

Detection of Water-logging Areas Based on Passive Remote Sensing Data in Jessore District of Khulna Division, Bangladesh

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Abstract- Water-logging is one of the major environmental problems and challenges of socio-economic development in the south-western part of Bangladesh. In this research paper, Jessore district of Khulna division was selected as the study area to detect water-logging and damaged agriculture lands. To carry out this detection, Landsat imageries from 1972, 1989 and 2014 were used. A post classification comparison of change detection was followed to calculate transformation of water and agriculture in the study area. About 32830 hectare lands were extracted as waterlogged areas, which is 13% of the total land. Moreover, agriculture has been decreased while water bodies have upward trend. In this analysis, a multi-regression analysis was performed using *Upazila* wise water-logged as independent variable and *Upazila* wise damaged agriculture lands as dependent variable. This result shows a strong correlation between waterlogged and damaged areas, which was 93% at 95% confidence level with *P* value < 0.5. The overall accuracy assessment for water and agriculture were 92%, 91% and 95% in 1972, 1989 and 2014 respectively

Index Terms- Agriculture, Bangladesh, Change Detection, Jessore, Landsat, Water-logging.

I. INTRODUCTION

The south-western coastal zone area of Bangladesh has been facing drastic water-logging problems. The part of the district Jessore is located in this zone and has been affected as well. Some *upazilas* of this district are directly affected with regular water-logging and drainage congestion problems due to vulnerable climate, over silted up riverbed and low capacity of drainage systems.^[1] The entire district sways badly water-logging during all seasons. Around 2% to 20% people of Jessore district were found affected water-logging problem.^[1] People of that region suffer a lot and get affected by various water borne diseases. The healthy sanitary systems totally collapse during water-logging period. Social environment, local economy, and ecology has been hampered and degraded due to prolonged water-logging. In addition to these problems, damages of agriculture crops has been shown to be a major disaster due to water logging. In the study paper, temporal remote sensing of Landsat imageries of 1972, 1989 and 2014 were used to detect water-logged areas in order to calculate damaged agricultural crops in the study area.

According to WARPO (2005), the nearby river bed and sediment system was interrupted which causes intensifying the Water-logging situation.^[2] Climate change vulnerabilities also effects directly or indirectly to drainage congestion by storm surge.^[3] A research work using satellite image analysis reveals that the water-logging problem is increasing gradually in this region.^[4]

Paul et al., (2000) used Landsat 5 TM imageries to detect open water bodies and floodplain of the Murrumbidgee River near the city of Wagga Wagga, Australia^[5]. They found that optical Landsat is very useful for detecting water bodies and floodplain in their study. NDVI and NDWI have important application to identify water-logged areas. Sahu (2014) used integrated GIS and remote sensing in order to detect water-logging areas in the part of Purba Medinipur district of Keleghai river basin, India. Finally, he used a statistical analysis that shown a strong correlation of water-logged areas and canal density.^[6]

II. OBJECTIVE OF THE STUDY AND STUDY AREA

The main objective of this study is to detect water-logged areas in Jessore district using temporal Landsat imageries. The specific objectives are as follows:

- 1) To assess water bodies and agriculture using multi-temporal data sets.
- 2) To assess agriculture damaged areas.

The study area is located in the south-western part of Bangladesh. The entire Jessore district lies between latitude N 22° 50' to N 23° 20' and longitude E 88° 50' to E 89° 30' (Figure 1). The whole area covers about 2606.94 square km with total population approximately 2764547.^[7] The study area consists of 4 municipalities and 8 *upazilas*; Jessore Sadar, Abhaynagar, Bagherpara,

Chaugachha, Keshabpur, Jhikargachha, Manirampur and Sharsha. The major rivers are Chitra, Bhairab, Kobadak, Betna and Mukteshwari. The whole region's land surface is characterized by Ganges-tidal floodplain. Most of the areas are nearly flat and poorly drained. The average maximum temperature is 34°C which sometimes crosses over 40°C during summer. The average minimum temperature is 15°C. April is the hottest while January is the coldest month. The average rainfall is about 198 mm. June to October month covers about 80% of total precipitation.^[8]

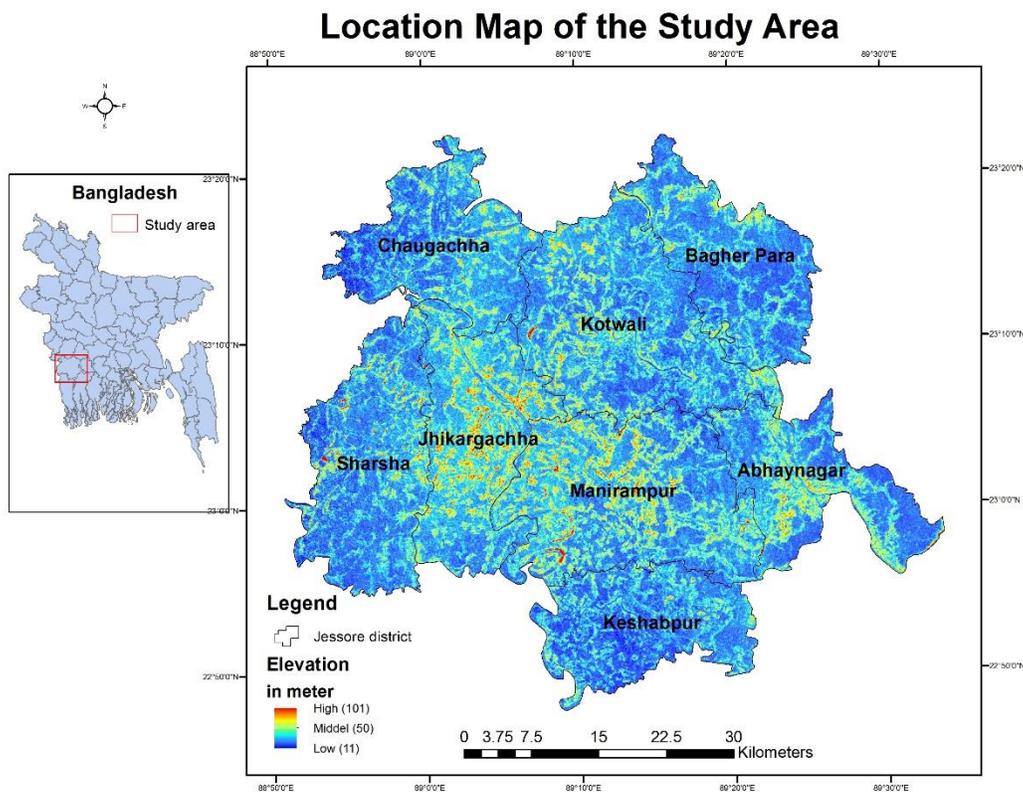


Figure 1 Location map of the study area on elevation data.

III. DATA MATERIALS AND METHODOLOGY

In this study, temporal Landsat imageries from 1972, 1989 and 2014 were used. Mainly four channels e.g. NIR, Red, Blue, and Green were opted for extracting spectral information for water-logged and agriculture from the study area. The main characteristics of the remotely sensed imageries are given in Table 1.

These passive Landsat data were collected and downloaded from the GLCF's (Global Land Cover Facility) as free of cost. An *Upazila* vector polygon map of the study area was collected from Bangladesh Local Government and Engineering Department (LGED) to mask out the study area from the whole scene of Landsat imageries. Finally, the vector shape file was used in zonal tool to extract *Upazila* wise water-logged and damaged agricultural areas.

Table 1 Metadata of remote sensing

Landsat	Row/Path	Date of accusation	Resolution (Meter)	Projection
MSS	044/148	1972-12-11	60	UTM/WGS 84
TM	044/138	1989-11-11	30	UTM/WGS 84
OLI_TIRS	044/138	2014-02-05	30	UTM/WGS 84

The overall methodological framework for the study is presented in Figure 2. These three sets of passive Landsat imageries from 1972, 1989 and 2014 were used for detecting water-logged and agriculture areas using Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) respectively.

A. NDVI for Vegetation

NDVI is a widely used vegetation index for delineating vigor vegetation using near infrared (NIR) and RED band. NDVI is a non-linear function which ranges between -1 to +1 where water, rocks, and bare soils are indicated by values in -1 range and the vigor of vegetation is indicated by values near to +1.^[9] The following equation (i) is used to calculate vegetation in the study:

$$[NDVI = (NIR - RED) / (NIR + RED)] \dots \dots \dots (i)$$

To identify agricultural lands, values between +0.6 to +0.8, +0.6 to +0.7, and +0.5 to +0.8 were extracted from the resultant NDVI images of 1972, 1989 and 2014 respectively.

B. NDWI for Surface Water

The NDWI can be identified water logged areas using green and NIR channel. The NDWI has been developed to achieve the goal.^[10] Similar to NDVI, it produces -1 to +1 values. However, most of the water bodies are found in near to +1 value. The main equation (ii) of this index is below:

$$[NDWI = (GREEN - NIR) / (GREEN + NIR)] \dots \dots \dots (ii)$$

In this study, NDWI values between +0.5 to +0.9, +0.6 to +0.8, and +0.4 to +0.9 were classified as water logged areas from 1972, 1989 and 2014 imageries.

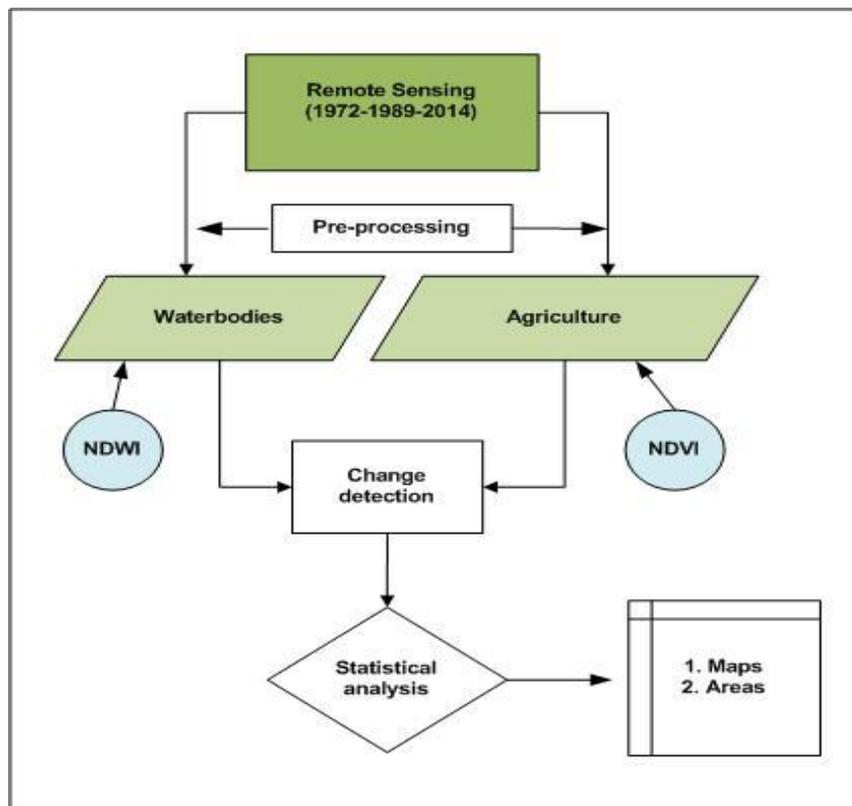


Figure 2 The main methodology followed to carry out this study

C. Accuracy Assessment

Accuracy assessment is an important part for classifying remote sensing data. In this study paper, an accuracy assessment/error matrix was used to compare reference data and classified images. The error matrix compares the relationship between known reference data (ground truth) and the corresponding results of an automated classification.^{[11][12]}

D. Change Detection Analysis

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times.^{[9][13]} In this paper, post-classification comparison method of change detection was used to find out conversion of water and agriculture areas. Post classification comparison change detection is widely used and easy to understand.^{[9][14]}

IV. RESULTS AND DISCUSSION

From this analysis, it is found that there is an apparent declined tendency of agricultural lands from 1972 to 2014. Agriculture lands have decreased by 50% and 25% in 1989 and 2014 respectively from the 1972 in the study (Figure 3). The main reasons for this downward percentage are mainly development and anthropogenic interventions. Moreover, population pressure, natural disaster, salinity, urbanization are exposed as the key driving forces in order to lead this situation. On the other hand, water bodies have gradually increased from 1972 to 1989 and 2014 (Figure 3).

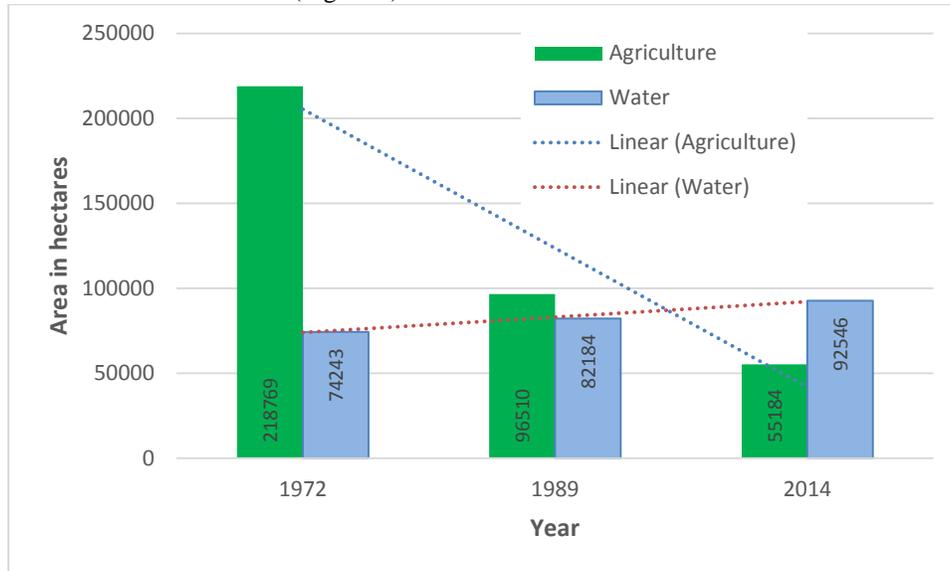


Figure 3 Decrease and increase tendency of agriculture and water areas in 1972, 1989 and 2014.

Post classification comparison of change detection method was used to produce a detailed changes information of water and agriculture from 1972, 1989 and 2014 classified images (Table 2 and Figure 4). In this stage, the 1972 classified image was overlaid with the classified images of 1989 and 2014 in order to get the changes of water and agriculture. Likewise, resultant map of 1989 was overlaid with the 2014 image. Table 2 reveals that water and agriculture have decreased by -35% and -30% from 1989 to 2014. On the other hand, water and agriculture have increased tendency from 1972 to 2014.

Table 2 Change detection tabulation of water and agriculture

Feature	Temporal Data (hectares)					
	1972-1989		1989-2014		1972-2014	
		Change (%)		Change (%)		Change (%)
Water	47700	122%	30800	-35%	16800	43%
Agriculture	46000	62%	36100	-30%	9900	13%

For detecting water-logged areas using these three classified images, a union operation was used in raster calculator in ArcGIS platform. It means all common and seasonal water bodies in these three classified images were leveled as permanent water-logged areas (Figure 5). Due to this reason, all Landsat imageries were collected from the winter season of Bangladesh. In this study, about 32830 hectare lands were extracted as water-logged areas, which is 13% of the total land.

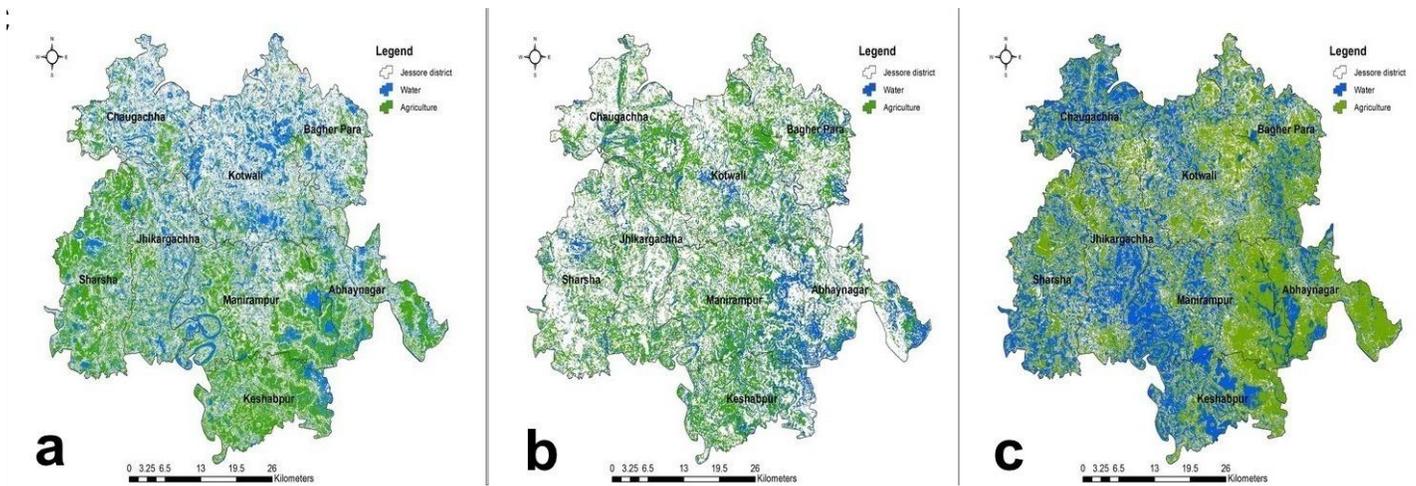


Figure 4: Spatial distribution of water and agriculture in 1972 (a), 1989 (b) and 2014 (c)

In order to delve how many areas were damaged, identified water-logged areas were multiplied with the classified agriculture maps of 1972, 1989 and 2014. Finally, the *Upazila* vector map used for deriving spatial distribution of agriculture damaged areas using zonal statistics. Figure 3 indicates that, a clear increased tendency of agriculture damage due to water-logging from 1972 to 2014. Most of the vulnerable *Upazilas* are in terms of damage; Monirampur, Jessor *sadar*, Keshabpur and Jhikargachha (Figure 6).

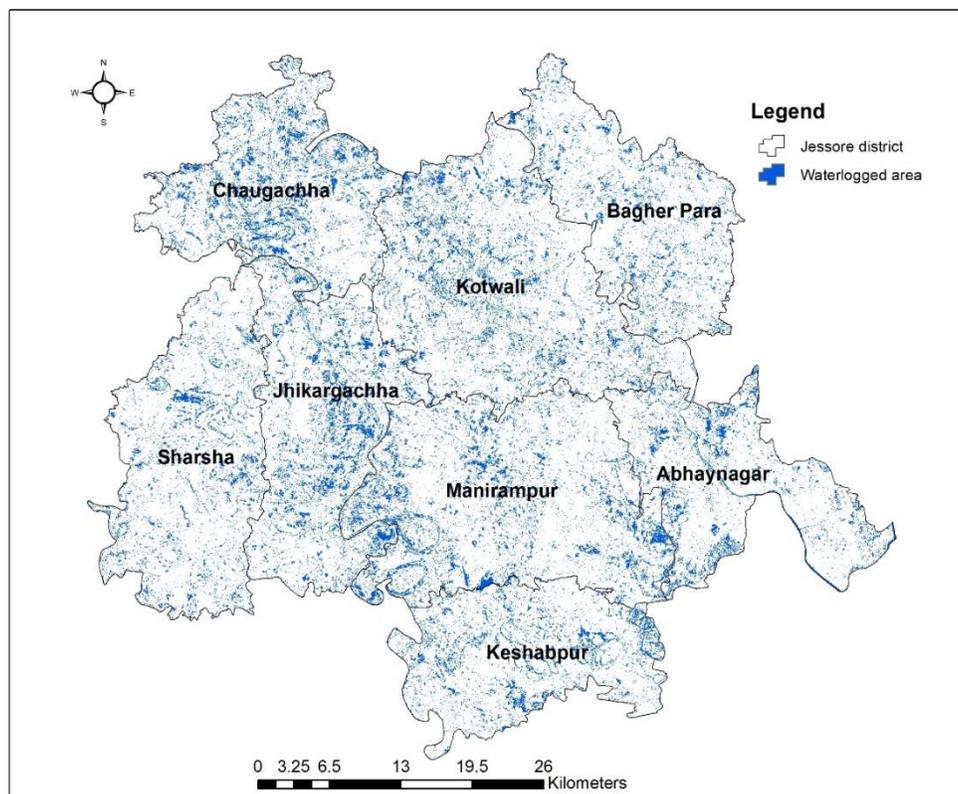


Figure 5 Identified water logged areas using multi-temporal Landsat imageries in Jessore district

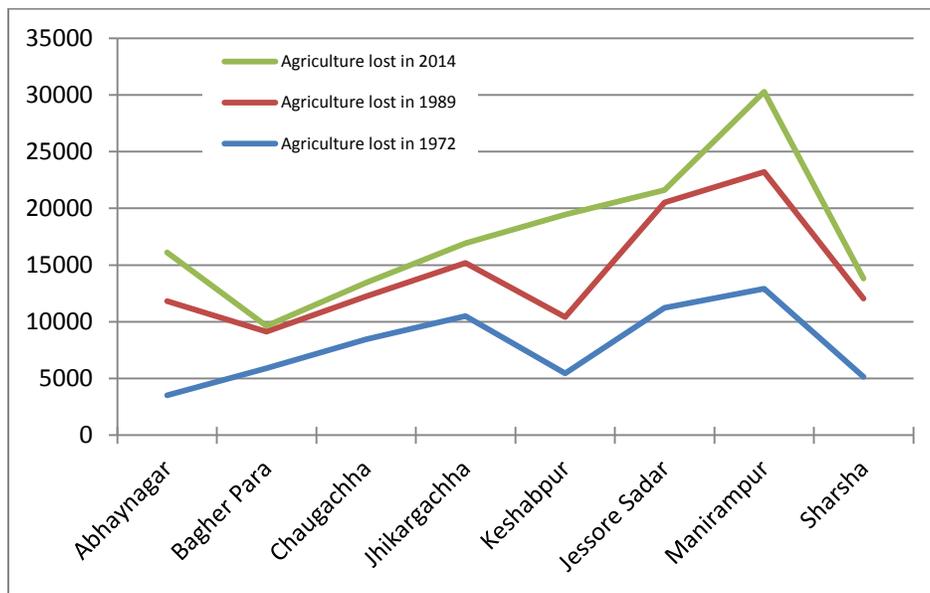


Figure 6 Agriculture damaged areas based on the analysis of 1972, 1989 and 2014 imageries

To identify relationship between water-logged and agriculture damaged areas, a multi-regression analysis was performed. In this analysis, water-logged areas of the eight *upazilas* added as independent variable while agriculture damaged areas of the same *upazilas* were used as dependent variable. Finally, this result (Table 3) shows a significant positive correlation (93%) at 95% confidence level with *P* value < 0.5. It indicates that, if there are more water-logging phenomena then agriculture damage will be higher. Water-logged areas have robust influence for leading damage of agriculture lands and crops which can be affected to local ecology, biodiversity and livelihoods.

Table 3 Regression of water logged areas and agriculture damaged areas in the study area.

Regression Statistics	
Multiple R	0.96562124
R Square	0.932424379
Adjusted R Square	0.881742664
Standard Error	412.7821285
Observation	8

About more than 1500 pixels were selected as reference data for both classified water and agriculture images. The overall accuracy assessment for water and agriculture were 92%, 91% and 95% in 1972, 1989 and 2014 respectively.

V. CONCLUSION

Landsat imageries are shown to be a useful material to detect water-logged areas in this study. Using medium resolution (30 meter) passive data for extracting water and agriculture in rural and semi-rural area can be viable. Normalized difference vegetation index (NDVI) and normalized difference water index (NDWI) were also appropriate for generating lucid information for water and agriculture respectively. In this research, some other important environmental and socio-economic data have not used. Therefore, such kinds of data are recommended for further research on the field in the study area. In terms of environmental degradation and damage of agriculture crops, the government and development agencies should take into account as serious issue in the entire south-western part of Bangladesh.

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