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MULTI-TEMPORAL ANALYSIS OF ENVIRONMENTAL STRESS AND RAINFALL VARIABILITY IN BALASORE DISTRICT, ODISHA

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Abstract: A monsoon dependent region critically faces high environmental stress when the rainfall pattern of that region shows significant variation. This research work critically evaluates how over a 13 years period of time the environmental stress has been increased significantly in the Balasore district of Odisha due to variation in rainfall mechanism. To justify this, geospatial data sets such as LST, NDVI, NDMI and rainfall data of 13 years i.e. 2013 to 2025 of Balasore district were integrated to assess the environmental stress across the region. This research work also applies quantitative statistical techniques such as Coefficient of Variation (CV) and Mann-Kendall trend test, to analyses the rainfall anomalies. Through these two techniques, the trend of rainfall whether increasing or decreasing along with fluctuation percentage throughout the study region have been assessed. Additionally, the findings of the study also evaluate the intensity of environmental stress and ecological imbalance associated with climatic heterogeneities. The integrated environmental stress map also highlights the spatial hotspots and vulnerable zones. As a whole, this research work provides significant insights for environmental sustainability, resource management and copping mechanism to reduce climatic induced environmental stress.

Index Terms **-** Environmental stress, Coefficient of Variation (CV), LST, Mann-Kendall trend test, NDMI, NDVI and Rainfall variation.

1. INTRODUCTION:

Environmental stress can be defined as change in regular ecological system caused by change in climate and anthropological activities [8]. These changes can be analyzed by integrating geospatial indicators such as LST (Land Surface Temperature), NDVI (Normalized Difference Vegetation Index), and NDMI (Normalized Difference Moisture Index) [10]. Rainfall pattern analysis also plays pivotal role in understanding regional climate change along with change in environmental stress [1].
Change in rainfall variability also plays significant role in modifying these indicators [2] [4]. Accelerated urban expansion along with irregularity in rainfall pattern reduces the moisture value, increases the land temperature and lowers the NDVI value.
Over the time period, Balasore region experiences change in rainfall pattern due to its proximity to Bay of Bengal and gentle slope gradient with flat surface [13]. These changes not only affect the ecological stability and water resources but also contributes to change in environmental stress [12].

Overall, this research work establishes the relationship between environmental stress and variability in rainfall pattern across the 12 blocks of Balasore district from 2013 to 2025 by using remote sensing techniques and statistical techniques. In this research work, geospatial indices like LST, NDMI and NDVI have been used to analyze the change in environment due to change in rainfall pattern.

1.1. LITERATURE REVIEW:

When coastal areas like Balasore experiences high degree of urbanization along with rainfall pattern change, then environmental stress becomes a critical phenomenon [3]. The collective consequences of rapid urban growth and precipitation fluctuation not only disturb the natural ecosystem of the region but also affects the livelihood of the region [5].
To analyse the rainfall variability pattern along with rainfall trend, many research studies use statistical techniques such as Mann-Kendall test and Coefficient of Variation (CV) [9]. If the region's rainfall CV value is higher, then it indicates that the region has greater variability in rainfall pattern and high degree of rainfall variation [6]. Moreover, Mann-Kendall non parametric statistical technique is also used to detect the rainfall trend of a region. It also helps to analyse whether total precipitation of a region is significantly increasing or decreasing [14].
Additionally, accelerated urbanization also contributes to change in environmental stress [11]. When built up area increases then it also reduces the vegetation cover and increases the land surface temperature [7]. Various studies have also revealed that; the cumulative impact of rainfall variability and urbanization predominantly affects the inter ecological conditions [15]. Hence, correlating statistical methods such as CV and Mann-Kendall test with spatial indicators gives a detailed understanding of environmental stress effect.

1.2. OBJECTIVES:

1. To analyse the environmental stress trend in Balasore district by using geospatial techniques and remote sensed data.
2. To examine the changing spatio temporal dynamics of rainfall pattern in Balasore district from 2013 to 2025.

1.3. STUDY AREA:

Balasore is the northern most district of Odisha. it s also called as "Granary of Odisha" due to its high agricultural output and rich geographical significance. It has 12 administrative blocks and two sub divisions. Geographically, it is located at 21°03′ N to 21°59′ N latitude and 86°20′ E to 87°29′ E longitude. In the northern part it is bounded by West Bengal and in the east by Bay of Bengal. It is distinguished by coastal plain topography with low elevation and gentle slope. This district of Odisha is traversed with magnificent river systems such as Budha Balanga, Shubarna Rekha, Jalaka, Sone and Gangadhara river. That's why, this region is characterized with fertile alluvial soil. It is also characterized with tropical monsoon climatic system as maximum rainfall occurs during the month of June to September. The total population of the district is near about 2.32 million by census 2011. This district exhibits 789% literacy rate with sex ratio of about 957 females out of 1000 males. Moreover, Balasore is an important center for Défense Research, where ballistic missiles are tasted. This high lightens its role in the national security. Figure 1 shows the location of the study area.

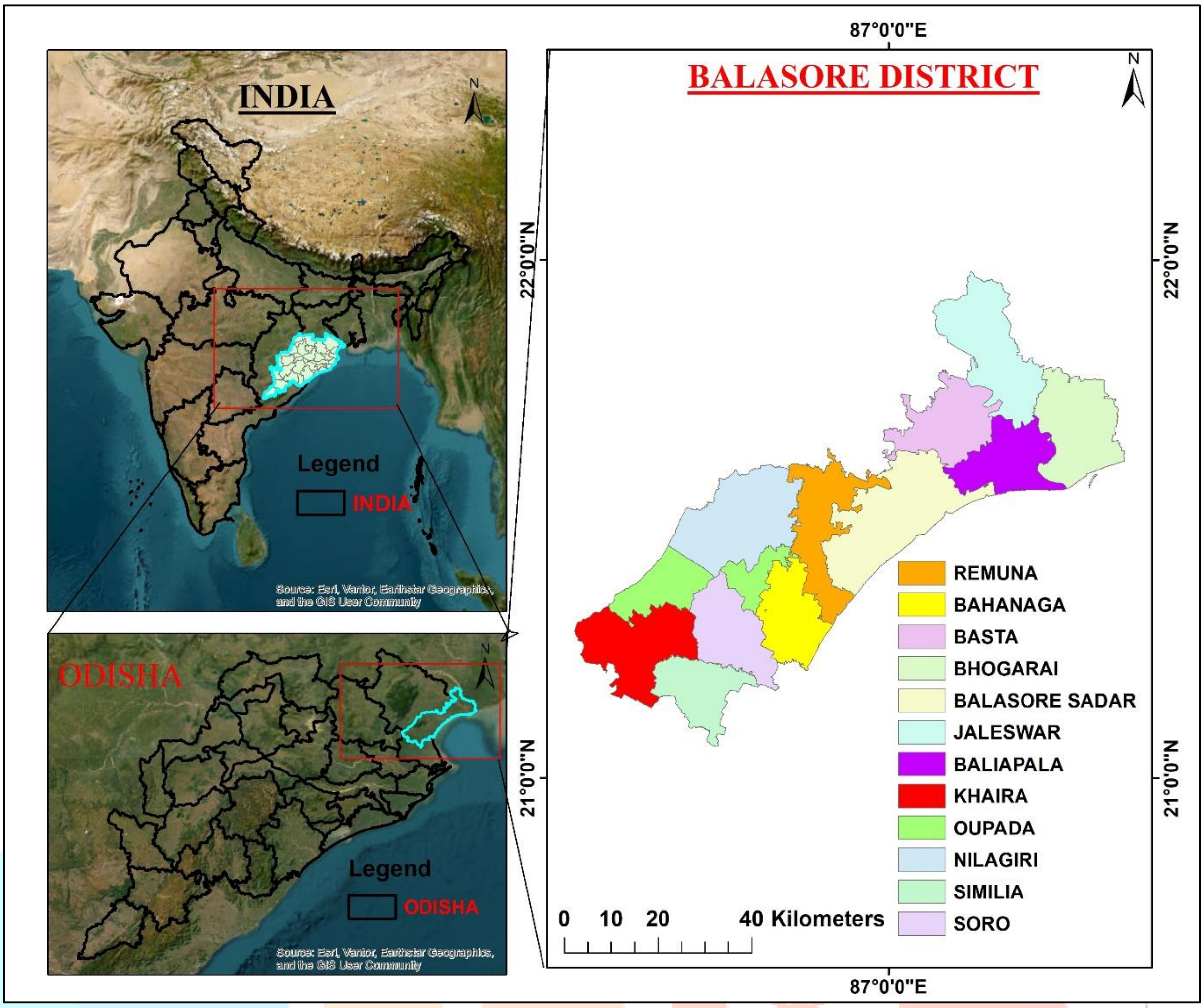

Figure 1. Location map of the Balasore District
(Source: Generated by the author based on the Census of India, 2011)

2. RESEARCH METHODOLOGY:

This research work has been conducted by using the applications of remote sensing techniques and secondary rainfall data of Balasore district from 2013 to 2025. It follows an analytical framework of satellite data acquisition, image processing, calculation of LST, NDVI and NDMI along with theirs stress values. It also uses statistical techniques such as Mann–Kendall and coefficient of variation (CV) to analyse the rainfall trend. In this research work, year 2013 has been selected as base year while year 2025 has been selected to show the most recent condition. This allows us to understand the changing pattern of environmental stress dynamics in Balasore district.

2.1. Data Collection:

2.1.1. Satellite Data Acquisition: Multispectral satellite data of Balasore District for the time period of 2013 and 2025 were collected by using the USGS, i.e. United States Geological Survey platform. In this work, the Landsat-8 collection Level-1 C2 L1 images were used. Cloud cover was between 0 to 10% so that the data quality can be maintained.
2.1.2. Rainfall Data: Block wise 13 years rainfall data of Balasore district has been collected from Balasore district collectorate office.

2.2. Data Analysis: For this work, all the analyses were done using ArcGIS and MS Excel.

2.2.1. LST Calculation: First all the required parameters such as TOA, BT, NDVI, PV and LSE were calculated for the year 2013 and 2025 and then the LST (LAND SURFACE TEMPERATURE) for 2013 to 2025 was calculated by using the formula shown in Eq. (1).

$$LST = (BT)/(1 + (\lambda \times BT/c2) \times \ln(E)) \tag{1}$$

2.2.2. NDVI calculation: The NDVI (NORMALIZED DIFFERENCE VEGETATION INDEX) of Balasore, for the time periods 2013 and 2025 were calculated by using formula shown Eq. (2).

$$\frac{\boldsymbol{NIR}\ (\boldsymbol{Band}\ 5) - \boldsymbol{RED}(\boldsymbol{Band}\ 4)}{\boldsymbol{NIR}\ (\boldsymbol{Band}\ 5) + \boldsymbol{RED}\ (\boldsymbol{Band}\ 4)} \tag{2}$$

2.2.3. NDMI calculation: The NDMI (NORMALIZED DIFFERENCE MOISTURE INDEX) of Balasore, for the time periods 2013 and 2025 were calculated by using formula shown Eq. (3).

$$\frac{\boldsymbol{NIR}\ (\boldsymbol{Band}\ 5) - \boldsymbol{SWIR}(\boldsymbol{Band}\ 6)}{\boldsymbol{NIR}\ (\boldsymbol{Band}\ 5) + \boldsymbol{SWIR}\ (\boldsymbol{Band}\ 6)} \tag{3}$$

2.2.4. NORMALIZATION calculation: Then the Normalization values of LST, NDVI, NDMI and Rainfall of Balasore, for the time periods 2013 and 2025 were calculated by using formula shown Eq. (4), Eq. (5), Eq. (6) and Eq. (7) respectively.

$$\mathbf{LSTnorm} = \frac{\boldsymbol{LST} - \boldsymbol{LSTmin}}{\boldsymbol{LSTmax} - \boldsymbol{LSTmin}} \tag{4}$$

$$\mathbf{NDVInorm} = \frac{\boldsymbol{NDVI} - \boldsymbol{NDVImin}}{\boldsymbol{NDVImax} - \boldsymbol{NDVImin}} \tag{5}$$

$$\mathbf{NDMInorm} = \frac{\boldsymbol{NDMI} - \boldsymbol{NDMImin}}{\boldsymbol{NDMImax} - \boldsymbol{NDMImin}} \tag{6}$$

$$\mathbf{RAINFALLnorm} = \frac{\boldsymbol{RAINFALL} - \boldsymbol{RAINFALLmin}}{\boldsymbol{RAINFALLmax} - \boldsymbol{RAINFALLmin}} \tag{7}$$

2.2.5. STRESS VALUE calculation: Then the Stress values of NDVI, NDMI and Rainfall of Balasore, for the time periods 2013 and 2025 were calculated by using formula shown Eq. (8), Eq. (9) and Eq. (10) respectively. As LST indicates high stress, hence only LST normalization value has been calculated.

$$\mathbf{NDVI\ Stress} = \mathbf{1} - \boldsymbol{NDVI_{norm}} \tag{8}$$

$$\mathbf{NDMI\ Stress} = \mathbf{1} - \boldsymbol{NDMI_{norm}} \tag{9}$$

$$\mathbf{Rainfall\ Stress} = \mathbf{1} - \boldsymbol{Rainfall_{norm}} \tag{10}$$

2.2.5. Coefficient of Variation (CV) of Rainfall Calculation from 2013 to 2025: To analyses the spatial differences of inter and intra rainfall variability across the 12 Blocks of Balasore from 2013 to 2025, the statistical technique has been used. The formulas to calculate the rainfall variability has been shown in Eq. (11), Eq. (12) and Eq. (13) respectively.

$$\boldsymbol{CV} = \left(\frac{\boldsymbol{\sigma}}{\boldsymbol{\mu}}\right) \times \mathbf{100} \tag{11}$$

Here, σ stands for standard deviation and $\bar{X}$ indicates mean rainfall

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i \tag{12}$$

Here, $\bar{X}$ indicates mean rainfall , X_i= rainfall value of the i^{th}year i.e. rainfall value of year 2013 and n indicates total number of observations i.e. 13 years.

$$\sigma = \sqrt{\frac{\sum(X - \bar{X})^2}{n - 1}} \tag{13}$$

Here, $\bar{X}$ indicates mean rainfall, X indicates individual rainfall value from year 2013 to year 2025 and n indicates total number of observations i.e. 13 years. All the values have been calculated by using MS-Excel and tables have been prepared. All the rainfall coefficient values has been arranged according to the interpretation given in Table-1.

Table 1. Interpretation Table for Coefficient of Variation in Rainfall

CV (%) Range	Variability Level	Interpretation
< 20	Low	Stable rainfall conditions
20 – 30	Moderate	Moderate variability in rainfall
> 30	High	High variability (unstable rainfall)

(Source: Source: Subrahmanyam & Subramaniam (2013), https://doi.org/10.13140/RG.2.2.28927.38563)

Table 2. Year wise Rainfall Data of 12 Blocks of Balasore district from June to September Month

SERIAL NO	BLOCKS	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	TOTAL
1	BHOGRAI	1227	1627.2	1383.7	1142.1	959.5	1145.5	1141.2	824.4	1359.2	1261.6	1222	1310	1279.5	15882.9
2	BASTA	1340	1490	1143	1288	1143	1156	955	1074	1183	1060	1244	1094	1193	15363
3	JALESWAR	1250	1327	969	1018	964	1089	1053	856	1229	1143	721	1184	814	13617
4	BALIAPAL	1300	1635	1148	1090	1093	1185	1001	829	1263	1031	1089	1121	818	14603
5	BALASORE	1284	1440.5	1506	1022	1325	1348	801	821	1162	1087.5	1036	972	1234	15039
6	REMUNA	773	1252	1453	885	961	1239	852	823.5	1179	1087	1008	867	1239	13618.5
7	NILAGIRI	1374	1403.1	1254	1304	994.8	1404	948.8	1014.8	1278.5	1019	1075	955	1383	15408
8	SORO	715	1662	1314	1258	579	1371	1211	789	854	1108	1333	733	1158	14085
9	BAHANAGA	896	1131	1434	1024	833	1226	745	960	901	1180	944	752	1223	13249
10	SIMULIA	903.3	1267	1403	1043	890	1382	1223.3	792	921	1244	1330	481	753	13632.6
11	KHAIRA	1807	1625	1323	1295	787	1477	1220	1016	794	1304	919	869	1204	15640
12	OUPADA	898	1694	1333	969	952	1302	1404	937	693	1465	1111	814	1249	14821

(Source: Rainfall data collected from Balasore district Collectorate Office)

Table 3. Mean, Standard Deviation and Coefficient of Variation Rainfall Data of 12 Blocks of Balasore District

SERIAL NO	BLOCKS	TOTAL	MEAN	STANDARD DEVIATION	CV	INTERPRETATION
1	BHOGRAI	15882.9	1221.761538	189.6469089	15.52241603	LOW VARIABILITY
2	BASTA	15363	1181.769231	131.4324359	11.12166678	LOW VARIABILITY
3	JALESWAR	13617	1047.461538	173.9529624	16.60709783	LOW VARIABILITY
4	BALIAPAL	14603	1123.307692	200.6717122	17.86435841	LOW VARIABILITY
5	BALASORE	15039	1156.846154	214.9264977	18.57865862	LOW VARIABILITY
6	REMUNA	13618.5	1047.576923	201.9563782	19.27842946	LOW VARIABILITY
7	NILAGIRI	15408	1185.230769	177.9385563	15.01298827	LOW VARIABILITY
8	SORO	14085	1083.461538	308.6096901	28.48367747	MODERATE VARIABILITY
9	BAHANAGA	13249	1019.153846	198.9007662	19.51626508	LOW VARIABILITY
10	SIMULIA	13632.6	1048.661538	273.2021639	26.05246344	MODERATE VARIABILITY
11	KHAIRA	15640	1203.076923	306.1986438	25.45129392	MODERATE VARIABILITY
12	OUPADA	14821	1140.076923	281.3285683	24.67627952	MODERATE VARIABILITY

(Source: Calculated by the author using data from Table 1, Table 2 and MS Excel)

2.2.6. Assessment of Rainfall trend by using MANN–KENDALL TEST: To analyses the rainfall across the 12 Blocks of Balasore from 2013 to 2025, this non -parametric statistical technique has been used. First the rainfall data with average rainfall data across the 12 Blocks of Balasore district has been arranged chronologically to find the test statistics i.e. **S.** The value has been calculated by using the following Eq. (14).

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sign}(X_j - X_i) \tag{14}$$

Here, $j > I$. The value is +1 if $X_j - X_i > 0$, the value is 0 if $X_j - X_i = 0$ and the value is -1 if $X_j - X_i < 0$. Based upon this all the **S** values have been compared and calculated from 2013 to 2025 and arranged in Table-4.

Table 4. Test Statistics "S" Values of Rainfall Data of 12 Blocks of Balasore District

Year	Avg Rainfall	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
2013	1147.27	1	1	-1	-1	1	-1	-1	-1	1	-1	-1	-1
2014	1462.82		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
2015	1305.31			-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
2016	1111.51				-1	1	-1	-1	-1	1	-1	-1	1
2017	956.78					1	1	-1	1	1	1	-1	1
2018	1277.04						-1	-1	-1	-1	-1	-1	-1
2019	1046.28							-1	1	1	1	-1	1
2020	894.73								1	1	1	1	1
2021	1068.06									1	1	-1	1
2022	1165.84										-1	-1	-1
2023	1086											-1	1
2024	929.33												1
2025	1128.96												

(Source: Calculated by the author using Eq. (14) and MS Excel)

From Table-4 we can observe that, total number of -1 is 51 and total number of +1 is 27. Hence **"S"** value is

$$-\mathbf{51}+\mathbf{27}=-\mathbf{24}$$

Now the Variance of S or **Var(S)** has been calculated by using Eq. (15) i.e.

$$Var(S)=\frac{n(n-1)(2n+5)}{18} \quad \textbf{(15)}$$

Here, n is 13 as we have taken 13 years of rainfall data. So, **Var(S)** equals to:

$$Var(S)=\frac{13(13-1)(2*13+5)}{18}=268.67$$

Finally, the **Standardized value "Z"** of the Test Statistic has been calculated by using the formula given in Eq. (16) i.e.

$$if\ S<0, then\ Z=\frac{S+1}{\sqrt{Var(S)}} \quad \textbf{(16)}$$

Hence, **Z** value of Balasore District from 2013 to 2025 is:

$$\frac{-24+1}{\sqrt{268.67}}=-1.40$$

This indicates that the rainfall trend across the 12 Blocks of Balasore district from 2013 to 2025 has been decreased.

3. DISCUSSION:

3.1. Environmental Stress Analysis For the year 2013:

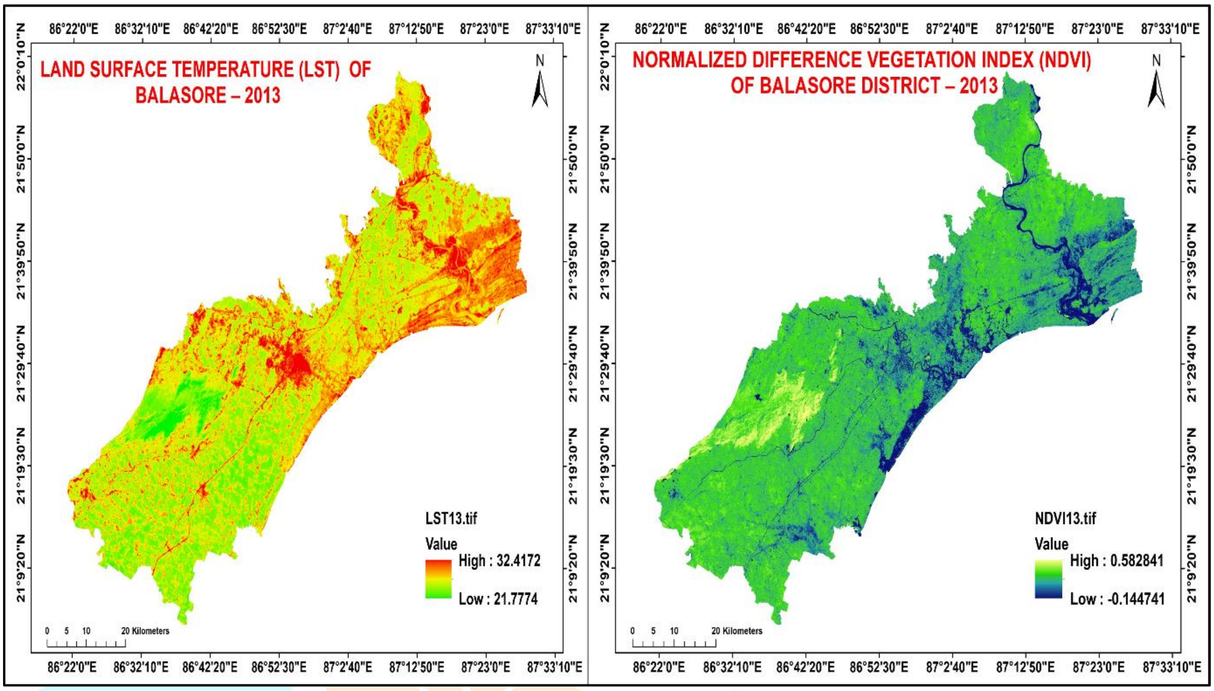

Figure 2. LST and NDVI of the Balasore District in 2013
(Source: Generated by the author by the Author using ArcGIS software)

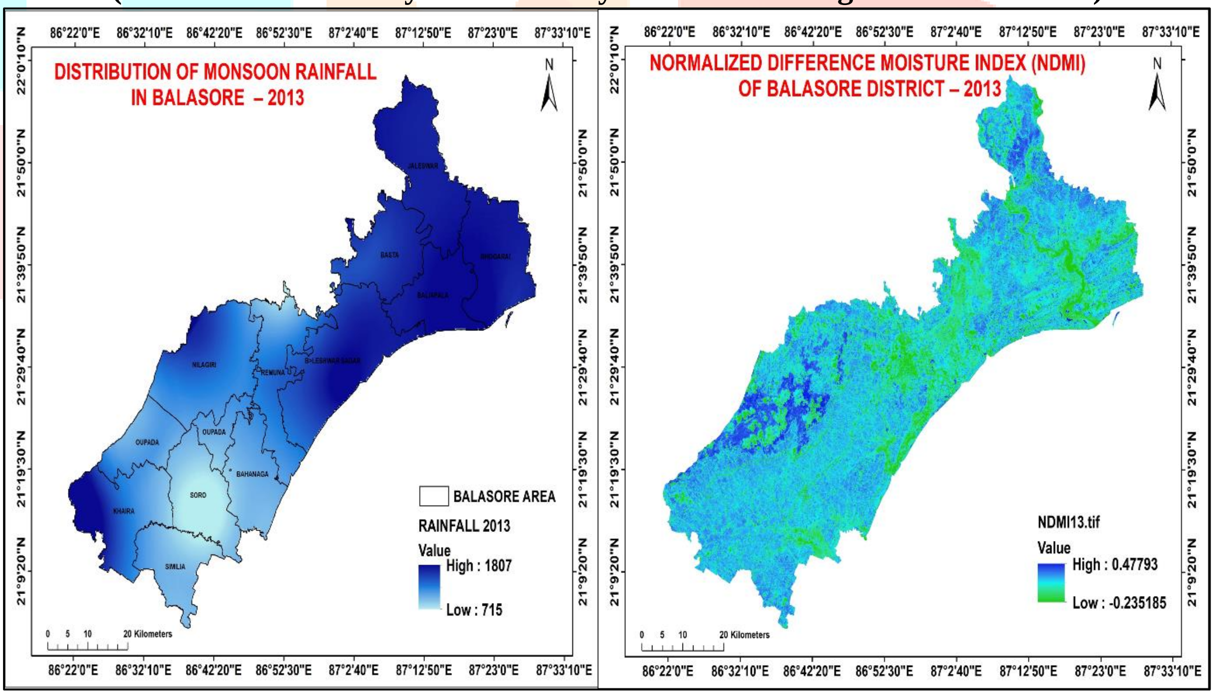

Figure 3. Rainfall distribution and NDMI of the Balasore District in 2013
(Source: Generated by the author by the Author using ArcGIS software)

3.1.1. Environmental Stress Characteristics in 2013:

Figure 2 and Figure 3 represents the Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), Normalized Difference Moisture Index (NDMI), and rainfall distribution pattern across 12 Blocks of Balasore district during 2013. These maps significantly represent the ecological conditions and variability in precipitation during this period. Table 5, in support with the Figure 2 and Figure 3 indicates the spatial variation in LST, NDVI, NDMI and rainfall across the 12 blocks of Balasore district.

Table 5. Environmental Parameters Range Across The 12 Blocks of Balasore District in 2013

PARAMETER	HIGH VALUE	LOW VALUE
LST	32.4172 °C	21.7774 °C
NDVI	0.58284	-0.14474
NDMI	0.47793	-0.23519
RAINFALL	1807 mm	715 mm

(Source: Prepared by the Author using data from Figure 2 and Figure 3)

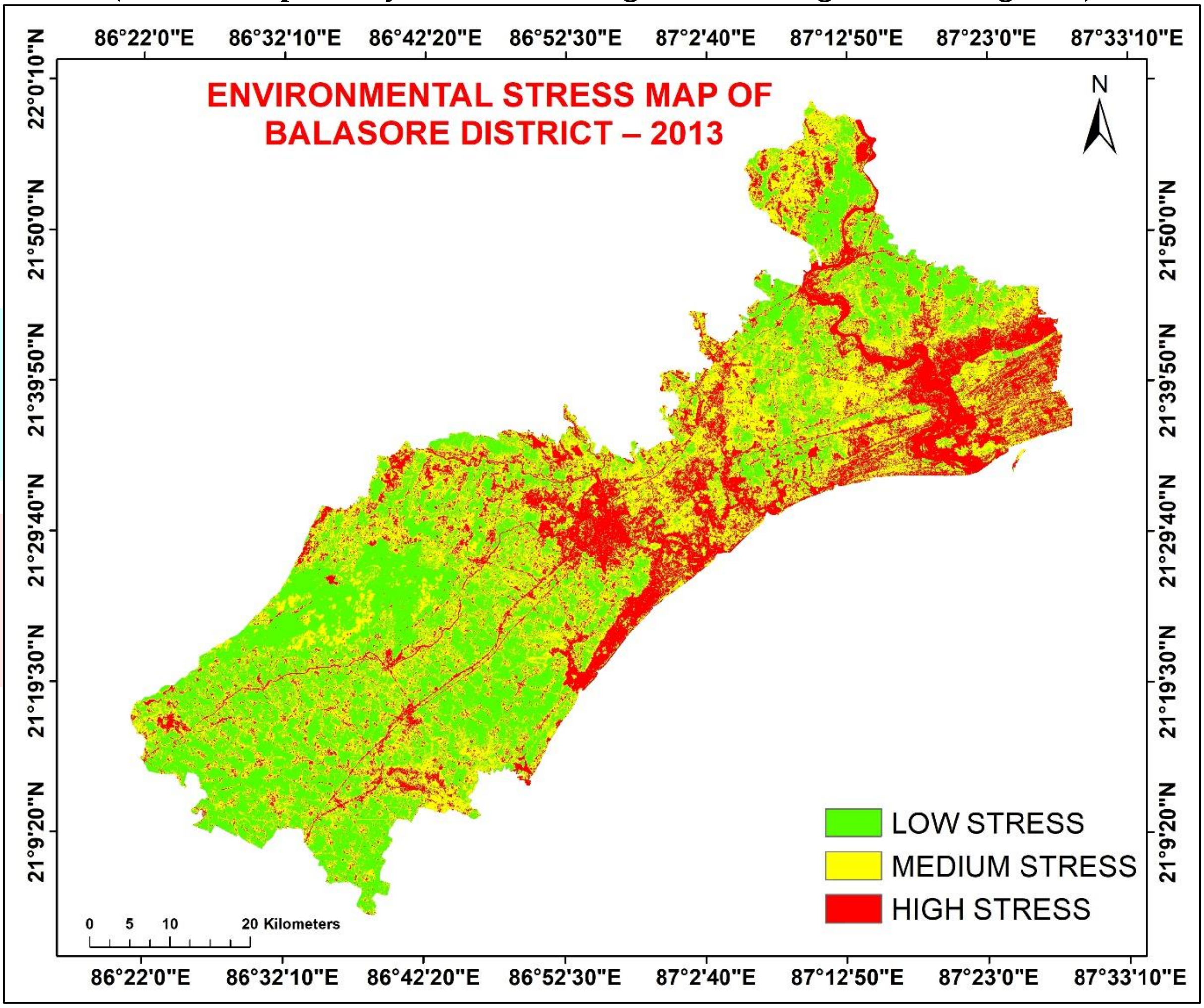

Figure 4. Environmental Stress in Balasore District during 2013
(Source: Generated by the author by the Author using ArcGIS software)

The Figure 4 reveals the Environmental stress in Balasore district during 2013. As we can see, during 2013 high stress zones are significantly concentrated in the eastern and northern parts mostly around the coastal regions. In other hand low to moderate stress zones are covering the western and central parts of the district. This variability indicates uneven distribution of environmental stress effect in Balasore during 2013 year. How ever, the southern part reflects mixed pattern of environmental stress. This indicates environmental degradation due to land use changes and uneven rainfall distribution. The LST value during this time period ranges up to to 32.41 °C where as high NDVI and NDMI values ranges up to 0.58 and 0.47 respectively. The Rainfall during this time period has high value of 1807 mm whereas the low value is 715 mm. This further supports the pattern of environmental stress distribution. i.e. areas having high thermal stress, lower rainfall, low moisture and low vegetation cover experiences high environmental stress.

Therefore, the analysis of environmental stress effect in Balasore district during 2013 reveals that interior regions have stable environmental stress while the coastal regions have higher environmental stress. This reflects the pivotal role of surface factors and climatic variability in moderating stress distribution.

3.2. Environmental Stress Analysis For the year 2025:

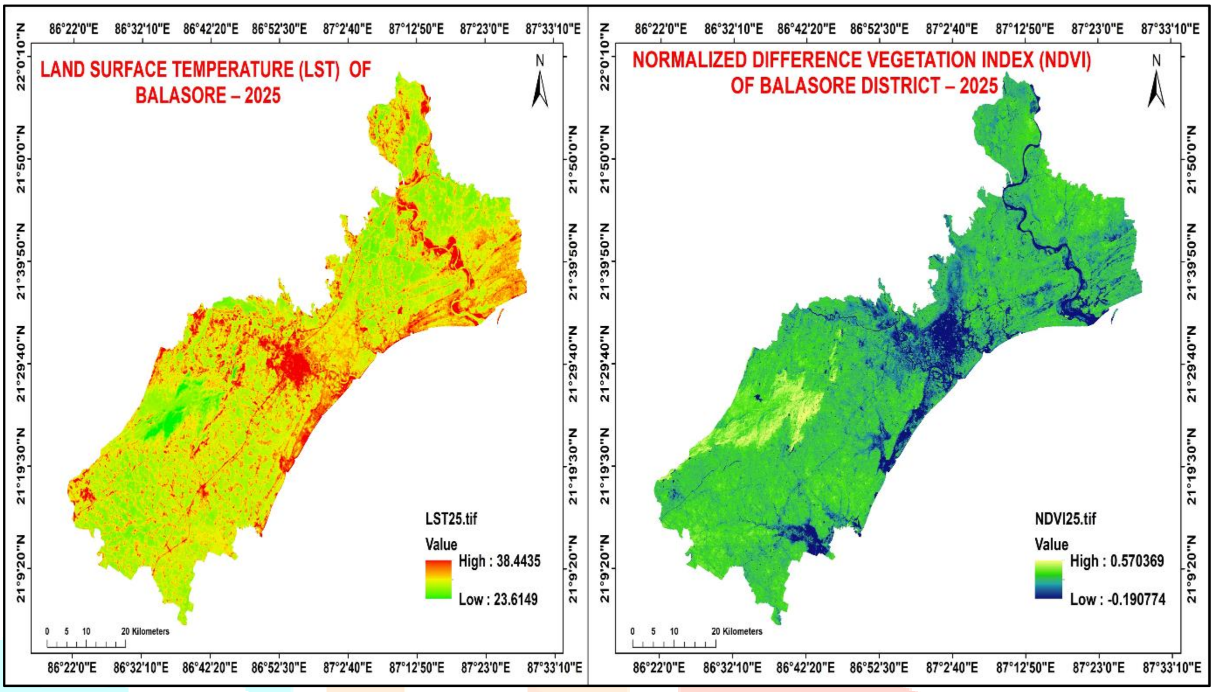

Figure 5. LST and NDVI of the Balasore District in 2025
(Source: Generated by the author by the Author using ArcGIS software)

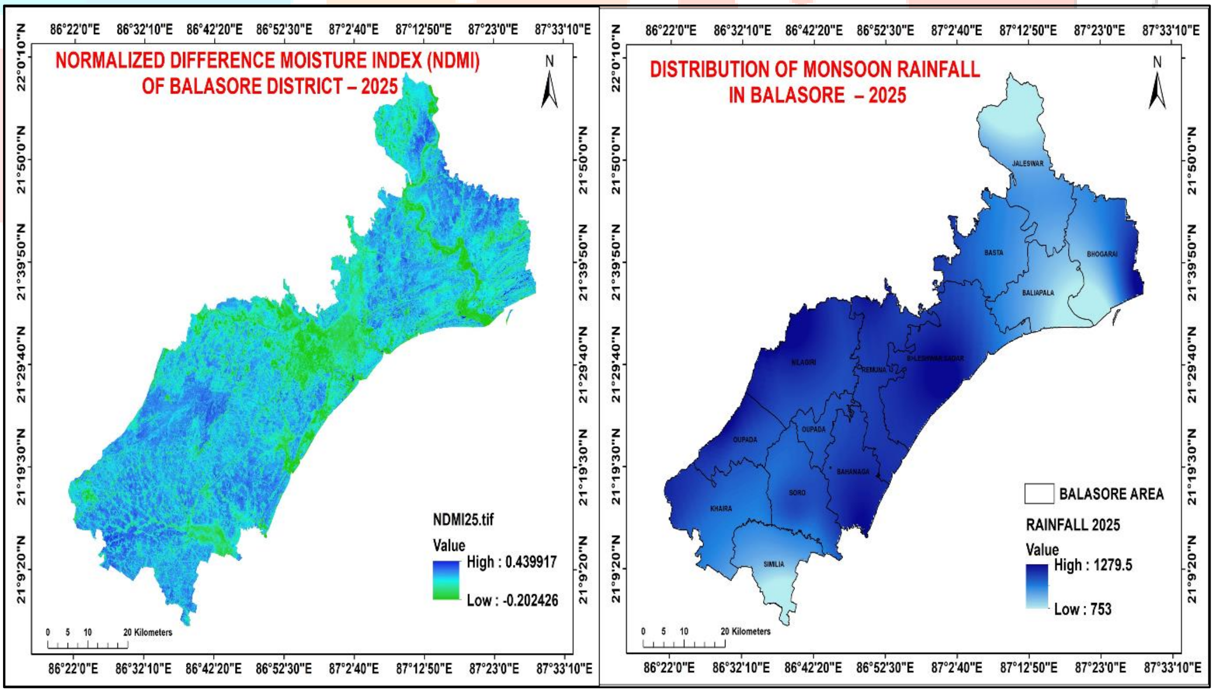

Figure 6. Rainfall distribution and NDMI of the Balasore District in 2025
(Source: Generated by the author by the Author using ArcGIS software)

3.2.1. Environmental Stress Characteristics in 2025:

Figure 5 and Figure 6 represents the Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), Normalized Difference Moisture Index (NDMI), and rainfall distribution pattern across 12 Blocks of Balasore district during 2025. These figures significantly indicate the ecological conditions and variability in rainfall trend during 2025. Table 6, along with the Figure 5 and Figure 6 quantifies the variation in LST, NDVI, NDMI and rainfall across the 12 blocks of Balasore district.

Table 6. Environmental Parameters Range Across The 12 Blocks of Balasore District in 2025

PARAMETER	HIGH VALUE	LOW VALUE
LST	38.4435 °C	23.6149 °C
NDVI	0.570369	-0.19077
NDMI	0.439917	-0.20243
RAINFALL	1279.5 mm	753 mm

(Source: Prepared by the Author using data from Figure 5 and Figure 6)

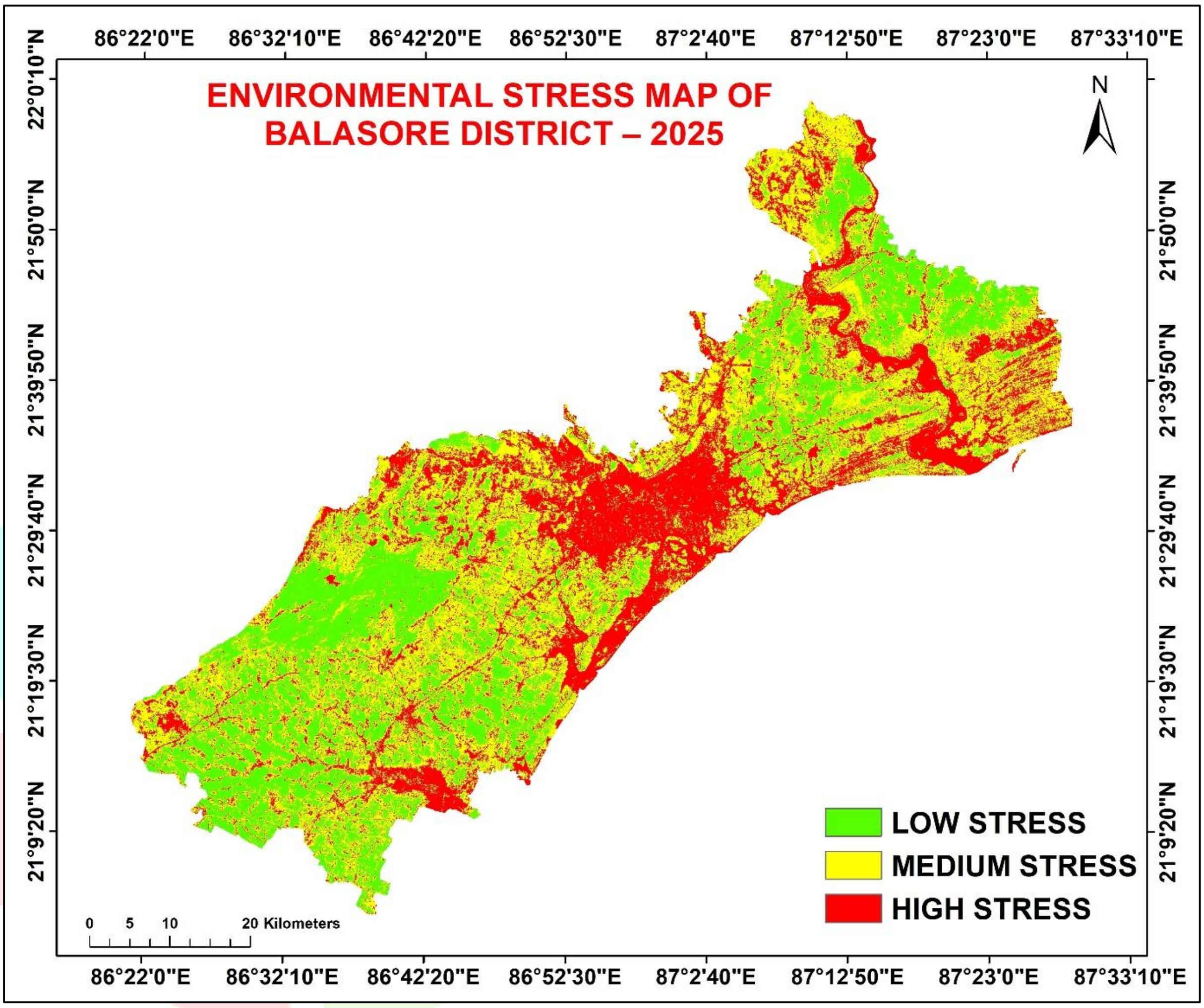

Figure 7. Environmental Stress in Balasore District during 2025
(Source: Generated by the author by the Author using ArcGIS software)

The Figure 7 reveals the Environmental stress in Balasore district during 2025. By comparing Figure 4 and Figure 7 we can notice directional shift of environmental shift has occurred throughout the study area. As compared to 2013, high stress zones have distributed throughout the eastern, central and north eastern parts of the district during 2025. Moreover, the low to moderate stress regions have changed to high stress zones during 2025. This indicates environmental deterioration. The high stress zones around coastal belts, have also expanded in 2025. In other hand, the western and south western portions of the district exhibit low stress zones. The LST value during this time period ranges up to to 38.44 °C where as high NDVI and NDMI values ranges up to 0.57 and 0.43 respectively. The Rainfall during this time period has high value of 1279 mm whereas the low value is 753 mm. we can observe that except land surface temperature all values have been decreased. This further supports the pattern of environmental stress distribution. i.e. gradual spread of high stress zones over stable regions.

Therefore, the analysis of environmental stress effect in Balasore district during 2025 reveals that the increasing environmental vulnerability in Balasore district is due to persistent rainfall variability, decreased moisture availability, reduced vegetation and increasing land temperature.

3.3. Integrated Environmental Stress and Rainfall Variability Relationship:

Table 7. High and Low Environmental Stress Affected Areas Across The 12 Blocks of Balasore District From 2013 to 2025

CATEGORY	2013 AREA (KM²)	2013 (%)	2025 AREA (KM²)	2025 (%)	CHANGE (KM²)	INTERPRETATION
HIGH ENVIRONMENTAL STRESS AREA	862	38.68 %	910.0341	41.57 %	48.0341	INCREASED
LOW ENVIRONMENTAL STRESS AREA	1367	61.32 %	1279.02	58.43 %	-87.98	DECREASED

(Source: Calculated by the Author using Zonal statistics data from Figure 4 and Figure 7 and MS-Excel)

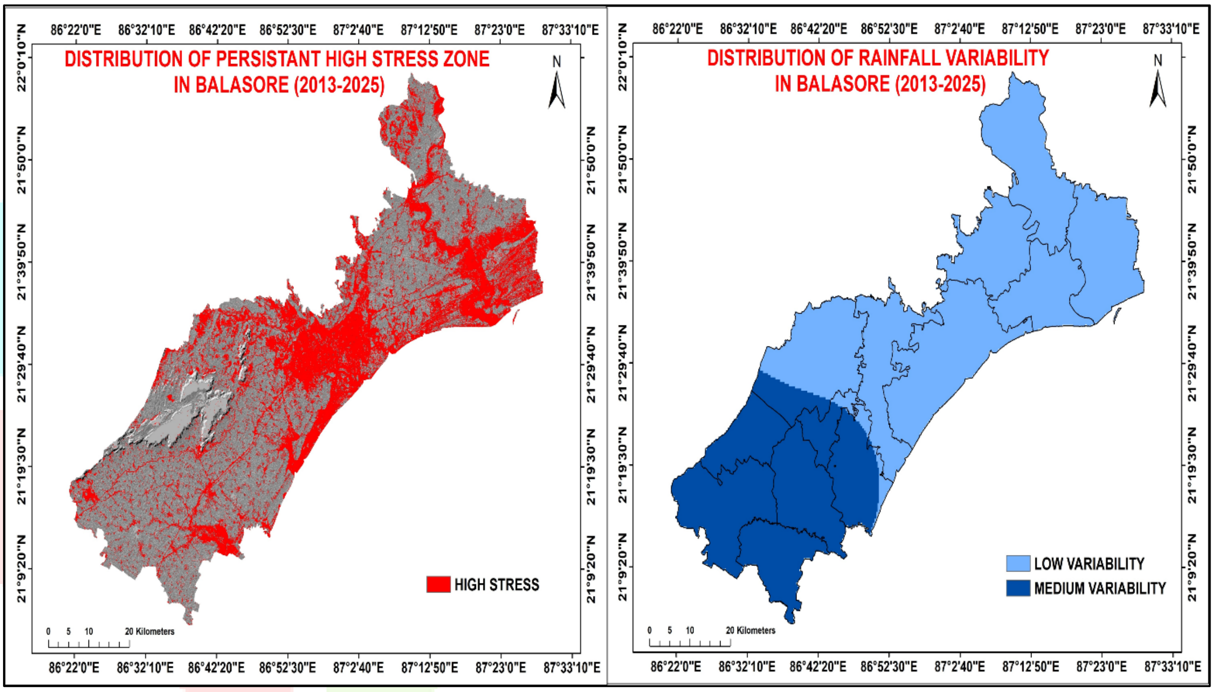

Figure 8. Integrated Stress and Rainfall variability across the 12 Blocks of Balasore District from 2013 to 2025

(Source: Generated by the author by the Author using ArcGIS software)

From the Table 7 and Figure 8 we can observe that environmental high stress zones are not randomly distributed. These zones are highly concentrated mostly across the central, eastern and north -eastern parts of the district. This indicates that from 2013 to 2025, these parts of the district have witnessed high change in environmental conditions. However, most of the high stress zones are persistent in those areas where rainfall variability is low. But in medium variability regions high stress spared is less as compared to low rainfall variability regions.

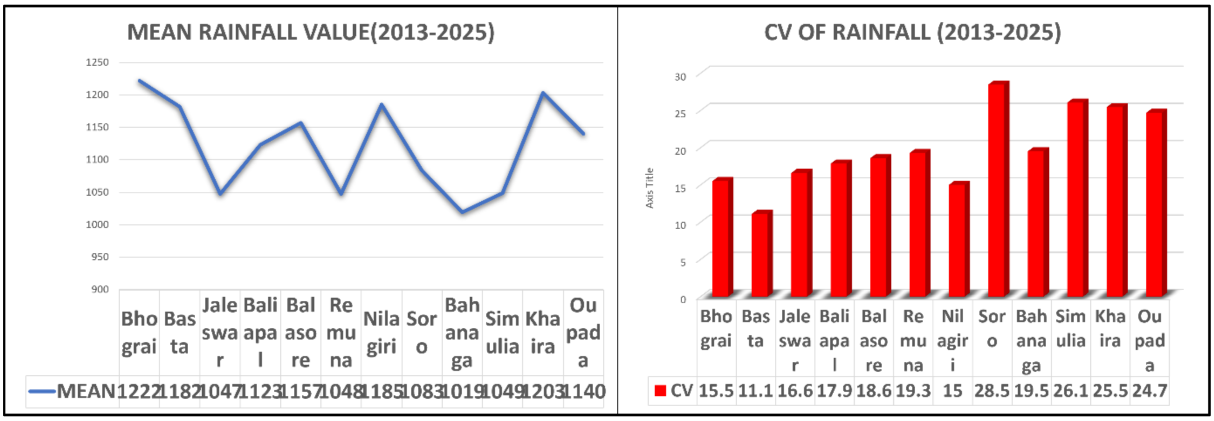

Figure 9. Mean and CV of Rainfall across the 12 Blocks of Balasore District from 2013 to 2025 (Source: Generated by the author by the Author using Table 3 data and MS-Excel)

The Figure 9 reveals the mean rainfall and coefficient of variation (CV) distribution across the 12 blocks of Balasore district. As we can notice over the time period the mean rainfall has decreased and the CV is showing fluctuation. Blocks such as Khaira, Nilgiri and Bhograi exhibits high mean values whereas Blocks such as Jaleswar, Simulia and Bahanaga has low mean value of rainfall. Further, Blocks such as Oupada, Khaira, Simulia and Soro has high coefficient of variation in rainfall where as Basta and Bhograi has lower variability in rainfall conditions. This indicates that high environmental stress zones across the 12 Blocks of Balasore district are significant where rainfall availability is lower rather than variability alone. This proves that environmental stress effect in Balasore is the combined effect of rainfall distribution, decline in moisture as well as vegetation cover and increase in land surface temperature.

4. CONCLUSION:

This research work is based upon a multidimensional interdisciplinary quantitative approach. This research work analyses the dynamics of environmental stress in Balasore district of Odisha by integrating remote sensing techniques along with rainfall variation for the time period 2013 to 2025.

The research highlights that the environmental stress effect across the 12 Blocks of Balasore district has been increased and the rainfall trend has been decreased from 2013 to 2025. This is also substantiated by the data of Table 5, Table 6 and Table 7. In 2013, high environmental stress area was only 38.68% whereas in 2025 it is 41.75%. The maximum rainfall in 2013 was 1807 mm but in 2025 it is 1279.5 mm. Furthermore, low stress areas also have been decreased significantly from 2013 to 2025 i.e. 61.32% to 58.34%. The spatial analysis of geospatial indicators also reveals that except land surface temperature other indicators such as NDVI and NDMI has been decreased from 2013 to 2025 throughout the district.

The analysis of rainfall by using statistical techniques such as Mann-Kendall test and Coefficient of Variation i.e. CV reveals that environmental stress in Balasore district is strongly depend upon uneven distribution of rainfall and deficiency of rainfall. It I also associated with its uneven temporal distribution pattern. The findings of the research work bring out the need for urban climate resilient planning and sustainable resource management to curb the growing effect of environmental stress effect in Balasore district of Odisha.

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