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Environmental Health Analysis of Industrial Area: A Case Study on Urban Area, Khulna, Bangladesh

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Abstract: Environment is anything that instantly surrounds an object and has a direct influence on it. The aim of this research is to analyze the current scenario of softscape and Hardscape features along with the temporal change over a period of 10 years. We collect primary data from the field survey and Landsat 7 and 8 raster data have been used for different analysis in this study. Image classification, Normalized Difference Vegetation Index (NDVI), Normalized Difference Built Index (NDBI), Normalized Difference Water Index (NDWI), Land Surface Temperature (LST) etc. remote sensing tools are used in this project for analyzing current scenario of the softscape and hardscape features of the environment. This study makes a decision on the point that vegetation coverage has been reduced by 33.28% within the time frame of 10 years where the health of the vegetation is increased by 0.11 in 2014 but it reduces by same amount in 2019. Though there is a strong relationship between NDBI and LST, for imbalance situation between softscape and hardscape features of the area, LST has reduced with the increase of NDBI value. Besides, the pollution effects in adjacent rivers are dipping as a result of reducing industrial activities in that area. Finally, for any development in this area, socio-economic conditions and land use of the area must be considered consciously.

Keywords: Eco-system, Environment, Pollution, Vegetation, Environment Profiling

1. Introduction

Environment is a platform where humans are born, raised, and live. It is simply the part of human existence that can't even be thought of avoiding. More precisely, Environment is anything that surrounds an object instantly and exerts a direct influence on it (Gisbert, 2010). In today's fast developing world protecting the environment is a crying need as it depends on our entire existence. The word relevant to climate is also very important to human life, and that is Ecosystem. An ecosystem is a population of living organisms that communicate as a group, together with the non-living components of their environment.

Environmental policy is the method of preparing sustainable development on the environmental basis (Ellis, 2010). It can also describe as the theory and practice of making good, interrelated decisions about the natural environment, working landscapes, public health, and built environment. Green planning is carried out primarily by the primary planning departments through different agencies (Daniel, 2009).Environmental pollution is characterized as contamination of the earth / atmosphere system's physical and biological components in such a way that normal environmental processes are

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adversely affected (Iyyanki & Manickam, 2017).Pollutants may be naturally occurring substances or forces, but when reaching natural levels, they are called pollutants. Any use of natural resources at a rate higher than the capacity of nature to recover itself can result in air, water and land pollution. Ecosystem is a biological system that consists of all the species present in a given physical environment. The species communicate with it, with each other (Tsujimoto et al., 2017). It can be seen as the complex interactions between ecosystem biotic and abiotic elements that include material cycles and energy flow as broad terms (Lyon & Brigham, 2005).An Ecological Profile can be described as a more detailed replacement of the usual socio-economic profile, giving equal coverage to the physical, biological, socio-economic, cultural and built environments.

Industry profiles are in-depth documents that provide insight into an industry from where it started to where it appears to be going. Environmental health is the public health division which is concerned with all aspects of the natural and built environment that influence human health. Industries create various kinds of pollution like air pollution, water pollution, noise pollution etc. which are very much harmful to the environment. People suffer various kinds of diseases like respiratory illness, brain and nervous system effect, water borne disease, deafness etc.

Climate and biodiversity play a major role in human life, or in other words human life relies entirely on these. But the inventions which are also responsible for man's better life are responsible for environmental and biodiversity destruction. Each development has more or less an environmental impact. Therefore, managing these impacts is very important to ensure a living Earth state. Understanding the components of these is very important for maintaining or regulating the climate and ecosystem. Bangladesh is a rapidly developing country that hopes to very soon become a developed country. The environment and the ecosystem are at risk of being disrupted at a high rate in this process of development and this may pose a threat to the country's population. Environmental profiling based on the industrial area and its change of ecosystem and pollution effect has not been assessed yet in Khulna city. The scope of this study is to differentiate short-term and long-term plans can be built with the current environmental situation. Besides the atmospheric quality can be enhanced by reducing the emissions and taking measurement of the source of pollution. The objective of this research is to analyze the condition of the softscape and hardscape environmental features of the study area over a period of time. Data used in this study might be obsolete and have some inaccuracy as environment is a continuous changing process.

2. Methods and Materials

2.1. Study Area

Ward 7 and 8 among 31 wards of Khulna City Corporation (KCC), Bangladesh, is selected as a study area in this project that is located in between 22°50' and 22°52' north latitudes and in between 89°31' and 89°34' east longitudes. Ward 07 has an area of 118.6 acre and ward 08 has 234.75 acre with a population of 14800 and 18550 respectively. As in figure 1, Bhairab river has passed on one side of the study area and the area consists of many industries and colonies of workers from that industry. This area is highly trend to pollution from the industries and low-income people from the industries lives there.

2.2. Methods

To obtain the study objective sequential and systematic steps are adopted. The initial reconnaissance survey has done to find out the existing environmental condition of the area. Secondary data has been collected by reviewing different articles and satellite has been downloaded from the USGS in the interval of 5 years from 2019.After data collection from different sources the environmental profiting has been done based on the data.

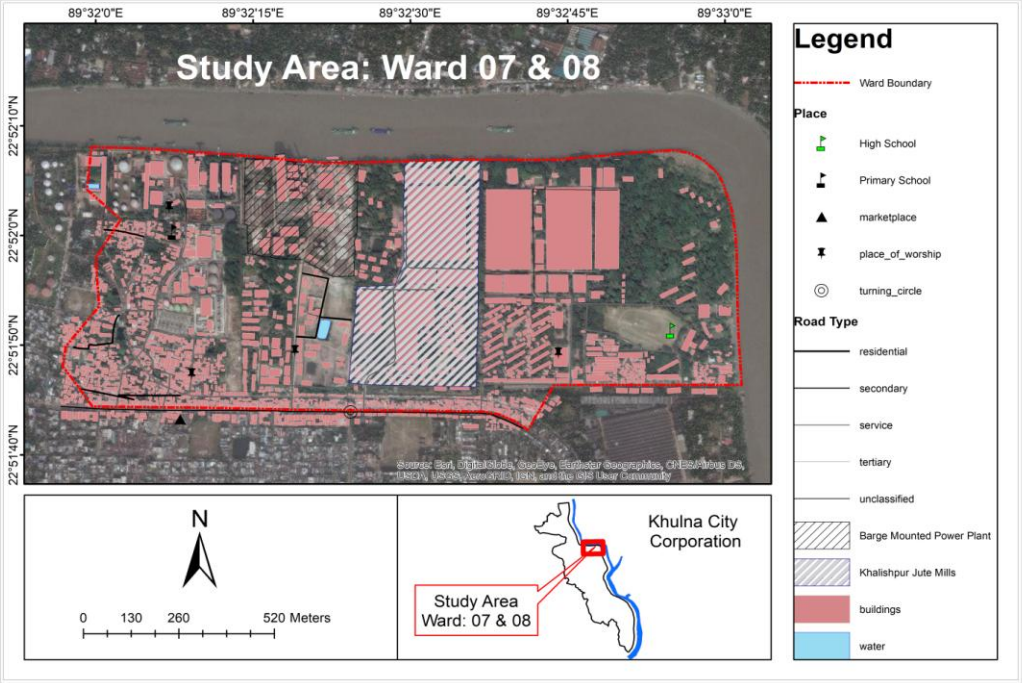

Figure 1: Study Area: Ward 07 &08 (Source: Author, 2020)

2.2.1 Data collection

Primary data has been collected from the reconnaissance survey. Existing utilities and infrastructure, existing waterbody, vegetation, location and influence area of pollution source has been observed during the survey in figure 2. In case of secondary data, data is collected by past research, study papers published by NGOs or researchers related to Khulna city water and sanitation situation and Satellite Image. The existing water supply data was collected through KWASA (Khulna Water and Sewerage Authority). The data format was a shape file (.shp), gathered from secondary sources such as BBBike, USGS, Google Earth Pro etc. Landsat Image has used mostly for the analysis.

2.2.2 Landsat Data

Landsat 7 and 8 images were collected from USGS for analysis for the year 2009, 2014 & 2019. Landsat 7&8 measures different ranges of frequencies along the electromagnetic (Macarof & Statescu, 2017).

Table 1: Landsat Data Information

Sl. No.	Landsat	Path	Row	Acquisition Date
1	08	137	44	09/10/2019
2	08	138	44	31/10/2014
3	07	138	44	25/10/2009

[Nasa Landsat Science]

2.2.3 Data Processing

Image has been classified from the Landsat data using Image Classification tools in the ArcGIS. By this classification, land use change has been identified over the period of time and from that land use change can be predicted.

a) Land use classification: In ERDAS Imagine Software, the obtained satellite images were optimized for increased clarity by means of most filter techniques. The True Color Composite (TCC) was created to choose training dataset for various LULC classes using appropriate band combinations for all images (Good & Giordano, 2019) (Foody, 2002). Depending on the Maximum Likelihood Supervised Classification (MLSC) method, the images obtained by Landsat were categorized into four large LULC groups (water body, built-up area, vegetation and open area) for 2009, 2014, and 2019. In terms of generating LULC maps at each LULC class, about 25 samples were gathered. Using 180 ground truths from reachable field measurements and Google Earth photos, the accuracy of land cover maps was assessed. These 180 pixels were selected by means of a simple random procedure (Pontius & Millones, 2011).

b) Normalized Difference Vegetation Index (NDVI): A widely popular tool for monitoring vegetation Situations Using Red (R) and Near Infrared (NIR) bands, NDVI is calculated which is 3 and 4 band respectively of Landsat 7 and 4 and 5 band respectively of Landsat 8.

$$NDVI = \frac{NIR-RED}{NIR+RED} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

c) Normalized Difference Built-up Index (NDBI): It is applied to track buildup areas. It is suitable for evaluating buildup expansion through remote sensing and GIS methods. By using Shortwave Infrared (SWIR) and Near Infrared (NIR) bands which is 4 and 5 band respectively of Landsat 7 and 5 and 6 band respectively of Landsat 8, NDBI is calculated.

$$NDBI = \frac{SWIR-NIR}{SWIR+NIR} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

d) Normalized Difference Water Index (NDWI): NDWI in next equation is a normalized difference water index is known to be strongly related to the plant water content. NDWI is 2 and 4 band respectively of Landsat 7 and 3 and 5 band respectively of Landsat 8. (Sinergise, 2019)

$$NDWI = \frac{GREEN-NIR}{GREEN+NIR} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

e) Land Surface Temperature (LST): Thermal band (band10) of Landsat 8 and (band06) of Landsat 7 images was used for determining LST image. Various steps are involved in the estimation of LST from Landsat image (Essa et al., 2012). The digital number of thermal bands was first rescaled into Top of atmosphere radiance (TOA) using Equation (1).

$$L_\pi = M_L \times (DN) + A_L \ldots\ldots\ldots\ldots (4)$$

Where, M_L = multiplicative rescaling factor; A_L = additive rescaling factor; DN = digital number of thermal bands. TOA radiance requires a mixed signal which comprises both land and atmosphere emissions. Accordingly, ambient adjustment was done to remove the influence of atmosphere. TOA radiance involves a mixed signal that incorporates all ground and air pollution. Thus, ambient adjustment was performed to minimize the emission from the environment. Therefore, TOA radiance was converted into surface leaving radiance (LT) using Equation (2)

$$L_T = \frac{(L_\pi) - L_\mu - \tau \times (1-\varepsilon) \times L_d}{\tau \times \varepsilon} \ldots\ldots\ldots\ldots\ldots (5)$$

Where,L_μ = upwelling radiance;L_d = downwelling radiance; W = transmission;ε = emissivity. The atmospheric parameters like transmission (τ), upwelling radiance (L_μ) and downwelling radiances (L_d) values were obtained from an atmospheric correction tool. Then, the surface leaving radiance was converted into LST using Planck's law as given in Equation (3). $T_S = \frac{K_2}{\ln(1+\frac{K_1}{L_T})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$

Where, K_1, K_2 = Thermal Constants; T_s = Land Surface Temperature. (Bala & Prasad, 2018)

2.2.4 Analysis

To fulfill the research objective, data obtain from different sources are analyzed through different GIS and Remote Sensing tools using ArcGIS and ERDAS Imagine software. Trend analysis of different environmental parameters are analyzed and pollution range and effects on adjacent river has shown over different interval of time though Remote Sensing Analysis. Though the area is susceptible to pollution hazards, the pollution has been emphasized in the analysis phase. Beside for the industrialization of this area, the vegetation and land surface temperature have much valuation in the environment profiling of the area.

3. Analysis and Findings

3.1 Elevation and Water Logging Scenario

For profiling the environment, elevation of the area plays a significant role in forecasting the inundation of the area during the flood. Besides decisions of the development of any project on these lands is based upon the elevation of the area. From the figure (03) it is seen that the average elevation of the area is in between 5 meters to 9 meters. Some of the area has elevation above 10 meters. But the land beside the river line, the elevation is less than 4 meters. When there will be flood or the river will over flow more than 4 meters during the rainy season than those area will be inundated. That low land is in the industrial area, they used this land for the dock for the shipment of goods.

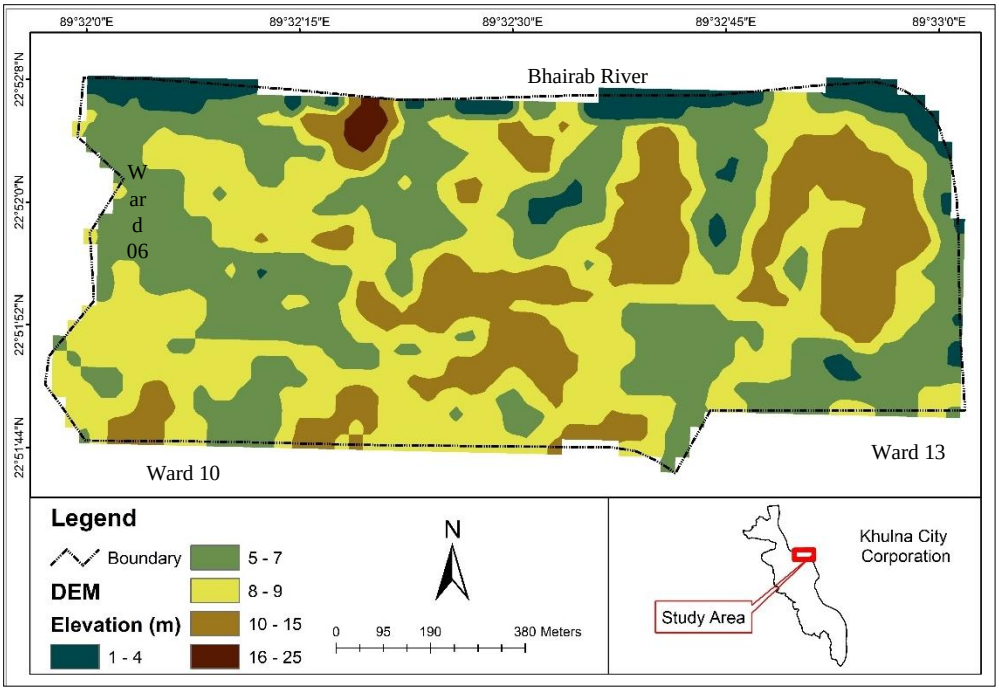

Figure 2: Elevation model of ward 07 & 08

Source: Author, 2020

Water logging is a burden for the citizen of Khulna city. This is not exception in this area too. Every year during the rainy season, people in this area suffered much from this problem. It is seen that ward 07 experience water logging much during the rainy season. The reason for this water logging is due to the bad condition of the drainage system. In ward 08, all the storm water runoff to the adjacent river which lead to no water logging during the rainy season. But in case of ward 07, people experience more water logging problems during the monsoon season and diurnal high tide. (Nargis, 2001)

3.2 Land use and Land Change

Land use human activities which are directly related to land, exploit its resources or have an impact on it. Land cover is the land's physical attributes, whereas land use is a pattern of human activities conducted within a socio-economic framework. Natural land cover is changed by using man to meet farming, homesteading, or other demands. The maximum land is used for Industrial purposes. Jute Mill, Oil Depo and Power Plant are the industries in this area. In the northern part of the area there is Bhairab River and the industries grew up based on this river line. Residential area covers the major part of the region in the southern part of the area. This residential is based upon the workers from the industry. Colonies of the workers is basically government quarter and for the low-income workers.

Figure 3: Land use change of Study Area

Source: Author, 2020

Change in land use is a process through which human activities transform the natural landscape, referring to how land has been used, usually stressing the functional role of land for economic activities. In the figure-05, the land use has change remarkably over a period of time. Built up area has increased remarkably from 2009 to 2019. Green cover of the area has reduced due to the expansion of the mills.

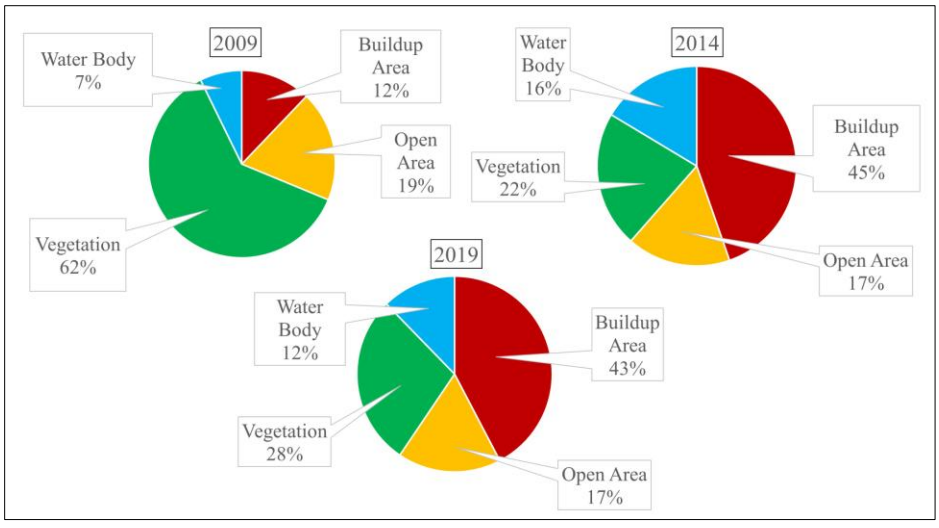

Figure 4: Land use Percentage of different interval of time

Source: Author, 2020

In the above figure 06 it is seen that the vegetation of the area is 61.52% in 2009. This percentage has decreased to 22.11% in 2014 and again it increases to 28.24% in 2019. The reason of increasing vegetation in 2019 is because of the increase of tree plantation by the Industries in their yard. As the river is meandered in this area, it is susceptible to river erosion in this bank of the river. So, industries planted trees in the bank of the river to protect it. Besides, the buildup area has increased to 44.66% from 12.14% from 2009 to 2014. This means the expansion of industries in the year range. New industry has been setup like oil depo and power plant in this area. Again, though the waterbody has been increased in 2014 from 2009 but the waterbody has decreased in 2019. This classification has been done based on the Landsat image where the resolution of the image is 30m, the accuracy of this classification is not quite satisfactory.

3.3 Effect of Temperature Change on Built Environment

Land surface temperature (LST) is troposphere pigment temperature. LST depends on how much sunlight each geographic area receives. Besides sunlight, the land cover also affects LST, which leads to changes in the temperature of the surface of the earth.

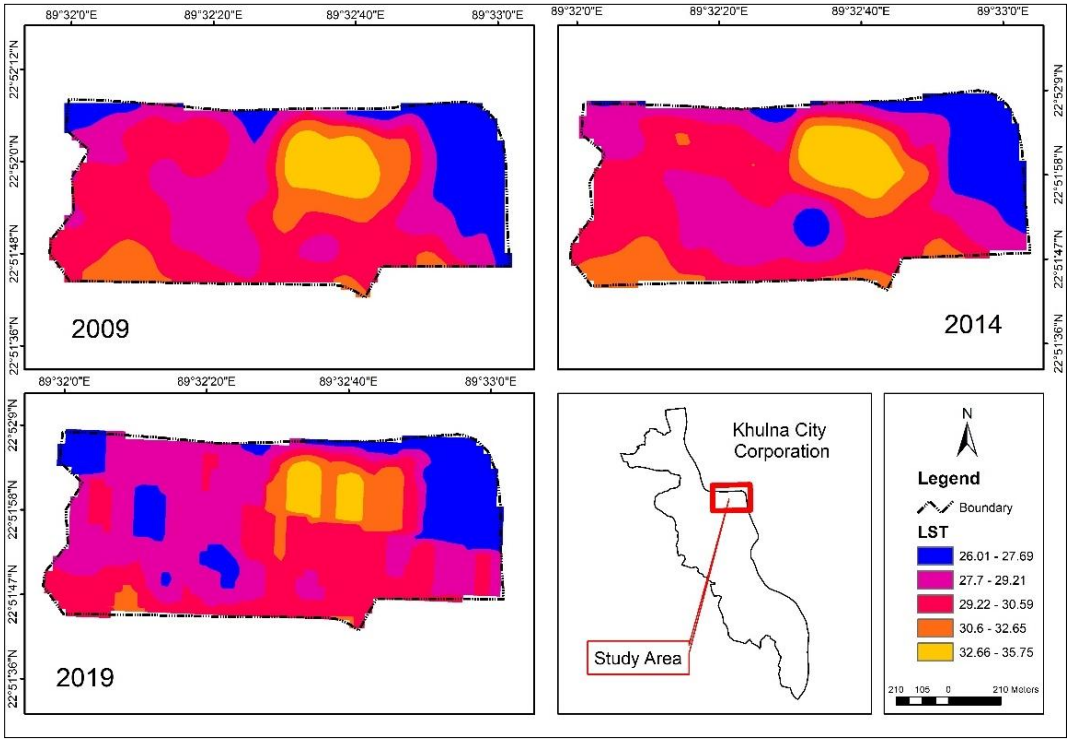

Figure 5: Changing phenomena of Land Surface Temperature of Study Area

Source: Author, 2020

Above figure 7 indicate the built environment of the area in different interval of time. The area is susceptible to high temperature due to the industrialization of the area. In 2009, the area is full of industrial activities. The average LST is in the range between 32-35

degree Celsius in the eastern region of the area. But by the flourishment of the industry, the average LST of the area has increased its range during the year 2014. But the year 2019, LST has change remarkably in the industrial area. The temperature has fallen down. It's because of the shutting down of the industries. The production of the industry has fallen down and for that there has been remarkable change in LST. But this LST has relation with built index.

There is a statistical correlation between LST and Built environment of the area showing in figure 9. As there is strong relation with the temperature of the area with the buildup condition, this analysis elaborates the relationship between two data, LST and NDBI. This relationship holds a strong position about the correlation of the data as well as the dependency of the temperature with the buildup condition in the area. The inflated NDBI value here demonstrates the region's developed area. The land surface temperature would shift along with a rise throughout the built-up area. Also, the negative value of NDBI indicates the region's vegetation portion. The temperature will rise in that region where there is a built-up area, and again as there is a vegetation area, the temperature is relatively low.

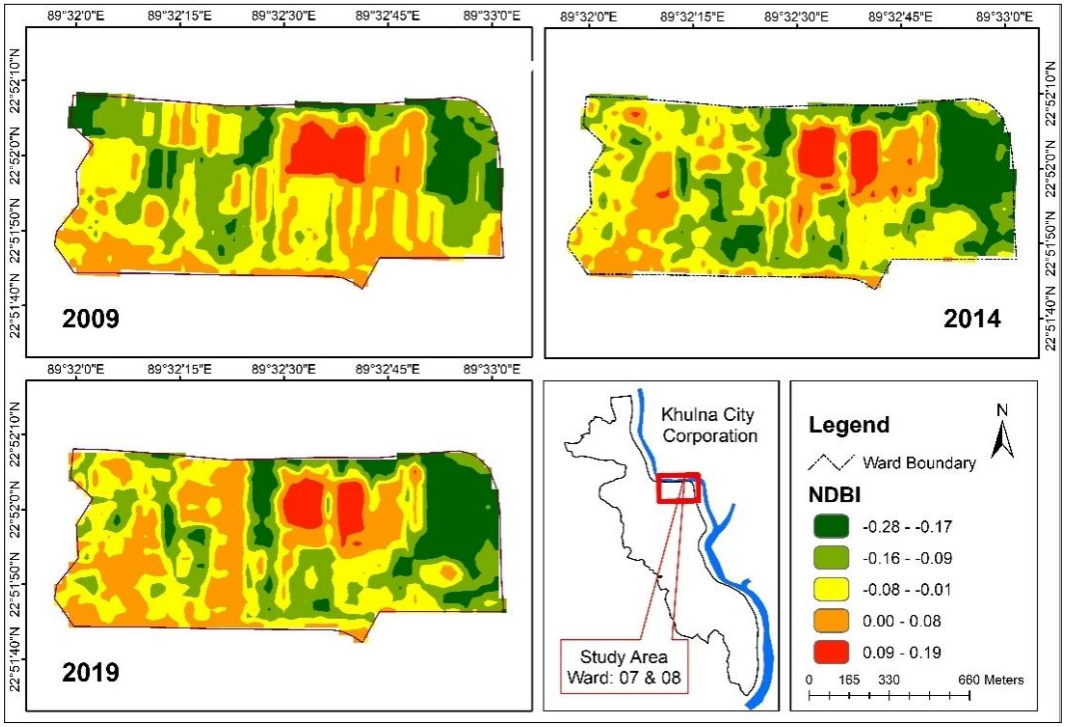

Figure 6: Built Environment of study area

Source: Author, 2020

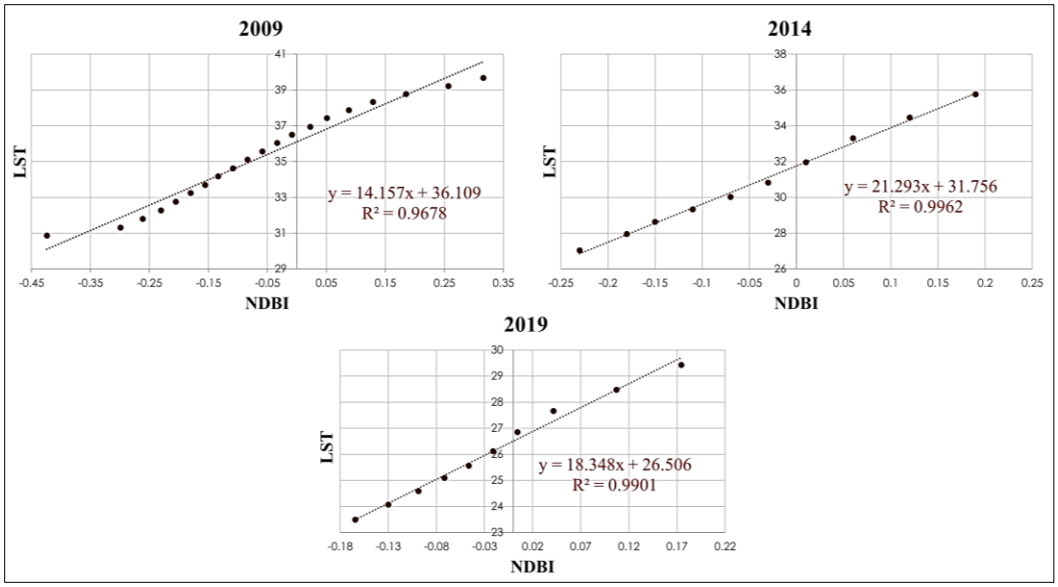

Figure 7: Relation between LST and NDBI

Source: Author, 2020

3.4 Ecosystem and Vegetation Health

There are various methodologies for studying seasonal changes in vegetation through satellite images, one method of which is to apply vegetation indices relating to the quantity of greenness. The Normalized Difference Vegetation Index (NDVI) is a measurement of the balance between energy received and energy emitted by objects on Earth.

When NDVI is applied to plant communities, this index sets a value for how green the area is, i.e., the amount of vegetation present in a given area and its state of health or growth strength. The NDVI is an index without dimensions so its values range from –1 to+ 1. In a practical sense, the values below 0.1 correspond to water bodies and bare ground, whereas higher values are indicators of high photosynthetic activity linked to scrub land, temperate forest, rainforest, and farming. (Tovar, 2011)

From the figure-10, by analyzing vegetation index deciduous trees and shrubs are present in the region. Here in 2009, the value of NDVI is 0.34 where as it increases to 0.45 in 2014. It means that the health of the vegetation is increased during that period but the value of NDVI decreases to 0.30 in 2019. The quantity and health of the vegetation decreases during that period.

NDVI is significantly influenced by temperature on a global level, and also the rise in plant activity in the Northern Hemisphere is largely attributed to a rise in temperature (Mao et al., 2013) (Maselli, 2004) (Shabanov et al., 2002). In addition, rainfall has a significant regional effect on the NDVI, particularly in arid and semi-arid areas. However, certain regions at various times are influenced significantly by climatic factors. In South East Asia, the rise in tree species before 1997 was greatly affected by the rise in

temperature, whereas the decline in vegetation cover was largely caused by the shift in rainfall since 1997 (Camberlin et al., 2007) (Park & Sohn, 2010) (Piao et al., 2015) (Piao et al., 2011) (Pei et al., 2019). For the current study area, as it is industrial area, there is a shortage of vegetation cover of the area besides the rapid buildup area may cause the rise of certain amount of temperature which may influence the value of NDVI. This interference of NDVI can be assessed in the large area whereas the current study area is very small to perform this assessment for the interreference. So, this assessment is skipped in this analysis.

From the figure 7 and 10, LST has declining over the time which causes the variation of NDVI value in the study area. It is seen that the value of NDVI is also decreasing with the decrease of temperature of the area. This declining of NDVI value, vegetation, can influence the micro climate of the area which may result in the deficiency of rainfall in the area. In 2009, the amount of vegetation is more than the previous years which make the temperature of the surrounding area more. But gradually this temperature is declining with the declination of the vegetation quantity in the area.

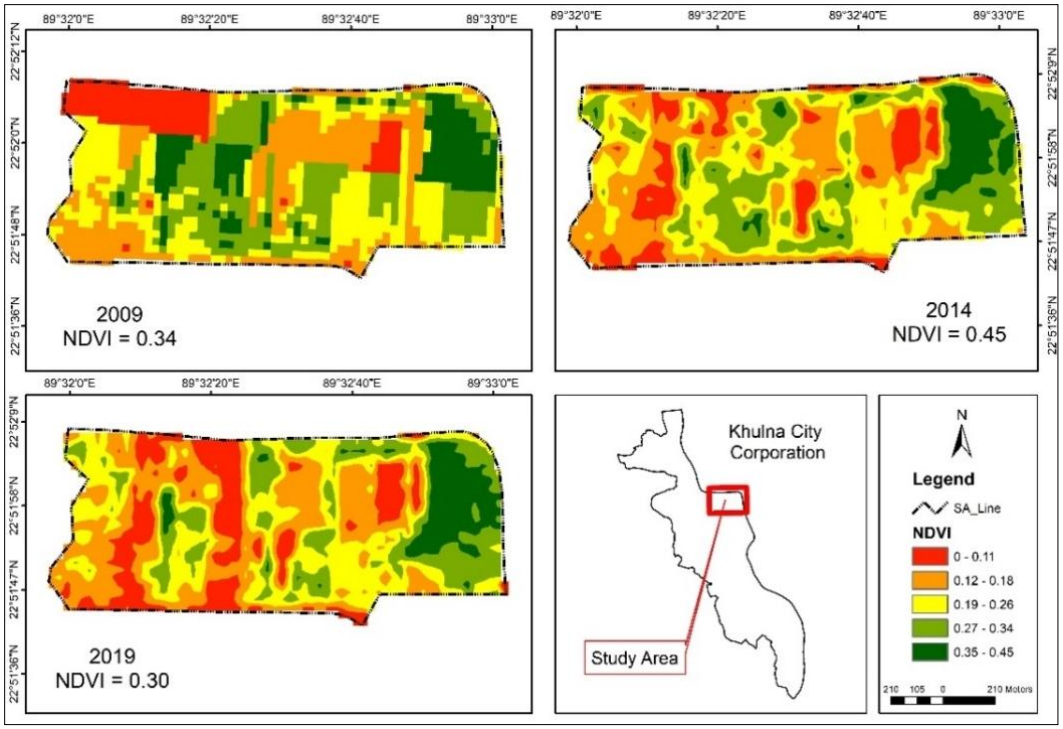

Figure 8: Vegetation Health of the area

Source: Author, 2020

3.5 Effects of Pollution on Adjacent Land use

The study area is very vulnerable to pollution due to the industrialization of the area. Surrounding environment of the industry is polluted by somehow by the effect of industrial activities. Oil Depo, Power Plant and Jute Mill present in the area. By the influence of this, soil, water and air pollution happened this area.

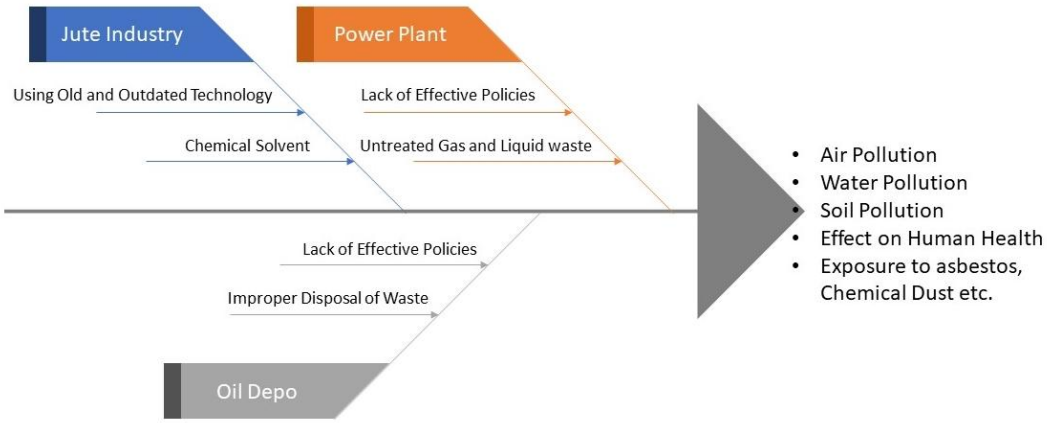

Figure 9: Cause & Effect Diagram of Pollution by Industry in the area

Source: Author, 2020

The causes of pollution by three industry has been figured out and the effects of this pollution has been shown the figure-11. Old and outdated machineries have been used in the jute industries which leads to the air pollution to the surrounding areas. Asbestos from the Jute causes serious air pollution to the surrounding area. Here the pm2.5 has been crossed above the danger level. Again, the untreated gas and oil from power plant causes serious air and water pollution in the area. The oil leaked from the power plant dumps into the soil and causes soil pollution too. Besides, oil depo presents besides the Bhairab River. This depo loads and unloads the oil from the ship. Here some oil is disposed into the water and some of them leaked into the soil. This makes serious water and soil pollution through the activities of depo. No concerned authority is found to observed the activities of the industries to control the pollution which is the violation of Environmental laws and ordinance.

A stretch of 30 meters of special and heavy-duty crops, 20 meters of buffer zone layout for small and medium-sized industries and 10 meters for light industries should be given for the buffer zone. The buffer zone development is one measure that can be used to minimize noise pollution. Besides the pollution spread out intensity is highly depended on the environmental elements and micro-climate of the area. The air and odor pollution are completely depended on the air flow and direction. Considering the area location and average meteorological data, an average 150-meter buffer from the industry is considered as highly concentrated pollution area in figure 12. This pollution intensity might be less or more than the buffer areas. This buffer areas covers almost every workers colonies in the area. Beside this pollution has influenced on the river too but this has been neglected as it is outside the area boundary. This pollution buffer only affects the workers colonies, it doesn't affect the others normal residential area.

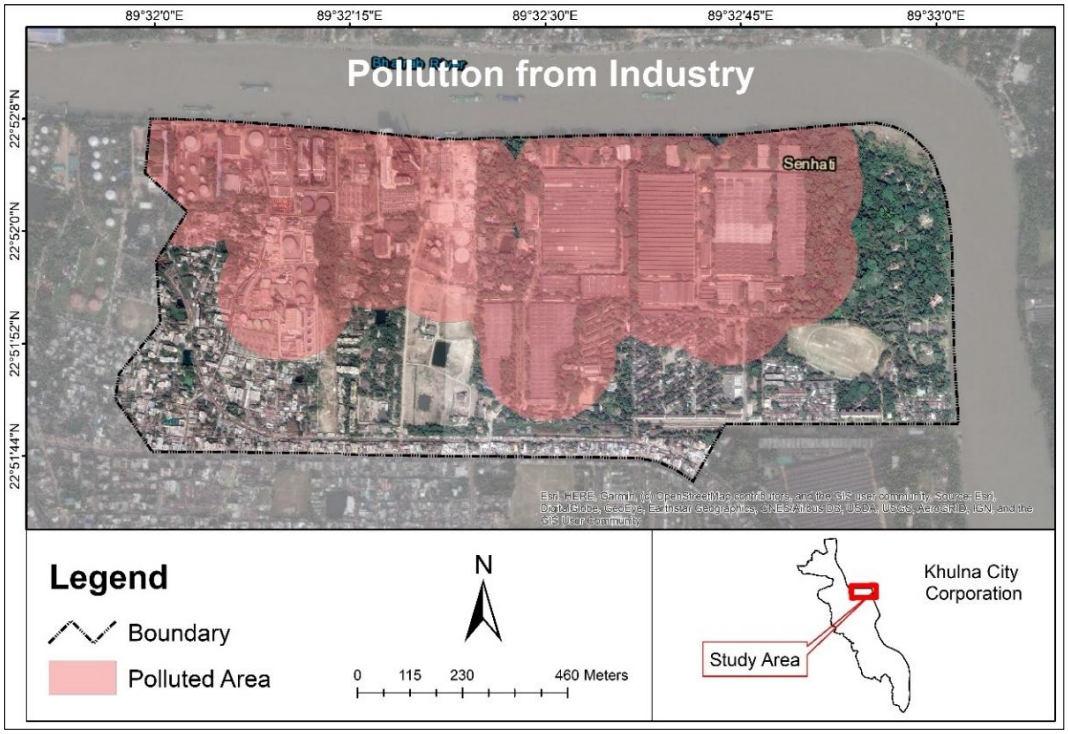

Figure 10: Pollution effective range by the Industry

Source: Author, 2020

The industrial waste is dumped into river which causes serious water pollution. The water turbidity is determined by the remote sensing by the process of NDWI. NDWI is considered to be closely linked to the water content of plants. Therefore, it is a very strong proxy for water stress in plants. By analyzing it, the pollution can be identified. The high reflectance indicates the enrichment of vegetation content in water and low reflectance indicate the absence of vegetation content in water. The polluted water has absence of plant content. In figure-13, low reflectance of water is seen in the study area in 2009. Industrial activities are highly operated during that time. So, the pollution level is much on the river during that period of time. By the course of time, the activities of industries in pulling down and the production has fallen in a remarkable way. In that period, the pollution has fallen down which is seen in 2014 and 2019 respectively. But the ship building industry has developed around the ward 30 and 31. So the pollution has more in that area. As the river has high and low tide, so the data may variate in the certain moment of time.

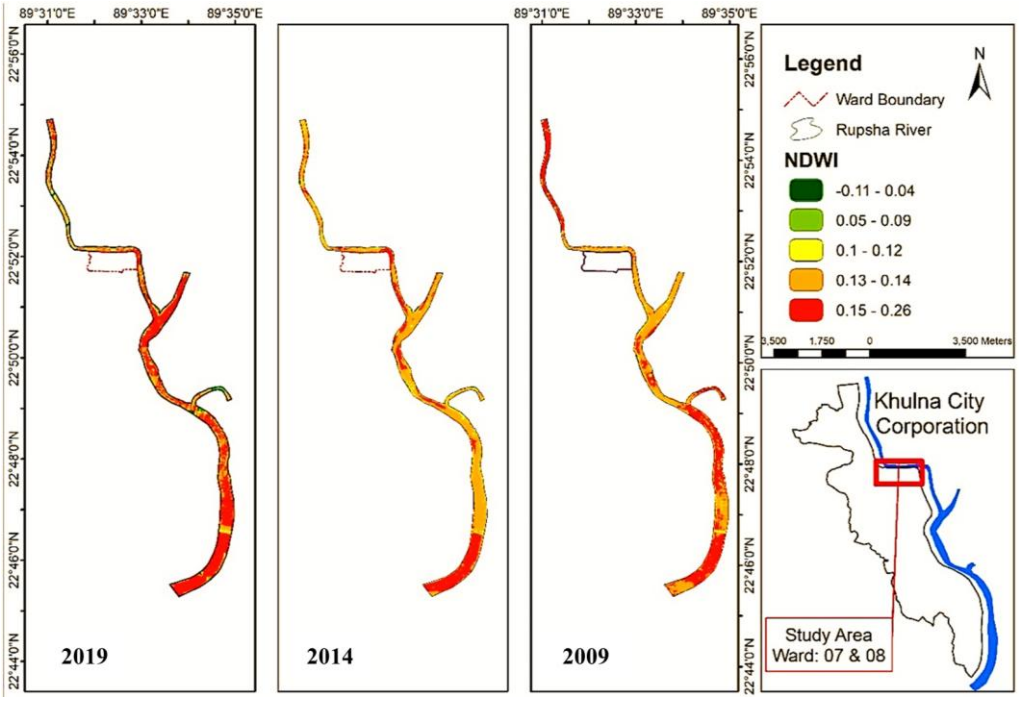

Figure 11: Pollution affected on the Rupsha and Bhairab River by the Industry
Source: Author, 2020

4. Conclusion

To identify the main environmental issues of the present situation, the environmental profile is very important. Among the 31 wards of Khulna City Corporation the pollution effects are much in these areas due to the industrialization of the area. This pollution affects much on the water quality of the river as well as air and soil pollution. Besides the elevation of the area is quite high to susceptible to flood. But due to the bad condition of drainage, water logging caused much on the ward 07 during the rainy season. Maximum land use used for the industrial use. This land use has changed during the course of time. Buildup area has increased and the vegetation cover has decreased during that interval of time in a frame of 15 years. Though the buildup area has increased but the industrial activities has diminished during that time frame which causes much on the LST and NDBI. The value of LST and NDBI has changed during the period of time. But the vegetation health has given some interesting fact about the area. In 2009 the vegetation health is 0.34 which increases to 0.45 in 2014 and again reduced to 0.30 in 2019. The quality of vegetation has increased for a certain period of time but again it decreases to the previous state. No dense trees have found in the region which indicate that the ecosystem in that area is not in a better condition. The limitation of this research is enough data has not found. All the data used in the study are might be obsolete as environment is a continuous changing process. As some data are obsolete, the results of the study may have some inaccuracy with respect to present or future scenario. Maximum people living in this area is government low-income worker. So, for implementing any project in this area, socio-economic condition and land use of the area have to considered consciously.

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