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Spatio-Temporal Variation of Rainfall and its Disastrous Impact on Coastal West Bengal.

Amit Kumar Majumder *

*Research Scholar, Department of Geography, University of Calcutta

Abstract: Coastal West Bengal (CWB) is situated at southern part of Gangetic West Bengal (a meteorological subdivision of India). Annual average rainfall amount is decreasing and annual number of rainy days is increasing. With this, an occurrence of heavy rain disaster has also been increased but number of flood occurrence in a year has been reduced. Number of human death due to heavy rain disaster and flood has also been increased. Economic damage is also witnessed by the grasp of such disastrous events and paralyses the normal life.

Key Words: Rainfall; disastrous heavy rainfall and flood events; damage and casualties; correlation between event and casualty.

Introduction: Excessive rainfall often takes the catastrophic shape and some time turns up to heavy rain to flood event. Cyclonic storm is one of the main reasons behind the flood over CWB. Depression forms over Bay of Bengal give rise to incessant rainfall for few days. Often it takes the form of heavy rain disaster. During summer monsoon season heavy rainfall is very common phenomenon and induces water logging condition or inundates an area. Thus the excessive or heavy rainfall largely affects agricultural production, physical assets and thousands of valuable lives. Day by day, the disastrous events are increasing. They are paralysing human lives and economy with higher intensities.

Study Area: Coastal West Bengal (CWB) lies at the southern part of West Bengal and touches the Bay of Bengal with two districts, Purba Medinipur and South 24 Parganas. CWB extends from $21^{0}26'$ N to $23^{0}01.02''$ N and $87^{0}27'$ E to $89^{0}09'$ E and encompasses about 20,419 sq. km spatial area.
Generally South 24 Parganas ,Purba Medinipur and southern part of North 24 Parganas are included in Coastal West Bengal. In this study Howrah and Kolkata these two districts have also been included in the study area. From meteorological point of view almost same impact is observed in this extended area of CWB.

Data Consideration: Monthly average rainfall, number of rainy days in a month and heaviest rainfall in a month from 1981 to 2010 of 10 observatories (Alipur, DumDum, Diamond Harbour, Canning, Sandheads, Sagar Island, Contai, Digha, Haldia, and Uluberia) are collected from India Meteorological Department. Occurrence of floods and heavy rain disaster and its casualties are detected from Annual report of IMD-namely "Disastrous extreme Weather Events "and annual report by the Department of Disaster Management, Govt. of West Bengal from 1981 to 2011.

Methodology: In this study descriptive statistics is used on secondary data to determine the average values of variables. Trend analysis is also used to know the increasing or decreasing trend of variables. Pearson co-relation of co-efficient is applied to establish the correlation among the variables and significance is tested to confirm its statistical significance. Variability is determined using coefficient of variation. For comparison of mean level difference Mann-Whitney U test and Kruskal-Wallis test is used instead of one way ANOVA (data is not being pass assumption of normality and homogeneity).

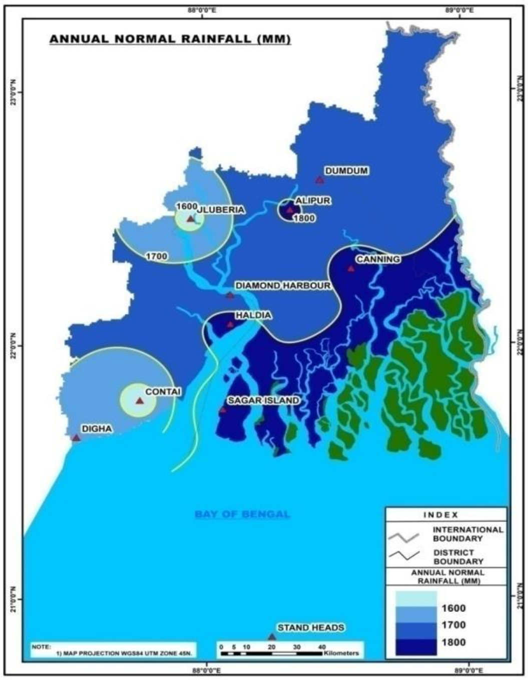
Objectives: The study is conducted to fulfil the following objectives –

1) Identification of rainfall characteristics.
2) Identification of flood and heavy rain disasters.
3) Identification of casualties and damages by disastrous floods and heavy rain event.
4) Determination of co-relation between annual frequency and intensity of flood/ heavy rain disaster and their induced damages/ casualties.

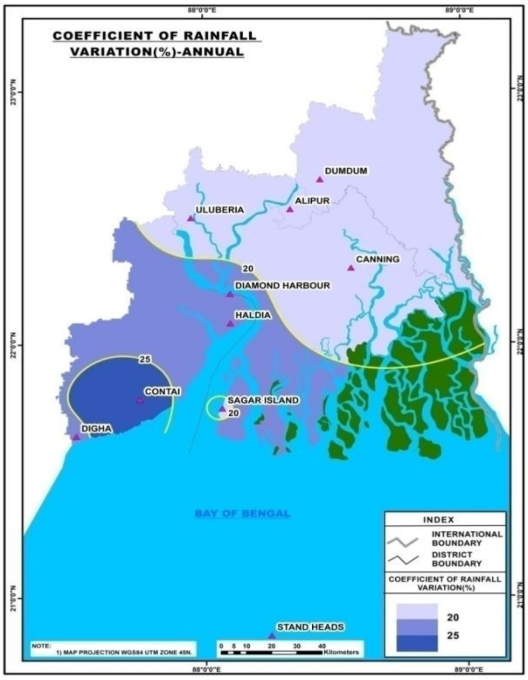
Results and Discussion:

(I) Rainfall Characteristics:

Rainfall-Annual normal rainfall of CWB is determined to be1861.8 mm and ranges from 1569.3 mm (Contai) to 3556 mm (Sandheads). Observatories of south eastern part(map no.1) receives more rainfall (>1800m.m.). Highest share is seen during south west monsoon season (73.44%). During hot (12.51%) and retreating monsoon (11.49%) season such share is very low. July is the wettest month when 20% of annual total rainfall is followed. Annual and seasonal rainfall during south west monsoon, winter and hot seasons are reducing except during retreating monsoon season. Annual rainfall at Alipur, Contai, Digha, Canning, Diamond Harbour and Uluberia are on the increase. Gradual decrease is found at DumDum, Haldia, Sagar Island, and Sandheads.



Map 1-Annual Normal Rainfall



Map 2: Co-efficient of Rainfall Variation

Rainy Days- On an average 78 rainy days (days with rainfall of 2.5 mm or more) are witnessed. Variation among observatories are found from 57(Sandheads) to 85(Alipur) in number. Number of rainy days is comparatively more (more than 80) in eastern part of CWB. About 71.43% rainy days occur in summer monsoon season. In rainiest two months, July (19.62%) and August (19.86%) 16 rainy days individually have identified. An increasing trend is observed in annual rainy days and also in the seasons of South West Monsoon and retreating monsoon. But in case of winter and hot seasons a decreasing trend is prevailing.

Rainfall amount and number of rainy days is significantly correlated (r=0.616). In few years some of the observatories have witnessed more than 100 rainy days in a year, as well as rainfall amount of those years is very high at respective observatories. Opposite phenomenon is also experienced in 1990, when at Halida and in 2001 at Alipur number of rainy days are exactly 100 but their annual rainfall amount is much lesser than normal. Years of excessive rainfall always does not coincide with the large number of rainy days in a year. Only one incident of excessive rainfall is observed when number of rainy days is more than 100, at Sager Island in 2001.

Onset and withdrawal of South West Monsoon-Normal onset date of south west monsoon over the CWB is 7th June (CWB a part of Gangetic west Bengal, onset and withdrawal date of this meteorological subdivision is assumed in case of CWB) . Normal onset date (varies from 25th May to 23rd June) is delayed for five days during study span and one day early withdrawal (varies from25th September to 26th October) is marked instead of 10th October.

Rainfall Variability- Average co-efficient of rainfall variation (C.V.) is18.89% and comparatively very high C.V. is

observed at Sandheads (45.11%) and lowest C.V. is registered to Canning (15.75 %). South west corner of CWB comparatively witness high C.V.(map no.2) Variability of rainfall during monsoon season (18.7%) is low, in hot season about 50% and variability increases in winter (89.72%) and retreating monsoon season (63.01%).

Heaviest Rainfall- Heaviest rainfall in a day at any observatory of CWB is 884.5 mm at Sagar Island on 22nd July 1991. 1981, 1984 and 2004 are the years when heaviest rainfall has been recorded on the day of onset of south west monsoon. Most of the heaviest rainfall days are recorded at Sandheads observatory. Second (651m.m.) and third highest (615m.m.) heaviest rainfall also observed at Sandheads, (on 26th July, 1989 and on 17th may, 1995). It happened due to formations of deep depression over Bay of Bengal. Incessant rainfall occurred over a vast area of

CWB on 5th June and 6th June 1984 as a result heaviest rainfall of a whole day in such year has seen at Uluberia (328.6 mm),Alipur (289.9 mm), Dum Dum (383.2 mm), Haldia (296.6 mm). Heaviest rainfall in a day is also experienced in the month of May to September. During this time rainfall amount in a day is very high which is due to occurrence of Norweaster, depression or cyclonic disturbances, south west monsoon etc.

Excessive Rainfall- All the observatories except Canning have experienced excessive rainfall (125% or more rainfall of annual normal). Maximum number of excessive rainfall is recorded at Digha (5).In some successive years (1983-84, 1988-90, and 2001-02) such occurrence was repetitive.

(II) Disastrous Flood and Heavy Rain events:

Disastrous flood events -The Coastal West Bengal has faced the destructive claws of 42 devastating flood (severe intensity-17, moderate-11, and flash-14). In the year 1997 the study area encountered the flood six times (severe-1, flash- 5). In decadal overview of the flood occurrence, the first decade (1981-1990), the flood has taken place for 11 times. While in the next decade (1991-2000), the selected study area witnessed the flood 16 times. In the last decade (2001- 2010), the area experienced the devastating flood 11 times. Considering the month wise distribution of flood occurrence, it is observed that occurrence of flood is relatively high from May to October. It is also noticed that in the monsoon season (33), mainly in August (10) September (10) and July (8) Coastal West Bengal suffered frequently. Flood frequency is very high in Purba Medinipur (22) and North 24 Parganas(14). A slight positive trend(r=0.184) is persist in annual frequency of flood though the trend is not statistically significant (sig.0.322).

Disastrous Heavy rain events- During the study period 129 disastrous heavy rain occurrences have been counted. In the year of 1995 maximum occurrences (18) have been observed. High frequency of heavy rain disaster has been counted during the decade of 1991– 2000, 71 in number while frequency of such disaster in following(2001-2010) and preceding(1981-1990) two decades are 32 and 18 respectively and rest 8 occurrences are recorded in 2011.
In the South West Monsoon season 101 events occurred. During the hot season (14) and retreating monsoon season (13) attack of heavy rain disaster is comparatively low. Even in cold season Coastal West Bengal was affected once by heavy rainfall. In the months of June (22), July (27), August (26), September (26) occurrences are very high. Disastrous effect of heavy rain is very much dominant in Kolkata (64) while in Purba Medinipur (27), North 24 Parganas (26), South 24 Parganas (26); Haora (19) numbers of occurrences are also very high. No significant increasing trend is observed in annual frequency of heavy rain disaster (r= 0.007).

Rainfall and flood/heavy rain occurrences

A significant positive correlation (r=0.563) is found between annual rainfall and number of heavy rain disaster. Positive correlation (r=0.330) also persists between number of rainy days and number of heavy rain disaster. Annual rainfall and annual flood frequency also maintain a positive correlation(r=0.309).Number of rainy days in a year correlates positively (r=0.264) with annual flood frequency.

Heaviest Rainfall day and disastrous heavy rain/ flood events- In some cases heaviest rainfall is identified as the reason of occurrence of flood and heavy rain disaster. On 21st June 1981 recorded rainfall is 507.5 mm. at Sandheads and made the part of CWB is under inundation. Severe flood and heavy rainfall was also been observed on 29.09.1986 and the rainfall amount on this day is 593.6 mm at Sandheads. Two separate moderate floods were occurred on 6th September, 2001 and 14th September, 2005 respectively and on these two days rainfall is attributed 118.2 mm at Sagar Island and 241.3 mm rainfall was measured at Digha as heaviest rainfall of respective two years. In some cases occurrence date of heavy rain disaster and heaviest rainfall amount in a year is same. Such as, 6th June 1984, 12th June 1988, 24th June 1992, 22nd September 2006 are identified as the days of heavy rain disaster and heaviest rainfall amount on those dates are 383.2 mm (Dumdum), 454 mm (Sandheads), 514.8 mm (Sandheads), 211.6 mm (Alipur) rainfall were recorded.

Excessive Rainfall:-Excessive rainfall is an important factor of heavy rain and flood disaster. Out of 30 years excessive rainfall is observed in 14 individual years but 23 flood occurrence and 73 heavy rain occurrence is witnessed in the years of excessive rainfall. Contrary to this even not a single flood or heavy rain disaster is not seen in 1983 though it is a year of excessive rainfall.

Table 1: Years of Excessive Rainfall and annual Flood/Heavy Rain frequency-

Year	1981	1983	1984	1986	1988	1989	1990	1993	1995	1999	2001	2002	2005	2007
Flood Frequency	2	0	2	1	0	1	4	0	3	3	2	0	3	1
Heavy Rain Frequency	5	0	2	0	4	1	12	14	18	5	3	1	6	2

Source-Computed from IMD data

(III) Casualty and damages by Flood and Heavy Rain disaster:-

Casualties due to flood - In the considered study area the disastrous flood has snatched 342 human lives and 335 people were missing. Caused their impalpable death. Few years are identified for huge casualty like 1997(70), 2007(70), 2005(35) and 1986(32). A slight increasing trend (r=0.176) is noticed to annual frequency of flood.

Except the human death, previous records also depict huge house damage and numerous people become affected. In 1981, 2000 houses were damaged. Near about one million people were affected in the year 1984. 3 lakh people were also victimised and 1100 house damages has also been enlisted in the year 1989. Again, one lakh people were under of influence of such disaster and 12000 houses were damaged and in this same year 375000 people were affected. Further 96000 people were affected and damage of 1364 houses were also reported. In 2004 the suffering population of the study area is about 890000 and more than 18000 dwelling houses were destroyed and 56865 houses were damaged, along with it Rs.6802665 lakh is estimated as agricultural loss. Effect of flood had been spread over 20000 people and about 15000 houses were collapsed due to the flood in 2008.Incessant heavy rainfall from 17.09.2000 to 21.09.2000 and just after it continuous discharge from dams and barrages caused a severe flood, all over the North 24 Parganas. About 960 sq. k.m. areas of 652 mouzas were affected caused damage to 265000 houses, crops, school buildings etc. More than 19 lakh people were affected. Assessed economic loss is Rs.62, 207 lakh.

Casualties due to Heavy rain disaster- Though the heavy rainfall is not a major disaster as cyclone or flood but it paralyses normal life. Due to heavy rain 449 human live loss and injury to 179 people were reported. During 19th to 25th September, 2006, continuous rainfall hampered normal life and caused death to 84 persons. Lakh of people become homeless, huge damages to crops has been reported and more than 70,000 houses were reported to rupture. Death due to heavy rain disaster shows a significant positive trend(r=0.562). The successive years from 2002 to 2008, heavy rainfall snatched countless human lives. During heavy rainfall, due to the capsization of fishing trawlers numbers of fisherman become missing such as in 4th week of October, 2000, 96 fishermen were reported to be missing near Digha coast. Heavy rainfall also causes damages to river embankments. On 27th September, 1996 near about 1000 ft long embankment of Ichhamoti river breached. Crops damage by the hit of heavy rainfall is a normal phenomenon. Amount of damaged crop is one lakh rupees for submerge of cropped area due to heavy rainfall on 17th May' 2009. House damage is another type of economic loss by the hit of disasters, mainly mud walled, thatched roof houses become damaged. For instance almost 1100 houses damaged in Purba Medinipur on 26th September 1995. In Contai 10000 mud houses were damaged on 9th September, 1999. 500 houses destroyed in North 24 Parganas by the hit of another heavy rainfall on 27th September, 1996. On 14th and 15th May incessant rainfall destroyed 20000 houses in the district of South 24 Parganas.

(IV) Correlation between annual frequency and intensity of extreme weather events and annual damages/ casualties by extreme weather events:

Such correlation is tested with hypothesis and due to unavailability of damage data of all the floods and heavy rain disasters, hypothesis is tested on casualty data.

Hypothesis:"Higher the frequency and intensity greater the casualties"

To test the hypothesis higher the frequency greater the casualties, Pearson's correlation coefficient is used where annual frequency of floods and heavy rain is taken as independent variable and casualties by flood/heavy rain is selected as dependent variable.

Null hypothesis (H_0) is assumed, there is no correlation between annual frequency of any extreme weather event and number of casualties by such event (H_0: P=0).Alternative hypothesis (H_1) is assumed, a correlation between annual frequency of flood/heavy rain event and number of casualties by such event exists (H_1:P≠0).Degree of freedom (df) =N-2, N=Number of years here31-2=29.Significance level (α) is 0.05with two tailed test.

A significant correlation is observed between annual frequency of floods and annual casualties by flood. So we can conclude that higher the frequency greater the casualty is proved. But no significant correlation is established between annual occurrences of heavy rain and annual casualties by heavy rain. So, the null hypothesis is accepted for heavy rain event and null hypothesis is rejected against alternative hypothesis for flood. Therefore, the conclusion higher the frequency greater the casualty is proved but this hypothesis is not proved in case of heavy rain incident.

Hypothesis –Higher the intensity greater the damage/casualty-

All the flood events are categorised into three intensity groups by IMD but no such categorisation is seen in case of heavy rain. So this hypothesis is tested only for flood.

Three types of floods are identified, namely, severe moderate and flash flood. For the violations to assumption of normality [significance value of Shpiro –Wilk test (p) of severe intensity group (.000) and flash flood group (.000) is less than α(0.001) but for moderate group p value (.125) is greater than level of significance (p>α)] and assumption of homogeneity of variance [Significance value (p) is 0.000 which is less than α (0.05)] a non parametric test, Kruskal-Wallis test is used. Mean rank of casualty by severe flood is much higher (mean rank-31.08) than that of moderate intensity (mean rank-19.0) and flash flood (mean rank-11.97). There is a statistically significant ($\aleph^2(2)$ =22.029, p=0.000) difference in casualty by flood between various intensity groups of flood event.

Mann Whitney U test is used to identify significance of difference combining two groups individually out of three. Mean rank difference is statistically significant (U=25.5, p=0.01) between severe flood intensity group and moderate intensity group. Difference in mean rank between severe flood group and flash flood group is also statistically significant (U=18, p=0.000) but the mean difference between moderate and flash flood group is not statistically significant (U=37.5, p=0.069). Therefore, the hypothesis: higher the intensity greater the casualty is proved partially in case of flood event. Casualty by severe flood is significantly higher than casualty by moderate flood. Casualty of severe flood is also significantly higher than casualty by flash flood. But casualty by moderate flood is greater than flash flood but the difference is not statistically significant.

Conclusion: Studying the rainfall details of three decades it is found that the elongated south western wind in summer season is associated with more number of rainy days. Though the average rainfall amount gets reduced by it. This explains the intensity of rain also diminished. Besides this the number of excessive rainy days and heaviest rainfall amount of a single day of any year has also been reduced. Thus it can be sum of that flood, caused by rainfall are day by day in decreasing trend.

Though excessive rainfall days are in increasing trend and in many cases they left a destructive impact lesser than flood. For repetitive occurrences of heavy rain event, total casualty is greater than flood events. Sometimes calamitous effect of heavy rain often exceeds the gigantic impact of flood. A massive population hike and their habitation in the vulnerable area results in a great loss of physical assets property and lives in flood and excessive rainfall.

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