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Impact of Climate Change on Agricultural Sector of a Drought Prone Area: A Case of Bargarh District, Odisha

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Abstract: Global climate change is a process that affects every one of us differently. Significant climate changes have been seen throughout the past century. The life of more than 700 million people in rural India depends on climate-sensitive businesses like agriculture, forestry, and fisheries as well as on natural resources like water, feed, and biodiversity. Today's climate variability-related uncertainties pose serious threats to global economic growth. This paper aims to analyse how climate change causes drought in an area and how drought has its impact on agricultural sector and production. Drought is caused due to deficiency of rainfall and it is a complex natural hazard. Unlike other environmental disasters, it starts slowly, has its effect for a longer duration of time and covers a vast area. In India, it upsets the country's food security by seriously affecting our agricultural economy, which is heavily dependent on monsoon. Drought causes economic, social and environmental loss quite frequently. Management of drought needs proper storage and usage of rain and ground water in drought prone areas. Drought assessment is very important to manage water resources in lean period. It plays a vital role in managing water demands especially in agriculture sector. In the present study, monthly temperature and rainfall data for 35 years (i.e., 1985 to 2020) were collected and analysed for drought assessment. The dry spell periods were calculated using agricultural drought indices i.e. spatial rainfall on monthly basis and Soil Moisture Index.
Keywords: Climate variability, Drought management, Dry spell, Soil Moisture Index, Spatial rainfall on monthly basis

I. INTRODUCTION

India is basically an agrarian country where over 700 million people directly dependent on climate sensitive sector like agriculture, fisheries, etc. Due to change in climate, many climates extreme events happen like flood, drought, cyclone, and others hydrological disaster. Because of distinct Geo-climatic and socio-economic characteristics of Odisha, it has been prone to several natural as well as human-caused calamities to varying degrees. Food production system is extremely sensitive to natural calamity's life flood, drought, cyclone etc. The impacts of natural disasters on agriculture and the natural resources and environmental sectors can be direct or indirect. Agriculture is primary objective in rural areas. Most people are dependent on the agriculture sector to increase the livelihoods. In the last 20 years western Odisha has faced 11 times severe drought condition, due to productive capacity over the year gradually decreasing. Bargarh is one of the districts in Western Odisha, where 70% of the total population depends upon agriculture and agro based production. The present study attempts to examine the impact of climate change on agriculture of the drought prone district. Bargarh district is one of the districts in western Odisha which is severely affected by Cyclone and flood. Occurrence of Cyclone is very less as compared to drought still District Disaster Management plan of the district mainly focuses on measures for cyclone. In Bargarh district, Paddy is mostly grown and the water requirement for the crop is extremely high. Because of drought, the productivity of the paddy crop was being affected by the years. Agriculture and livelihood of rural population was mostly affected by the drought. The occurrence of drought is relatively high in Bargarh district (14 times) due to low rainfall which increases the number of dry spell days in the summer season. There has been a decrease of 33% of annual rain fall rate in last 35 years. The impact of drought is highest in Bargarh district as compared to other drought prone areas, affecting 47% of the crops especially paddy which is a kharif crop, due to scarcity of water.

II. STUDY AREA

Bargarh District lies in the western most corner of Odisha between 20°43" to 21°41" North Latitude and 82°39" to 83°58" East Longitude. The District is surrounded by the State of Chhattisgarh on the North, Sambalpur District on the East, Balangir and Subarnapur Districts on the South and Nuapada District on the West. The geographical area of the Bargarh district is 583400 ha (5834 sq.km) and 59.77% of the geographical area belongs to the cultivated area i.e., 348740 ha. (3487.40 sq.km).

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The district is having a total population of 14, 81,255 which is 3.38% of the entire district of the entire state. Out of the total population of the district the rural population is 13, 31,145 (89.86 percent) and urban population is 1, 50,110 (10.14 percent). In Bargarh district, out of the total population, 762092 (51.4%) people belong to working class group out of which 577083 (76%) people depends upon agriculture sector as their livelihood.

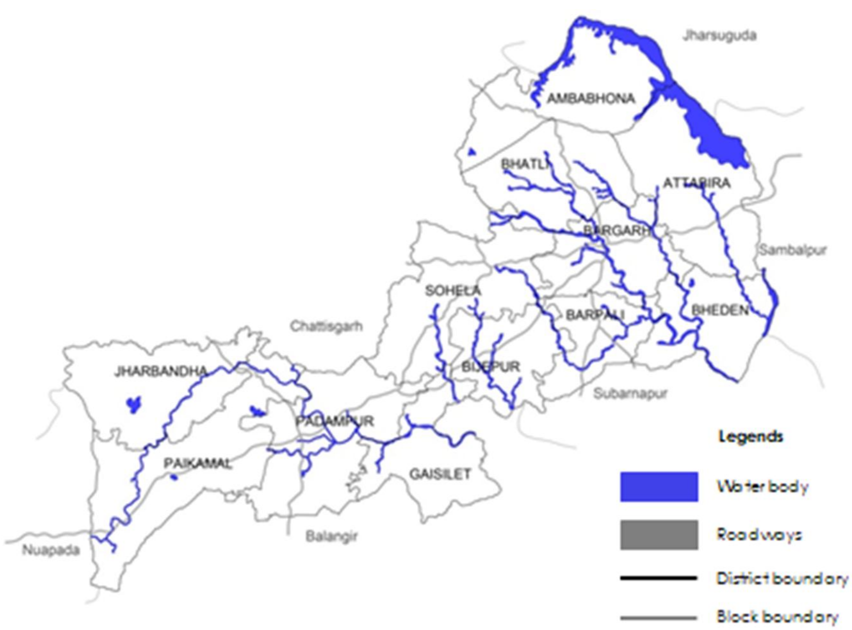
Table 1. Study area profile

STUDY AREA PROFILE	
Study Area	5834 sq.km.
No. of blocks	12
Total Population	14, 81,255 (Census 2011)
Urban Population	1, 50,110
Rural Population	13, 31,145
Total working Population	762092
Population dependent on agriculture	577083

Table 2. Bargarh district climatology

BARGARH DISTRICT CLIMATOLOGY	
Climate	Tropical climate
Avg. Annual Maximum Temp.	41 °C
Avg. Annual Minimum Temp.	12 °C
Avg. Annual rainfall	1367 mm
Avg. Annual Humidity	65%

The climate in Bargarh District is harsh, with a hot, dry summer followed by a humid monsoon and a chilly winter.The temperature varies between 10 ° Celsius and 46° Celsius. The winter season lasts between November and February. After that, the hot season begins and lasts through the second week of June. The south-west monsoon season is from mid-June to the end of September. The average annual rainfall in the District is 1367 mm. During summer temperature varies from 35° to 45°C. May is the hottest month with the maximum mean daily temperature of 41°C. In winter temperature varies from 9 to 27°C. December is the coldest month of the year. The relative humidity is varying from 14% to 92% during summer and monsoon. The average humidity during summer is 25% to 30% and in monsoon 75%.



Map 1: Map of Bargarh District

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III.LITERATURE STUDY

A. *What is drought?*

Drought is a natural calamity caused by weather. For months or years, it affects large areas. It affects food production and life expectancy, as well as the economic performance of big regions or countries. Drought is a common occurrence in the climate. It can be found in almost all climatic zones, and its properties vary greatly between areas. Drought is a natural hazard. It is caused by a lack of precipitation over a long period of usually a season or longer. There is a water deficit for some activity, group and environmental sector as a result of this insufficiency. Drought is also linked precipitation timing. Drought is frequently linked with other climatic conditions such as high temperature, high wind, and low relative humidity.

B. *Types of drought*

1) *Meteorological or Climatological Drought:* It is defined in terms of the magnitude of a precipitation shortfall and the duration of this shortfall event. Meteorological Drought is based on the degree of dryness or rainfall deficit and the length of the dry period.
2) *Agricultural Drought:* It refers to the consequences on agriculture by factors such as rainfall deficiencies, soil water deficits, reduced ground water, or reservoir levels needed for irrigation. With a focus on precipitation deficits, differences between actual and potential evapotranspiration, soil water deficits, decreased groundwater or reservoir levels, and other factors, agricultural drought connects various meteorological (or hydrological) drought characteristics to agricultural impacts.
3) *Hydrological Drought:* It is based on how rainfall deficiencies affect many aspects of the water cycle, including stream flow, lake and reservoir levels, and groundwater table drop. Hydrological droughts are not directly related to precipitation shortfalls; rather, they are related to the effects of periods of precipitation shortfall on the surface or subsurface water supply.

C. *Indicators of drought*

4) Indicators are variables or parameters used to describe drought conditions.
5) Precipitation, temperature, stream flow, groundwater and reservoir levels, soil moisture, and snowpack are all drought indicators.

D. *Indices of drought*

Indices are typically computed numerical representations of drought severity, assessed using climatic or hydro meteorological inputs including the indicators listed above. They aim to measure the qualitative state of droughts on the landscape for a given time period. Indices are technically indicators as well. Identification of short-term wet periods within long-term droughts or short-term dry spells within long-term wet periods is made possible by monitoring the climate at different timescales. Indices can help users communicate effectively with a variety of audiences and users, including the general public, by demystifying complex relationships. The severity, location, timing, and length of drought occurrences are all quantitatively assessed using indices.

Agricultural drought indices:-

1) *Spatial rainfall on monthly basis*

Spatial rainfall input helps to find the level uncertainty of rainfall in the monsoon season. Spatial rainfall gives the information of the number of dry and wet days in the monsoon period and intensity of rainfall during this period. Dry spells are defined as extended periods of dry days. Dry spells happen due to insufficient rainfall during the rainy season i.e. having no rainfall or rainfall less than 10 mm in a day.Spatial rainfall determines the precipitation level that can help to forecast and monitor drought.

2) *Spatial soil moisture index*

Soil moisture plays an important role in agricultural monitoring, drought and flood forecasting, forest fire prediction, water supply management, and other natural resource activities. Observations of soil moisture can predict impending drought or flood conditions before other, more conventional indicators are set off. Surface Soil Moisture (SSM) is the relative water content of the top few centimeters soil, describing how wet or dry the soil is in its topmost layer, expressed in percent saturation. According to surface soil moisture levels the drought area taking agriculture into consideration can be divided into 3 categories :-

- Severe agricultural drought- 50% or more reduction in crop area with major reduction in crop yield.
- Moderate agricultural drought- 25% -50% reductions in crop area, poor moisture levels of crop vegetation, significant reduction in crop yield.
- Mild agricultural drought- 10%-25% reduction in crop area and slightly reduced greenness of crops leading to slight reduction in crop yield.

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IV. DATA COLLECTION & ANALYSIS

A. To study and identify the reasons of climate change that is responsible for drought.

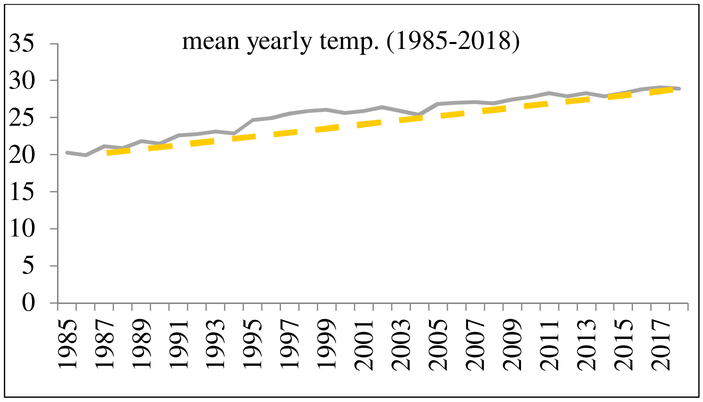


Fig. 1: 35 years temperature variation of the district

This graph shows an estimate of the mean annual temperature for the larger region of Bargarh. The dashed yellow line is the linear climate change trend. The trend line is going up from left to right, the temperature trend is positive and it is getting warmer in Bargarh due to climate change. There has been an increase of 10% of annual mean temperature in last 35 years. The district receives rainfall from South–West monsoon. The average annual rainfall in the district is 1367mm. There has been a decrease of 33% of annual rain fall rate in last 35 years. This graph shows an estimate of the mean annual precipitation level for the larger region of Bargarh. The dashed yellow line is the linear rainfall change trend. The trend line is going down from left to right, which shows that the precipitation trend is negative and there is scarcity of rainfall in Bargarh due to climate change.

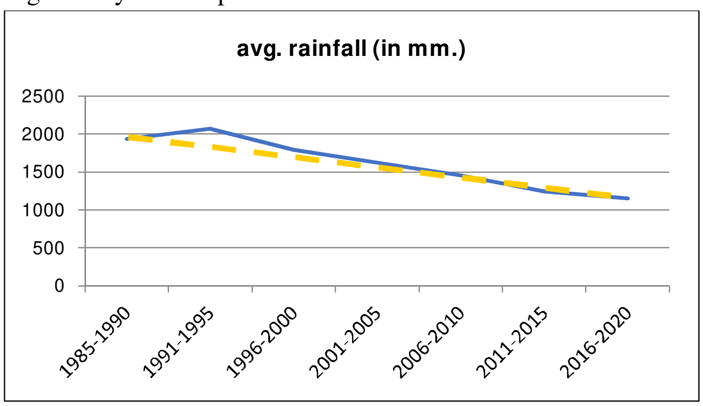


Fig. 2: Average rainfall over the last 35 years

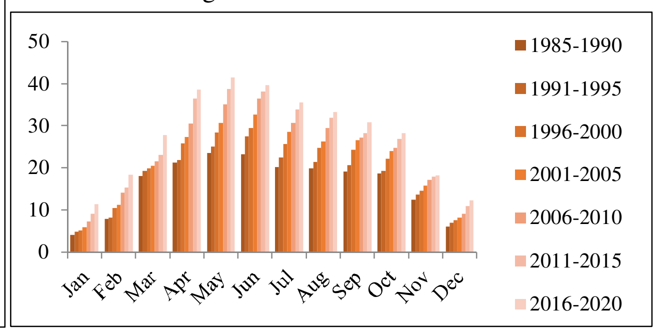
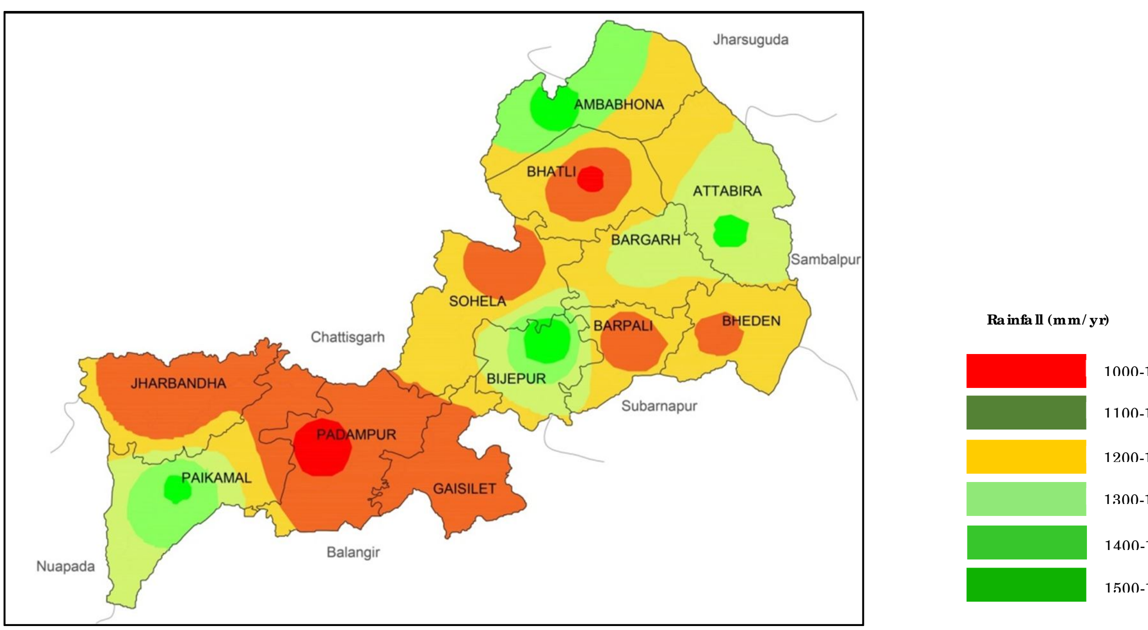


Fig. 3: Monthly temperature variation of the district in last 35 years

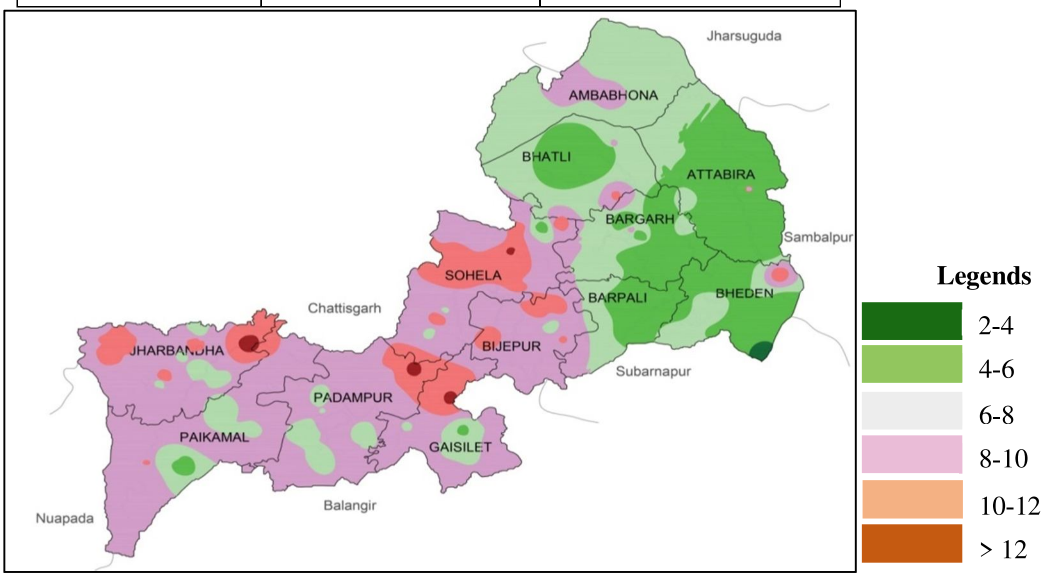


Map 2: Rainfall variation of the district

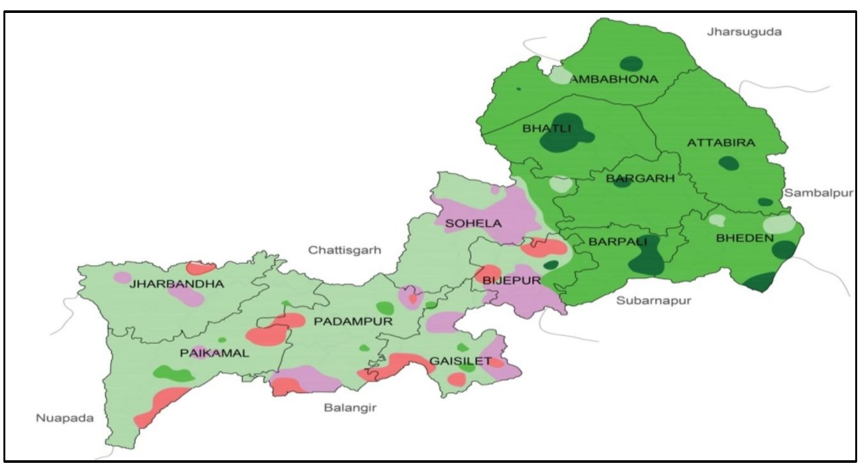
The Depth to water level in pre-monsoon period (May 2019) varies from 1.37 mbgl to 11.0 mbgl having the average being 5.8mbgl. Depth to water level in post-monsoon period (Nov 2019) varies from 1.15 mbgl to 7.20 mbgl the average being 3.13 mbgl.

Table 3. Ground water level

Block	Pre- monsoon	Post-Monsoon
Ambabhona	6.13 m	5.16 m
Attabira	5.98 m	5.03 m
Bargarh	6.02 m	4.24 m
Barpali	5.89 m	5.12 m
Bhatli	6.09 m	5.88 m
Bheden	5.53 m	4.98 m
Bijepur	8.01 m	6.96 m
Gaisilet	8.24 m	7.54 m
Jharbandh	8.04 m	6.25 m
Padampur	8.61 m	6.04 m
Paikmal	8.13 m	6.99 m
Sohella	8.33 m	6.14 m



Map 3: Pre monsoon ground water level



Map 4: Post monsoon ground water level

B. To Study And Analyze The Parameters Of Drought And Its Impact On Agriculture

Drought is a chronic and passive issue in Odisha's Bargarh district. The district's backwardness is mostly due to its periodic drought.

INFORMATION REQUIRED FOR DROUGHT ASSESSMENT AFFECTING CLIMATE

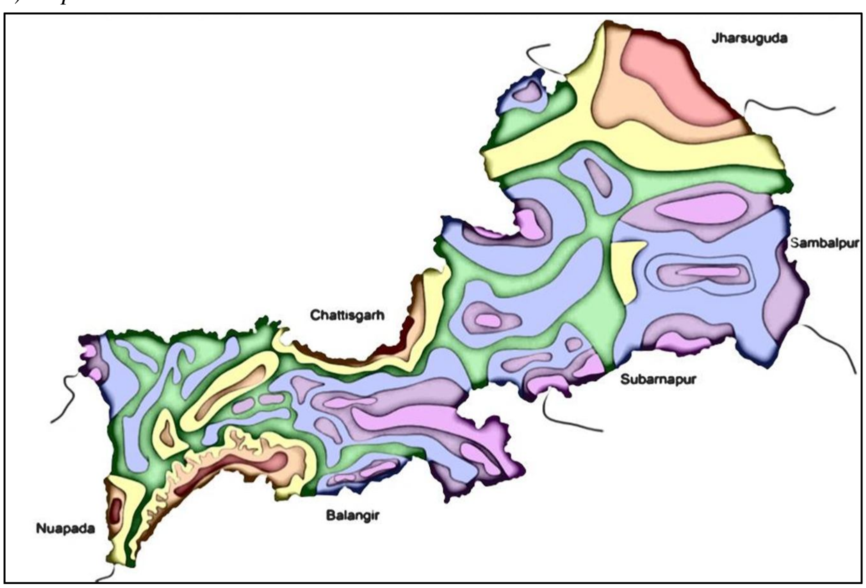
1) Spatial Rainfall on Monthly Basis

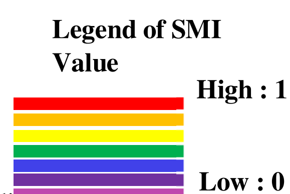
Table 4. Dry spell in the drought years

Year	2015		2017		2020	
Monsoon months	Dry spell (in days)	Total rainfall during dry spell (in mm)	Dry spell (in days)	Total rainfall during dry spell (in mm)	Dry spell (in days)	Total rainfall during dry spell (in mm)
June	21	89.45	23	141.23	20	87.28
July	17	114.56	19	112.11	19	131.89
August	19	127.73	14	80.14	18	109.86
September	16	109.64	18	121.57	23	98.67

The variation in the distribution of rainfall over time results in drought, abnormal and normal rainfall in different years. In the last 5 years, there has been occurrence of drought three times. The time scale rainfall data of those three years was taken to observe the dry spell which happened at Bargarh district during June to September. It is observed that 50-60 percent of the month remains in dry spell having no rainfall or rainfall less than 10 mm in a day. Therefore, insufficient rainfalls lead to drought conditions and negatively impact crop growth and yields. An optimal amount of rainfall is necessary for optimal crop growth and yields. Drought conditions can lead to soil moisture stress, causing plants to wilt, and reducing crop yields.

2) Spatial soil moisture index





Map 4: Soil moisture index map of Bargarh district

The index values range from 0 to 1 with 0 indicating extreme dry condition and 1 extreme wet condition.

The soil moisture index in the north east and south west districts are in good condition due to geographic profile of the district.

While rest of the district have low water content in the top layers of the soil contributing to drought which affects the agricultural production of the district.

Due to variation in surface soil moisture of the district, the drought area can be divided into 3 zone:-

- Severely affected
- Moderate affected
- Mild affected

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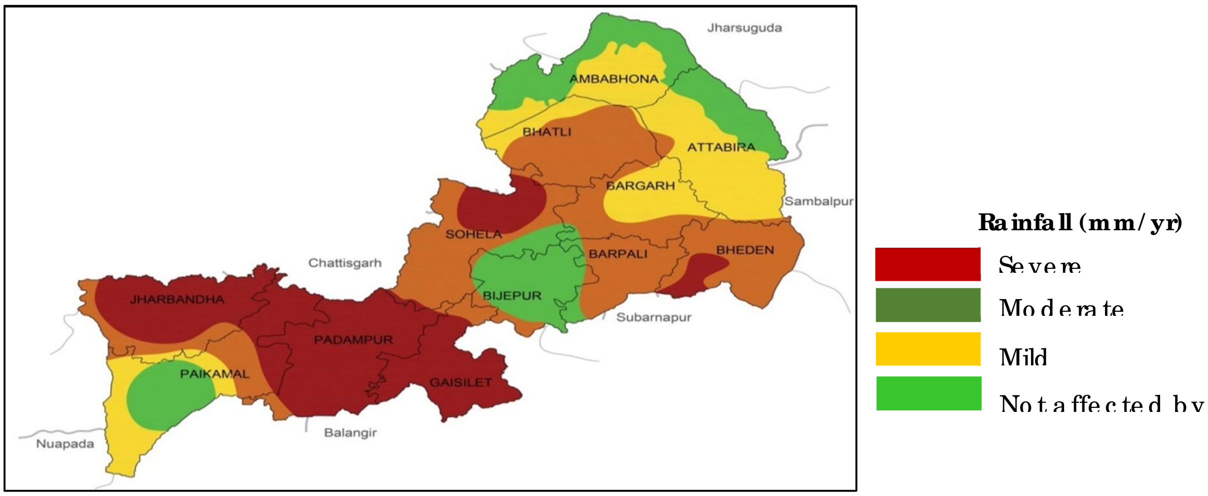
3) Drought profile of the district

Table 5. Year of drought occurrence

Frequency of Drought (1985-2020)	
Moderate Drought	14
Severe Drought	05
Season wise monsoon deviation from normal	-27%
Drought situation	2nd worst affected district (47.3% agriculture loss)
Year of drought occurrence	1987, 1992, 1995, 1998, 2000, 2002, 2003, 2005, 2009, 2011, 2015, 2017, 2018, 2020



Map 5: Area affected by drought

Table 6. No. of village affected by drought

No. of village affected by drought					
Year	1995	2005	2015	2017	2020
Number	332	451	486	538	564

Table 7. Agricultural area affected by drought

Block	Block Area (in sq.km)	Total agricultural Area (in sq.km)	Area affected by drought
Ambabhona	605 (10.3%)	223.73	42.50(19%)
Attabira	629 (10.7%)	287.76	69.06(24%)
Bargarh	694 (11.8%)	316.43	34.80(11%)
Barpali	286 (4.9%)	238.45	90.61(38%)
Bhatli	427(7.3%)	260.30	78.09(30%)
Bheden	371 (6.3%)	301.50	132.6(44%)
Bijepur	322 (5.5%)	274.00	-
Gaisilet	322 (5.5%)	237.10	170.7(72%)
Jharbandh	635 (10.8%)	255.70	150.8(59%)
Padampur	307 (5.2%)	239.79	191.8(80%)
Paikmal	594 (10.1%)	378.85	-
Sohella	445 (7.6%)	373.65	168.1(45%)

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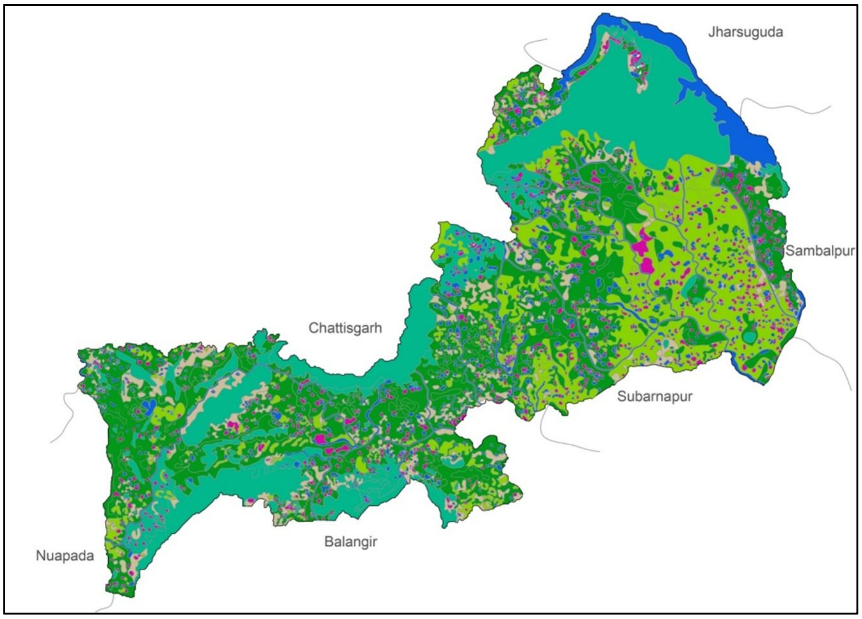
The impact of drought is higher in Padampur block followed by Gaisilet and Jharbandh. There has been significant loss of crop area in the study area due to drought. The blocks like Bijepur and Paikmal doesnot experience agricultural drought due to sufficient water available for irrigation from River Mahanadi and canal water supply from Nuapada district, respectively.

C. To Study And Analyze The Total Agricultural Production And Its Decline Over The Years Due To Drought

1) Agricultural profile of the district

The map below shows the significant reduction of agricultural land in the last 35 years.



Agricultural area – 3851.40 sq.km

Forest area – 820.10 sq.km

Barren Land – 103.95 sq.km

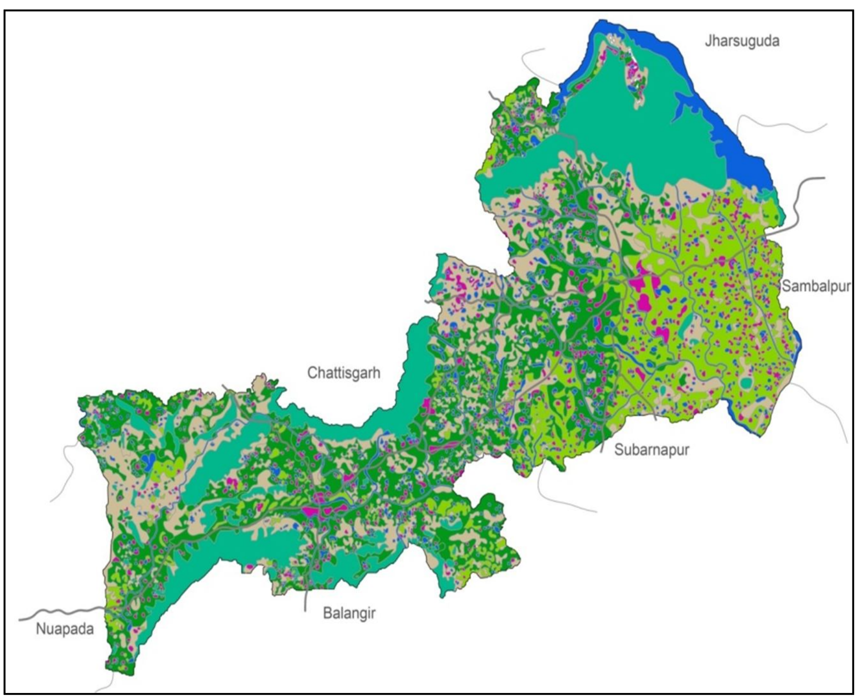
Water bodies – 525.06 sq.km

Settlements – 534.18 sq.km

Existing land use

- Agricultural area
- Forest area
- Barren Land
- Waterbodies
- Settlements

Map 6: Distribution of agricultural areas in 1985



Agricultural area – 3487.40

Forest area – 700.08

Barren Land – 233.36

Water bodies – 525.06

Settlements – 875.10

Map 7: Present distribution of agricultural areas

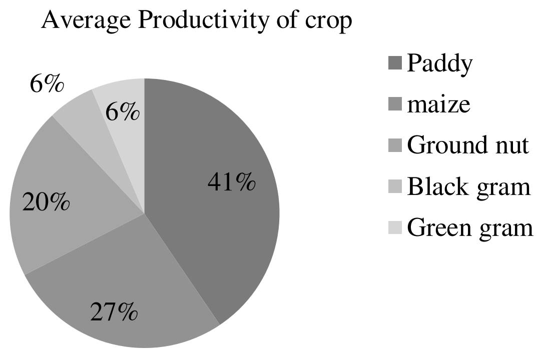


Fig. 4: percentage of productivity of crops (2020)

Table 8. Average productivity of crops

Major field crop	Cultivated area (in ha)	Productivity in kg/ha
Paddy	972	1833
Maize	93	1217
Groundnut	24	925
Black Gram	79	255
Green gram	48	290

Table 9. Comparison of avg. agricultural production (1985-2020)

Block	Agricultural production (1985-1995) in kg/ha	Agricultural production (1996-2009) in kg/ha	Agricultural production (2010-2020) in kg/ha	Remarks
Ambabhona	128	125	126	Decrease
Attabira	255	253	251	Decrease
Bargarh	302	298	309	Increase
Barpali	240	235	198	Decrease
Bhatli	178	167	114	Decrease
Bheden	184	174	146	Decrease
Bijepur	308	321	329	Increase
Gaisilet	116	101	81	Decrease
Jharbandh	109	97	74	Decrease
Padampur	101	89	68	Decrease
Paikmal	165	162	173	Increase
Sohella	223	207	179	Decrease

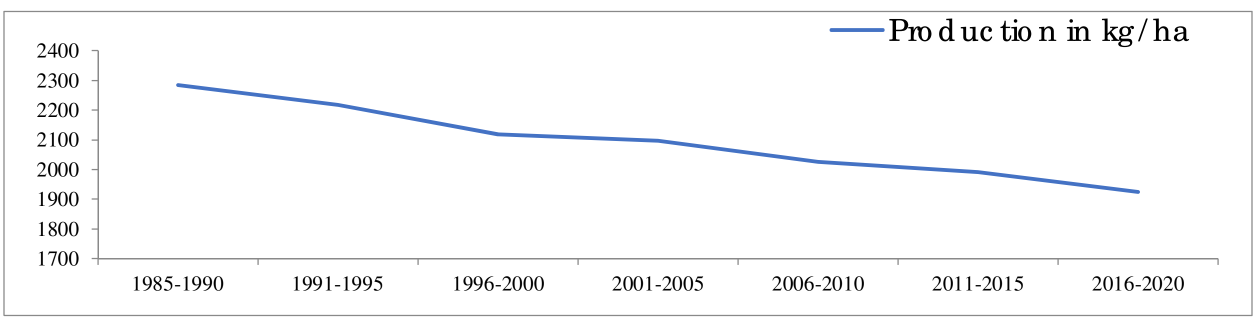


Fig. 5: Declination of productivity of crops

Table 10. Damage in area and productivity of crops

Year of drought occurrence	Cultivated area (in hectares)	Damaged area (in hectares)	Area damaged (in %)	Estimated crop production (in MT)	Crop produced (in MT)	Crops damaged (in MT)	Crop damaged (in %)
1995	435687	92578	21.2%	965918	737512	288406	28.6%
2005	409825	105235	25.67%	816371	595681	220690	30.6%
2015	401582	109891	27.36%	785494	554856	230638	29.3%
2017	395236	119852	30.02%	760038	649103	110935	24.5%
2020	362765	124109	34.21%	675831	498423	17408	26.2%

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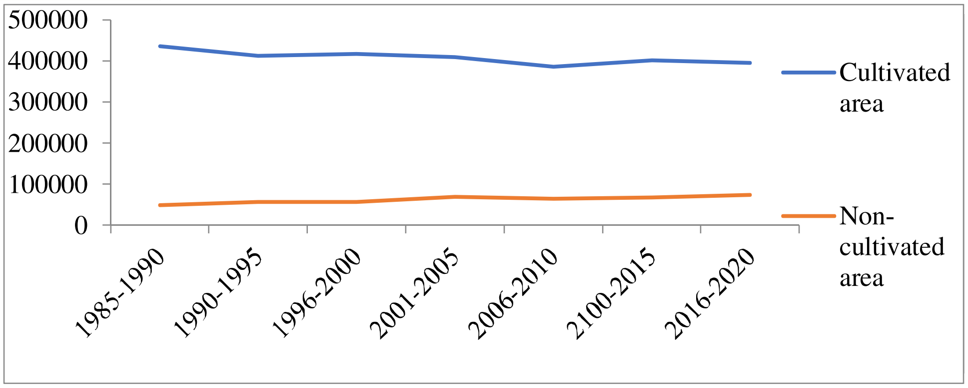

Fig. 6: Declination of cultivated area and increase of non-cultivated area in the district

As, the cultivated area of the district is decreasing over the time, there is a decrease in the annual production of crops as well due to drought by 21% in last 35 years.

Paddy is the major crop in Bargarh district, but as paddy cultivation requires a lot of water, the production of paddy is decreasing at a rapid rate.

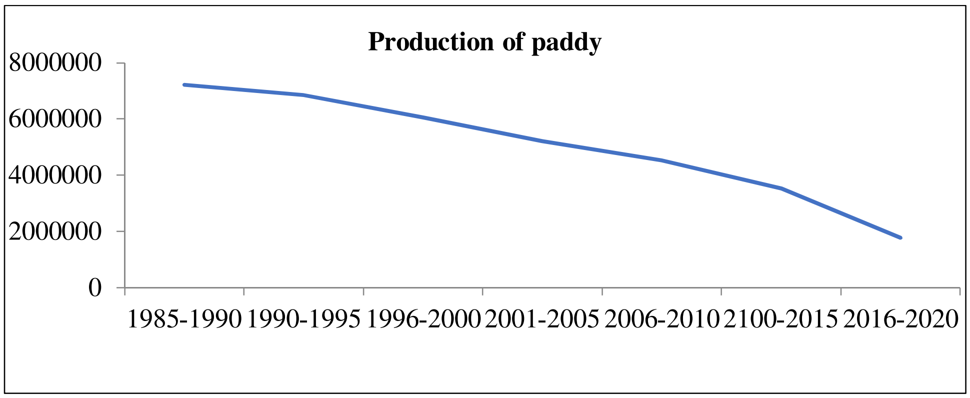

Fig. 7: Decrease in paddy production in last 35 years

There is a decrease in the cultivated area by 33% and increase in non-cultivated land by 48% from 2000 to 2022 due to non-availability of adequate water for irrigation.

Bargarh was once known as the rice bowl of India as it produced rice and exported to other states. But, in the last few decades there has been a significant fall in the production of paddy due to drought. The farmers of Bargarh have switched paddy cultivation to other food product cultivation due to climate change and economic demand as well. In 1985, the total cultivated area for paddy was 3068 ha and the total production was 2350 kg/ha but, In 2019, the total cultivated area for paddy had decreased to 972 hectare while productivity was1833 kg/ha. There has been decrease of 32% of area cultivated for paddy. Due to climate change there has been decrease in water availability which impacts the production of paddy which is dependent on water throughout its cultivation process. The farmers and cultivators due to shortage of water area switching from paddy cultivation to other type of cultivation like cauliflower, corn etc.

D. Inferences Derived

From the above study and data analysis it is derived that climate change plays a vital role for an area to be called as drought prone area. Factors of climate change like Precipitation, Temperature and surface water are responsible for agricultural drought.

In the study area, it is derived that some parts of Bargarh district are majorly affected by drought (Gaisilet, Jharbandh and Padampur) while some part are moderately affected by drought (Bheden, Sohella, Bhatli and Barpali). This uneven distribution of drought is due to uneven rainfall over the district which affects the surface soil moisture that is responsible for good crop yield. While, Bargarh block, Attabira, Bijepur and Paikmal is not affected by drought as these area is directly benefited from Hirakud dams and various canal projects for irrigation.

V. RESULT AND RECOMMENDATIONS

A. Results

To suggest measures and recommendation to minimize/ mitigate the impact of climate change on agricultural sector few proposals has been made. They are:-

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1) *PROPOSAL-1:- Implementation of new or existing irrigation system by using water sensitive planning techniques.*

a) Proposal of new canal system and renovation of existing canal systems.
- Proposal of drip irrigation system
- Proposal of dug out sunken ponds
- Proposal of detention basins

b) Implementation of new agricultural techniques to increase production.
- Cover cropping
- Crop rotation
- Rice- Fish Farming

c) Artificial recharge systems through MGNREGA scheme in community level and individual level

2) *PROPOSAL-2:- Drought risk governance*

d) Conducting training programs

e) Working out on Crop Contingency Plan for providing agriculture subsidy to the farmers like seed subsidy, fertilizer subsidy etc.

B. Recommendations

1) Proper water management and storage in dams/reservoirs
2) Managing the watershed and following water rationing
3) Select the right crop that requires less water in drought-prone areas
4) Implementing soil-conservation techniques
5) Afforestation and reduction of firewood usage
6) Use alternative land models for water preservation
7) Training people on water conservation
8) Modifying cropping patterns and selecting drought-resistant crop variants
9) Employing better grazing patterns
10) Planting more shrubs and trees
11) Protecting surface water by introducing drip irrigation system.

VI. CONCLUSION

The upgrading and expansion of the water system is an urgent developmental concern that is also an opportunity to adapt to climate change. The development of new water resources and the adaptation of existing urban water systems to become more resilient will require a range of different solutions, many of which will take time and/or result in substantial costs. These solutions will need to respond to issues such as the availability of water resources, the nature and condition of existing water infrastructure and the availability of resources. Water sensitive urban planning will solve issues and help to develop and manage systems, and existing urban demand patterns for water.

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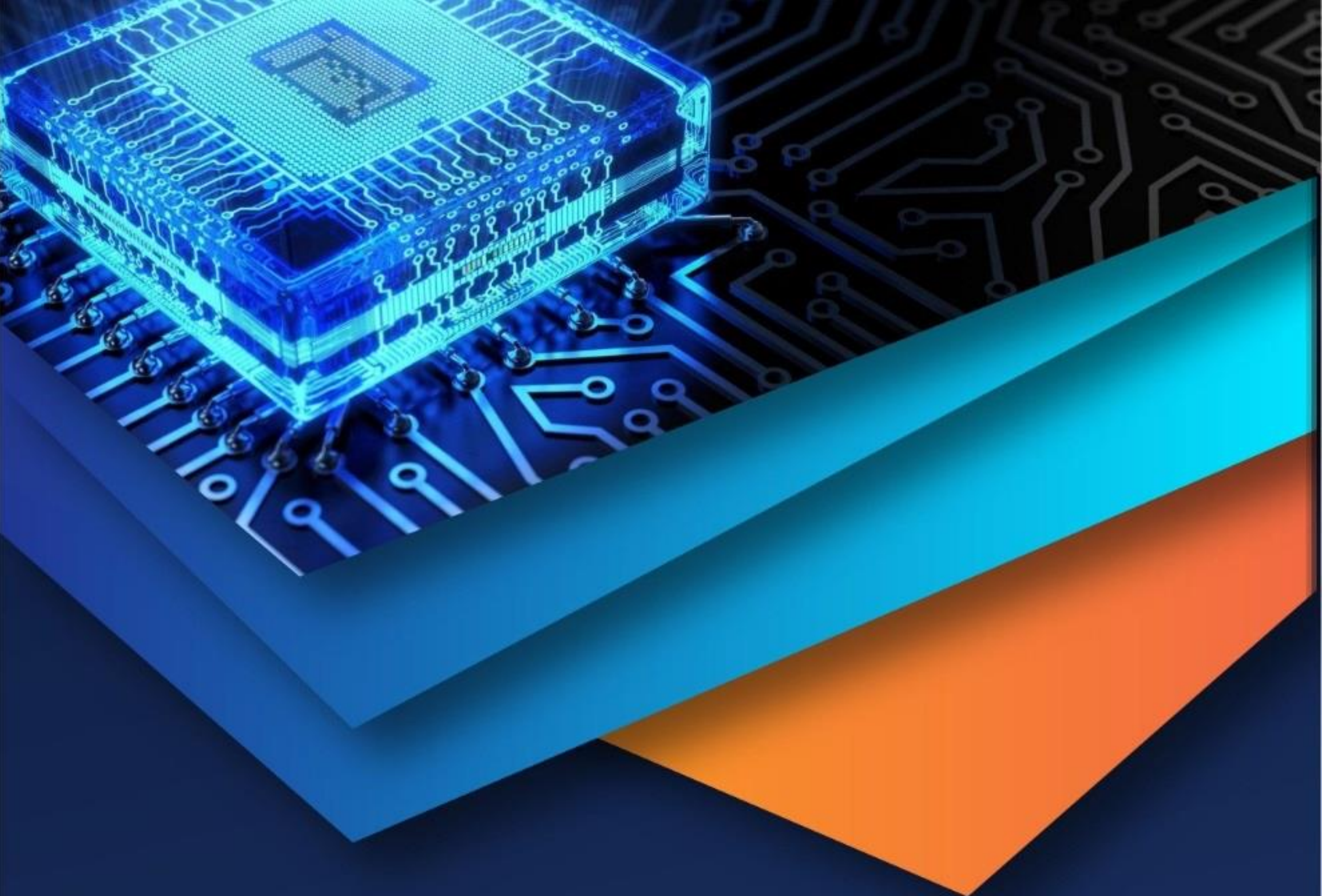

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