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WATER QUALITY ASSESSMENT AND MONITORING EFFECTS ON AQUATIC LIFE OF THE BALU RIVER USING REMOTE SENSING TECHNIQUES

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ABSTRACT

Due to growing urbanization, effluents from different sectors and factories near the river, untreated waste water disposal from Tejgaon Industrial area of Dhaka City and other human activities of the Balu River which is the study area, has always been one of the Bangladesh's highly polluted and shrinking rivers among four highly polluted rivers of Bangladesh. This extensive water contamination problem threatens human health and aquatic life. Uncertain water kills more people than war every year and combines all other types of violence. The aim of this study is the assessment and monitoring of the streams water quality and aquatic life with remote sensing techniques from satellites. In this research paper, Total Suspended Material (TSM) is measured using three sets of Landsat images from 2000 to 2021 time period to observe temporal changes in water quality over time. Turbidity, Chlorophyll-a (chl-a) and Land Surface Temperature (LST) are also observed in this study. The study found that in Balu River TSM decreased by 5%, Chl-a increased by 685%, Turbidity increased by 685% and LST increased by 25% correspondingly in last 20 years, indicating that the water is hazardous to aquatic life. The findings might be used to develop a strategy for improving water quality and monitoring aquatic life and also agriculture at around of the Balu River.

Keywords*: Remote sensing, Total suspended material, Chlorophyll-a, Balu river, Water quality, Landsat image.*

1. INTRODUCTION

Water is an essential component for all living organisms to live. Aquatic habitat and a variety of resources critical to organism life are under threat from a variety of physical factors, including land use change, contaminants, anthropogenic climate change, and difficult circumstances (Mushtaq & Pandey, 2014). Surface water resources preserve a portion of these resources and provide both human needs, such as drinkable water and leisure, as well as environmental needs, such as supporting high levels of biodiversity (Ismail et al., 2019). Water quality is deteriorating as a result of growing population expansion, a soaring pace of industry and urbanization, and global warming. These occurrences will worsen in the future, and various forms of studies have identified the diminishing aquatic environment as one of the most serious hazards to society (Torbick et al., 2013) . As a result, there is an increasing requirement for monitoring the water quality characteristics of waterways. Water quality is often assessed using physical, chemical, and biological criteria, as well as identifying the origin of any potential contamination that may affect water quality (Khattab & Merkel, 2014). Water quality monitoring is carried out utilizing basic procedures based on in-situ observations, which are then confirmed by laboratory testing of the collected water.

Chlorophyll-a (Chl-a) is the most significant aspect of trophic status because it works as a connection between nutrient content, specially phosphorus and nitrogen, and algal development. The issue of eutrophication is frequently linked to Chl-a concentrations (Han & Jordan, 2005; Wojtkowska & Bojanowski, 2021). Eutrophication, characterized by algal growth, is an enhancement of water by dissolved nutrients that produces massive reforms in the ecosystem, ultimately leading to the deterioration in hydrology and depletion of fish species (Liu et al., 2014). As a result, constant inspection and mapping of the Chl-a characteristic are required. Satellite-based Remote Sensing (RS) is a powerful method for routinely assessing geographic and temporal changes in water quality parameters, and it may be a good way to integrate water quality data collected through standard in situ observations (Giardino et al., 2001). The benefits of this approach are numerous, with the most significant being the ability to estimate Chl-a concentrations across the canal (i.e., a broader geographical extent) without necessitating the time-consuming and intensive field survey for monitoring. RS imagery gives regular and extensive coverage of rivers and streams, while GIS (Geographic Information System) provides a foundation for fast mapping and effectual visualization. The Landsat sensor has been a significant source of satellite photos for waterbodies monitoring applications due to its geographic resolution of 30m ground pixel resolution (Bartholomew et al., 2002). The accessible and major historical archives of Landsat images allow researchers to use such products to evaluate numerous phenomena such as Chl-a concentration, land surface temperature (LST), and total suspended material (TSM). Numerous studies have demonstrated the viability of using Landsat data to estimate water quality metrics over waterways (Guan, 2009; Ledesma et al., 2019; Liu et al., 2014).

Excessive turbidity, or cloudiness, in drinkable water is unpleasant and may also be harmful to one's health. Pathogens can find food and habitat in turbidity. Turbidity can encourage pathogen renewal in water distribution systems if it is not eliminated, leading to waterborne illness outbreaks that have caused substantial instances of gastroenteritis across the world. Suspended solids (turbidity particles) provide microorganisms with "shelter" by decreasing their exposure to antibacterial agents. Furthermore, organic-source waters with high turbidity may result in a significant chlorine requirement. As a precaution against probable recontamination, the free chlorine residual in distribution systems may be reduced. Contaminants in drinking water can cause harm to people through a variety of ways of exposure (ingestion, inhalation, and cutaneous). According to WHO (Nkurunziza et al., 2009) and EU DWD (Lambrou et al., 2010) guidelines, the turbidity of drinking water should not exceed 10 NTU (Nephelometric Turbidity units) after treatment. Consumers normally tolerate the appearance of water with a turbidity of less than 5 NTU.

The Balu River is strongly intertwined with the environmental balance of Dhaka. The ancient Balu's appearance deteriorated throughout the years. Today, the Balu River is being decimated abruptly by the noxious problem of pollution. It is recognized as one of the most contaminated areas of Bangladesh's river system. The water of the Balu River is constantly changing in quantitative and qualitative terms. Water quality and quantity have deteriorated at an astonishing rate as a result of the rapid growth of development activities, urbanization, and industrialization. The quantity of water is reduced as a result of residential and commercial buildings along the waterway. The rise in temperature with each day is also conducive to a decrease in the amount of water (Afroz et al., 2020; Hasan et al., 2014). The quantity of water has reduced so fast as a result of population growth that it poses a serious threat to the residents of the Balu River, including the people of Dhaka. River erosion and deposition are natural phenomena in the Balu River, and they are also capable of reducing water amounts. Significant amounts of these venomous modern squanders have been communicated into the stream as a result of the majority of the enterprises and processing plants located on the banks of the Balu or extremely close to the waterway framework without directing waste treatment units in previous decades. Dhaka's urban sewage is also churning in the Balu River (Hadiuzzaman et al., 2006; Hasan et al., 2014; Uddin & Jeong, 2021).

This study has been conducted over a 20-year period involving the processing and interpretation of satellite pictures of the Balu River. The primary objective of this study is to investigate and monitor the quality of various Balu River water parameters from 2000 to 2021 using multi-spectral Landsat satellite imagery. Three Landsat images from 2000, 2011, and 2021 were used in the analysis. The period from 2000 to 2021 has been divided into three time periods to investigate the quality of different water parameters: 2000-2011, 2011-2021, and 2000-2021, respectively. This study also observed how the various water parameters of this river vary over time

2. STUDY AREA

The Balu River is a tributary of the Shitalakshya River. This river flows through Gazipur, Dhaka, and Narayanganj districts. It flows over the Belai Beel and the vast wetlands northeast of Dhaka and flows into the Shitalakshya River near Demra. Apart from a faint connection between Shitalakshya and the Suti River near Kapasia, it has also joined the Turag River through the Tongi canal. During the monsoon season, Balu River carries water from Shitalakshya and Turag. The length of the river is 44 km, the average width is 69 m and the nature of the river is serpentine. Identification number of Balu River given by Bangladesh Water Development Board or "Paubo" is River No. 48 of North-Central Region (Balu River – Wikipedia 2020). The location of our study area is shown in figure 1.

Figure 1: Location of the study area (https://en.wikipedia.org/wiki/Balu_River)

3. METHODOLOGY

The main purpose of this study is to get an idea of the amount of pollution in the Balu River from 2000 to 2021 and how it is affecting the aquatic life in the Balu River through remote sensing. Basically, three separate years of landsat have been used to determine the extent of this change in water quality. The Landsat images used in this study are from Landsat 5 TM and Landsat 7 ETM+ sensors dated January, 2000, January 2011, and May 2021, respectively, and obtained through Earth Explorer, whose path is 137 and row is 44. Changes in the water quality of the Balu River have been identified through four indices of remote sensing. The indices are: Chlorophyll-a (Chl-a), Turbidity (TNTU), Total Suspended Material (TSM), and Land Surface Temperature (LST). The methods used for this study are represented schematically in figure 2.

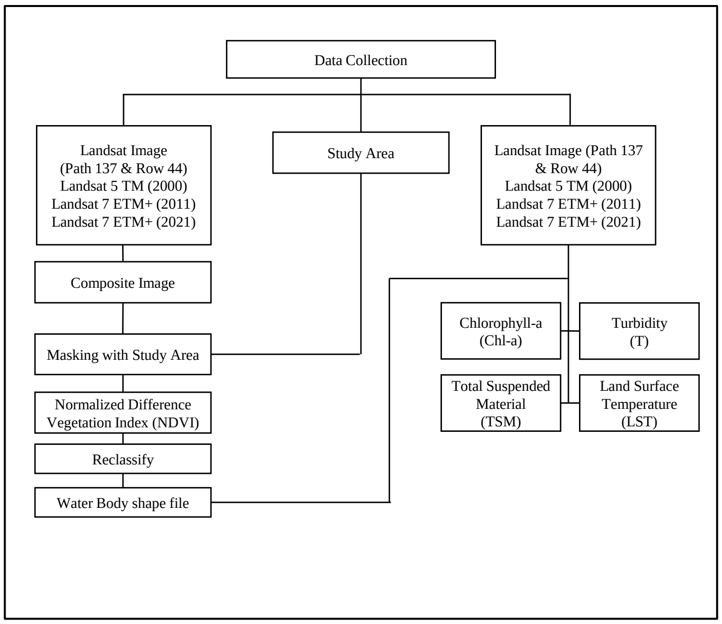

Figure 2: Methodology Flow Chart

3.1 Data Collection

The properties of the Landsat images that are used in this research are presented in Table 1. For visible, near-IR, and mid-IR wavelengths, the TM (Thematic Mapper) sensor has a spatial resolution of 30 m, while for the thermal-IR band, it has a spatial resolution of 120 m. The spectral bands on the ETM+ (Enhanced Thematic Mapper Plus) are similar to those on the TM, with the exception that the thermal band (band 6) has a better resolution of 60 m. The production system, on the other hand, has now resampled all TM/ETM+ photos to a 30 m resolution. (Shopan et al., 2015)

Table 1: Properties of the Landsat images

Path/Row	Acquisition Date	Satellite	Sensor	Spatial Resolution (m)	Cloud Cover
137/44	January 19, 2000	Landsat 5	TM	30	<10%
	January 25, 2011	Landsat 7	ETM+	30	
	May 12, 2021	Landsat 7	ETM+	30	

3.2 Data Processing & Analysis

In this study, software (ArcGis 10.4.1) was used for satellite image analysis. The images are prepared for analysis by composing different bands of Landsat images together. Google Earth Pro was used to identify the study area of the Balu River, and Google Earth Pro later created the KML (Keyhole Markup Language) format of the Balu River for analysis. The KML file was later converted to a layer by ArcGis with the help of a conversion tool. With the help of extraction tools, that layer is transferred to the composite image and clipped with composite images. Then the pixels that contain negative pixel values have been identified and separated as the water body of the Balu River on an NDVI (Normalized Difference Vegetation Index) map. Except for the water body (negative pixel), the rest of the index is removed by polygon to maintain the accuracy of research. In this process, three separate shape files are created for three separate years. Equation (1) used to calculate the NDVI (Normalized Difference Vegetation Index). There are currently a number of algorithms that determine water quality by relating spectral bands to water quality. From Landsat image analysis, Brezonik et al. (2005), Zhou et al. (2006), and Schiebe et al. (1992) established various equations to estimate different water quality indicators. The water quality parameters are evaluated in this study using the equation (2), (3), (4) which were chosen for those studies based on their accuracy levels.

$$NDVI = (NIR-RED)/ (NIR+RED) \quad (1)$$
$$Ln\ (Chl\text{-}a) = 6.71+ (0.0537*band\ 1)-(1.559*(band\ 1/band\ 3)) \quad (2)$$
$$T_{NTU} = 0.545*Chl\text{-}a \quad (3)$$
$$TSM = 92.4-(516*band\ 2) + (135.8*band\ 3) + (955.3*band\ 4) \quad (4)$$

Where, *NIR*= band 4, *RED*= band 3, *Chl-a*= concentration of chlorophyll-a (µg/l), T_{NTU}= Concentration of Turbidity (NTU), *TSM*= concentration of Total Suspended Material (mg/l).

The following equation was used to estimate the surface water temperature of the Balu River utilizing effective satellite sensor or brightness temperature techniques employing Landsat thermal infrared data. (Mia et al.,2017)

$$L_\lambda = (Lmax_\lambda - Lmin_\lambda)/ (Qcal_{max}-Qcal_{min}) * (Qcal-Qcal_{min}) + Lmin_\lambda \quad (5)$$
$$T_b = K_2 /ln\ ((K_1/L_\lambda) +1) \quad (6)$$

Where, L_λ= Spectral radiance ($Wm^{-2}sr^{-1}\mu m^{-1}$), $Lmax_\lambda$= Maximum value of radiance, $Lmin_\lambda$= Minimum value of radiance, $Qcal_{max}$= Calibrated Quantized maximum value , $Qcal_{min}$= Calibrated Quantized minimum value, Q_{cal}= Calibrated Quantized value which converted in radiance, K_1= Constant of first calibration ($Wm^{-2}sr^{-1}$), K_2= Constant of Second calibration (K), T_b = temperature (K).

After determining all the parameters through the equation, the water quality of the Balu River is determined with the shape file obtained from the NDVI map.

4. RESULT & DISCUSSION

The spatial and temporal changes of the water index, Total Suspended Material (TSM), Chlorophyll-a (Chl-a), Turbidity (T_{NTU}), and Land Surface Temperature (LST) of our study area in 2000, 2011, and 2021 are shown in Table 2.

Table 2: Spatial and Temporal Changes of Water Quality Index

Water Quality Index	Unit	Average Value			% Change		
		2000	2011	2021	2000-2011	2011-2021	2000-2021
TSM	mg/l	28025	20299	26664.8	-28%	31%	-5%
Chl-a	mg/l	6.63	6.55	52.07	-1%	695%	685%
T_{NTU}	NTU	10.84	10.70	85.14	-1%	696%	685%
LST	°C	18.14	17.91	22.58	-1.5%	26%	25%

4.1 Temporal Changes of Total Suspended Material (TSM)

Using the Landsat image of 2000, 2011 and 2021, the highest values of total suspended material (TSM) values were found at 50000 mg/l, 28719.602 mg/l and 48807.99 mg/l, respectively, and the lowest values of total suspended material (TSM) values were found at 6049.499 mg/l, 11877.200 mg/l and 4521.61 mg/l, respectively (figure 3). It is observed that, in the period from 2000 to 2011, the TSM quantity of the Balu River decreased by 28%. TSM quantity increased in 2011 to 2021 time period by 31%. Overall In the 2000–2021 time period, the TSM quantity of the Balu River decreased by 5%, which is a little bit good sign for this river. The alarming fact is , in the last 10 years, various factories have sprung up around the Balu River, which discharges huge amounts of untreated wastewater, raw organic compounds, and heavy metals into the Balu River. Also, treated and untreated waste water discharged from Tejgaon Industrial Area flows into Hatirjheel and later into the Balu River through Rampura canal. As TSM levels increase, light penetration decreases adversely. The result of photosynthesis is influenced by the primary producers. As a result, these floating materials frequently enter the gills of fish and kill them (Ocean Optics, 2004). Fish reproduction is also hampered due to high TSM. The TSS standard for tannery and textile effluents is 150 mg/l in Bangladesh (Afroz et al., 2020). According to the study, the obtained TSM value is much higher, which is harmful to aquatic life in the river and degrades water quality. Although the level of TSM has decreased in the last 20 years, it is not very effective for overall environment of Balu River.

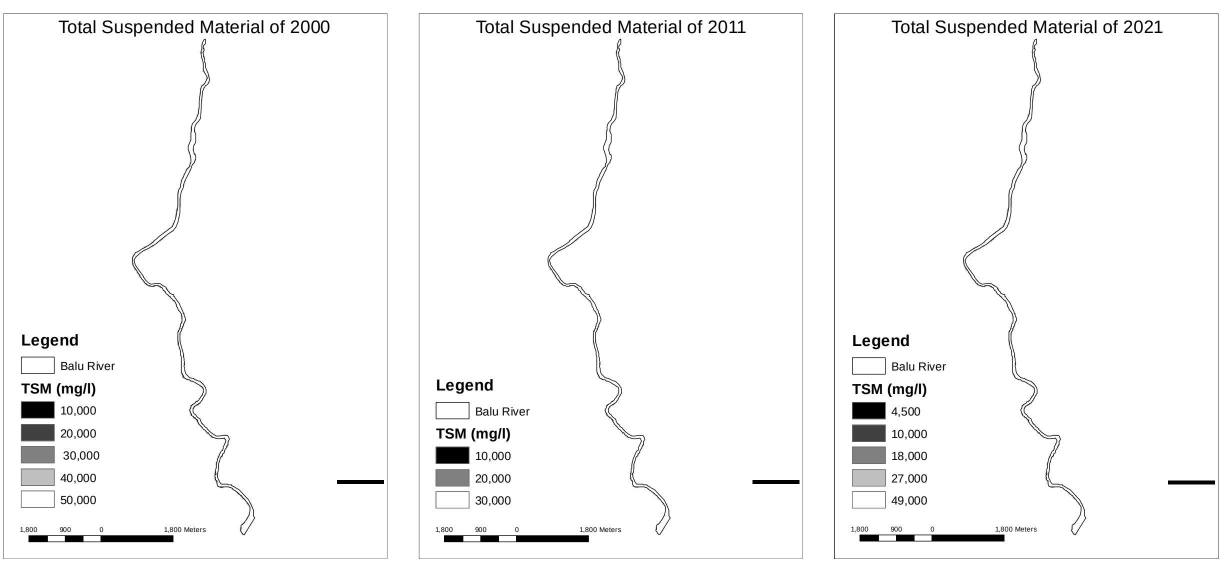

Figure 3: Total Suspended Material (TSM) of Balu River from 2000 to 2021

4.2 Temporal Changes of Chlorophyll-a (Chl-a)

Using Landsat images from 2000, 2011, and 2021, the highest values of Chlorophyll-a (Chl-a) were found to be 9.164 mg/l, 9.102 μg/L, and 87.570 mg/l, respectively, and the lowest values were 4.095 mg/l, 3.999 mg/l, and 16.573 mg/l, respectively (Figure 4). Between 2000 and 2011, the amount of Chl-a in the Balu River decreased by 1%. However, between 2000 and 2021, the amount of Chl-a in the river increased by 685%, which is a highly concerning condition for this river. The primary green photosynthetic pigment found in all plants is chlorophyll-a. The concentration of chlorophyll-a in estuarine, coastal, or marine waters is used to estimate photosynthetic plankton biomass. It is a widely used indicator of water quality, with low levels indicating good condition. While high levels of Chl-a are not bad for water, long-term high Chl-a is a threat to water (Shopan et al., 2015). Chl-a levels in the Balu River are rising, which might pose concerns in the future.

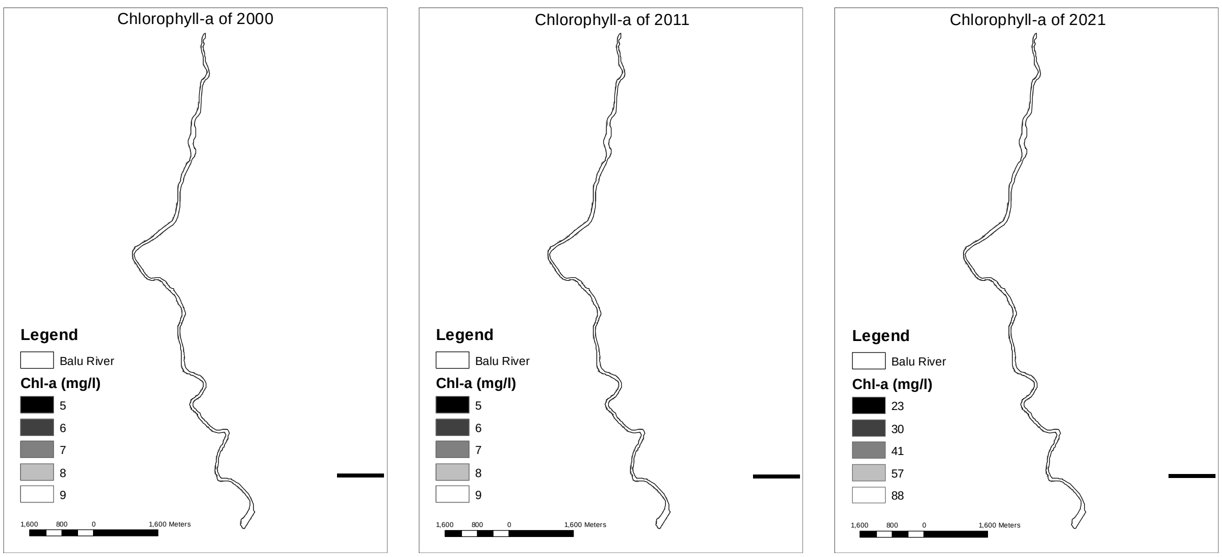

Figure 4: Chlorophyll-a (Chl-a) of Balu River from 2000 to 2021

4.3 Temporal Changes of Turbidity (T_{NTU})

Using the Landsat image of 2000, 2011 and 2021, the highest values of turbidity values were found to be 14.98 NTU, 14.88 NTU and 143.18 NTU, respectively, and the lowest values of turbidity values were found to be 6.70 NTU, 6.53 NTU and 27.10 NTU, respectively (figure 5). It is observed that the turbidity of the Balu River has increased 685% in the last 20 years. In the last 20 years, huge infrastructural development has taken place in the vicinity of the Balu River, which has contributed to increasing the turbidity of the Balu River. In addition, storm water from Dhaka city, factories located on the banks of the river, and untreated waste water from factories emanating from Tejgaon Industrial Area in Dhaka are also mixed in the Balu River. As a result, the turbidity of the water here is increasing, which is a major threat to the environment and aquatic life of the Balu River. When turbidity increases in ponds such as lakes, rivers, and reservoirs, light cannot reach the bottom of the water. As a result, submerged plants, which are the main food source for fish and shellfish, cannot grow properly. This leads to a food crisis that hinders their growth. Also, high turbidity reduces the amount of dissolved oxygen in the water so that the fish cannot properly absorb oxygen through their gills (USEPA, 2005).

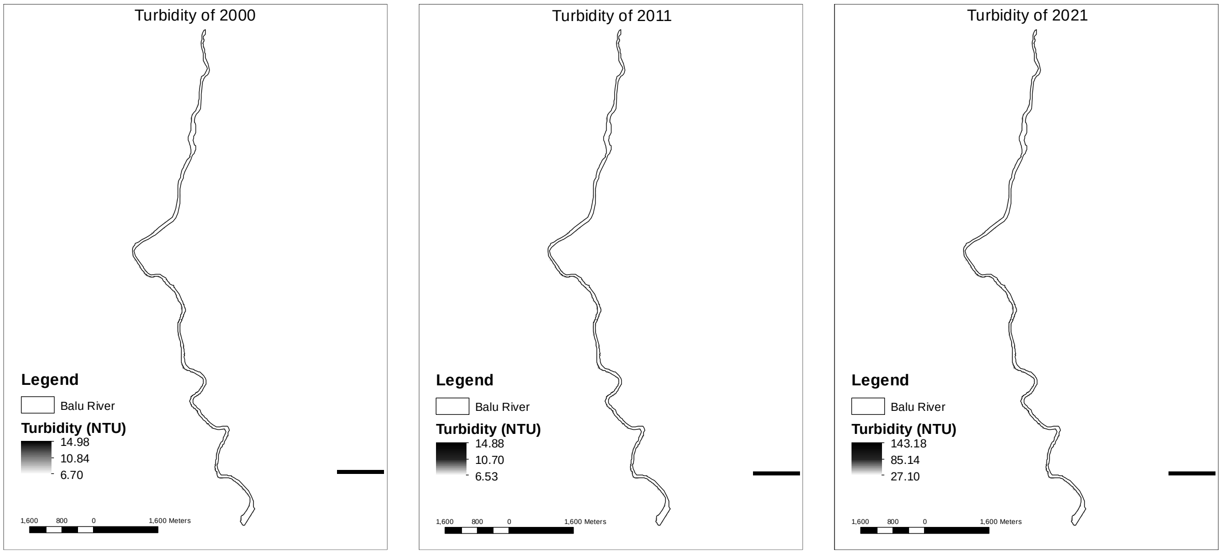

Figure 5: Turbidity of Balu River from 2000 to 2021

4.4 Temporal Changes of Land Surface Temperature (LST)

Using the Landsat image of 2000, 2011 and 2021, the highest values of land surface temperature (LST) values were found at 19.72°C, 20.17°C and 24.542°C, respectively, and the lowest values of land surface temperature values were found at 16.56°C, 15.64°C and 20.619°C, respectively (figure 6). It is observed that the temperature of the Balu River has increased 25% in the last 20 years. In the last 20 years, turbidity in the waters of the Balu River has increased significantly. The amount of heat in turbid water is higher than that of pure water, which results in a gradual increase in the temperature of the Balu River. Since most of the factories built around the Balu River do not have treatment plants, the waste water is directly mixed with the river water. This is another reason for the rising water temperature here. In addition, due to the change in the global environment, the temperature of the earth is increasing day by day, as a result of which the water temperature of the Balu River is also increasing. The increasing LST of the Balu River is an alarming situation for the environment.

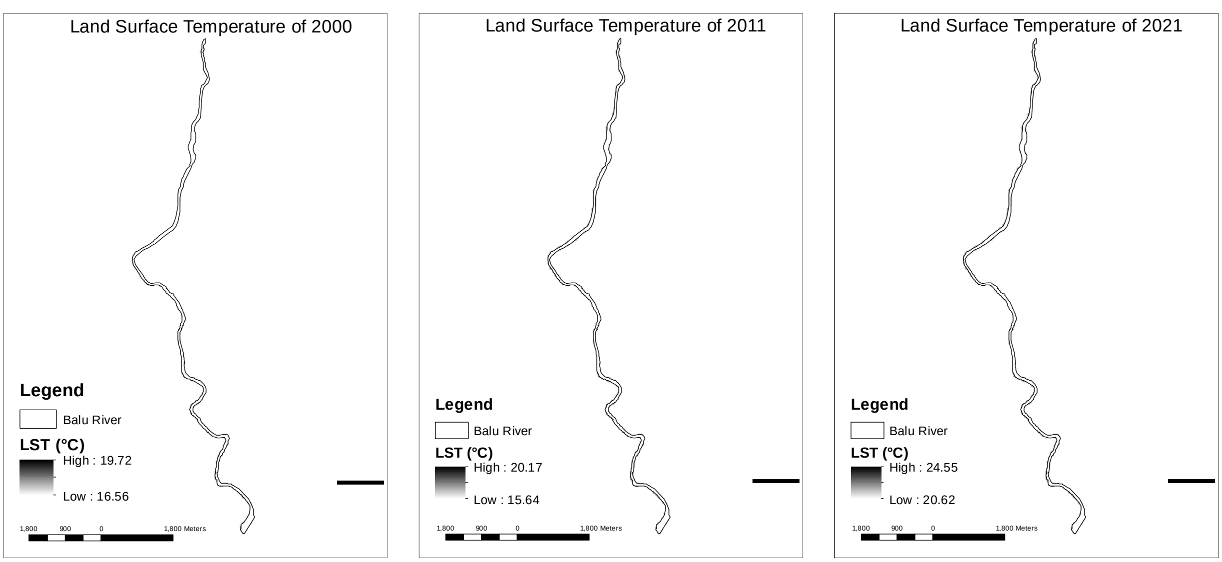

Figure 6: Land Surface Temperature (LST) of Balu River from 2000 to 2021

5. CONCLUSION

The Balu River is the major river that flows alongside Dhaka. City people rely heavily on the Balu for drinking purposes, fishing, and transporting goods. The impact of changing water supply and quality is highly susceptible in densely populated places such as Dhaka and Narayanganj. In the past, satellite pictures were not used to analyze the Quality of water of Balu River. This study was successful in detecting temporal change of Balu River in last 20 years, particularly water bodies of this river.

In this study, Total Suspended Material (TSM) is quantified using three sets of Landsat photos from 2000 to 2021 to investigate temporal changes in water quality through time. This research also looks at Turbidity, Chlorophyll-a (Chl-a), and Land Surface Temperature (LST). The study discovered that in the previous 20 years,

- TSM in the Balu River decreased by 5%,
- Chl-a increased by 685%,
- Turbidity increased by 685%, and
- LST increased by 25%

Which suggesting that the water is harmful to aquatic life. Total suspended materials in the Balu River rise drastically over the research period. We also saw a rise in LST by satellite image assessment. According to this study, the water in Balu is degrading day by day as a result of its nearby point and nonpoint sources, which include outflows from tannery enterprises, sewage, and municipal wastewater. Recognition of water bodies and detection of differences in the balance of water bodies in this research region using satellite pictures would be beneficial to quantify the water bodies, which would be valuable for city inhabitants and policymakers, and could also be used to promote water conservation.

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