Research Paper

REMOTE SENSING APPROACH IN WETLAND AND LAND DEGRADATION ASSESSMENT: A SCENARIO OF MODHUMOTI MODEL TOWN, SAVAR, BANGLADESH

Save Wetlands, Remove Modhumoti Model Town

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Abstract

Due to rapid urbanization, people destroy core environmental elements such as water, land for habitation purpose without thinking about adverse environmental consequences. Modhumoti Model Town is such type of housing project which is situated at a river zone. Bangladesh Environmental Lawyers Association (Bela) filed a writ against the project and after three times (in 2004, 2005 and 2013) assembling the case, the High Court declared the project was illegal and should restore the wetland. Overruling the law, the development procedure is still constant which destroys the natural wetland and its surroundings. The study aims to assess the extent of water and land degradation due to human settlements using Geographic Information System (GIS) and Remote Sensing (RS) approaches. Modhumoti Model Town is selected as the study area which is situated at Amin Bazar, Savar. Landsat TM 4-5 and OLI 8 have been used to calculate several indices such as Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI), Normalized Difference Built-up Index (NDBI) and Normalize Difference Water Index (NDWI) in the year of 1998, 2004, 2010, 2014 and 2019 before and after verdicts. Results indicate that NDVI, SAVI, NDWI were decreasing where NDBI was increasing sequentially. Now, both semi-pucca and pucca settlements are around 240 in amount and the project area completely blocks the free flow of water from river. Furthermore, the analysis captures the consequence of law violence and shows that imposing verdict is not enough to protect the environment if it would not be strictly maintained.

Keywords

Environmental consequences, Writ, Overruling laws, GIS, RS

1. Introduction

Dhaka city was planned for l0 lakh people in 1959 (Hossain and Akther, 2011), whereas the population of Dhaka Metropolitan Area (DMP) is about 8906039 (Statistics, 2011). The population of Dhaka grows at an estimated rate of 4.2% per year, one of the highest among

Asian cities (McGee, 2006). The continuing growth reflects ongoing migration from the rural areas to the Dhaka urban region, which is accounted for 60% of the city's growth in the 1960s and the 1970s.In recent times, the city's population has also grown with the expansion of city boundaries. The process added more than a million people in the town in the 1980s (McGee, 2006). According to the Economic Review, Dhaka will become the home of 25 million people by the year 2025 (Davis, 2006, McGee, 2006).

People are filling the low lying areas to meet the demands of land for residential, commercial, industrial and so on (Kafy, 2018, Kafy et al., 2018). According to local news, around 49 housing projects without approval have been identified which are inside the flood flow zones by covering about 9,241 acres of land in Dhaka. Landfilling events are going on even after the enactments of the "Wetland Conservation Act, 2000". In Dhaka, yearly loss of wetland during 1989-1999 was 1.23 %, whereas, during 1999-2003, the damage was 5.67 %. Dhaka is still left with 19.3 % of wetland. If the current rate of loss of wetland continues, by the year 2037 all temporary wetlands of Dhaka will disappear (Zaman et al., 2010).

Remote sensing is a great medium of analysing environmental consequences. It has become a great source of data as a scene cover a larger area with a lot of spectral information (Kafy et al., 2019, Faisal and Khan, 2018). Moreover, to assess the environmental degradation rate and its extent, some environmental indices has been developed. Hence, there are many vegetation indices for detecting worth condition of vegetation cover, vegetation structure and leaf distribution using satellite images (Yengoh et al., 2015). The most popular and universally applied vegetation index is named as Normalized Difference Vegetation Index (NDVI). NDVI relies on the red and near-infrared band combination (Gascon et al., 2016). Additionally, In the assessment of water resources, the monitoring of water bodies extraction has become a necessary task. In order to do so, Normalized difference water index (NDWI) is an index that was developed by McFeeters to delineate the water features using satellite images (Gao, 1996, McFeeters, 1996). Generally, to delineate water features while reducing the appearance of vegetation and soil features, the NDWI uses near-infrared (NIR) and middle infrared (MIR) radiation (Gao, 1996).

Moreover, urbanization is one of the most critical land cover change factors as it increases the loss of agricultural lands by converting it to urban areas (Davis, 2006, McGee, 2006). Information on urban built-up area is needed to detect land use/land cover changes (LULC) (Singh et al., 2017). For detecting dynamics of urban built-up area, Normalized Difference Built-up Index (NDBI) index is widely used (Kafy et al., 2018, Gascon et al., 2016). Basically, the method named NDBI was introduced to evaluate urban zones from Landsat images (Verbeiren et al., 2008). Besides, Soil Adjusted Vegetation Index (SAVI) another important method used to minimize soil brightness influences from spectral vegetation using near-infrared and red wavelengths (Gilabert et al., 2002).

In this research, the study team identifies the adverse environmental effects of Modhumoti model town, Amin Bazar, Savar, Dhaka through combining GIS and Remote sensing technologies. The study team quantifies vegetation, measures the volume of changes water body, and differentiates urban zones measures the soil brightness influences through NDVI, NDWI, NDBI and SAVI method. Combining all of these methods, the study team finds out the overall environmental impact assessment because of Modhumoti Model Town.

2. Study Area Profile

Modhumoti model town is situated in Dhaka-Aricha highway, amin bazar, Savar, Dhaka. The coordinate location of Modhumoti model town is 90°18'2.878"E and 23°47'12.302"N. This

project is built without taking the permission of RAJUK. This project is declared illegal by the high court. The authority was asked to regain the reservoirs as it was before. But overruling the dictates, they began to continue the constructions work in there. It was first declared illegal in 2005. They the Modhumoti Model Town's authority appealed. But it was again rejected and the high court declared it completely illegal in 2012.

Figure 1: Modhumoti Model Town

The figures show that there have some constructions though it was illegal. But it is a matter of great sorrow that, the authority of this model town doesn't pay heed to the high court and they are continuously building new constructions. This figure shows that how they are built construction illegally. The number of constructions is 10 times more than it was in 2014. This project is built on the bank of the river and most portion of the river are filled to complete this project. Therefore, this eventually is influencing environmental impacts. The study team finds out the environmental loss because of this illegal, inimical project.

As the Modhumoti Model Town is a relatively smaller area to analyse Landsat 30-meter resolution images, the authors consider the study area as (5×5 sqkm) square. The square covers project area with its surroundings that helps to evaluate the overall condition.

3. Methodology

Modhumoti residential area is a project which is fully athwart with environmental sustainability. It has terrible effects on the environment which is destined not only here by the study team through Geographic Information System (GIS) and Remote Sensing approaches. The study team used NDVI, SAVI, NDBI and NDWI to evaluate the environmental effects.

Normalized Difference Vegetation Index (NDVI): NDVI quantifies vegetation based on the difference between red (R) and near-infrared (NIR) band values. Red (R) band refers to that which vegetation absorbs and near-infrared (NIR) refers to that which vegetation strongly reflects. According to Rouse et al., (1974) the NDVI equation is formulated as below (Rouse Jr et al., 1974):

$$NDVI = \frac{NIR - R}{NIR + R}$$

NDVI always ranges from -1 to +1. But there isn't an exclusive boundary for each type of land cover. High negative values of NDVI generally indicates that there is a massive possibility of water and if the values near to +1, there's a higher possibility of dense green leaves. But if

the NDVI is close to zero, it indicates that there aren't green leaves and it might be an urbanized area.

Soil Adjusted Vegetation Index (SAVI): In which areas the vegetative cover is low (i.e., < 40%) and the soil surface is manifested, the reflectance of light in the red and near-infrared spectra can influence vegetation index values. The SAVI was established as a adjustment of the NDVI to correct for the influence of soil brightness when vegetative cover is low.SAVI calculation is based on the difference between R and NIR values with a soil brightness correction factor (L) defined as 0.5 to accommodate most land cover types.

$$SAVI = \frac{NIR - RED}{NIR + RED + L} * (1 + L)$$

Normalized Difference Built-up Index (NDBI): NDBI is a process to convert satellite imagery into a land cover map. It was introduced to extract urban zones from Landsat images (Verbeiren et al., 2008).

For Landsat TM or ETM images, the calculation of NDBI is expressed below:

$$NDBI = \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4}$$

For Landsat 8 images, the calculation of NDBI is expressed below:

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR}$$

Normalize Difference Water Index (NDWI): NDWI index is the most appropriate used method for water body mapping. It is developed to depict open water features and enhance their presence in remotely-sensed digital imagery. The index uses the green and near Infra-red bands of remote sensing images. According to Mishra et al., (2015) the calculation of NDWI can be formulated below (Mishra and Prasad, 2015):

$$NDWI - \frac{NIR - MIR}{NIR + MIR}$$

4. Results and discussions

The Modhumoti Model Town is a growing and illegal construction site which destroys the whole ecological system of the riverine area. Several environmental indices indicate the extent of environmental changes in the area.

The Metro Makers and Developer Limited company is the owner of the town which developed a housing project by filling in 550 acres of wetlands. The wetland was identified as floodplain in the master plan of 1997. On August 2004, Bela filed a writ petition as public interest litigation against the project to the high court. The project did contradict with the Environmental Conservation Act, Town Improvement Act and Rajuk (Rajdhani Unnayan Kartipakkha) rules. The Bela challenged the legality of the project by addressing the laws. In the petition, Bela addressed that the natural characters of the area will be destroyed if the project continues. Also, to remain free flow of the water of the city, Bela appalled to the apex court to pass the necessary orders. The high court continued the project's development work after primary hearing.

On July 27, 2005, the high court declared that the Modhumoti Model Town project is unauthorised, illegal and against public interest. The court also rejected a writ filed by the owner Metro Makers. But high court also declared that interest of the purchasers is

protected. In 2006, Bela, Metro Makers Ltd, plot purchasers and Rajuk did file 5 separate leave to appeal petition against separate portion of the high court verdict with supreme court. Metro Makers and plot purchasers appealed by addressing a lot of investment for the plots and projects. Rajuk appealed for declaring the project as illegal.

On March 19, 2009, the Supreme Court upheld the high court verdict. But the court allowed the company, plot purchasers and Rajuk to move regular appeals before it against the high court verdict.

On August 7, 2012, the Appellate Division upheld the high court's decision and allowed the appeal of Bela. The court also dismissed Metro Makers, plot purchasers appeals and disposed of the appeal of Rajuk as well.

Finally, on July 11, 2013, the Appellate Division of the apex court released the full text of its 159-page verdict. The verdict was directed to Modhumoti Model Town owner Metro Makers and Developer Limited and the verdict was to restore within six months the wetland in Bilamalia and Bailarpur moujas of Savar where it had developed the project.

Above discussion indicates several timelines which have direct linkage with writ, appeal and verdict. Therefore, several year's images have been chosen for evaluating action after effects. The timeline of the images shows 1-year after-effects from different actions. These years are 1998 (indicates initial stages), 2004 (indicates the situation of filing writ petition), 2010 (One year after effect after court verdict), 2014 (one year later effect after final verdict) and 2019 (to evaluate the present situation).

As the project was running, and the natural riverbed was destroyed so that the area has been experienced a huge environmental change. Environmental indices do help to assess the environmental changes universally. The following sections evaluate the environmental consequences of the area by evaluating environmental indices and additional analysis.

4.1 Assessment of water body: The model town project was established by filling up the surface water body of a river. In previous, the river had a free flow of water towards the project area. The project area blocks the river channel and interrupts the free flow of water by causing flood, waterlogging and environmental degradation as well. NWDI was used to evaluate the overall water assessment. Figure 2 indicates the NDWI values of the project and surrounding area. The hierarchy of colour red to blue indicates low to high surface water availability. In 1998, the maximum NDWI value was 0.71 which shows higher surface water availability. The maximum NDWI value drops drastically in 2004 as 0.55. The project area was filled by sand and had experienced loss of water body. Most importantly, it destroyed the flowing channel. In 2010, the area still faces loss of water availability as the project verdict was hanging. After the final verdict, the area had experienced highest level of water losses as the maximum NDWI value was 0.31. Now, in 2019, the maximum NDWI value shows as 0.35 which is a little higher than 2014 but not enough at all. The whole NDWI value indicates that the surface water availability and its flow direction are completely destroyed and the water system is not restored even after verdict also.

The loss water system of the area can be visualized by the following figure 3. The figure indicates extent of water body available indefinite time interval. The hierarchy from blue to red indicates the water body found in 1998 to 2019, sequentially. The figure indicates that the area losses around 5.34 km^2 from 1998 to 2014. Unfortunately, in 2019, the water body has fallen around 2.23 km^2 from 10.54 km^2. The area is a small area but has great impact and significant loss in last 21 years. The project area is indicated as 'Main-boundary' in the figure.

Hence, it is clear that the project area was nothing but a river and the project area was established by filling up the river.

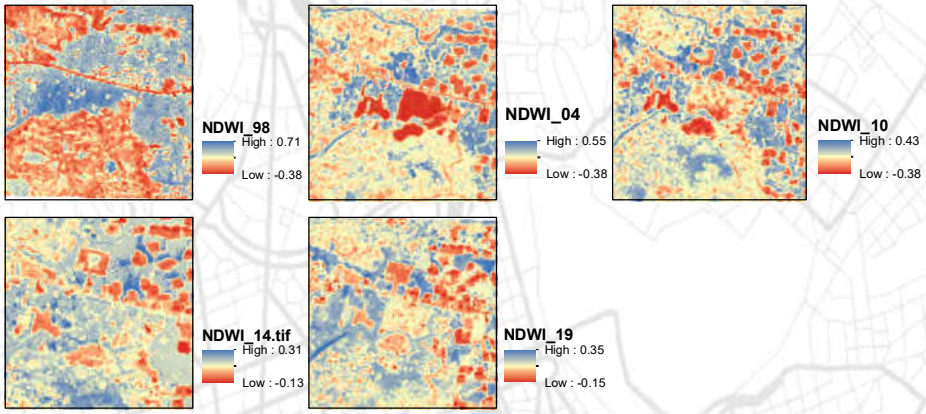

Figure 2: NDWI value of the study area

4.2 Assessment of vegetation and soil: The project area was filled by sand causes degradation of soil and vegetation properties. NDVI is a universal vegetation productivity index that helps to evaluate the extent of productivity of vegetation. The whole area is classified into three broad classes which are high (NDVI value 0.42-1), medium (0.08-0.42) and lowly productive (-1-0.08) vegetation (Table 1). These categories are also classified into several subcategories. The table indicates a clear vegetation overview of the area. In case of high productive class, productivity was decreased from 1998 to 2004 at 1.8%, increased from 2004 to 2010 at 2.8 %, decreased from 2010 to 2014 at 2.93% and increased from 2014 to 2019 at 2.3%. The noticeable fact is that in the year of 2004 to 2010, the high productive vegetation was increased and the reason might be stopping the developing works in the time interval. In case of medium productive classes, the overall shows increased productivity.

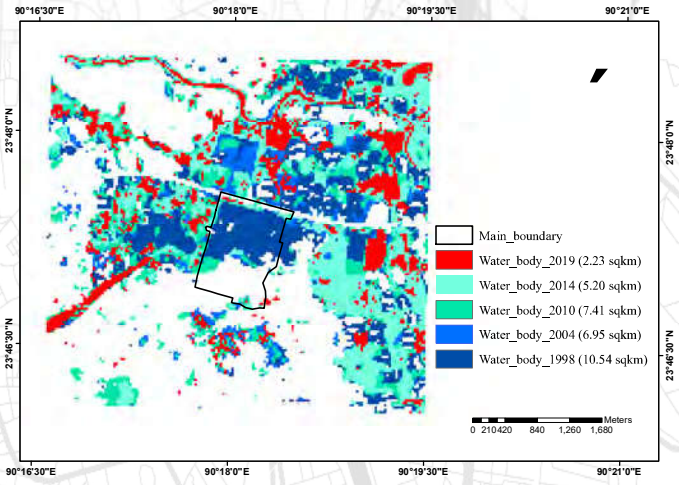

Figure 3: Overall water bodies of the model town and its surrounding area

The amount of land which is decreased from high productive class, they fall into the medium productive classes. The highest change was found from 2014 to 2019, and the amount of

change increasing change is around 28.24%. Moreover, in case of lowly productive class, all the class shows that NDVI values were decreased all the time and that means, overall vegetation impact was not well. The significant change shows from 2014 to 2019 and that is around 30.6% of lowly productive land was decreased. That means, the NDVI values are gone towards -1 which indicates increase of impervious layers.

Table1: Overall change in vegetation productivity coverage in percentage and km^2.

		Change in area coverage in percentage and km^2							
		From 1998 to 2004		From 2004 to 2010		From 2010 to 2014		From 2014 to 2019	
Vegetation Productivity Classes	NDVI Values	Percentage	Area (km^2)	Percentage	Area (km^2)	Percentage	Area (km^2)	Percentage	Area (km^2)
High Productive	0.97-1								
	0.54-0.97	-0.048	-0.011	0.004	0.001	-0.004	-0.001		
	0.42-0.54	-1.749	-0.394	2.775	0.626	-2.927	-0.660	2.328	0.525
	0.42-1	**-1.797**	**-0.405**	**2.779**	**0.626**	**-2.931**	**-0.661**	**2.328**	**0.525**
Medium Productive	0.34-0.42	-1.334	-0.301	5.969	1.346	-9.415	-2.122	21.491	-2.122
	0.29-0.34	1.354	0.305	3.574	0.806	-6.856	-1.545	17.314	-1.545
	0.24-0.29	2.280	0.514	3.841	0.866	-2.727	-0.615	9.172	-0.615
	0.16-0.24	5.722	1.290	2.040	0.460	12.950	2.919	-8.330	2.919
	0.08-0.16	6.529	1.472	-1.031	-0.232	13.234	2.983	-11.412	2.983
	0.08-0.42	**14.552**	**3.280**	**14.393**	**3.245**	**7.186**	**1.619**	**28.235**	**1.619**
Lowly Productive	0-0.08	5.415	1.220	-0.196	-0.044	8.706	1.962	-18.508	1.962
	-1	-18.170	-4.096	-16.976	-3.826	-12.961	-2.921	-12.055	-2.921
	-1 - .08	**-12.755**	**-2.876**	**-17.172**	**-3.870**	**-4.255**	**-0.959**	**-30.563**	**-0.959**

Furthermore, to estimate the vegetation index more accurately SAVI index has been to correct for the influence of soil brightness when the vegetative cover is low. Also, due to increase of built-up area as well as impervious surfaces over time, NDBI index helps will correlate the overall environmental condition of the area. Figure 4 shows environmental indices over different time period. Every image value indicates degradation of vegetation and up-gradation of hardscapes. In the meantime, the correlation coefficient indicates the extent of influence for one factor to another (Table 2). In the case of 1998, the correlation coefficient indicates that the 1-unit change of NDVI depends on 0.91-unit change of NDBI, negatively. Here intercept value for NDVI with NDBI is 0.004. Besides, NDVI has a positive relation with SAVI and the correlation coefficient value is 1.49. That means the 1-unit change of NDVI depends on 1.49-unit change of SAVI, positively. Both SAVI and NDBI are negatively correlated and the correlation coefficient is -1.63. That means the 1-unit change of NDBI depends on 1.63-unit change of SAVI, negatively. Hence, built-up areas increase by reducing vegetation covers of the study area. Similarly, all the correlation coefficients from different timeline show more or less similar result which is built-up area takes over vegetation lands. This analysis also shows that impervious surface that means built-up area, road, housing and so on are increasing continuously which adversely affects vegetations. As government declared to restrain the previous environmental condition such as free flow of water through the area, enough green spaces by demolishing built structures but the developing of making structures is continuous. Even after the final verdict, the housing project is still live and some influential person overran the site illegally. Figure 5 indicates number of structures in four different timelines.

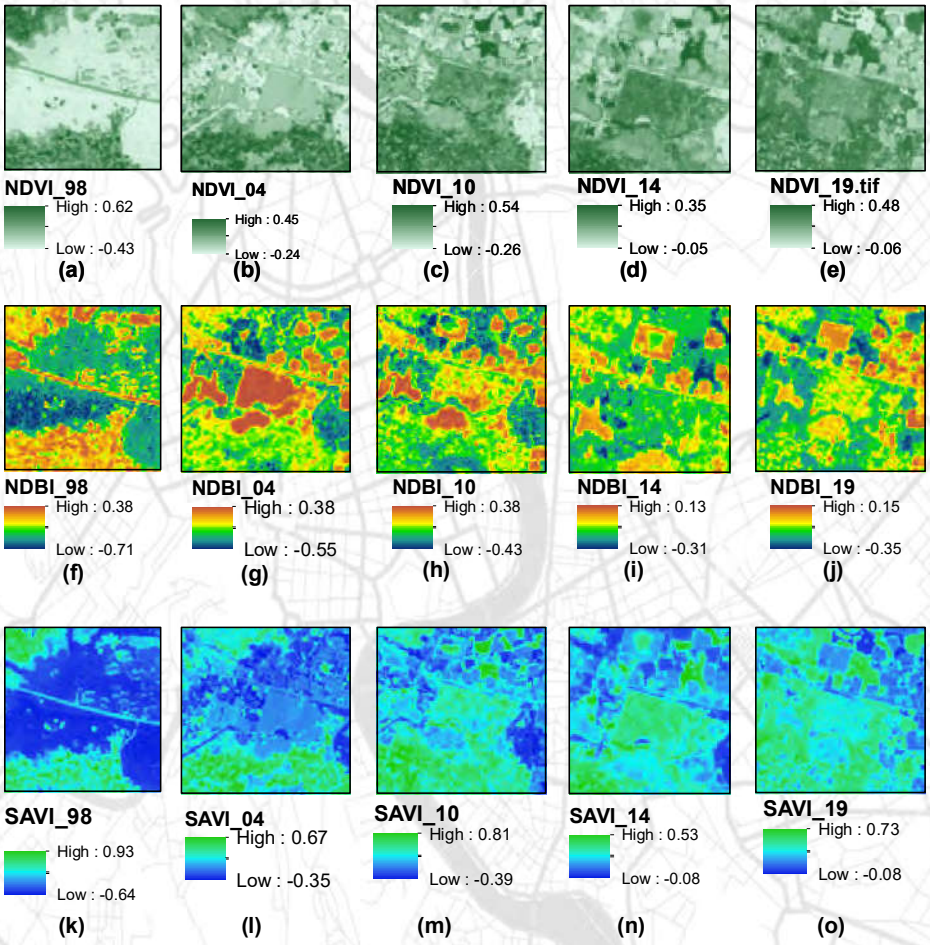

Figure 4: Environmental indices (a) NDVI in 1998, (b) NDVI in 2004, (c) NDVI in 2010, (d) NDVI in 2014, (e) NDVI in 2019, (f) NDBI in 1998, (g) NDBI in 2004, (h) NDBI in 2010, (i) NDBI in 2014, (j) NDBI in 2019, (k) SAVI in 1998, (l) SAVI in 2004, (m) SAVI in 2010, (n) SAVI in 2014 and (o) SAVI in 2019

Table 2: Correlation coefficient among NDVI, SAVI and NDBI of the study area

1998	NDVI	NDBI	SAVI
NDVI	1		
NDBI	-0.9128	1	
SAVI	1.4927	-1.6264	1

2004	NDVI	NDBI	SAVI
NDVI	1		
NDBI	-1.247	1	
SAVI	1.5007	-1.2025	1

2010	NDVI	NDBI	SAVI
NDVI	1		
NDBI	-1.0035	1	
SAVI	1.4963	-1.4903	1

2014	NDVI	NDBI	SAVI
NDVI	1		
NDBI	-0.9774	1	
SAVI	1.4988	-1.5314	1

2019	NDVI	NDBI	SAVI
NDVI	1		
NDBI	-0.9795	1	
SAVI	1.498	-1.5281	1

In 2004, structures were started building and the increasing number was continuous even after verdict also. In present years, the total number of semi-pucca and pucca structures are around 240. The graph represents continuous building of structures. The noticeable fact is

that total number of structures are built after 2014. That means, after the verdict, building of new structures have not been stopped rather have been increased rapidly. The scenario is happened only because of poor law maintenance. The figure 6 describes a clear overview of past and present condition of Modhumoti Model town.

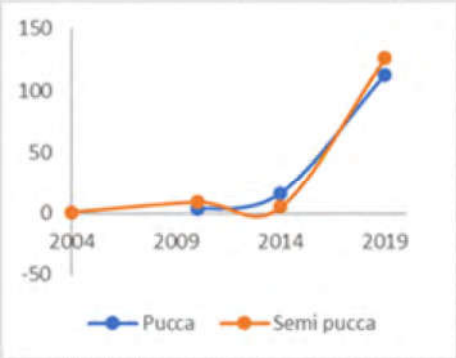

Figure 5: Number of structures in Modhumoti Model Town

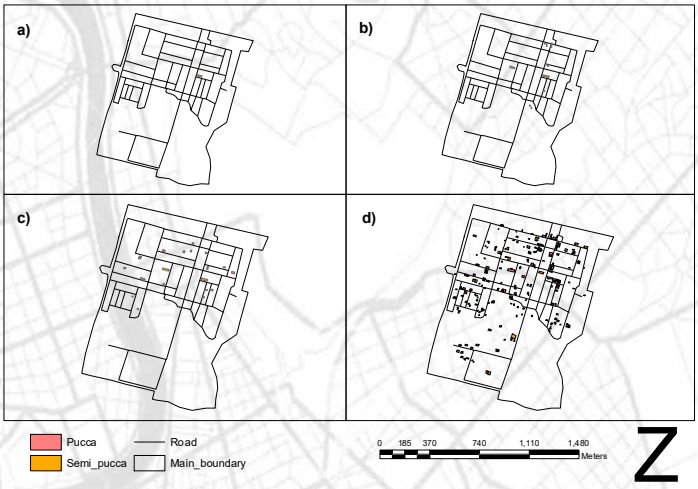

Figure 6: Structures of Modhumoti Model Town in the year of (a) 2004, (b) 2010, (c) 2014 and (d) 2019

The above analysis indicates that the model town project is not a blessing for the environment. It not only destroys the whole ecological system but also it is a proper example of violation of laws.

5. Conclusion

A Residential Town is not always a blessing for a country. Modhumoti Model town is a similar type of project which creates high facilities for a living, but in a broader sense it destroyed the whole ecological system. Overall environmental assessments indicate that the area has been lost its character. A live free-flowing water channel is completely destroyed and that forces to make the river dead. NDWI value indicates that previously the overall water condition was good but year after year due to the growing project the NDWI values are decreased. That mean, the river has lost its own tone and that turns to loss of availability of water. NDWI and SAVI indicate that amount of productive vegetation is decreased overtime period. Impervious surface availability is increased rather than softscape which are analysed using NDBI index. Most importantly, the case was hanging for several years and in the meantime the development work did not stop. The noticeable fact is, in the final verdict, the project was identified as illegal and ordered the owner to restore the wetland in the previous state but the condition of developing hardscape remains continuous. Even recent years, the model town has grown its full form. A complete community is living in the town with continuous urbanizing of the site.Hence, it is completely understandable that imposing law to an illegal development project is not enough yet. Practical maintenance, and forced to admire the laws and verdicts are also necessary as well.

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