THE LAND USE AND LAND COVER RELATION WITH AIR POLLUTANTS OF RAJSHAHI CITY: A REMOTE SENSING APPROACH

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ABSTRACT
Over the last few decades, significant damages have been observed in our environment. Being a densely populated country, Bangladesh has also faced significant environmental challenges over the last couple of years. To understand the pattern, researchers have analyzed land coverages in several parts of the world. This study presents an analytical study of the land coverages and land transition maps of the Rajshahi City located in Bangladesh. Our study was focused on the 1990,1998,2007,2014, and 2021 years. The maps were generated using ArcGIS 10.8 software. From our results, we observed that there was significant vegetation loss in the selected region over the years. The reduction in vegetation area is determined by a trend line of 0.8291% per year starting from 1990. Previous studies have shown that trees absorb the pollutants from the air and make the air cleaner. In this study, several graphs showing the decreasing rate of the absorption of air pollutants due to decreasing rate of vegetation are manifested. The increasing rate of air pollutants causes several life-threatening diseases and contributes to the rising temperature. To cope with this vegetation loss, we have proposed a partial solution that is rooftop gardening which supports Urban planning management with greenery.

*Keywords***:** *Vegetation; Remote sensing; Air pollutants; Rooftop gardening.*

1. INTRODUCTION
The population in Bangladesh is increasing rapidly. At a similar rate, transportation, industries, and factories are also expanding excessively. Huge economic and communication development are seen over the years. Due to this phenomenal growth in urbanization, every country is facing various challenges. Urbanization has profound impacts on the overall environment and ecological system. Due to the ever-growing urbanization, large forests and trees are being cut down resulting in less absorption of carbon dioxide and other pollutants from the atmosphere. Over the years, Rajshahi, which is one of the largest and most significant metropolitan cities in Bangladesh, has undergone rapid changes due to urbanization. Rajshahi was turned into a city corporation in 1991.

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The application of remote sensing and Geographic Information System (GIS) is widely used to generate LULC maps of an area. Every object on earth emits radiation which is captured by the sensor of the satellite creating Operational Land Imager/Thematic Mapper images consisting of multiple numbers of spectral bands. The satellite helps to explore the geographical dynamics of an area without physically visiting the place(da Silva et al., 2020). The surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil, etc. is known as land cover, and the purpose of the land service is known as land use. The socio-economic condition, as well as the urbanization and industrialization dynamics of an area, can be analyzed by classifying the area into different classes like vegetation, waterbody, built-up area, etc.

In Rajshahi city, the vegetation is decreasing and the built-up area is increasing with time due to rapid urbanization. A clear decrease in the number of local ponds is found over the years. While there were 729 ponds in the year 2002, the number of ponds decreased to 393 in the year 2017. The decrease in vegetation cover and increase in built-up area is also affecting the temperature of the city (Kafy et al., 2021) (Kafy et al., 2020).

Due to industrialization, the number of toxic gases and air pollutants is increasing which also causes the increase in temperature, overall climate change, and deterioration of AQI (Air Quality Index). Environmental sustainability is being affected negatively as most of the wetlands are converted into built-up areas. Additionally, the structure and function of the ecosystem are disturbed and there is an enormous loss of natural habitats. The amount of oxygen production is decreasing. As a result, the level of pollution is expected to worsen further in the future due to the increased number of motor vehicles in Rajshahi. Trees absorb the air pollutants and keep the air clean. But with the decreasing vegetation, the pollutant absorbing rate also decreases which further worsens the air quality of Rajshahi city.

Transportation facilities, urban construction, combustion, and fuel burning, generation of waste have their impacts on the urban air quality index. Clean Air Act regulated different categories of air pollutants. Air Pollutants like SO2, CO, NOx, PM2.5, PM10 are emitted from factories, oil refineries, power plants, and wood-burning fireplaces. In Bangladesh, air pollution is also increasing due to the use of lead in vehicles, and lead batteries (Biswas et al., 2002). Thus, Particulate matter is rising along with other droplets of air. It is also creating long-term health issues. Air pollution is a major concern for public health and respiratory illness. Middle school children are more susceptible to asthma and bronchial disease (Lin et al., 2001). Extrinsic skin aging, contact dermatitis, inflammatory and allergic conditions, atopic dermatitis, psoriasis, skin cancer, etc. are some of the many diseases that are triggered by pollutants in the air.(Islam et al., 2020a; Khaniabadi et al., 2019; Puri et al., 2017)

Recent research has proposed that air pollution should be kept under control utilizing green funding, reducing the use of lead and sulfur content in urban traffic, and ensuring environment-friendly construction works (Islam et al., 2020b). In those cities which are about to rise, and elevated urbanization is to be started, air pollution can be controlled by using good quality fuel in the vehicle, prohibiting the use of local fuel collected from different resources, and starting tree plantations (Hasan et al., 2016). As the climate of Bangladesh is moderate, it can be ideal for urban agriculture precisely Rooftop gardening in city areas (Uddin et al., 2016) (Ahmed et al., 2020). Rooftop farming benefits in local, regional, and national contexts can be achieved, and the constant factors of monetary valuation can be standardized (Chowdhury et al., 2020). It can help by meeting the growing demand for fresh fruits and vegetables and by imparting various environmental benefits (Kumar et al., 2019).

The main purpose of this study is to generate linear equations of percent area changes concerning years and evaluate the effect of vegetation loss on air pollution in Rajshahi city. It also discusses the overview of rooftop gardening as a partial solution to the increasing air pollution.

2. DATA AND METHODS

2.1 Study Area

Rajshahi City Corporation (RCC) is one of the major self-governing city corporations of Bangladesh. Geographically, the latitude and longitude of Rajshahi city lie between 24° 20’ N to 24°24’ N and 88°32’ E to 88°40’ E. It is situated within the Barind tract, 23m above sea level. The approximate area under Rajshahi city corporation is 48 km2. According to Bangladesh Population Census 2001 (Bangladesh., 2003), the population of Rajshahi city was 3,88,811. But the population had increased to approximately 4,49,756 according to the Bangladesh Bureau of Statistics, 2011 (BBS, 2011). Rural migration on a large scale plays a significant role in population growth. The city is located on the bank of the Padma River.

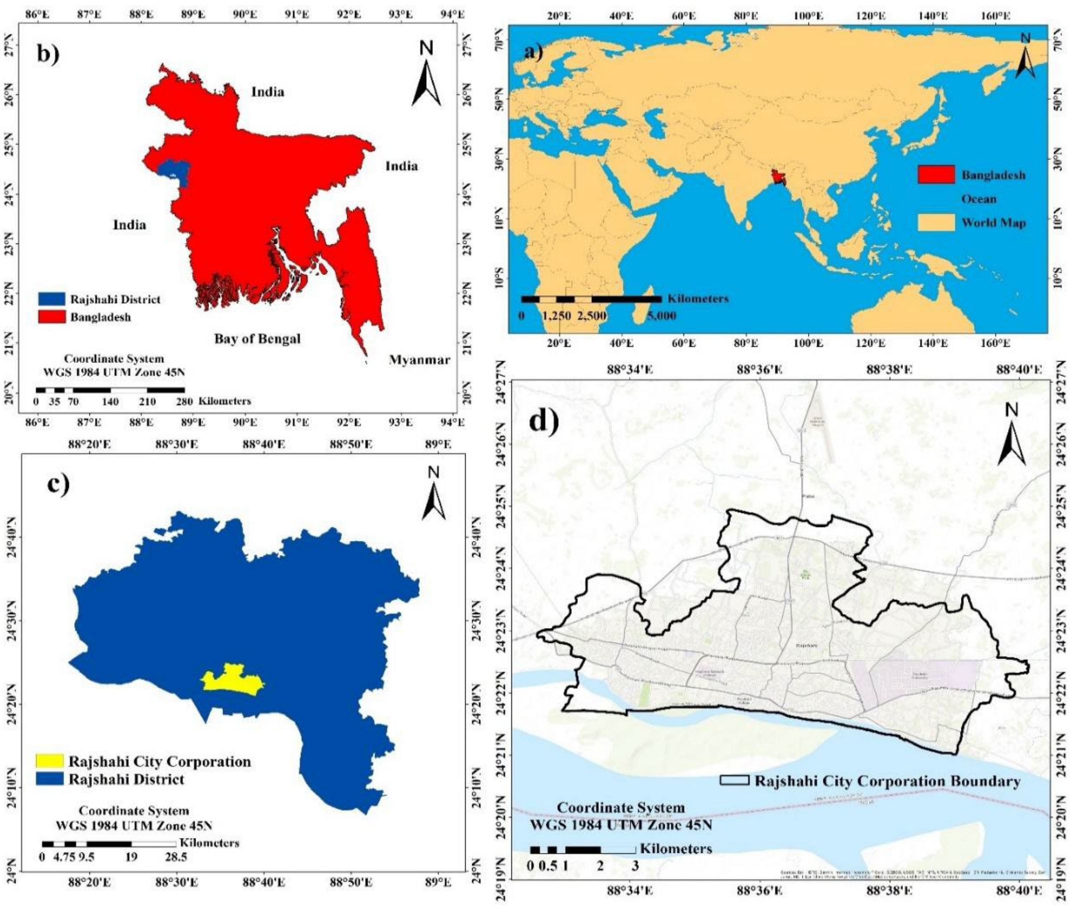

Figure 1. a) World map indicating the location of Bangladesh; b) Map of Bangladesh indicating Rajshahi District; c) Map of Rajshahi district indicating the location of Rajshahi City Corporation; d) Rajshahi City Corporation Map

2.2 Description of the satellite data

The data is collected from USGS Earth Explorer for the years 1990, 1998, 2007, 2014, and 2021. Land cloud cover was set at less than 10% but the data that has cloud cover close to zero is given priority. All data is collected from April to May to avoid seasonal variation. The data from mid-December to mid-February is avoided because of the winter season in Bangladesh when the leaves fall which can affect the land cover calculation. Table 1 contains the other important specifications of the data.

Landsat is the world's longest continuous acquired collection of space-based moderate-resolution land remote sensing data. It uses the passive remote sensing technique. Landsat circles the globe 14 times a day and returns to the same spot every 16 days. The equator crossing time of Landsat is 10:00 am +/- 15 minutes.

Landsat 5 was launched by NASA from Vandenberg Air Force Base on March 1, 1984. After providing data for 29 years, 3 months, and 4 days, the U.S. Geological Survey Flight Operations Team transmitted the last command on June 5, 2013. On the other hand, Landsat 8 was launched on an Atlas-V rocket from Vandenberg Air Force Base, California on February 11, 2013. It has been providing remote sensing data to this day. (Source: U.S. Geological Survey, 2019).

Table 1. Information about Landsat Images, U.S. Geological Survey, 2019

Year	Date	Land Cloud Coverage	Satellite Name	Sensor	Projection	Multi-Spectral Band Resolution
1990	6th May	1	Landsat 5	Thematic Mapper (TM)	UTM zone 45 N	30 meters
1998	10th April	2				
2007	19th April	0				
2014	15th May	0.05	Landsat 8	Operational Land Imager (OLI)		
2021	25th April	0.33				

2.3 LULC classification

Healthy vegetation absorbs blue and red-light energy to create chlorophyll and fuel photosynthesis. A plant with more chlorophyll will reflect more near-infrared energy than an unhealthy plant. The more plant reflects near-infrared, the redder it will show in the false-color combination of bands. This is one of the ways of detecting vegetation with Landsat images. The other categories of LULC are detected by a similar methodology. From Land cover/Land use (LULC) classification, the study area was divided into several categories but in this study, we have limited our study into 3 categories: vegetation, waterbody, and built-up and bare land.

True Color Composite (TCC) is generated in ArcGIS 10.8 software using suitable band combinations. The image acquired from Landsat is classified into 3 LULC classes, a) vegetation, b) waterbody, and c) built-up area and bare land. Trees, grassland, agricultural land, and playgrounds are included in the vegetation. Rivers, lakes, reservoirs, and ponds are included in the waterbody. In the built-up area and bare land, residential, commercial, and industrial buildings, railways, vacant land, sand, bare soils, and landfill sites are included.

A signature file was generated by taking around 40 training samples for each class. The signature file was used to classify the land cover using the Maximum Likelihood Classification technique.

3. RESULT AND DISCUSSION

2.1 Land use and Land cover (LULC) calculation

Sections Here, the change of land areas over 31 years starting from 1990 to 2021 is analyzed graphically (Figure 2) and statistically (Table 3). In this study, two trends of area change are evident.

Firstly, there is a continuous decrease in vegetation area. Figure 2 shows a significant decrease in vegetation area over the years. In 1990, the area of vegetation was 28.49 km2 which is about 60.479% of the total area of the city. This area decreases to 26.05 km2 in 1998 and continues to decrease over the years. In 2021, the vegetation area of the city is 18.31 km2 which is about 37.325% of the total area.

Secondly, there is an increase in the built-up area and bare land. In 1990, the built-up area and bare land were 15.26 km2 which is about 32.395% of the total area of Rajshahi city. This area increases over the years as more vegetation area is converted into built-up area to satisfy the need of the increasing population. The build-up and bare land area increased to 18 km2 in 1998, 21.47 km2 in 2007, 25.64 km2 in 2014 and 27.12 km2 in 2021. The area is about 54.789% of the total area of the city in 2021.

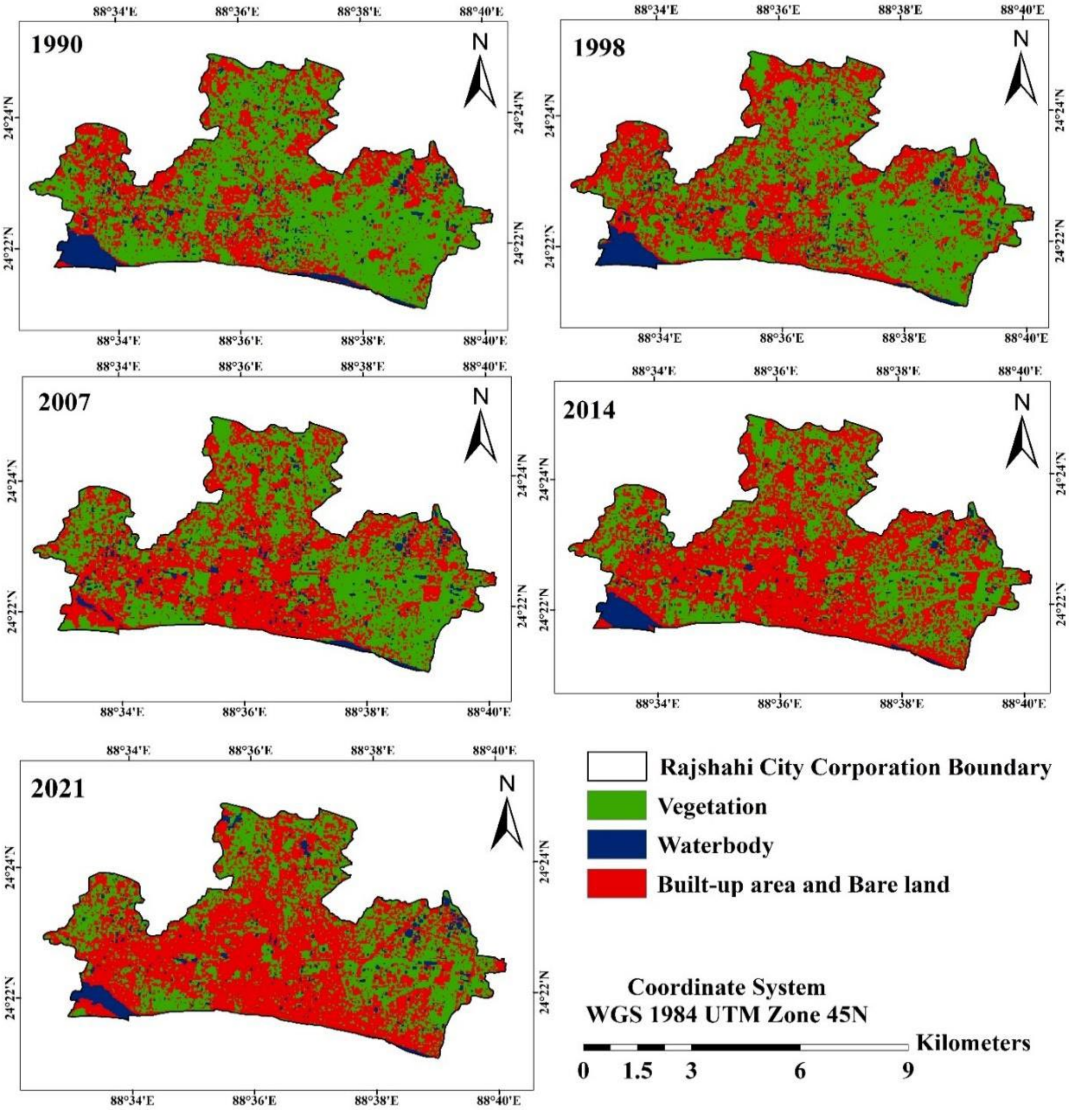

Figure 2. Land use/Land cover maps for Rajshahi City Corporation for respective areas

It is noticeable that the change in the waterbody is inconsistent over the years. Yearly precipitation, surface runoff, the drainage system of the city, the hydrological condition of the Padma River, etc. can affect the area calculation of the waterbody. In 1990, the area of the waterbody is 3.357 km^2 which is 7.126% of the total area of the city. Over the years, this area decreases to 4.83% of the total area in 2007. In 2014, the area of the water body increases to 5.22% of the total area. In 2021, the area again decreases to 5.092% of the total area of the city.

Accuracy assessment was done by taking around 300 pixels randomly. The kappa coefficient (|) and overall accuracy are calculated by generating a confusion matrix. It is a widely used quantitative method of accuracy assessment of the classified image (Table 2). (Rwanga & Ndambuki, 2017) (Hütt et al., 2016)

Table 2. κ and overall accuracy for respective years

Year	Overall Accuracy (%)	κ
1990	99.1847826	0.9895720

1998	99.1354467	0.9885495
2007	99.7333333	0.9966150
2014	98.7730061	0.9830770
2021	99.2000000	0.9898782

A LULC map of 2021 is simulated using MOLUSCE plug-in QGIS for validation of the study. Digital Elevation Map (DEM), Slope map, Aspect map, distance from roads map, distance from water map, and distance from urban area map of Rajshahi city is used as spatial variables for the simulation. The vegetation, waterbody, built-up area, and bare land area of the simulated 2021 paper are close to the corresponding actual area map of 2021.

Table 3. Land use/ Land cover area calculation from 1990 to 2021

Year	**Type**	**Area (km^2)**			**% Area**		
		Vegetation	Waterbody	Built-up area and Bare land	Vegetation	Waterbody	Built-up area and Bare land
1990	Actual	28.4884	3.3569	15.2595	60.479	7.126	32.395
1998	Actual	26.0494	3.0587	17.9967	55.301	6.493	38.206
2007	Actual	23.3607	2.2747	21.4694	49.593	4.829	45.578
2014	Actual	19.0043	2.4579	25.6426	40.345	5.218	54.437
2021	Actual	17.5818	2.3987	27.1243	37.325	5.092	57.583
	Simulated	18.3105	3.0357	25.8615	38.787	6.431	54.782

2.2 Land Cover Transition analysis

With the increase in population, the demand for urban residential and commercial buildings, and transportation systems also increase which justifies the loss of vegetation area. Figure 3 shows the graphical representation and Table 4 shows the statistical representation of land transition over the years. It is evident that more vegetation area has been converted into built-up area over time.

From 1990 to 1998, 15.479% of vegetation area is converted to built-up area and bare soil. On the other hand, 26.610% of vegetation area is converted to built-up area and bare soil from the year 1990 to 2021.

Approximately 3% of waterbody is converted to build-up area and bare land during the last 31 years. Again 10.114% of built-up area and bare land are converted to vegetation over 31 years. The conversion

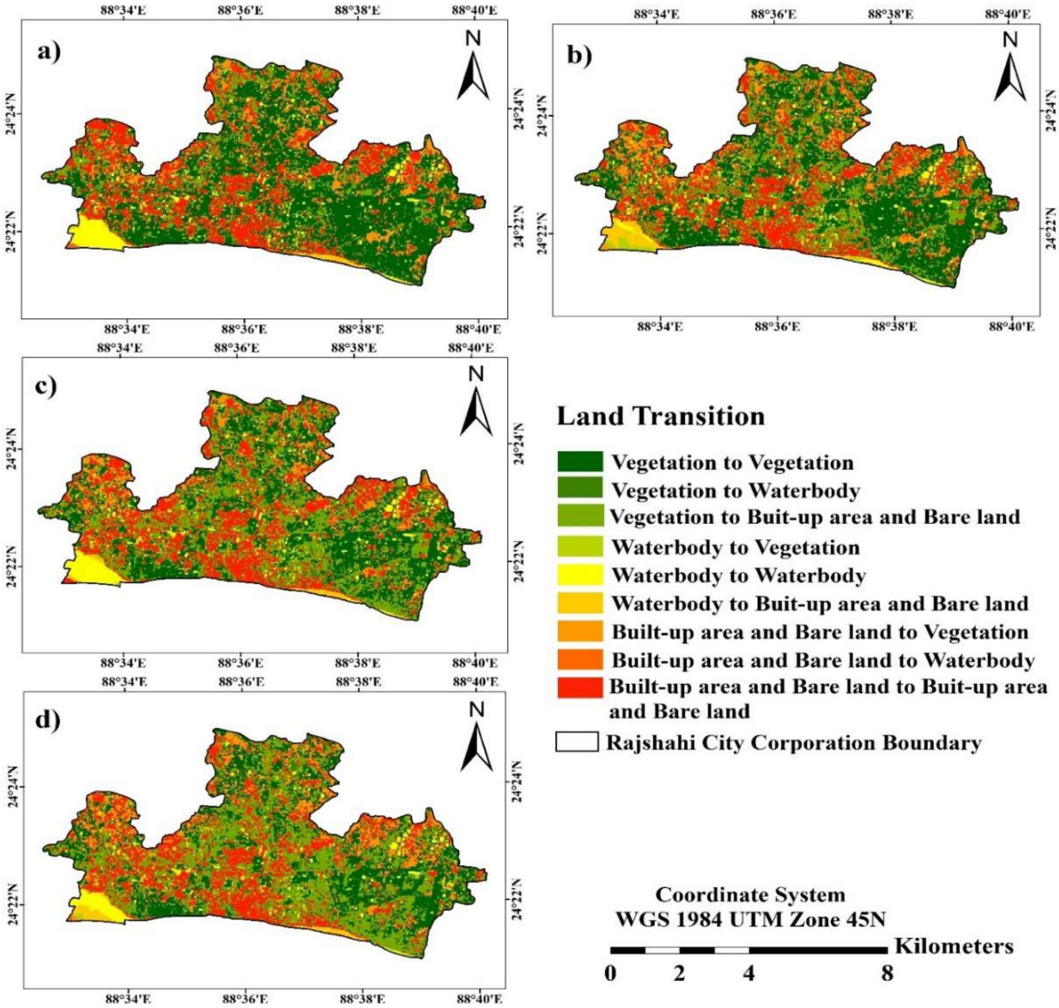

Figure 3. Land cover transition maps for a)1990 to 1998, b)1990-2007, c)1990-2014, d)1990-2021

of built-up area and bare land to vegetation is somewhat constant over the years which indicates that almost no land was turned from built-up area and bare land to vegetation over the years.

Table 4. Statistical land transition analysis

Change categories	**% Area**			
	1990-1998	1990-2007	1990-2014	1990-2021
Vegetation to Vegetation	44.112	36.823	30.717	26.610
Vegetation to Waterbody	0.888	1.169	0.684	1.049
Vegetation to Built-up area and Bare land	15.479	22.487	29.077	32.820
Waterbody to Vegetation	1.134	1.329	0.751	0.601
Waterbody to Waterbody	5.069	3.245	4.259	3.517
Waterbody to Built-up area and Bare land	0.923	2.553	2.116	3.008
Built-up area and Bare land to Vegetation	10.055	11.441	8.877	10.114

Built-up area and Bare land to Waterbody	0.536	0.416	0.275	0.526
Built-up area and Bare land to Built-up area and Bare land	21.804	20.538	23.244	21.755

Table 5 shows the total percentage of area change for vegetation, waterbody, and built-up and bare land over the progression of time. Over the years, the respective area categories change significantly. For the 31-year difference, the vegetation area decreases more than 4 times compared to the vegetation area reduction for the 8-year difference. The exact opposite scenario is observed for the built-up area and bare land.

. **Table 5.** Percent area change over years

Year Change	**Year interval**	**%Area Change**		
		Vegetation	Waterbody	Built-up area and Bare land
1990-1998	8	-5.178	-0.633	5.811
1990-2007	17	-10.886	-2.297	13.183
1990-2014	24	-20.134	-1.908	22.043
1990-2021	31	-23.154	-2.034	25.188

In Figure 4, the year difference starting from 1990 is plotted along the x-axis and the percent area change of vegetation along the y-axis. In the graph, the trend line and its equation are also manifested.

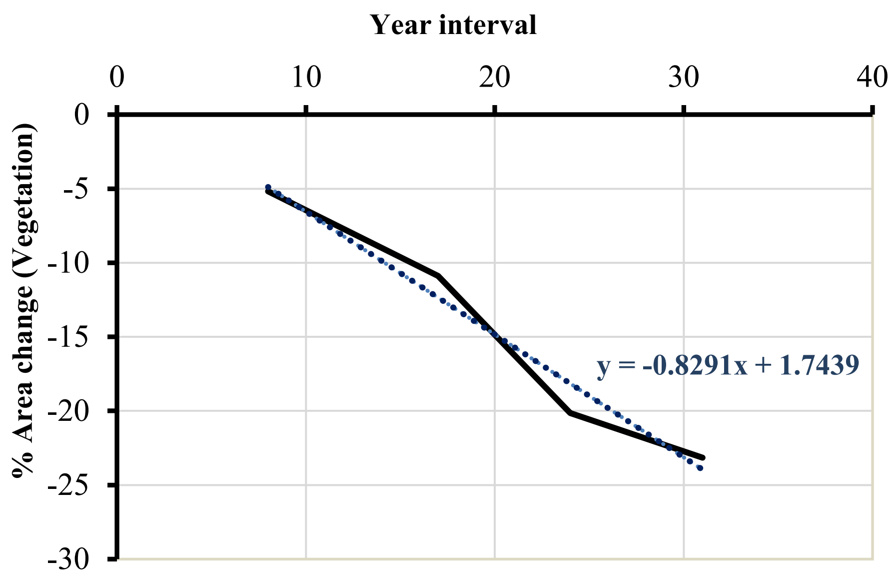

Figure 4. % Area changes of vegetation graph vs. Year difference

The equation of the trend line is,

$$y = -0.8291x + 1.7439$$

Here, x is the year difference counting from 1990 and y is the respective percent area change. For change of vegetation area between 1991 to 1993, $x_1 = 1$ and $x_3 = 3$, then $y_{1990-1993} = -1.6582\%$. Again, for change of vegetation area between 1991 to 1994, $x_1 = 1$ and

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$x_4 = 4$, then $y_{1990-1994} = -2.4873\%$. Therefore, for change of vegetation area between 1993 to 1994, $y_{1993-1994} = y_{1990-1994} - y_{1990-1993}$ or -0.8291%. From the calculation, it is evident that, according to the trend line, vegetation area decreases 0.8291% each year since 1990.

2.3 Pollutant's absorption calculation

Wherever Through their stomata in the leaf surface, bark, and roots, trees absorb harmful airborne particles and gaseous pollutants with normal air components thus cleaning the air. Researchers have conducted studies to find out the daily absorption rate of these fundamental gaseous pollutants on a daily basis. Table 6 shows the daily absorption rate of the pollutants by the leaves. (Ahmed et al., 2020)

Table 6. The daily absorption rate of gaseous pollutants

Pollutants	**Daily Average Absorption Rate (mg/m^2)**
CO_2	1750
PM_{10}	90
SO_2	12.19
NO_x	1.69

From the LULC study, it is evident that vegetation area is decreasing over time. But the population and source of air pollutants are increasing simultaneously. With the decrease of vegetation area, the pollutant absorption rate will also decrease over time. It will increase the pollutant contents in the air and make the air more unsafe for people. Figure 5 shows the decrease in pollutant absorption rate from 1990 to 2050.

The decrease in absorption of pollutants is calculated using the unitary method. From the graph, it is evident that approximately 20000 ton/km^2 of CO_2 gas could be absorbed by plants per day in 1990. But over time, this absorption capacity of the pollutant decreases due to a reduction in vegetation area. In 2022, the absorption rate of CO_2 is 14706 ton/km^2 per day. If the vegetation continues to decline at the same rate, then in 2050, the absorption rate of CO_2 will be below 10000 ton/km^2 per day.

Similarly, in 1990, the absorption rate of PM_{10}, SO_2 and NO_x were 1029.43, 139.43 and 19.33 ton/km^2 per day. This absorption rate decreases to 756.31, 102.44 and 14.2 ton/km^2 per day respectively in 2022. If the vegetation continues to decrease at the same rate, in 2050, the absorption rate of PM_{10}, SO_2 and NO_x will be approximately 517.33, 70.07 and 9.71 ton/km^2 per day respectively.

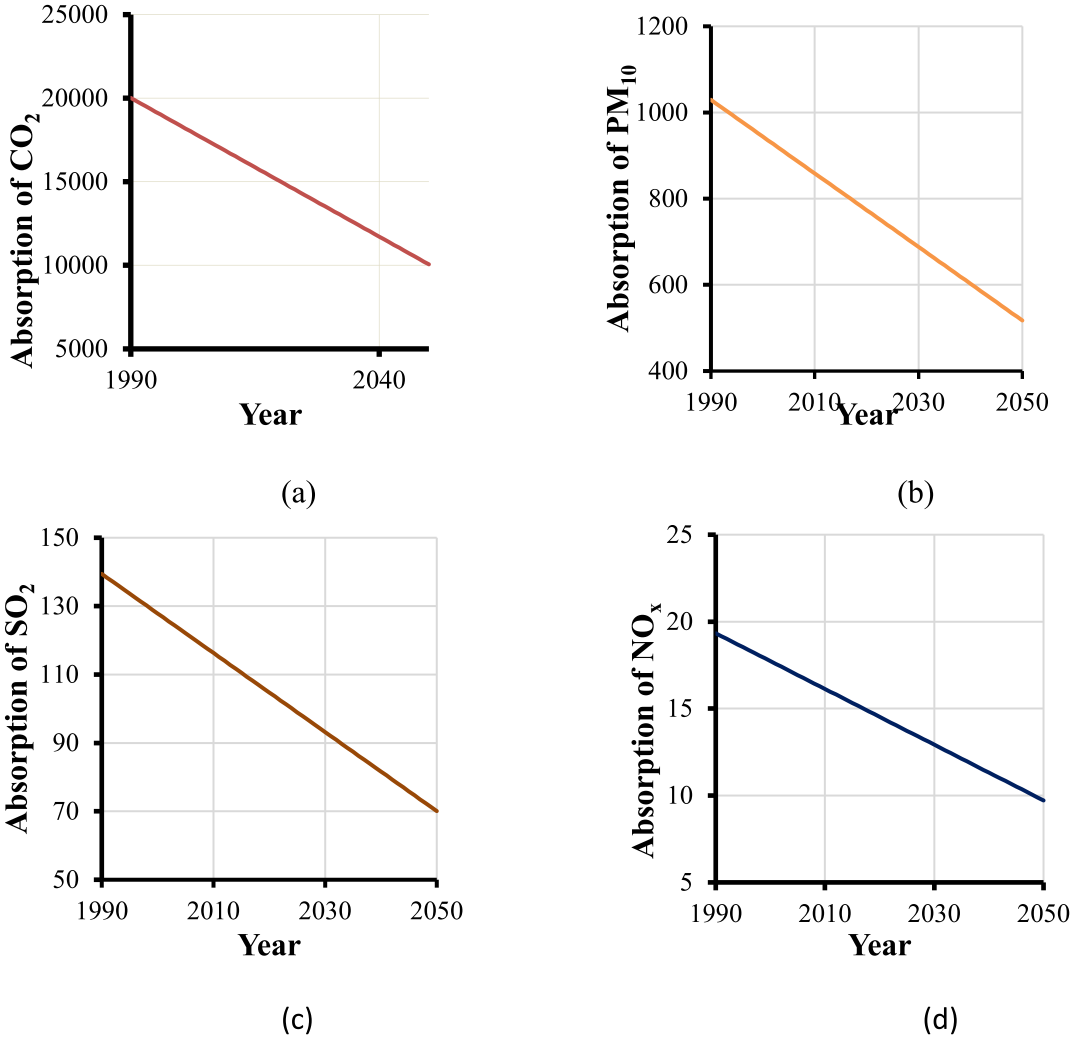

Figure 5. Pollutant absorption scenario over years for the decrease in vegetation area (a) Absorption of CO_2 over years, (b) Absorption of PM_{10} over years, (c) Absorption of SO_2 over years, (d) Absorption of NO_x over years

Pollutants' absorption rate is decreasing with time. It means more pollutants are trapped in the air over time. Again, with the increasing population, the emersion of air pollutants is increasing. It causes the air to be more polluted over time.

2.4 Rooftop gardening as a partial solution

According to our findings, we can see that the vegetation area and agricultural land in the Rajshahi region are decreasing for urbanization and industrialization. Avoiding over urban expansion, rational usage of space resources in case of densely populated areas and most importantly starting urban greening policies. Residential buildings, having a minimum amount of space on the rooftop, should be emphasized for the generation of vegetation and rooftop gardening. Through rooftop gardening, more Oxygen will be produced in a specific region than normal. In populated cities, rooftop gardening helps by energy efficiency and absorbing pollutants which is a consequential emergency. Hence, it can be an approach to minimizing the amount of Carbon Dioxide and other pollutants in the atmosphere.

4. CONCLUSION

This study identifies that the rate of decrease of the area of vegetation is 0.8291% per year. The built-up area is increasing with time due to rapid urbanization. With time, more vegetation area is converted into built-up area. It also shows the decrease of the absorption rate of the air pollutants as it has a direct relationship with vegetation. The absorption of air pollutants like CO_2, PM_{10}, SO_2 and NO_x by plants decreases with time resulting in more air pollution. From the comprehensive discussion and findings, the authors proposed that environment-friendly rooftop vegetation reformation is inevitable for reducing the fatality of air pollution. This Rooftop gardening project above all can facilitate urban sustainability in the future.

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