



## Environmental and Institutional Impacts of Tidal River Management: A Case Study on Pakhimara Tidal Basin in Southwestern Bangladesh

Md. Tareq Bin Salam<sup>1\*</sup>, Atika Ibnat Amin<sup>1</sup>, Tonami Afroz<sup>1</sup> and Md. Mahedi Al Masud<sup>2</sup>

<sup>1</sup>Soil, Water and Environment Discipline, Khulna University, Khulna-9208, Bangladesh; <sup>2</sup>Department of Social Services, Ministry of Social Welfare, Government of Bangladesh, Bangladesh

\*Corresponding author: tareqss@swe.ku.ac.bd

### Abstract

People in southwestern Bangladesh have been facing the waterlogging problem and protesting on the impacts for the nature for a long time. In the 1960s, the government introduced polders, embankments and cross dams to overcome the destructive scenario. Due to the failure of government initiatives, the local people of the coastal area cut into the polder so that the sediment deposited within the beel known as Tidal River Management (TRM). Then, TRM was applied several times in different catchments. The study was carried out from December 2018 to November 2019 to assess the positive and negative environmental and institutional impacts of TRM on Pakhimara beel in Tala Upazila (Sub-district), Satkhira District, by using the Sustainability Index of Tidal River Management (SITRM) framework. Sustainability Indices of TRM were designed to provide information on social, environmental and institutional gains. The environmental and institutional impacts were assessed by conducting household survey and Key Informant Interviews (KIIs). Agricultural impacts on crop, poultry, fisheries and vegetation, were also analyzed by comparing GIS map and agricultural production data (before and after TRM). This study investigated that Pakhimara beel was freed from waterlogging during the with-TRM event by 3,200 ha and the reduction of waterlogging increased agricultural land by 1,500 ha in 2018, compared to 2014. This study argued that only 54% of marginal farmers received crop compensation whereas 85% of crop production decreased due to TRM. For promoting sustainable TRM in the studied area, compensation should be guaranteed for all impacted parties, especially marginal farmers and the creation of employment opportunities, and settlement should be ensured.

**Keywords:** agricultural impact; employment impact; sustainability index; waterlogging

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### INTRODUCTION

The southwestern region of Bangladesh is the area most affected by climate in the country because of its geographic location. Due to climate change, this area remains as one of the most vulnerable areas that cover mainly of Khulna, Jashore, Bagerhat and Satkhira districts (Gain et al., 2017; Roy et al., 2017). Before the polderization, the local people experience

flooding twice a day (Nicholls et al., 2008). The government started the coastal embankment project in the coastal area to control tidal flooding and salinity intrusion for agricultural development (Dewan et al., 2015). The polders were considered to be effective in the early years of operation because they reduced floods and created stability in agriculture. However, tidal sediment could not be raised in the beel due to polderization, instead it fell into the river. Thus in a few

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years, the river could be no longer drained of rainwater, causing waterlogging (Islam, 2014). Sedimentation in the tidal rivers is the main reason for waterlogging (Sarwar and Khan, 2007). In this region people, agriculture, biodiversity and the environment received the worst impacts of this project. Many areas remained underwater for more than nine months in a year (Jakarya et al., 2016). People used their indigenous knowledge to save their crops from waterlogging (Brammer, 2014). To prevent the water congestion, local people initiated a temporarily solutions to cut away the embankments to allow the tidal flow in the flood plain. This process is called Tidal River Management (TRM) (Kibria, 2011; Gain et al., 2017; van Staveren et al., 2017).

TRM involves taking full advantage of the natural tidal flow in the rivers. In high tide, water enters into the beel and is deposited in its bottom, instead of the river, and this reduces waterlogging, improves the navigability of the river and creates stability in agriculture (Gain et al., 2017). TRM brings blessing for local dwellers by creating positive impacts on land development and food security (Masud et al., 2018; Mutahara et al., 2018; Gain et al., 2019b). However, TRM is a big challenge for the local people in implementing tidal basin because land owners want to sacrifice their land for implementing the project and compensation is not monotonous for all owners. Therefore, there is a significant conflict among stakeholders for implementing TRM (Dewan et al., 2015). Small farmers are being impacted badly whereas big land owners sometimes get more compensation. The study is going to reveal these problems and sort them in the implemented TRM tidal basin.

TRM has a potential influence on extending agriculture because of decreasing waterlogging (Khadim et al., 2013; Paul et al., 2013; Cornwall, 2018; Mutahara et al., 2018; Gain et al., 2019a). Due to waterlogging and intrusion of saline water in the agricultural land, soil salinity is increasing sharply in the southwestern part of the country (Salam et al., 2019) and almost 30% of the cultivable land has already been contaminated with the salinity (Khatun et al., 2019). Hossain and Salam (2019) mentioned that the physicochemical properties of the soil in the southwestern part of the country are hampered by various degree of salinity. Masud and Azad (2018) and Masud et al. (2018) stated

that TRM might enhance the crop yield and bring economic benefits by declining waterlogging and water congestion. However, financial benefits have not been determined due to the TRM. TRM also plays a role in the improvement of livelihoods (Seijger et al., 2019). If government take necessary actions for economic improvement of the stakeholders, TRM can be the best option for removing water congestion and improving the local living pattern. Shampa and Pramanik (2012); Seijger et al. (2019); Adnan et al. (2020) and Masud et al. (2020) studied the impacts of TRM on various components, like waterlogging, flood alleviation, livelihood pattern and agricultural sustainability in the catchment areas. In most of the cases, they found the positive outcomes in implementing TRM but the novelty of this research is that we study the tidal basin area where the TRM is being implemented.

TRM has been implemented in 12 out of 35 beels in the Ganges-Brahmaputra delta. According to Masud and Azad (2018), TRM potentially increases crop yields and thus improves the socio-economic condition of that area. Pakhimara is now the only active TRM project in Bangladesh. The Pakhimara TRM beel is located in Jalalpur Union of Tala Upazila of Satkhira District. The Kobadak River is a full tidal river. For about 150 years, the Kobadak River had no connection with the Padma stream. Without the implementation of TRM, the existence of this river cannot be sustained (Shampa and Pramanik, 2012). The government adopted a projection of 2011 under the name of "Project phase 1 to remove the Kobadak River dam" to protect the residents of the Kobadak River and basin. One of the parts of project was the establishment of TRM in the Pakhimara beel. TRM project was launched in July 7, 2015, with the cooperation of the administration. The implementing authority of the project was the Bangladesh Water Development Board (BWDB). In the meantime, the TRM project had been in place for 3 years and 10 months until December 2018. During the visit on April 7, 2018, the Deputy Commissioner of Satkhira informed the public that the TRM program would be continued until 2021 (Uttaran et al., 2013). Thus, TRM raised controversial thoughts for the local stakeholders. Due to the long time, the project already gave the negative effects to the local dwellers in the implementing areas. This research allowed us to identify the TRM approach on

the Pakhimara beel to gather knowledge of the way and the degree this technique influence people's life.

## MATERIALS AND METHOD

### Selection of the study areas

Four villages were selected from three different unions in Pakhimara tidal basin for analyzing with and without-TRM conditions (Figure 1). The study areas are located at a  $22^{\circ}35'0''$  to  $22^{\circ}50'0''$  N and  $89^{\circ}5'0''$  to  $89^{\circ}20'0''$  E. The average temperature of the study areas was 28 °C. April and May were the hottest months and the temperature varied from 35 °C to 42 °C. On the contrary, January was the coolest month of the year and the temperature ranged from 10 °C to 12 °C. Mostly, the study area received highest rainfall in July and August successively, and the average rainfall was 220

mm (SRDI, 2007). The study was conducted from December 2018 to November 2019. Therefore, the tenure of the study was one year. A total of 27 beels were situated in the Ganges-Brahmaputra catchment area. In most of the cases, farmers tended to use the beels for their agriculture production, like crops and fisheries. Four out of 27 of them had already been introduced with TRM and the remaining 23 were non-TRM beels. However, beels play an important role of local farmer's livelihood.

### Methods of data collection

The analysis was completed by using both primary and secondary data. Primary data were collected through household surveys and KII (Key Informant Interviews). The secondary data were gathered from several documents of government, journals, websites, books and non-governmental organization named Uttaran.

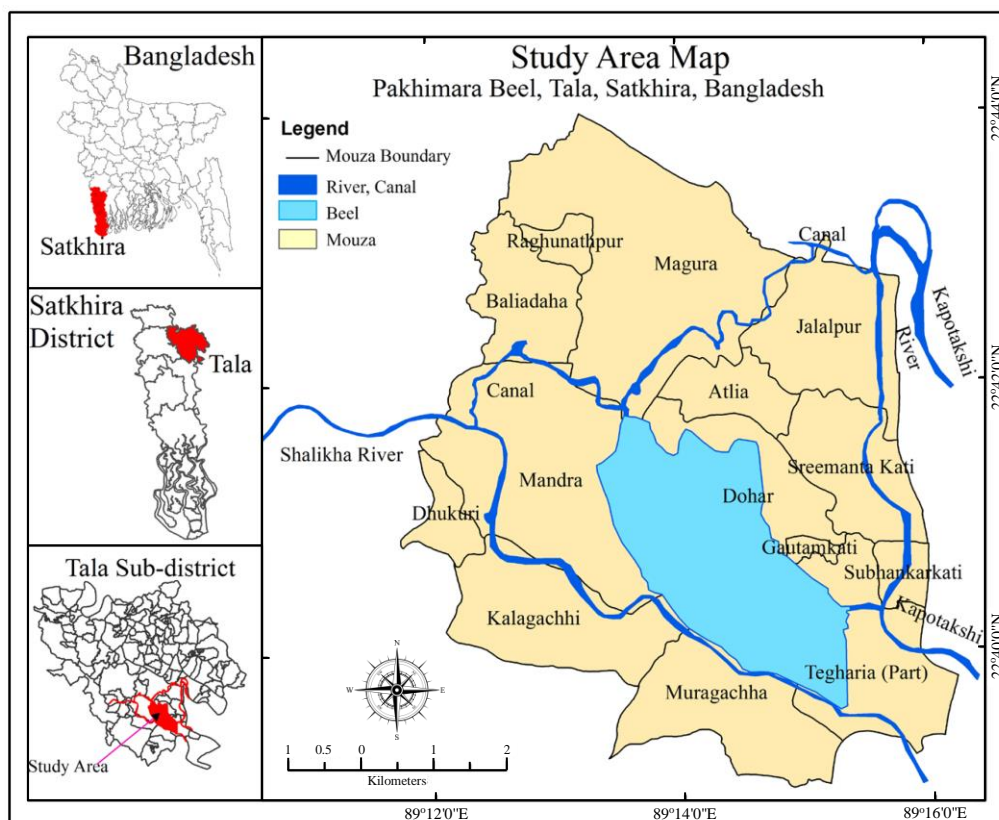


Figure 1. Map of the study area (Hussain et al., 2018)

### Sustainability index of tidal river management (SITRM)

These days, the term sustainability seems to cover many aspects. Masud et al. (2018) used different sustainability indices for detecting potential SITRM components and indicators

based on the information of social, environmental and economic benefits. This index comprised six components and 21 indicators. In this study, we used five components and 13 indicators of SITRM to assess the environmental and institutional impacts of TRM that are presented in Table 1.

Table 1. Sustainability indices of TRM

Components	Indicators
Sedimentation	Waterlogging
Environment	Crop production Vegetation with settlement Employment Terrestrial biodiversity Migration Water quality (drinking water problem)
Human health	Health impact (diarrhea disease) Sanitation
Institution (community participation)	Awareness and coordination Compensation
Institution (governance)	Rotation of TRM in the beels Water governance

Source: Masud et al. (2018)

Table 2. Sample size determination for household survey at Pakhimara beel

Village	Total household	Farmer household	Target household	Sample size
Baliya	723	719	431	44
Dohar	783	548	329	34
Mandra	730	584	350	36
Tegharia	141	141	85	10
Total population (N) = 1,195				
Total sample size (n) = 124				

### Assessing the environmental and institutional impacts of TRM

#### Sample size determination

This study used household surveys to collect data relating to crop production, livestock, as well as trees, employment, migration and water quality issues from different villages in the Pakhimara tidal basin for the two time periods of 2012-14 (without TRM) and 2016-18 (with TRM). This study identified that 60% of respondents were small-scale farmers (who had <1 acre of cultivable land), 34% respondents were middle farmers (who had 1-5 acre of cultivable land) and 6% respondents were big farmers (who had >5 acres of cultivable land) at Pakhimara beel. Farmers having less than 1 acre of cultivable land at Pakhimara beel were the target population of this study. The sample size (n) was determined by using the following equation, as proposed by Kothari (2004).

$$n = \frac{z^2 \times p \times q \times n}{e^2 \times (N - 1) + Z^2 \cdot p \cdot q}$$

Where,

- Z = the value of standard variate at a given confidence level (for 95% confidence level, z is 1.96)
- P = sample proportion (for 10% household, p is 0.1)
- Q = 1-p = 0.9
- N = population size of the village
- E = sampling error (within 5% true value, e is 0.05)

A stratified random sampling method was used for household surveys. The sample size of this survey was 124 that covered a maximum of 44 households from Baliya and a minimum of 10 households from Tegharia Village (Table 2).

#### Method for assessing the waterlogging and vegetation with settlement

Waterlogging and vegetation with settlement have been analyzed using remote sensing technology. The images of 2014 represented 'without TRM' phase and 2018 represented 'with TRM' phase. For representing pre-monsoon, monsoon and post-monsoon periods three images were captured during April, August

and December, respectively, for 2014 and 2018. All satellite images were classified into three classes, including water body, agricultural land and vegetation with settlement. The acquisition of the images was performed in 22 April, 12 August, 18 December 2014, and 1 April, 7 August, 13 December 2018. The methods for assessing the riverbank erosion, awareness and coordination, rotation of TRM beel, and water governance issues in the Pakhimara tidal basin were discussed by involving 30 KIIs in expert judgement. Members of beel committee, surveyors, teachers, social service officers and businessman who have adequate knowledge about the Pakhimara beel were selected for KIIs.

## RESULTS AND DISCUSSION

### Assessment of the environmental and institutional impacts of TRM

#### Changes of terrestrial biodiversity (livestock and trees)

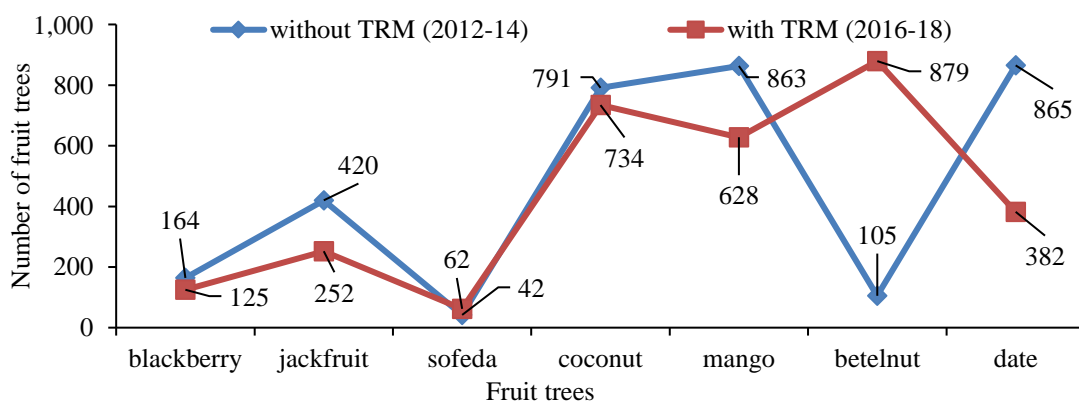
This research involved hen, duck, goose for bird animals and cow and goat for the four-legged animal, as the available livestock; blackberry (*Rubus plicatus*), jackfruit (*Artocarpus heterophyllus*), mango (*Mangifera indica*), sofeda (*Manilkara zapota*), date (*Phoenix dactylifera*), coconut (*Cocos nucifera*) and betel nut (*Areca catechu*) for fruit trees; and neem (*Azadirachta*

*indica*), mahogany (*Swietenia macrophylla*) and sissou (*Dalbergia sissoo*) for timber trees, which were available in two time periods without-TRM (2012-14) and with-TRM (2016-18) in the basin. Table 3 presents that hen and cow were most abundant in these periods. The total number of birds, animals and four-legged animals were decreased by 58% and 60%, respectively, at with-TRM phase, as compared to the without-TRM phase.

The changes in livestock in the tidal basin occurred due to the reduction of grazing land because beel created a lack of fodder for livestock. Figure 2 shows that betel nut (*Areca catechu*) and mahogany (*Swietenia macrophylla*) were the most abundant trees in the basin. The total number of fruit trees and timber trees decreased by 27% and 28%, respectively, at with-TRM phase as compared to without-TRM phase in the basin. During TRM implementation, the peripheral dam to protect the village in the Pakhimara beel was not built high and strong enough. During the full moon, the height of the tide increased and the dam and its overflowing area were flooded that allowed saline water to intrude in the homestead area and reduced the production of fruit and timber trees. Individually, only the number of betel nut (*Areca catechu*) increased by eight times at with-TRM phase, as compared to without-TRM phase.

Table 3. Changes in livestock (bird animals and four-legged animals) in the tidal basin

TRM phase	Bird animals			Change		Four-legged animals		Change	
	Hen	Duck	Goose	Total	Percentage	Cow	Goat	Total	Percentage
Without TRM (2012-14)	1,226	1,098	112	2,436		537	395	952	
With TRM (2016-18)	614	397	13	1,024	-58%	233	150	383	-60%



a.

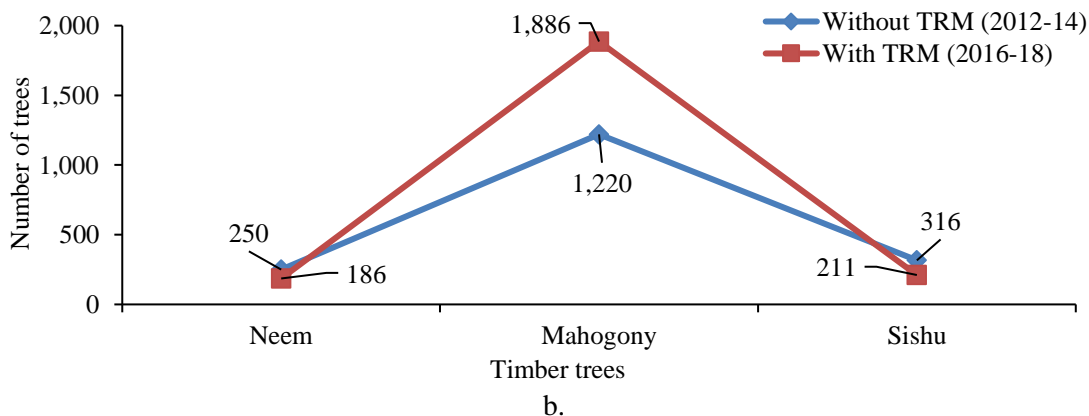


Figure 2. Changes in fruit trees (a) and timber trees (b) in the tidal basin

*Rate of migration*

Migration is usual in this tidal basin as it is a running TRM project in Bangladesh. Unemployed people migrated to cities in search of temporary work. When the beel was filled and waterlogged was removed, people began to move back to their land. The people of this area temporarily migrated

(15%) and most of them moved to urban areas (80%) to seek for new occupation. They permanently migrated to other areas during 2012-14 (0.8%) and 2016-18 (16%) (Figure 3). Temporary migration of the people increased by 65% at with-TRM (2016-18) and permanent migration increased by 14% at with-TRM (2016-18).

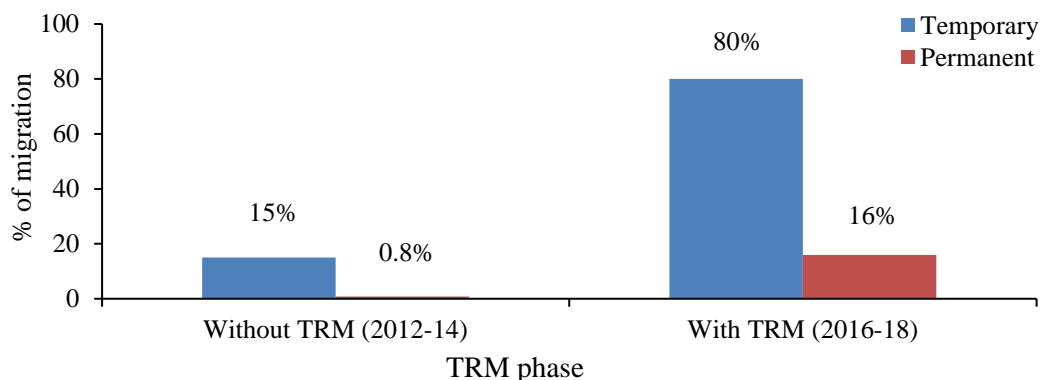


Figure 3. Changes in migration in the tidal basin

*Changes in agricultural production*

This study assessed the changes in the yields for five major agricultural production, including boro, vegetables, prawn, shrimp and white fish, in four villages. During TRM, the yield of boro decreased by 98% (Table 4). Before the implementation of TRM project, fish or paddy

and vegetables were cultivated at the same time in the beel. However, during the TRM operation, vegetables were not cultivated but catch fisheries (natural wetlands) were available. The average production of fisheries (shrimp and white fish) dropped by 85% at with-TRM event (Table 4).

Table 4. Changes in the agricultural production in the tidal basin

TRM phase	Agricultural production in total land (ha)				
	Boro	Vegetable	Prawn	Shrimp	White fish
Without TRM (2012-14)	150	120	122	436	89
With TRM (2016-18)	4	33	13	58	12
Change	-98%	-72%	-89%	-87%	-83%

Figure 4 presents the occurrence of drinking water problem due to waterlogged condition. Before the TRM implementation, the whole area was gone underwater and the people were forced to use unsafe drinking water due to the absence of pure drinking water. During the TRM phase, the problems reduced slightly.

Figure 4 also demonstrates that 74% of households living in the basin area faced problems related to drinking water at without-TRM (2012-14) phase and 69% of households were challenged with water problem at with-TRM (2016-18) phase. The problems improved by 5% with-TRM event when compared to the without-TRM event.

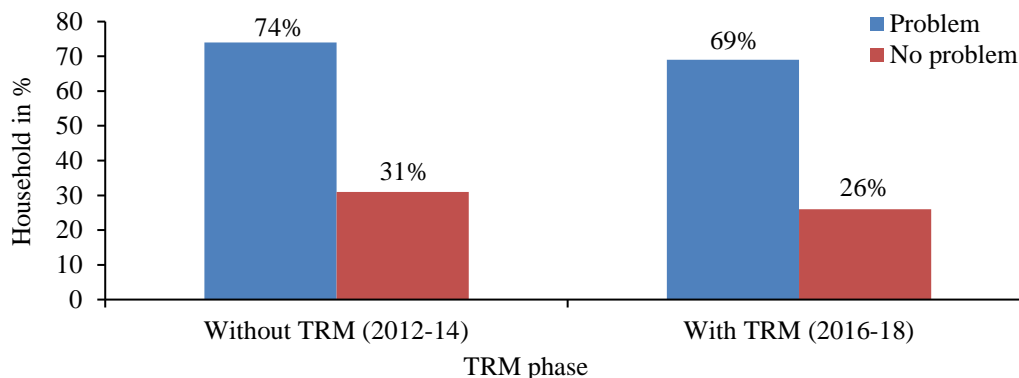


Figure 4. Drinking water problem

*Cases of sanitation and diarrhea disease in different TRM periods*

The waterlogged conditions can affect the environment by expanding water-borne diseases (like diarrhea) there is a negative relationship between sanitation and water-borne diseases which occur due to the low sanitation system. This study revealed that 62 cases from the total households suffered from diarrhea during with-TRM event. This number increased to 163 cases during with-TRM event as there is still a present waterlogged condition in the lower part of the beel. In waterlogging conditions, people suffered from sanitation problems for 180 days at (without-TRM) event and 90 days at (with-TRM).

*Compensation scenario*

The main reason for the uncertainty of this project was the complexity of compensation. Only the land owners got crop compensation. Poor farmers who were dependent on the Pakhimara beel were being deprived of it. The problem was the complication of the withdrawal. For this reason, many farmers were not interested

in applying for withdrawals. This study found that only 54% of marginal farmers and 73% from other farmer received crop compensation (Table 5).

Table 5. Farmers receiving crop compensation from the government

Farmer type	Farmer get compensation %
Marginal farmer (<100 decimal land)	54%
Another farmer (>100 decimal land)	73%

**Assessment of the changes in waterlogging and vegetation with settlement**

The study used six satellite images for pre-monsoon (April), monsoon (August) and post-monsoon (December) in 2014 and 2018 for TRM at Pakhimara beel, in terms of agricultural land, water body and the vegetation with settlement. TRM operation took place in the Pakhimara beel in 2015 and it was supposed to be completed in 2018. The results of the images are summarized in Table 6.

Table 6. Changes in waterlogging and vegetation with settlement at Pakhimara tidal basin

Land use (ha)	2014 (without-TRM)			2018 (with-TRM)		
	April	August	December	April	August	December
Water body	900	9,800	1,100	1,600	4,300	4,700
Vegetation with settlement	3,700	0	2,500	3,800	1,300	1,600
Agricultural land	5,200	0	6,200	4,400	4,200	3,500

Table 6 and Figure 5 indicated that the agricultural land occupied 53% (5,200 ha) of the total area during the pre-monsoon (April) period of without-TRM in 2014. Due to TRM operation, this value reduced to 44% (4,400 ha) during 2018. The water body held 100% (9,800 ha) and 11% (1,100 ha) of the total land in 2014 for monsoon and post-monsoon. The values dropped to 44% (4,300 ha) during monsoon in 2018 (with-TRM) but increased to 36% (4,700 ha) in post-monsoon in 2018 (with-TRM). During the monsoon period (with-TRM event)

5,500 ha land were respectively freed from waterlogging in 2018 as compared to 2014 (without-TRM). This reduction of waterlogging increased agricultural land and crop yields by 0 to 4,200 ha at monsoon in 2018, compared to 2014. However, in the pre-monsoon period, 900 ha of land faced waterlogging in 2014 (without-TRM), which then increased to 1,600 ha during TRM event. Moreover, the vegetation with settlement was increased by 1,300 ha for monsoon in 2018 (with-TRM) as compared to 2014 (without-TRM).

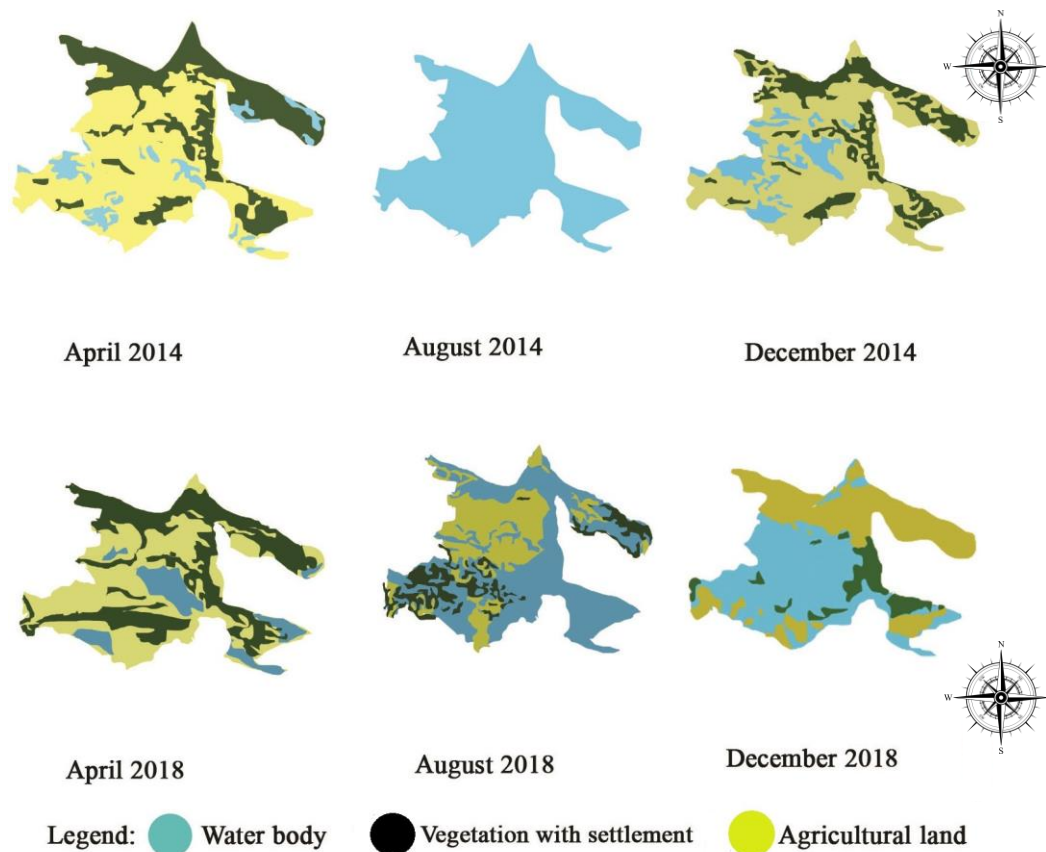


Figure 5. The satellite images for pre-monsoon, monsoon and post-monsoon in 2014 and 2018 for TRM

#### Assessment of the riverbank erosion, awareness and coordination, and rotation

This research assessed the opinions of key informants by applying a 5-grade Likert scale for these indicators in the tidal basin. The Likert scale is a five-point scale that is used to scaling the opinions of an expert in survey research. The level of respondents' satisfaction is presented in three conditions, including 'disagree' (1 & 2), 'neutral' (3) and 'agree' (4 & 5) (Saranya and Karthikeyan, 2015).

Table 7 demonstrates four important performances under riverbank erosion in the Pakhimara tidal basin. In terms of government authority/NGOs' efforts in resettling people if necessary and installing concrete blocked on the riverbank to protect from erosion, the maximum score of 5 and the minimum score of 1.6 were obtained. This indicator captures 54% satisfaction and earns 2.7 out of 5 point.

Table 8 presents five important performances under the awareness and coordination of



community people in the Pakhimara tidal basin. The maximum score of 3.6 and the minimum score of 1.5 were yielded for people's willingness

to be involved in TRM project and active role of CBOs (community-based organisations) and local NGOs regarding TRM project.

Table 7. Expert opinion regarding riverbank erosion

Riverbank erosion	Score for satisfaction (out of 5)
GOs' efforts in raising the awareness of people living in the bank side	1.8
CBOs' efforts in raising the awareness of people living in the bank side	2.7
Building concrete blocks on the riverbank to protect from erosion	1.6
Government authority/NGOs' efforts in resettling people if necessary	5.0

Table 8. Expert opinion regarding awareness and coordination of TRM

Awareness and coordination	Score for satisfaction (out of 5)
People's willingness to be involved in TRM project (compensation, dam, cut point, time fixation and area)	3.6
Active role of CBOs and local NGOs regarding TRM project	1.5
Coordination between GOs and CBOs for village protection dam	2.8
Coordination between GOs and CBOs for TRM project time fixation	2.1
Coordination between GOs and CBOs for compensation	1.6

Overall, 13 indicators were used to assess the impacts of TRM, five of which were positive, while the rest were negative, during the TRM implementation period in the tidal basin (Figure 6). From the assessment, TRM improved the waterlogging condition, which was a major burden for the local people. Sterrett (2011) concluded in his research that TRM has a positive influence on improving drainage capacity and removing water congestion. TRM also had a positive influence on lowering riverbank erosion, as well as improving sanitation and drinking water quality. These all parameters ensured good water governance. On the contrary, local dwellers were negatively impacted in terms of crop production due to the loss of land in the tidal basin. Rate of migration also increased due to the lack of employment opportunities. A total of 12% of the migration was estimated due to waterlogging problem (Chu, 2007). Ahmed (2008) and Adri (2009) identified that prolonged waterlogging leads to working males' migration to the cities for searching job by leaving their wives and children at home.

Overall, basin biodiversity changed due to shift in hydrological behavior. By assessing the key indicators, it can be recapitulated that TRM negatively affected the basin area, although it might be beneficial for catchment area.

The most essential advantages of TRM were sediment management (Khadim et al., 2013) and the removal of waterlogging from beel (Tutu, 2005; Paul et al., 2013; Jakarya et al., 2016), which could extend fisheries, agriculture, employment promoting better socio-economic condition. CEGIS (2003) and Paul et al. (2013) conducted socio-economic analysis in TRM implemented area to analyze the livelihood pattern of local people. They concluded that TRM improves to grow biodiversity by strengthening environment and finally, improving socio-economic conditions of the people living in the coastal area.

The overall scenario may be nullified by some complexities, like riverbank erosion, the reduction of agricultural land, and the loss of employment in the basin areas. De Die (2013) and Gain et al. (2017) stated that conflicts may be triggered due to the implementation of non-acceptance TRM. Therefore, TRM should be implemented by involving all level of stakeholders in the implementation area. Paul et al. (2013) and Gain et al. (2017) described in their study that riverbank erosion, disruption of road network, inundation of agricultural land and low rate of compensation to the land owners might be the potential causes for arising TRM complexity. The present study also discovered the same indicators negatively impacted the TRM basin areas.

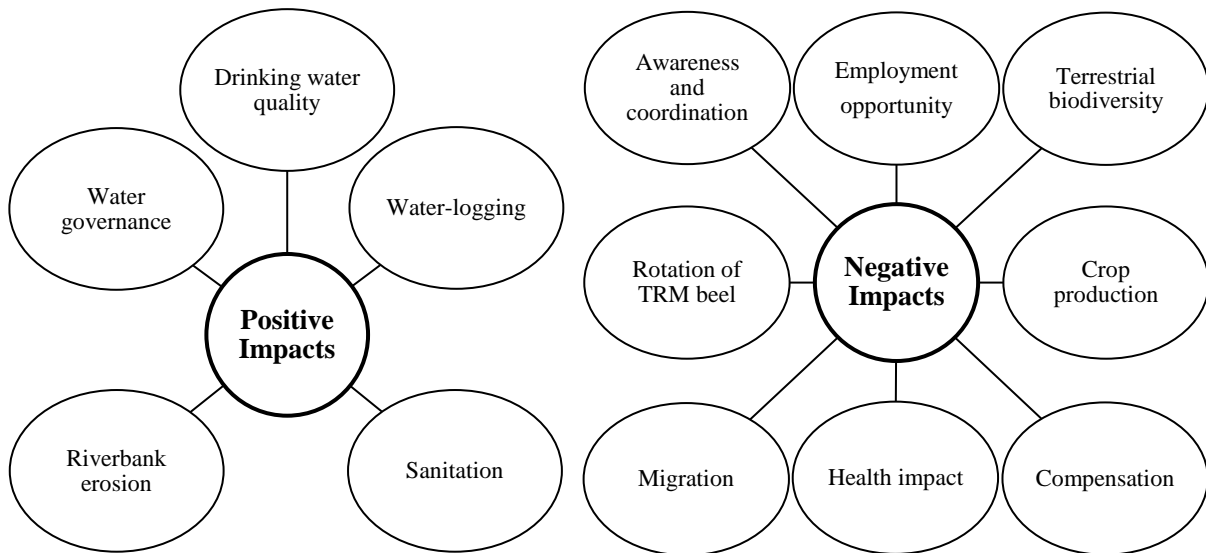


Figure 6. Positive and negative impacts of TRM

Bangladesh has set a long term protection strategy in the long run, called Bangladesh Delta Plan (BDP 2100) (GoB, 2014), in which TRM could be acknowledged as a problem solving factor for waterlogging (Saranya and Karthikeyan, 2015; van Staveren et al., 2017). However, a lot of conflicts and interests took place for implementing the project (Gain et al., 2017; Cornwall, 2018; Mutahara et al., 2018). Without healthy monitoring, nothing could make a success. Marginal farmers in the tidal basin were negatively impacted due to TRM. In the southwest Ganges-Brahmaputra delta, TRM could be operated in more than 35 beels (Nicholls et al., 2008; Amir, 2010). TRM has been implemented in 12 of 35 beels (Gain et al., 2017). In most of the cases, TRM could remove waterlogging but brought conflicts among the stakeholders (De Die, 2013). For a successful outcome, the compensation as well as economic benefits should be equally distributed and biodiversity and migration protection should be ensured. Bangladesh got the TRM concept from the Netherlands where successful economic and protection of biodiversity were observed for implementing TRM (Khan et al., 2014; van Staveren and van Tatenhove, 2016).

## CONCLUSIONS

TRM is an important issue for the local people of Pakhimara beel area. The TRM project was approved for implementation in four years but the authority failed to complete TRM project in

time (2018). This project produced both positive and negative impacts, with most indicators showing negative impacts. In Pakhimara beel, local people did not face the impact of waterlogging in their daily activities although the navigability of the river was deteriorating, and thus, TRM implementation was not their main demand. For ensuring sustainable TRM, proper compensation distribution should be ensured along with the creation of employment opportunities and settlement.

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