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Title: Assessment of Drought Dynamics in Purulia Districts, West Bengal for Appropriate Adaptation to Climate Change Impacts

The frequent occurrence of drought due to global warming has become one of the significant global issues. The developing short-term drought events accompanied by rising temperature, high evapotranspiration (ET), and low soil moisture occurred frequently around the world. In India warming has shown an increasing trend of frequent drought occurrences which mostly across the rice belt of northern and eastern India significantly impacted India's rice production. In West Bengal, the Purulia district experiences drought frequently due to monsoon irregularities. Rainfall is the major water resource used for agriculture in the red and laterite zone (RLZ). As a result, this district, with a large tribal population remains as the most underdeveloped and socially vulnerable regions in West Bengal. Despite having average rainfall around 1200 mm annually, incidences of crop failure in Purulia have been frequent during the recent decades. Therefore, a comprehensive geospatial analysis of the different drought incidences, it's characteristics including frequency, intensity, duration, it's spatial-temporal extent and influences on agricultural production in Purulia remained a prime concern of the present research. Attempts have been made to suggest appropriate drought risk reduction strategies through suitable water resources management which have been validated through a pilot action- research in few villages with the help of an established nongovernmental organisation.

The rainfall-based Standardized Precipitation Index (SPI) and evaporation-based Standardized Precipitation Evapotranspiration Index (SPEI) were computed over 1, 3 and 12-month time scales to explore variation in drought frequency, intensity, and duration in the RLZ over the last 120 years. Results indicated a minor change in the long-term droughts (12-months) condition while a major change is observed in short-term (1, 3-months) droughts characteristics. In the year 1998, 2002, 2005 and 2015, severe wet-drought could be detected during monsoon months but annually the rainfall did not depart much from the long-term annual mean. On the other hand in the years 1993, 1996, 2004, 2007, 2011 and 2012, annual rainfall was greater than normal yet drought condition prevailed for the pre and post-monsoon periods. The analysis brought out that the onset and monthly deficit of monsoon rainfall were the prime drivers of droughts in Purulia. Long-duration droughts of 8 to 10 months prevalent during 1930-1960, were found to be less frequent in the recent years. But after the 1990s, the area experienced more frequent short-term (of 4-5 month duration) droughts. The most extreme to severe (50%) droughts prevailed during the sowing months in monsoon seasons which could be attributed to rainfall variability and rising temperature due to climate change at a regional scale over the sub-humid RLZ.

In the present study, MODIS derived indices like NDVI anomaly, VCI, TCI, TVDI and Z_{PET} have been used for monthly drought assessment in monsoon seasons. Inconsistent temporal trends in drought variability were observed during the wet monsoon months in Purulia. Drought intensity was found to be variable, either peaking in June (2010) or in August (2015). Ground-level drought conditions during the monsoon months of June to September in 2015 could be further validated by SAR backscatter of multi-temporal data of 2015 to 2020. In 2015, higher backscatter values increased in June but decreased significantly in July and August due to rainfall deficit. The above mentioned temporal patterns of drought during each month were similar to the patterns obtained from agricultural drought assessment using MODIS-derived drought indices, indicating that SAR technique monitored monthly droughts efficiently in sub-humid RLZ well, particularly during the monsoon seasons when multispectral satellite data are rare or unavailable.

Hydrological droughts were accessed from the ground water level data of 1256 wells of the Purulia. A good concurrence was observed among meteorological, agricultural, and hydrological drought indices. These three types of droughts in the sub-humid RLZ were of short duration though more frequent in the recent years. Extreme droughts mostly occurred in monsoon months. The Mann-Kendall (MK) trend test and Sen's slope estimator revealed that Purulia experienced a significant dry trend ($p < 0.05$) in the monsoon season, which indicated probability similar trend in future.

Areas more prone to extreme droughts with crop failure could be identified through spatial analysis. The droughts were found to be more frequent and severe in the western part of the district compared to eastern. The majority of the blocks have undergone drought incidences for once in 3 years during monsoon season. The prolonged (5 monsoon month) extreme drought in 2010 substantially (43%) affected Aman and other kharif crops productions. The short-term monsoon drought in 2015, 2005 and 2000 also extensively (20%) affected Aman and other kharif crops productions. Decadal declines of main agricultural working population were observed in the southern and eastern blocks.

Assessment the gap between irrigation water requirement and availability undertaken by the present study is significant for optimizing sustainable water resource management in the area. The total crop water requirement for different crops and availability from different water sources indicated significant deficiency of irrigation in dry even in normal years, often resulting in crop failure. The vulnerability and risk assessment through the IPCC AR 4 and 5 frameworks have been attempted. While the 'exposure' has been found to be higher in western blocks compared to eastern blocks, high 'sensitivity' and low adaptive capacity have made the eastern blocks more vulnerable to droughts. The Eastern blocks (Kashipur, Hura, and Purulia-I) were classified under high risk. Irrigation deficit, poor socio-economic condition of marginal farmers and limited livelihood options contribute to the high drought risk for these areas.

The research could suggest few adaptation strategies for drought risk reduction in the RLZ. These include: (a) suitable agricultural land use for sustainable agricultural (b) assessment of potential groundwater zones making micro-irrigation systems more efficient; (c) identification of optimum sites for rainwater harvesting structures for expanding the irrigation systems; (d) rural land use management including reforestation, e) using the traditional drip irrigation techniques in nutrition garden and use of less water-intensive crops. The strategies could be validated using a case study in few villages of Kashipur block with the help of a reputed NGO. It is observed from the analysis that these adaptations have helped the farmers in increasing their agricultural cropping intensity through supplementary micro-irrigation during short dry-spells and has a potential to reduce drought risk.

Considering the all results of the present study, it is concluded that inspite of adequate amount of annual rainfall, rising temperature and uncertain monsoon rainfall have resulted in frequent occurrence of short-term droughts in the sub humid RLZ with poor water retention capacity of soils. Both drought frequency and intensity have been found to increase, particularly in the wet months leading to frequent crop failures. The research argues for the need of meeting the irrigation water deficiency through micro-irrigation and appropriate cropping practices blending traditional methods and application of modern geoinformatic techniques for land and water use management for effective drought risk reduction

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Signature of the Supervisor

Dr. Sugata Hazra
Professor
School of Oceanographic Studies
Jadavpur University, Kolkata-32

Saleita Roy
22.02.2022

Signature of the Candidate