Analysis of projected rainfall changes over the Athi River Basin based on ensemble averages of the best performing model runs

1.1 Changes in Future Rainfall under RCP 4.5 and RCP8.5 Scenarios over the Athi River Basin

Future projected changes in rainfall over the Athi River Basin were assessed for 10-year periods from 2021-2100 and 30-year periods for near (2011-2040), mid (2041-2070), and far (2071-2100) future climates relative to current climate (1961-2000/1976-2005) using CORDEX-Africa regional climate model (RCM) runs forced by GCM simulations under three emission scenarios (RCP2.6, RCP4.5, RCP8.5).

Based on assessment of the performance of 24 model runs taken from five CORDEX-EA simulations, Ogega et al (2020) identified four RCM runs that outperform ensemble means of the 24-model or individual model averages in describing the spatio-temporal characteristics of precipitation over Eastern Africa. The top four performing model runs are the **REMO2009** forced by *MPI-M-MPI-ESM-LR* GCM for *r1i1p1* ensemble member (**MPI-REMOr1**), **SMHI Rossby Center Regional Atmospheric Model (RCA4)** driven by the *r1i1p1* members of *CNRM-CERFACS-CNRM-CM5* (**CNRM-RCA4r1**) and *MPI-M-MPI-ESM-LR* (**MPI-RCA4r1**) models, and **RCA4** driven by *r2i1p1* member of *MPI-M-MPI-ESM-LR* (**MPI-RCA4r2**) global model. All four (**MPI-REMOr1, MPI-RCA4r1, CNRM-RCA4r1,** and **MPI-RCA4r2)** model data were used for the present assessment of projected precipitation changes under RCP8.5 scenario over the Athi River Basin. However, only three model runs (**MPI-REMOr1, MPI-RCA4r1,** and **CNRM-RCA4r1**) were available for projected rainfall change assessments under RCP4.5 scenario.

Figure 1 shows projected decadal MAM seasonal rainfall changes (mm/day) over the Athi River basin based on ensemble averages of the top best model runs under RCP 4.5 and RCP 8.5 scenarios. Although the MAM season is characterized by high temporal and spatial variations in future projected rainfall changes, drier signals appear to dominate during 2021-2030 under the two emission scenarios relative 2o 1961-2000. On the other hand, wetter signals are projected for much of the future decades from 2030 under RCP 4.5 and RCP 8.5 scenarios. Significantly wetter signals are projected over the Upper Athi River Catchment in mid (far) future climates under RCP4.5 (RCP8.5) emission scenarios.

Future projected rainfall changes for October-November-December season follow similar patterns as MAM projections except that significantly wetter signals are indicated for most future decades under the two emission scenarios (**Figure 2**). Accordingly, relative to 1961-200 climate weakly wet to weakly dry signals are projected in the near-future decadal climates (2021-2040) over the Athi River basin. On the other hand, wetter signals are projected for middle to far future best-model simulated climates under both RCP 4.5 and RCP 8.5 scenarios.

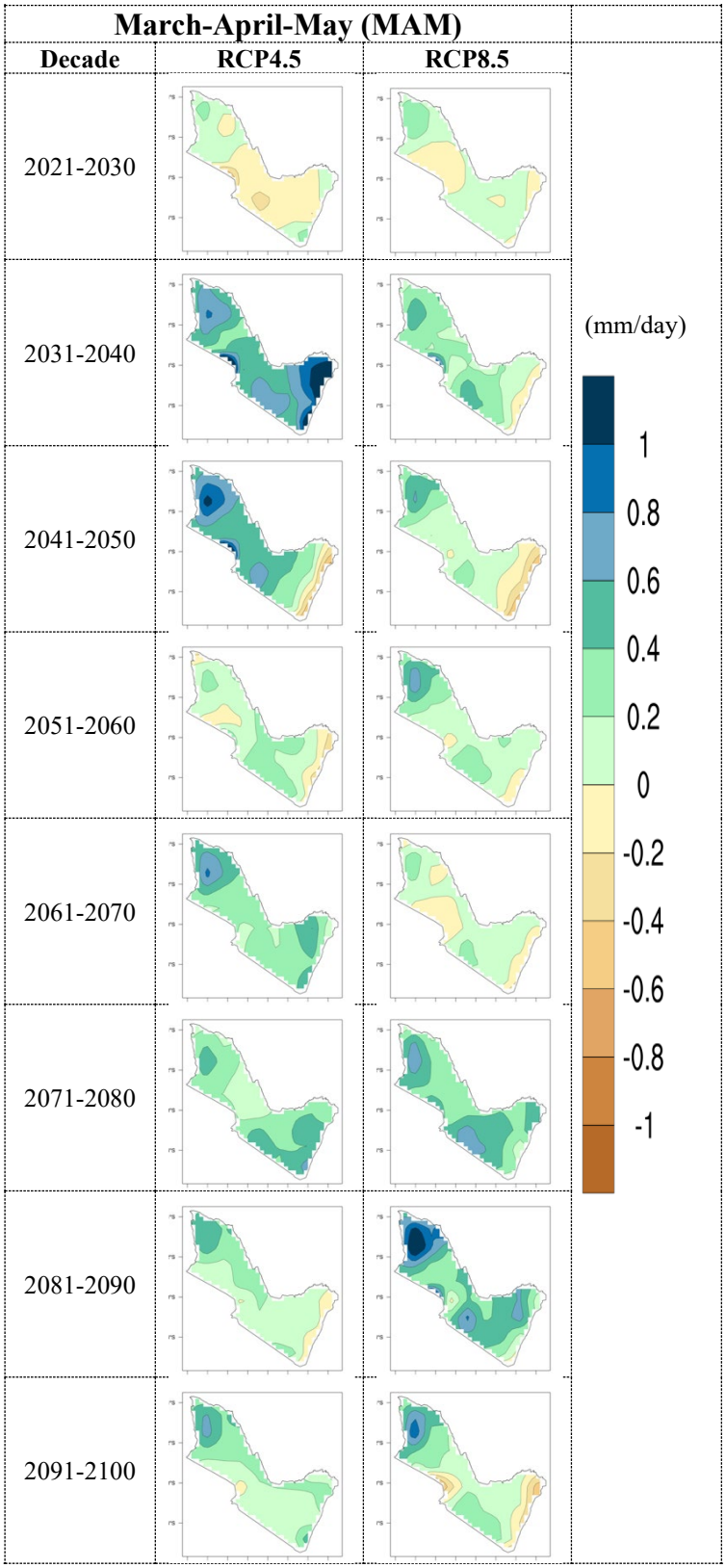

Figure 1: March-May seasonal rainfall average changes (mm/day) over Athi River basin based on the best performing RCMs under RCP4.5 (left) and RCP8.5 (right) scenarios for future ten-year periods (rows) from 2021 relative to historical simulations for the period 1961–2000.

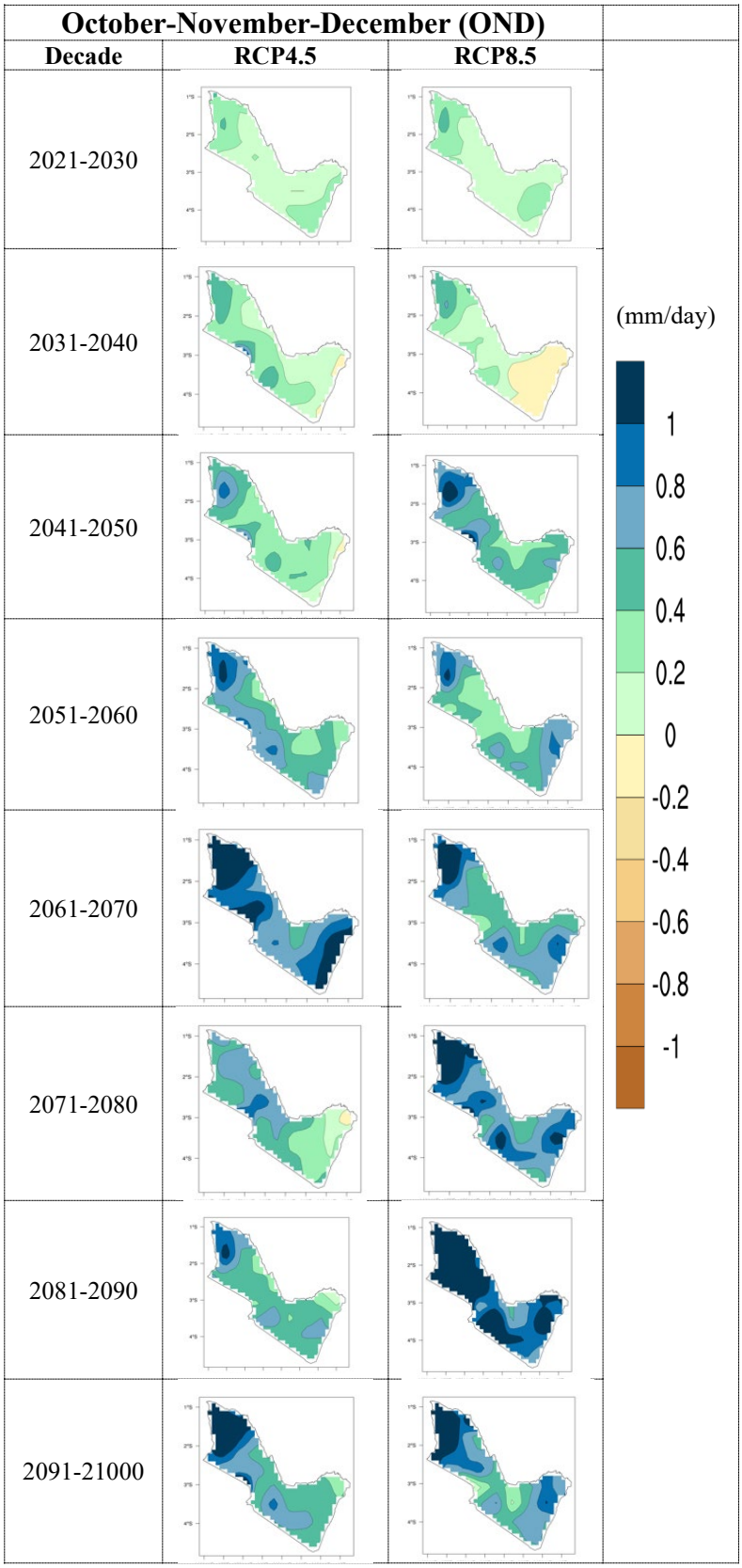

Figure 2: October-December seasonal rainfall average changes (mm/day) over Athi River basin based on the best performing RCMs under RCP4.5 (left), and RCP8.5 (right) scenarios for future ten-year periods (rows) from 2021 relative to historical simulations for the period 1961–2000.

1.2 Changes in Projected Droughts and Wetness over the Athi River Basin under RCP 4.5 and RCP8.5 Scenarios

In addition to spatial seasonal rainfall projected changes discussed above, the degree of dryness and wetness of rainfall changes are examined through analysis of 12-month Standardized Precipitation Index (World Meteorological Organization, WMO, 2012) for individual 30-year present climate (1976-2005) and three future climate periods (near, mid, and far-future climates) under RCP4.5 and RCP8.5 scenarios over the Athi River basin. The Standardized Precipitation Index (SPI) is constructed by fitting a probability distribution to a long record of precipitation and transforming it to a normal distribution with zero mean. A 12-month SPI reflects long-term precipitation patterns. Distinctive wet and dry signals in 12-month SPI usually are tied with streamflows, reservoir levels, and even groundwater level at longer time scales (WMO 2012). According to WMO (2012), SPI values between -1.5 to -1.99 indicate "severe" dryness (wetness) while values less than -2.0 (greater than 2.0) indicate "extremely" dry (wet) climate. It is indicated further that a drought event occurs any time when the SPI is continuously negative and reaches an intensity of -1.0 or less.

Figure 3 shows SPI time series averaged over the Athi River Basin for current (1976-2005) climate and mid (2041-2070) and far (2071-2100) future climates under the RCP4.5 and RCP8.5 scenarios. Analysis of catchment-averaged SPIs provides informative summary of precipitation differences between epochs and scenarios, and helps in identifying the timing and duration of excessive dryness (reds) and wetness (blues) for individual scenarios and epochs. In addition to the response of climate to scenario forcing, temporal SPI variations for any epochs/periods depict basin-wide interannual variability of rainfall. Overall, longer and/or more frequent drier events are projected in the far-future climate under the RCP 8.5 scenario.

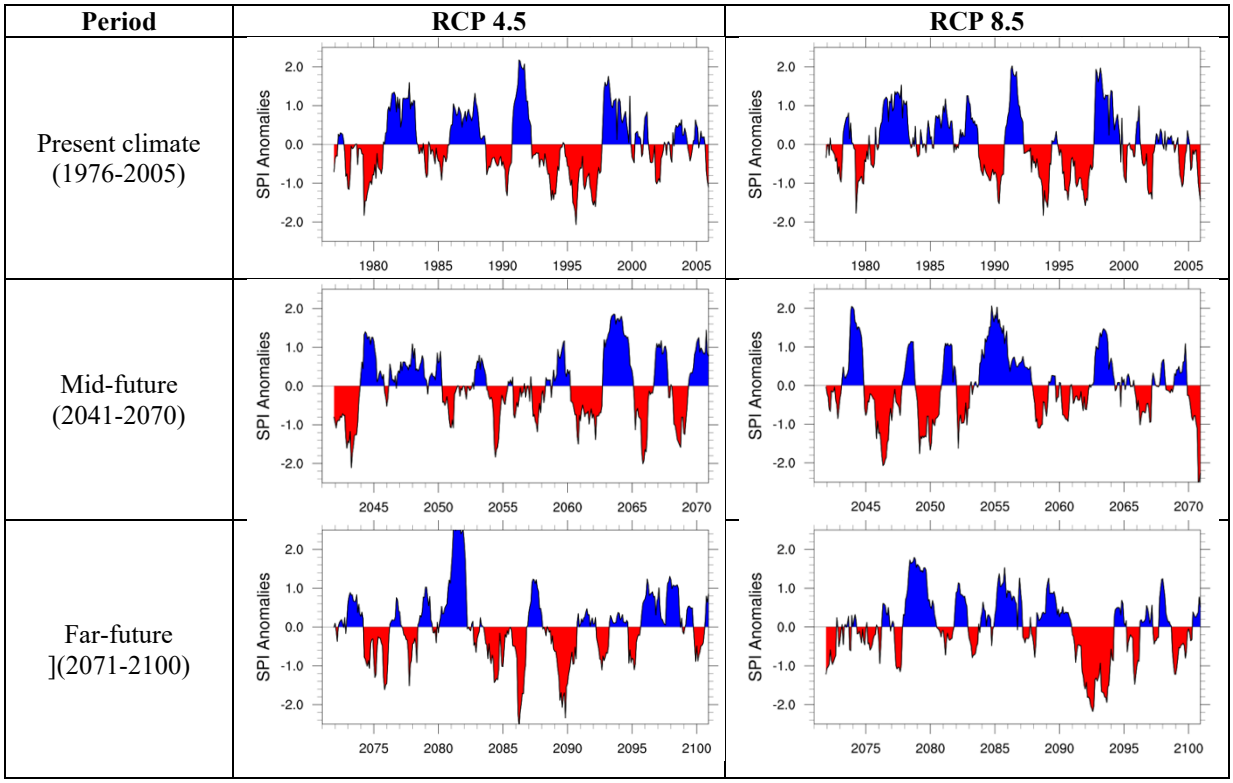

Figure 3: Twelve-month Standardized Precipitation Index (SPI) over the Athi River Basin for present (1976-2005; top), mid (2041-2070; middle) and far (2071-2100; bottom) future climate periods under RCP4.5 (left) and RCP8.5 (right) scenarios.

Area-average SPI may make comparison between events difficult because of the cancelling out of opposite signals across the Athi River Basin. The spatial variation and intensity of events can be readily identified by comparing the number of years exceeding a given SPI threshold at each grid point. Differences in frequency of occurrences between projected and present climates (future minus present) are used to assess future changes in *severe* and *extreme* droughts.

Figure 4 shows projected changes of *severe* droughts (SPI between -1.5 to -1.99) for near, mid, and far-future periods relative to the present climate (1976-2005) under the RCP4.5 and RCP8.5 scenarios over the Athi River Basin. For the present baseline climate, the percentage of *severe* droughts is higher for 4-model ensemble mean (RCP8.5) compared to the 3-model average for RCP4.5 in the Upper Athi river basin (bottom-right), while more frequent *severe* droughts are projected in the coastal areas under the RCP4.5 scenario. Although spatially mixed signals are indicated, *severely* dry climates are projected to intensify in the mid- to far-future periods under both scenarios.

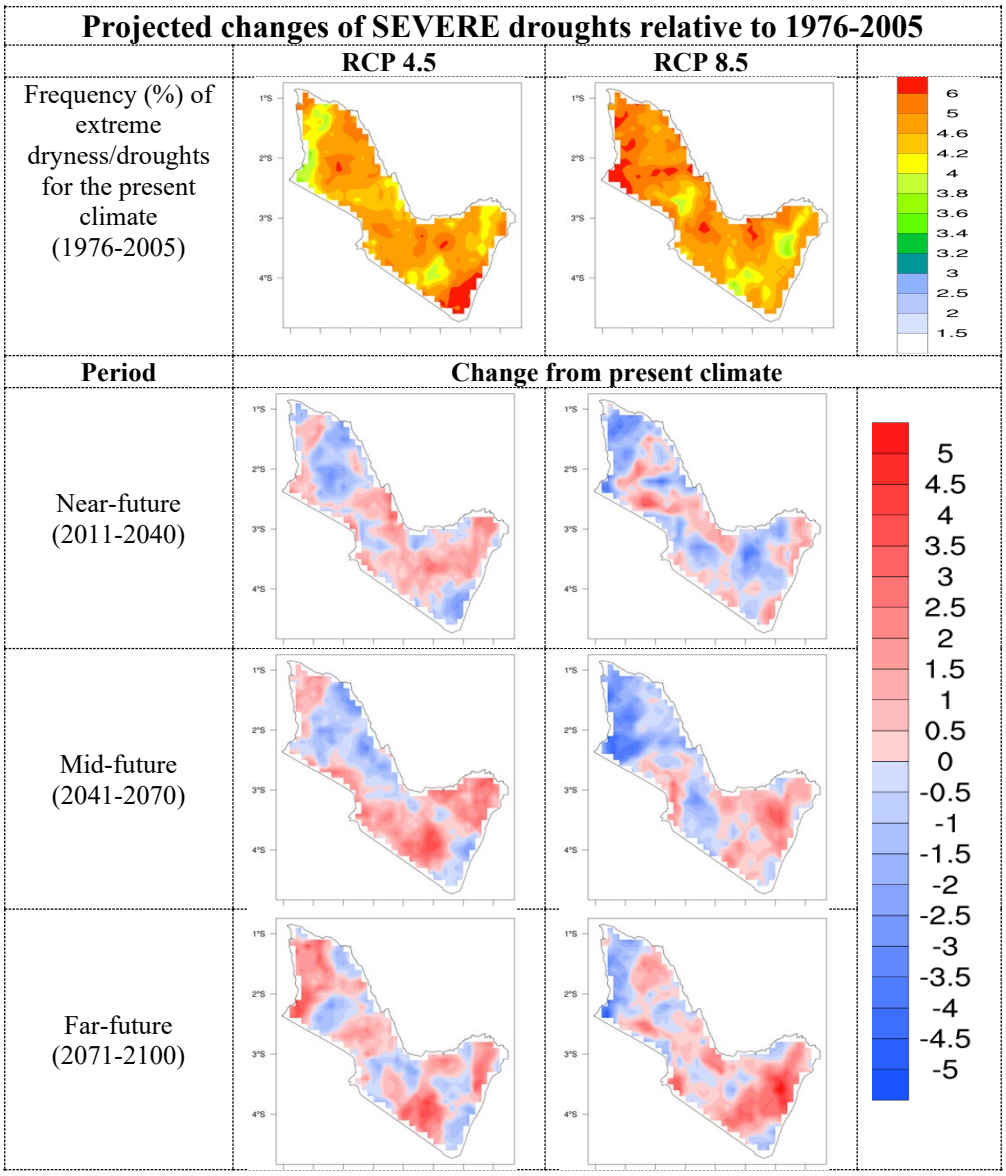

Figure 4: Frequency of ***severe*** droughts for present climate (1975-2005; top) and projected changes in ***severe*** droughts for near (2011-2040; second row), mid (1941-2070; third row) and far (2070-2100; bottom row) future periods relative to the current climate under RCP 4.5 (left) and RCP 8.5 (right) scenarios.

The frequency of ***extreme*** droughts (SPI less than -2.0) for the present-day climate and projected changes for near, mid, and far future climates under the RCP4.5 and RCP8.5 scenarios over the Athi River Basin are shown in **Figure** 5. Although the frequencies of ***extreme*** drought occurrences for the baseline climate are much lower than the corresponding values for *severe* drought events because of the rarity of ***extreme*** events, projected changes in ***extreme*** droughts have spatially more consistent and widespread signals under both RCP 4.5 and RCP 8.5 scenarios. Accordingly, ***extreme*** droughts are projected to increase for the three future periods under both scenarios across much of the Upper Athi River Basin. Compared to the *severe* droughts, the frequency of more ***intense*** droughts is projected to be substantially higher for the ***extreme*** drought indicator in the Upper Athi River Basin. On the other hand, the extent and frequency of ***severe*** droughts are higher than that for **extreme** category in the coastal regions for mid- to far future projected climates under both scenarios.

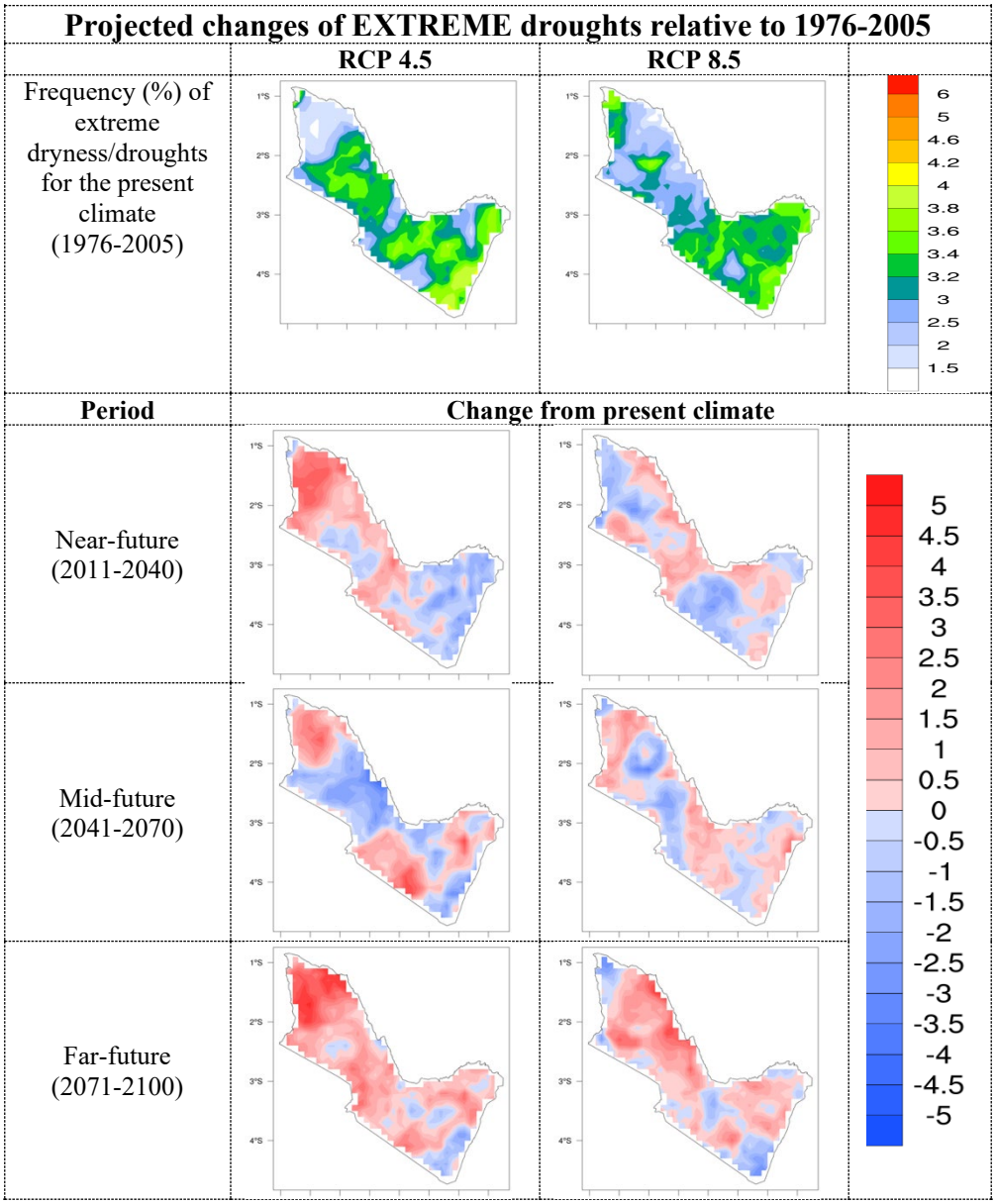

Figure 5: Frequency of ***extreme*** droughts for present climate (1975-2005; top) and projected changes in ***extreme*** droughts for near (2011-2040; second row), mid (1941-2070; third row) and far (2070-2100; bottom row) future periods relative to the current climate baseline under RCP 4.5 (left) and RCP 8.5 (right) scenarios.

References

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