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Effect of the Changes in Land Use/Land Cover Patterns on the Water Quality of Shitalakshya River, Narayanganj, Bangladesh

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Abstract— The degradation of water quality is a crucial global environmental issue. The effect of changes in land-use patterns on water quality is widely renowned. Several studies have analyzed the dependency in diversified ways. Among various researches assessing the temporal and spatial connection between water quality and land use has become a useful technique to identify the influences of urbanization in the aquatic system. Besides, this type of researches becomes a reference for the urban planner as guidance for implementing better decision policies to protect water quality along with optimized land use practice. The purpose of this study was to find out the effect of changes in land-use patterns on the water quality within the Shitalakshya River. Water quality parameters from 2012 to 2018 were utilized by incorporating along with the RS data of similar years through GIS. Moreover, statistical programming tools were used to observe the dependency between land use patterns and water quality. The Shitalakshya River usually receives rainfall and discharges from five sub-bases, namely Bandar, Demra, Narayanganj Sadar, Rupganj, and Sonargaon. The results indicated a significant inverse relationship between vegetation area and water pollution. The urban region had adverse effects on the water quality, whilst the impact of the barren soil on the water quality was very multifaceted. In addition, the influences of the landscape uniformity on the indicators of water quality surrounded by the watershed were also analyzed, the result of which specified there was a significant damaging relationship between them.

Keywords— Urbanization; Water Quality Parameters; Shitalakshya River; land-use change; Relationship.

I. INTRODUCTION

The degradation of water quality is a crucial global environmental issue [1]. Water bodies are a significant measure of the urban landscape and water quality is determined by the configuration of land use types and the spatial arrangement of land-use trends surrounded by a catchment area [2]. Municipal areas are hot spots that have many influences on the environment [3]. These are the unique ecological unit that poses both complications and solutions to sustainable development issues in a rapidly urbanizing world [4]. Urban extension contributes to water quality depletion with rapid urbanization and industrialization. Degradation of water quality is triggered by extreme land use and industrial pollution [5]. This is owing to the rising prevalence of impermeable surfaces and anthropological actions in the urbanization cycle [6]. Besides, numerous natural and anthropogenic aspects, including intensity of soil types, precipitation, topographical and geological characteristics, agricultural activities, suburbanization, and industrial and wastewater ejection, can have a critical impact on water quality [7]. Water quality is linked to major alterations in vegetation patterns and human activity [8]. Land use has been one of the vital contributing aspects of municipal water pollution [9].

Land Use Land Cover (LULC) states two distinctive terms over and over again used interchangeably. Land cover can be well-defined as the physical appearance of the surface of the ground involving water, vegetation, soil, and other physical characteristics created by anthropological activities such as settlements, while land use mentions land used by humans' habitations for trade and industrial activities [10]. LULC forms are spatially and temporally based on social use in terms of natural and socioeconomic growth. In other words, changes in land use can disturb the land cover and vice versa. Fluctuating into an undesirable impact through land-use viewpoint for public activities affects land cover to change, particularly in water, biodiversity and earth radiation, trace gas emissions and other procedures that come together to affect the climate and the biosphere [11]. These variations are due to one key reason in terms of dimension and trend, namely "population growth." Rising population growth contributes straight and incidentally to changes in LULC, particularly from the mandate for the water resources, agricultural activities, and built-up area. Ecological expertise is highly worried about changes in LULC's affecting biodiversity and river ecosystems [12]. LULC changes in the urbanization and deforestation watershed environment can gradually and adversely affect water quality and ultimately impact the function of a water bio-network. Therefore, recognizing the spatial and temporal differences that happen in a watercourse over time and unfolding the relationship between the hydrological components of the watercourse would make it possible to formulate better water management strategies. In particular, isolated sensing has been generally used to classify and map LULC fluctuations with different procedures and data sets and Landsat images, which better classify different components of the landscape on a wide scale [13]. While various methods of classification have been proposed, supervised methods of classification are considered prime for the study of change detection. Recently, scholars applied supervised classification to identify various LULC changes for multiple research purposes [14].

Due to its unregulated urbanization and industrialization, unmanageable waste disposal, and significant soil erosion and tree cutting, the Shitalakshya River watershed region was chosen for a study on change detection. Rapid urbanization in the study area has resulted in more than a few problems such as aquatic animal fragmentation, river pollution and soil erosions owing to deforestation and municipal and industrial waste disposal. This research is performed using GIS to discern the degree of changes that have taken place in the Shitalakshya River watershed for 28 years (From 1990 to 2018). The goal of this study is to investigate possible pollutant sources in the Shitalakshya River between 2012-2016 and 2018; Identify the various LULC groups and trends of watershed changes from 1990 to 2000, 2000 to 2015 and from 2015 to 2018; and assess the correlation of LULC changes in the contribution to the Shitalakshya River pollutant sources.

II. DATA & METHODOLOGY

Study Area

Shitalakshya River is a distributary of the Brahmaputra. It flows in its initial stages in a southwest direction and then in central Bangladesh east of the city of Narayanganj until it merges with the Dhaleswari near Kalagachhiya. The river is about 110 kilometers (68 mi) long and is 300 meters (980 ft) at its widest, near Narayanganj. The geographical coordinates of the study area are 23°50'09" N to 23°34'02" N for latitude and 90°32'43" E to 90°33'41" E for longitude. The catchment areas of the Shitalakshya River are nearly 624 km2 and cover 38 km length of the Shitalakshya River. The river usually receives rainfall and discharges from five sub-bases, namely Bandar, Demra, Narayanganj Sadar, Rupganj, and Sonargaon. The river with the adjacent sub-basins is shown in [Figure-1]

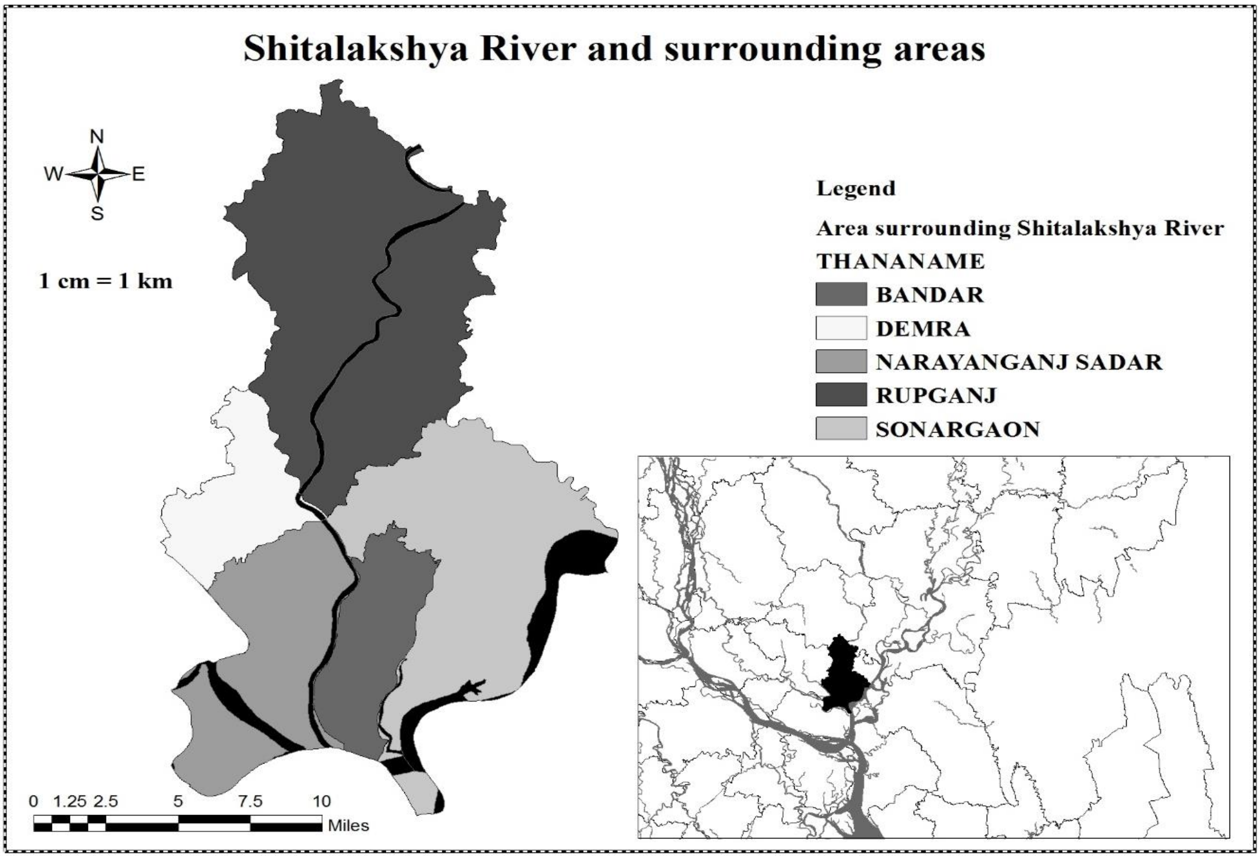

Figure 1: Shitalakshya River and surrounding areas.

This serves as a water source for the cooling process of power plants near the river. Also, local people use river water for various purposes such as bathing, washing, etc. Rapid urbanization in the Narayanganj has also amplified due to the extreme population growth, especially from the perspective of land use. For the increasing, the local population and industrialization, the use of river increased for public services such as transportation, sanitation, and water supply. The changes in inland use have grown continuously these days. These activities indirectly contribute to commercial growth surrounding the area of the Shitalakshya River. Therefore, the pollution level of the river water increased drastically. Eventually, it affects the human health of the surroundings, local aquatic ecosystem and increases the normal cost cooling process in the power plants, as they need to treat the water before use in cooling and have to treat after the use to effluent it in the river water. On the other hand, urbanization affects the aquatic ecosystem by releasing a huge amount of municipal wastes that are a course of eutrophication of the river. So that the area is chosen to be studied as it is a very sensitive and critical area for humans, the aquatic ecosystem, and the economy of the city.

Data Sources:
The Haripur Power Plant near the Shitalakshya River is selected as a sampling station. Primary data were collected from 2012 to 2016 and 2018 to obtain the latest quality of water. Satellite images of selected study areas for 1990, 2000, 2015, and 2018 were collected from the USGS Earth Explorer. Landsat 4-5 TM (Thematic Mapper) data was collected for 1990, 2000, 2012, and 2013, while Landsat 8 data was collected for 2014, 2015, 2016, and 2018.

Data Analysis:
After the collection of secondary data of water quality parameters (From 2012-2016 and 2018), a statistical summary was done for the parameters. The Environment Conservation Rules (ECR), 1997 is used as a standard, this standard is initially provided by the Department of Environment (DoE) of the government of Bangladesh. On the other hand, the collected satellite images are used in Geographic Information System (GIS) based software ArcGIS 10.3 to classify the land-use pattern of the research area. Errors were found in the satellite images due to the cloud and quality of the images. Therefore, Cohen's kappa coefficient (k) was used as an accuracy check. The Kappa coefficient is used to measure the arrangement between two groups of classifications of a dataset while modifying for accidental treaties between the groups [15]. The Kappa coefficient makes usage of both the total accuracy of the ideal and the accuracies within each category, both in terms of the analytical model and the field-surveyed trial points, to accurate the chance arrangement between classes [16].

Cohen's kappa measures the arrangement between two raters where each classified N objects into C equally exclusive groups. The definition of (k) is:

$$k = \frac{P_0 - P_e}{1 - P_e} \text{..........................(1)}$$

Where P_o is the relative observed arrangement among raters.

$$P_0 = \frac{\text{Original Observation}}{\text{Total Observation}} \times 100 \text{................(2)}$$

And P_e is the theoretical possibility of the chance arrangement, using the observed data to calculate the possibilities of each observer randomly sighted each category.

$$P_e = \sum \text{Original Observation} \times \text{Correct Observation....(3)}$$

In this study, the differences between the observed and correctly observed land-use patterns of the catchment area of the Shitalakshya River were tested.

Environmentalists and other scholars have established many metrics to examine the effects of the landscape pattern on the environmental processes [17]. To make a correlation among metrics and the irregular actions of some metrics across trials, Shannon’s diversity index (SHDI) was used as the indicator of landscape metrics in this research. SHDI specifies the area diversity in a landscape based on the statistics theory, and it is calculated with the following form:

$$SHDI = -\sum_{i=1}^{m} \left(pi \ln pi \right) \text{.........................(4)}$$

Where pi is the proportion of the occupied land-use type i and m is the number of the land-use types present. The SHDI is a complex gauge to analyze the diversity of the same landscape at different times. The large value of SHDI means that the land-use pattern is several and the degree of disintegration is high. It has been used to calculate the ratios of the four land-use types and then analyze the correlation between the SHDI and the indicators of water quality.

To compare proper relationships multiple regression has been also used in this study. The multiple regression equation explained above takes the following form:

$$Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 ...... + \beta_n X_n + C \text{.........(5)}$$

III. RESULTS AND DISCUSSION

Land Use Mapping:
According to [Fig. 2] the area of the catchment areas is classified into four major classes (water, Vegetation area, built-Up area, and barren soil). The numerical values of the user pattern are as follows Table-1.

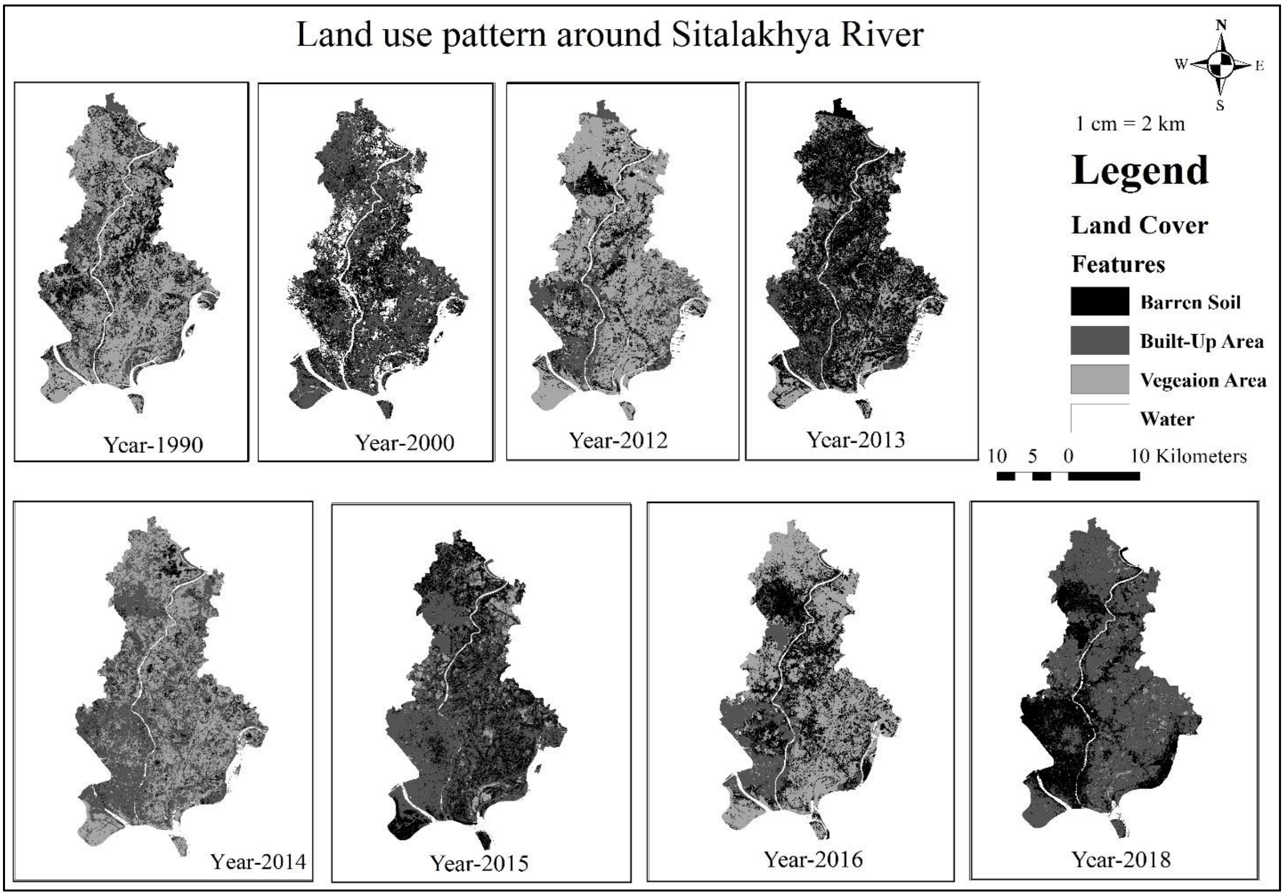

Figure 2: Variation of land use pattern near the Shitalakshya River.

Table 1: Total Land coverage and Percentage (1990-2000-2012-2016-2018).

Class		Total Area and Percentage							
		1990	**2000**	**2012**	**2013**	**2014**	**2015**	**2016**	**2018**
Water	**km^2**	31	33	33.5	28	23.6	22	20.7	17
	%	5.0%	5.3%	5.4%	4.5%	3.8%	3.5%	3.3%	2.7%
Vegetation Area	**km^2**	324	260	256.1	156.1	238.6	139	131.3	107
	%	51.9%	41.7%	41.0%	25.0%	38.2%	22.3%	21.0%	17.1%
Barren Soil	**km^2**	130	112	120.1	273.7	177.6	270	209	189
	%	20.8%	17.9%	19.2%	43.9%	28.5%	43.3%	33.5%	30.3%
Built-up Area	**km^2**	139	219	214.3	166.2	184.2	193	263	311
	%	22.3%	35.1%	34.3%	26.6%	29.5%	30.9%	42.1%	49.8%

It can be seen in Table-1 that the area covered by water in the year 1990 was 31 km2 which was approximately 5% of the land types whereas the maximum area was covered by vegetation (324 km2) among the different categories. During the particular year, the percentage covered by barren soil was 20.8 % and the build-up area was 22.3 %. In contrast to 1990, a drastic change happened in the year 2018. During these years, the built-up area enlarged drastically. The land use land classification result showed an approximately 13% increment in a built-up area for the year 2000. The analysis showed a gradual increment for the built-up area whilst a reduction in the area covered by water. For these 28 years, approximately the area covered by water reduced to 14 km2. The vegetation area was showing a reduction trend as well. Basically, declination in these two types of land patterns converted into barren soil by filling the different water bodies which used to be essential for maintaining biodiversity and towards built-up areas due to unplanned urbanization as well as industrialization. However, for the years 2013 and 2015, there were slight differences in the trend. This is because of the irregular presence of brickfields in this region. As most of the brickfields have temporary structures so that the map shows those lands in different situations at different times. The color pattern of brickfields and barren land is almost similar for the band combination which was being used during the supervised land classification done in Arc-GIS.Table-2. That represents the actual changes in land use patterns within the years. It is clearly visible that the area of the river is reducing day by day and the area of built-up area and barren soil is increasing.

Table 2: The Rate of Changes in land use pattern in different years.

Land Class	Rate of Changes (%)						
	1990-2000	**2000-2012**	**2012-2013**	**2013-2014**	**2014-2015**	**2015-2016**	**2016-2018**
Water	0.32%	0.08%	-0.88%	-0.71%	-0.26%	-0.21%	-0.59%
Vegetation Area	-10.26%	-0.62%	-16.03%	13.22%	-15.96%	-1.23%	-3.89%
Barren Soil	-2.88%	1.30%	24.62%	-15.40%	14.81%	-9.78%	-3.21%
Built-up Area	12.82%	-0.75%	-7.71%	2.88%	1.41%	11.22%	7.69%

As the variation of land use pattern is determined in ArcGIS where satellite images of different periods are used, there may have some error due to the clouds in the Arial images. For more accuracy, the Kappa coefficient has been determined. The result indicates the accuracy of the analysis as the Kappa coefficient value is close to 1. The value of the Kappa coefficient has been shown in the following Table-3.

Table 3: Kappa Coefficient value of several years.

Year	1990	2000	2012	2013	2014	2015	2016	2018
Overall Accuracy	75%	55%	65%	83%	88%	78%	80%	73%
Kappa Coefficient	1.19	2.11	1.43	1.10	1.06	1.15	1.12	1.23

In this research, satellite images were obtained from the USGS Earth Explorer website. Even though the satellite images of each year were captured in January and February, some of the images of certain years were obscured by the cloudiness. Whenever clouds are visible, the image analysis for those years is slightly affected. Table 3 reveals that the Kappa Coefficient for 2014 is 1.06, which is closer to 1 and reflects the minimum errors with an accuracy of 88%. Also, the Kappa Coefficient for the years 2013, 2016, 2015, 1990 are found 1.10, 1.12, 1.15 and 1.19 respectively which are indicating the accuracy of analysis as 83%, 80%, 78% and 75% correspondingly that are most accurate next to the analysis of 2014's images. However, including a calculated Kappa Coefficient of 2.11, about 55% of images from 2000 were accurate. As the majority of maps indicate higher accuracy, thus it's a quite accurate analysis of the maps.

Water quality around Dhaka and Narayanganj from the surrounding rivers can no longer be considered as a source of water for human consumption (DoE, 2001). The river contains waste such as effluents include radioactive chemicals, heavy metals, hazardous compounds, germs, and nitrogen coming from numerous industries located around. Besides, the slums in and around the city of Narayanganj make their toilets outdoors which leads to microbiological pollution of the river system. These pollute the Shitalakshya River natural system. In a previous study [18] Water Quality Index (WQI) of the Shitalakshya River has been calculated and the study found very poor water quality during the study period. The following table 4 represents the statistical summary of a few physiochemical water quality parameters during the study period.

Table 4: Statistical summary of Water quality parameters of the Shitalakshya river (From 2012-2018).

Parameter	Unit	ECR-97 (Standards)	Maximum Value	Minimum Value	Mean Value	Variance	Standard deviation
pH	-	6.5 – 8.5	7.87	7.13	7.47	0.14	0.37
DO	mg/l	6	5.87	0.23	2.88	0.48	0.69
Color	Pt-co	15	52.50	2.73	20.27	4.72	2.17
Conductivity	μ/c	550	1151.75	130.50	519.89	680.29	26.08
TDS	mg/l	1000	637.25	64.40	277.45	1350.76	36.75
TSS	mg/l	10	136.25	20.20	63.69	30.55	5.53
Hardness	mg/l	200 – 500	196.50	38.50	107.21	27.32	5.23
Cl^-	mg/l	150-600	147.50	9.20	50.72	141.87	11.91
Turbidity	JTU	10	146.50	17.60	50.57	37.03	6.08
Alkalinity	mg/l	128	450.00	35.20	170.08	606.98	24.64
Temperature	℃	20 – 30	32.08	21.20	28.20	1.26	1.12
BOD	mg/l	0.2	6.5	2.8	4.9	0.18	0.42

According to the Environment Conservation Rules, 1997 (ECR-97) there has standards of various parameters for drinkable water. Table-4 contains the standard value prescribed by ECR-97. The tested water quality

parameters were then compared along with the standard values to evaluate the presence of being in the limit.
ECR-97 requirements were met in terms of pH and temperature, as shown in Table 4. The mean pH is 7.47, while the ECR-97 standard ranges from 6.5 to 8.5 pH. The average water temperature was determined to be 28.20°C, despite the fact that the maximum temperature was 32.08°C when the standard temperature is 20-30°C. Water hardness standards in ECR-97 range from 200 to 500 mg/l, and this research revealed a mean value of 107.21 mg/l, which is close to the limit. As compared to this, the levels of color, TSS and BOD were extremely high, whereas the rates of DO were significantly lower than the standard value.

In addition, Table 4 shows the variance and standard deviation (SD) of several water quality indicators. To put it simply, variance is a measure of the spread of numbers concerning their average value. However, the standard deviation is the degree of the amount of variation or dispersion of a set of values. Variance and standard deviation are used to evaluate whether that parameter remains constant throughout the year or not. In this study, the pH, DO, temperature, and BOD variance measurements were found to be near zero. This indicates that these characteristics are fairly constant throughout the year. Nevertheless, Conductivity, TDS, and Alkalinity all have extremely high variation values, revealing that these parameters change over time or are influenced by other circumstances.

Several parameters are used to define the quality of water. Though the quality of parameters depends on different factors and phenomena. A variety of factors influenced certain parameters for the final result deviation. The relationship between different land-use patterns and water quality data was analyzed by SPSS (Table-5). Table-5, it shows the relationship between water quality parameters and the land-use pattern. Initially, regression analysis was done by considering several physiochemical water quality parameters, however, the relationship was not considered for most of the parameters as the P-value was greater than 0.05. The null hypothesis was rejected along with the above-mentioned water quality parameters and this indicates having a strong relationship among the different land-use types and particular parameters.

Table 5: The correlation coefficients among different land-use and water quality parameters of the Shitalakshya River defined by Multiple Regression (From 2012-2018).

Variables	DO	Phosphate	Hardness	Turbidity	Alkalinity	COD
Water	0.79	-0.96	-26.26	-53.76	-36.05	27.16
Vegetation Area	0.75	-0.80	23.92	50.67	-33.64	-24.63
Barren Soil	0.76	-0.80	23.95	50.75	-33.22	-24.67
Built-up Area	-0.75	0.75	23.92	50.69	33.34	24.64
Constant	5.53	3.44	207.61	128.33	187.40	53.78
Multiple R	0.66	0.63	0.48	0.42	0.97	0.00
R Square	0.43	0.40	0.23	0.18	0.94	0.00
Adjusted R Square	0.06	0.00	-0.29	-0.37	0.91	-0.25

Note: Mean value of the parameters were taken for the analysis of the multilinear regression

From the values, it can be seen that there was an explicit description between DO and the area covered by water. It reflects that DO depends on the flowing water. Hindrance in natural river water flow consequences reduction in DO level. Moreover, there exists an inverse relationship between the DO level and the built-up area. Subsequently, aquatic life is getting affected. The phosphate level in river water is increasing because of unplanned rapid urbanization as well. The growing population is responsible for this mean value of the parameters for analyzing the multilinear regression in phosphate and nutrients levels through municipal wastes. A significant negative relationship exists with the area covered by vegetation and barren soil along with phosphate and COD level, which represents that the agricultural fields surrounding the river didn't generate a notable amount of nutrients to accelerate the eutrophication process. However, hardness and turbidity indicate that the area covered by vegetation and barren soil played a vital role in reducing the phosphorus pollutants. Vegetation and barren soil in this region can efficiently reduce the phosphate salts conveyed into the river as their high level of presence reduce the surface runoff during rainfall. This summarizes that the increase of vegetation land will reduce the concentration of phosphate, which will increase essentially dissolved oxygen concentration. On the other hand, the built-up area played an adverse character in influencing the water quality. The built-up area was positively linked to each component except the DO. It indicates that the growth of the built-up area tends to degrade the quality of water.

According to the SHDI value, it states the more the SHDI value, the larger the variety is and the minor the deterioration of water quality is. As the diversity of landscape increases, it consequently makes the coverings more consistently distributed. Typically, in most ecological researches, the values of SHDI are within 1.5 to 3.5. The index is hardly become greater than 4 [19]. Therefore, Table-6 represents a much stable value of SHDI for the study, this is because the research focuses on the effect of land-use categories and water quality in the study area. Whilst, there are several additional features correlated to the water quality, such as the environment, Ecosystem, and mass population, etc. In the upcoming days, it will help to improve the technique and indicators to intensely expose the causes affecting the change of water quality in the Shitalakshya River.

Table 6: The correlation coefficients among changed land-use and water quality parameters of the Shitalakshya River defined by Shannon's diversity index (SHDI) method.

Variables	DO	Phosphate	Hardness	Turbidity	Alkalinity	COD
SHDI	1.79	1.78	1.79	1.76	1.78	1.75

IV. Conclusion

It was shown that built-up areas were positively correlated with indicators of water quality in the Shitalakshya River Basin, while vegetated areas and water areas were negatively correlated with them, but the influence of barren areas was complex. Built-up area, vegetation area, and Barren lands also have a substantial impact on several water quality measures. The results of the regression between landscape indicators and water quality indicators showed that SHDI was correlated to a majority of the water quality variables, indicating that changes in landscape diversity can contribute to the improvement of water quality. It is important to prohibit or restrict industrialization in local land use planning based on the previously described results and the existing circumstances of local water quality in the Shitalakshya River Basin. Since the built-up is more closely related to the local water quality, it is especially important to maintain the area for better water quality. Expansion of urban land should be restrained to ensure the minimum land area required for city development within a watershed is met. It is also necessary to strengthen the landscape diversity since the more equally patches of each species are spread in a landscape, the less water pollution there will be. The current way of transforming agricultural land into vast non-agricultural activities with relatively low density continues in the absence of regulation of land use and the framework for legislation. As a consequence of these studies, local land-use optimization and water pollution management may be improved, and policies to coordinate water resource use and protection can be developed. Previous research suggests that their landscape diversity has an impact on the water quality in their catchment, but it is still essential to include some other ecological indicators and assess their impact on the water quality. We should, in particular, enhance the way of assessing the relationship between land use and water quality, and not only rely on a basic regression. Specifically, our research focuses on the impact of land-use types and landscape patterns on water quality within the study region. This means that land-use planning must be maintained in order to safeguard and sustain a balanced environment. Water quality is affected by a variety of factors, including climate, rainfall, and population density. To better understand why water quality changes within a watershed, we will enhance the approach and indicators in the future.

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