# iFEED Climate Change Calibrated Statements

Results from bias-corrected CORDEX, CMIP, CP4A and P25 models, except for return levels, which are from un-bias corrected CP4A.

Values come from IQR, except for return levels, where they come from the confidence intervals from the bootstrap resample.

## Tanzania

**Change in rainfall amount**

Compared to the 1971 – 2000 period, end of century climate change (2071 – 2100; RCP8.5) results in rainfall increases in the March – May rainy season of 4.7 to 24.0 mm/month. Rainfall may increase or decrease in the October – December rainy season by between -3.6 to 13.3 mm/month (low robustness, medium agreement). Rainfall is expected to decline during the June-September dry season by between -2.1 to -0.3 mm/month (low robustness, medium agreement).

Robustness Assessment:

Low robustness for the rainy season as there is disagreement amongst the CORDEX and CMIP5 models for the sign of change in the rainy season. In the dry season the majority of CORDEX models and CP4A and P25 show rainfall declines, however there is disagreement in the CMIP5 models.

Agreement Assessment:

Numerous studies have found that climate change will increase precipitation in East Africa, however there is some disagreement based on location and whether GCMs or RCMs are used.

**Change in rainy season duration**

Compared to the 1972 – 1999 period, end of century climate change (2072 – 2099; RCP8.5) results in declines in the rainy season duration across most of Tanzania with RCP8.5 (-7.8 to 2.9 days), except the northern coast which may seen increases in rainy season duration (low robustness, high agreement).

Robustness Assessment:

There is disagreement on the sign of change in the rainy season duration for CORDEX and CMIP5 models, and the coast of Tanzania is also an area where models struggle to represent rainfall characteristics.

Agreement Assessment:

Other studies find the same, although there is limited work in this area.

**Change in temperature -> cassava toxicity implication statement**

Compared to the 1971 – 2000 period, end of century climate change (2071 – 2100; RCP8.5) results in increases in annual temperature of approximately 3.6 – 4.8$^{o}$C (high robustness, high agreement).

Robustness Assessment:

All CORDEX, CMIP5, CP4A and P25 models show increases in temperature. Less than 10% of models are outliers (defined as 1.5 * IQR).

Agreement Assessment:

Literature finds increases in temperature with climate change.

**Change in drought -> cassava toxicity implication statement**

Compared to the 1971 – 1999 period, mid and end of century climate change results in increases the number of months which count as drought months for both RCP4.5 and 8.5 (high robustness and high agreement).

By mid-century (2031 – 2059), the number of drought months per year increases by between 1 – 4 months with RCP8.5, and 1 – 3 months with RCP4.5.

By end-of-century (2071 – 2099), the number of drought months per year increases by between 5 – 6 months with RCP8.5, and 4 – 5 months with RCP4.5.

Robustness Assessment:

All CORDEX and CMIP5 models show increases in drought months. This occurred regardless of whether SPEI of -1 or -2 was used to define drought, or whether a running mean of 1 or 3 months is used to define drought. This is mainly because temperature increases are consistent across models, and outweigh any rainfall increases.

Agreement Assessment:

The literature shows increases in drought in Africa, calculating using different models, indicators of droughts, and different ways of calculating SPEI.

**Change in rainfall extremes -> soil erosion implication statement**

Compared to the historical period (1970 – 2000), end of century climate change (2070 – 2100; RCP8.5) results in small decreases in the number of rainy days, and increases in rainfall on wet days as well as increases in intense rainfall ($95^{th}$ percentile).

During the March – May wet season the change in number of wet days is small (low robustness, low agreement). There is a small decrease in the number of wet days during the October – December wet season of between -2 to 0 days (medium robustness, medium agreement).

During the March – May wet season, the amount of rainfall on wet days may increase by 0.2 to 2.0 mm/day (low robustness, medium agreement), and the amount of intense rainfall may increase by between 1.4 – 3.9 mm/day (medium robustness, medium agreement). Intense rainfall may increase during the October – December wet season by between 0 – 2.6 mm/day (medium robustness, medium agreement), and the amount of rainfall on rainy days may increase by between 0.6 to 1.6 mm/day (medium robustness, medium agreement).

Rainfall associated with very rare rainfall events is also expected to increase by the end of the century with RCP8.5. Rainfall associated with 1-in-2 year rainfall events is expected to increase by 40 – 50%, while rainfall associated with 1 - in-20 year events may increase by 60% (low robustness, medium agreement).

Robustness Assessment:

The majority of models show increases in rainfall extremes, however rating as medium robustness as rainfall in general is more uncertain in climate models.

Agreement Assessment:

Agreement in the literature that rainfall extremes increase with climate change.

**Growing degree days**

Due to temperature increases, mid and end of century climate change results in increases in the number of growing degree days for maize that are accumulated during the rainy season in both RCP4.5 and RCP8.5 across most of the country (medium robustness, medium agreement).

In the historical period (1972 – 1998), 500 growing degree days for maize are accumulated during the rainy season in the majority of years (> 96%) (medium robustness, medium agreement). 1000 growing degree days are accumulated in 86% of years (medium robustness, medium agreement), and 1500 growing degree days are accumulated within 57% of years (low robustness, medium agreement).

By mid century (2032 – 2058), with the RCP4.5 and RCP8.5 climate change scenarios 500 GDD are still met within rainy season in the majority of years (> 96%) (medium robustness, medium agreement). The number of years where 1000 GDD are accumulated increases, and is met within 86 – 95% of years in RCP8.5 (medium robustness, medium agreement) and 90 – 96% of years with RCP4.5 (low robustness, medium agreement). The number of years where 1500 GDD are accumulated also increases, and is met within 61 – 83% of years in RCP8.5, and 63 – 85% of years with RCP4.5 (medium robustness, medium agreement).

By end-of-century (2071 – 2097), with the RCP4.5 and RCP8.5 climate change scenarios 500 GDD are still met within rainy season in the majority of years (> 96%) (low robustness for RCP8.5, medium robustness for RCP4.5, medium agreement). The number of years where 1000 GDD are accumulated increases, and is met within 91 – 98% of years in RCP8.5 and 91 – 97% of years with RCP4.5 (medium robustness, medium agreement). The number of years where 1500 GDD are accumulated also increases, and is met within 78 – 91% of years in RCP8.5, and 71 – 87% of years with RCP4.5 (medium robustness, medium agreement).

Robustness Assessment:

Increases in temperature and therefore GDD are robust, however there is more uncertainty about the change in the length of the rainy season.

Agreement Assessment:

High agreement that the number of growing days should increase, although limited work in this area that I could find, and could not find other work that looked specifically at GDD in the rainy season.

# Malawi

**Change in rainfall amount**

Compared to the 1971 – 2000 period, end of century climate change (2071 – 2100; RCP8.5) results in rainfall declines in the June – September dry season of between -3.9 to -1.0 mm/month (medium robustness, medium agreement). During the November to April wet season rainfall may decline or increase by between -13.2 to 8.2 mm/month (low robustness, low agreement).

Robustness Assessment:

Low robustness as there is disagreement amongst the CORDEX and CMIP5 models for the sign of change in rainfall.

Agreement Assessment:

Results (including uncertainty in results) in line with literature.

**Change in rainy season duration**

Compared to the 1972 – 1999 period, end of century climate change (2072 – 2099; RCP8.5) results in declines in the rainy season duration with RCP8.5 (-14.9 days to -5.5 days) (medium robustness, high agreement).

Robustness Assessment:

All CORDEX, CMIP5, CP4A and P25 models bar one show declines in the rainy season duration, however there is a great deal of variation in the magnitude (0 - ~ 25 day reduction).

Agreement Assessment:

Other studies find the same, although there is limited work in this area.

**Change in temperature -> cassava toxicity implication statement**

Compared to the 1971 – 2000 period, end of century climate change (2071 – 2100; RCP8.5) results in increases in annual temperature of 4.0 – 5.1$^{o}$C (high robustness, high agreement).

Robustness Assessment:

All CORDEX, CMIP5, CP4A and P25 models show increases in temperature. Less than 10% of models are outliers (defined as 1.5 * IQR).

Agreement Assessment:

Literature finds increases in temperature with climate change.

**Change in drought -> cassava toxicity implication statement**

Compared to the 1971 – 1999 period, mid and end of century climate change results in increases the number of months which count as drought months for both RCP4.5 and 8.5 (high robustness and high agreement).

By mid-century (2031 – 2059), the number of drought months per year increases by between 4 – 5 months with RCP8.5, and 4 months with RCP4.5.

By end-of-century (2071 – 2099), the number of drought months per year increases by between 6 – 7 months with RCP8.5, and 5 months with RCP4.5.

Robustness Assessment:

All CORDEX and CMIP5 models show increases in drought months. This occurred regardless of whether SPEI of -1 or -2 was used to define drought, or whether a running mean of 1 or 3 months is used to define drought. This is mainly because temperature increases are consistent across models, and outweigh any rainfall increases.

Agreement Assessment:

The literature shows increases in drought in Africa, calculating using different models, indicators of droughts, and different ways of calculating SPEI.

**Change in rainfall extremes -> soil erosion implication statement**

Compared to the historical period (1970 – 2000), end of century climate change (2070 – 2100; RCP8.5) results in small decreases in the number of rainy days, and increases in rainfall on wet days as well as increases in intense rainfall (95$^{th}$ percentile).

During the November – April wet season the number of wet days may decrease by between -2.6 to -1.0 (medium robustness, high agreement). The amount of rainfall on wet days may increase by 0.5 to 1.6 mm/day (medium robustness, medium agreement), and the amount of intense rainfall may change by between -0.1 – 2.3 mm/day (low robustness, medium agreement).

Rainfall associated with very rare rainfall events is also expected to increase by the end of the century with RCP8.5. Rainfall associated with 1-in-2 year rainfall events is expected to increase by 30 – 40%, while rainfall associated with 1 - in-20 year events may increase by 40% - 70% (low robustness, medium agreement).

Robustness Assessment:

The majority of models show increases in rainfall extremes, however rating as medium robustness as rainfall in general is more uncertain in climate models.

Agreement Assessment:

Agreement in the literature that rainfall extremes increase with climate change.

**Growing degree days**

Due to temperature increases, mid and end of century climate change results in increases in the number of growing degree days that occur for maize during the rainy season in both RCP4.5 and RCP8.5 across most of the country (medium robustness, medium agreement).

In the historical period (1972 – 1998), 500 growing degree days for maize are accumulated during the rainy season in the majority of years (> 96%) (medium robustness, medium agreement). 1000 growing degree days are accumulated in 85% of years (medium robustness, medium agreement), and 1500 growing degree days are accumulated within 36% of years (medium robustness, medium agreement).

By mid century (2032 – 2058), with the RCP4.5 and RCP8.5 climate change scenarios 500 GDD are still met within rainy season in the majority of years (> 96%) (medium robustness, medium agreement). The number of years where 1000 GDD are accumulated increases, and is met within 91 – 96% of years in RCP8.5 and 91 – 95% of years with RCP4.5 (low robustness, medium agreement). The number of years where 1500 GDD are accumulated also increases, and is met within 45 – 69% of years in RCP8.5, and 40 – 59% of years with RCP4.5 (medium robustness, medium agreement).

By end-of-century (2071 – 2097), with the RCP4.5 and RCP8.5 climate change scenarios 500 GDD are still met within rainy season in the majority of years (> 96%) (medium robustness, medium agreement). The number of years where 1000 GDD are accumulated increases, and is met within 87 – 97% of years in RCP8.5 and 86 – 96% of years with RCP4.5 (medium robustness, medium agreement). The number of years where 1500 GDD are accumulated also increases, and is met within 60 – 78% of years in RCP8.5, and 36 – 67% of years with RCP4.5 (medium robustness, medium agreement).

Robustness Assessment:

Increases in temperature and therefore GDD are robust, however there is more uncertainty about the change in the length of the rainy season.

Agreement Assessment:

High agreement that the number of growing days should increase, although limited work in this area that I could find, and could not find other work that looked specifically at GDD in the rainy season.

# Zambia

**Change in rainfall amount**

Compared to the 1971 – 2000 period, end of century climate change (2071 – 2100; RCP8.5) results in rainfall declines in the June – September dry season of between -0.4 to -0.1 mm/month (medium robustness, medium agreement). During the November to April wet season rainfall may decline or increase by between -8.4 to 7.0 mm/month (low robustness, low agreement).

Robustness Assessment:

Low robustness as there is disagreement amongst the CORDEX and CMIP5 models for the sign of change in rainfall during the wet season.

Agreement Assessment:

Results (including uncertainty in results) in line with literature.

**Change in rainy season duration**

Compared to the 1972 – 1999 period, end of century climate change (2072 – 2099; RCP8.5) results in declines in the rainy season duration with RCP8.5 (-11.5 to -4.7 days) (medium robustness, high agreement).

Robustness Assessment:

All CORDEX, CMIP5, CP4A and P25 models show declines in the rainy season duration, however there is a great deal of variation in the magnitude (0 - ~ 20 day reduction).

Agreement Assessment:

Other studies find the same, although there is limited work in this area.

**Change in temperature -> cassava toxicity**

Compared to the 1971 – 2000 period, end of century climate change (2071 – 2100; RCP8.5) in increases in annual temperature of 4.2 – 5.6$^{o}$C (high robustness, high agreement).

Robustness Assessment:

All CORDEX, CMIP5, CP4A and P25 models show increases in temperature. Less than 10% of models are outliers (defined as 1.5 * IQR).

**Change in drought -> cassava toxicity**

Compared to the 1971 – 1999 period, mid and end of century climate change results in increases the number of months which count as drought months for both RCP4.5 and 8.5 (high robustness and high agreement).

By mid-century (2031 – 2059), the number of drought months per year increases by between 4 – 5 months with RCP8.5, and 4 months with RCP4.5.

By end-of-century (2071 – 2099), the number of drought months per year increases by between 6 – 7 months with RCP8.5, and 5 months with RCP4.5.

Robustness Assessment:

All CORDEX and CMIP5 models show increases in drought months. This occurred regardless of whether SPEI of -1 or -2 was used to define drought, or whether a running mean of 1 or 3 months is used to define drought. This is mainly because temperature increases are consistent across models, and outweigh any rainfall increases.

Agreement Assessment:

The literature shows increases in drought in Africa, calculating using different models, indicators of droughts, and different ways of calculating SPEI.

**Change in rainfall extremes -> soil erosion**

Compared to the historical period (1970 – 2000), end of century climate change (2070 – 2100; RCP8.5) results in small changes in the number of rainy days, and increases in rainfall on wet days as well as increases in intense rainfall ($95^{th}$ percentile).

During the November – April wet season the number of wet days may decrease by between -2.5 to -0.7 (medium robustness, high agreement). The amount of rainfall on wet days may increase by 0.4 to 1.3 mm/day (medium robustness, medium agreement), and the amount of intense rainfall may increase by 0.5 – 2.5 mm/day (medium robustness, medium agreement).

Robustness Assessment:

The majority of models show increases in rainfall extremes, however rating as medium robustness as rainfall in general is more uncertain in climate models.

Agreement Assessment:

Agreement in the literature that rainfall extremes increase with climate change.

**Growing degree days**

Due to temperature increases, mid and end of century climate change results in increases in the number of growing degree days that occur for maize during the rainy season in both RCP4.5 and RCP8.5 across most of the country (medium robustness, medium agreement).

In the historical period (1972 – 1998), 500 growing degree days for maize are accumulated during the rainy season in the majority of years (> 96%) (low robustness, medium agreement). 1000 growing degree days are accumulated in 93% of years (low robustness, medium agreement), and 1500 growing degree days are accumulated within 37% of years (medium robustness, medium agreement).

By mid century (2032 – 2058), with the RCP4.5 and RCP8.5 climate change scenarios 500 GDD are still met within rainy season in the majority of years (> 96%) (medium robustness, medium agreement). The number of years where 1000 GDD are accumulated increases, and is met within 96 – 99% of years in RCP8.5 and 95 – 99% of years with RCP4.5 (medium robustness, medium agreement). The number of years where 1500 GDD are accumulated also increases, and is met within 54 – 79% of years in RCP8.5, and 49 – 69% of years with RCP4.5 (medium robustness, medium agreement).

By end-of-century (2071 – 2097), with the RCP4.5 and RCP8.5 climate change scenarios 500 GDD are still met within rainy season in the majority of years (> 96%) (low robustness, medium agreement). The number of years where 1000 GDD are accumulated increases, and is met within 97 – 100% of years in RCP8.5 (medium robustness, medium agreement) and 95 – 99% of years with RCP4.5 (low robustness, medium agreement). The number of years where 1500 GDD are accumulated also increases, and is met within 74 – 87% of years in RCP8.5, and 51 – 76% of years with RCP4.5 (medium robustness, medium agreement).

Robustness Assessment:

Increases in temperature and therefore GDD are robust, however there is more uncertainty about the change in the length of the rainy season.

Agreement Assessment:

High agreement that the number of growing days should increase, although limited work in this area that I could find, and could not find other work that looked specifically at GDD in the rainy season.

# South Africa

**Change in rainfall amount**

Compared to the 1971 – 2000 period, end of century climate change (2071 – 2100; RCP8.5) results in rainfall declines in the June – September dry season of between -3.8 to -1.6 mm/month (medium robustness, medium agreement). During the December to May wet season rainfall may decline or increase by between -2.8 to 3.0 mm/month (low robustness, low agreement).

Robustness Assessment:

Low robustness as there is disagreement amongst the CORDEX and CMIP5 models for the sign of change in rainfall.

Agreement Assessment:

Most of the literature finds rainfall declines in southern Africa with climate change.

**Change in rainy season duration**

Compared to the 1972 – 1999 period, end of century climate change (2072 – 2099; RCP8.5) results in declines in the rainy season duration with RCP8.5 (-15.6 to -5.6 days)(medium robustness, high agreement).

Robustness Assessment:

The majority of CORDEX, CMIP5, CP4A and P25 models except 4 show declines in the rainy season duration, however there is a great deal of variation in the magnitude (0 - ~ 25 day reduction).

Agreement Assessment:

Other studies find the same, although there is limited work in this area.

**Change in temperature -> cassava toxicity implication statement**

Compared to the 1971 – 2000 period, end of century climate change (2071 – 2100; RCP8.5) in increases in annual temperature 33.9 – 5.2$^{o}$C (high robustness, high agreement).

Robustness Assessment:

All CORDEX, CMIP5, CP4A and P25 models show increases in temperature. Less than 10% of models are outliers (defined as 1.5 * IQR).

Agreement Assessment:

Literature finds increases in temperature with climate change.

**Change in drought -> cassava toxicity implication statement**

Compared to the 1971 – 1999 period, mid and end of century climate change results in increases the number of months which count as drought months for both RCP4.5 and 8.5 (high robustness and high agreement).

By mid-century (2031 – 2059), the number of drought months per year increases by between 3 – 4 months with RCP8.5, and 2 - 4 months with RCP4.5.

By end-of-century (2071 – 2099), the number of drought months per year increases by between 5 – 6 months with RCP8.5, and3 - 5 months with RCP4.5.

Robustness Assessment:

All CORDEX and CMIP5 models show increases in drought months. This occurred regardless of whether SPEI of -1 or -2 was used to define drought, or whether a running mean of 1 or 3 months is used to define drought. This is mainly because temperature increases are consistent across models, and outweigh any rainfall increases.

Agreement Assessment:

The literature shows increases in drought in Africa, calculating using different models, indicators of droughts, and different ways of calculating SPEI.

**Change in rainfall extremes -> soil erosion implication statement**

During the December – Mayl wet season the number of wet days may decrease by between -0.9 to -0.3 (medium robustness, high agreement). The amount of rainfall on wet days may increase by 0.2 to 0.8 mm/day (medium robustness, medium agreement), and the amount of intense rainfall may change by -0.6 to 0.4 mm/day (medium robustness, medium agreement).

Robustness Assessment:

The majority of models show increases in rainfall extremes, however rating as medium robustness as rainfall in general is more uncertain in climate models.

Agreement Assessment:

Agreement in the literature that rainfall extremes increase with climate change in large parts of South Africa. Studies with CP4A and P25 also find declines in some indices of extremes along the western coast, with most increases in indices occurring in the east.

**Growing degree days**

Due to temperature increases, mid and end of century climate change results in increases in the number of growing degree days that occur for maize during the rainy season in both RCP4.5 and RCP8.5 across most of the country (medium robustness, medium agreement).

In the historical period (1972 – 1998), 500 growing degree days for maize are accumulated during the rainy season 74 – 84% of years (medium robustness, medium agreement). 1000 growing degree days are accumulated in 48 – 58% of years (medium robustness, medium agreement), and 1500 growing degree days are accumulated within 18 – 29% of years (medium robustness, medium agreement).

By mid century (2032 – 2058), 500GDD are accumulated within the rainy season in 82 – 90% of years in RCP8.5 and 76 -85% of years for RCP4.5 (medium robustness, medium agreement). The number of years where 1000 GDD are accumulated increases, and is met within 63 – 75% of years in RCP8.5 and 55 – 68% of years with RCP4.5 (medium robustness, medium agreement). The number of years where 1500 GDD are accumulated also increases, and is met within 37 – 50% of years in RCP8.5, and 27 – 42% of years with RCP4.5 (medium robustness, medium agreement).

By end-of-century (2071 – 2097), 500GDD are accumulated within the rainy season in 76 – 88% of years in RCP8.5 and 76 - 85% of years for RCP4.5 (medium robustness, medium agreement).The number of years where 1000 GDD are accumulated increases, and is met within 66 – 76% of years in RCP8.5 (low robustness, medium agreement) and 56 – 69% of years with RCP4.5 (medium robustness, medium agreement). The number of years where 1500 GDD are accumulated also increases, and is met within 38 – 57% of years in RCP8.5, and 26 – 43% of years with RCP4.5 (medium robustness, medium agreement).

Robustness Assessment:

Increases in temperature and therefore GDD are robust, however there is more uncertainty about the change in the length of the rainy season.

Agreement Assessment:

High agreement that the number of growing days should increase, although limited work in this area that I could find, and could not find other work that looked specifically at GDD in the rainy season.