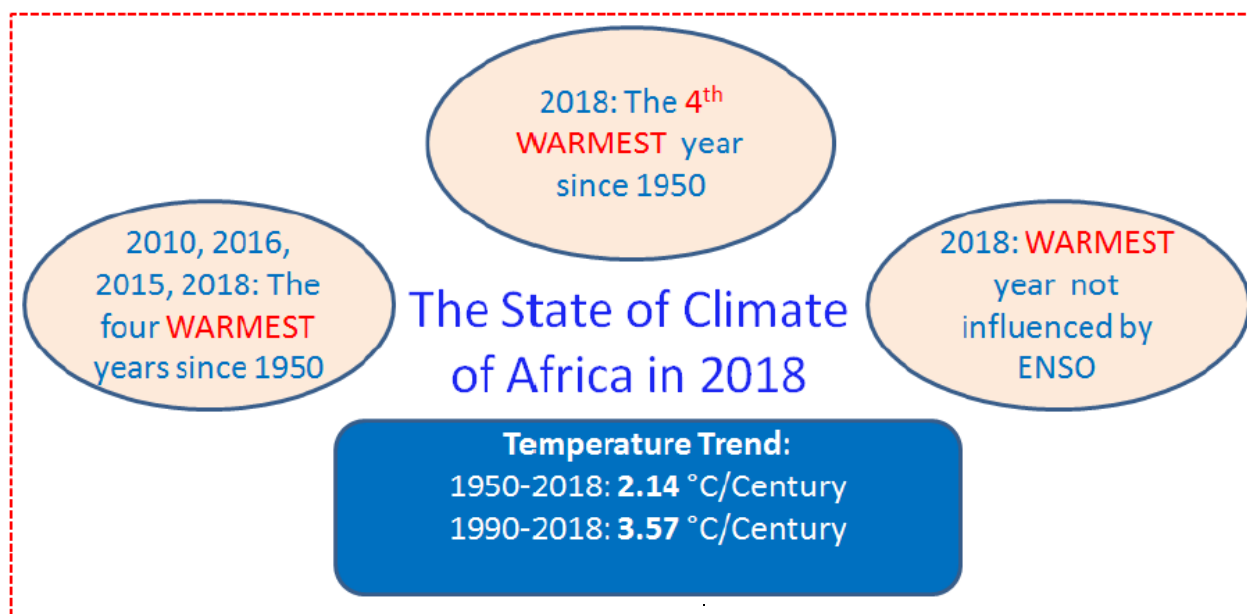
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## Africa

- The number of extremely dry and wet years is expected to increase in sub-Saharan Africa during this century.
- Drying in the Mediterranean area and in much of southern Africa is expected.
- There may be an increase in East and West African rainfall.
- Some areas, such as the Ethiopian highlands, could benefit from a longer growing season.
- Rangeland degradation and more frequent droughts may lead to reduced forage productivity and quality, particularly in the Sahel and southern Africa.
- Mangrove forests protect coastal zones from storms and floods and forests in general regulate water flows and reduce flooding.
- Through its impact on forests, climate change also will affect wildlife, bush meat and non-timber forest production, which are important for food security in several parts of Africa.
- Availability of water rather than increases in temperature will affect forest growth in Africa.
- African forests will generally face deforestation, degradation, increased forest fires and major changes, e.g. in mountain ecosystems.
- Sea level rise poses a threat to coastlands, lagoons and mangrove ecosystems, especially on eastern and western shores of Africa.
- Changes in coastal ecosystems and delta areas, such as destruction of coral reefs, will have direct effects on the productivity of fish stocks.
- Productivity of the East African lakes could decline.
- Temperature increases as such may not affect pond aquaculture in the tropical regions, but the availability of water may become an issue.

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Source: compiled from IPCC, 2007, for the  
FAO-Adapt, 2011



| Region          | Year | Value (°C) | Ranking |
|-----------------|------|------------|---------|
| Africa          | 2018 | +0.70      | 4th     |
| Northern Africa | 2018 | +0.84      | 3rd     |
| Southern Africa | 2018 | + 0.86     | 3rd     |
| Western Africa  | 2018 | + 0.52     | 7th     |
| Eastern Africa  | 2018 | + 0.70     | 5th     |
| Central Africa  | 2018 | +0.82      | 3rd     |
| Madagascar      | 2018 | -0.29      | 35th    |

# Eastern Africa - Observed climate trends

## - Temperature

- 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 (Hulme et al., 2001; Jones and Moberg, 2003; Kruger and Shongwe, 2004; Schreck and Semazzi, 2004; New et al., 2006; IPCC, 2007; Rosenzweig et al., 2007; Trenberth et al., 2007; Christy et al., 2009; Collins 2011; Grab and Craparo, 2011; Hoffman et al., 2011; Mohamed, 2011; Stern et al., 2011; Funk et al., 2012; Nicholson et al., 2013).
- The Equatorial and Southern parts of eastern Africa have experienced a significant increase in temperature since the beginning of the early 1980s (Anyah and Qiu, 2012). Similarly, recent reports from the famine early warning systems network (FEWS NET) indicate that there has been an increase in seasonal mean temperature in many areas of Ethiopia, Kenya, South Sudan, and Uganda over the last 50 years (Funk et al., 2011, 2012). In addition, warming of the near surface temperature and an increase in the frequency of extreme warm events has been observed for countries bordering the Western Indian ocean between 1961 and 2008 (Vincent et al., 2011b)

# Eastern Africa- Observed climate trends - Precipitation

- 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 (Nikulin et al., 2012; Sylla et al., 2012)
- Precipitation in Eastern Africa shows a high degree of temporal and spatial variability dominated by a variety of physical processes (Roselland Holmer, 2007; Hession and Moore, 2011).
- Williams and Funk (2011) and Funk et al. (2008) indicate that over the last 3 decades rainfall has decreased over eastern Africa between March and May/June.

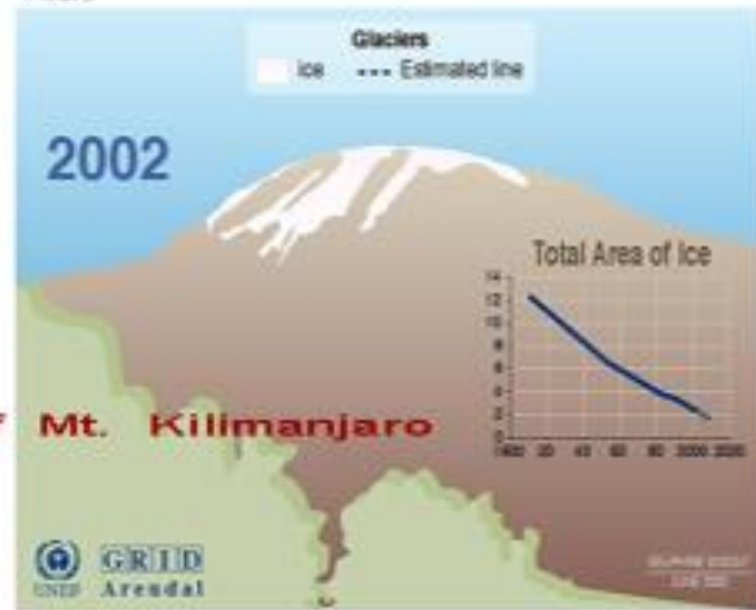
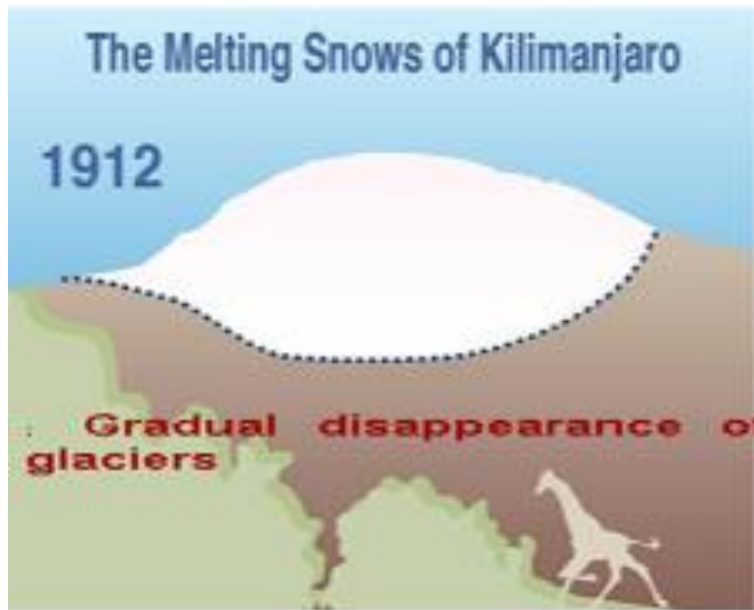
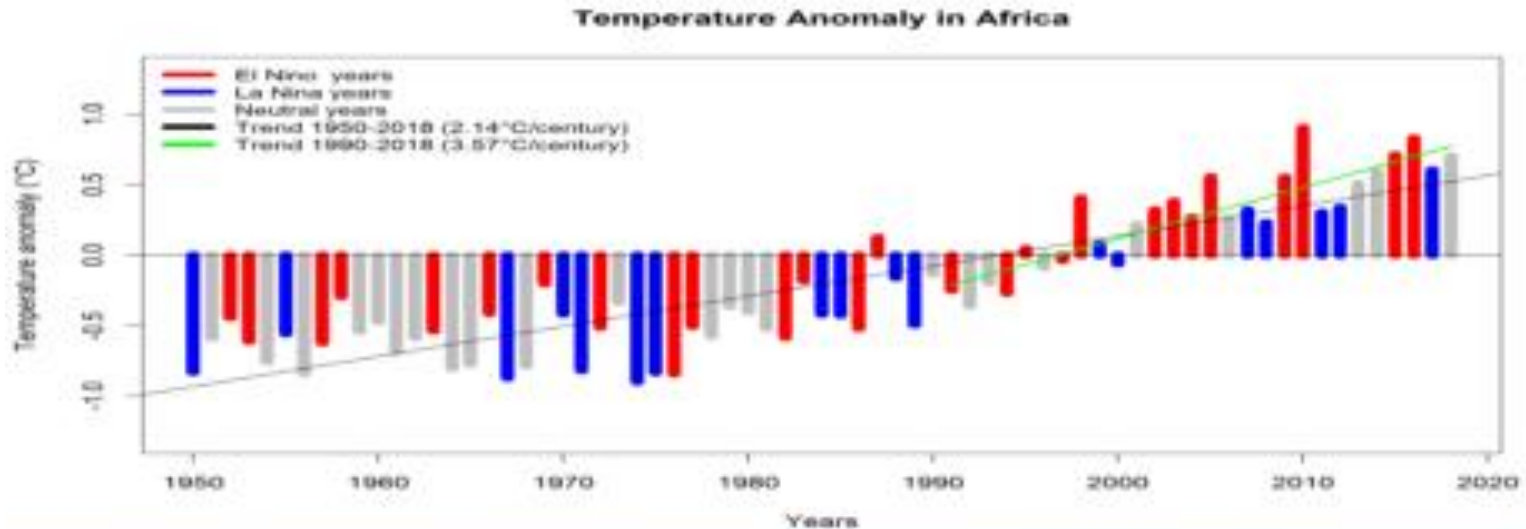
# Eastern Africa - Projected climate - Precipitation

- 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 (Funk et al., 2008; Williams and Funk, 2011).
- An assessment of 12 CMIP3 GCMs over Eastern Africa suggests that by the end of the 21st century there will be a wetter climate with more intense wet seasons and less severe droughts during October-November-December (OND) and March-April-May (MAM) (WGI AR5 section 14.8.7)

# CLIMATE CHANGE PROJECTIONS— AFRICA, EAST AFRICA

- There is low confidence in projected increases of heavy precipitation over most of Africa except over East Africa, where there is a high confidence in a projected increase in heavy precipitation (Seneviratne et al., 2012).

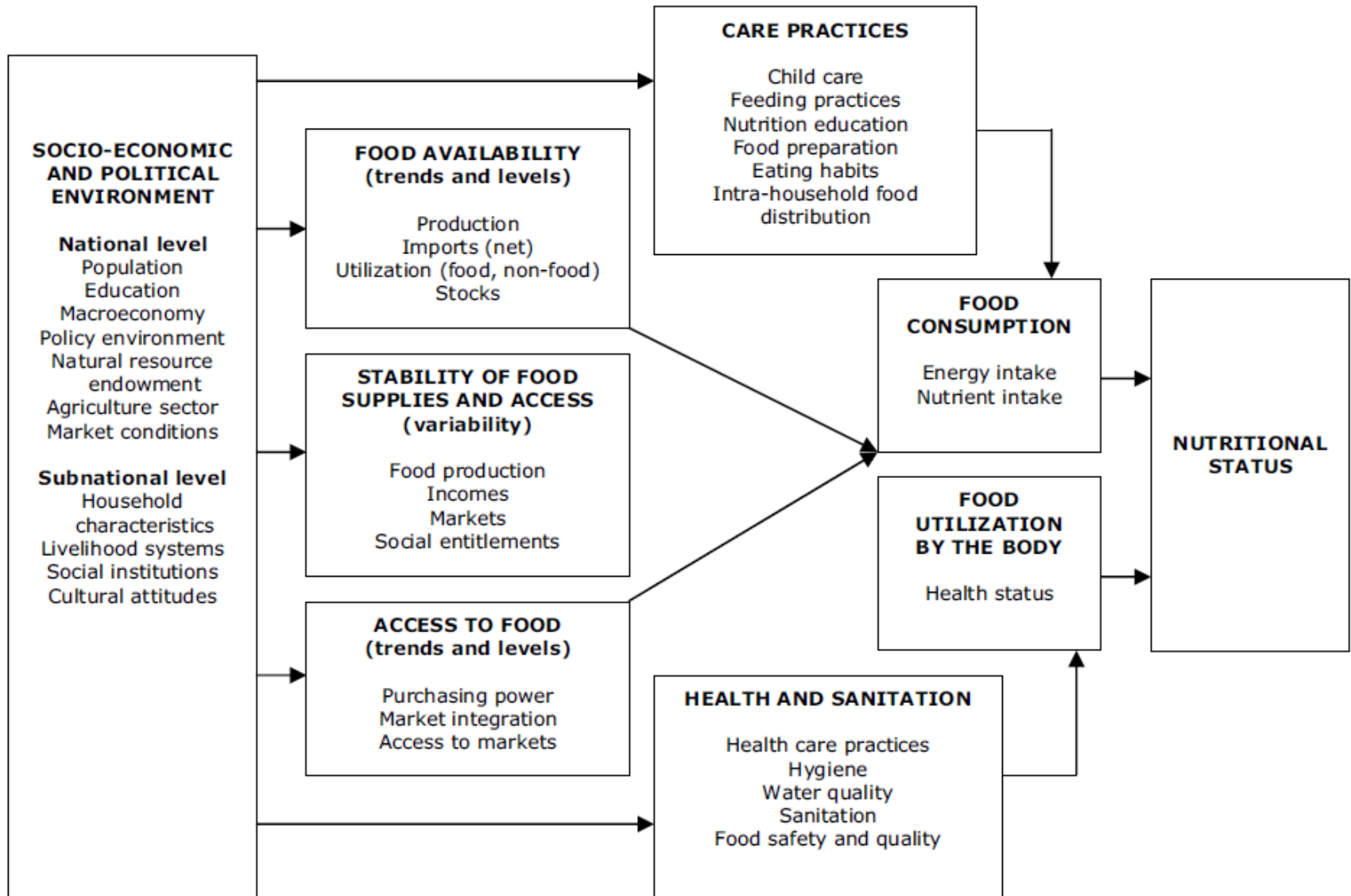




*Trends in the mean annual temperature anomalies (°C) over Africa for 1950-2018 period.*

*Data source:* [http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.GHCM\\_CAMS/.gridded/.deg0p5/.temp/](http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.GHCM_CAMS/.gridded/.deg0p5/.temp/)

# FRAMEWORK FOR POSSIBLE PATHWAYS TO NUTRITIONAL STATUS



# RISKS OF CLIMATE CHANGE TO AGRICULTURE & FOOD SECURITY

- Four out of the eight key risks identified by IPCC AR5 have close relations with or direct consequences to food security:
  - Loss of rural livelihoods and income
  - Loss of marine and coastal ecosystems, and livelihoods
  - Loss of terrestrial and inland water ecosystems, and livelihoods
  - Food insecurity and breakdown of food systems

# LINKAGES CLIMATE CHANGE- AGRICULTURE- FOOD SECURITY

A range of physical, biological and biophysical impacts bear on ecosystems and agro-ecosystems, translating into impacts on agricultural production. This has quantity, quality and price effects, with impacts on the income of farm households and on purchasing power of non-farm households. All four dimensions of food security and nutrition are impacted by these effects.

Source: FAO, 2015

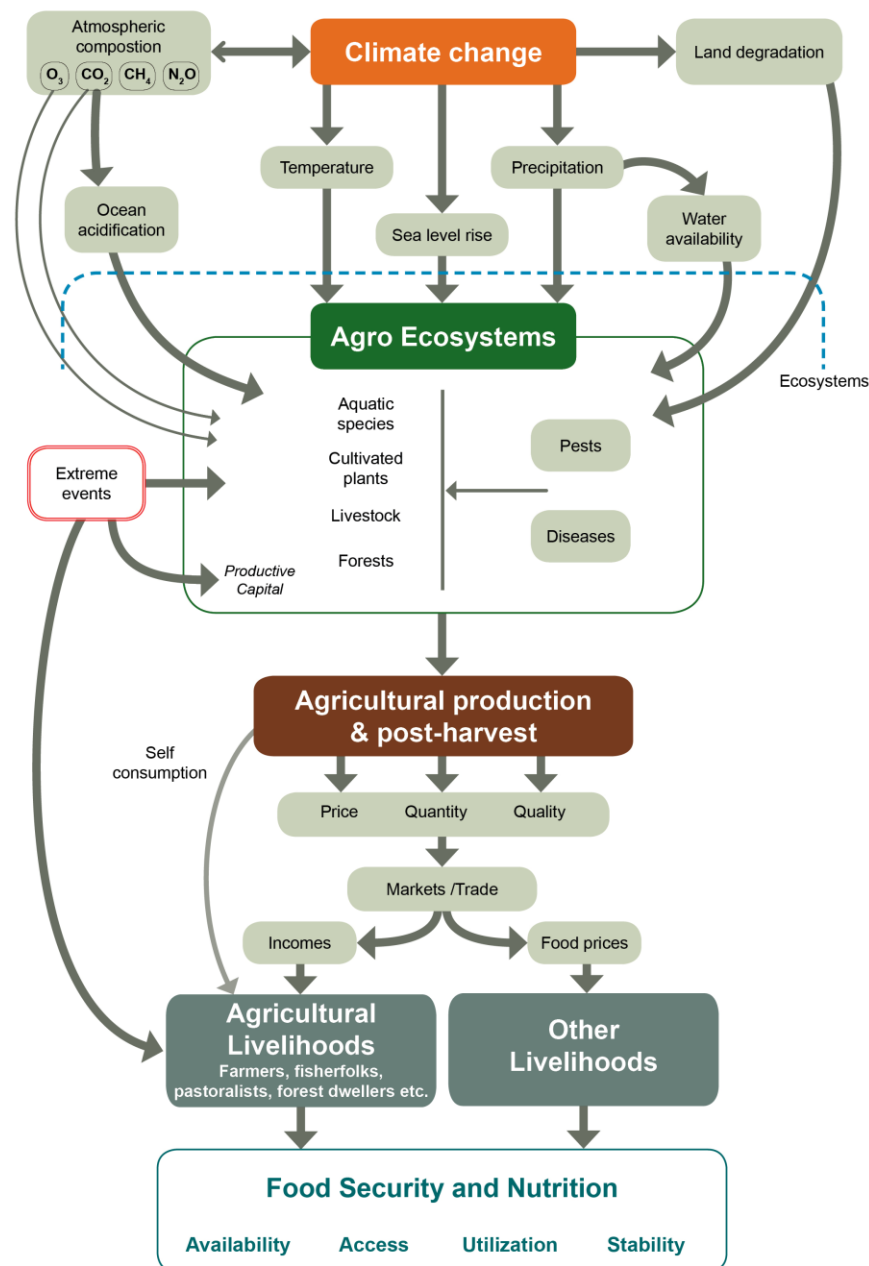
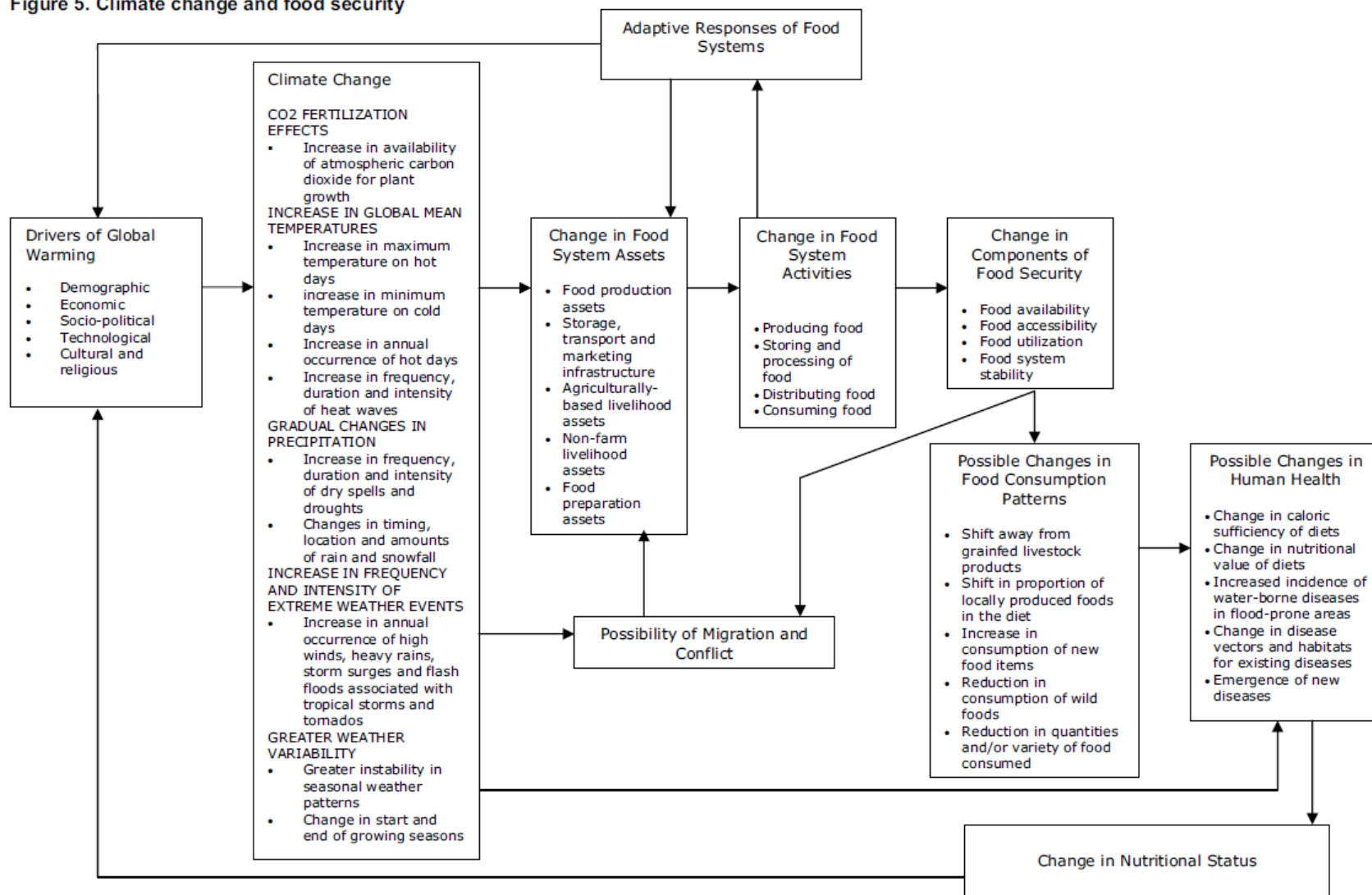


Figure 5. Climate change and food security



SOURCE: FAO/NRCB.  
Figure produced for this report.

# FOOD SECURITY DIMENSION AND CONSEQUENCES OF CLIMATE CHANGE

## AVAILABILITY

*(sufficient quantity of food for consumption)*

- Reduced agricultural production in some areas locally (especially at tropical latitudes) could affect dietary diversity
- Changes in the suitability of land for crop production
- Changes in precipitation patterns could affect the sustainability of rain-fed agriculture in some areas
- Increases in temperature could lead to longer growing seasons in temperate regions and reduced frost damage
- CO<sub>2</sub> fertilisation could increase yields for those crops with the physiology to benefit from CO<sub>2</sub> enrichment

## ACCESS

*(ability to obtain food regularly through own production or purchase)*

- Lower yields in some areas could result in higher food prices
- Loss of income due to the potential increase in damage to agricultural production

## STABILITY

*(risk of losing access to resources required to consume food)*

- Instability of food supplies due to an increase in extreme events
- Instability of incomes from agriculture

## UTILISATION

*(quality and safety of food, including nutrition aspects)*

- Food security and health impacts include increased malnutrition
- Ability to utilise food might decrease where changes in climate increase disease
- Impact on food safety due to changes in pests and water pollution

# IMPACTS ON FOOD AVAILABILITY COMPONENT

The food availability dimension of food security encompasses issues of global and regional food supply, and asks the basic question: can we physically produce enough food to feed our population?

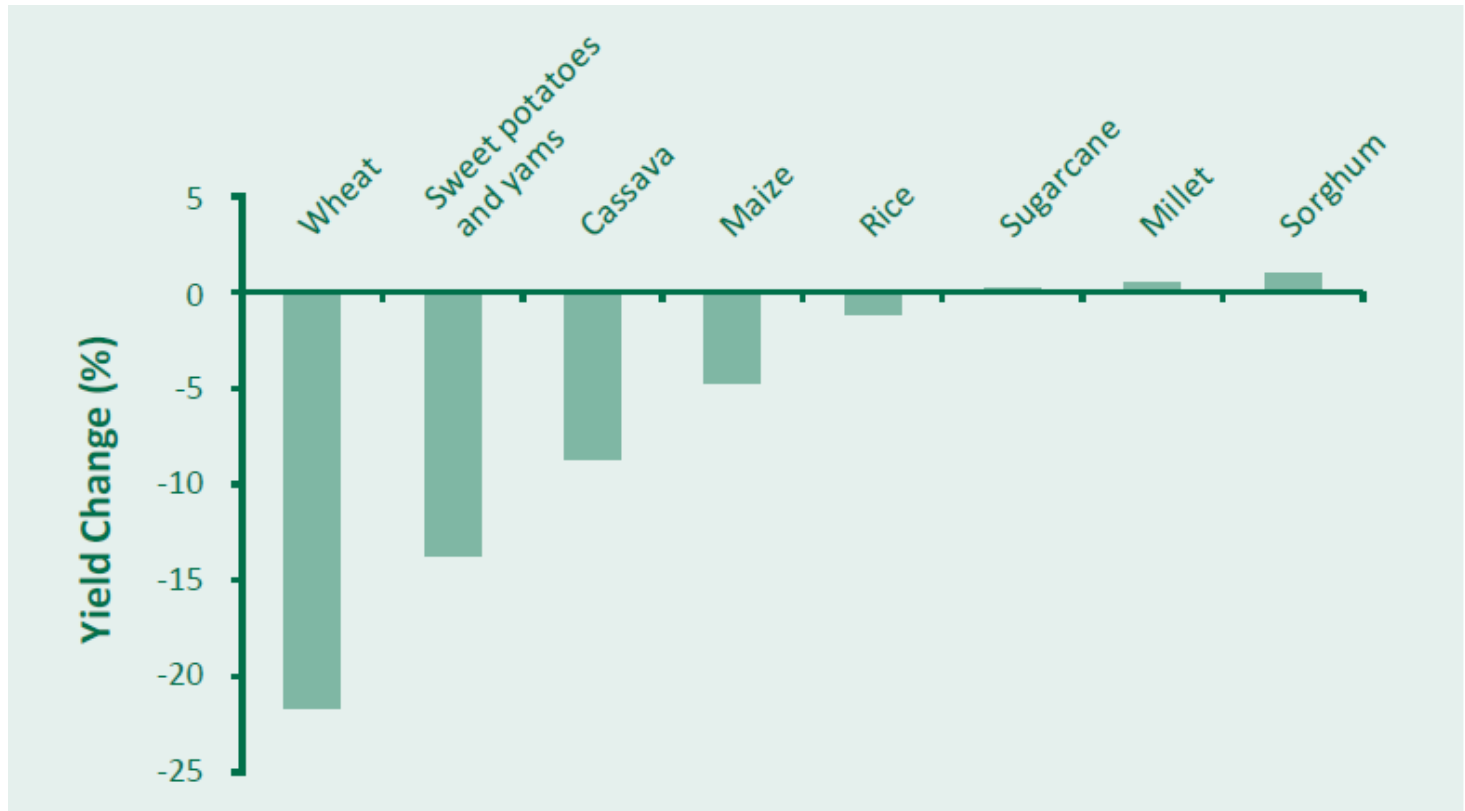
This so-called Green Revolution allows the world today to produce 170% more cereals on just 8% more cropped area than 50 years ago

Global level this productivity growth has more than kept pace with the large observed increases in population, and global per capita cereal production currently stands at almost exactly 1 kg/person/day – or more than enough, on average, to feed everyone on the planet.

African cereal yields have grown at less the half the Asian rate, and despite an 80% increase in the amount of cropped area on the continent, total cereal production has not kept pace with population growth.

So how might climate change affect global and regional food supply? Climate change will have potentially large effects on both agricultural yields and potential cropped area, with global trade acting as a potential buffer when countries trade and when climate shocks are not uniform across space.

## Projected changes in Sub-Saharan African crop yields due to climate change, 2050

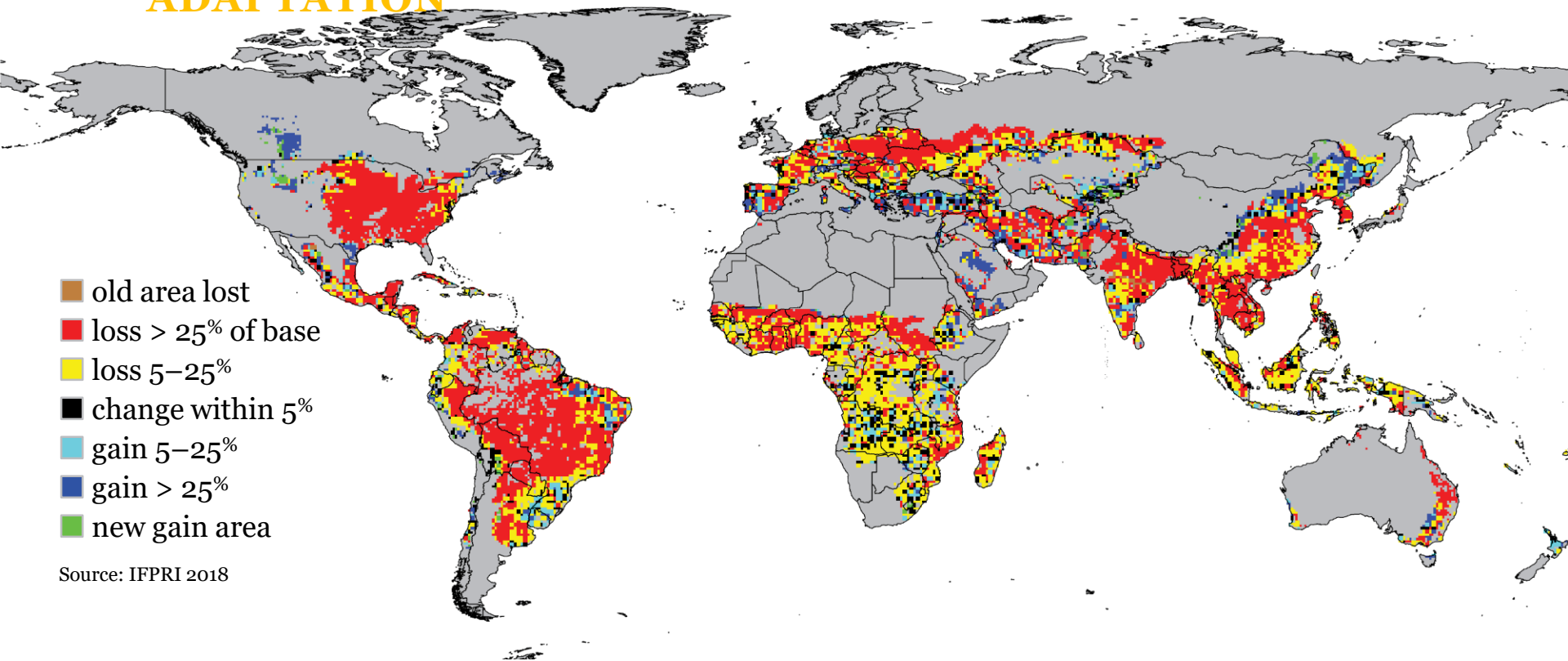


Source: IFPRI RESEARCH BRIEF, 2010



# CLIMATE CHANGE

## PROJECTED 2050 GLOBAL MAIZE YIELDS WITHOUT ADAPTATION

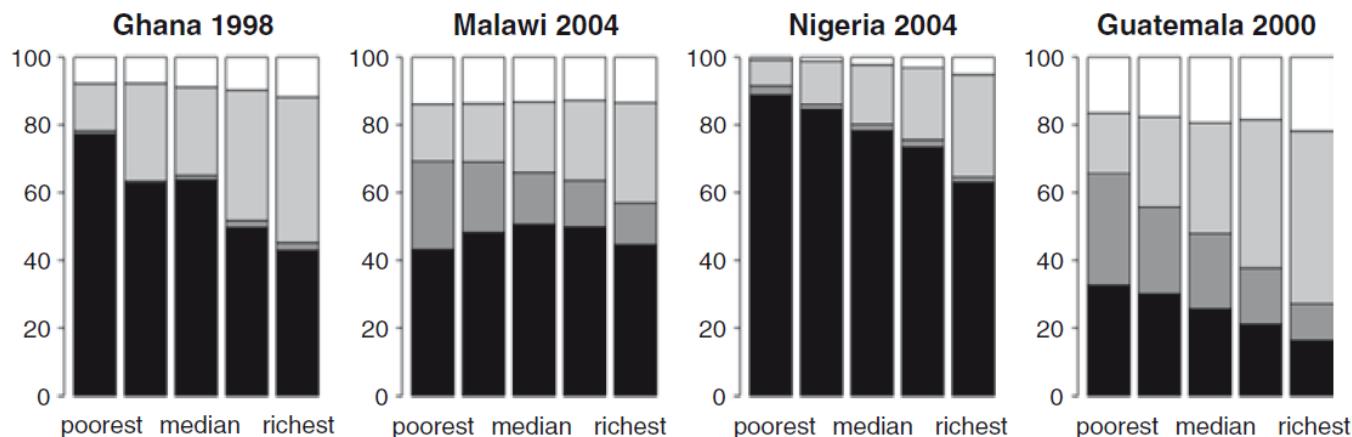


Source: IFPRI 2018

# IMPACT OF CLIMATE ON ACCESS COMPONENT

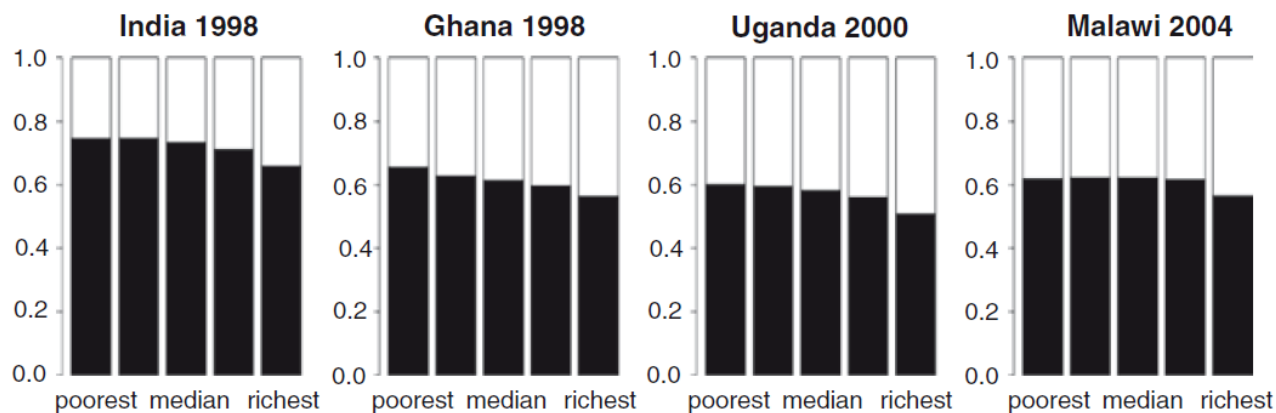
- Food access refers to the ability of an individual to acquire food, either through its production or its purchase.
- Farmers access to food is secure if they command sufficient amounts of “entitlements” (factors of production) to produce enough food.
- Non farm households, access to food is a function of incomes and prices – how much money one has to spend on food, and how much the food costs.
- Effects of climate change on food access for a given household therefore requires addressing the role of climate change in relation to four basic questions: **how households earn their income**, **the nature of their exposure to food prices**, **how well integrated their local food markets are with global markets**, and **their broader longer-run prospects for livelihood improvement**.

## EXAMPLE/ILLUSTRATION: COUNTRY HOUSEHOLDS BY INCOME SOURCES



**Source:** (Davis et al. 2007 in Burke and Lobell, 2010, pg. 22) Percentage of rural household income derived from agricultural sources, by income quintile for selected countries. *Black* = on-farm income; *dark grey* = agricultural wage income; *light grey* = off-farm income; *white* = transfer income/other. For instance, the poorest 20% of rural Ghanaian households derive about 80% of their income from farm activities

## EXAMPLE 2: FOOD EXPENDITURE AS A % OF TOTAL H/HOLD EXPENDITURE



**Source:** (Burke and Lobell, 2010, pg. 24) Food expenditure as a percent of total household expenditure.

# FOOD UTILIZATION AND CLIMATE CHANGE

- Food utilization component of food security relates to the nutritional aspects of food consumption.
- Food utilization requires satisfactory answers to three questions: does the food an individual eats contain all the energy, protein, and nutrients necessary to lead a healthy and productive life?
- Climate change exacerbates undernutrition through three causal pathways related to (or through combined effects on) food security, care practices and health.
- Quantifying the effects of climate change on undernutrition is a complex exercise, due to the multiple causal pathways leading to under nutrition.
- However recent studies suggest that climate extremes such as floods and droughts might have a negative impact on nutrition outcomes.
- Climate change can also increase the incidence of diseases, such as malaria, thereby increasing the caloric requirements of affected populations and reducing the body's absorption and utilization of essential nutrients, effectively increasing overall nutritional needs.

# Answers to poor food availability, access and utilization by Sub Saharan Africa

- Even without climate change, SSA remains the most food-deprived region worldwide and the only one with projected increases in childhood malnutrition despite recent increases in economic prosperity and gross domestic product, which were generated through agriculture.
- Compared with historic climate records, climate change will cause shifts in yield and area growth and increased food prices, thereby lowering food affordability, reducing calorie availability, and increasing childhood malnutrition.
- Cereal production growth in the region is projected to decline by 3.2 percent as a result of climate change, with increased area expansion of 2.1 percent partially compensating declines in yield growth of 4.6 percent.
- The most potent force for reducing malnutrition is raising food availability and rural incomes through increased agricultural productivity. Agricultural productivity enhancements will thus be critical in counteracting the adverse impacts of climate change in the region.

# OPTIONS FOR CLIMATE CHANGE ADAPTATION IN AGRICULTURE

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| Altering exposure                                                                                                                                                                                                                                                                                    | Reducing sensitivity                                                                                                                                                                                                                                                                                                                             | Increasing adaptive capacity                                                                                                                                                                                                                                                                                               |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"><li>• Assess impacts and map hazard zones</li><li>• Conduct proper land and water-use planning</li><li>• Protect watersheds and establish flood retention zones</li><li>• Resettle humans and restructure agriculture</li><li>• Change cropping patterns</li></ul> | <ul style="list-style-type: none"><li>• Develop or adopt suitable crop, plant and animal varieties</li><li>• Improve irrigation and drainage systems</li><li>• Enhance soil nutrition and on-farm water management</li><li>• Diversify cropping and agricultural activities</li><li>• Adopt disaster-prevention construction standards</li></ul> | <ul style="list-style-type: none"><li>• Develop adaptive strategies and action plans</li><li>• Diversify sources of household income</li><li>• Improve water and other infrastructure systems</li><li>• Establish disaster and crop insurance schemes</li><li>• Promote technical transfer and capacity building</li></ul> |

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# Lessons learnt over March to May 2014 Season at Nyando CCAFS Site

John Gathenya<sup>1</sup>, David Stern<sup>2</sup>, Harun Ogindo<sup>2</sup>, James Musyoka<sup>2</sup>, Thomas Mawora<sup>1</sup>, Illa Absalom<sup>1</sup>, James Kinyangi<sup>3</sup>

<sup>1</sup>University of Reading, <sup>2</sup>Maseno University, <sup>3</sup>CCAFS, Eastern Africa

## When to plant

- March to May season starts properly in early March and lasts about 90-110 days (Fig 1).
- February and June rain is unreliable.
- Farmers plant from February to mid March.
- The seasonal climate forecast is released first week of March.

- Planting in mid February gives a longer season (110 days) but at the risk of long dry spells and possible replanting (Fig 2). The seasonal forecast is not yet released

- Planting in mid March gives a shorter season (90 days), a lower risk of replanting and a chance to benefit from the seasonal forecast (Fig 2).

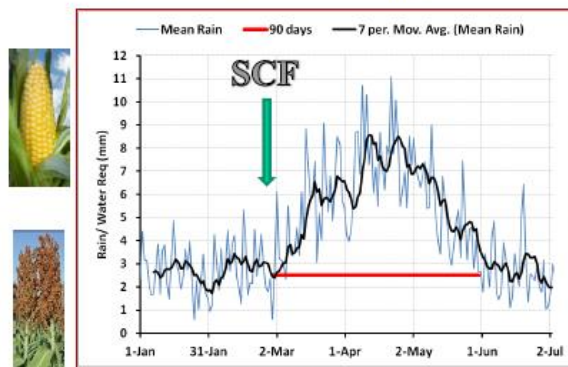


Fig 1 Kisumu Met. March-June rainfall

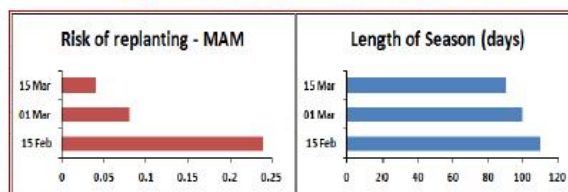


Fig 2 Risk of replanting and length of season

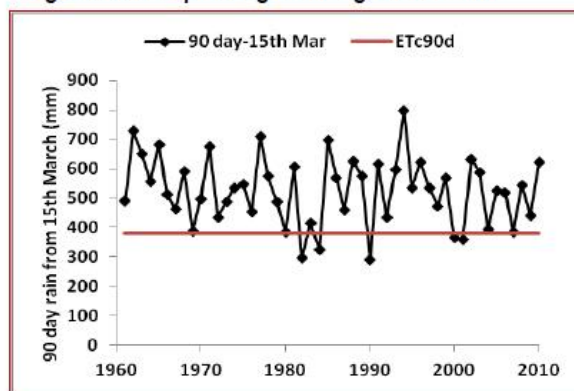


Fig 3 Kisumu Met. 90 day seasonal rainfall totals

## What to plant

- The annual crops grown here take from 60 to 120 days to mature.
- Crops that take 90 days or less fit better into the season; they can be planted in mid March when dry spell risks are lower and still get enough days in the season.
- 120-day crops are best planted in mid February and hence encounter the dry spell risks.
- Farmers should select crops and practices that reduce sensitivity to dry spells.

The FAO CROPWAT gives crop water requirement Etc of **270 mm** for **60-day crops**, **380 mm** for **90-day crops** and **490 mm** for **120-day crop varieties** under Kisumu climate. Etc  $\approx 4.2x$  (Days to Maturity). 90 day seasonal rainfall total < 380 mm for 1/10 years (Fig 3).

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# Crop-Climate Risk Factsheet – March to May Season at Nyando CCAFS Site

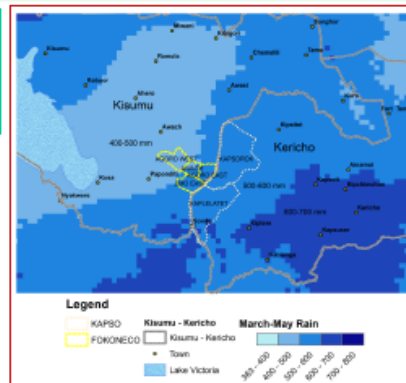
John Gathanya<sup>1</sup>, David Stern<sup>2</sup>, Harun Ogindo<sup>2</sup>, James Musyoka<sup>2</sup>, Thomas Mawora<sup>1</sup>,  
Illa Absalom<sup>1</sup>, Ruth Muriuki<sup>3</sup>, James Kinyangi<sup>4</sup>

<sup>1</sup>University of Reading, <sup>2</sup>Maseno University, <sup>3</sup>Egerton, University, <sup>4</sup>CCAFS, Eastern Africa

For at least 6 out of 10 years, farmers in Nyando CCAFS site have a good chance of getting sufficient rainfall for a good yield in the March to May season if they plant crop varieties that mature in 90 days or less. The chance is only 3 out of 10 years if 120-day varieties are selected. The risk can be reduced by choosing shorter duration varieties, timely planting, retaining more rainwater in the soil by adding manure, mulching and ridging.

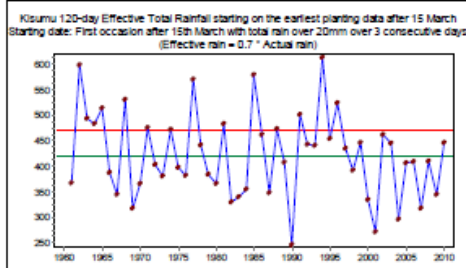
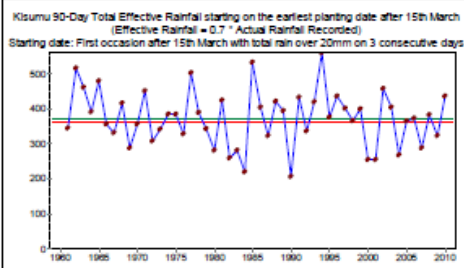
Nyando CCAFS site is located on the border of Kisumu (Jimo E., Agoro W., Agoro E., Awach) and Kericho (Kaplelatet and Kapsorok ) Counties. The average rainfall for the March – May season is 500 mm.

Major crops grown are maize, sorghum, beans, groundnut, pigeon pea and cowpea. There are varieties that require from 60 to 120 days from emergence to maturity. The seasonal crop water requirement depends mainly on the days to maturity.



We used FAO model CROPWAT and Kisumu Airport Met climate data to estimate the seasonal water requirement of various crops. We obtained 350 mm for 90-day crop varieties and 470 mm for 120-day crop varieties.

We used daily rainfall data of Kisumu Airport Met Station to calculate the seasonal rainfall totals over the growing period of 90 or 120 days starting from the successful planting date. The earliest starting date was 15<sup>th</sup> March and the effective rainfall was assumed to be 70% of the rainfall received. The red line (Fig 2 and 3) shows the crop water requirement. The chance of getting enough rainfall in the season is obtained by counting the points above the red line and dividing by the total number of seasons which is 50. It is 6/10 for the 90-day and 3/10 for the 90- and 120-day crop varieties.



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# TECHNOLOGIES, PRACTICES, APPROACHES FOR BUILDING RESILIENT LIVELIHOODS

| Agriculture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Livestock                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Fisheries                                                                                                                                                                                                                                                                                                                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"><li>• Crop diversification</li><li>• Appropriate crop selection (drought/saline/flood tolerant)</li><li>• Intercropping</li><li>• Crop breeding</li><li>• Conservation agriculture</li><li>• Adjustment of cropping calendars</li><li>• Seed systems</li><li>• Terracing</li><li>• Post-harvest management (storage, food drying, food processing)</li><li>• Livelihoods diversification</li><li>• Crop insurance</li><li>• Integrated pest management</li><li>• Urban gardening</li></ul> | <ul style="list-style-type: none"><li>• Proofing of storage facilities</li><li>• Livestock shelters</li><li>• Strategic animal fodder reserves</li><li>• Fodder conservation</li><li>• Resilient animal breeding</li><li>• Vaccination to reduce or prevent the spread of animal disease</li><li>• Grazing and pasture resource management</li><li>• Strengthening pest management systems to cope with threats</li><li>• Biosecurity in animal production systems</li><li>• Agro-silvopastoral systems</li></ul> | <ul style="list-style-type: none"><li>• Implementation of the Code of Conduct for responsible fisheries.</li><li>• Fisheries, aquaculture, vessel and infrastructure insurance</li><li>• Safety in the design, construction and equipment for fishing vessels</li><li>• Aquaculture biosecurity measures to reduce or prevent the spread of fish disease</li></ul> |

# TECHNOLOGIES, PRACTICES, APPROACHES FOR BUILDING RESILIENT LIVELIHOODS

| Natural Resource Management                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Water                                                                                                                                                                                                                                                                                                                                                                                                                                | Land                                                                                                                                                                                                                                                                                                                                                                                                     | Forests                                                                                                                                                                                                                                                                                                                                                  |
| <ul style="list-style-type: none"><li>• Rainwater harvesting, conservation and storage to improve capture and utilization of rainfall</li><li>• Water reserves to buffer droughts</li><li>• Efficient irrigation such as drip and furrow irrigation that use less water and reduce water loss</li><li>• Management of fragile catchment areas</li><li>• Capture of floods or recharge of groundwater for use in dry season</li></ul> | <ul style="list-style-type: none"><li>• Restoration of degraded lands.</li><li>• Land use and territorial planning</li><li>• Sustainable wetland management</li><li>• Land and soil management</li><li>• Field or network drainage to minimize flood impact</li><li>• Appropriate energy sources and technologies to reduce pressure on land.</li><li>• Secure natural resources tenure rights</li></ul> | <ul style="list-style-type: none"><li>• Integrated Fire Management</li><li>• Forest pests prevention</li><li>• Agro-forestry</li><li>• Afforestation/reforestation</li><li>• Preventive silviculture</li><li>• Prescribed burning</li><li>• Fire breaks</li><li>• Improved cook stoves and alternatives to wood energy to reduce deforestation</li></ul> |

# Research gaps (relevant to climate change, agriculture & food security)

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|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Climate science         | <ul style="list-style-type: none"> <li>• Research in climate and climate impacts would be greatly enhanced if data custodians and researchers worked together to use observed station data in scientific studies. Research into regional climate change and climate impacts relies on observed climate and hydrological data as an evaluative base. These data are most often recorded by meteorological institutions in each country and sold to support data collection efforts. However, African researchers are generally excluded from access to these critical data because of the high costs involved, which hinders both climate and climate impacts research.</li> <li>• Downscaling General Circulation Model (GCM) data to the regional scale captures the influence of topography on the regional climate. Regional climate information is essential for understanding regional climate processes, regional impacts, and potential future changes in these. In addition, impacts models such as hydrology and crop models generally require input data at a resolution higher than what GCMs can provide. Regional downscaling, either statistically or through use of regional climate models, can provide information at these scales and can also change the sign of GCM-projected rainfall change over topographically complex areas (Section 22.2.2.2).</li> </ul> |
| Food systems            | <ul style="list-style-type: none"> <li>• Socioeconomic and environmental trade-offs of biofuel production, especially the effect on land use change and food and livelihood security; better agronomic characterization of biofuel crops to avoid maladaptive decisions with respect to biofuel production</li> <li>• Vulnerability to and impacts of climate change on food systems (production, transport, processing, storage, marketing, and consumption)</li> <li>• Impacts of climate change on urban food security, and dynamic of rural–urban linkages in vulnerability and adaptive capacity</li> <li>• Impacts of climate change on food safety and quality</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Water resources         | <ul style="list-style-type: none"> <li>• Characterization of Africa's groundwater resource potential; understanding interactions between non-climate and climate drivers as related to future groundwater resources</li> <li>• Impacts of climate change on water quality, and how this links to food and health security</li> <li>• Decision making under uncertainty with respect to water resources given limitations of climate models for adequately capturing future rainfall projections</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Livelihoods and poverty | <ul style="list-style-type: none"> <li>• Methodologies for cyclical learning and decision support to enable anticipatory adaptation in contexts of high poverty and vulnerability (Tschakert and Dietrich, 2010)</li> <li>• Frameworks to integrate differentiated views of poverty into adaptation and disaster risk reduction, and to better link these with social protection in different contexts</li> <li>• Ethical and political dimensions of engaging with local and traditional knowledge on climate change</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Adaptation              | <ul style="list-style-type: none"> <li>• Research to develop home-grown and to localize global adaptation technologies to build resilience</li> <li>• Equitable adaptation frameworks to deal with high uncertainty levels and integrate marginalized groups; and that identify and eliminate multi-level constraints to women's adaptive ability</li> <li>• Multi-tiered approach to building institutional and community capacity to respond to climate risk</li> <li>• Potential changes in economic and social systems under different climate scenarios, to understand the implications of adaptation and planning choices (Clements et al., 2011)</li> <li>• Principles/determining factors for effective adaptation, including community-based adaptation</li> <li>• Understanding synergies and trade-offs between different adaptation and mitigation approaches (Chambwera and Anderson, 2011)</li> <li>• Additional national and sub-national modeling and analysis of the economic costs of impacts and adaptation, including of the "soft" costs of impacts and adaptation</li> <li>• Monitoring adaptation</li> </ul>                                                                                                                                                                                                                                                 |

THANK YOU FOR LISTENING