Monitoring the status of the extreme rainfall events in Ghana

Robert Johnson[1], Winifred Ayinpogbilla Atiah[1], Francis K. Muthoni[2], Leonard K. Amekudzi1, Fred Kizito[2,3]

Author affiliation [1]Kwame Nkrumah University of Science and Technology, [2]International Institute of Tropical Agriculture, and [3]The Alliance of Bioversity and CIAT

Published by International Institute of Tropical Agriculture

December, 2022

The Sustainable Intensification of Mixed Farming Systems Initiative aims to provide equitable, transformative pathways for improved livelihoods of actors in mixed farming systems through sustainable intensification within target agroecologies and socio-economic settings.

Through action research and development partnerships, the Initiative will improve smallholder farmers' resilience to weather-induced shocks, provide a more stable income and significant benefits in welfare, and enhance social justice and inclusion for 13 million people by 2030.

Activities will be implemented in six focus countries globally representing diverse mixed farming systems as follows: Ghana (cereal–root crop mixed), Ethiopia (highland mixed), Malawi: (maize mixed), Bangladesh (rice mixed), Nepal (highland mixed), and Lao People's Democratic Republic (upland intensive mixed/ highland extensive mixed).

Cover photo credit: Bob McCaffrey.

Contents

Summary

Agriculture in Ghana is predominantly rainfed. The rainfall regime is experiencing significant spatial and temporal changes. These has altered the frequency and magnitude of extreme weather events that cause droughts of floods. This study applied a bias-corrected daily CHIRPS-v2 product to estimate selected annual extreme rainfall indices from the joint CCl/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI). The frequency-based extreme rainfall indices examined includes the number of consecutive dry and wet days (CDD and CWD), and the number of heavy (R10mm) and very heavy precipitating days (R20mm). The intensity-based rainfall extreme includes the total rainfall amount (PRCPTOT), the simple daily intensity index (SDII), very (R95p), and extremely (R99p) wet days, daily (RX1day) and 5-day (RX1day) maximum rainfall. The spatial-temporal variations of the extreme rainfall indices were mapped to guide decision makers on occurrence of drought and flood events in northern Ghana.

Background information

Climate change prevalent with highest impact in developing countries where they are confounded by prevalent high poverty, population explosion and limited coping mechanisms. Previous monitoring studies focus on the changes in the rainfall amount, but the temporal changes are equally important. The extreme rainfall events are linked to drought and flood that can cause drastic losses in the agricultural production. In northern Ghana farmers are highly vulnerable to climate change due to double exposure to droughts and heavy precipitation events that cause flooding. Severe crop losses are reported in northern Ghana due to co-occurrence of droughts and floods in the about 70% of the seasons (Yiran and Stringer, 2016). Severe flood events are becoming more frequent in northern Ghana and were reported in 2007, 2010, 2012, 2017, 2018, and 2019 growing seasons (Atanga and Tankpa, 2021). Flooding inundates farms, destroy physical infrastructure, and disrupt socio-economic activities. The droughts can cause near total crop loss. Monitoring the magnitude, frequency and trends of the rainfall extreme events is an essential step for designing sustainable climate change mitigation measures. The joint CCI/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI) defined standard indices for monitoring climate extremes across the globe. These extreme indices support formulation of adaptation and mitigation measures.

Material and methods

Study Area

The study focused on northern Ghana in area covering the Guinea and Sudan Savanna agro-ecological zones (Figure 1). Northern Ghana which comprises the three northernmost administrative regions of Ghana, namely: the Upper West Region, Upper East Region and Northern Region. The region experiences a unimodal rainfall pattern with rainfall being modest in most parts of the area which allows for cultivation of cereal crops and legumes [11]. About 75% of the population in this zone is engaged in economic activity, with agriculture and other agro-based sectors remaining the mainstay of the local population [12]. The population density within the entire area compared to the geographical size is low which could be partly attributed to emigration, in addition to geography and the severe nature of the climate. Climate is characterized by a tropical monsoonal climate system with two dominant seasons (wet and dry). Rainfall is largely controlled by the West African Monsoon (WAM) and convective activities due to the movements of the Inter-tropical Discontinuity (ITD). The ITD oscillates from South to North and retreats to the South annually. Agriculture is the main economic activities though the crop-livestock mix varies over space and time.

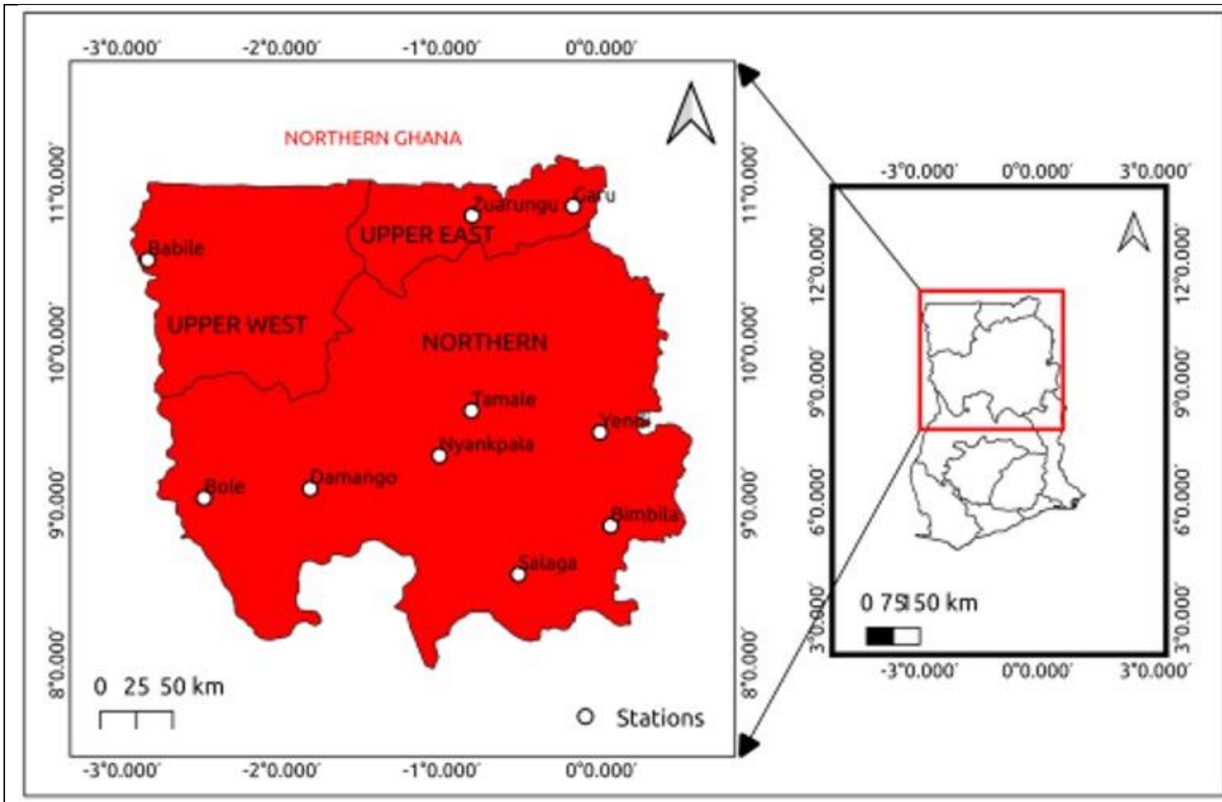

Figure 1. Map of the study area with agroecological zones and the location of gauge stations that were used for bias correction of the satellite rainfall product.

Climate data and analysis

Gridded daily time series rainfall data for 35 years (1981 - 2015) with spatial resolutions 0.05°×0.05° was obtained from the Climate Hazards Group Infrared Precipitation with Stations version two (CHIRPS-v2; Funk et al., 2015). The CHIRPS-v2 data was bias corrected using the gauge data using the bias correction and spatial disaggregation (BCSD) method. Ten extreme rainfall indices were selected from the joint CCI/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI) and calculated for each year (Table 1). The frequency-based extreme rainfall indices examined includes the number of consecutive dry and wet days (CDD and CWD), and the number of heavy (R10mm) and very heavy precipitating days (R20mm). The intensity-based rainfall extreme indices include the total rainfall amount for precipitating days (PRCPTOT), the simple daily intensity index (SDII), very (R95p), and extremely (R99p) wet days, daily (RX1day) and 5-day (RX1day) maximum rainfall. The SDII was calculated as the ratio of total rainfall to the number of days when precipitation is higher than a dry day threshold. The annual indices were averaged to reflect the status of the index in each pixel.

Table 1. Selected extreme rainfall indices computed over the study area.

Indices	Identity	Formular	Expression	Units
CDD	Consecutive Dry Days	$RR_{ij} < 1mm$	Max num of continuous days with RR < 1 mm	Days
CWD	Consecutive Wet Days	$RR_{ij} > 1mm$	Max num of continuous days with RR > 1 mm	Days
R10mm	Num of heavy rainfall days	$RR_{ij} > 10mm$	Yearly Count of Days when Days rr ≥ 10mm	Days
R20mm	Num of heavy rainfall days	$RR_{ij} > 20mm$	Yearly Count of Days when Days rr ≥ 20mm	Days
PRCPTOT	Yearly Wet Day Rainfall total	$\sum_{i=1}^{n} RR_{ij}$	Yearly total rainfall in wet day(rr > 1 mm)	mm
R95p	Very Wet Days	$R95p_j = \sum_{i=1}^{n} RR_{ij}$	Yearly Total Rainfall when rr > 95 percentile	mm
R99p	Extremely Wet Days	$R95p_j = \sum_{i=1}^{n} RR_{ij}$	Yearly Total Rainfall when RR > 99 percentile	mm
SDII	Simple Daily Intensity Index	$SDII_i = \frac{\sum_{i=1}^{N} RR_{ij}}{N}$	Yearly Mean Rainfall (RR ≥ 1 mm)	mm/days
RX1day	Daily Max Rainfall	$Rx1day = RR_{ij}$	Yearly max 1-day rainfall	mm/day
RX5day	5-Day Max Rainfall	$Rx1day = RR_{ij}$	Yearly max 5-day rainfall	mm/day

Results and discussions

The mean total annual wet day rainfall (PRCPTOT) ranged from 700 - 1400mm (Figure 2). The maximum PRCPTOT was over 1400 mm at the extreme north-western and south-eastern of study area (Figure 2). The extreme wet days (R99p) and the very wet days (R95p) ranged from 11 – 16 and 10 – 25 days, respectively (Figure 2). The Upper East region recorded the lowest very and extreme wet days (10 -11). The SDII ranged between 7 – 14 mm/day with largest area averaging 9.5 mm/day. The northern tip of the study area had the highest SDII (12 – 14 mm/day). The daily maximum rainfall (RX1DAY) for the largest area was below 60 mm/day, and showed similar trend as the RX5DAY, though the values of the latter was almost double (Figure 2).

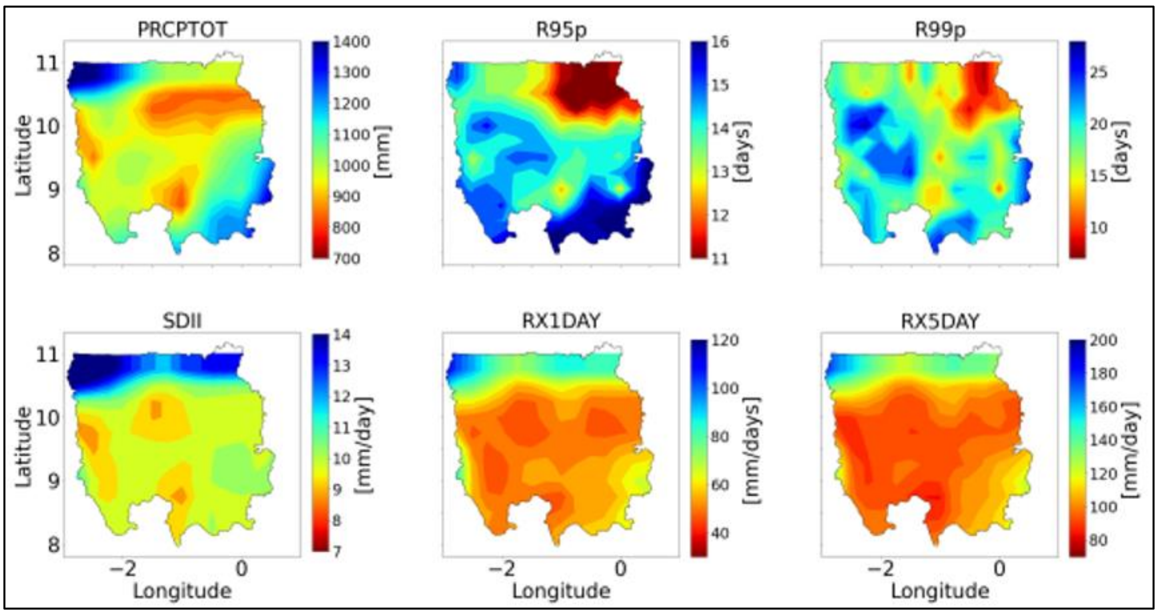

Figure 2. Extreme rainfall intensity indices averaged between 1981 to 2015 over Ghana. The codes for the extreme rainfall indices are presented on Table 1.

The consecutive dry days (CDD) ranged from 60 – 120 and increased in a South-North direction. Longer CDD leads to prolonged dry spells that shortens the length of the growing period (Figure 3). The CWD ranged from 5– 40 days but did not show an apparent spatial gradient. The heavy rainfall events (R10mm) are predominant in the region but the largest area experience less than 17 days of extreme heavy rainfall (Figure 3).

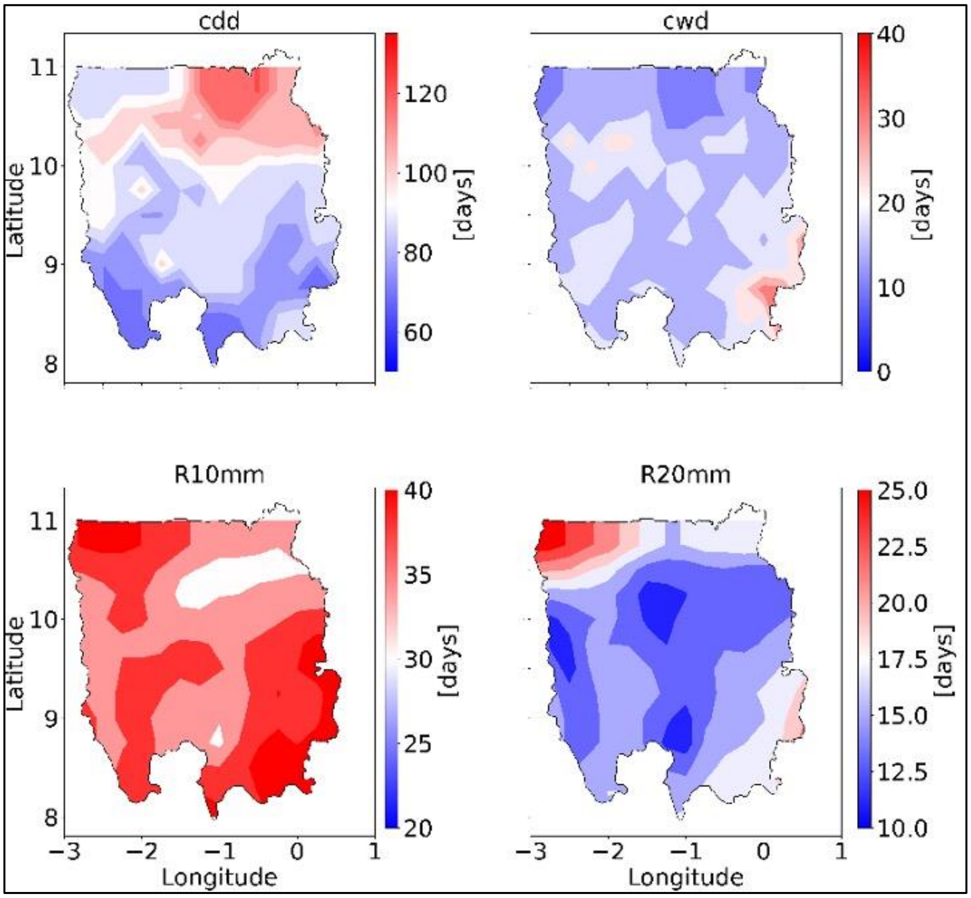

Figure 3. Frequency-based extreme rainfall indices in Ghana. The codes for the extreme rainfall indices are presented on Table 1.

Figure 4 shows the correlation between different extreme rainfall indices to total precipitation (PRCPTOT). The extreme (R20mm) and very heavy (R10mm) rainfall events contributes 94% and 97% of the PRCPTOT, respectively. This signifies that the total annual rainfall is dominated by high intensity downpours that may leads to increased run-offs and floods.

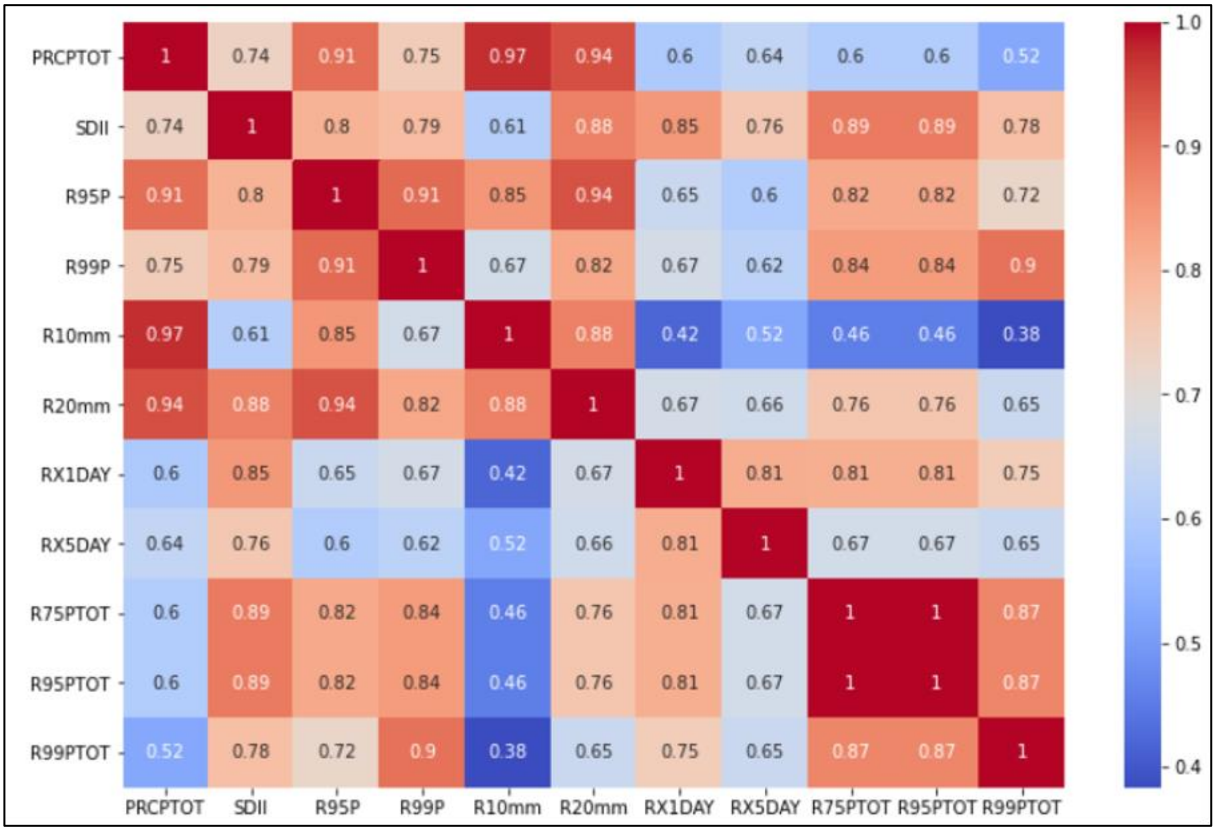

Figure 4. Heat-map showing the contribution of various rainfall extreme indices to total precipitation.

Conclusions

This report presents the spatial-temporal status of the extreme rainfall indices in northern Ghana. Results highlights the sensitivity of the Savannah zone in northern Ghana that experience lower the total rainfall (PRCPTOT) with over 100 consecutive dry days and less than 15 consecutive wet days. The total annual rainfall in northern Ghana is dominated by high intensity downpours that may accentuate the run-offs and flood events. The results further emphasize the need for scaling out the climate smart agricultural technology in Savanna zone in northern Ghana especially those can enhance water harvesting to cope with longer dry spells of over 100 days.

References

1. Atanga, R.A. and Tankpa, V., 2021. Climate Change, Flood Disaster Risk and Food Security Nexus in Northern Ghana. Frontiers in Sustainable Food Systems, 5(273).
2. Funk, C. et al., 2015. The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. Scientific Data, 2(1): 150066.
3. Yiran, G.A.B. and Stringer, L.C., 2016. Spatio-temporal analyses of impacts of multiple climatic hazards in a savannah ecosystem of Ghana. Climate Risk Management, 14: 11-26.

CGIAR INITIATIVE ON Mixed Farming Systems

https://www.cgiar.org/initiative/19-sustainable-intensification-of-mixed-farming-systems/