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Monitoring the spatiotemporal dynamics of waterlogged area in southwestern Bangladesh using time series Landsat imagery

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ABSTRACT

Waterlogging is becoming a major environmental problem and challenge for socio-economic development in the southwestern part of Bangladesh. In this study, the Satkhira district was selected as the study area to quantify waterlogging area delineation. To portray these dynamics, Landsat imageries from 1973, 1989, 1995, 2000, 2005, 2010 and 2015 were used. A training dataset was generated in ArcGIS, and a supervised classification was carried out using the random forest algorithm in the R Studio. The overall classification accuracy and kappa statistics was 95% and 91% respectively. Post-classification change detection comparisons were made in QGIS to calculate the transformations of the respective land cover areas in the study site. Areas of approximately 832, 3033, 13,562, 11,547, 27,162, 40,056, and 35,606 ha were observed as waterlogged in the above mentioned years, respectively, which indicates that the acreage of waterlogged areas increased approximately 43 fold from 1973 to 2015. Moreover, the Land Use Land Cover (LULC) change matrix showed that waterlogged area was increased from 5% to 12% during 2000–2005, further rose from 12% to 18% during 2005–2010 and decreased from 18% to 16% during 2010–2015. The most water logged sub-district was Debhata (38%) while Koloroa has the lowest (4%) waterlogged area. The study is an effort to reconstruct the history to understand the dynamics of the waterlogging as past ground monitoring information is absent. Regarding environmental degradation, the government and development agencies should consider these results a critical issue in the entire southwestern part of Bangladesh.

1. Introduction

Global surface water has great importance as it affects the climate, biological diversity and human well-being (Miah et al., 2017; Pekel et al., 2016; Abdullah and Rahman, 2015; Rockström et al., 2009). However, it can become a disaster when an area is suddenly inundated and waterlogged due to various reasons. Waterlogging is the long-term inundation of areas as a result of poor drainage due to natural and or manmade causes (Shamsuddoha and Chowdhury, 2007). Globally, many countries, reported waterlogging as a problem for instance Australia (Brooke et al., 2017; McFarlane and Williamson, 2002), China (Zhang et al., 2012), India (Ritzema et al., 2008), Netherlands (Barrett-Lennard, 2003), Russia (Rukhovich et al., 2014), USA (Horowitz et al., 1995). In the southwest coastal region of Bangladesh, waterlogging emerged as a new problem at the beginning of the 21st century (Brammer, 2014; Shamsuddoha and Chowdhury, 2007). A part of the Satkhira district is located in this area and has been impacted as well. It has become a big problem in recent years due to: natural changes in river flow; raised sediment in riverbeds due to sediment deposition on floodplains protected by embankments, a lack of proper regulation and maintenance of sluice gates of the polders (circular embankments), and shrimp farming (Khan et al., 2015; Rawlani and Sovacool, 2011).

Water logging creates an anaerobic condition in the root zone (Barrett-Lennard, 2003), invites water loving wild plants (Shapiro, 1995), and makes unsuitable for agricultural operation (Kijne, 2006), accumulates toxic salts (Chhabra, 1996), lowering soil temperature (Trought and Drew, 1980). It also cause waterborne disease infestation (Beck et al., 1994), socioeconomic damage, social disruption and death (FAO, 2015). It is a pressing concern against the backdrop of climate change that is becoming worse for the people of southwest Bangladesh (Awal, 2014). The continued waterlogging has caused notable displacements, creating humanitarian challenges regarding safe water supply, sanitation, shelter, food security, and job opportunity (Alam et al., 2017; Abdullah and Rahman 2015; Awal, 2014; Salauddin and

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Ashikuzzaman, 2011; Sarker, 2012; McAdam and Saul, 2010). Socio-economic and agricultural activities have largely been thwarted due to waterlogging (Adri and Islam, 2010, 2012). The local people are severely affected, particularly in the rainy season when peak monsoon hits the region (Awal, 2014; McAdam and Saul, 2010).

The intensity of damage is severe, For instance, over 27,000 houses were destroyed with another 43,000 houses partially damaged during the year 2011 in Satkhira alone (FAO, 2015). It is reported that loss incurred due to water logging includes the death of livestock (50), damage of crops 849 ha (completely) and 540 ha (partially). Further, 859 tube-wells were damaged, 28 schools was destroyed, 1200 shrimp farms were destroyed completely, and another 2975 shrimp farms were damaged.

Remote sensing as a monitoring system is very useful as it can provide the necessary data for investigations of land use and land cover changes, disaster monitoring, and other environmental issues (Abdullah et al., 2015, 2011; Ji et al., 2006). Pekel (2016) studied global surface water using Landsat imagery irrespective of waterlogged area. The remote sensing based waterlogged area monitoring is not common. However, there are several studies which used remote sensing as a tool to study waterlogging problem (Chowdary et al., 2008; Tralli et al., 2005; Dwivedi et al., 1999). Waterlogging area is not easily accessible. So, satellite remote sensing can be used to assess the waterlogged area with limited cost, in a short time and with a limited effort in compared to ground monitoring. In addition to that remote sensing provides reconstructing past datasets where ground monitoring across the scales was not available. So, it is an important tool which can be used efficiently in policy formulation and planning especially in data sparse situation. The study is the first attempt to monitor waterlogging area using long-term remote sensing data in Bangladesh.

In Satkhira, insufficient efforts have been made to address the problem of waterlogging. Most of the study area is based on non-spatial data. Although the waterlogging sometimes induced large scale disasters in the regions, research initiatives for addressing the problem have not been taken into account so that specific policies can be tailored to minimize the risks and maximize the benefits for individuals, households, and communities. Therefore, the study was aimed to quantify the waterlogged area of southwestern Bangladesh using time series analysis of Landsat satellite imagery to formulate proper monitoring of waterlogged area in the southwest coastal region of Bangladesh.

2. Materials and methods

2.1. Study area

Areas waterlogged are not well documented in Bangladesh. However, visual observation of satellite imagery revealed that Satkhira is one of the most vulnerable area in Bangladesh. Hence, the study site was chosen. Satkhira is a southernmost coastal district of Bangladesh that is a part of the Khulna division. This district is bounded on the north by the Jessore district, on the east by the Khulna district, on the south by the Bay of Bengal and the west by India. It lies between 21°36' and 22°54' north latitudes and between 88°54' and 89°20' east longitudes (Fig. 1). The district consists of seven sub-districts. Low elevation characterizes the district. Historically, the district is vulnerable to waterlogging. Hence, the district is chosen as the study site.

2.2. Satellite data acquisition

The Landsat imagery was downloaded from the USGS Global Visualization Viewer website. Satellite data for the years of 1973, 1989, 1995, 2000, 2005, 2010 and 2015 were collected for the month of March. Cloud-free surface reflectance product of Landsat was downloaded for the study. Different vegetation index products, e.g., NDVI, EVI, were also downloaded. The main characteristics of the remotely sensed imageries are given in Table 1.

2.3. Data processing

The Satkhira district boundary (shape file) was chosen as an area of interest (AOI) in the study. All of the downloaded bands were batch clipped using python scripts in the QGIS environment (QGIS, 2015). All of the clipped layers were then stacked and bricked as a multiband raster image for each year considering a "No data value" as − 9999.

All of the multiband images were then set as False Color Composite in ArcGIS. Then, training points were generated (Fig. 2) for three predefined "classes" e.g., land, waterlogged and river, to quantify the waterlogged area and land area. Approximately 450–600 training points were generated based on the image classification requirements and post classification refinement. The training data were generated using GPS data collected on the ground, visual observations, and high-resolution ancillary data.

2.4. Image classification using the random forest algorithm in R

Random forest is a non-parametric method in which a regression tree (CART) and classification are used to model or predict multi source data with nonlinear response variables. RF have the best performances among the CART methods (Prasad et al., 2006). Random forest has been used in various applications, including predicting soil type (Lemercier et al., 2012), soil organic carbon content (Kheir et al., 2010), basal area and trees per hectare (Hudak et al., 2008), and Satellite image classification (Youssef et al., 2016; Rodriguez-Galiano et al., 2012; Bosch et al., 2007; Pal, 2005). Image classifications were done using the random forest algorithm in the R software (Studio, 2016). Required packages were loaded first in R Studio. Then, a working directory containing all of the image files was set. The training dataset for classification was loaded. Using those training data, surface reflectance (SR) imagery, digital elevation model (DEM) data and vegetation index, the random forest model classifications were generated. Finally, the model was applied to the whole scene. Flowchart of the study is shown in Fig. 3.

For the supervised classification using the "Random Forest" (RF) algorithm, where the number of levels for each tuning parameter was three, the data were split into 70% training data and 30% validation data, and the number of cross-validation resamples during model tuning was five. After the code had been run, the confusion matrix, statistics, and the overall statistics including accuracy and kappa (Table 2) were obtained. Finally, the regulated output was obtained.

2.5. Change detection through QGIS

The change detection analysis was conducted in QGIS SAGA using the cross-classification and tabulation tool. The change detection procedure was used for land use land cover change (LULC) during three intervals: 2000–2005, 2005–2010 and 2010–2015. This technique produced a description of the main types of change in the study area. Cross tabulation analysis on a pixel-by-pixel basis facilitated the determination of the quantity of conversions from a particular land cover class to other land use categories and their corresponding area over the period evaluated. A new thematic layer containing different combinations of "from–to" change classes was also produced.

3. Results

Waterlogging is becoming a big problem in southwestern Bangladesh. Fig. 2 shows that the waterlogged area was 3033 ha, 13,562 ha, 11,548 ha, 27,162 ha, and 35,606 ha in the years 1989, 1995, 2000, 2005, and 2015, respectively. The lowest waterlogged area occurred in 1973 (832 ha), and the highest occurred in 2010 (40,056 ha), which was 0.37% and 18% of the total area of the Satkhira

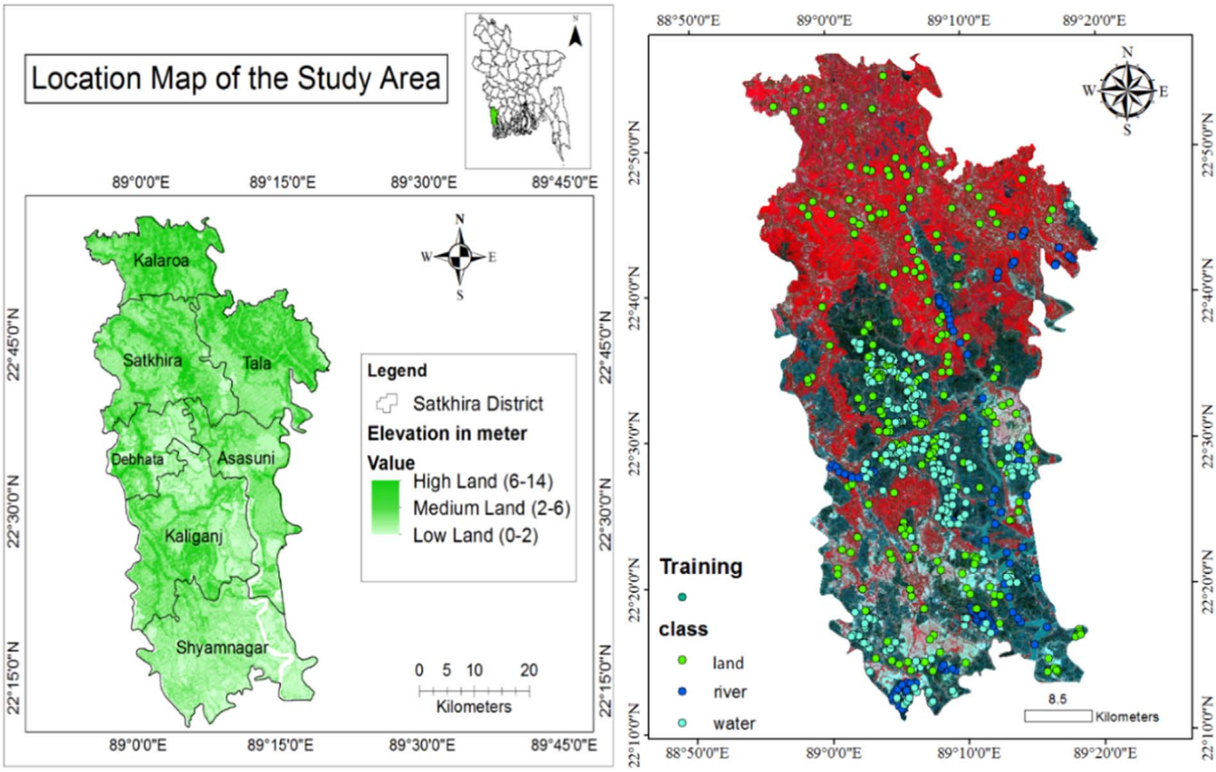

Fig. 1. Study area map showing the elevation with training data of three classes.

Table 1
List of satellite imageries used in this study with some important parameter.

Landsat	Row/Path	Date of acquisition (Julian day of year)	Resolution (Meter)	Projection UTM/WGS
MSS	044 and 045/148	1973-033	60	UTM/WGS 84
TM	044 and 045/138	1989-011	30	UTM/WGS 84
TM	044 and 045/138	1995-028	30	UTM/WGS 84
TM	044 and 045/138	2000-010	30	UTM/WGS 84
TM	044 and 045/138	2005-007	30	UTM/WGS 84
TM	044 and 045/138	2010-037	30	UTM/WGS 84
OLI	044 and 045/138	2015-044	30	UTM/WGS 84

district, respectively. This figure also shows that central and southern areas (Asasuni, Kaliganj, and Debhata) were more affected by the waterlogging problem than the other areas of the Satkhira district.

3.1. Land area

The study site was classified into three main classes, namely, land, river, and waterlogged area. The land area includes built-up, cropland and fallow land. Land area during the period of (1973–2015) is shown in Table 3 and Fig. 2.

3.2. River

River area includes small and large channels and rivers. River areas during 42 year periods are shown in Table 3. This indicates that river area has decreased approximately 2 fold from 1973 to 2015 (Table 4).

3.3. Waterlogged area

Waterlogged area included lands under long-term inundation as a result of inadequate drainage, flood, and shrimp farming. Waterlogged area during intervals within the range from 1973 to 2015 is shown in Table 3 and Fig. 3. This indicates that the waterlogged area increased approximately 43 fold from 1973 to 2015(Table 3). Table 4 showed the annual change (%) of land, river, and waterlogged area. These results indicate that overall land area and river area are decreasing, and the waterlogged area is increasing in the Satkhira district.

3.4. Cross tabulation of land use and land cover classes of the study area over time

Tables 6–9 show change matrices for all classes in Satkhira district from 1989 to 1995, 1995–2000, 2000–2005, 2005–2010, and 2010–2015 respectively. Values in rows reflect changes within the original area of a given class, while values in columns reflect additions to the original area of that class, with values in parentheses reflecting the percentage of the total area.

3.4.1. 1989–1995

The LULC change matrix shows that the area percentage of land was decreased from 97.01% to 90.83% from 1989 to 1995 as a result of the conversion of land into waterlogged area. The area percentage of river was reduced from 1.66% to 1.35%, and the remaining 0.31% was converted to other land use categories, largely to land (0.29%).

However, significant land cover conversion occurred in the waterlogged area; out of 1.34%, 0.61% waterlogged area remained as the same land use category whereas the remaining 0.73% was converted to other land categories, predominantly to land (0.65%). The area

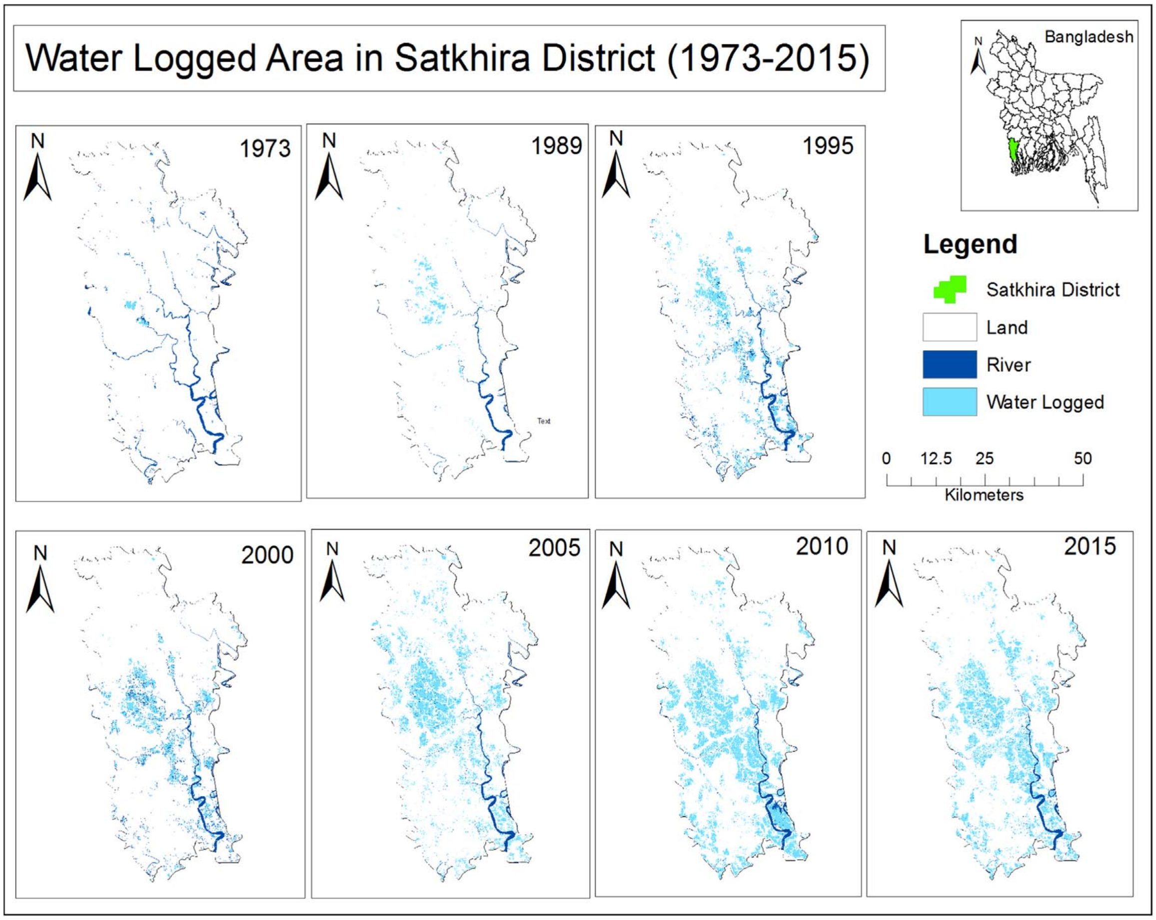

Fig. 2. Maps of waterlogged area in the Satkhira district from 1973 to 2015.

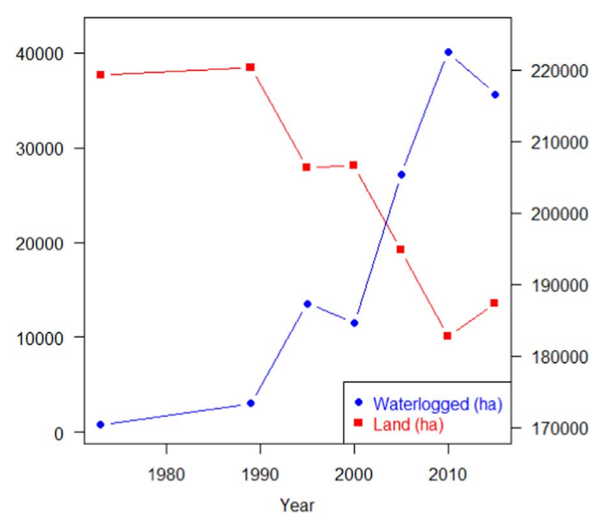

Fig. 3. Temporal change of waterlogged and land area in the Satkhira district.

waterlogged was increased from 1.34% to 5.97% from 1989 to 1995.

3.4.2. 1995–2000

During the 1995–2000 LULC change matrix shows that out of 90.83% land, 86.18% of the land area was retained as the same land use category, whereas the remaining 4.65% was converted into other categories, predominantly to the waterlogged area (2.96%) (Table 7). The area waterlogged was decreased from 5.97% to 5.08% from 1995 to 2000. Out of 5.97%, 1.86% waterlogged area remained as the same land use category, whereas the remaining 4.11% was converted to other categories, predominantly to land (3.55%).

Table 2
Accuracy assessment for the classified images.

Year	Classified image	Overall classification accuracy	Overall kappa statistics
1973	Landsat 1-3 MSS	1.00	1.00
1989	Landsat 4-5 TM	0.94	0.91
1995	Landsat 4-5 TM	0.96	0.90
2000	Landsat 4-5 TM	0.97	0.96
2005	Landsat 4-5 TM	0.95	0.90
2010	Landsat 4-5 TM	0.92	0.87
2015	Landsat 8 OLI	0.94	0.84

3.4.3. 2000–2005

The LULC change matrix from 2000 to 2005 in the Satkhira district showed that (Table 8) out of 90.97% land, 81.92% of the land area was retained as the same land use category, whereas the remaining 9.05% was converted into other categories, predominantly to waterlogged area (8.41%) (Table 8). The area of land was decreased from 90.97% to 85.78% from 2000 to 2005 as a result of the conversion of land into the waterlogged area. However, significant land cover conversion occurred in the waterlogged area. Out of 5.08%, 2.80% of the waterlogged area remained as the same land use category, whereas the remaining 2.28% was converted to other categories, predominantly to land (2.19%). The area under waterlogged was increased from 5.08% to 11.96% from 2000 to 2005.

Table 3
Area of land use and land cover (LULC) types of the classified images.

LULC	Area (ha)						
	1973	1989	1995	2000	2005	2010	2015
Land area	219218.40	220326.21	206291.16	206615.43	194822.73	182767.68	187368.03
River	7662.96	3762.90	7269.57	8959.86	5135.85	4298.40	4148.28
Waterlogged	831.96	3033.45	13561.83	11547.27	27161.73	40056.48	35606.16

Table 4
Annual change in land use and land cover (LULC) types of the classified Landsat images in 1973 to 2015.

LULC	% Annual change					
	1973–1989	1989–1995	1995–2000	2000–2005	2005–2010	2010–2015
Land	0.03	− 1.06	0.03	− 1.14	− 1.24	0.50
River	− 3.18	15.53	3.88	− 8.54	− 3.26	− 0.70
Waterlogged	16.54	57.85	− 2.48	27.04	9.49	− 2.22

Table 5
Cross tabulation of land use and land cover categories of the Satkhira District from 1989 to 1995 (Ha).

1995	1989 Area in ha (%)			Total (1989)
	Land	River	Waterlogged	
Land	204147(89.88)	4037(1.78)	12142(5.35)	220326(97.01)
River	659(0.29)	3070(1.35)	35(0.02)	3763(1.66)
Waterlogged	1485(0.65)	163(0.07)	1385(0.61)	3033(1.34)
Total (1995)	206291(90.83)	7270(3.20)	13562(5.97)	227123(100.00)

3.4.4. 2005–2010

The LULC change matrix (Table 9)from 2005 to 2010 in the Satkhira district showed that out of 85.78% land, 75.09% of the land area was retained as the same land use category, whereas the remaining 10.69% was converted into other categories, predominantly to waterlogged area (10.26%) (Table 9). The area under land was decreased from 80.78% to 80.47% from 2005 to 2010 as a result of the conversion of land into waterlogged area. Out of 2.26%, 1.35% of the river area was retained as the same land use category, whereas the remaining 0.91% was converted to other land use categories, largely to land (0.64%).

However, significant land cover conversion occurred in the waterlogged area. Out of 11.96%, 7.10% waterlogged area remained as the same land use category, whereas the remaining 4.86% was converted to other categories, predominantly to land (4.73%). The area waterlogged was increased from 11.96% to 17.64% from 2005 to 2010.

3.5. Waterlogged area in Sub-districts

The total area (ha), minimum area water logged (ha), and maximum area water logged (ha) by sub-districts are shown in Table 5. It indicates the comparative vulnerability of sub-districts. Debhata having the highest (38%) waterlogged area while Koloroa has the lowest (4%) waterlogged area (Fig. 4).

4. Discussion

Waterlogging is becoming a huge problem in southwestern Bangladesh. The trends of waterlogged area using the forty-two years of historical data of the Satkhira district showed an increasing trend with the exception of 2015. The lowest waterlogged area occurred in 1973 (832 ha), and the highest occurred in 2010 (40,056 ha), which was 0.37% and 18% of the total area of the Satkhira district, respectively. Debhata sub-district being adjacent to the coast having the highest (38%) waterlogged area while Koloroa has the lowest (4%) waterlogged area.

The rivers of Bangladesh are mostly deltaic, so the tidal impact is high (Brammer, 2014). This causes the intrusion of saline water, leading to salinity increases in agriculture lands. With the increase of soil salinity, people of this locality are compelled to change their livelihood from crop production to saline water shrimp farming (Deb, 1998). The southwestern coastal region of Bangladesh is one of the most productive and profitable areas for shrimp farming (Abdullah et al., 2013; Ahmed et al., 2008; MOFL, 1997). A shrimp farm usually needs brackish water that is stored in the shrimp pond (Rahman et al., 2013).

Thus, shrimp farming in the coastal areas has adverse effects on the environment and agriculture. The influx of seawater for aquaculture causes the salinization of soils and groundwater, affecting the productivity of crops (Anwar, 2003; Faruqee and Choudhry, 1996). The high demand and perceived monetary benefits of shrimp have induced many farmers to convert farmlands that have been intruded by saline water into shrimp farms (Hossain et al., 2013; Rahman et al., 2013; Ali, 2006: Mondal et al., 2001).

In an environment that is progressively salinizing, matched against the need for adaptive approaches to sustainable production, there are concerns about the benefits of shrimp farming among the local population, particularly with the poor and marginalized. In Bangladesh, it is estimated that the net profit from shrimp cultivation is twelve times higher than high yielding rice varieties (Shang et al., 1998). The growth

Table 6
Cross tabulation of land use and land cover classes of the Satkhira District from 1995 to 2000 (Ha).

2000	1995 Area in ha (%)			Total (1995)
	Land	River	Waterlogged	
Land	195736.14(86.18)	3836.79(1.69)	6718.23(2.96)	206291.16(90.83)
River	2813.04(1.24)	3860.10(1.70)	596.43(0.26)	7269.57(3.20)
Waterlogged	8066.25(3.55)	1262.97(0.56)	4232.61(1.86)	13561.83(5.97)
Total (2000)	206615.43(90.97)	8959.86(3.94)	11547.27(5.08)	227122.56(100.00)

Table 7
Cross tabulation of land use and land cover classes of the Satkhira District from 2000 to 2005 (Ha).

2005	2000 Area in ha (%)			Total (2000)
	Land	River	Waterlogged	
Land	186058.71(81.92)	1465.56(0.65)	19090.44(8.41)	206614.71(90.97)
River	3781.17(1.66)	3472.11(1.53)	1706.58(0.75)	8959.86(3.94)
Waterlogged	4982.85(2.19)	198.18(0.09)	6364.71(2.80)	11545.74(5.08)
Total (2005)	194822.73(85.78)	5135.85(2.26)	27161.73(11.96)	227122.56(100.00)

Table 8
Cross tabulation of land use and land cover classes of the Satkhira District from 2005 to 2010 (Ha).

2010	2005 Area in ha (%)			Total (2005)
	Land	River	Waterlogged	
Land	170551.89(75.09)	962.46(0.42)	23308.38(10.26)	194822.73(85.78)
River	1463.22(0.64)	3055.59(1.35)	617.04(0.27)	5135.85(2.26)
Waterlogged	10752.30(4.73)	280.35(0.12)	16129.08(7.10)	27161.73(11.96)
Total (2010)	182767.41(80.47)	4298.40(1.89)	40054.50(17.64)	227122.56(100.00)

Table 9
Waterlogged area distribution over the sub-districts.

Name	Total area (ha)	Min. area waterlogged ha (%) in Year	Max. area waterlogged ha (%) in Year
Shyamnagar	45416.25	45.72 (0.10) in 1973	10494.9 (23) in 2010
Asasuni	27370.62	19.44 (0.07) in 1973	5118.93 (18.70) in 2015
Kaliganj	44495.82	216 (0.49) in 1973	14003.19 (31.47) in 2010
Debhata	16942.32	417.96(2.47) in 1973	6369.48 (37.60) in 2010
Satkhira Sadar	36533.16	63.72 (0.17) in 1973	4370.76 (11.98) in 2005
Tala	33561	52.92 (0.16) in 1973	1690.65 (5.04) in 2015
Koloroa	22759.38	14.04 (0.06) in 1973	811.8 (3.57) in 2005

in saline shrimp farming over the past 20 years can be viewed as an effective adaptation to the increasing salinity in the region. (Amoako Johnson et al., 2016; Gain and Giupponi, 2014). Cyclones and storm surges, particularly Cyclones Sidor in 2007 and Aila in 2009, have contributed to rapid salinization of the delta, including agricultural lands, freshwater ponds, canals and rivers (Mahmuduzzaman et al., 2014). The cyclic events of waterlogging are shown in Fig. 5.

Most of the rivers originate in the upstream mountains, such as the Himalayas and others. The river water carries an enormous amount of sediment (Shukla et al., 2017). Due to the flow velocity distribution, this sediment deposits mostly in the southern part of Bangladesh causing riverbed and canal bed filled with sediments (Swapan and Gavin, 2011). As a result, water holding capacity of the river reduced, in the rainy season when the river water is high, this water overtops the river banks. So, government built the embankments or polder, starting with the Embankment and Drainage Act 1952 (Hoq, 2007; Quassem and van Urk, 2006; Islam, 2006; Hassan, 1999; MOFL, 1997). Before the polders were constructed in this region, rivers and boats provided the only means of transportation for traffic and goods, but after the embankments were established, they began to be used as walking paths, and soon more roads, culverts and bridges were developed here as well. As a result, problems have arisen with discharging the water from those

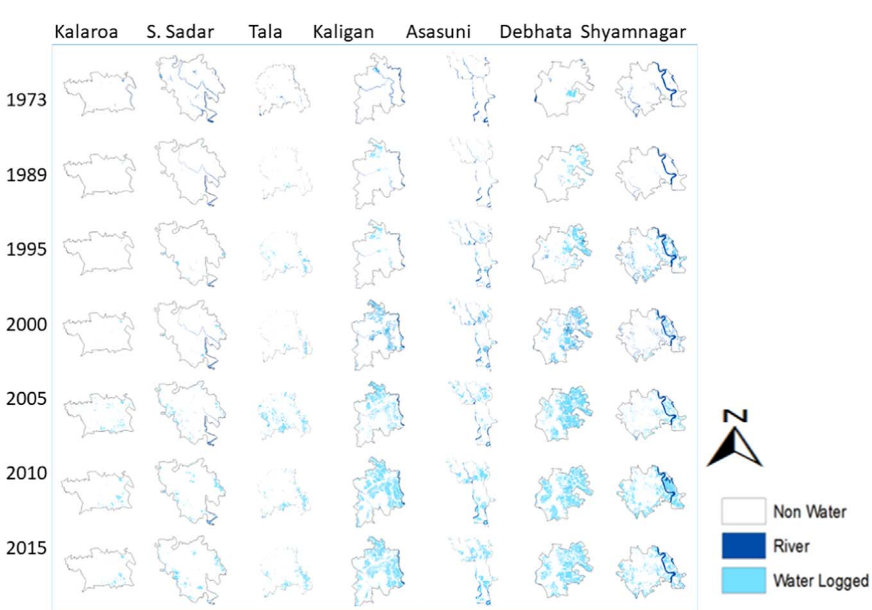

Fig. 4. Maps of waterlogged area in the sub-districts of Satkhira from 1973 to 2015.

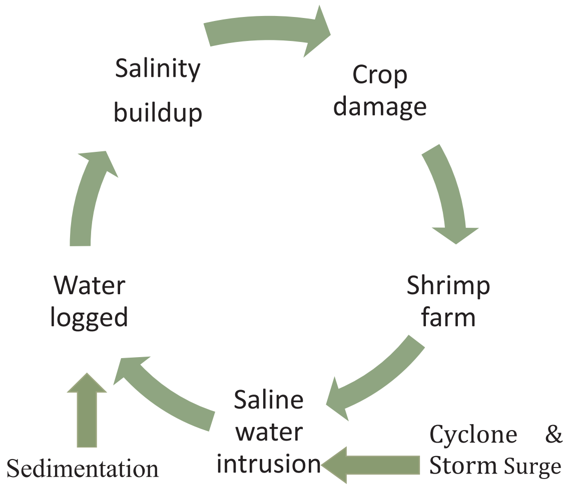

Fig. 5. Vicious cycle of waterlogging in the coastal districts.

regions. The slope of land in those regions is in the north-south direction, but most of the structures were designed and developed in the east-west direction (Rahman et al., 2013). During the construction period of those structures, many channels and discharge paths of water were closed, but comparatively fewer culverts were developed at that time. Because the number of culverts were less than actual demand of the locality, height for water discharge and pillars of bridges also helped to increase siltation. Therefore, the rivers and channels lost the natural flow of water, which contributed to the waterlogging in those regions (Rahaman, 2013). Improper switch gate planning caused drainage congestion in this area which led to waterlogging. The construction of unplanned bridges and roads that hinder the natural flow of water (Hossain et al., 2015; FAO, 2015). A polder is connected to the river with a channel, but over time, there has not been proper management, and the channel is closed so that the river water cannot enter this polder. These polders are generally lower than the river level. In the rainy season, the water enters the polder, causing waterlogging. This situation often lasts for at least six months. Future studies may include the whole of coastal area for details study on waterlogging problem in Bangladesh. In the study we consider only optical sensor. So, future study may include microwave data like SAR. As SAR has better capacity to delineate land and water.

5. Conclusion

Landsat images have been shown to be a useful material to detect waterlogged areas in this study. Using passive remote sensing data, waterlogged area detection has a great potential importance to make policies and management practices to minimize losses from that problem. From this research, the following conclusions are reached. The waterlogged area using the forty-two years of historical data of the different sub-district of the Satkhira shows an increasing trend. Among seven sub-district, the three sub-district most affected by waterlogging are Shyamnagar, Debhata and Kaliganj. The least affected sub-district is Koloroa, but without proper management policies, this area may also be affected soon. Among the three land use land cover classes, the total areas of land and river have decreased, and waterlogged area has increased in the Satkhira district. Long-term satellite image data have demonstrated that the maximum conversion from land to waterlogged area occurred in 1973–1989, and it gradually increased year after year up to 2010 and slightly decreased in 2015 in the study area. The overall findings revealed that due to perpetual siltation in the rivers and as a consequence of unplanned development interventions on the river system, long-lasting waterlogging in the human settlements is taking place in Satkhira, resulting in considerable loss and damage to dwellings, standing crops, shrimp farms, roads, and educational institutions and so on. The paper was intended to assist the relevant institutions of the Government of Bangladesh to address the underlying causes of water logging. The research will improve people's resilience to the threat of recurring and long-lasting waterlogging problem.

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