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IMPACT OF WATERLOGGING ON LAND USE, BIODIVERSITY AND ECOSYSTEM SERVICES IN TALA UPAZILA, BANGLADESH

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Abstract

Waterlogging has become a major issue due to its severe impact on the south-western region of Bangladesh. This study aims to assess the trend of waterlogging and to find out the impact of waterlogging on land use, biodiversity and ecosystem services in the Tala located in the south-western region of Bangladesh. Satellite images of 1990, 2000, 2010 and 2021 were analyzed to portray the trend of waterlogging and questionnaire survey, FGDs and KIIs were used to discover the impacts of waterlogging on land use, biodiversity and ecosystem services in the study area. Satellite image analysis has shown that there is an ascending trend (increased by 154.5% between 1990 and 2000, by 135.9% between 2000 and 2010 and by 23.6% between 2010 and 2021) of waterlogging in the Tala upazila. Qualitative investigations revealed that waterlogging due to siltation in the associated rivers and unplanned human interventions, has been posing threats to the crop lands by turning them marshy. Biodiversity of aquaculture species, agricultural crops, aquatic wild animals, livestock, trees, birds etc. have been severely affected by waterlogging. Waterlogging is highly responsible for the low production of crop and aquaculture species, shortage of safe drinking water, habitat loss, sanitization, migration of people and so on.

Keyword: Waterlogging, Land use, Biodiversity, Ecosystem services, Tala Upazila

Introduction

Waterlogging indicates a state when water supersedes air from the soil pores resulting in soil to be saturated because of water level rise (Mancuso & Shabala, 2014). It can be caused by a combination of several factors such as downpour (for the site), poor external drainage (runoff), poor internal drainage (water movement in the soil profile) and the poor water storing capability of soil (Cox & McFarlane, 1995). This hydrogeological emergency emerged in the south-western coastal region of Bangladesh at the end of the twentieth century. This emergency has been worsened from 2006, although it gradually manifested since the 60's and, from the onset of monsoon downpour of 2011, the greatest disaster was ever being observed (Unnayan Onneshan, 2006). Awal (2014) and Awal & Islam (2020) concluded three main causes of waterlogging in Bangladesh: a) siltation caused by blocking upstream of the Padma river flow and death of the Mathavanga river, b) floodplain deprivation due to siltation caused by embankment or polderization, and c) human intervention and lack of proper administrative step. Waterlogging can have a multitude of effects on the environment, richness of animals and the daily life of people in the affected area. Shrinkage of cultivable land (Masud et al.; 2014; Tareq et al., 2016); lack of safe drinking water, shelter, food security, sanitation, etc. (Awal, 2014; Islam, 2014) are the major problems occurring in the southwestern region of Bangladesh due to waterlogging led flooding.

Land use change, in general, refers to a process of converting or transforming the natural landscape of a particular land area due to 'wild' or human related activities, generally highlighting the utilizaton of land for economic events (Lee-Gammage, 2018; Paul & Rashid, 2017). A significant change pattern of land use was observed in the Satkhira district significantly (Rahman & Begum, 2011; Khan et al., 2015; Tauhid Ur Rahman & Ferdous, 2019).

Biodiversity can heavily be impacted by waterlogging adversely. Houk et al. (2004) and Barrett- Lennard (2003) found evidence that the interaction between waterlogging and salinity has a major effect on crop productivity. A reduced number of birds, livestock, fisheries, plants and vegetation from the flora and fauna were noticed in some Unions of Dumuria and Keshabpur Upazilas of South-western region (Masud et al., 2014; Tareq et al., 2016).

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Costanza et al. (1997) defined ecosystem services as "the benefits human populations derive, directly or indirectly, from ecosystem functions". The services are provisioning services, regulatory services, cultural services and support services. Provisioning services indicate tangible products obtained from ecosystems such as fish, vegetables etc. (Rolando et al., 2017). Waterlogging has pronounced effects on provisioning services. For example, since the 2000s, annual shrimp production has increased from 19587 MT to 37102 MT, and fish production from ponds has risen from 5,682 to 39,599 MT in the Satkhira district (DoF, 2021). Regulating services are benefits that are obtained from the regulation of ecosystem processes (Kumar et al., 2019). For example, Awal (2014) stated that, waterlogging destroyed safe drinking water sources, latrines, houses, and made people (especially women) bound to live surrounded by trapped water. Cultural services indicate non-material benefits. Support services highlight services necessary for maintaining the integrity and functioning of the ecosystem (Everard, 2016). For example, according to Tareq et al. (2016), an alarming rate of migration occurred in the Tala upazila of Satkhira due to waterlogging.

Coastal zone is consistently struck by cyclones, sea level rise, storm surge due to the interaction between land, ocean and atmosphere with each other, which makes the region diverse and dynamic. The vast coastal zone of Bangladesh has an area covering 47,201 km², 32% of the country, being the landmass of 19 districts (Abu et al, 2003). Among the districts, Satkhira is located on the southwest end of Bangladesh and is enclosed by Jashore district on the north, the Bay of Bengal on the south, Khulna district on the east, the West Bengal State of India on the west. Tala upazila of this district is a representative one which is a regular victim of flooding and waterlogging and thereby may negatively get impacted on the aspects of land use change, biodiversity and ecosystem services. Very few studies had been undertaken addressing these issues in previous studies. So, this study attempted to investigate the trend of waterlogging in the Tala upazila over the last 30 years and the impact of waterlogging on land use change, biodiversity and ecosystem services in this upazila.

Materials and Method

Location of the study area

Tala upazila, covering a total area of 337.24 km², is situated in the Satkhira district, Khulna Division of Bangladesh (Figure 1). Tala is located between 22°32' to 22°50' north latitudes and between 89°05' to 89°20' east longitudes (Ferdous, 2013).

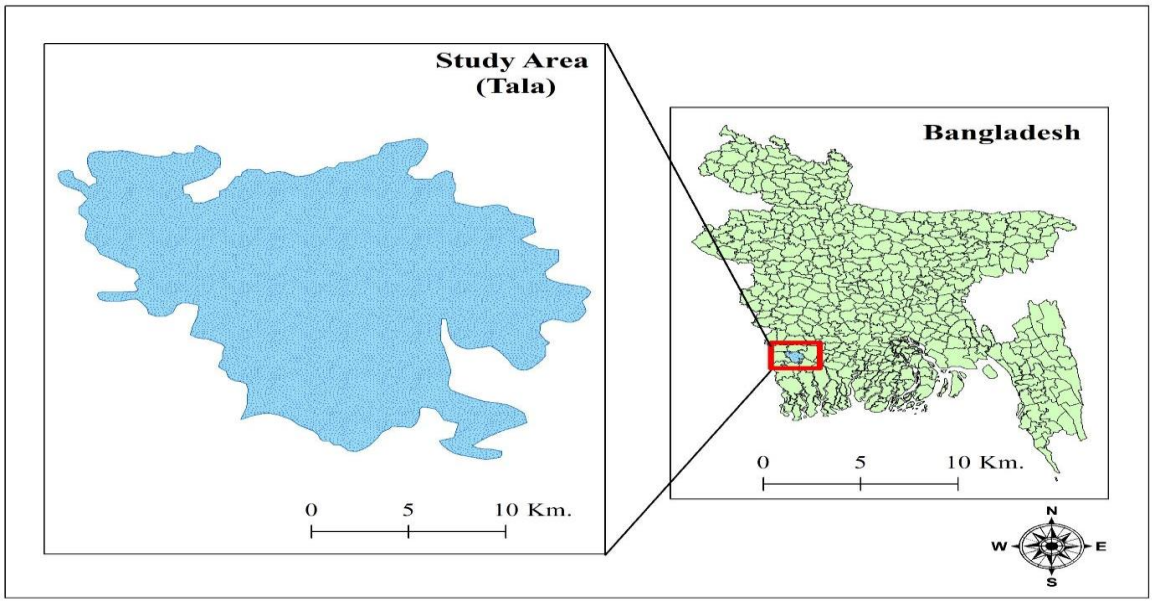

Figure 1. Location of the study area

Sample size and sampling period

Individuals are selected as the sampling unit and simple random sampling has been used to collect data during September 2022. Sample size was estimated as 138 at 5% significance level following the equation provided by Kothari (2008). The survey was conducted in September, 2022.

Data collection

Primary information has been collected using questionnaire survey, focus group discussion (FGDs), and key informant interview (KIIs). These qualitative tools have been used to assess the impact of waterlogging on land use, biodiversity and ecosystem services of the area. Semi-structured questionnaire was used for the questionnaire survey and two FGDs have been conducted in the study area with each containing 12 participants. In addition, a total of four key informants were interviewed during the assessment. Key informants include the Upazila Fisheries Officer, the Upazila Chaiman, a businessman and a student of the study area. The key remote sensing derived dataset for inundation analysis was collected from the Global Surface Water Explorer data hub developed by the Joint Research Center of the European Commission [https://global-surface-water.appspot.com/download]. This dataset was produced at annual and seasonal intervals by leveraging multi-temporal Landsat imagery from 1984 to 2021 (Pekel et al., 2016). However, for this analysis annual (yearly) data for three years – 1990, 2000, 2010 and 2021 as representative of decadal water extent to estimate changes over decades were used. Additional information for the analysis was collected from journals, books, the internet etc.

Data analysis

The yearly water extent data of the European Commission comes in three discrete classes – permanent water, season water and land area. For the convenience of the analysis, the seasonal and permanent water classes were merged into a single class, and coded this as "1" and the land area as "0" for the year 1990, 2000 and 2021. All these data were clipped out by the study area polygon and projected to Bangladesh Transverse Mercator (BTM) projection for accurate area calculation. The spatial analysis procedure stated below was performed using ArcMap10.8 software; and the qualitative data obtained from questionnaire survey, FGDs and KIIs were analysed using SPSS and MS Excel software. The total water area was calculated from the water extent dataset for all four years (1990, 2000, 2010 and 2021) in hectare units to understand the change in water extent over decades (Figure 2).

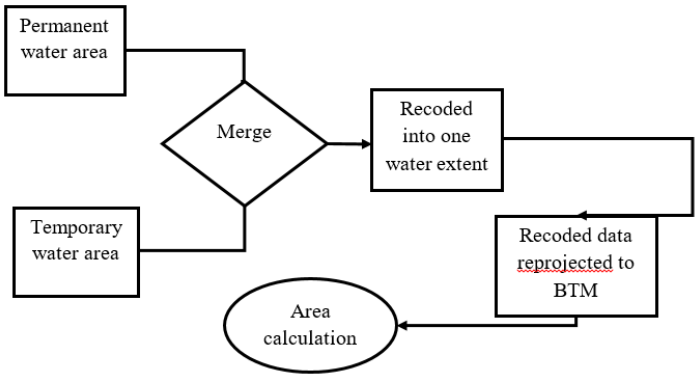

Figure 2. Flowchart representing the process of area calculation from satellite images.

The change map of the water area was generated by subtracting coded water data of 1990 from the coded data of 2021. After subtraction a value of "0" indicated that there was water in both years. A value of "1" indicated water existed in only 2021 i.e., water area increased from 1990 to 2021, whereas a value of "-1" indicated that water area decreased over the years from 1990 to 2021. To determine the duration of the inundated water area, decadal coded data (i.e., 1990, 2000, 2010 and 2021) were summed up together to obtain a single map with four values where value "1" indicates water occurrence for 1 year, value "2" indicates water occurrence for 2 years, value "3" indicates water occurrence for 3 years and value "4" indicates water occurrence for 4 years.

Result

Assessment of waterlogged area of Tala upazila

Tala upazila goes down under water and remains waterlogged for most part of the year due to the low elevation of the area. Previously, these lands were used for traditional agricultural practices. But people could no longer practice their traditional crop culture as it started to be inundated in 2000. So, many people at present are forced to change their occupations from farmers and some even migrated from the area (Tareq, 2016).

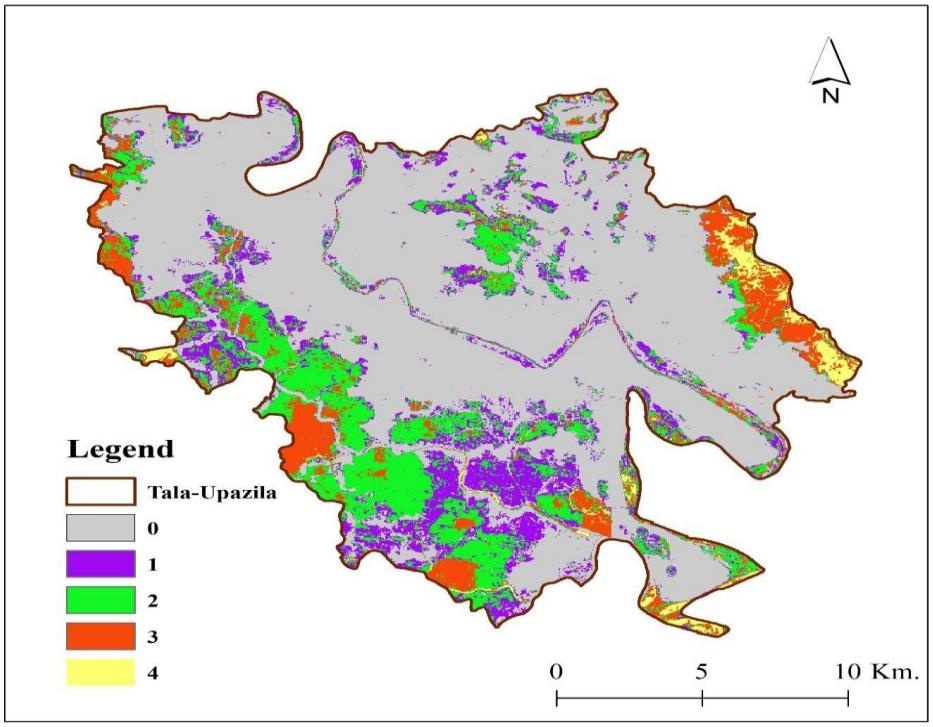

Figure 3. Frequency of water occurrence in Tala, Satkhira

After observing decadal (ten years interval data i.e., 1990, 2000, 2010 and 2021) data it was evident that water area changed over the decades. Approximately as much as 3796 ha area was waterlogged only in one (indicated by value 1) of the decadal years, whereas 5128 ha area was waterlogged in two (indicated by value 2) years, and 2608 ha area was waterlogged in three (indicated by value 3) years. Roughly about 733 ha area was waterlogged in all of the four decadal years (Figure 3).

The analysis of the satellite images of four years (1990, 2000, 2010 and 2021) was performed to quantify this trend of water extent. The analysis showed that there was barely any waterlogged area (1468.67 ha) in 1990, whereas, around 3737.78 ha of Tala upazila was occupied with water in 2000. This estimate became much higher in 2010 with a water covered area of around 8816.02 ha. With the continuing inundation after 2010, the waterlogged situation of 2021 became worse. As much as 10898.93 ha was covered with water. Fig. 4 shows the water covered area of 1990, 2000, 2010 and 2021. Analysis of the trend of the total water covered area in Tala upazila showed an ascending pattern. This indicated that the waterlogging problem in Tala upazila is increasing gradually (Figure 5).

The overall estimated increased water area was 9821.58 ha and decreased water area was 385.11 ha between 1990 and 2021. Therefore, the overall water area has increased from 1990 to 2021 in the study area (Figure 6). The average living period of the survey participants in the area was 51 years and during this period they have been facing waterlogging problems for the past 4-5 decades, which extends even more according to some residents. It is also

evident that the residents of the area have been suffering waterlogging problems for at least 4 months (June and October) a year.

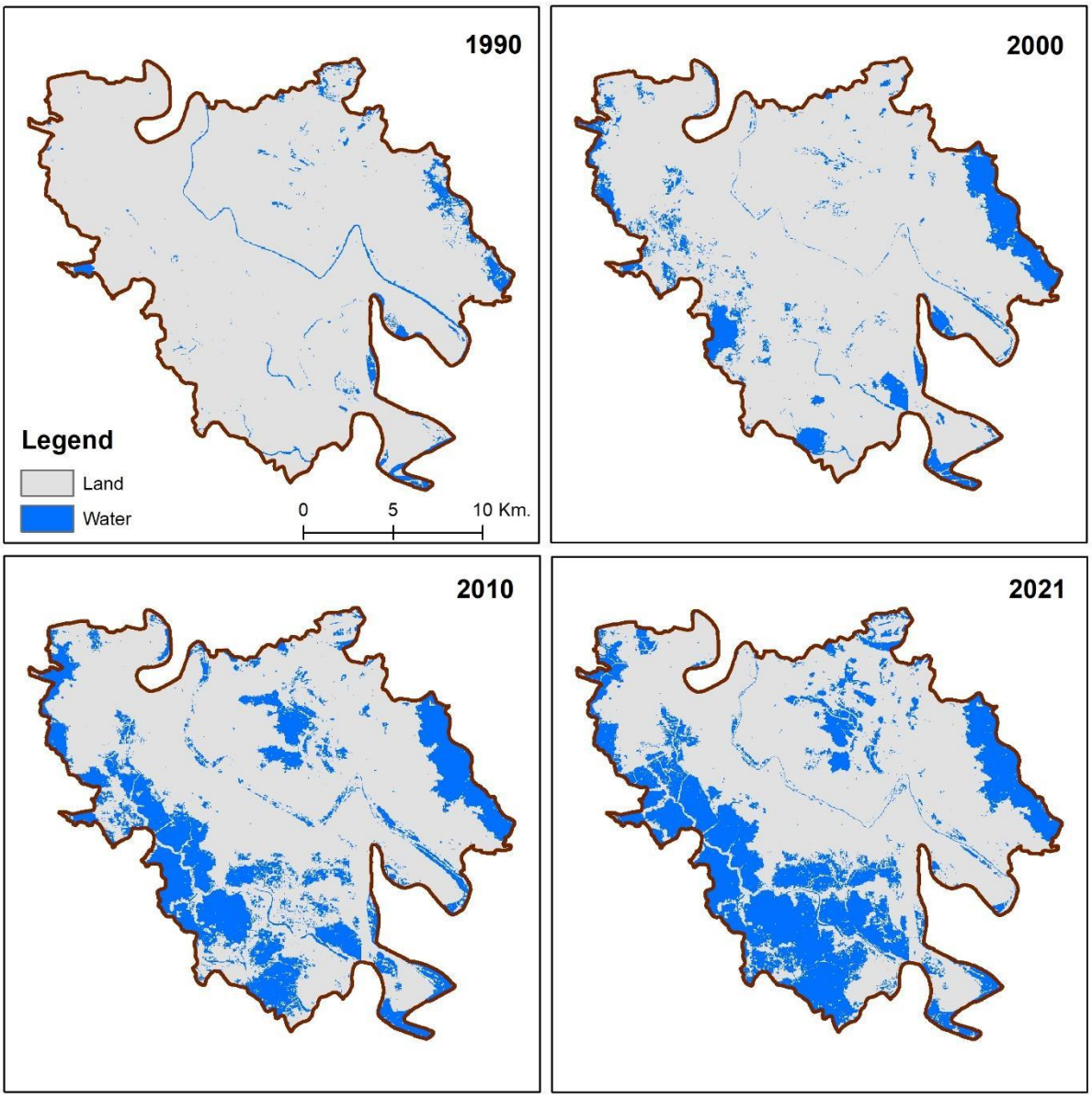

Figure 4. Images of waterlogged areas in Tala upazila during 1990. 2000, 2010 and 2021. (*Source: EC JRC/Google)*

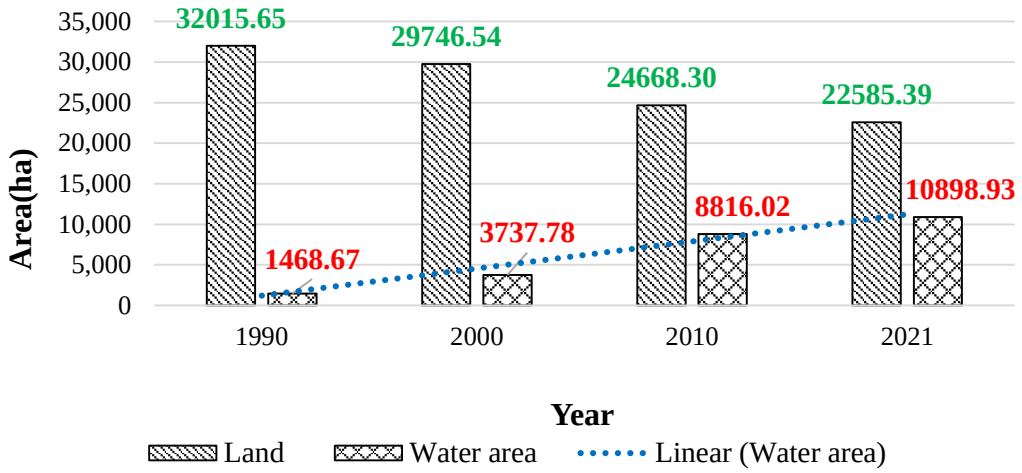

Figure 5. Trend of waterlogging in Tala, Satkhira.

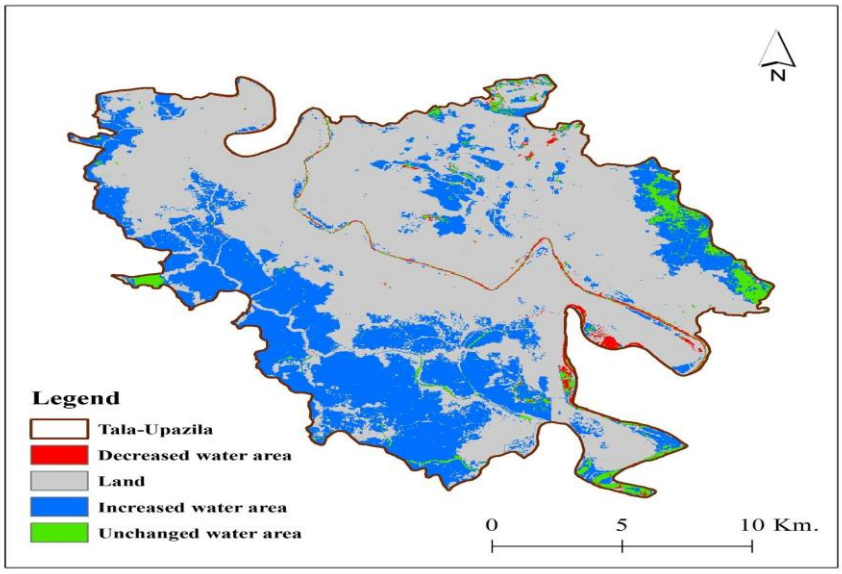

Figure 6. Change of water area between 1990 and 2021.

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Impacts of waterlogging on land use

According to the survey of local residents, the main causes of waterlogging are as follows: i) increased sedimentation, ii) siltation over the nearby river (the Shalta river), and iii) no drainage facilities (Figure 7). Based on their opinion, the siltation in the Shalta river of Tala upazila caused dysfunction in the drainage system of the locality which has been causing the majority of the area to become waterlogged for so long.

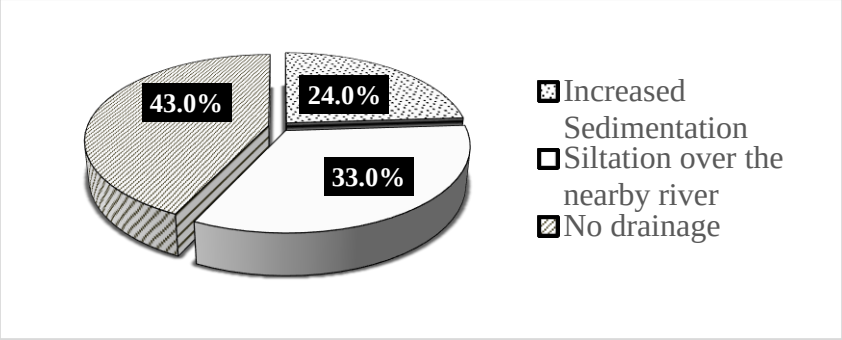

Figure 7. Causes of waterlogging in the study area.

Most of the people of the study area depend on aquaculture and agricultural farming for their livelihood. Due to the siltation in the nearby Shalta river, the drainage system of the area totally died and the low elevation of the area it remains waterlogged for a long time every year. Low land is submerged in water for 1-2 feet during monsoon (Tareq, 2016). Monsoon overflow cannot be contained by the shallow river and cause suffering to people. However, the monsoon does not cause the water to recede. Low lands continue to be marshy for a while, which hinders the production of *Aman*. Crop productivity in the area has decreased as a result of prolonged waterlogging. Awal & Islam (2020) also portrayed the Shalta river as one of the local rivers responsible for waterlogging problem in the south-western region because of sedimentation in the river.

Many cultivable lands have been turned into *ghers* for cultivating fish and other aquaculture species because of waterlogging. Many lands were left unused because they became marshy for a long period in a year and for this reason, farmers found no ways other than turning them into *ghers*. This eventually decreased the agricultural production of the area and also caused many crops to become uncultivable in the area. Tareq (2016) also found a similar problem in different unions of Tala upazila where small landowners were forced to lease their land to *gher* owners because of waterlogging.

Impacts of waterlogging on biodiversity

Nature and extent of waterlogging significantly affects local biodiversity in the study area. Waterlogging reduces the availability of birds and fishes, restricts the opportunity to rear livestock. It restrains all sorts of plant growth, fruit trees and timber trees. Masud et al. (2014), Tareq et al. (2016), Ferdous (2013), and Tareq (2016) also found impact of waterlogging on the biodiversity of the south-western region of Bangladesh. As per the opinion of the local people, agricultural crops are affected the most. The detail impacts of waterlogging on different species are as follows:

Wild and aquaculture species

According to the FGDs, there is a mixed impact of waterlogging on the availability of native aquaculture species and wild fish species. The survey showed some aquaculture species and wild fish species increased probably due to waterlogging induced salinity intrusion. Due to the increased salinity the cultivation of Bagda (*Penaeus monodon*) became easier and as a result its availability has increased drastically during the last 10 years. The survey data also showed that Harina chingri (*Metapenaeus monoceros*) culture also increased over the last 10 years which can be due to the fact that these are brackish water or marine water species.

The survey data also revealed that the availability of Ilish (*Tenualosa Ilisha*), Vetki (*Lates calcarifer*), Rui (*Labeo rohita*), Katla (*Catla catla*), Silver Carp (*Hypophthalmichthys molitrix*), Chaka Chingri (*Fenneropenaeus indicus*) and Tengra (*Mystus gulio*) have decreased over the last 10 years due to waterlogging (Figure 8).

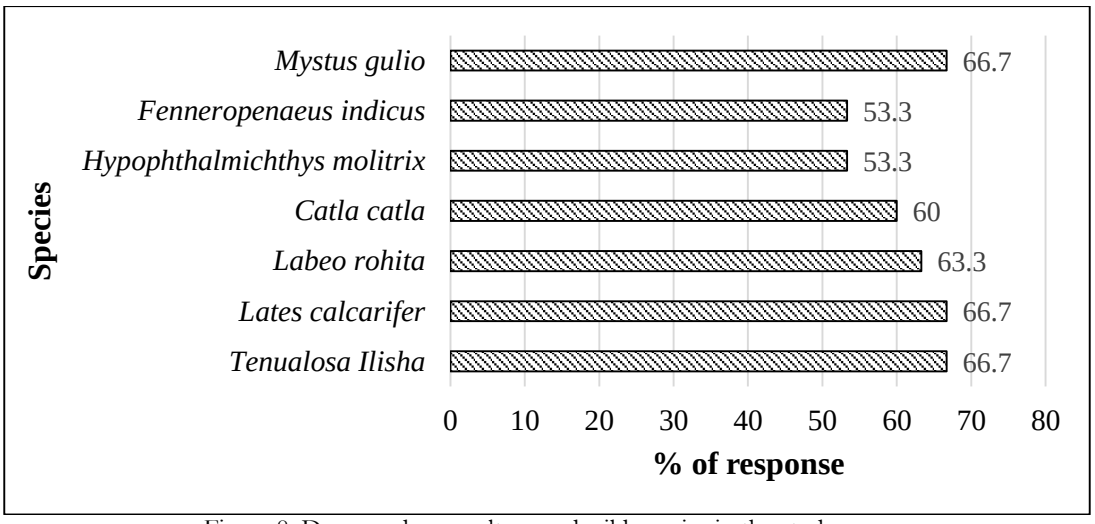

Figure 8. Decreased aquaculture and wild species in the study area.

Waterlogging has also caused some species to nearly disappear from the area. Some indigenous fish species like Bele (*Awaous grammepomus*), Gozar (*Channa marulius*), Boal (*Wallago attu*), Aor (*Sperata aor*), Datina (*Acanthopagrus latus*), Shol (*Channa striata*), Cheng (*Channa orientalis*), Chitra (*Scatophagus argus*) (Fig. 9) are rarely seen in the area. This decline over the past few years is due to waterlogging. According to some studies (Tareq et al., 2016; Ferdous, 2013; Tareq, 2016), the abundance of indigenous fish also reduced in some of the unions of Tala upazila.

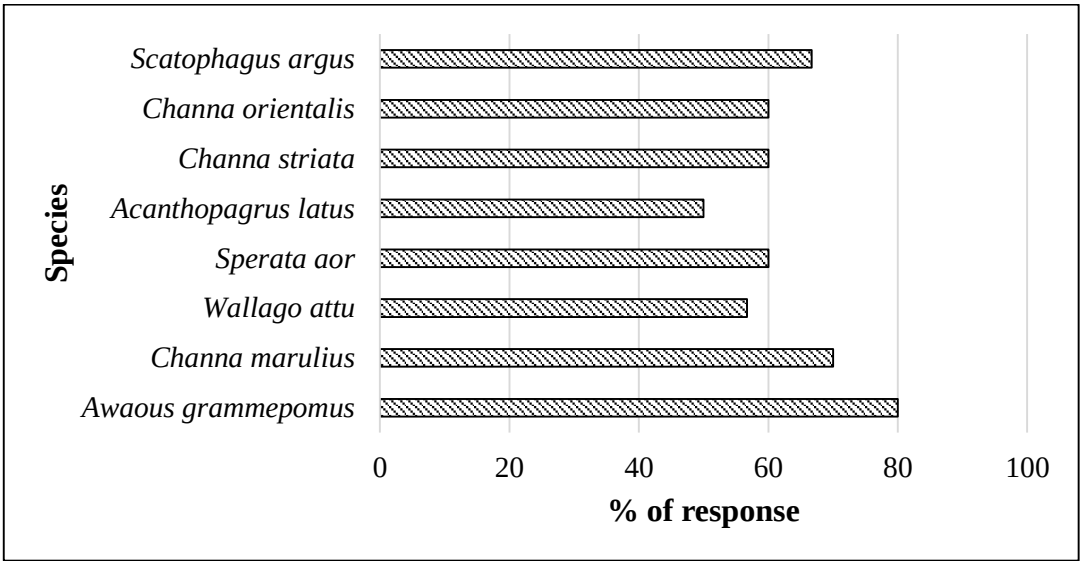

Figure 9. Rarely seen aquaculture and wild species in the study area.

Other animals

The survey data showed that several animals which were seen quite often in the locality have been showing massive decrease over the last 10 years. Species such as Kamot (*Glyphis gangeticus*), Kumir (*Crocodylus palustris*), Hashpakhi (*Dendrocygna javanica*), Bok (*Ardeola grayii*), and Shushuk (*Platanista gangetica*) are not seen in the area often (Fig. 10).

Tareq et al. (2016) also found reduced Hashpakhi (*Dendrocygna javanica*) abundance in the Khalishkhali union of tala upazila.

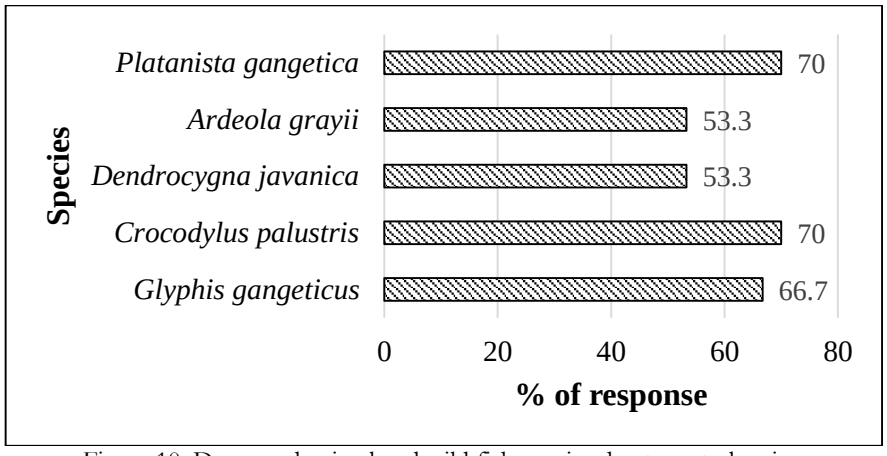

Figure 10. Decreased animal and wild fish species due to waterlogging

Agricultural crops

Waterlogging has affected most of the agricultural crops of the area. Aman (*Oryza sativa*) and Gom (*Triticum aestivum*) are not suitable for culture in the area anymore, and Sorisha (*Brassica nigra*), Alu (*Solanum tuberosum*), Mete Alu (*Dioscorea alata*), Kochu (*Colocasia esculenta*), Pan (*Piper betle*) etc. (Figure 11) cultivation has decreased over the years because of waterlogging. Many of these either cannot stand waterlogged situations or are affected by waterlogging induced salinity intrusion. Similar pattern of some of the traditional crops cultivated in Tala was found to be decreased over time due to waterlogging in some studies. Tareq (2016) mentioned that as the lowlands went under water (2389 hectares) in 2000, farmers couldn't cultivate Aman rice in those areas. This problem took a devastating turn in 2011 when 11,524 hectares of agricultural land was inundated.

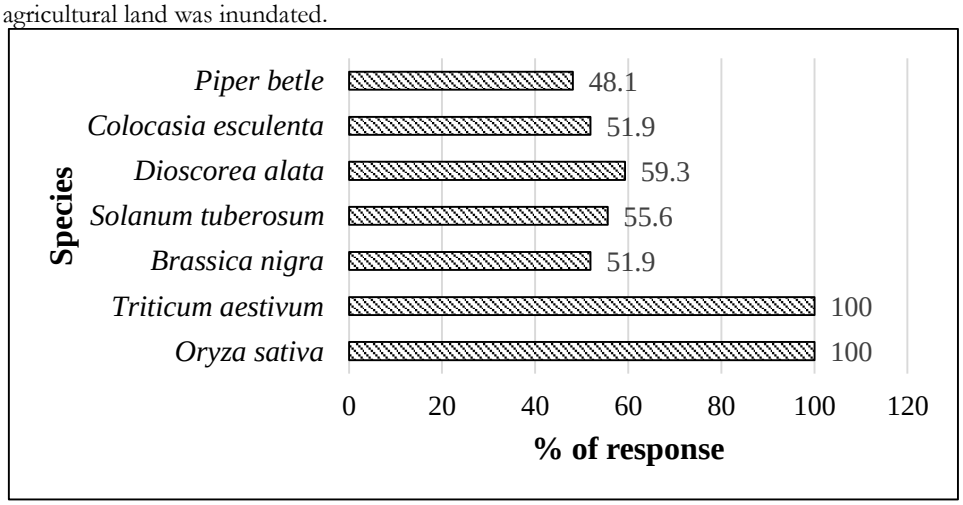

Figure 11. Decreased agricultural crop species due to waterlogging.

On the other hand, because of the blessing of floating culture system, Potol (*Trichosanthes dioica* Roxb.), Shim (*Canavalia gladiata*), Borboti (*Vigna unguiculata* subsp. *sesquipedalis*), Badha kopi (*Brassica oleracea*), Ful kopi (*Brassica oleracea* var. *botrytis*), Begun (*Solanum melongena*) (Fig. 12) etc. cultivation has increased. *Boro* is currently the commonly cultured rice variety of the area. Cultivation of jute has also increased. Tareq (2016) also mentioned the culture of these vegetables with the intervention of floating bed culture in the study area.

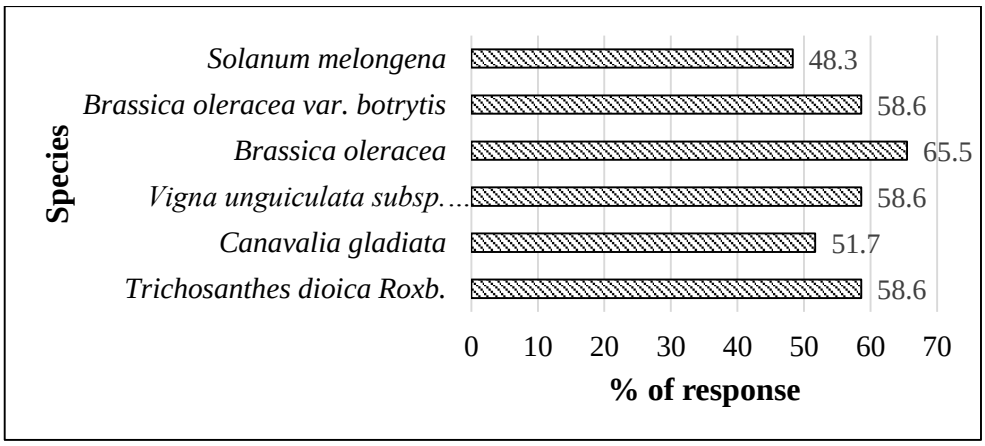

Figure 12. Increased agricultural crop species due to waterlogging.

Trees

Waterlogging affected most of the trees; some trees can grow in the slightly elevated areas but as most of the area remains waterlogged, growing fruit or commercial trees has become impossible. According to the mean response of the local people Aam (*Mangifera indica*), Kathal (*Atrocarpus heterophyllus*), Kola (*Musa paradisiaca*), Lichu (*Litchi chinensis*), Pepe (*Carica papaya*), Mahogany (*Swietenia macrophylla*), Shimul (*Bombax ceiba*), Narikel (*Cocos nucifera*) (Fig. 13) etc. trees have alarmingly reduced from the area due to waterlogging. Similar results were found by Ferdous (2013) in two unions of the study area.

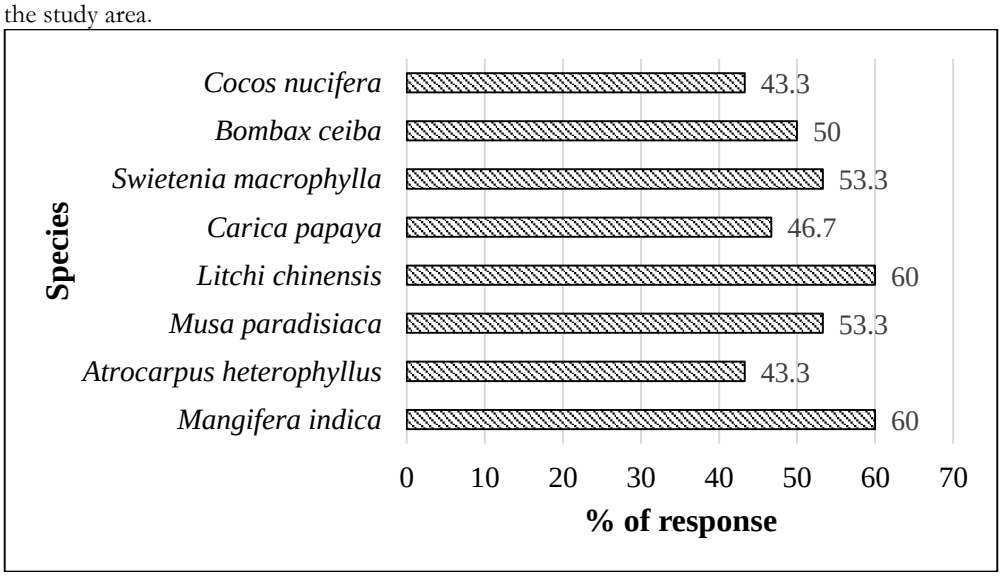

Figure 13. Decreased tree species due to waterlogging.

Though the number of casualties from natural disasters over the last ten years have been low, waterlogging caused misery in the food supply and to the grazing grounds of livestock. Residents of the area reported that due to the scarcity of the land to grow grass they had to fully depend on the market-bought artificial feed which many people cannot afford and as a result, the number of livestock is reducing. This misery of waterlogging also did not leave the aquaculture sector and wild indigenous fish species untouched. Due to the waterlogging induced salinity intrusion freshwater species suffered to survive in the area and decreased over the last ten years. Some species even nearly disappeared from the area due to the same reason.

Impacts of waterlogging on ecosystem services

Waterlogging affected the traditional crop and fish culture of the area immensely. Production of many traditional crops has dropped over the course of years. While many crop cultures decreased because of water congested conditions i.e., reduced cropland for production, others reduced by the higher salinity of the soil possibly because of waterlogging. Based on the response of the local people, waterlogging also severely affected other classes of ecosystem services (Table 3). Main provisioning services affected by waterlogging in the study area are the production of crop and aquaculture. Some people have to live through constant migration throughout the year to find a place to live that would not affect their daily chores. Ferdous (2013); Masud et al. (2014); Awal (2014) and Tareq et al. (2016) concluded that waterlogging has been reducing the crop production in the southwestern region of Bangladesh. The mostly affected supporting services in the area are homestead and crop land. Awal (2014) mentioned that waterlogging has narrowed agricultural lands even in dry seasons and has destroyed houses and schools. Safe drinking water in the area is a major impacted regulating service. Other regulating services include freshwater for aquaculture, freshwater for irrigation and sanitization (Table 1). Getting pure and safe drinking water is also quite a challenge for the residents of the area. It is especially a nightmare for the poorer people of the area to get a safe drinking water tube well or buy drinking water from the market. Ferdous (2013) pointed out in his study that even tube wells for safe drinking water have been affected by waterlogging and people have to fetch water from long distances for safe freshwater for drinking and other domestic purposes. Waterlogging has also affected the sanitation of the area and especially women had to live surrounded by the stagnant water (Awal, 2014). A survey regarding the impact of waterlogging on different ecosystem services are mentioned in Table.1.

Table 1. Impact of waterlogging on different ecosystem services

Ecosystem Services	**Type**	**Impact of waterlogging**
Provisioning Service	Crop production	Many traditional crop productions are reduced because of reduced cropland and waterlogging induced salinity intrusion.
	Aquaculture production	Some type of aquaculture increased (e.g. *Penaeus monodon*) while some decreased (e,g, *Labeo rohita*).
Supporting Service	Homestead	Many people became landless and had to migrate throughout the years.
	Crop land	Land for crop farming have decreased over the last few years.
Regulating Service	Safe drinking water	Safe drinking water is hard to get.
	Freshwater for aquaculture	Freshwater supply for aquaculture became a challenge.
	Freshwater for irrigation	Irrigation is hard because of very little freshwater supply.
	Sanitation	Lack of sanitary latrines

Management

Activities of governmental and non-governmental organizations:

According to the information based on key informant interviews (KII), two governmental organizations, such as Bangladesh Water Development Board (BWDB), Satkhira; and Department of Fisheries (DOF), Satkhira, and three non-governmental organizations namely, Unnayan Prochesta (UP), Uttaran, Satkhira, and Satkhira Unnayan Sangstha (SUS) have been working on the waterlogging issue in the area. Some of their activities are listed in Table 2.

Table 2. Activities of GOs and NGOs in the study area

Organization	Activities
Governmental Organizations (GOs)	
Bangladesh Water Development Board (BWDB), Satkhira	Development of drainage system, sluice gate and dike management, TRM project
Department of Fisheries (DOF), Satkhira	Canal digging, training, providing government incentives, suggestions
Non-governmental organizations (NGOs)	
Unnayan Prochesta (UP)	Small canal digging, encouraging indigenous species culture, encouraging vegetation along the *gher* bed etc.
Uttaran, Satkhira	Providing microcredit, giving training etc.
Satkhira Unnayan Sangstha (SUS)	Group based works: Encouraging fish culture, granting microcredit etc.

Other management measures

The main cause of waterlogging in the area appears to be the siltation of the nearby Shalta river. According to FGDs and KIIs, many management attempts have been taken by the local people and the govt. and non-govt. organizations are working in the study area to alleviate the impact of waterlogging. For example, an attempt was taken to dig the Shalta river for two years (2009-2010). Apart from that, different indigenous techniques have been adopted by the local residents such as, floating vegetable culture, partition *gher* culture, digging small drainage etc. Dev (2013) also mentioned the use of floating bed culture in Satkhira as soilless agriculture as an adoption measure. Apart from these, there have been plans for digging three more canals by the Department of Fisheries (DOF) according to a key informant.

Conclusions

The southwestern region of Bangladesh is prone to natural disasters due to its geographical location. Tala upazila of Satkhira experiences waterlogging every year due to its low elevation, siltation in the major running rivers, lack of drainage and unplanned polderization, sedimentation, excess rainfall etc. Waterlogging turned the highly fertile land of Tala useless for crop culture and many croplands have been turned into *ghers* for aquaculture. The problem of waterlogging is increasing and the total waterlogged area is accounting for a greater number in each consecutive year. This problem has detrimental effects on the biodiversity of the study area. Waterlogging has been posing a mixed impact on aquaculture. Some aquaculture species have been increasing whereas many indigenous fish species declined at an alarming rate from the area. Other animals and livestock are also being affected by waterlogging. Waterlogging also has a negative impact on agriculture and trees of the area. Although the intervention of some indigenous adaptation has enabled the culture of some agricultural crops, many traditional agricultural practices have ceased because of waterlogging. Sources of safe drinking water have been at a risk since waterlogging took place in the area and sanitization is in question because of waterlogging. Loss of homestead and cropland has been causing people to migrate from the area. The overall impacts of waterlogging in Tala upazila are on the negative spectrum and it is causing unbearable sufferings to the local people. Though some NGOs and local people have been working on the mitigation of waterlogging in the area, a well-planned scheme is needed to be taken to battle against the problem.

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Conflict of Interest

The authors declare no conflict of interest.

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