Carving Drought Impact Over PuruliaDistrict, West Bengal, India

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, thespatial 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/ Puruliablock 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 aretheweapons of thedrought-hit Purulia/Kashipur farmers.

Keywords: Arid, Ayodhya Hills, Drought, El Nino, GIS/ERADAS, Groundwater, Kala-baishakhi.

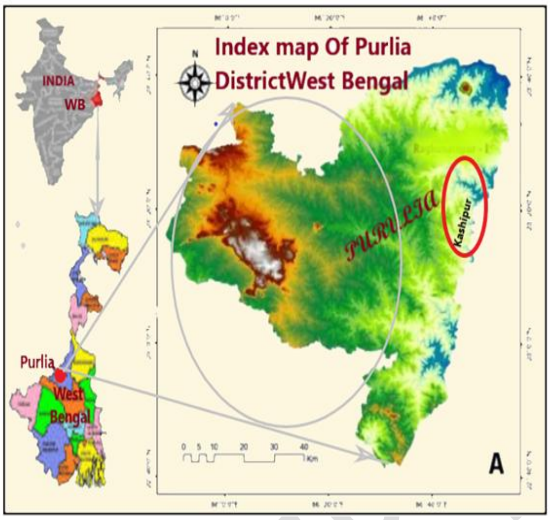
1. INTRODUCTION

The pre-independenceManbhum district of Bihar -Bengal-Orissa Provinces, named Puruliadistrict,was declared on November 1st 1956, on the division of old Manbhum estate housed in West Bengal and Bihar. ManbhumDist. 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. Thesoutheastwas shared with Bokaro, Dhanbad,Hazaribagh, and RanchiDist. of Jharkhandalongthe 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^{o}42'35" and 23^{o}42'0" N lat.; and 85^{o}49'25" and 86o54'37"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 ofan area of 451.31 sq. km, Table 1, Mura et al., 2021[1].

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

Study area	Area	Population2023	Population density (2023)	Av. Annual R/F	High Pt.	Agri.	Irrg^{n}	Forests	Drought Prone
	Km^2	million	Per/km^2	mm	hills	rainfed	%	%	Area
Purulia;WB	6259	3.386	468	1406	Ayodhya	60%	21.6	29.68	Central/ Southern

The rivers that flow in the district arethe Damodar,Kangsabati, Dwarakeswar, and Kumari. Large/small damswere built over rivers Kangsabati, Burda, TilaitarPanchet, MaithonGopalpur, Pardi,andMurguma. These damsmostly douse the northern fringe, but mosthilly terrain is rainfed, with runoff directly todrainslacking to cater to the irrigation perspective. Few check dams have been built to augment the summer needs for drinking water, bovine/ forestryrequirements, irrigation and industrial needs (Fig. 1 a and b).



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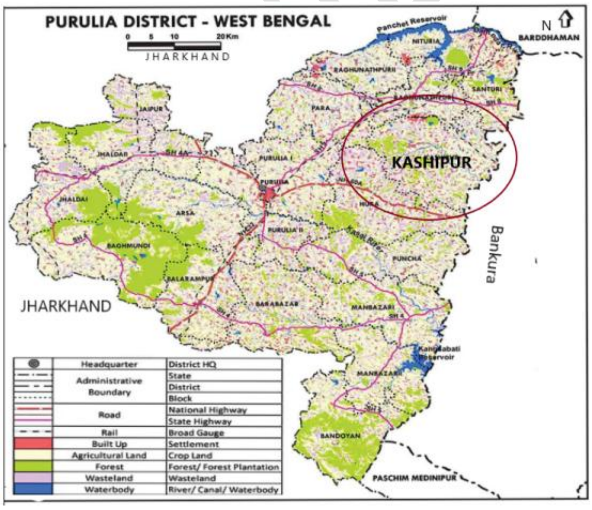


Fig. 1. (a). Index map (b) Vegetation map of Purulia district in W.B. (Source: Mura et al., 2021)

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 (Mahato et al., 2021[2]).

1.1 The Study Area

Kashipur is an administrative block in the Purulia district.Moreover,it is housed inthe eastern hillslopes of Ayodhya Hills. The area is451.31 km2.The districtbelongs to the Raghunathpur subdivision of West Bengal (W.B.), India. It has 13-gram panchayats (G.P.s), one panchayat samiti, 137-gramSansads (village councils), 211 mouzas, 98 inhabited villages, and three census towns. The Kashipur has a population density of 448.4 persons/Km^2(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%. (Census Report 2011[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, Kundu et al., 2018[5], (Fig. 1).The Kasai Nala isthe main tributary, and other drains falling are Kangsai Nala,Girigiri nallah and SaharjoraNalah.The district has a geographical area of 6256.46 km^2, a Forest vegetative area of 750.48km2, cultivated land of 186.21km2, Fallow land of 1155.31 Km^2, Net sown area of 3102.40Km^2,the area not fit for cultivation 1062.06Km^2 with cropping intensity 106.88, (DPR, Purulia Dist. 2020-21[4]).
The average (av.) rainfall, mainly during SW-monsoon in the Purulia district, is from 1100 to 1500 mm/ annual. The surfacecomprises hard rockand laterite, which are irregularlyspread with Gondwanadepositstowards the NE-ly part.The geohydrological strata are available within the weathered and the secondary fractured zones. (Sarkar et al., 2023[6])

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) duringthe 20th and first decade of the 21st century, (Kar et al. 2012[7], Palchoudhury et al, 2013[8],Goswami et al., 2019[9], Rah et al, 2023[10]).The agricultural drought in the Purulia district is common depending uponagricultural drought based on monthly rainfall deficits (Roy et al., 2020[11];Goswami et al., 2023[12]).India combatedseven drought periods from 1876 to date (1876–1882, 1895–1900, 1908–1924, 1937–1945, 1982–1990, 1997–2004, and 2011–2015 (Mishra et al., 2019[13])

West Bengal,especially Purulia and Bankura districts, is a humid tropic area close tothe 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 (Mishra et al., 2017[15];Ghosh et al., 2019[16]; Mishra et al., 2020[17])

The groundwater (G.W.) excellence and its adaptability to beportable, domesticand irrigation uses in the Kashipur block (extremelydrought-prone) butfit in few patches (Kundu et al., 2018[5], Das et al., 2021[17]Baral et al., 2023[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 tothe risk of extreme droughts (Behera et al., 2017[19], Bera et al., 2022[20], Sarkar et al., 2023[6])

Studies by Mishra et al., 2012[22], from 1908—2009, reveal 28meteorological droughts, the highest frequency in June. The Kashipur block suffers from a hard-hitdry summer, and chilled cold winterandsoil moisture loss is about 50% as the soil retention capacity of the area is less (Raha et al., 2023[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 (Bera et al., 2022[20]).Drought at irregular intervals has shattered theeconomic and societal life of people of the western part of Bengal. They are at relatively higher risk and vulnerability. So, theyneed more attention to reduce the sufferingof CC vagaries and havoc on eco-health and the economic strength of people of the area(Das et al., 2020,[25] Singha et al., 2023[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. Pastliterature reports that fewer studies have considered various aspects but have failed to give a clear picture. The presentintegrated 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 pretentiousareas and drought severity assessment
2. **Estimation**, analysis and relative vulnerability of the drought intensityPuruliadist. byRS/GIS geospatial methods.Analysis of the types of droughts and seasonsthat occur.
3. Ideal crop planning, implementation and suggestive management in Kashipur Block.

3.METHODS

When studyingan area's drought, one should describethe type of drought and itsimpact on the designated area over time.

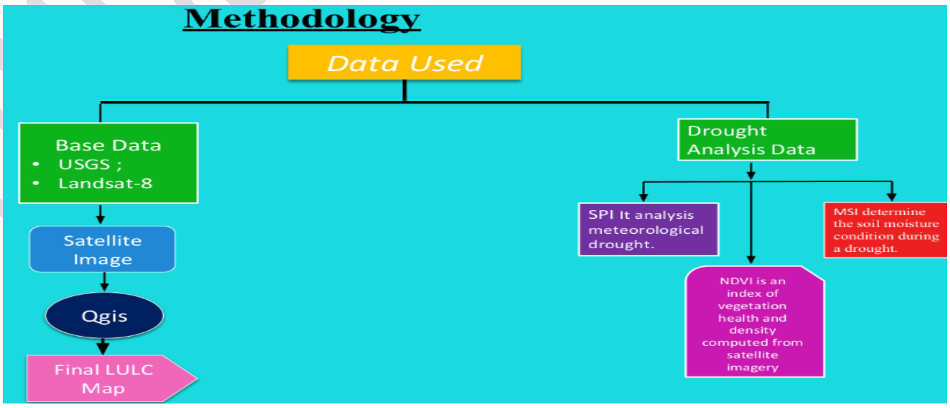


Fig. 2. The methodology applied in the present drought study

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,duringsurgedtemperature, wind, or precipitation). Drought disasters can be of four types. They are i) Meteorological,Hydrological,Agricultural and Socioeconomic Drought, Table 2.

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 depletefor less average rainfall for a long span	when the daily river discharge is ≤the daily variable threshold considering seasonality.	Meteorological drought orSoil moisture droughtimpacts 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	Negative fiscalImpacts on farming include less water availability, water quality, growth rates, rise in stress on vegetation, crop loss, affected plants, and

		evaporates moisture from soils and plants.	reduced yields.
Socioeconomic	The shortfallin supply and demand, Beingan agro-based country with 1.4 billion, droughts impactfarm 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 WRMngt, 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,desertificationurbanisation,topsoilloss,deforestation, oldfarmingpractices, Climate Change Natural Disasters, stripping ofthe 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.

3.1.1 Drought Indices

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

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

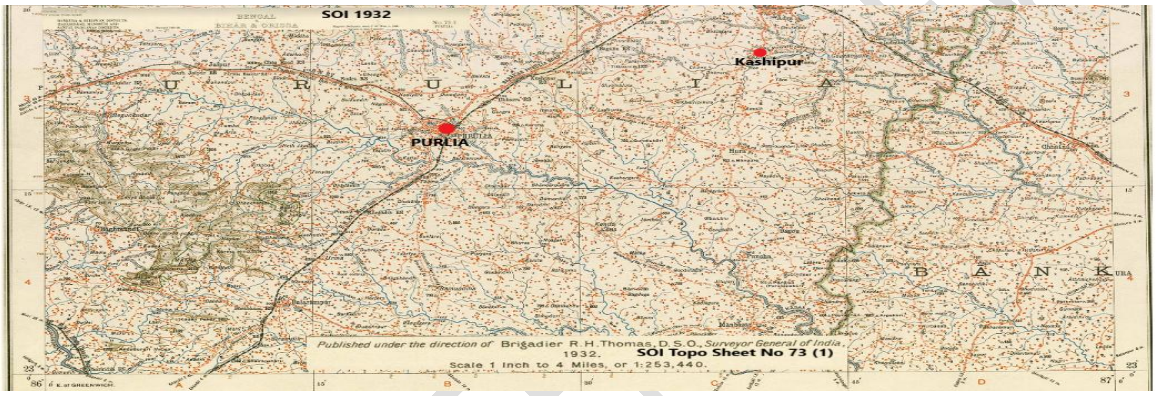
Index	Equation	Where	Classification
Drought Index (DI),	$DI = \frac{P - X}{\sigma}$	P= annual rainfall X =– Long-term mean; SD (σ) = Standard deviation	Categories;)*Light*, DI = < - 1.49 *moderate drought*, DI = < - 2.0 *severe* , DI = > -2.0 *very severe drought*
Based on the rainfall deficit (IMD), it is called SPI.	$AI = \left(PE - AE/_{PE}\right) * 10$	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 stateduring droughts	It is estimated by Knowingthe 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)	$NDVI = (NIR - R)/(NIR + R)$	NIR = near-infrared band, R = Red band;higher values of NDVI show less drought	An influential indicator thatmonitors vegetation cover and detects frequent incidence and persistence of drought
Vegetation Condition Index	VCI = (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.)

Other famousdrought indices (Dis) are i)the i) AridityAnomaly 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 usingthe standardized SPI method (Press report, 2012,WMO-No. 1090 in 2012). IMD uses Standardized SPI (SSPI) from 2013 and the Aridity Anomaly Index(AAI) (Guhathakurta 2016[26]). IMD has reinstated categories of (the SPI range) for an area withisa)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 the5th century A.D., the Jaina Bhagavati-Sutra reported that the Purulia area was among the 16Mahajanapadas (under Vajra-bhumi).The East-India Company, the Britishersobtained 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, Manbhum, with H.Q. at Manbazar, including Bankura, BurdwanfromW.B. and Dhanbad, Dhalbhum, from Bihar and Saraikelaof 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).

(a) 

(b) 

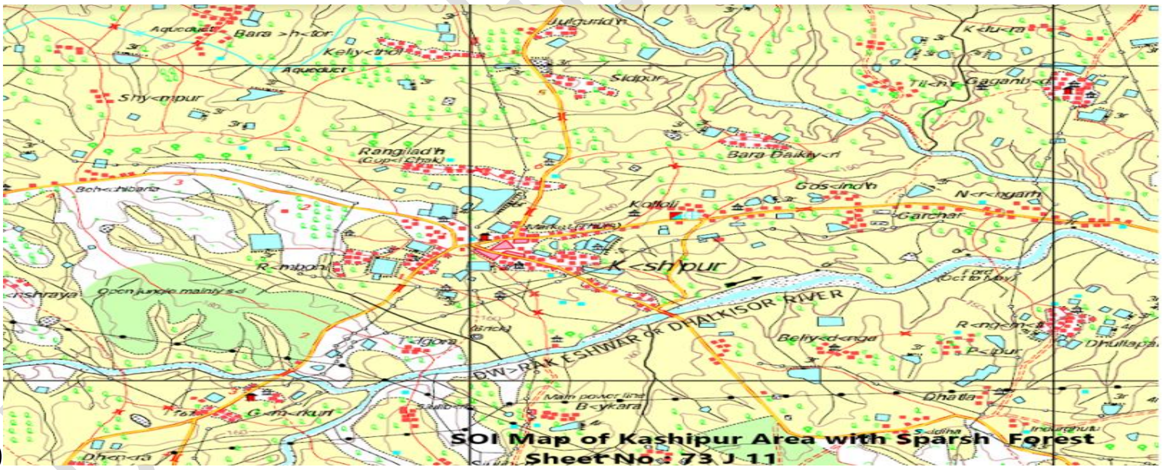
(c) 

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)

3.1.3 El Nino southerly Oscillation (ENSO)

ENSO phenomenon occurs irregularly, categorised as warm (El Nino) and cold (La Nina), ratherthan 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 ElNio-driven ENSO causes weather changes such as rainfall, floods, droughts, andtemperature and environmental anomalies in India and globally. They can even directly induce outbreaks of infectious diseases that threaten public health.

Considering Satelight 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).

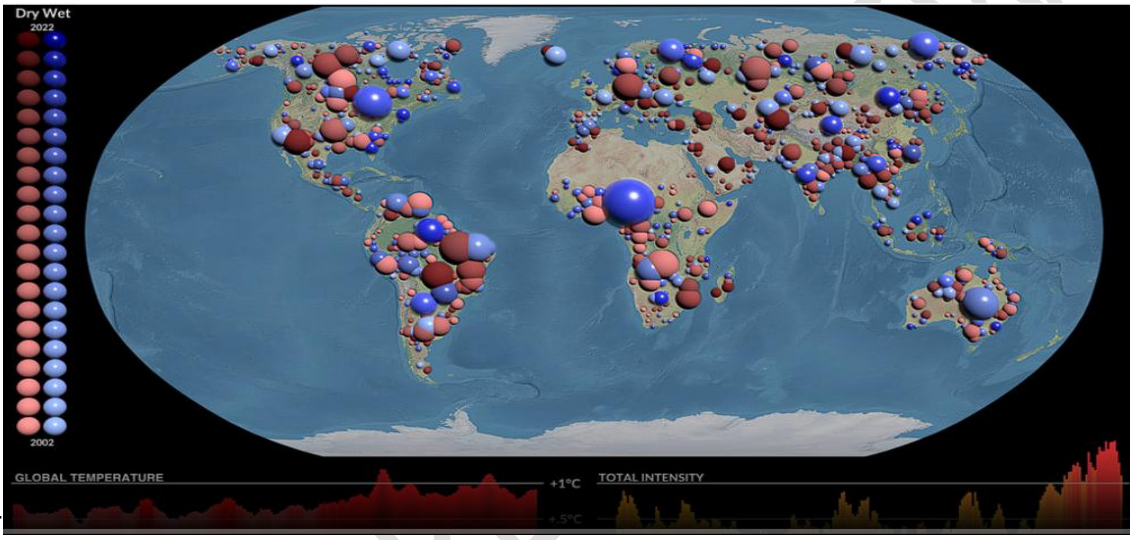


Fig.4(a). NASA, Water Cycle Extremes: Droughts and Pluvials, Updated: December 10th, 2023Visualizations by:Mark Subba Rao, (cons. by:Bailing Li and Matthew Rodell);

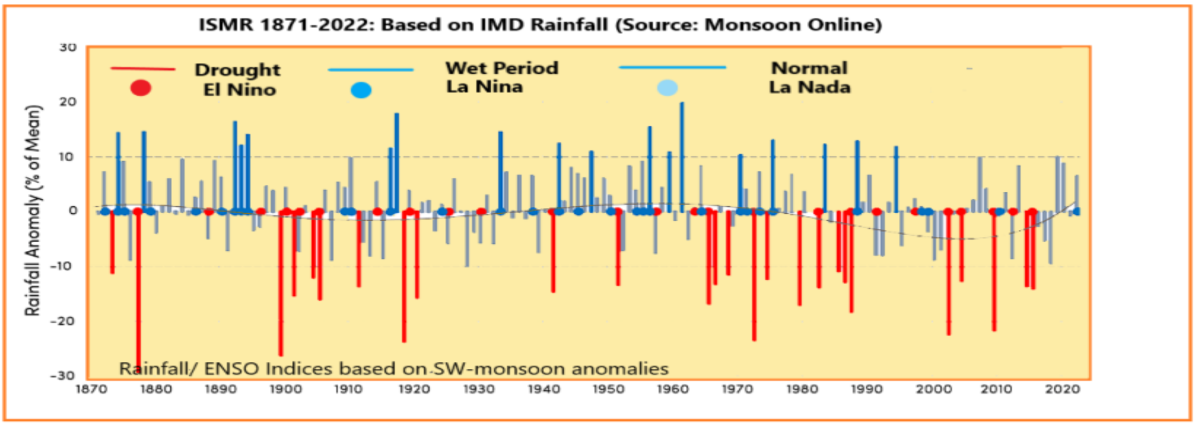


Fig.4(b). The Indian Summer Monsoon Rainfall Vs ENSO (1871 – 2022),(IMD data)

The study of the relationship between the ENSO and IBMR was more vigorous from 1901 to 1940, 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)(Mishra et al., 2017[27], Koll RM: IITM, 2023[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 seenwhere the Puruliadistrict is affected in Table 4.

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

SST anomalies	Years	Droughtseverity (21st 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 isa 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 (Hari et al., 2020[29]; Zhang et al., 202[30]).The (ITCZ') and Sea surface temperature play a vital role in monsoon rainfall in

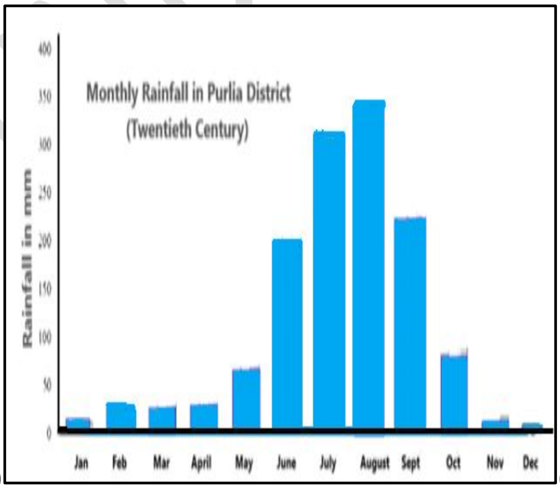
India. The monsoon trough, or ITCZ, is the convergence zone where northeast or southeast tradewinds meet.India encountered droughts/ Famines in the Puruliadistrict during the 17th, 18^{th,} 19th and 20thcenturies are 12 major famines (1769–1770, 1783–1784, 1791–1792, 1837–1838, 1860–1861, 1865–1867, 1868–1870, 1873–1874, 1876–1878, 1896–1897, 1899–1900, and 1943–1944) which led to the deaths of millions,(Fig. 5 (a & b) (Maharatna, 1992[31], Mallick et al, 2023[32]).From 1899 to 1920, India confronted 07 drought years, followed by 1941-1965,withthree 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. (Dunn and Dey 1942[33]).The area is mainly covered by laterite soil and represents undulating topography with moderate to gentle slopes, Fig. 5 (b).In thelaterite-covered area in Kashipur block, meteorological drought under climate anomalies invites droughts in agricultural regions,bullying food security (Goswami 2019[34], Bera et al., 2022[20])

3.2.3Climate

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 ^{0}C to 45^{0} C in Summer,makingthe climate moisture-deficient. S.W. monsoons provide significant rainfall. On rainy days, the R.H. (relative humidity)is75% to 85 %, but 25-35% in Summer, Fig 5 (b).

(a) 

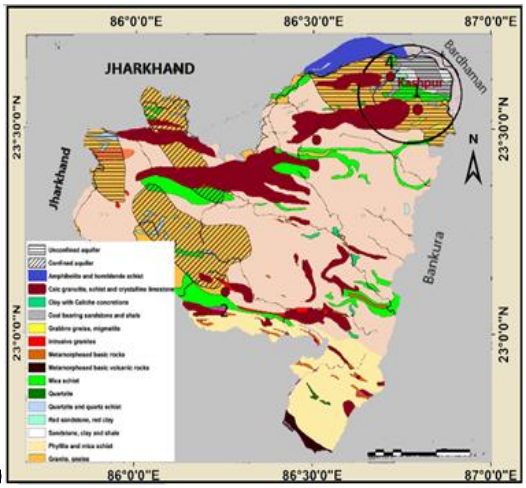
(b) 

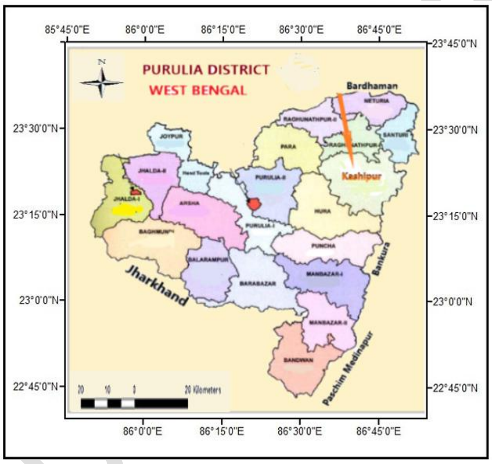
Fig. 5.a)Monthly av. rainfall (b) Geology map of Purulia dist.,(Adapted: Bera et al, 2023)

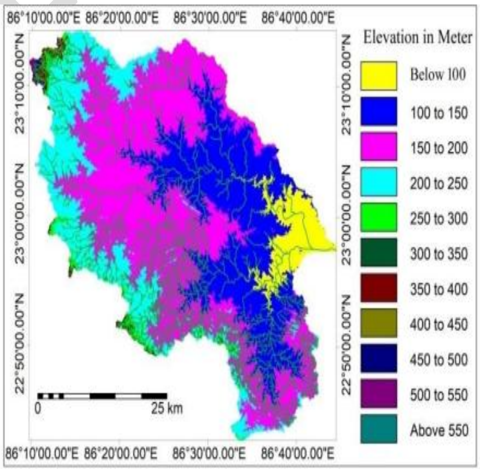
3.2.4 Soil

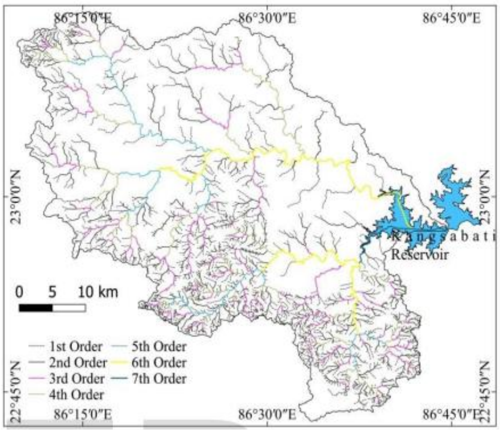
The soil of Purulia is red, alluvial soil, and Laterite soil. Red and laterite soil dominates the landscape, gradually merging with old alluvium in the East with gravelly patches. Thesoils of the block are acidic (Strong to modest). Electrical conductivity (E_c) is average (<1.0 dS/m). The Soil Organic 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(Pandiaraj et al., 2018[35];Mishra et al., 2018[36].Mahato et al., 2022[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).

(a) 

(b) 

(c) 

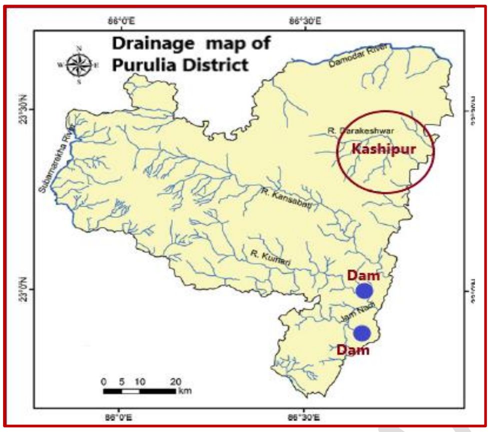
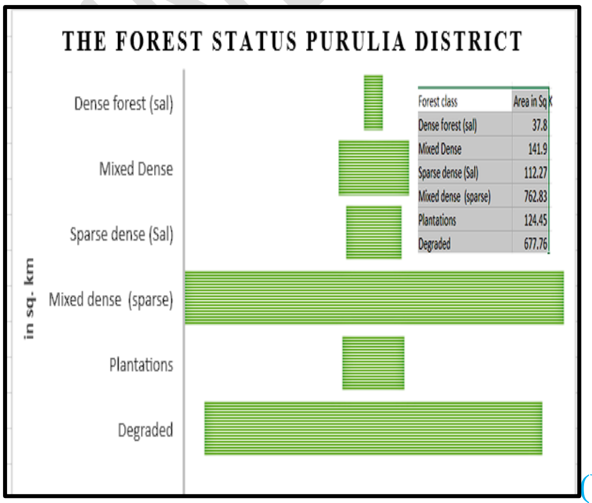
(d) 

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

Traversed by the Tropic of Cancer,Purulia (between 22º42'N and 23º43'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 km^2 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 asa 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 viridisL.(Khutura Sak, Khada Sag or JungaliChaulayi), Oldenlandiacorymbosa 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)



(b) 

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

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), (Mahato et al., 2021[23]), About 310sqkm area of Kashipur, in Raghunathpur-I, Para block, are less suitable zone covers for agriculture which warrants immediate rejuvenation (Bera et al., 2017[38}])

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)	Medium (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

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 Chhatnaand 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 calleda "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-bearingminerals in the crystalline gneisses, G.W.is often polluted with Fluoride much above the permissible limit(Nag et al., 2016[40], Kundu et al., 2018[5])

3.3.4 Irrigation

Until Independence, irrigation (Diversion Schemesonly) ontheKangsabati 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.

3.4Drought Frequency and Severity

The apocalyptic famine that caused famine in Bengal province (including West and East Bengal during 2ndWorld War, in the year 1943 was 1332209(registered deathsdue to famine (Maharatna's thesis 1992[31], Page-220). The Kashipur block witnessed famines, The Great Bengal Famine (1769-70), The Odisha famine *(NaankaDruvikhya, 1966),*Bihar famine (1873-1874) and The Bengal Famine (1943) when the Kashipur block was worst affected.

Table 6. The categories of droughts and severity in(Purliadist) 20th& 21stcentury

Type of drought/ Monsoon period	Very Severe (years)	Severe (Years)	Moderate (years)	Mild droughts
Premonsoon (April to June);	1922, 1953, 1966 (Nil in 20th 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, Bala-rampur, Jagannathdi, Jamkiri, Lara Jibonpur,

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.

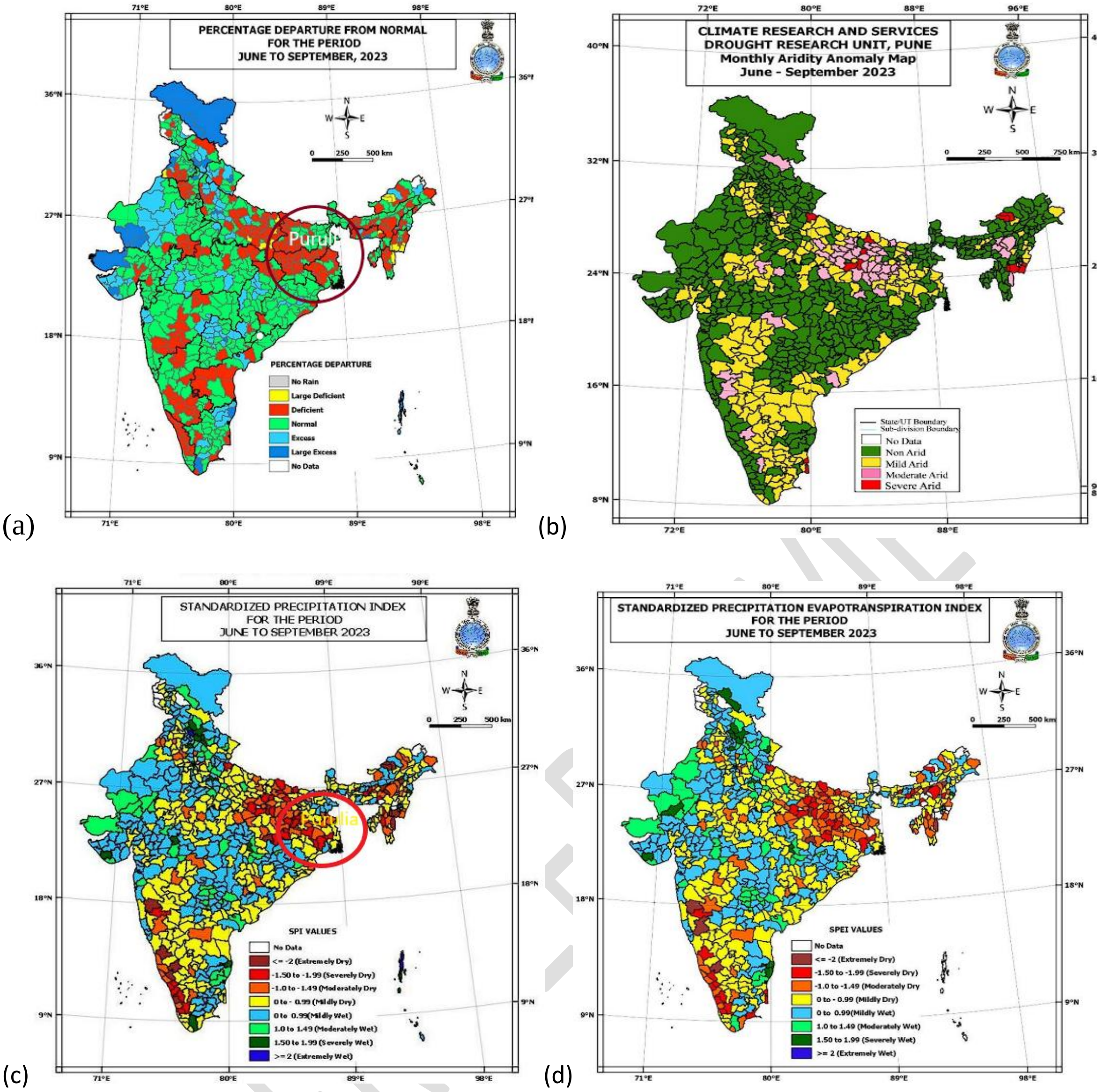


Fig.8. Drought position during June to Sept 2023; (a)Rainfall departure (%) from Normal (June to Sept. 2023)(b) Mild drought Purulia 2023 as per AAI; (c) Mild drought in Purulia District (SPI) ; (d) Standardized Precipitation Evapotranspiration Index (SPEI) (Source IMD)

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. 2019[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 876Km^2 of forest area (2015-16), which has surged to an area of

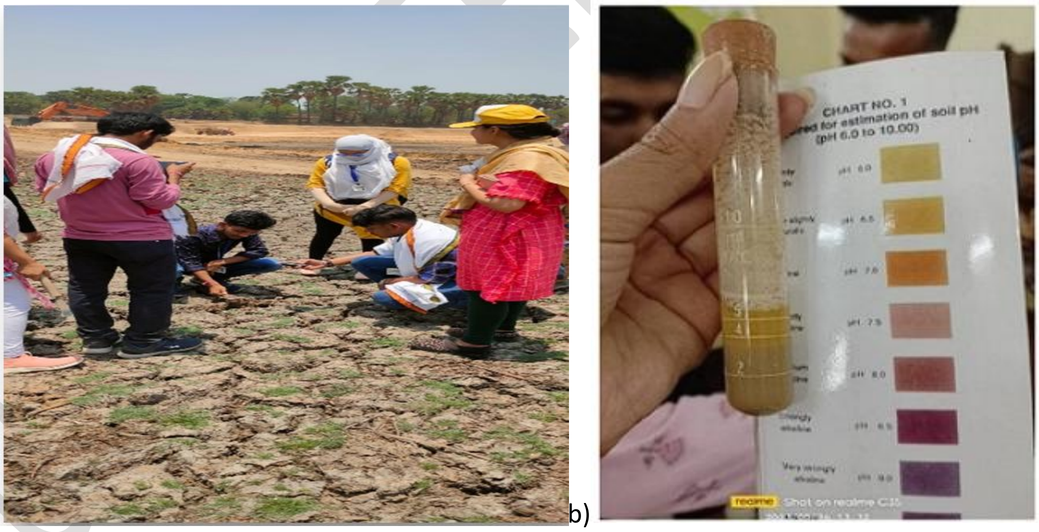
1153.21 $Km^{2,}$ including social forestry by 2023. The district is under food insecurity related to a lack of employment opportunities and livelihood. Vulnerability may be assessed regarding multiple factors/indicators, exposing people to food insecurity through reduced availability, access and utilisation. 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, unsanitisedareas, lack of healthcare facilities, poor education poverty and less attention from Govtsubsidies.

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.

a)


b)

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

Soil moisture is the primarywater 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 shallnot improve growth or Yield. (Fig.10 a and b and Table 6)

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	Nearlyacidic	>5.0%	Ginger,Turmeric
S-3	2325350N/6842329E	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 adrought-proneWest Bengal district with high rainfall variability and extreme temperature conditions. The Kashipur block from Purulia comprisesa 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 the Purulia block, andthe Dwarakeswar River can yield higher Rabi crops. The annual rainfall in Purulia is less,and the crop yield is more stable in Purulia withfewerwater-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 duringdrought 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. Thedroughtsin independent India have replaced faminewith moisture stress or rainfall deficiency, which causes crop failure. Thesignificant droughts after India's Independence are in Bihar (1966-67), Maharashtra(1972and 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 changeand 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 bedue toanthropogenic 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 (Kundu et al., 2019[42]). The shallow rupture zones in the district can hold water and become dry quickly, resulting in less recharge of the groundwater aquifer (Sarkaret al., 2023[43])

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

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

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 gulley 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.

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, 2021[44]

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)

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

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 planningand 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 patternsas per agriculture advice with proper crop planning using energy-efficient models and indigenous Knowledge centres.
- As the target area is onthe 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 optionsto be added with bovine or livestock/beekeeping, fish culture, perennial/medicinal trees, floriculture and other microenterprise options.
- Climatechangein land use and cover patterns, considering topography, soil depth, and water availability, should be considered when introducing climate-smart agriculture (Mishra et al., 2020[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

Hazardsand 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 changepromoted by global warming is aperilous ecologicalproblemlinkedtooverall development and economic growth.

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

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