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Satellite Remote Sensing Data Analysis for Flooded Area and Weather Study -Case Study of Dhaka City, Bangladesh-

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Abstract: Bangladesh suffered damage on accounts of the most catastrophic flood during the year of 1988, resulting in untold suffering to the people, crops were lost, lives were lost, infrastructures were damaged, and so on. The flood problem is therefore great important. The present study dealt by using MOS-1, MESSR data with other thematic maps to evaluate the affect and damage area in collaboration with land cover classification in the year of 1988, and analyse the weather condition for Dhaka and Tokyo by using ten years accession report catalogue of Landsat TM. In this paper, estimation method of flooded area on the basis of land cover classification was presented and mean value and standard deviation of clear rate for different season and probability distribution of clear rate for weather analysis was examined.

Key words: *Mos-1 MESSR data, Landsat TM data, estimation of flooded area, probability distribution of clear rate, low tropical flat plain.*

1. Introduction

Bangladesh is South Asian country, situated world highest precipitation area (Brouwer,1994). The country is predominantly a flat deltaic and river-irrigated land. The runoffs from the huge catchments of three major rivers, Brahmaputra, Meghna and Ganges pass through Bangladesh and only 8% of the 1,555,260 km^2 of their basin with their many numbers of tributaries lie in Bangladesh, funnels nearly all the outflow to the Bay of Bengal. Rainfall is abundant from June to November and occasional tropical cyclone strikes the coastal area, bringing torrential rainfall. During these times heavy rainfall occurs simultaneously in Bangladesh and the upper part of Ganges, Brahmaputra and Meghna's catchments beyond the boarder of the country. As a result Ganges, Brahmaputra and Meghna receive heavy runoffs from their tributaries and also receive the full monsoons from Bay of Bengal, which become beyond the control of these rivers carrying capacity and easily spread out of low topographic flat plain along the down stream reaches of these rivers within Bangladesh. Because of Himalayan snow melt and abundant rainfall, Bangldesh's great rivers race southward slicing off chunks of precious land and flooding 20 ~ 25% of the nation annually.

The flood of 1988 in Bangladesh was the most terrible cataclysm and set 100 years new records, which inundated an estimated area 82,000 km^2 (57% of total area) and supersede the previous record of the extent of 1987 flood (40% of total area). Flood commenced in the beginning of July and the peak flow (190,800 m^3/s) of three rivers reached within a period of 72 hours between 30 August and 2 September (Rasid and Pramanik, 1990). Flood caused total affected people 46.7 million, including 2,379 dead, number of house affected 12.8 million including 3.8 million totally destroyed and 3.4 million damaged, crop damaged 7.54 million ha, including total destruction of 4.26 million ha, and partial losses in 3.28 million ha (Baba,1992), beside these the damage of infrastructure were enormous.

In this study, land cover classification was carried out first and finally flooded area was estimated on the basis of land cover classified results. For the estimation of flooded area unclassified result was not counted in the estimation matrix for the simplicity of calculation.

Cloud is very important for the sensitivity of climate and plays dominant role for change of weather. This paper provided the annual change of cloud amount from which clear rate and its probability distribution was obtained.

2. Study area

The selected study area was conducted in Dhaka district, capital city of Bangladesh, which covered 320 km^2 (20 km ×16 km) shown in **Figure 1**. Latitude and longitude of lower left and upper right corners of inner rectangle are 23°23′ N, 90°20′ E and 23°50′ N, 90°35′ E.Main crops are rice, jute, potatoes, pulses, wheat and vegetable, etc. This is the particularly most highest population dense areas, population density is

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2500 to 4000/km^2. The average yearly precipitation is 2642 mm of which more than seventy percent occurs during the monsoon from June to October. Early monsoon started from May and late monsoons remain up to November, dry winter period from November to February and humid summer from March to June. Maximum and minimum air temperature and humidity are 40°C & 11°C and 99% & 36%, respectively.

3. Data Acquisition

In order to estimate the flooded area of Dhaka two image data were considered for same study area, which were taken on 17 October 1988 and 27 January 1989 during the flood and dry season, respectively. Sub scenes were extracted from the MOS-1, MESSR full scenes of 2400 pixels and 1800 lines (path 50 & row 87) with thinning out rate of 1. Each image has 400 pixels and 320 lines after geometric correction. Both one pixel and one line cover 50 m on ground surface. For weather analysis ten year's data was taken from accession report catalogue of Landsat TM for Dhaka (path 137 & row 44) and Tokyo (path 107 & row 35).

4. Land cover classification using MOS-1, MESSR data

4.1 Geometric correction

Geometric correction is need to avoid geometric distortion from a distorted image. To establish the relationship between the image coordinate system and the geographic coordinate system positions of seven ground control points (GCPs) were chosen. GCPs were selected from points easily identified on the satellite image and on topographic maps of Dhaka city generalized land use map (1:25000) produced by Bangladesh Space Research and Remote Sensing Organization (SPARRSO). Geometric correction was carried out by using Affine transformation. The used Affine transformation equations are as follows:

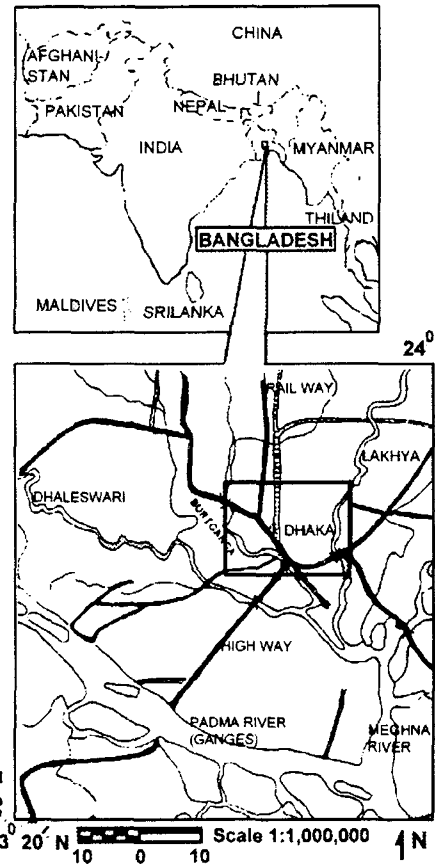


Figure 1 Selected study area (inner rectangle)

$$P = aX + bY + c \quad (1)$$
$$L = dX + eY + f \quad (2)$$

where a, b, c, d, e and f are constant, P and L indicate pixel and line numbers on the image coordinates, and X and Y are the Universal Transverse Mercator (UTM) coordinates, originating from the intersection point of the Equator and the longitude 141°E. The UTM coordinate values of the seven chosen GCPs are (X_i, Y_i), and the image coordinate values are (P_i, L_i), where $i = 1, \ldots 7$. The image coordinate values are ($P_i^{/}$, $L_i^{/}$), corresponding to UTM coordinate (X_i, Y_i) of the GCPs, were obtained using equations (1) and (2):

$$P_i^{/} = aX_i + bY_i + c \quad (3)$$
$$L_i^{/} = dX_i + eY_i + f \quad (4)$$

The absolute differences between the calculated values ($P_i^{/}$, $L_i^{/}$) and the measured values (P_i, L_i) were within 3 pixels, and was considered to be satisfactory.

4.2 Land cover classification

For applying land cover classification method a rectangle were cut out from each original image for different classification. Three corner points of rectangle were selected on the basis of topographical map. The rectangle covered the area 20 km × 16 km is shown in **Figure 1**, and the result yielded 400 pixels × 320 lines on the display monitor. In the new image, the CCT count of each pixel was resampled from the old image by the nearest neighbour interpolation. For land cover classification, the one-cell classification method was used. This method is generally known as parallel-piped classifier or multi-level slice classifier (Japan Association on Remote sensing, 1993). Land covers for the image which was taken on 17 October 1988 and 27 January 1989 were classified into ten and eight categoies, respectively, are shown in **Table 1**. Classifications have been done by using the software "Remote-10" (The Remote Sensing Society of Japan, 1989) on the basis of false color composition of satellite image compared with Dhaka city land use map (1:25,000). The CCT count area for each category was determined with threshold values which were the mean values plus or minus four times the standard deviation, using the spectrum CCT counts of the training area bands 1~ 4 for each category. This helped in determining to which CCT counts area a pixel belonged. Pixels seen in more than one category were classified into the shortest-distance method.

Table 1 Land cover classification

	17 October, 1988		27 January, 1989	
	Legend	**Area (%)**	**Legend**	**Area (%)**
Water area	1 River 1	0.13	1 River 1	2.68
	2 River 2 (with deposit water)	4.96	2 River 2	2.29
	3 Lake (with deposit water)	20.31	3 Lake (with deposit water)	1.22
	4 Deposit water 1	7.93		
	5 Deposit water 2 (with diff. dense gas)	17.12		
	Total	**50.45**		**6.19**
Non-water area	6 Cultivated land	7.16	4 Low land	23.33
	7 High land	1.88	5 Cultivated land	19.15
	8 Residential area	26.58	6 High land	3.25
	9 Commercial area	8.64	7 Residential area	29.76
	10 Cloud	0.65	8 Commercial area	7.05
	Total	**44.91**		**82.54**
Unclassified		4.64		11.27
Total		**100.00**		**100.00**

5. Flood study of 1988

5.1 Considering data

Normally flood occurs in Bangladesh in rainy season. Although it is arduous to get cloud free satellite image data and if the satellite does not pass over the flooded area during peak flood, the area can be covered during its next global coverage. MOS-1 satellite overpass the same area after 16 days interval. There was continuous rainfall in Bangladesh during the flood and flood waters receded slowly and existed for over than four months. Due to the rare cloud free data we had to consider the image data which was taken (17 October 1988) more than one month after the peak flow of three major rivers. Object aimed at estimation of flooded area by separating water and non-water bodies on the basis of land cover classified results.

5.2 Flooded area

Table 2 shows a matrix for the estimation of flooded area on the basis of land cover classified results during the flood and dry season. The diagonal element's **b** and **c** of this matrix indicate non-water and actual water area percentage during the flood and dry season, respectively, on the other hand **a-c** indicate water area during the flood and non-water area during dry season. Element's **a** and **b** of last column are total water and non-water area percentage during the flood while elements **c** and **d** of last row indicate total water and non-water area percentage during dry season. So, **a-c** which indicates non-water area during dry season and water area during flood season is considered as flooded area, while **b** which indicates non-water area during dry and flood season is considered as non-flooded area. **Table 3** shows the final classified results and comparison of results between flood and dry season. One can understand that what kind of change should take places and how much percentage of area remains unchanged and changed their position from water area to non-water area during the flood and dry season, vice versa. It is to be said on the basis of matrix shown in **Table 2** and comparing with **Table 3** that actual water area is from 4.16% to 4.42% (adding

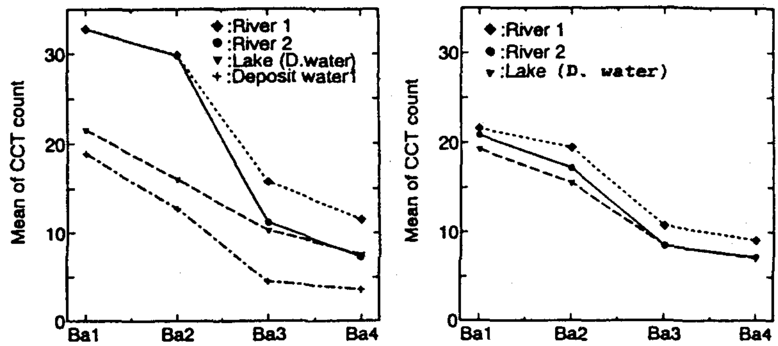
Table 2 Matrix for estimation of flooded area

		Dry season		
		Water area	Non-water area	Total
Flood season	Water area	**c**	**a-c**	**a**
	Non-water area	**0**	**b**	**b**
	Total	**c**	**d**	**100%**

characteristics of measured signal in water bodies that lead to increase of the reflection of solar radiation.

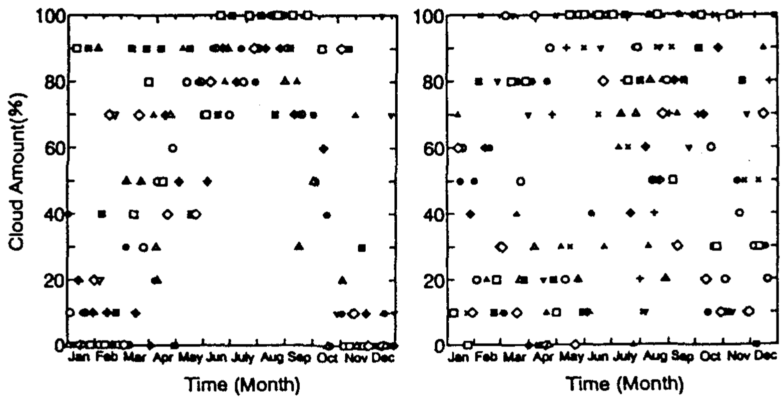
6. Weather analysis

Rainfall is uneven, and abundant from June to November in Bangladesh. Moist air penetrates from south east to inland of Bangladesh and heavy monsoon rains occur, which is well known in the region and tropical cyclones strike the coast bringing torrential rainfall. Rainfall is greatly reduced from December to March with minimum values in February and March of dry seasons. Annual variation of cloud amount for about ten years in Dhaka and Tokyo are shown in **Figure 4**. Tokyo has no such weather type of heavy rainfall in summer like Dhaka. Climatic factor is the most important factor in governing rainfall in the river catchments of Ganges, Brahmaputra and Meghna experienced broadly humid tropical climates but Bangladesh experience humid sub-tropical.



(a) October (b) January

Figure 3 CCT value for 4 band of different water categories



(a) Dhaka (b) Tokyo

+:'84, ×:'85, ▼:'86, ▲:'87, ●:'88, ○:'89, ■:'90, □:'91, ◆:'92, ◇:'93, △:'94, ▽:'95

Figure 4 Time series curve for annual variation of cloud amount

6.1 Clear rate

Clear rate is defined by the equation of $X = 10 - C/10$, where X is clear rate and C is cloud amount. When $C = 0, 10, \ldots 100\%$ then $X = 10, 9, \ldots 0$, cloud amount 0% and 100% corresponding clear rate 10 and 0, considered as clear and bad weather (overcast), respectively. The relation of standard deviation and mean value of clear rate for each season is shown in **Figure 5**. For Dhaka standard deviation and mean values in summer are very small, indicates many days were cloudy and bad weather was stable for long period, and the weather in autumn was unstable as compared with other season, i.e., frequently changeable, winter has high mean value of clear rate, 8. But in case of Tokyo the weather is mild due to the narrow dispersion range of mean and moreover also moderately changeable due to the high standard deviation. So, Tokyo has no severe weather that can exist for long time like Dhaka.

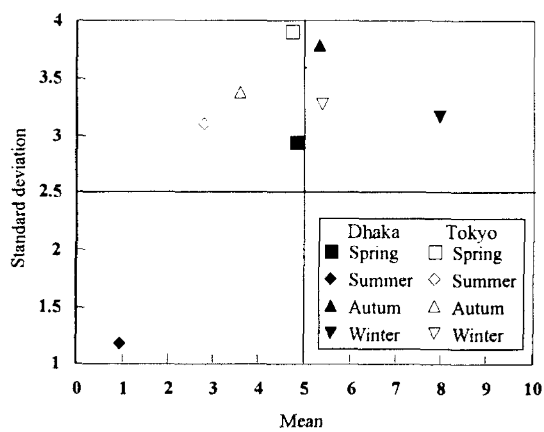


Figure 5 Mean value and standard deviation of clear rate

4.16% and 0.26% which belongs to unclassified during flood season and water area during dry season), and ignored 1.77% considered as error which belongs to non-water area in flood season and water area during dry season. It is therefore said that at least 41.09% areas were remained under flooding condition during the image data taken and considered as flooded area. In a similar way, we analyzed the image data for 9 May 1989, beginning of the early monsoon, and examined the actual water area (3.91%) which is very resembled to above mentioned results and 17.14% areas were estimated as temporary deposit water in the beginning of early monsoon deposited by rainfall.

Table 3 Water and non-water areas during the flood and dry season

		January (dry season)			
		Water area	Non-water area	Unclassified	Total
October (flood season)	Water area	4.16	41.09	5.20	50.45
	Non-water area	1.77	38.20	4.94	44.91
	Unclassified	0.26	3.25	1.13	4.64
	Total	6.19	82.54	11.27	100.00%

Our estimated flooded area would be a little less than that of actual flooded area at peak time, because we analyzed the image data which was taken after the peak flood. But we have tried to adopt the technique to estimate the inundate area in collaboration with land cover classification during the flood. One can estimate actual flooded area using this technique if purvey peak flood data.

5.3 Application of Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI) is calculated from radiometrically normalized red and near-infrared bands (i.e., Band 2 and 3 of the MOS-1, MESSR) as following equation:

$$\mathrm{NDVI} = (B3 - B2)/(B3 + B2) \qquad (5)$$

where $B2$ and $B3$ are the CCT values for MOS-1, MESSR band 2 and 3, respectively. The NDVI of flooded area is expected to be smaller compared with before flooding, because the vigorous vegetation has high NDVI and the water has low NDVI. After classification of image data into categories, NDVI's were calculated for each category. Mean value and standard deviation for residential area, commercial area, highland and cultivated land are shown in **Figure 2**. Mean values of NDVI are positive for high land and cultivated land in October, which indicate high dense vegetation than those of others. They were influenced by deciduous trees with leaves in spring and summer and without leaves in winter, and also depend on crop growing seasons. Mean values of NDVI of residential area and commercial area are negative, which indicate the area with low dense vegetation. The standard deviation values in October are higher than those in January. In October there was inundated water and rainfall which made the soil wet for long time. Inundation water and moisture contents of the submerged soil caused low NDVI, on the other hand non-flooded high dense vegetation indicated high NDVI, which lead to the increase of standard deviation.

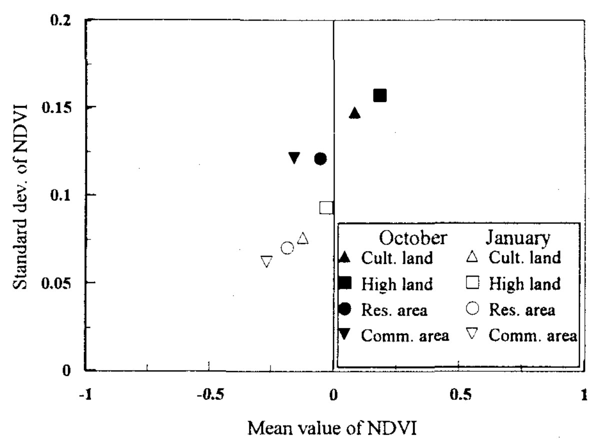


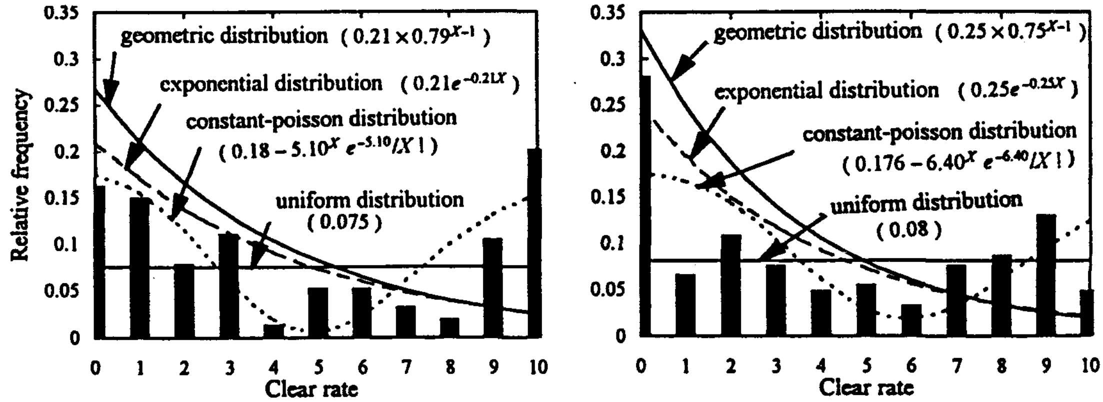
Figure 2 Mean value and standard deviation of NDVI

5.4 CCT count for each band of different water categories

CCT counts for each band of different water categories are shown in **Fig. 3(a)** and **(b)** during flood and dry season. The different spectral characteristics for river, lake and deposit water and the usefulness of band 1 to 4 can be understood from these Figures, which establish the relationship of river, lake and deposit water. CCT count for river water is higher than that of lake and deposit water and during the flood it is more higher, because river water contained more turbidity than lake and deposit water and the amount of turbidity was more larger during the flood, which influence the amount of energy back scattered and the spectral

6.2 Probability distribution of clear rate

In order to find out the probability distribution as best fit curve, geometric, constant-poisson, exponential and uniform distributions were considered as probability density function. We derived constant-poisson distribution by the help of uniform and poisson distribution. **Figure 6** shows the results of best fit curves with their equations as probability density function. We can calculate the probability of occurrence of good or bad weather at one position by using the probability density function. RMS (Root Mean Square) error of probability distribution are shown in **Table 4**. Judging by the RMS error, it is to be said that constant-poisson distribution is the best fit curve for Dhaka and Tokyo.



(a) Dhaka (b) Tokyo

Figure 6 Probability distribution as best fit curve

7. Conclusion

This study dealt with the satellite remote sensing data for flood study of 1988 in Dhaka and weather analysis of Dhaka and Tokyo. The points of conclusion are described as follows:

Table 4 RMS error for probability distribution of clear rate

	geometric	exponetial	const-poiss.	uniform
Dhaka	0.079	0.067	0.039	0.061
Tokyo	0.078	0.060	0.055	0.066

1. The estimation method of the flooded area using the matrix described by the land cover classification results in flood and non-flood season was proposed.

2. It became clear that the standard deviation of NDVI in inundated and partially inundated area is higher because of the flooded water and the soil moisture content with low NDVI.

3. The river turbid water during the flood showed higher mean value of CCT count than that of clear lake and deposit water.

4. Regarding the probability density function of clear rate obtained from cloud amount, constant-poisson distribution is the best fit curve for Dhaka and Tokyo.

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