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THE RAINFALL DISTRIBUTION CHARACTERIZATION AND FLOOD EXTENT MAPPING USING SAR SATELLITE IMAGE: A CASE STUDY IN NORTH WESTERN PART OF BANGLADESH

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ABSTRACT
Bangladesh is a flood-prone area among Asia for the geological location. Due to this natural disaster, infrastructure damages and human life losses occur every year in this country. Efficient monitoring and prediction of the flood in this county are very difficult without using satellite data. Flood mapping is a process which uses for damage assessment and risk management and helping rescuers during the flood. Somehow, Rainfall associated with flooding affects the study area with life loss and crop loss. The study area is the north western part (Rajshahi, Naogaon and Natore) of Bangladesh. The objective of this study is to define the extent of the flood in the study area during rainy season comparing two years of 2016 and 2017 and to identify the characterization of rainfall distribution during this period. The study also illustrates the links between evolving rainfall structure and spatial extent of flooding. The whole analysis is based on SAR (synthetic aperture radar) satellite images from Sentinel-1, have free access from ESA. The software is used for SAR imagery processing using threshold method to derive the flood extent and google earth is used to visualize the result of image processing. The results help operating estimation and detection of flooded area and determine the extent of flood causing damages in the study area. Finally, the study explores that due to the changing contribution of rainfall distribution, the extension of flooding is increased to a great extend or not in Rajshahi, Naogaon and Natore. It also helps to find that the rainfall distribution does really responsible for the flood in the study area or other reasons do responsible for it.

Keywords: Flood Extent; Rainfall distribution; SAR Image; Flood Mapping.

INTRODUCTION:
Approximately one billion people live in extreme flood areas, which may be double by 2050 due to climate change and population increase (Long et al., 2014). A flood is described as an overflow or increase of the expanse of water which submerges urban or rural land. It results from the rising volume of water and the water flows its usual boundaries of village, city. Much of the districts are situated on low-lying and flood-prone areas, which made it particularly vulnerable to seasonal monsoon rains. In 2007, Bangladesh was seriously damaged by deadly monsoon flooding which led to over 1,000 deaths and in 2017 history is repeating (George, 2017). Prediction of precipitation and flooding has definite importance from a societal and economic perspective (Villarini et al., 2011).

Relevant study on the flood extent mapping has done to identify the intensity of the flood locations. The study areas are Rajshahi, Naogaon and Natore of Bangladesh. Earth Observation (EO) data which are collected from space, is being used for effective monitoring of floods and precipitation data is collected for rainfall distribution characterization. Mainly the data required for the flood extent mapping is Sentinel-1 freely available from European Space Agency (ESA) which special resolution is 5m-40m. The product type is Level-1 Ground Range Detected (GRD) Sentinel-1 image, for SAR image analysis SNAP tool is used, DEM for ortho-rectification archived optical images, land cover with vector data.

The time selection of the conducted image is to be considered due to the weather condition (Pustina, 2014). The methods and procedures in the relevant studies were followed to some extent to achieve the accurate flood extend map of the research area. Precipitation data helps to identify the characterization of rainfall distribution and it links to the inundation of flood (Villarini et al., 2011). The flood extent information is used for vulnerability and risk assessment.

Basically, the objective of the research practice is to determine the extent of flooded areas of the considered research area. The research explores the flood extend map which includes damage assessment of flooded mapping and severity of flood from the previous year. The application of SAR satellite image leads to a fast image processing system and provides flood extension area (Villarini et al., 2011). The study will help to risk assessment for economic activity and potential location at the risk of flooding. The study is based on the use of satellite remote sensing, geographic information system (GIS) and hydro-meteorological data to evaluate flood situation and assessing the impact of flood disaster with the aid of pre- and post-flood satellite images (Bhatt et al., 2016).

METHODOLOGY

A simple threshold method is applied which was successfully applied in Malwari, January 2015 and also used in Australia, Europe and Africa (Pustina, 2014). The materials for the research are Sentnel-1 images, SNAP 6.0, ArcGIS 10.2.2 and Google Earth. For data preparation, sentinel-1 images of 13th April 2016, 28th August 2016, 26th May 2017 and 27th August 2017 are collected from European Space Agency *(*ESA). Advantages of SAR images are easy detection capability of smooth water and accuracy of detention almost 95%. The images are dereferenced, filtered with the adaptive Gamma filter and masked. To fulfil the second objective, rainfall data is collected from Bangladesh Meteorological Department (BMD).

The research conducts the following steps in SNAP software: Data preparation, pre-processing (Calibration, Speckle filtering), binarization by band maths, Post-processing (Geometric correction). Then image processing for making maps and visualizes in Google Earth. Pre-processing includes calibration and spectacle filtering. Binarization is used to separate water from non- water region and it also analysis the filtered backscatter co-efficient where magnitude depends on the data. ArcGIS 10.2.2 is used to make flood extent map of the studied area (Rajshahi, Naogaon and Natore) and to visualization of the water band in Google earth is resulted to the flood extend map which classifies the water regions Africa (Pustina, 2014). To complete the other objective, rainfall data of the months of 2016 and 2017 analyses to know the relation between rainfall and flood. SPSS are used to correlate the rainfall amount and flood extent with the ANOVA and coefficient of the regression analysis.

RESULTS AND DISCUSSIONS

Two different sentinel-1 images are used for understanding the flood extent in Rajshahi, Naogaon and Natore districts. Table 01 and Figure 01 represent a comparison of the extent of mapping of Rajshahi, Naogaon and Natore from August 2016 to August 2017 which was determined by sentinel image processing. The analysis has made a sense to understand the extent of the inundation of water of the present-past year. The extent of flooding evaluated is only illustrating the increase in flood extent from the previous year and not the entire extent.

Flood extent to the floodplain:

Four different sentinel-1 images are used for understanding the flood extent in Rajshahi, Naogaon and Natore districts.

Table 1: A list of water extent area in Rajshahi, Naogaon and Natore

Study Area	Total area (in sq. km.)	2016		2017	
		Water extent area in April (in sq. km.)	Water extent area in August (in sq. km.)	Water extent area in May (in sq. km.)	Water extent area in August (in sq. km.)
Rajshahi	2382.22	125.49	227.59	116.247	203.12
Naogaon	3449.22	38.24	246.164	21.502	514.67
Natore	1914.19	17.094	179.032	37.415	176.032

In the study, a comparison of the extent of mapping of Rajshahi, Naogaon and Natore from April 2016 to August 2017 which was determined by sentinel image processing is represented in Table 01, Fig. 1 and Fig. 2. The analysis has made a sense to understand the extent of the inundation of water of the present-past year.

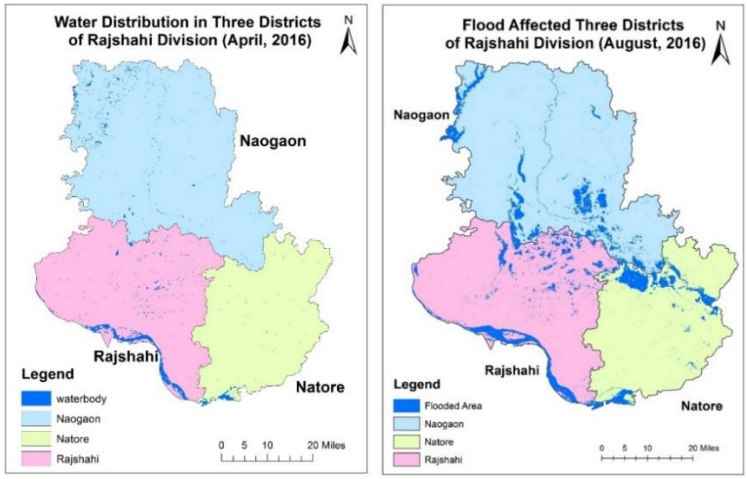

Fig. 1: Water Distribution in three Districts of Rajshahi Division in April 2016 (a) and Flood Affected three districts of Rajshahi Division in August 2016 (b)

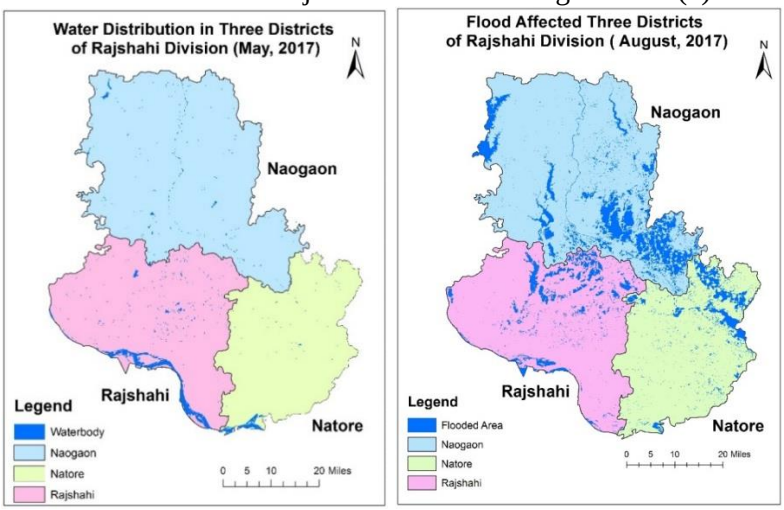

Fig. 2: Water Distribution in three Districts of Rajshahi Division in May 2017 (a) and Flood Affected three districts of Rajshahi Division in August 2017(b)

The water extent area is less in April than the month of August in 2016 over the study area [Fig. 1]. Similarly, water extent area is less in May 2017 than August 2017 in the study area [Fig. 2]. So, it assures that inundation of water in the august month in 2016 and 2017.

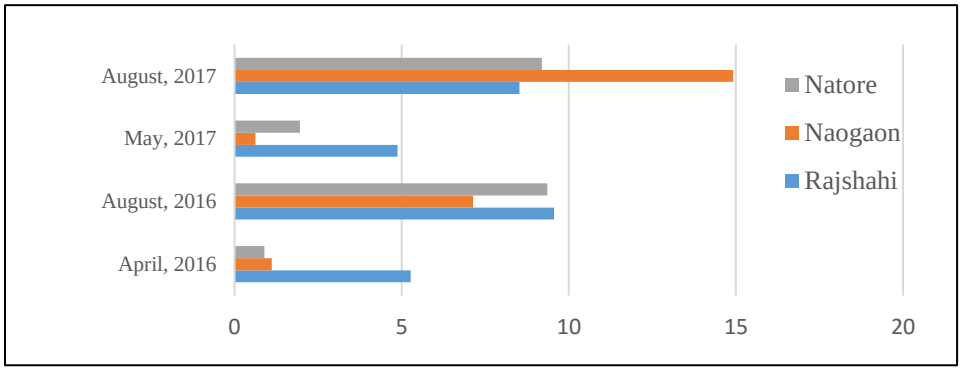

Fig. 3: Comparison of two months of Percentage of the extent of water 2016 and 2017 in Rajshahi Naogaon and Natore

Flood extent of Rajshahi district is less in 2017 than 2016 [Fig. 3]. In 2016, the flooded area was 227.59 sq. km and in 2017 it was 203.12 sq. km since August. The flood extended area has decreased 1.03% from 2016 to 2017. Flood extent of Naogaon has increased in amount this year [Fig. 3].

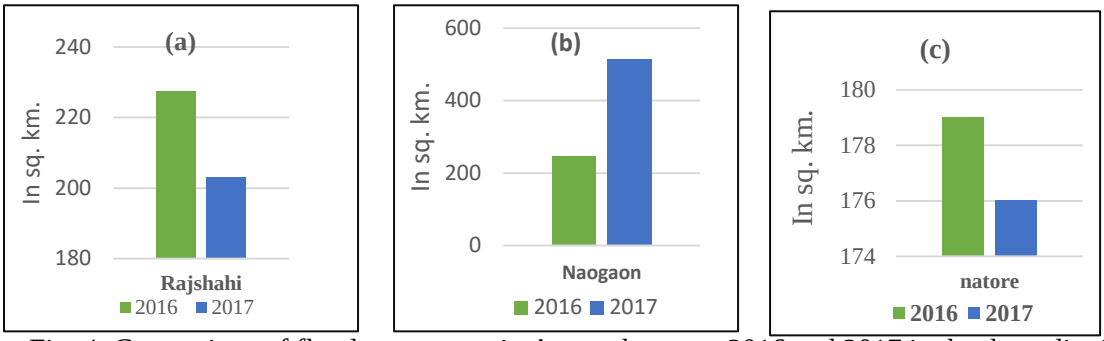

Fig. 4: Comparison of flood extent area in August between 2016 and 2017 in the three district

In 2016, the flooded area was 246.164 sq. km. and in 2017, the area was 514.67 since August [Table 01]. The total area of Naogaon is 3449.22 sq. km. The flood exteded area has increased 7.79% from 2016 to 2017. Flood extent of Natore is less in amount in 2017. In 2016, the flooded area was 179.032 sq. km and in 2017, the area is 176.032 sq. km since August [Table 01]. The total area of Natore is 1914.195 sq. km. The flooded area was 9.35% and 9.19% respectively in 2016 and 2017 of the total area of Natore district. The flood extended area has decreased to 0.16% from 2016 to 2017.

Visualization of flood:

The extent of flooding between August 2016 and August 2017 is determined from the Sentinal-1 images. From the Google earth images, it helps to find out easily the flooded area among three districts. A comparison of flood extent of the present year and past year is shown in Fig. 5. From all the map, it is shown that the extension of inundation of water is more this year until august than the previous year in Naogaon. The time to maximum flood extent is very rapid in the Naogaon Floodplain, depending on the season.

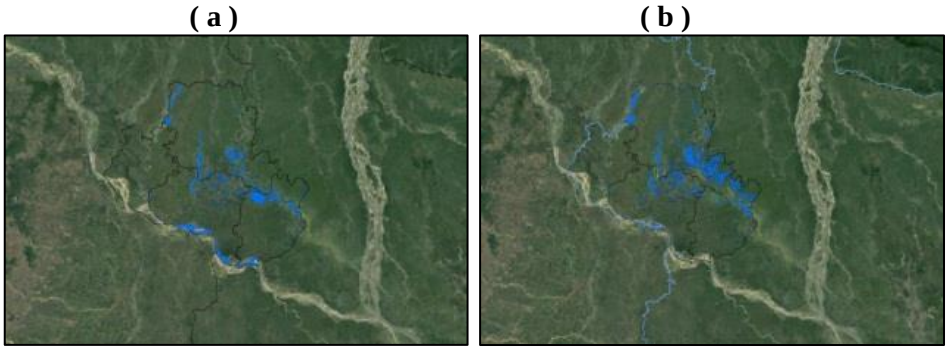

Fig. 5: Visualization in google earth respectively year of 2016 (a) and 2017 (a)

Rainfall distribution to the floodplain: Rainfall distribution is analysed according to the meteorological data collected from Bangladesh Meteorological Department (BMD). Average rainfall is high in August 2016 and 2017 [Fig. 5]. In Naogaon and Rajshahi the average precipitation is higher than the Natore [Fig. 5]

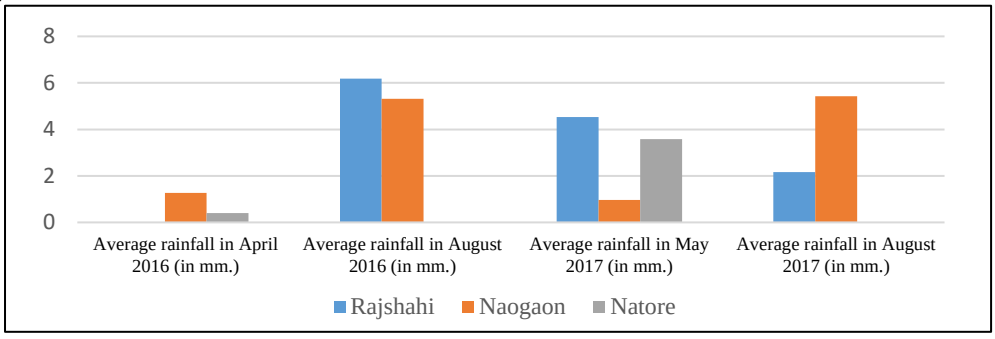

Fig. 5: Comparison of the average rainfall distribution in 2016 and 2017

Relationship between evolving rainfall structure and spatial extent of flooding:
The relationship are shown according to the Regression analysis. For regression analysis, water extent area is independent variable and rainfall distribution is the dependent variable.

Table 2: Descriptive Statistics of the water extent area and rainfall

	Mean	Std. Deviation	N
Water Extent area	6.1179	4.45437	12
Rainfall	2.4856	2.38210	12

The mean water extend area is 6.12 sq. km and the Std. deviation is 4.45 sq. km which indicates that specific areas have huge extension of water in season. The mean rainfall length is 2.49 mm and Std. Deviation is 2.38 mm.

Table 3: Correlation between rainfall distribution & flood extent area

		Water Extent area	Rainfall
Pearson Correlation	Water Extent area	1.000	.390
	Rainfall	.390	1.000
Sig. (1-tailed)	Water Extent area	.	.105
	Rainfall	.105	.

The correlation value between rainfall distribution and flood extent area is 0.390 which indicates that they are moderately correlated. So according to the correlation, the extension of water level into the ground or flooding is not strongly depended on rainfall distribution. Other vital reason depends on the rainfall distribution [Table 03].

Table 4: Model Summary of the regression analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.390[a]	.152	.067	4.30254

a) Predictors: (Constant), Rainfall

From Table 4, the Residual (R) value is 0.39 and the R-square value is 0.152 which indicates that from the predicting rainfall data, 15.2% data are accounted for water extension area. The increase in data collection would increase the data accountability.

Table 5: ANOVA[b] of the regression analysis

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	33.138	1	33.138	1.790	.211[a]
	Residual	185.118	10	18.512		
	Total	218.256	11			

a) Predictors: (Constant), Rainfall b) Dependent Variable: Water extent area

From Table 5, the F-value is 1.7 and Significance (Sig.-value) is .211. So the resultants of the variables are statistically significant.

Table 6: Coefficients of the regression analysis

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.307	1.837		2.344	.041
	Rainfall	.729	.545	.390	1.338	.211

a. Dependent Variable: Water extent area

Here from unstandardized Coefficients of Table 6, it is indicating the increase in 1 mm rainfall would probably cause 0.729 sq. km water extent area.

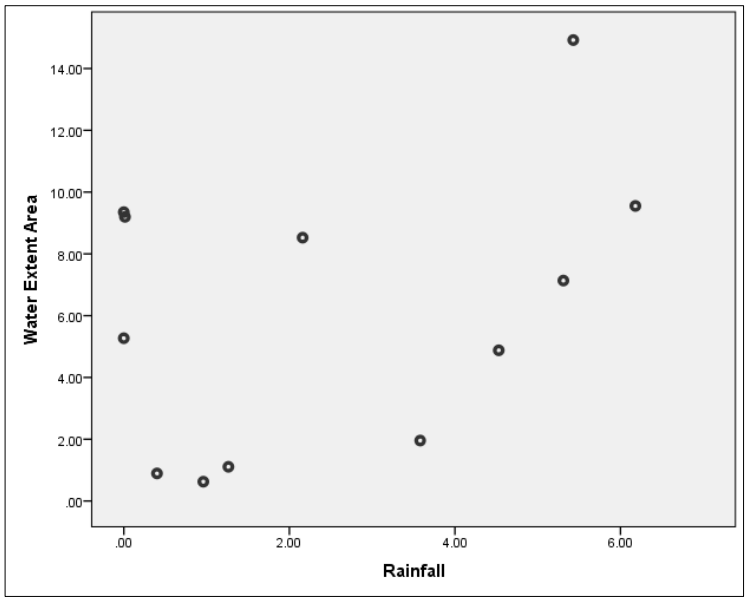

Fig. 5: Scatter-plot of rainfall distribution and water extent area of the study area

The increase in water extent area is increased according to the increase in the rainfall distribution in the study area. In highest length (in mm) rainfall distribution indicates the most extension of water level in the surface [Fig. 5].

CONCLUSIONS

In this research, it has explored the range of inundation of water in the study area. After a qualitative comparison of rainfall between the months of summer and monsoon in 2016 and 2017, it has shown that the rainfall was a moderate reason for flood in the study area. As all the three districts are situated on the bank of rivers, it might be the responsible for causing a flood. At monsoon, over water is bypassed by the Farakka Barrage from India which may be the reason of inundation of water in the study area. In this case, international water law should need to be applied by the authority to distribute the river water carefully and reduce the casualties in flood time.

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