



Carving Drought Impact Over Purulia District, West Bengal, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Purulia was the westernmost district of West Bengal (from 1956) and is drought-prone due to deficient rainfall, its undulating topography with rugged hilly terrains and its positioning near the Tropic of Cancer, the spatial evaluation of vulnerable and risk-prone places.

The various impacts of drought, such as meteorological, hydrological, and agricultural, are assessed by considering the meteorological parameters, vulnerability, and risk levels. The fundamental factors impacting susceptibility and risk are recognised, and the drought years are analysed. The methodologies applied GIS technology, EREDAS, and secondary data were collected to analyse the type of drought. The intensities and types of droughts: a spatial analysis and relative vulnerability assessment of the Kashipur/ Purulia block by Remote Sensing and GIS. Analysis of pre- and post-monsoon meteorological and Agricultural drought.

Agriculture is a climate-sensitive activity. The mechanism is to know the farmers, what crops to grow, when suitable, the climatic parameters, temperature, rainfall concentration, and seasonal hazards. A well-planned agriculture practice has been proposed, and an adequately calculated water budget, catchment treatment plan, and implementation of a perfect crop plan, seeds, manures, and pesticides are the weapons of the drought-hit Purulia/Kashipur farmers.

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1. INTRODUCTION

The pre-independence Manbhum district of Bihar-Bengal-Orissa Provinces, named Purulia district, was declared on November 1st 1956, on the division of old Manbhum estate housed in West Bengal and Bihar. Manbhum Dist. They were bifurcated as Purulia District, whose boundary was shared with Bankura District (dist.) of West Bengal (W.B.). The boundaries were Burdwan Dist. on the N.E. (Northeast) and Midnapore Dist. The southeast was shared with Bokaro, Dhanbad, Hazaribagh, and Ranchi Dist. of Jharkhand along the East and west. The Kashipur block in Purulia dist. It is semi-arid, drought-prone, and housed on the eastern slope of the Ayodhya Hills range (<https://purulia.gov.in/history/>). Purulia District (Dist.), (22°42'35" and 23°42'0" N lat.; and 85°49'25" and 86°54'37" E Long.) is composed of 79.37 sq. km (1.27%, Urban) and 6179.6 sq. km (98.73 %, Rural). Kashipur is a block in the Northeast of an area of 451.31 sq. km, Table 1 [1].

The rivers that flow in the district are the Damodar, Kangsabati, Dwarakeswar, and Kumari. Large/small dams were built over rivers Kangsabati, Burda, Tilaitar Panchet, Maithon Gopalpur, Pardi, and Murguma. These dams mostly douse the northern fringe, but most hilly terrain is rainfed, with runoff directly to drains lacking to cater to the irrigation perspective. Few check dams have been built to augment the summer needs for drinking water, bovine/ forestry requirements, irrigation and industrial needs (Fig. 1 a and b).

The semi-arid hilly and plateau region is highly drought-prone and is housed in the Chhota Nagpur Plateau within the transition zone of the Indian-Eurasian-Himalayan Plate. The clayey loam soil of the Purulia district is acidic (pH range 5.5 and 7.2 and Nitrogen 0.04%) and water-scarce, situated within the agroclimatic region

of the Eastern Plateau, hills and subregion Chhota Nagpur South and West Bengal Plateau [2].

1.1 The Study Area

Kashipur is an administrative block in the Purulia district. Moreover, it is housed in the eastern hillslopes of Ayodhya Hills. The area is 451.31 km². The district belongs to the Raghunathpur subdivision of West Bengal (W.B.), India. It has 13-gram panchayats (G.P.s), one panchayat samiti, 137-gram Sansads (village councils), 211 mouzas, 98 inhabited villages, and three census towns. The Kashipur has a population density of 448.4 persons/ Km² (Census, 2011) (Fig. 1 a and b).

Presently, the Kashipur block has about 2 Lakhs of population accommodated in 31150 HH, a population density of 448.4 per/Km², and a rate of demographic growth of about 6%. [3]. The projected population of Kashipur Block in 2024 will be 268,111. The block was confronted with severe droughts in 1914, 1921, 1935, 1976, 1982, and 2008. The Dwarakeswar (Dhalkisore) River (ephemeral) is the major river flowing through the block [4] (Fig. 1). The Kasai Nala is the main tributary, and other drains falling are Kangsai Nala, Girigiri nallah and Saharjora Nalah. The district has a geographical area of 6256.46 km², a Forest vegetative area of 750.48 km², cultivated land of 186.21 km², Fallow land of 1155.31 Km², Net sown area of 3102.40Km², the area not fit for cultivation 1062.06Km² with cropping intensity 106.88, (DPR, Purulia Dist. 2020-21[5].

The average (av.) rainfall, mainly during SW-monsoon in the Purulia district, is from 1100 to 1500 mm/ annual. The surface comprises hard rock and laterite, which are irregularly spread with Gondwana deposits towards the NE-ly part. The geohydrological strata are available within the weathered and the secondary fractured zones [6].

Table 1. The status and geographical positioning of Purulia district, West Bengal

Study area	Area	Population 2023	Population density (2023)	Av. Annual R/F	High Pt. hills	Agri. rainfed	Irrgn %	Forests %	Drought Prone Area
Purulia;WB	Km ² 6259	million 3.386	Per/km ² 468	mm 1406	Ayodhya	60%	21.6	29.68	Central/Southern

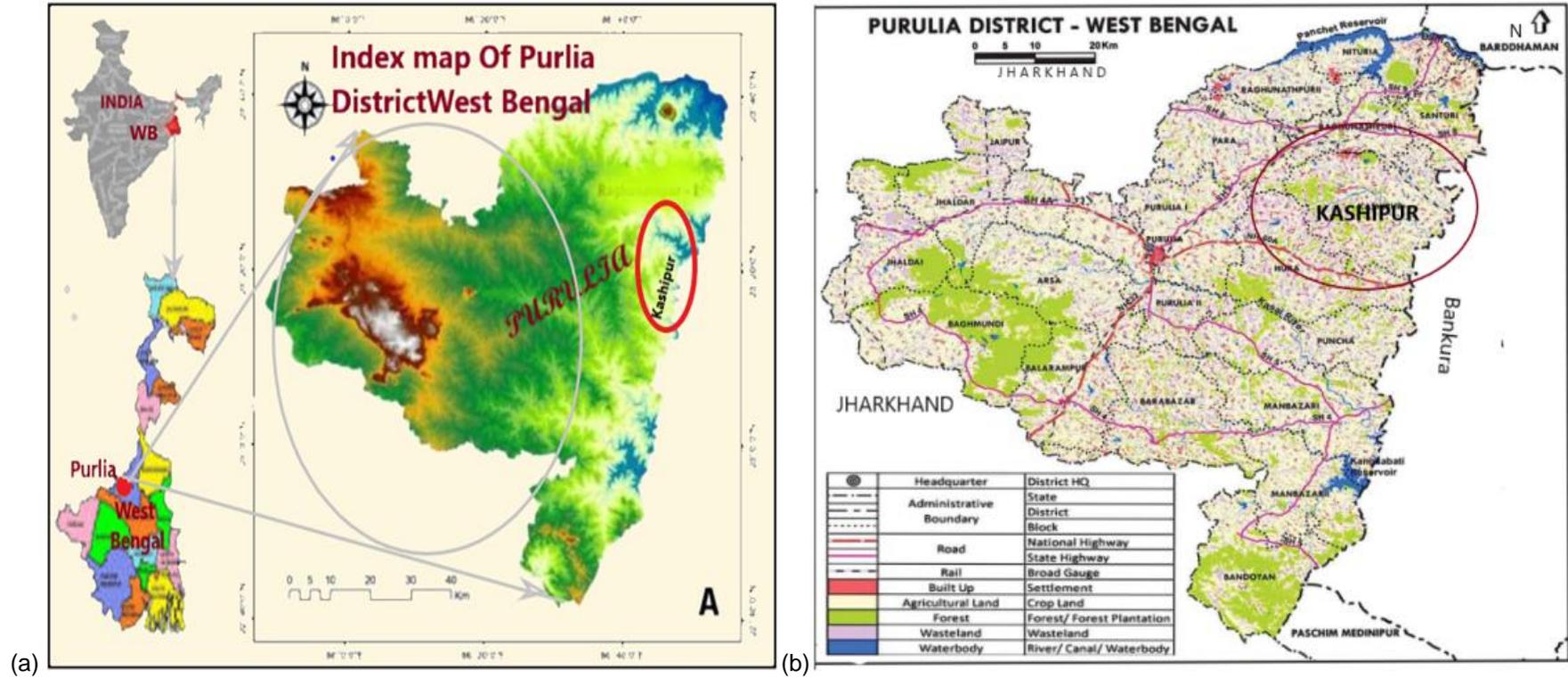


Fig. 1. (a). Index map (b) Vegetation map of Purulia district in W.B.
(Source: Mura et al. 2021)

2. REVIEW OF LITERATURE

Purulia district in West Bengal is prejudiced by meteorological drought events with a trend in declining rainfall and moisture stress during premonsoon months (June and July) and a rising trend during post-monsoon months (Aug and Sept) during the 20th and first decade of the 21st century [7,8,9,10]. The agricultural drought in the Purulia district is common depending upon agricultural drought based on monthly rainfall deficits [11,12]. India combated seven drought periods from 1876 to date (1876–1882, 1895–1900, 1908–1924, 1937–1945, 1982–1990, 1997–2004, and 2011–2015 [13].

West Bengal, especially Purulia and Bankura districts, is a humid tropic area close to the Bay of Bengal (BoB) that frequently confronts vagaries of nature like floods, Kalbaisakhi, cyclones, monsoon rainfall, heatwaves, hailstorms, etc. There is a decreasing trend due to a decrease in rainfall and the intensification of dry conditions and vice versa [14,15,16,17].

The groundwater (G.W.) excellence and its adaptability to be portable, domestic and irrigation uses in the Kashipur block (extremely drought-prone) but fit in few patches [5,17,18]. Monsoon precipitation surges G.W. (Groundwater) level in an average depth of 1 - 4 m and in Summer depletes by 8 - 10 m, wells about 85% dry and vulnerable to the risk of extreme droughts [19,20,21,6].

Studies by Mishra et al. 2012 [22], from 1908–2009, reveal 28 meteorological droughts, the highest frequency in June. The Kashipur block suffers from a hard-hit dry summer, and chilled cold winter and soil moisture loss is about 50% as the soil retention capacity of the area is less [23], Singh et al. 2023 [24]. There is a continuous trend in the reduction of the groundwater (G.W.) table of the Purulia block and confronting G.W. drought [20]. Drought at irregular intervals has shattered the economic and societal life of people of the western part of Bengal. They are at relatively higher risk and vulnerability. So, they need more attention to reduce the suffering of CC vagaries and havoc on eco-health and the economic strength of people of the area [25,26].

The Kashipur block has confronted severe droughts in the past and present. In the 20th century, the block combated one or two severe to moderate droughts every decade. Past literature

reports that fewer studies have considered various aspects but have failed to give a clear picture. The present integrated study covers the block's economic and social status and the Purulia district.

2.1 Primary Objectives of the Project

A highly populated, drought-prone, and agriculture-based area needs to be studied, as the people of the district are financially and socially backward. The objective of the Present study is:

1. Demarcation of drought pretentious areas and drought severity assessment
2. Estimation, analysis and relative vulnerability of the drought intensity Purulia dist. by RS/GIS geospatial methods. Analysis of the types of droughts and seasons that occur.
3. Ideal crop planning, implementation and suggestive management in Kashipur Block.

3. METHODS

When studying an area's drought, one should describe the type of drought and its impact on the designated area over time.

To work on the drought in Purulia, India, the investigator should have meteorological data, the drought indicators like season-wise rainfall, conditions of the Indian summer monsoon, Temperature, ONI (Oceanic Nino Index), Stream flow, ENSO (El-Nino Southerly Oscillation), Geohydrological data, Periphery reservoir status, Soil moisture data etc. (Fig. 2).

3.1 Drought Types

Drought occurs when the natural rainfall declines over a long period, during surged temperature, wind, or precipitation). Drought disasters can be of four types. They are i) Meteorological, Hydrological, Agricultural and Socioeconomic Drought, Table 2.

3.1.1 Drought indices

The various drought indices recommended by the India Meteorological Dept. and other countries are given in Table 3.

Other famous drought indices (Dis) are i) the i) Aridity Anomaly Index (AAI), ii) Palmer Drought

Severity Index (PDSI), iii) Standardized Precipitation Index (SPI), Standardized Precipitation Evapotranspiration Index (SPEI), Standardized Water Level Index (SWI), etc. WMO recommends monitoring dry spells in an area using the standardized SPI method (Press report, 2012, WMO-No. 1090 in 2012). IMD uses Standardized SPI (SSPI) from 2013 and the Aridity Anomaly Index (AAI) [26]. IMD has reinstated categories of (the SPI range) for an area with is a) Mildly wet(0 to 0.99), b) Mildly dry(0 to -0.99), c) Moderately dry(-1.00 to -1.49), d) Severely dry(-1.50 to -1.99), e) extremely dry(≤ -2.00 or less) f) Moderately wet (1.00 to

1.49), g) Severely wet(1.50 to 1.99), and h) extremely wet(≥ 2.00), (IMD).

3.1.2 Purlia's history

In the 5th century A.D., the Jaina Bhagavati-Sutra reported that the Purulia area was among the 16 Mahajanapadas (under Vajra-bhumi). The East-India Company, the Britishers obtained the 'Diwani' of Bengal, Bihar, and Orissa. 1765. In 1805, Regulation XVIII denoted the Purulia as a Jungle Mahals district composed of 23 Parganas and Mahals. Later, Regulation XIII of 1833 split the Jungle Mahals, forming a new district,

Table 2. Various types of droughts, their causes, conditions of occurrence and Impact

Type of Drought	Cause	Conditions	Impact
Meteorological	Rainfall deficit for an extended period	<25% mild, Moderate and severe drought when R/F deficiency is between 26 to 50% & >50% (IMD)	This includes war, natural disasters, crop failure, extensive poverty, economic disasters, and government policies.
Hydrological	Surface and G.W. levels deplete for less average rainfall for a long span	when the daily river discharge is \leq the daily variable threshold considering seasonality.	Meteorological drought or Soil moisture drought impacts ecosystems and society. It can affect insect outbreaks, wildfire, and carbon, nutrient, and water cycling footprints.
Agricultural	A drop in soil moisture and G.W. level below PET and less Yield and adverse plant responses, primarily vegetables, tree nuts, and medicinal herbs.	Deficient R/F / soil moisture during the growth season causes crop stress and wilting. At below-average temperatures, the wind evaporates moisture from soils and plants.	Negative fiscal Impacts on farming include less water availability, water quality, growth rates, rise in stress on vegetation, crop loss, affected plants, and reduced yields.
Socioeconomic	The shortfall in supply and demand, Being an agro-based country with 1.4 billion, droughts impact farm yield,	Water scarcity upsets people and impacts the disposal of food grains, fodder, and other economic goods.	Negative economic impacts. Influence the demand and supply of economic goods, poor WR Mngt, and socioeconomic well-being.
Famine (in an area)	Severe and prolonged hunger in the population of a region or country, resulting in common acute malnutrition/ death by hunger and diseases.	>20% of households (H.H.) face food insecurity and lack. nutrition-children exceeding 30%	Diseases, malnutrition, starvation, sociopolitical instabilities, migration, slums, poverty, fewer economies, few choices for income, and falling hygiene standards
Desertification	Continuous droughts caused, desertification urbanisation, topsoil loss, deforestation, old farming practices, Climate Change Natural Disasters, stripping of the land of resources,	The squalor of vegetation, soil erosion, agriculture, etc. Measures taken globally to fight desertification.	Desertification in India has lost nearly 31% of its grasslands. In 4 years, India (2015-19) lost over 30 million hectares of healthy land to degradation (Down to Earth; (Zumbish, October 27th 2023), U.N. data.

Table 3. Various drought Indices used for the study of droughts in India)

Index	Equation	Where	Classification
Drought Index (DI),	$DI = \frac{P - X}{\sigma}$	P= annual rainfall X= Long-term mean; SD (σ) = Standard deviation	Categories;) <i>Light</i> , DI = < -1.49 <i>moderate drought</i> , DI = < -2.0 <i>severe</i> , DI = > -2.0 <i>very severe drought</i>
Based on the rainfall deficit (IMD), it is called SPI.	$AI = \frac{PE - AE}{PE} * 10$	Where PE = Water demand of a plant (as calculated by the Penman method); A.E. = actual E.T.	We classified into three types: <25% Mild, 26-50% Moderate and >50% severe drought.
Moisture Stress Index (MSI)	Determine the soil moisture state during droughts	It is estimated by Knowing the MIR band and NIR band of Land-sat data. MSI = Band 7/Band4 {for Land-sat TM }; MSI =Band8/Band4{for Landsat ETM+}	MSI ranges from 0 to 4. (a good indicator of Agricultural drought)
Normalised Difference Vegetation Index (NDVI)	$NDVI = \frac{NIR - R}{NIR + R}$	NIR = near-infrared band, R = Red band; higher values of NDVI show less drought	An influential indicator that monitors vegetation cover and detects frequent incidence and persistence of drought
Vegetation Condition Index	$VCI = \frac{NDVI - NDVI_{Min}}{NDVI_{Max} - NDVI_{Min}} * 100$	$NDVI_{max}$ = maximum NDVI $NDVI_{min}$ =Minimum NDVI	VCI values between 50 to 100 % indicate optimal or above-normal conditions (Hazra et al.)

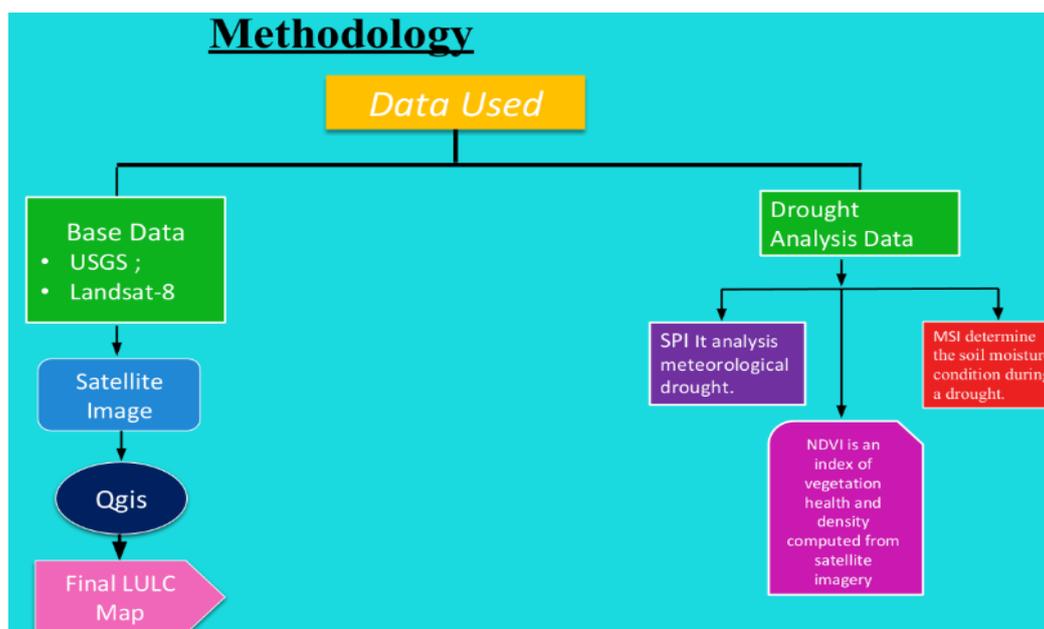


Fig. 2. The methodology applied in the present drought study

Manbhum, with H.Q. at Manbazar, including Bankura, Burdwan from W.B. and Dhanbad, Dhalbhum, from Bihar and Saraikela of Odisha. The livelihood of people in Purulia is agriculture, and about 70% of people have occupations as farmers or agricultural labourers. Regular droughts and meteorological events wash out

their Yield, hence their livelihood, Fig. 3 (a, b, and c).

3.1.3 El Nino Southerly Oscillation (ENSO)

ENSO phenomenon occurs irregularly, categorised as warm (El Nino) and cold (La

Nina), rather than the average ocean temperature in the equatorial Pacific region. The ripple effect of these waves causes weather changes amalgamated with the ENSO phenomenon. Studies from NASA reveal that the El Nio-driven ENSO causes weather changes

such as rainfall, floods, droughts, and temperature and environmental anomalies in India and globally. They can even directly induce outbreaks of infectious diseases that threaten public health.

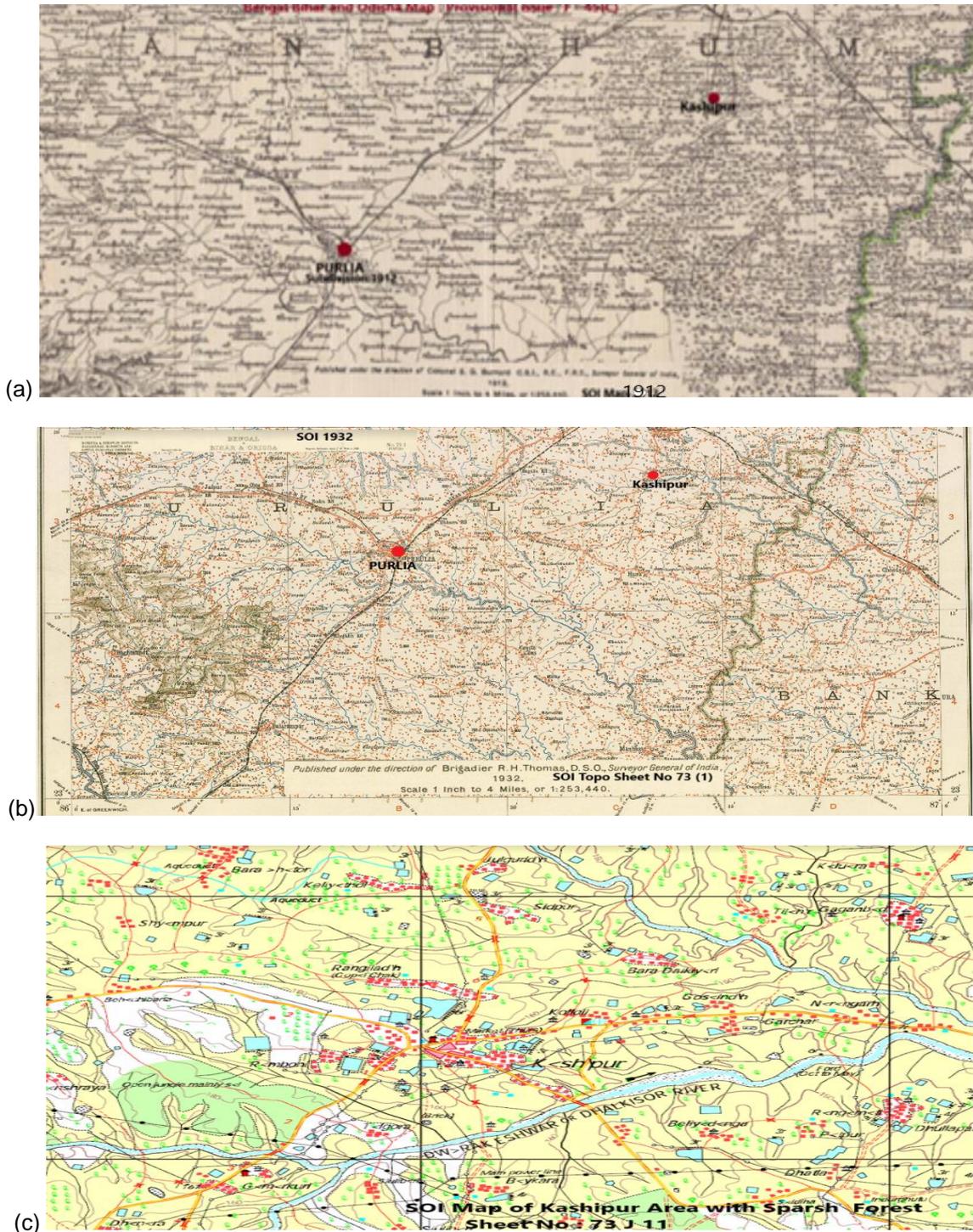


Fig. 3. (a): SOI Purlia District map in 1912 (1:250000scale); (b) SOI of Purlia District map in 1932 ; (c)SOI map of Kashipur Block in 2005 (Gradual diminishing vegetation)

Considering Satelite data for the period (2002-2021), NASA Scientists reported a worldwide intensity of extreme wet and dry events (combined extent, duration, and severity) due to global warming. Floods and droughts occurred, causing > 20% of the economic losses than in other years. The financial impacts are high in the world, and fatalities are extremely high. In another spell (2015-2021), the world faced seven warmest years (Historical record). As per ONI, there are four extreme wet and dry events globally annually. The climate changes have reduced the rate by three/ year in the last 13 years <https://svs.gsfc.nasa.gov/5087/> (Fig. 4 a & b).

stable between 1941 and 1980, and later weakened from 1981 onwards (the start of the golden spike period of the Anthropocene). The ONI (Oceanic Nano Index)-ISMR relationship was robust and stable in north India, Fig. 4 (a and b) [27,28].

3.1.4 Oceanic Nino Index (ONI)

The ONI is one measure of the El Niño-Southern Oscillation, and other indices can confirm whether features consistent with a coupled ocean-atmosphere phenomenon accompanied these periods (as per NASA). Comprehensive work has been done to correlate El Nio, ONI, and ISMR with droughts in India. It is seen where the Purulia district is affected in Table 4.

The study of the relationship between the ENSO and IBMR was more vigorous from 1901 to 1940,

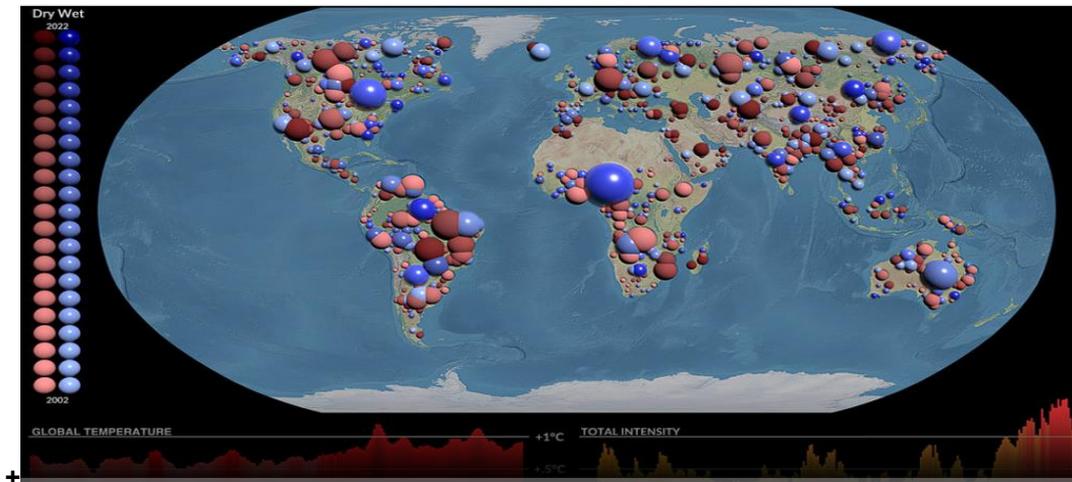


Fig. 4(a). NASA, Water Cycle Extremes: Droughts and Pluvials, Updated: December 10th, 2023 Visualizations by: Mark Subba Rao, (cons. by: Bailing Li and Matthew Rodell);

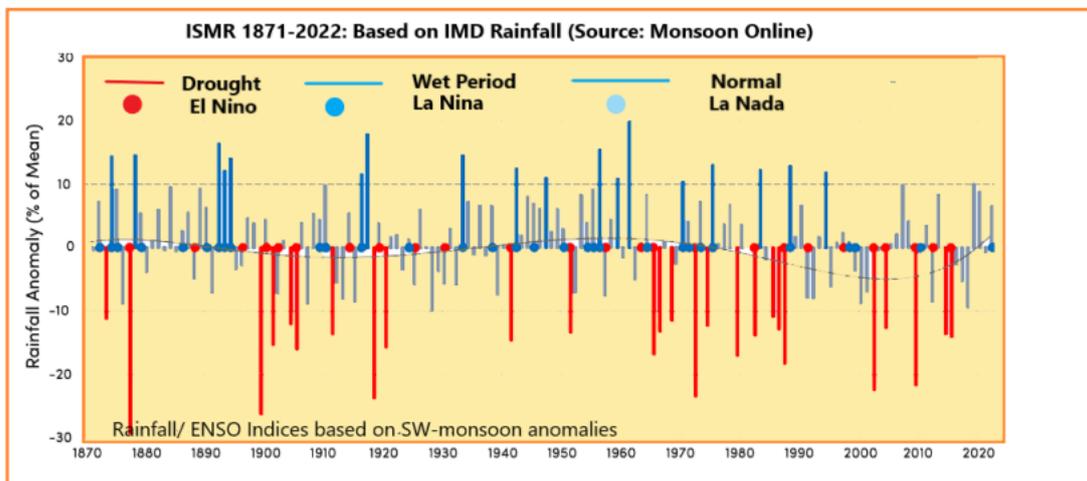


Fig. 4(b). The Indian Summer Monsoon Rainfall Vs ENSO (1871 – 2022),(IMD data)

Table 4. The EL Nino/ La Nina years droughts associated in Purulia Block West Bengal

SST anomalies	Years	Drought severity (21 st century)
EL-Nino yrs	1877;1880;1884; 1887; 1891; 1899, 1905, 1911,1914, 1918, 1923, 1925, 1929, 1929, 1930, 1932, 1939, 1941, 1951, 1953, 1965, 1969, 1972, 1976, 1097, 1987, 1997, 2002, 2004, 2006, 2008, 2009, 2014, 2015, 2016,2023 (34yrs)	1941, and 2016 (extreme severe droughts)
Drought with El Nino	1877, 1891, 1899, 1905, 1911, 1914, 1918, 1925, 1939, 1941, 1951, 1953, 1965, 1969, 1972, 1982, 1987, 2002, 2004, 2006, 2008, 2009, 2014, 2015, 2016, 2023(26 years)	No year with El Nino is a drought year, except 1953, 2015,& 2016
Drought La-Nina/ La-Nada	1901, 1904, 1907, 1913, 1915, 1920, 1921, 1922, 1966, 1968, 1974, 1976, 1979, 1982, 1985, 2000, 2005, 2010, 2018(19 years)	Severe drought years are 2005, 2010

3.2 The Impact of Nor'westers

The arid Purulia climate fluctuates from tropical savanna (A.W.) in the south to humid subtropical towards the north. The rainfall occurs during the Summer and often causes violent thunderstorms with Cumulonimbus clouds Kal-baishakhi. The high winds and heavy rain usually lash Kashipur block and even Purulia District, originating from the Chota Nagpur Plateau. These thunderstorms, accompanied by squalls, form when moist/humid high-altitude air and high-temperature infiltrate. These extreme meteorological events, Kalbaisakhi, generally occur during the evening or dawn (few days) during the premonsoon period, causing fatalities or devastating the standing crops in the field.

3.2.1 Intertropical Convergence Zone (ITCZ) Positioning / ISMR

The intertropical convergence zone (ITCZ') plays a vital role in influencing the changes in the ISMR (Indian summer monsoon rainfall). The ITCZ (or monsoon trough) has become strong and moved north, with a surge in ISMR in the 21st century. The ITCZ swings over the Gangetic plain in Summer with intermediate breaks, which influences the outset of the southwest (S.W.) monsoon (between June and Sept).

The Monsoon front gives rainfall in the Purulia district when the ITCZ shifts at the fringe zone of the S.W. monsoons and the N.E. trade winds. The ITCZ shifts within 20°- 25° N Lat. (near Tropics of Cancer) in July when housed in the Indo-Gangetic Plain. The S.W. monsoons blow from the Arabian Sea towards BoB [29,30]. The (ITCZ') and Sea surface temperature play a vital role in monsoon rainfall in India. The monsoon trough, or ITCZ, is the convergence zone where northeast or southeast trade winds meet. India

encountered droughts/ Famines in the Purulia district during the 17th, 18th, 19th and 20th centuries are 12 major famines (1769–1770, 1783–1784, 1791–1792, 1837–1838, 1860–1861, 1865–1867, 1868–1870, 1873–1874, 1876–1878, 1896–1897, 1899–1900, and 1943–1944) which led to the deaths of millions, (Fig. 5 (a & b), [31,32]. From 1899 to 1920, India confronted 07 drought years, followed by 1941-1965, with three droughts in India. Strong ENSO activities propelled by IOD (Indian Ocean dipole) extreme events have less ISM, including in India. The incidence of 10 drought events between 1965 and 1987 was due to ENSO. As per ONI the El Nino years in the 21st century is 2002–03; 2004–05; 2006–07; 2009–10; 2014–16; 2018–19, and 2023,

3.2.2 Geology

Geologically, Kashipur blocks are dominated primarily by rocks of the Chhota Nagpur Plateau of Proterozoic hard granite gneiss available at a shallow depth. Proterozoic soft, flaky phyllite and mica schist belong to the Singhbhum Group and are composed of quartz, muscovite, and biotite mica. The area is part of the Chhota Nagpur Gneissic Complex of the Eastern Indian Peninsular Shield, north of the Singhbhum Craton [33]. The area is mainly covered by laterite soil and represents undulating topography with moderate to gentle slopes, Fig. 5 (b). In the laterite-covered area in Kashipur block, meteorological drought under climate anomalies invites droughts in agricultural regions, bullying food security [34,20].

3.2.3 Climate

The undulated topography has an elevation from 150 m to 300 m. The Purulia is housed on the plateau of W.B. and confronts a high drought

next to Bankura. The climate is highly evaporative and has low precipitation. The weather is hard-hit: dry Summer, moderate monsoons, and cold winter. Temperature variation ranges from 12 °C to 45° C in Summer, making the climate moisture-deficient. S.W. monsoons provide significant rainfall. On rainy days, the R.H. (relative humidity) is 75% to 85 %, but 25-35% in Summer, Fig 5 (b).

3.2.4 Soil

The soil of Purulia is red, alluvial soil, and Laterite soil. Red and laterite soil dominates the landscape, gradually merging with old alluvium in the East with gravelly patches. The soils of the block are acidic (Strong to modest). Electrical conductivity (E_c) is average (<1.0 dS/m). The Soil Organic Carbon (SOC) is medium to low (48% to 33% of samples), nitrogen deficient, Phosphorous (P) (70-80%) and medium Sulphur (S) about 60%. The soil is thin, coarse-grained, poor in organic matter, and inferior in water-holding capacity, so it is less fertile, warranting reclamation. Purulia has poor economic and human growth but is rich in tourism, culture and heritage [35,36,37].

3.3 The Geomorphology

The topographic and the stream order map of the Purulia district infer that the western edge of the district is at a higher elevation than the eastern fringe, and the drainage pattern shows that the western part of the district has fewer drainage channels, mostly in hilly topography. The district has sporadic vegetative forests consisting of Sal, mixed with Neem, Mahua, Palash, Kusum, Kendu, 27 types of bamboo species, and many climber and medicinal plants; the evapotranspiration is high (Hazara et al., 2017), Fig. 6 (a-d).

Traversed by the Tropic of Cancer, Purulia (between 22°42'N and 23°43'N lat.) has pan-India (Presence Across the Nation) significance because of its tropical location, topography and funnel-like shape. It funnels not only the tropical monsoon current from the Bay to the sub-tropical

chunks of Northwest India. The district has 1857.26 km² of forests in the Ayodhya Hills range, 29.7% of the area. Purulia district is "Ahalya Bhum", the land with a stony heart. It is ranked as a scheduled tribe population in W.B. (Census,2011)

3.3.1 Natural Vegetation

The natural vegetation of the blocks consists of trees, shrubs, grass and weeds. The primary tree species are Sal, Mahua, Palas, Kend, Arjun, Shimul, Pipal etc. Some important shrubs and herbs are Lal Bharendra, Nishinda, Maranphal, Ghetu etc. The grasses found in the field are Sar, Kans, Matha, Kansira, etc. Commonly growing *Amaranthus viridis* L. (Khutura Sak, Khada Sag or Jungali Chaulayi), *Oldenlandia corymbosa* L (Pitpada, Corymb Diamond Flower, Daman Pappar, etc.), *Vernonia cinerea* (L.) (Purple fleabane, Pirina, Sahadevi), *Solanum sisymbriifolium* Lam (ild tomato etc), are typical drought tolerance Angiosperms in Kashipur having tremendous medicinal values, (Latha et al. 2010; Mandal et al. 2014).

The district acts as a gateway between the developed industrial belts of West Bengal and the hinterlands of Orissa, Jharkhand, Madhya Pradesh and Uttar Pradesh. The district has about ≈30% of its area covered by forests of various types. Fig. 7 (a and b), [23], About 310sqkm area of Kashipur, in Raghunathpur-I, Para block, are less suitable zone covers for agriculture which warrants immediate rejuvenation [38,39].

3.3.2 Agriculture in Purulia District

Considering the topographical area, the land use and the Land cover area of the Purlia district, it is found that the forest land in lateritic hills is the highest, and the forest cover is very sparse. Similarly, the agricultural fields are in more lands without significant drainage systems, and about 60% of land area with rainfed agriculture today is without irrigation. The land use and land cover show that the Kashipur block is less productive (Table 5)

Table 5. The Land use and land cover of the Purulia district (without Homestead/water bodies)

Dist/ Block	Land use for Agriculture (Land type)				Forest cover(Ha)	Gochar (Grazing land)(Ha)	Others	Total
	Highland (Ha)	Mediu m (Ha)	Lowlands (Ha)	Total				
Purulia	91137.6	35052.8	14021.3	1402127	877153	14788	60171.5	943309
Kashipur	746.28	661.14	284.58	746.28	80188	NA	NA	45232

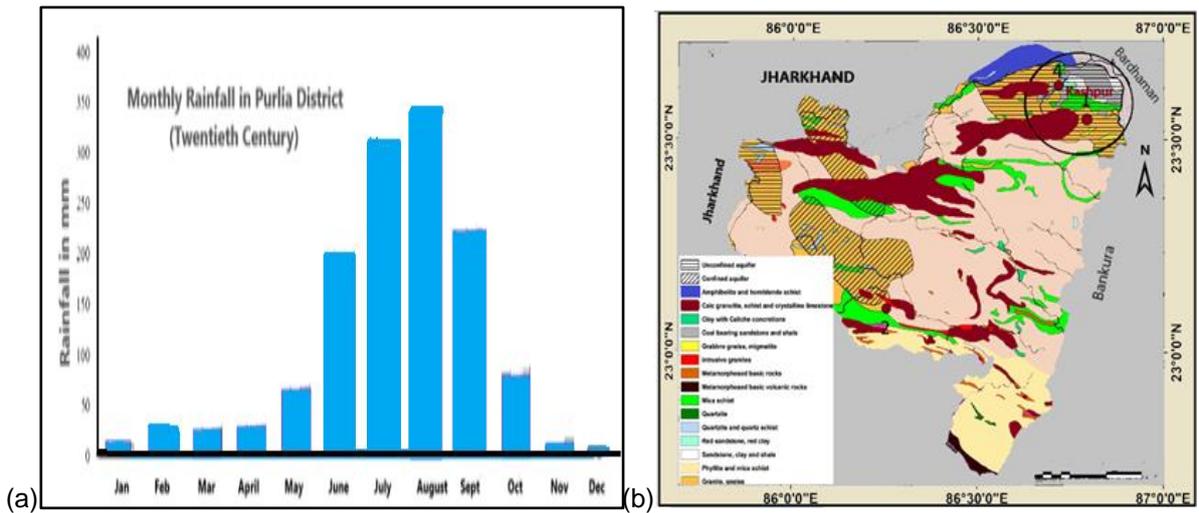


Fig. 5. a) Monthly av. rainfall (b) Geology map of Purulia dist.,(Adapted: Bera et al, 2023)

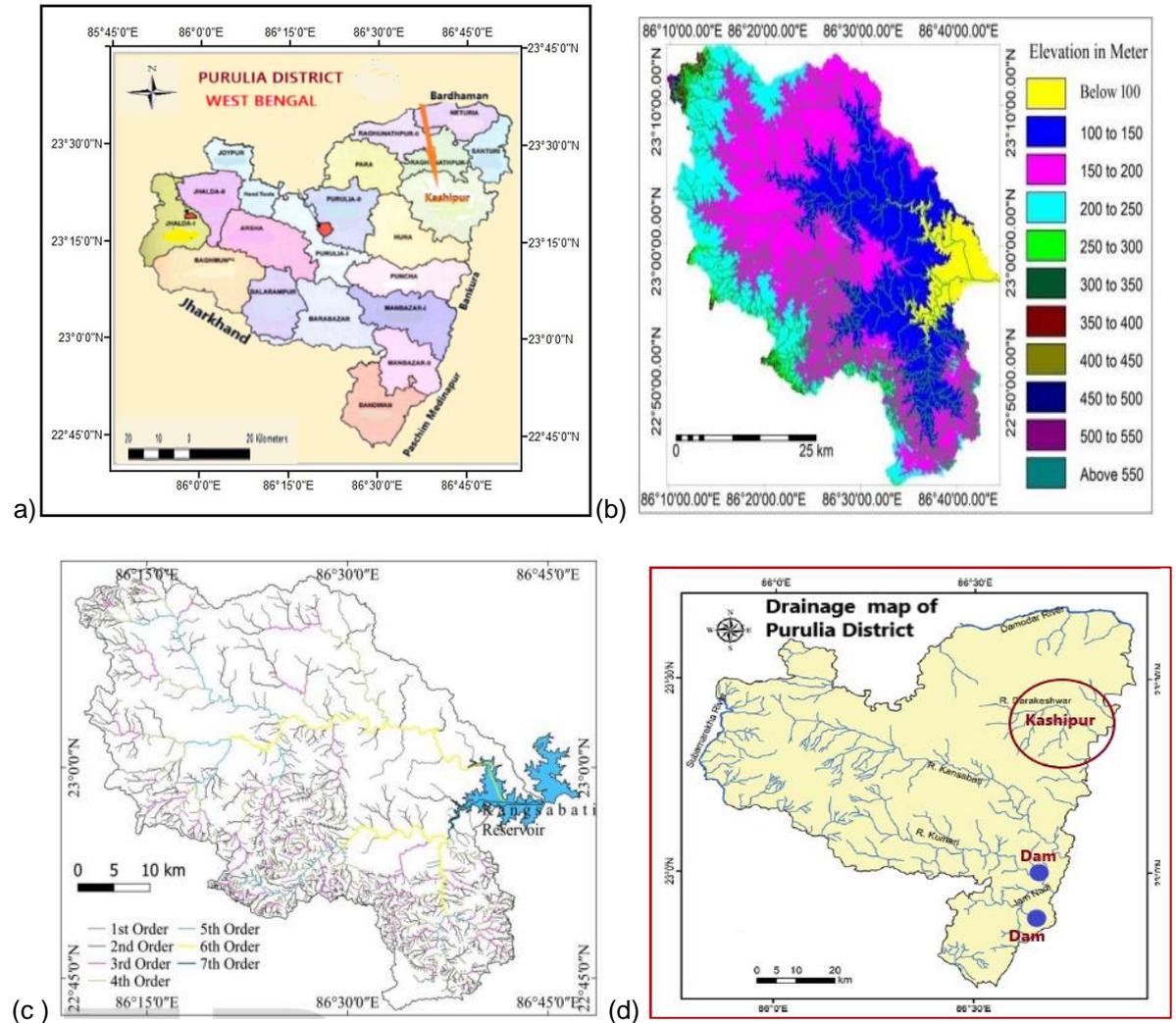


Fig. 6. (a) Block (b) Topographic (c) The stream order and (d) Drainage map of the Purulia district W.B

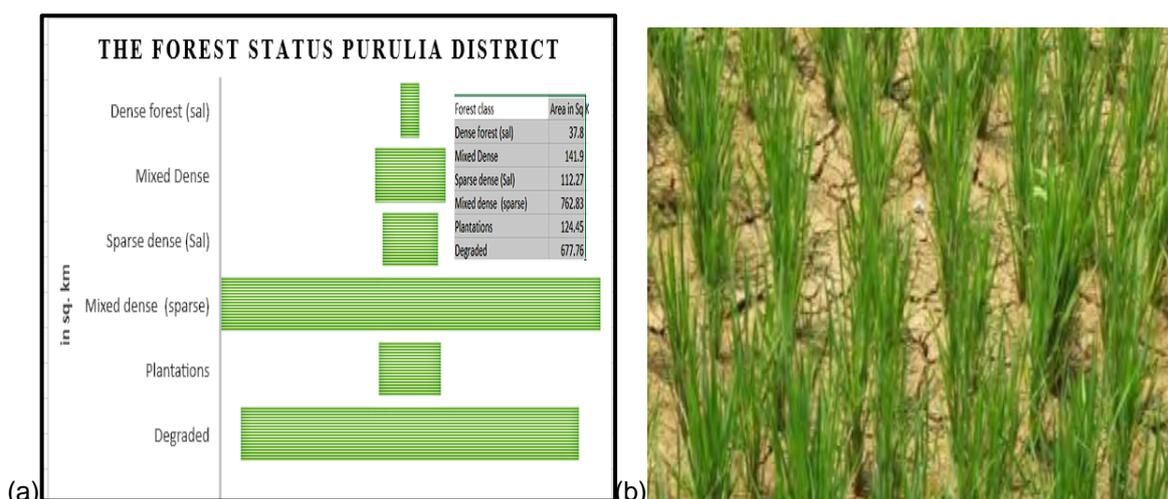


Fig. 7. (a)The various forests in Purulia's Hilly terrain (b). Paddy crop under moisture stress

The net-cropped area of Kharif paddy cultivation (83%), cropping intensity is 114.59, in Purulia District, <https://purulia.gov.in/district-profiles/>. Though the Kashipur block is close to the Panchet reservoir and lies in the periphery, the land topography is such that the lands are deprived of irrigation. On rain-deficient days, the land undergoes either moisture stress conditions, drought, or severe drought.

3.3.3 Hydrogeology

The rocks of Chhatna and Kashipur are usually rugged, massive and compact but are generally fractured, jointed and traversed by veins of quartz and pegmatitic. These rocks disintegrate and decompose near the land surface, commonly called a "weathered zone". This zone and fracture zones within the hard stones are the area's central groundwater (G.W.) storage. However, due to the high content of Apatite in Pegmatites and fluoride-bearing minerals in the crystalline gneisses, G.W. is often polluted with Fluoride much above the permissible limit [40,5].

3.3.4 Irrigation

Until Independence, irrigation (Diversion Schemes only) on the Kangsabati and the Damodar. River and the Irrigation potential created only 139000 ha (<https://www.wbiwd.gov.in/index.php/applications/about>). W.B. Govt is in the run to develop irrigation schemes in Kashipur Block WHT - Water harvesting Tank, WDS - Water Detention Structure, SFMIS-Surface flow Minor Irrigation Schemes, WHR - Water Harvesting Reservoir, CD - Check Dams. The latest West Bengal Irrigation & waterway

Dept has intended to renovate and rehabilitate the old dam of the Dangra Irrigation Project housed in Kashipur, Purulia Dist.

3.4 Drought Frequency and Severity

The apocalyptic famine that caused famine in Bengal province (including West and East Bengal during 2nd World War, in the year 1943 was 1332209 (registered deaths due to famine [31], Page-220). The Kashipur block witnessed famines, The Great Bengal Famine (1769-70), The Odisha famine (Naanka Druvikhya, 1966), Bihar famine (1873-1874) and The Bengal Famine (1943) when the Kashipur block was worst affected.

The drought scenario of the Purulia block remains within the mild and moderate categories occurring in the north, east and northwest portions (Rangamati, Lalpara, Patpur, Kashipur villages, etc.). The southern part of the Purulia was susceptible to severe drought but less prone to extreme droughts. The extreme drought occurred in the southwestern part (Sunra, Seja, Kashidi, Shampur, Gopalpur, and Saharbera villages) towards the western study area, Table 6.

3.4.1 Various drought Indices in 2023

The Standardized Precipitation Index (SPI) expresses the actual rainfall as a standardised departure from the rainfall probability distribution function. In this study, the severity and spatial pattern of meteorological drought relating to groundwater and reservoir storage were analysed in the blocks of Kashipur.

Table 6. The categories of droughts and severity in (Purulia dist) 20th & 21st century

Type of drought/ Monsoon period	Very Severe (years)	Severe (Years)	Moderate (years)	Mild droughts
Premonsoon (April to June);	1922, 1953, 1966 (Nil in 20 th century)	1907, 1916, 1921, 1955, 1957, 1962, 1968, 1985; Place: Seja, Sunra, Kashidi, Chaka	1903, 1924, 1935, 1939, 1941, 1975, 1992, 1996, 1998; Places Bhatin, Balampur, Lara, Jagannathdi.	Bodma, Jorthol, and Tilaboni almost every year
Monsoon (July to September);	1966, 2005, 2010	1941, 1957, 1968, 1972, 1985, 1992	1907, 1912, 1938, 1945, 1955, 1962, 1979, 1983, 1988, 2003, 2014	2023; Seja, Sunra, Kashidi, Chaka, Lajhna
Post Monsoon	1914, 1921, 1935, 1976, 1982, 2003, 2008	1981, 2000, 2001, 2005, 2010, 2015, 2016;	1902, 1911, 1909, 1953, 2004, 2006	Bhatin, Balampur, Jagannathdi, Jamkiri, Lara Jibonpur,

SPI has been used to quantify the precipitation deficiency amount used for 1901–2015. From the TRMM rainfall data, SPI has been calculated between 1982 to 2012. As per Bhunia et al. [41], the drought frequency for 117 years is Mild (46 years), Moderate (8 years), Severe (4 years), Extreme (3 years) and normal drought years 56 years, Fig 8 (a-d).

3.4.2 Socioeconomic drought Vulnerability

Purulia District is vulnerable to drought, mainly agricultural droughts. It is closely related to food insecurity and can be defined as the probability of an acute decline in food excess or consumption below minimum survival needs. Forests are sources of socioeconomic growth in an area; Purulia district has 876Km² of forest area (2015-16), which has surged to an area of 1153.21 Km² including social forestry by 2023. The district is under food insecurity related to a lack of employment opportunities and livelihood. Vulnerability may be assessed regarding multiple factors/ indicators, exposing people to food insecurity through reduced availability, access and utilisation. Vulnerability indicators include forced migration, marginalisation, borrowing, skipping meals or food shortage, change of occupation, forced unemployment, failing health conditions, etc. During drought severity, even large landholders are susceptible to food insecurity.

3.4.3 Drought Perception

The Gram panchayat Kashipur falls in the Purulia district, situated in West Bengal state, with a

population of 2580. The male and female populations are 1336 and 1244 respectively. The size of the area is about 2.35 sq. km. Kashipur is one of the drought-prone areas in the Purulia district. During the Survey, it became evident that people living with droughts with erratic rainfall, food scarcity, Poor climatic conditions, unsanitised areas, lack of healthcare facilities, poor education poverty and less attention from Govt subsidies.

3.5 Soil Moisture Survey

In the hydrological cycle, soil moisture at the surface layer (0–5 cm) is an important hydrological variable influencing the feedback between the land surface and atmospheric processes that leads to climate irregularity.

Soil moisture is the primary water source for crops that influence crop production and is essential for hydrologic applications such as flood and drought monitoring, weather forecasting, and weather management.

A reading of 7 is neutral; Crops typically grow well when pH is between 6 and 7.5. A soil with a pH of 6 is ten times more acidic than a soil with a pH of 7, and pH 5 is 100 times more acidic than a pH of 7. The role of fertilizer can be summarised as a. low/less fertilizer addition increases growth and Yield, and high or no fertilizer and medium fertilizer application may or may not augment Yield. Application of more fertilizer shall not improve growth or Yield. (Fig. 10 a and b and Table 6).

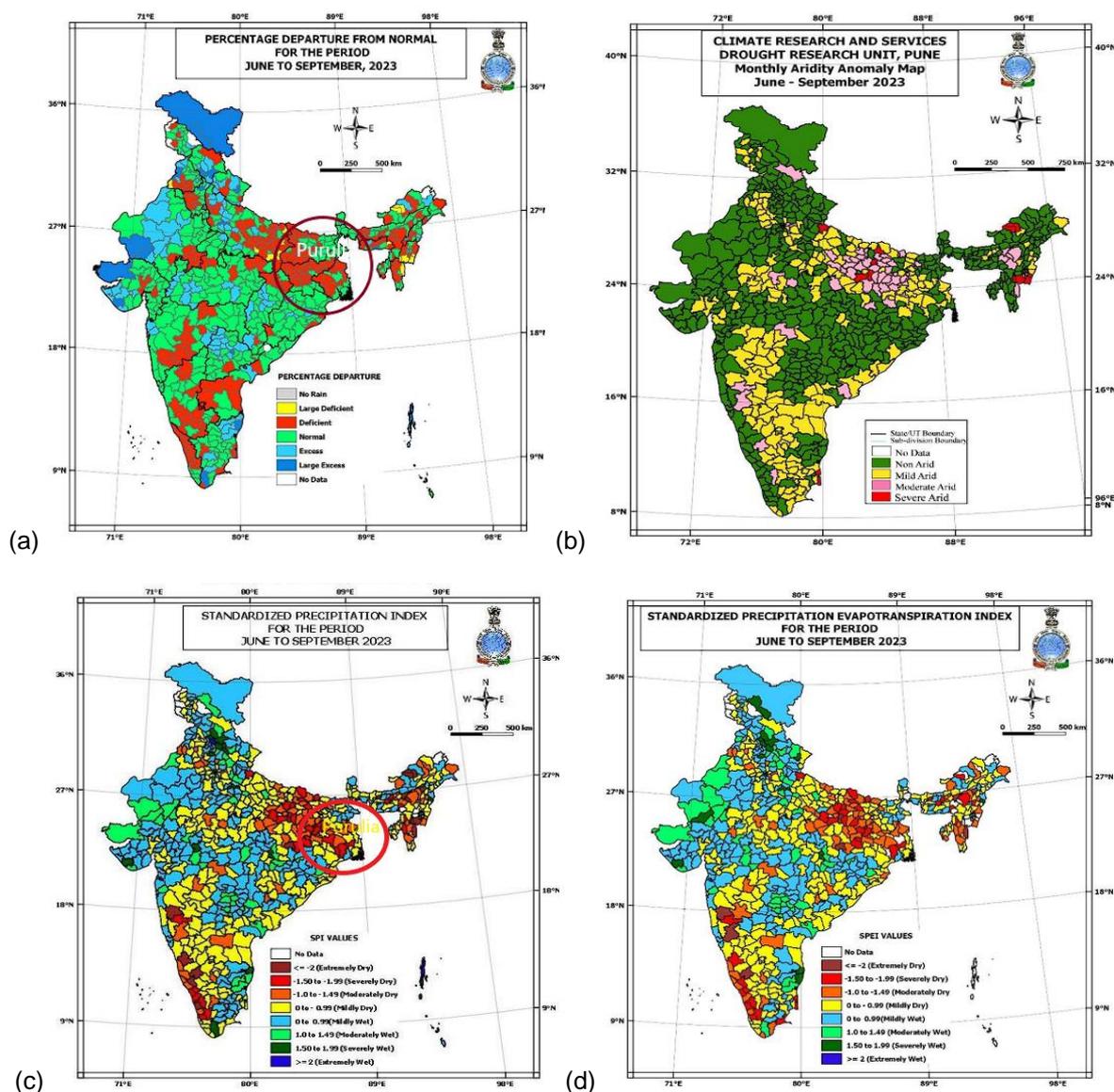


Fig. 8. Drought position during June to Sept 2023; (a) Rainfall departure (%) from Normal (June to Sept. 2023) (b) Mild drought Purulia 2023 as per AAI; (c) Mild drought in Purulia District (SPI) ; (d) Standardized Precipitation Evapotranspiration Index (SPEI) (Source IMD)

Table 7. The test results of the water, soil samples and probable crops in the area

Sample(S)	Lat/Long	pH	Features	SOC(%)	Crops
S-1	2325428N/8642386E	6.5	slightly acidic	0.5%-7.5%	Chilli, Coriander
S-2	2325425N/8642383E	≈6.5	Nearly acidic	>5.0%	Ginger, Turmeric
S-3	2325350N/8642329E	7	Neutral	>5.0%	Garlic, Papaya
S-4	2326286N/8642457E	7	Neutral	0.5%-7.5%	Ladyfinger/Watermelon

SOC: Soil Organic Carbon

3.5.1 Crop Yield

Purulia is a drought-prone West Bengal district with high rainfall variability and extreme temperature conditions. The Kashipur block from

Purulia comprises a poor tribal population vulnerable to drought impacts. The crop yield in the Purulia district and Kashipur block has been high during summer crops compared to the other seasonal crops in the districts. Dams surround



Fig. 9. (a)The drought-prone dry land and (b) drought monitoring of Kashipur block

the Purulia block, and the Dwarakeswar River can yield higher Rabi crops. The annual rainfall in Purulia is less, and the crop yield is more stable in Purulia with fewer water-scarce crops. The rainfall can be directly proportional to growth and yield production. The Kashipur block of the Purulia district is more vulnerable to deficiency in rainfall. The production /yield in Kashipur is affected during drought and non-drought years.

4. DISCUSSION

In independent India, famine is no longer a disaster due to the overall management of water resources and assured food security. The droughts in independent India have replaced famine with moisture stress or rainfall deficiency, which causes crop failure. The significant droughts after India's Independence are in Bihar (1966-67), Maharashtra (1972 and 2013), the W.B. Bengal (1979-80), Gujarat (1987), and the Maharashtra drought (2013) (Wiki Pedia).

Drought Rainfall patterns in the Purulia District are consistent with the rainfall patterns of both West Bengal and India. Potential causes of this tendency may be closely related to geo-environmental factors like global climate change and the association between India's monsoon patterns and ENSO changes. The target area faces rainfall variability, which is dependent on ENSO. The role of the monsoon trough and depressions is decreasing. This may be due to the weakening of the monsoons due to the warming of the Indian Ocean. ITCZ shifting north and south between the Tropics of Cancer and Capricorn in the two hemispheres intervened in the rainfall pattern along with Tibetan High (T.H.),

Tropical Easterly Jet (TEJ), and Western disturbances.

In the last century, the average onset of the S.W. monsoon was delayed in GWB (Gangetic West Bengal) to June 13th instead of June 7th. The date of withdrawal almost remained unchanged, reducing the span of the S.W. monsoon in India by a week. However, the Purulia district shows an average rainfall of 1310.7mm during 1951-1980, which increased to 1324.0 between 1980 and 2010. The surge may be due to anthropogenic interventions over the geo-bio-hydro atmosphere.

The anomalies in erratic rainfall in the Purulia are associated with undulations, laterite cover, topography, altitude, gradient, rainfed agriculture, deforestation, urbanisation, and industrialisation added to the drought scenario in the 21st century [42]. The shallow rupture zones in the district can hold water and become dry quickly, resulting in less recharge of the groundwater aquifer [43].

The prevalence of frequent warm spells in winter is more than the frequency of cold spells. Cold spells clarify that winters are becoming warmer and drier. The frequency and intensity of BoB disturbances have escalated, and the cyclonic storms (C.S.) slamming Odisha, W.B. and Bangladesh coast pass over the Purulia Dist. and cause meteorological drought.

The shortcomings in agricultural practices are primitive and lack appropriate water conservation systems. Farming Boro paddy causes more loss and massive wastage of virtual water. Traditional cultivation has a higher footprint than modern methods.

Table 8. The soil cover of the Kashipur Block, Purlia District, West Bengal, India

Landscape	Tahr/Danga (Ha)	Baid land (Ha)	Kanali Land (Ha)	Bahal land (Ha)	Dungri Land (Ha)	Pathara Chatan (Ha)
Area (Ha)	5416	8575	14893	3159	8124	4964
Features	Undulating High with Lesser Soil Cover	Undulated land, medium Height/ Little Slope	Fertile and Low land	Fertile/ Low land in floodplain	Residual Hills	Granite/ laterite outcrop
Slope %	1:4(%)	2:3%	1 – 2%	0 -1%		Not fixed
Approx. area	25%	25%	35%	15%		
Plantation Optional	Adaptable trees, tall/deep-rooted grass.	Lemons, kaju nut, guava, sweet apple, etc., and cotton/ maize.	Light paddy, pulses, ground nut, other oil seeds, cotton, guava, Khesari Mustard, etc	Medium paddy, wheat, vegetables, potato, sugarcane. Mustard, cultivation of nitrogen-fixing trees and shrubs.		Fodder grasses can be tried.
Hydraulic structures	infiltration ditch, semicircular ponds /Pasture,	water recharge/ harvesting and storage ponds.	Ponds, watershed action trials, Check dams	Ponds, watershed action trials, Checkdams, community ponds.		Better Watershed Management options

Source: Mukhopadhyay R et al. [44]



Fig. 10. Some water harvesting structures and groundwater recharging units to combat drought

4.1 Adaptation to High Yield

The only river passing through the district is the Darikwa Swar River and its tributaries; the proposed water conservation hydraulic structures are gully plugging, open pond excavation, ditch

ponds, stepped ponds, stone Bundhs, water harvesting structures, and Check dams. Construction of bunds/ check dams, gully plugging, etc.) was rarely undertaken to conserve the runoff and minimise water usage. Take soil water conservation measures like infiltration

ditch, semicircular bunds, stone bunding, etc. Combating the drought is never hard, not crack if, otherwise, it is not severe or extreme drought.

To ameliorate the drought impacts, the proposed crop planning is to go for crops whose water requirements are less, preserving surface wasted runoff, cultivation of low variety paddy, ideal land use plan on undulating terrain, plot to plot water storage, and retrieval, (Fig. 8).

Steps ahead for ameliorating drought in Purulia District.

- I.T. tools like geographical information systems support leveraging indigenous knowledge of the community. A sky observatory and digital repository of crop scheduling are needed.
- Repository planning and local weather stations must be installed close (one in a 10 Km² area), and a crop advisory committee should be established to choose a crop variety. Also, emphasis should be placed on the "Save Hills" programme incorporated by the W.B. Govt.
- Shifting to climate-resilient smart agriculture by Changing the cropping patterns as per agriculture advice with proper crop planning using energy-efficient models and indigenous Knowledge centres.
- As the target area is on the barren hill slopes of the Ayodhya Hills, water retaining or harvesting structures are to be developed to recharge G.W. and surface water with water body renovation.
- Developing agroforests with local trees, rewilding, cropping, mixed cropping, and inter-cropping to be tried using efficient Bio-lab. Long deep-rooted grass to be planted for moisture retention and pasture uses and to reduce gulley erosion.
- Develop and boost the renewal of traditional grain banks with women as a lead for women's empowerment.
- Regional Policy Action Platform on Climate Change (RPAPCC) was formed in WB, India, for different crops.
- Dependency on mono livelihood options to be added with bovine or livestock/beekeeping, fish culture, perennial/medicinal trees, floriculture and other microenterprise options.
- Climate change in land use and cover patterns, considering topography, soil

depth, and water availability, should be considered when introducing climate-smart agriculture [45].

- The traditional, low-cost water storage systems like 'hapas'(tanks) and earthen or check dams, the women of Purulia need to be empowered by converting once-parched fields to productive multi-crop lands.

5. CONCLUSION

Hazards and disasters like drought (paucity in rainfall) are inevitable in subtropical areas, particularly along the Tropic of Cancer, the long-positioning Intertropical convergence zone, and the trough line from south to north. The drought affects the area's economic, socio-political, and environmental turmoil, which can be ameliorated by sufficient irrigation with crop rotation in the affected area. Climate change promoted by global warming is a perilous ecological problem linked to overall development and economic growth.

The state and the central government must take water conservation measures to optimise water use, augment irrigation potential, and minimise water spoilage/wastage. Befitting to topography and undulation terrain, micro, mini, small and medium-sized reservoirs/ water bodies must be created to arrest the surface runoff through water harvesting structures.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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