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# An Assessment of the Projected Future Intra-Seasonal Rainfall Characteristics in Uganda

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## Abstract

Rainfall is a key climate parameter that affects most operations that affect human life, especially in the tropics. Therefore, understanding the various factors that affect the distribution and intensity of this rainfall is important for effective planning among the different stakeholders in the weather and climate sectors. This study aimed at understanding how intra seasonal rainfall characteristics, especially Consecutive Dry Days (CDD) and Consecutive Wet Days (CWD), in the two major rainfall seasons will change under two future climate scenarios of RCP4.5 and RCP8.5 in Uganda, covering two future periods of 2021-2050 and 2051-2080. The results indicate a high likelihood of reduced consecutive rainfall days, especially over the Northeastern regions of the country, for both 2021-2050 and 2051-2080. However, the trends in the entire country for the two major rainfall seasons, March to May and September to November, are not significant. Nonetheless, the distribution of these days is important for most agricultural activities during different stages of crop growth. The consecutive dry days show a fairly increasing trend in the eastern part of the country, particularly in the second season of September to November. An increase in consecutive dry days implies more frequent dry spells in the midst of the growing season, potentially affecting some crops during critical growth stages.

## Keywords

Intra-Seasonal, Rainfall, Climate Change, Dry and Wet Spells, Uganda

## 1. Introduction

Weather and climate are important factors influencing agricultural production, which is the main source of food and a major economic activity in most developing countries (Lambert, 2014; IPCC, 2021). Rainfall, one of the weather parameters, is important in several other sectors such as aviation, construction, energy, health, recreation and tourism, among others (Shukla et al., 2014). The Intergovernmental Panel on Climate Change (IPCC, 2021) reported less confidence in the prediction of the changes in extreme events, especially precipitation in the tropics and subtropics, due to lack of sufficient data (Krishnamurthy, 2011). Despite shortcomings in data availability and access, understanding extreme rainfall events is crucial for agricultural planning as well as water management in a warming climate (Alexander et al., 2006).

Studies on precipitation such as Nsubuga et al. (2014), Yang et al. (2014) and Ongoma et al. (2018) have largely focused on mean precipitation. Yet, precipitation extremes, especially wet and dry spells, have more and far-reaching hydrological impacts than floods and droughts, which adversely impact human life and society (Aguilar et al., 2009). It should be noted that the mean climate will not have the most effect on society, but rather the changes in the frequency and intensity of extreme events (Huntingford et al., 2003). These changes will ultimately affect global water availability and may lead to decreased agricultural production, resulting in potentially widespread food shortages (Shiferaw, 2018).

Failure of a given rainy season in East Africa poses a major climatic shock to the nations that rely on rain-fed agriculture (Kuya, 2016). A study by Yang et al. (2014) indicated a reduction in March-May (MAM) seasonal rainfall (termed as the long rains) that led to food insecurity in most parts of the region. Similarly, Nsubuga et al. (2014) concluded that the reduction in the MAM rains greatly affects the seasonal rainfall trends of Southwestern Uganda yet it's one of the major food growing regions of the country.

Studies show that the Greater Horn of Africa (GHA), including Uganda, is one of the most vulnerable regions to current and projected future changes and variability of wet and dry spells (Osima et al., 2018). This is because the economies and livelihoods of people in this region heavily relies on rain-dependent systems and still lacks technology, resources and documented information needed to mitigate the adverse impacts of climate-induced risks, especially wet and dry spells (Shiferaw, 2018). The severity and frequency of rainfall extremes have been observed to have increased in several parts of the world (Liu et al., 2005; Sippel et al., 2017). The changes in frequency, intensity, extremity and duration of dry and wet spells may affect the natural environment, human beings and the entire ecosystem much more than changes in the total precipitation alone (Ye, 2018; Chemura et al., 2020; Haile et al., 2020; Breinl et al., 2020).

Studies conducted over East Africa using ETCCDI (Expert Team on Climate Change Detection and Indices) have shown that the maximum number of wet days has declined insignificantly. This decline is possibly as a result of climate change and variability, which has modified the rainfall regime of East Africa (Ongoma et al., 2018). Therefore, the present study examined the future projections of intra seasonal rainfall characteristics, specifically the metrics of Consecutive Dry Days (CDD) and Consecutive Wet Days (CWD), which play a key role in future agricultural systems and planning.

## 2. Materials and Methods

### 2.1. Study Area

Uganda lies in East Africa, astride the equator with its area lying between latitude 4˚12'N and 1˚29'S and longitude 29˚34'W and 35˚00'E (**Figure 1**). The country occupies 241,551 square kilometers of largely fertile arable land. It is bordered to the East by Kenya, to the North by South Sudan, to the West by the Democratic Republic of Congo, and to the South by Rwanda and Tanzania (**Figure 1**). The country is located on a plateau, averaging about 1100 meters above sea level sloping down to the Sudanese Plain to the north (Ministry of Water and Environment (MWE), 2022). Subsistence farming is the main source of household income for the majority of Ugandans where over 40% of the population is purely in subsistence agriculture (Uganda Bureau of Statistics (UBOS), 2022).

### 2.2. Data and Its Sources

CORDEX data was used where an ensemble of 10 Global Climate Models (GCMs) used in CMIP5 were downscaled using the RCA4 regional climate model. The

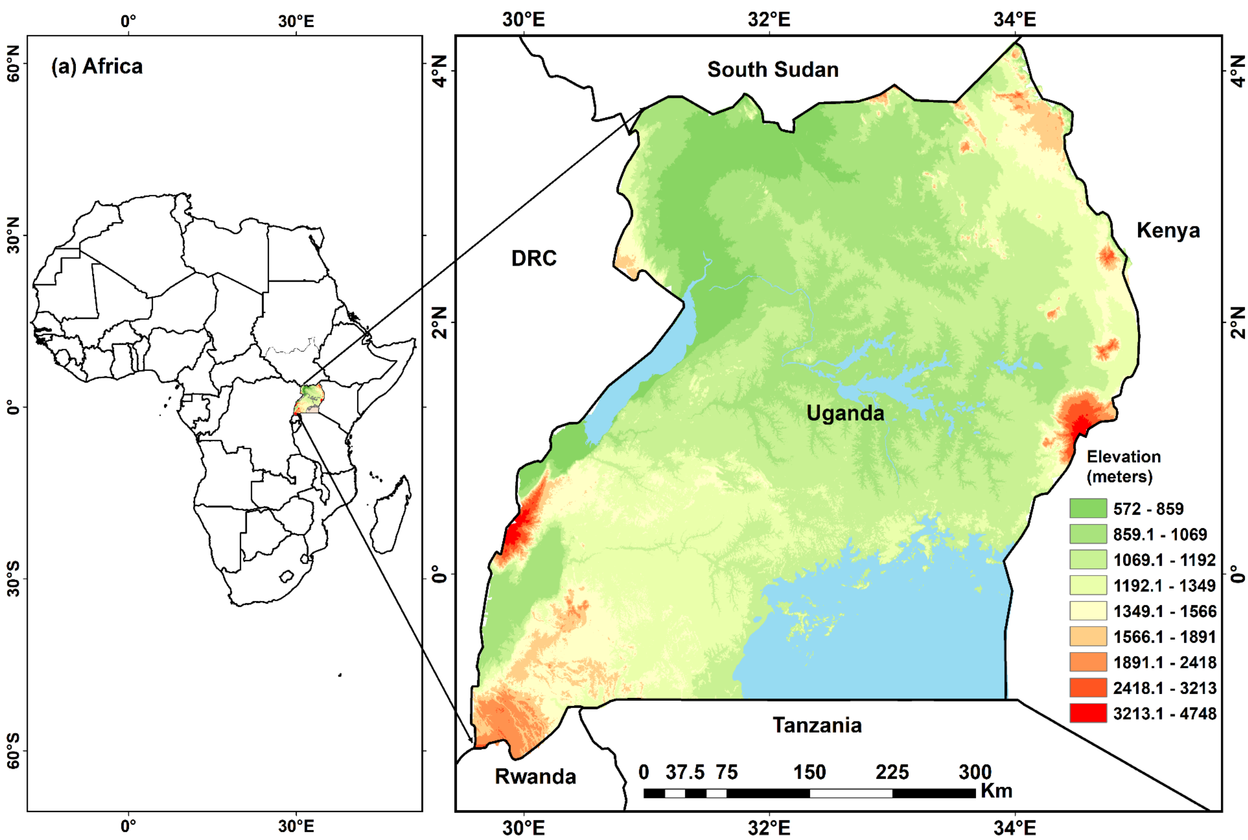


**Figure 1.** Map of the study area.

medium scenario of RCP4.5 and the high emission scenario of RCP8.5 were used for the two climate periods; classified as near future (2021-2050) and far future (2051-2080). The data was downloaded from the CORDEX Africa domain from CMIP6 housed at the University of Cape Town, Climate Systems Analysis Group (CSAG).

### 2.3. Methods of Analysis

In this study a rainy day is defined following a threshold of 1 mm, which is similar to the approach taken by Gudoshava et al. (2020). Consecutive dry days is described as maximum number of consecutive days with daily rainfall less than 1mm and consecutive wet days is maximum number of consecutive days with daily rainfall greater or equal to 1 mm.

The analysis of the CDD and CWD was conducted for two major rainfall seasons of March, April and May (MAM) and September, October and November (SON) , considering two future climate periods: 2021-2050 and 2051-2080, with the base period of 1986-2015. The CDD and CWD indices were computed using RClimDEX software developed by World Meteorological Organisation (WMO) Expert Team on Climate Change Detection and Indices (ETCCDI). Results of an ensemble of 10 GCMs are presented for RCP4.5 and RCP8.5. The time series of the individual GCMs in each climate period are also presented and analyzed in this study.

## 3. Results and Discussion

The results are presented for both CDD and CWD during the two major rainfall seasons of MAM and SON. These results include future projections that have been compared with the baseline period of 1986-2015.

### 3.1. MAM Projections

#### 3.1.1. Spatial Analysis

**Figure 2** shows the historical number of CWD (top panel) and CDD (bottom panel) in relation to the baseline period for the MAM season. Historical CWD range from 24 to 27 days in the north and north eastern parts of Uganda with central and southern parts CWD ranging from 12 to 18 days in the MAM season.

The results of the future projections indicate that, for most of the north and northeastern parts of the country, there are no substantial changes in the expected number of CWD compared to the baseline period of 1986-2015. In contrast, the southern parts show a projected increase of 1 to 2 days in CWD, particularly under RCP 8.5 scenario for the near future. It is important to note that these simulations do not consider the distribution of these wet days The trend of CWD in the far future (2051-2080) is comparatively similar to the near future, with a slight decrease in CWD expected in the northern parts of the country and a slight increase expected in the southern parts (**Figure 3**; top panel).

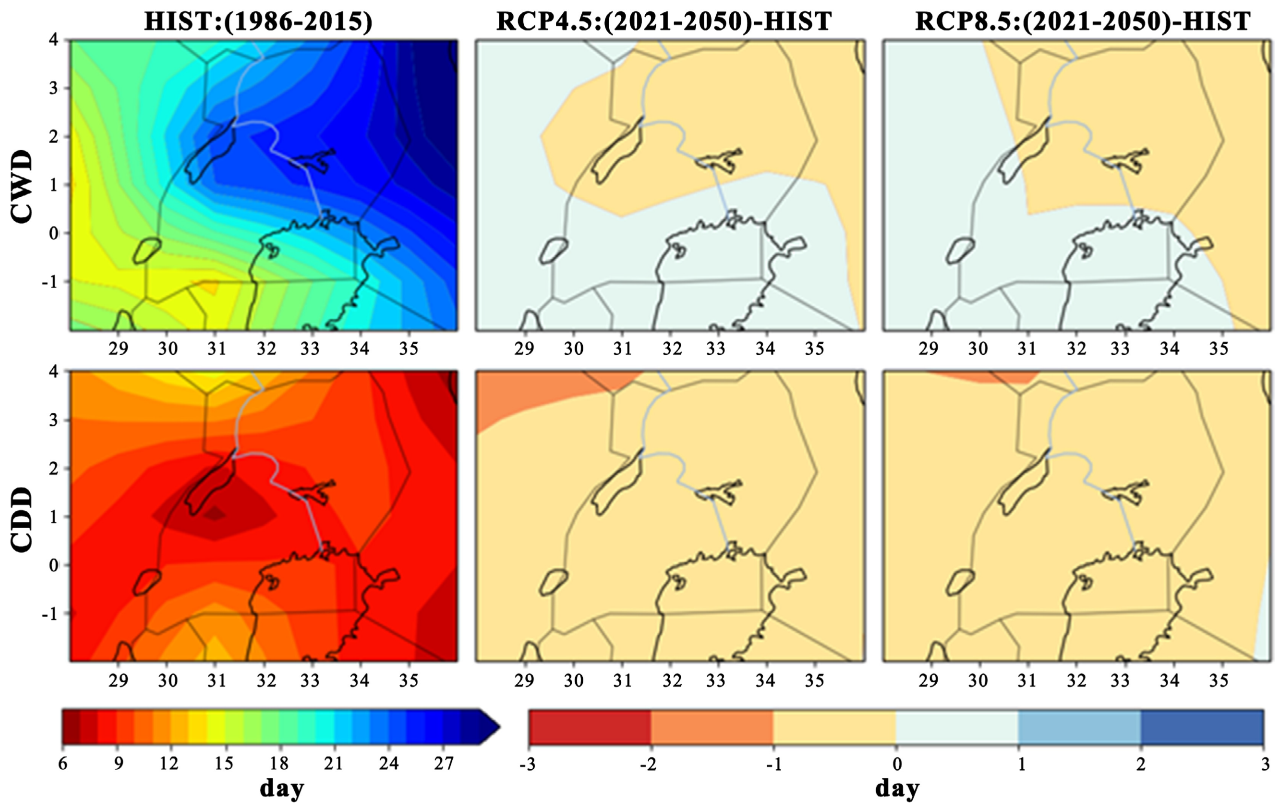


**Figure 2.** Projected MAM CWD and CDD in the near future (2021-2050).

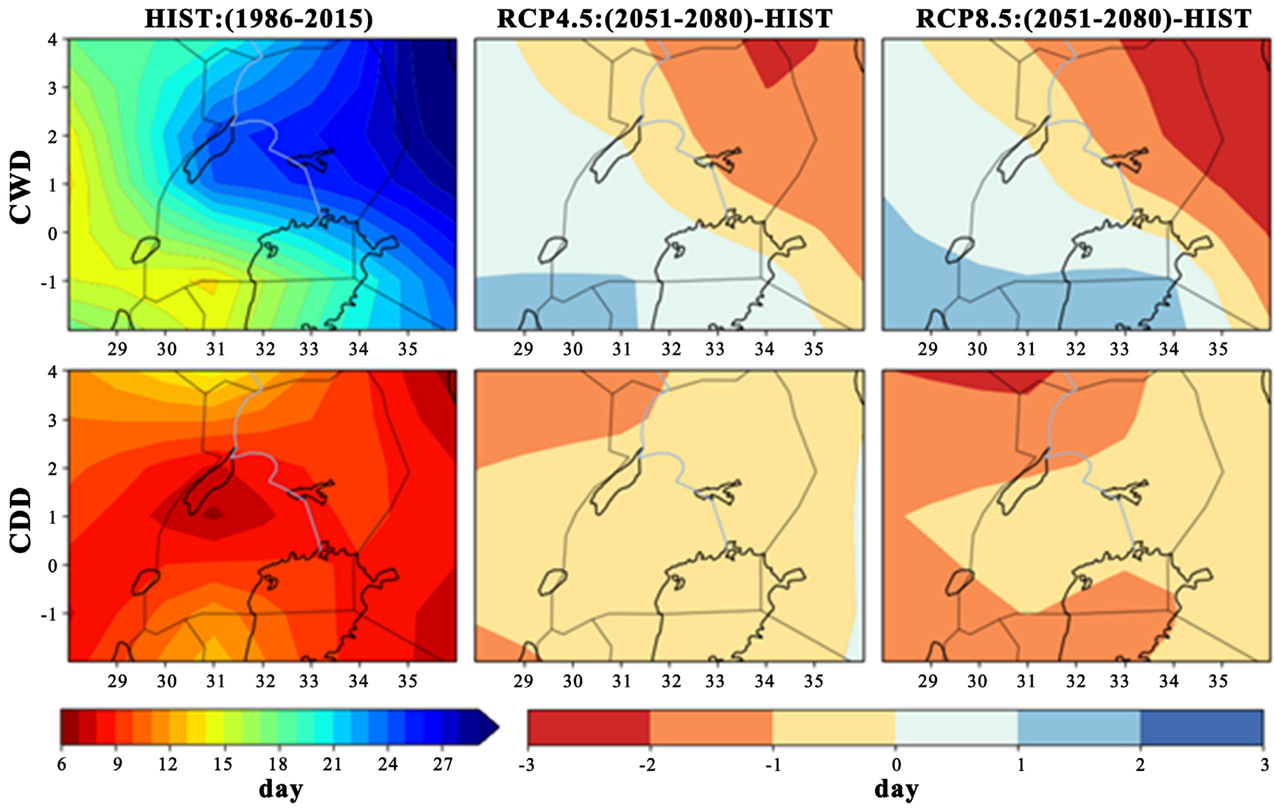


**Figure 3.** Projected MAM season CWD and CDD in the far future (2051-2080).

The historical CDD ranged from 6 days in the central regions to about 15 days in the southern and northern parts of Uganda (Figure 2; bottom). The results further indicate that in the near future, the CDD are not expected to change significantly from the historical values across most parts of the country under both RCP 4.5 and RCP 8.5 scenarios. However, in the far future, particularly under RCP 8.5 scenario, slight decreases of 1 to 2 days in CDD are projected for the southern and northwestern parts of the country during the MAM season (Figure 3; bottom).

### 3.1.2. MAM Time Series Analysis

Analysis was done showing the time series variability in terms of GCM downscaled outputs for both CDD and CWD in the near and far future and the results for RCP4.5 are presented in Figure 4 and Figure 5 for CDD and CWD, respectively.

Considerable variability in MAM CDD is observed across different GCMs with a range of 5 to 15 days for both near and far future under the RCP4.5 scenario. The trend is not different for RCP8.5, although these results are not presented here. Most of the higher values are from EC Earth model, while the lower values are from NorESM1 model.

On average, about 6 days are predicted for the near future while 8 days are projected for the far future. It should be noted that a dry spell exceeding 10 days

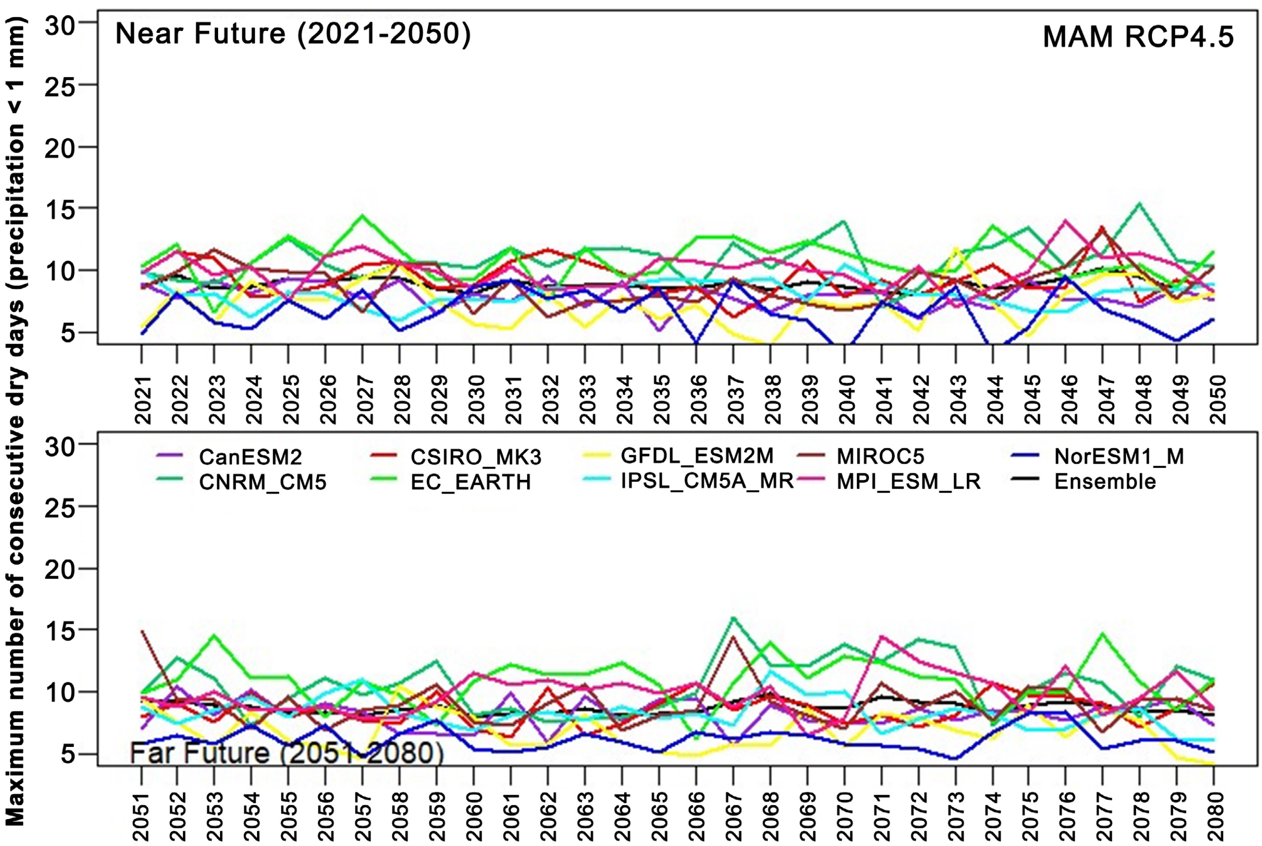


Figure 4. Time series simulations of CDD for individual GCMs during MAM season under RCP4.5.

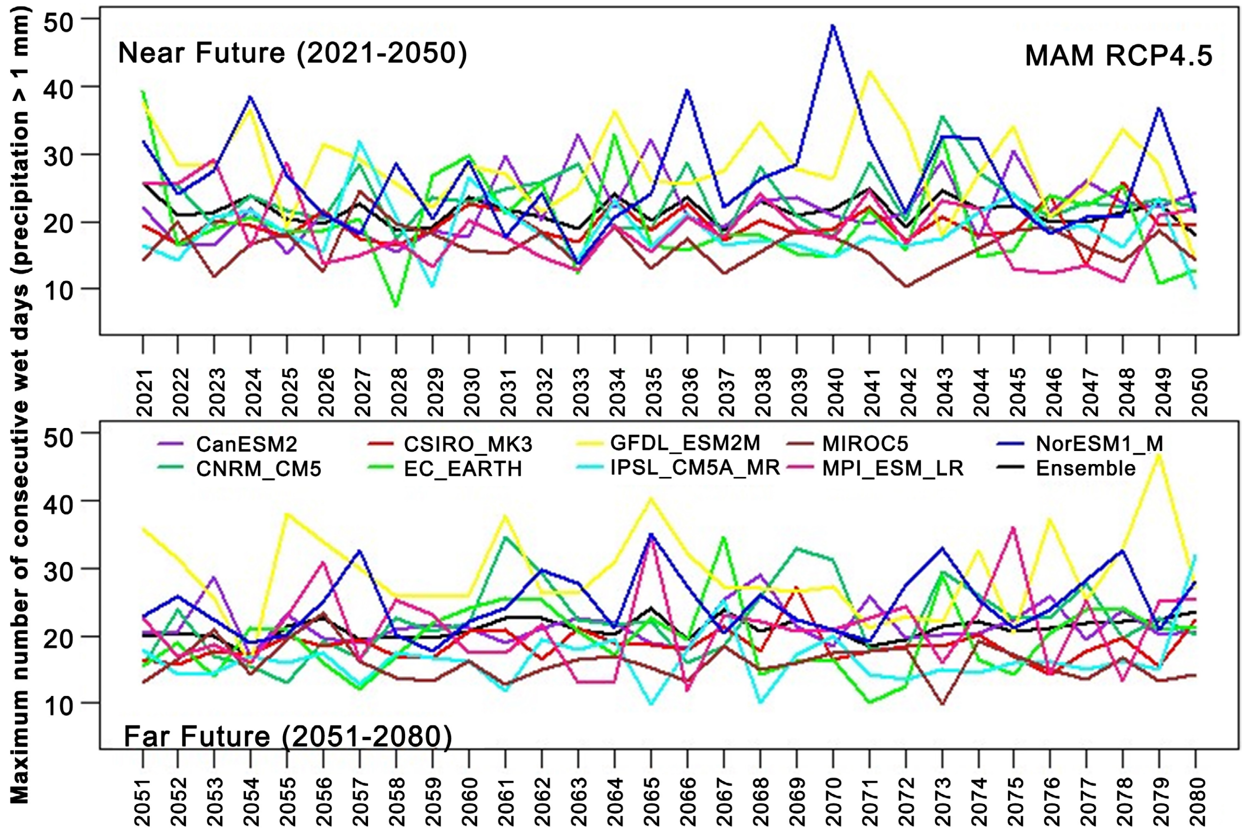


**Figure 5.** Time series simulations of CWD for individual GCMs during MAM season under RCP4.5.

can affect productivity of most crops, especially during their reproductive growth stages (Haile et al., 2020; Breinl et al., 2020). The projected increase in CDD is probably because of global warming and climate change, which is expected to cause dryness over most parts of the East African region (Philippon et al., 2015). This poses a threat to the country because these are major food growing, cattle keeping (south-west) and fishing (Lake Victoria basin) regions of the country.

The CWDs are higher than the CDDs, which is an expected outcome considering that this is a major rainfall season in the study area (Gitau et al., 2013; Omondi et al., 2014; Nicholson, 2017). The CDW range from 10 to 45 days across the GCMs in both near and far future with high values projected by GFDL_ESM2M model, while low values are projected by IPSL_CM5A_MR and EC Earth models.

## 3.2. SON Projections

### 3.2.1. Spatial Analysis

**Figure 6** shows the historical number of consecutive wet days (CWD; top panel) and consecutive dry days (CDD; bottom) in relation to the baseline period during SON season. Historical CWDs range from 12 to 16 days in the southern parts and 18 to 21 days in the central and northern parts of Uganda during the SON season (**Figure 6**; top panel).

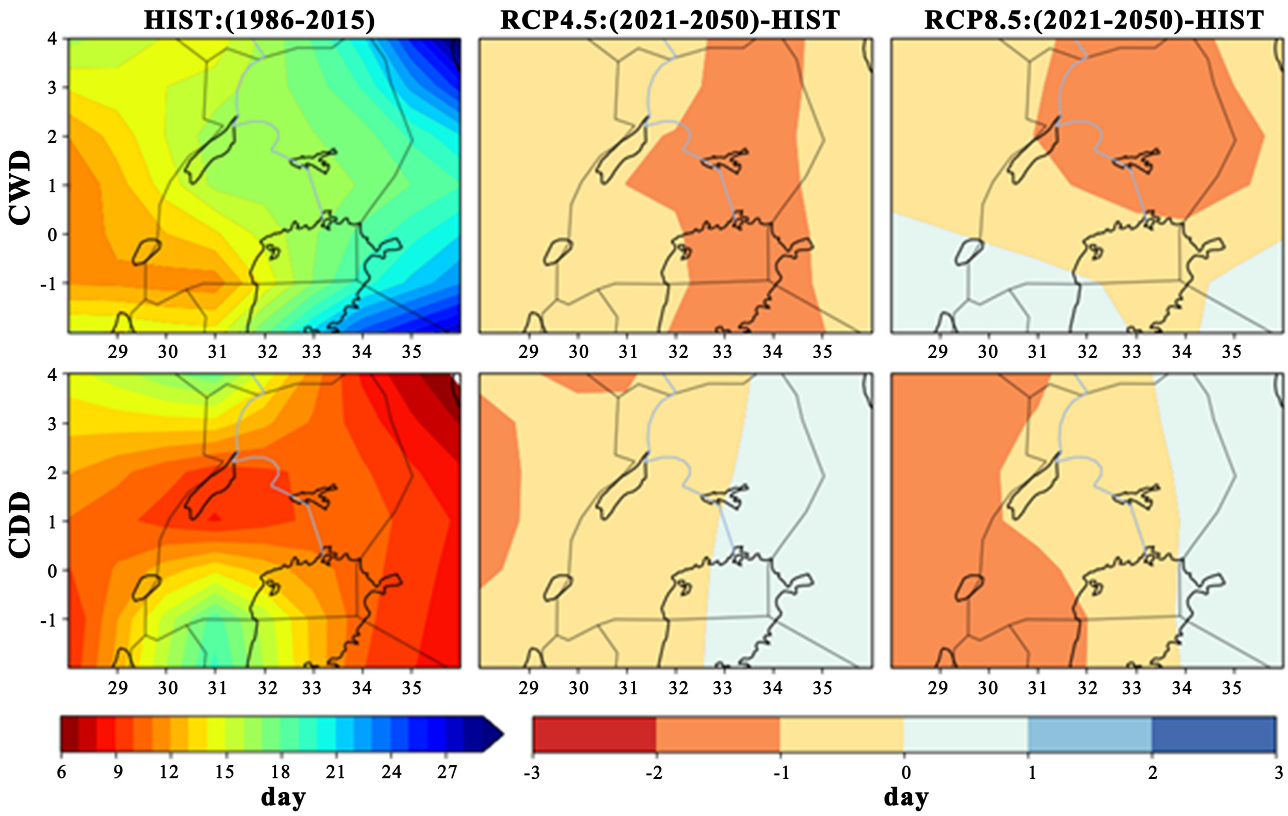


Figure 6. Projected SON season CWD and CDD in the near future (2021-2050).

The results depicted in Figure 6 further show that the future projections in the near future indicated no substantial changes in the expected number of consecutive wet days for most parts of the country apart from the north and north-eastern parts where a decrease of 1 to 3 days compared to be the baseline period of 1986-2015 is projected for both RCP4.5 and RCP 8.5 (Figure 6; top panel).

The trend of CWD during SON in the far future (2051-2080) is not far different from the near future with a slight decrease of 1 to 3 days in CWD expected in the northern parts of the country (Figure 7; top panel).

Historical CDD range from 9 days in the central and northern parts to about 15 days in southern parts of Uganda (Figure 6; bottom panel). In the near future during SON season CDD are not expected to change form the historical values in most parts of the country under both RCP 4.5 and RCP 8.5 apart from the southern parts where a decrease of 1 to 2 days is projected especially for RCP 8.5 (Figure 6; bottom panel). However, in the far future especially under RCP 8.5 most parts of southern and northwestern parts of the country are projected to have a slight decrease in CDD of 1 to 3 days during SON season (Figure 7; bottom panel).

#### 3.2.2. SON Time Series Analysis

Analysis was done to explore the variability in time series using downscaled

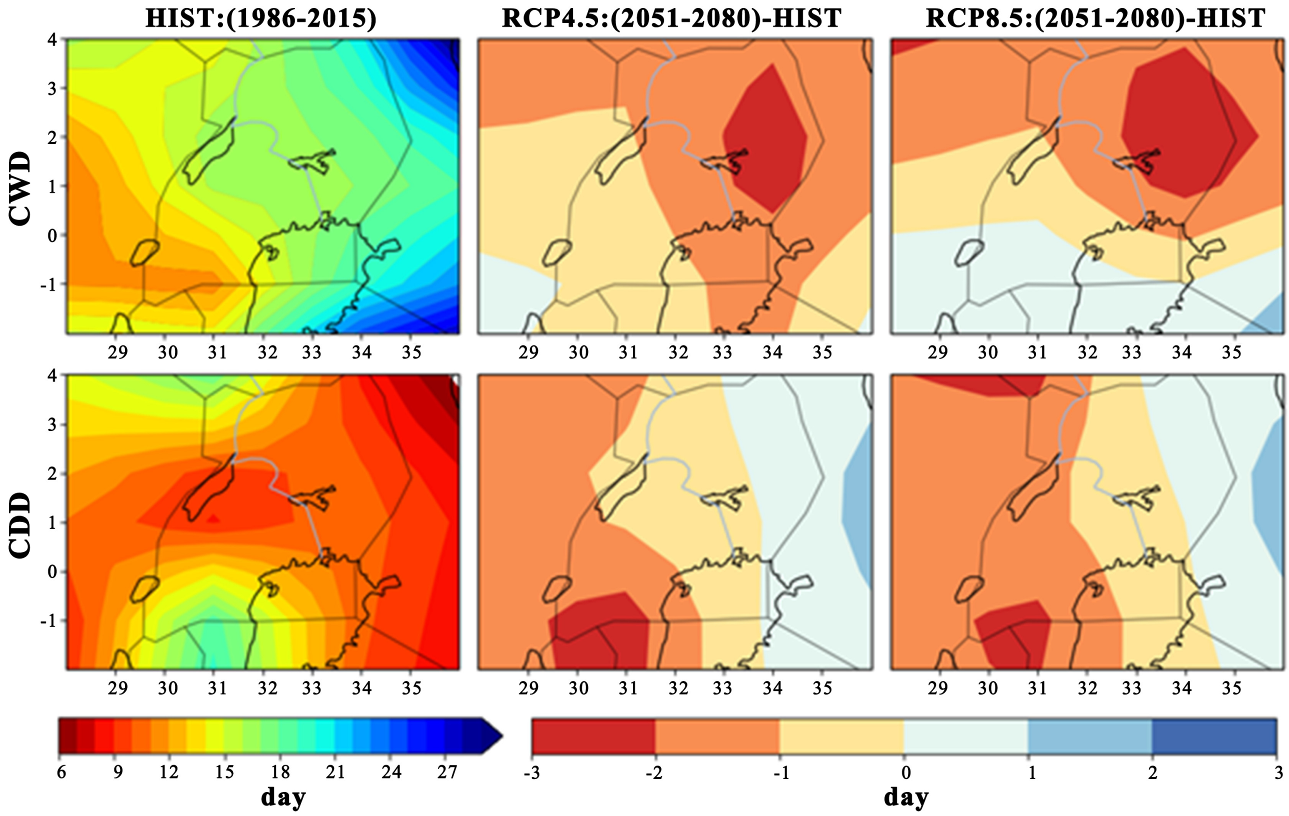


Figure 7. Projected SON rainfall season CWD and CDD in the far future (2051-2080).

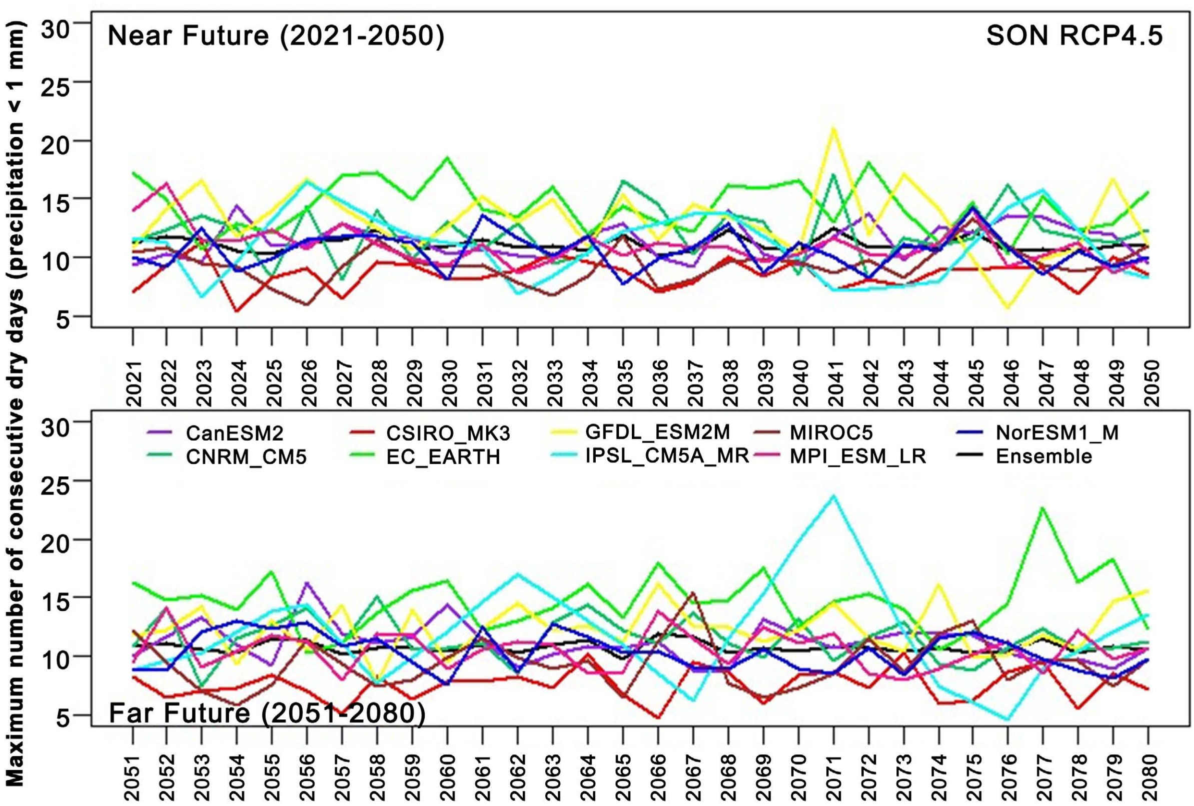


Figure 8. Time series simulations of CDD for individual GCMs during SON season under RCP4.5.

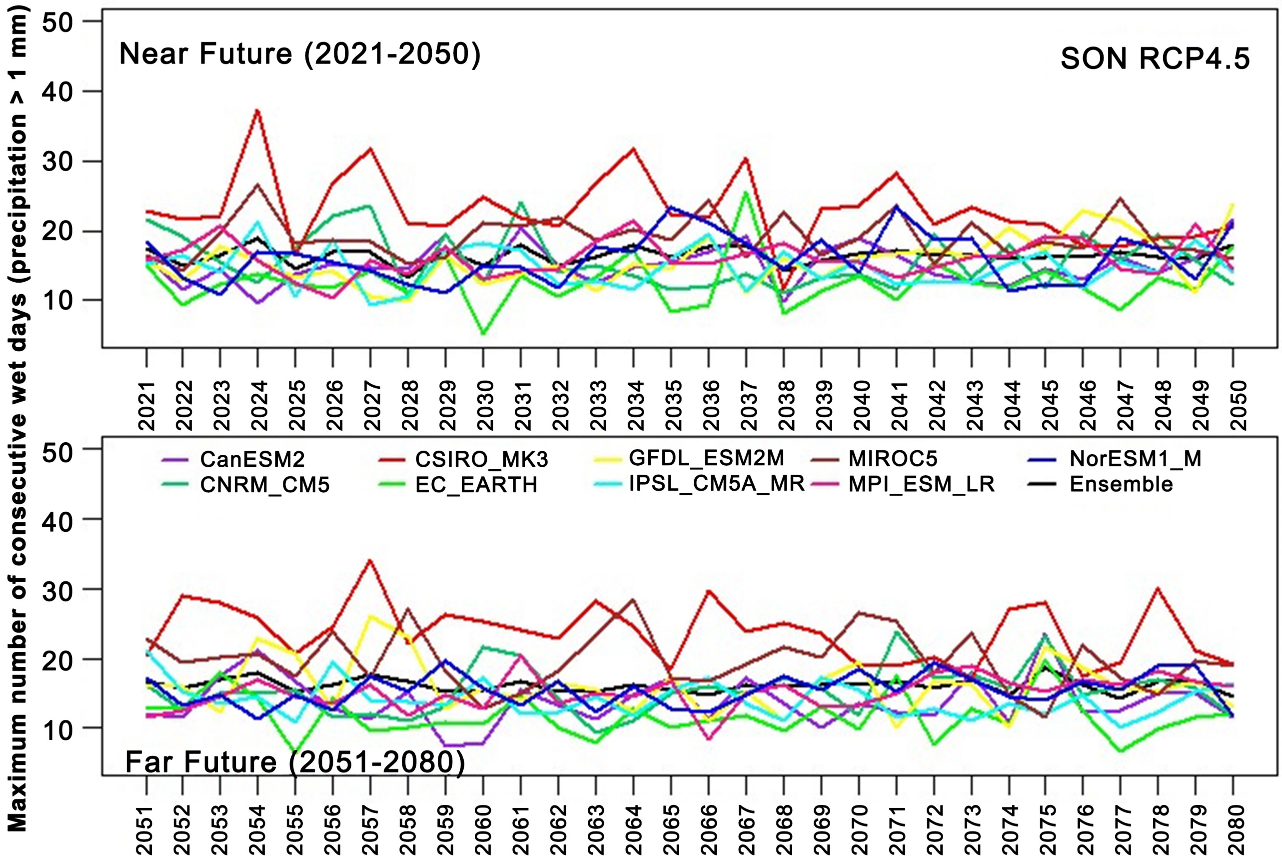


**Figure 9.** Time series simulations of CWD for individual GCMs during SON season under RCP4.5.

outputs from GCM for both CDD and CDW in the near and far future and the results for RCP4.5 are presented in Figure 8 and Figure 9 for CDD and CWD, respectively.

There is high variability in SON CDDs across the different GCMs with a range of 5 to 20 days in both the near and far future under RCP4.5 which is slightly higher than the projected CDDs for MAM season. The trend is not different for RCP8.5 which is not presented here. Most of the high values are from EC EARTH model with low values coming from CSIRO_MK3 model. On average about 12 days are predicted for the near future, while 14 days are projected for the far future.

The CWDs for SON are higher compared to the CDDs since SON is also a major rainfall season like MAM in the study area (Nicholson, 2017). CDWs for SON also range from 10 to 45 days across the GCMs in both near and far future with high values projected by CSIRO_MK3 model while low values are projected by EC EARTH model.

## 4. Conclusion and Areas for Further Research

The inter-seasonal rainfall characteristics, in addition to onset and cessation, are key parameters that determine crop productivity. The present study revealed that there would be no major changes in the consecutive dry and wet days in the two major seasons of MAM and SON for both near future and far future climate periods under both RCP4.5 and RCP8.5 scenarios.

However, it is important to note that this study did not consider the distribution of these wet days or dry days within the rainfall season, yet it is important for the different stages of crop growth. As a result, the study recommends further research to understand the actual distribution patterns of the dry days within the rainfall season.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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