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An Assessment of Declining Urban Greens under Patna Municipal Corporation Based on Normalized Difference Vegetation Index

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Abstract:
Urban Greens are technically new term considering the literature related to urban areas. The definitions of urban areas are not uniform all over the world, it varies country to country. In general urban areas are locations characterized by non-agricultural human population density and large human-built features in comparison to the areas surrounding it. Urban greens are related to vegetation greenness of a particular urban area which strikes the micro climate of that area. The purpose of this paper is to make an inventory of the extent and nature of the urban greens in Patna Municipal Corporation. Time series data analysis of Normalized Difference Vegetation Index (NDVI) is widely and commonly used for the study of spatiotemporal analysis of vegetation cover and effective greenness. The present study of the urban greens under Patna Municipal Corporation has also used the NDVI based method for the assessment of its rapid decline in last quarter century (1989 -2014). Six base years (1989, 1993, 1999, 2005, 2009, and 2014) were taken for the assessment and the results show that in last twenty one years the area under urban greens has shrunk to the one third of what it was in 1993, while the Built-up area has more than tripled in the last quarter century.

Keywords: Urban Greens; Micro climate; Urban Area; Normalized Difference Vegetation Index (NDVI)

1.0 Introduction:
Urban greens constitute the most important component of urban spaces. In fact, the green spaces are the providers of urban vegetation. They include urban farming, gardens, parks, avenue trees, institutional fields, golf course, cemeteries, green corridors along rivers and railway lines etc. The parks and other urban greens are an essential feature in an urban planner's blueprint. The famous French urban architect, Le Corbusier rightly considered parks and gardens as the *lungs of cities*. It is now strongly believed that the quality of life of a city, to a great extent, depends on the share of urban greens. Awareness, now, seems to be fast developing among the city - dwellers that just as urban areas need to upgrade and expand their *'grey infrastructure'* (roads flyovers and sewers etc.) so, too, they need to upgrade their '*green infrastructure*' (avenue trees, parks etc.) Urban greens refer to any area within the city limit which has been created and preserved for the purpose of growing plants.

There are some definitions which include open spaces under the urban greens. Danish urban library says that "Urban green encompasses all urban open spaces from designated public to private open spaces, including accessory urban open spaces e.g. along roads and railway lines." A comprehensible definition of urban green structure is important as open spaces, which are non-vegetated (not green) and may also have important function for recreation and environment improvement. In an urban area the open spaces can remain dry or with vegetation depending on climate and seasonal variation. The present study tries to understand the concept of urban greens on a broader level, and for this purpose the area under urban greens have been classified in two parts. The first class (**CLASS -1**) contains all the open spaces under a municipal/city area under urban greens, the open spaces can be categorized under INEFFECTIVE URBAN GREENS. While the second class (**CLASS -2**) tries to distinguish the pixel based real green area which shows enough photosynthesis that can be calculated by the Normalized Difference Vegetation Index (NDVI, between 0 -1, where higher value shows increasing and dense vegetation). The second class or Class -2 may also be considered as the EFFECTIVE URBAN GREENS.

The area urban greens should be preserved for the maintenance of environmental quality of the urban area. The consequences of gradual disappearance or shrinkages of effective urban greens (EUG) are manifold. Firstly, it will result in the decline in the quality of life of urban dwellers, which indirectly will lead to the malice - ridden urbanization. In India the level of urbanization increased from 27.8% in 2001 census to 31.2% according to 2011 census (Census of India, 2011). According to United Nation`s Report, India will witness the largest growth in its urban population and is estimated to add 497 million between 2010 - 2050. Thus, the population living in cities is growing at a rapid pace. Hence, the unprecedented increase is shrinking land - man ratio in the cities. This is having a profound effect on effective urban greens. Secondly, degeneration of urban greens will cause deterioration of healthy and aesthetic environment of the cities leading to the problems of air pollution and noise pollution. Consequently the urban - dwellers will suffer from various kinds of pollutant- induced diseases like respiratory, asthma, skin and eye irritation, deafness etc. Thirdly, effective urban greens efficiently reduce city atmospheric temperature. With the increase in urbanization the vegetated surface of an area is converted into impervious surface resulting in change pattern in absorption of solar radiation, storage of heat, surface temperature, evaporation rate, wind turbulence thus negatively a affecting the micro climate of the area (Mallick, et al., 2008). The variations in Land Surface Temperature (LST) with in a Municipal area are of highest concern to the study the urban climate and human - environment interactions (Ashraf, 2015). The reduction in ‘urban heat island’ effect is directly related to vegetation which provides shade and cools the surrounding area by evapo - transpiration cooling. Lastly, the consequence of vanishing effective urban greens is causing ‘urban stress’ (a new approach to the ill effects of shrinking urban greens) resulting in psychological disorder of a different dimension.

Maintenance of effective urban greens is a potential source of sustainability of the quality of life not only for the present but also for the future generation, so that the quality of life remains uninterrupted. The ‘regeneration’ of urban greens for the purpose of reconstituting the quality of urban life, in a way maintains the dignity of the urban mankind. It also heralds a new wave of sustainability for the betterment of the well-being of the residents. By doing so the needs of the present could be maintained without compromising with the ability of future generation to meet their needs, particularly in the context of the urban quality of life.

2. Materials and Methods:

Patna is one of the oldest continuously inhabited places in the world and Patna Municipal Corporation (PMC) is located between Latitude: 25°33'10''-25°39'03'' North and Longitude: 85°03'16''-85°16'10'' East, it lies on the south bank of the River Ganges. Patna Municipal Corporation is approximately 21.5 km long (east to west) and 11 km wide (north to south). The corporation area is important commercial centre. The commercial establishments within the city are mainly lined along the arterial and major roads and there is extensive mixed land use of commercial and residential use throughout the city.

The natural growth of Patna Municipal Corporation (PMC) has been towards the west till date, with the older part of it being in the east side of the city (Ashraf, 2014). This core area of PMC faces problems of overcrowding, which has lead to enormous pressure on the physical infrastructure and traffic congestion. The newer developed areas lying in the central and western part of PMC comprises of both plotted developments and apartment houses. The apartments in the newly developed area are again straining on the existing infrastructure, as the up gradation of the physical infrastructure has not been done in proportion to the increase in population being accommodated in the apartments. The Patna Municipal Corporation (PMC) covers an area of nearly 108.164 km^2 according to our remote sensing and georeferencing results. It is further divided into 72 wards. According to the 2011 census it had a total population of 16, 83,200. The density of population of the PMC is 15562 persons per km^2. The trends of population growth have been uneven in the period 1951-2011. The growth registered an increasing trend in the period 1961 to 1981 - from 28.52% to 64.14%. It reduced to 18.14% during 1981 to 1991, rising again in 1991 to 2001 to 48.97% and dropping again during 2001 to 2011 to 32.53% (Census of India, 2011).

Google Earth data for the present year (2015) and Survey of India latest Toposheet G45N2 and G45N6 are used for the reference area map creation. Patna Municipal Corporation (PMC) map* with 72 wards is used. [*Base MAP of PMC is as per 2001 Administrative command, the same base map and boundary is used by Department for International Development (DFID) UK for its developmental plans for Bihar with collaboration with the provincial government].

A discrete georeferenced map of Patna Municipal Corporation is prepared from scratch with all the required parameters. KML file was created in Google Earth Pro with the help of Polygon tool according to reference base map of PMC with 72 wards. For georeferencing and shape file conversion GRgarmin along with ISRO's Bhuvan were used and required ground referencing was done for getting the maximum accuracy in georeferencing.

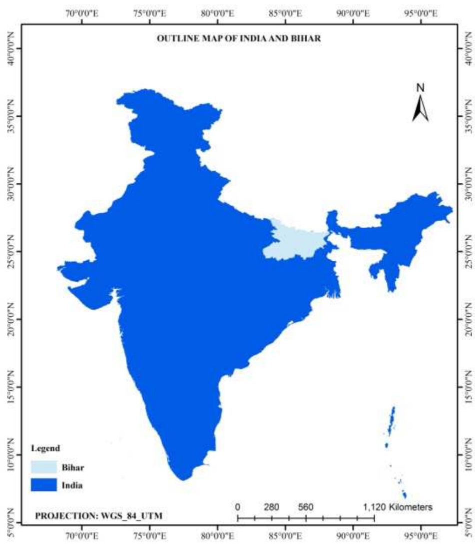


Fig. 1(A) Outline Map of India and Bihar

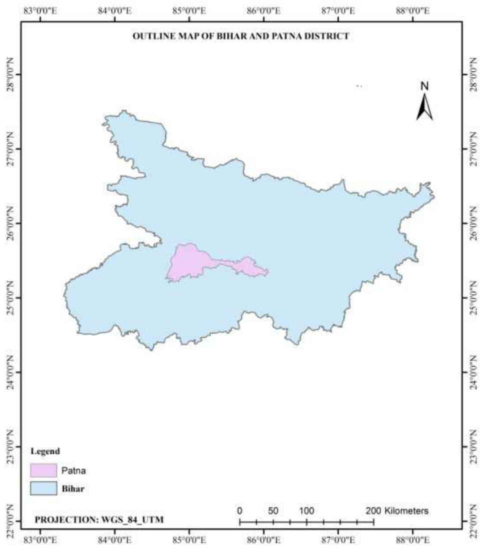


Fig. 1(B) Outline Map of Bihar and Patna District

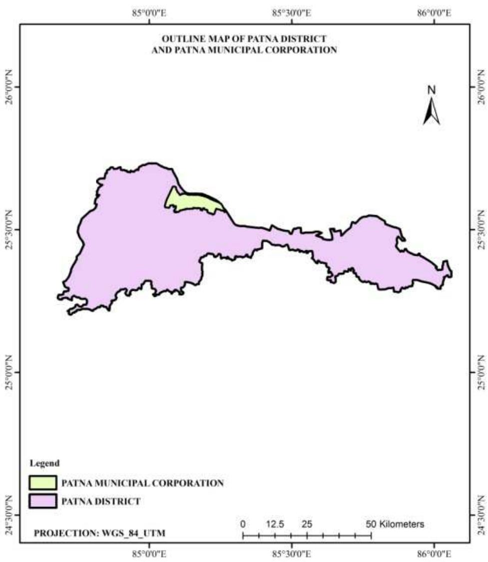


Fig. 1(C) Outline Map of Patna District and PMC

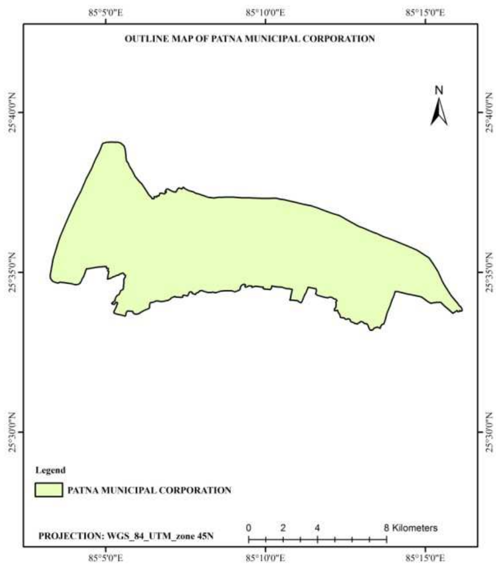


Fig. 1(D) Outline Map of Patna Municipal Corporation

Table 1: Details of Satellite Data

Satellite	Sensors	Date	Resolution	Band	Path/Row
Landsat - 4	TM	24/01/1989	Re sampled at 30.0 m	3, 4	141/42
Landsat - 4	TM	04/02/1993	Re sampled at 30.0 m	3, 4	141/42
Landsat - 7	ETM+	16/02/2003	Re sampled at 30.0 m	3, 4	141/42
Landsat - 5	TM	13/02/2005	Re sampled at 30.0 m	3, 4	141/42
Landsat - 5	TM	11/02/2010	Re sampled at 30.0 m	3, 4	141/42
Landsat - 8	OLI	06/02/2014	Re sampled at 30.0 m	4, 5	141/42

There are numerous Digital Image Processing techniques such as slicing, image reduction and magnification, transects, contrast enhancement, band ratioing and so on (Jensen, 1996); out of which NDVI happens to be the most widely used for the purpose of understanding green leaf concentration through calculation of Leaf Area Index (LAI) (Pandya et al. 2007). It is helpful in predicting chlorophyll status in the vegetation for the analysis of phenological as well as bio-technological processes of different types of tree species (Su 2002, Mukherjee and Banerjee 2005). This technique has been widely used for accurate description of greenness (vegetation cover) and land cover classification for various purposes such as preparation of vegetation index (De Fries et al., 1995), detection of land cover changes using Landsat TM and ETM+ images of different dates (Jomma and Kheir, 2005).

This study is mainly based on satellite data acquired from NASA's Landsat mission. The red and infrared bands are used to calculate the Normalized Difference Vegetation Index (NDVI) for the study area. Some precautions were taken in selecting the Satellite image. Cloud free images of same season were used for minimum error. All the satellite images were acquired from United States Geological Surveys (USGS) website. Lyon (1998) compared seven vegetation indices from three different dates of Landsat MSS image data for land cover change detection and concluded that, the NDVI differencing technique demonstrated the best vegetation greenness change detection. The band formula for NDVI is defined as

$$NDVI = (NIR - R) / (NIR + R) \quad \textbf{(1)}$$

Where NIR represents the spectral reflectance in near infrared band and R represents red band. The NDVI real value by definition would be between -1 and +1, where the increase in positive values shows the increasing trend in the vegetation greenness and the negative values indicate non vegetated surface feature such as fallow land and water etc. Maximum likelihood supervised classification has been done for the acquired spectral signature of the NDVI. The supervised classification is generally followed by knowledge based expert classification depending on reference maps to improve the accuracy of the classification process.

Table 2: Details of Software Used in Study

Software Used	Functions
Google Earth Professional 7.1.1	For overlaying RAW map and creating Polygon generated outline KML file
DNR Garmin 5.04	Converting KML file to Shape file, Georeferencing
ISRO Bhuvan	Evaluation of shapefile and georeferenced data
ArcMap 10.1	AOI clipping, Creating Georeferenced Map, Band math for NDVI, Creating Training samples, Supervised Maximum Likelihood Classification and Reclassifying data and output MAP generation
MS Excel 2007	Graphs and Charts

3. Results and Discussion:

The main objective of this study was to determine the declining area under urban greens over the years in Patna Municipal Corporation. Altogether six base years were selected depending on the availability of satellite data with minimum cloud coverage for the maximum accuracy. All the data were of the same period to reduce the variation of seasonal effect on the total urban greens (including open spaces) and effective urban greens. For the determination of areas under urban greens NDVI based land use land cover (LULC) maps are prepared for all the related base years. Four threshold classes are identified using maximum likelihood classification method under ArcMap namely urban greens (vegetative land), open spaces/field, waterbody, and Built-up area.

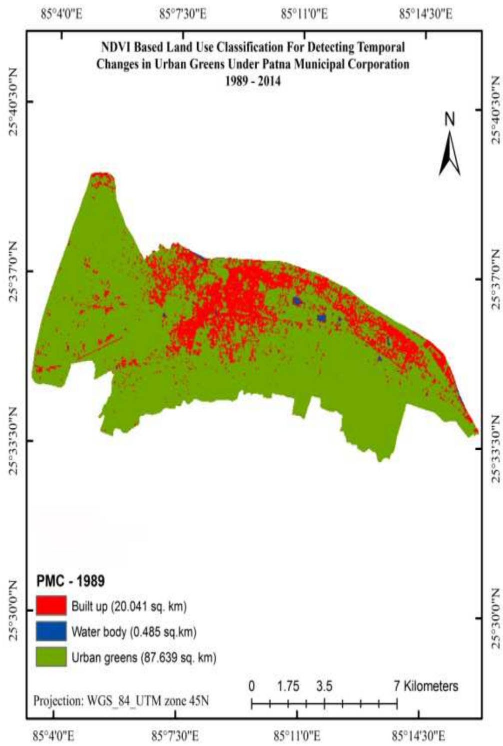
The processed result show significant changes in land cover land use pattern in Patna Municipal Corporation in last twenty five years including the area under total urban greens and effective urban greens. The area under total urban greens was 43.013 km^2 in 1989 which first increased to nearly 15% in 1993 to 50.3 km^2. But after 1993 to 2014 there is rapid decline in all the areas falling under urban greens including the most important part which has been categorized as Effective Urban Greens.

Table 3: Statistical Analysis of Land Cover Land Use Pattern in Patna Municipal Corporation (CLASS - 1 / Total Urban Greens)

Land cover / Land use	Area in km^2 1989	Area in km^2 1993	Area in km^2 1999	Area in km^2 2005	Area in km^2 2009	Area in km^2 2014
Built-up	20.040	23.561	32.154	39.654	55.0	62.395
Waterbody	0.485	0.356	0.998	0.424	0.859	0.674
Total Urban greens	87.639	84.247	75.012	62.716	60.045	50.715
Total	108.164	108.164	108.164	108.164	108.164	108.164

Table-3: Statistical analysis of Land Cover Land Use Pattern in Patna Municipal Corporation (CLASS -2 / Effective Urban Greens)

Land cover / Land use	Area in km^2 1989	Area in km^2 1993	Area in km^2 1999	Area in km^2 2005	Area in km^2 2009	Area in km^2 2014
Built-up	20.041	23.562	32.155	39.654	55.0	62.395
Waterbody	0.485	0.356	0.998	0.424	0.859	0.674
Open field / Ineffective Urban Greens	44.625	33.946	32.574	36.035	30.119	28.815
Effective Urban greens	43.013	50.4	42.437	32.051	22.185	16.28
Total	108.164	108.164	108.164	108.164	108.164	108.164



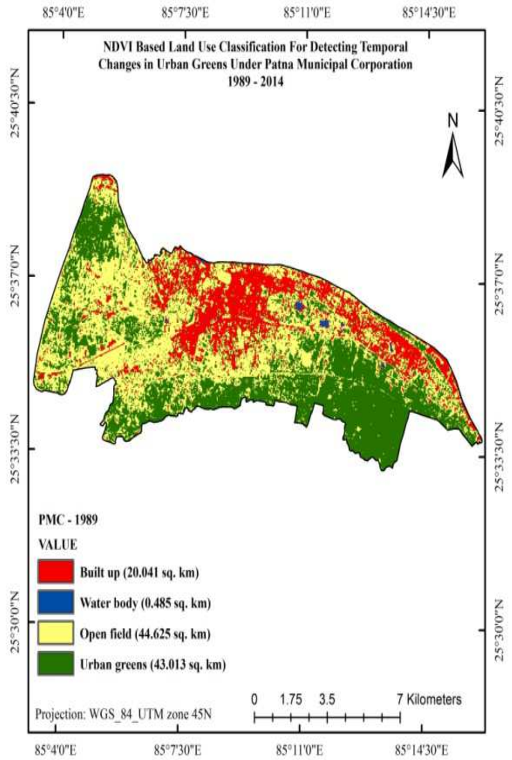
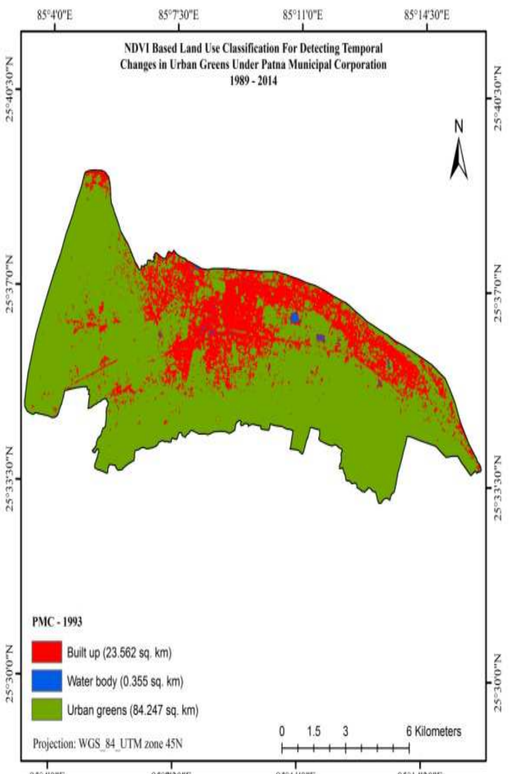


Fig. 2(A) PMC, CLASS - 1 (1989)

Fig. 2(A-1) PMC, CLASS -2 (1989)



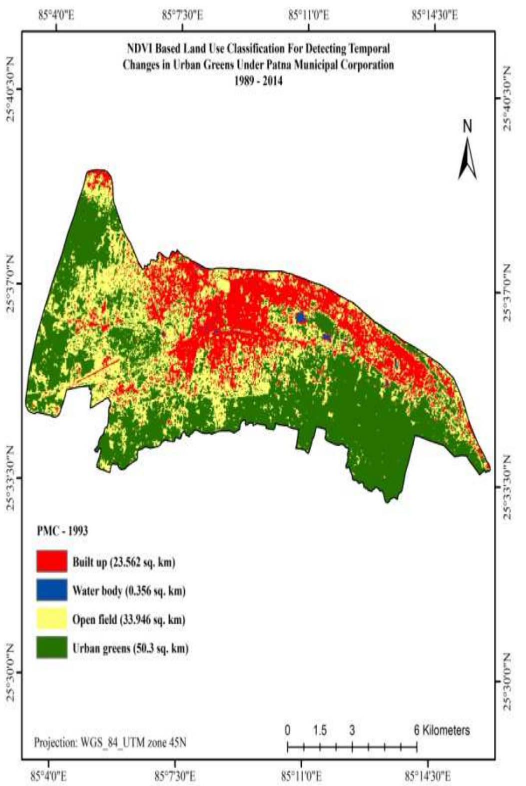


Fig. 2(B) PMC, CLASS -1 (1993)

Fig. 2(B-1) PMC, CLASS -2 (1993)

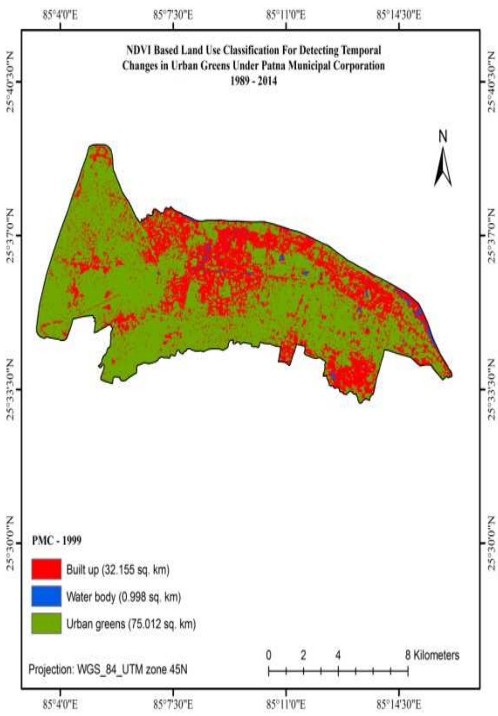


Fig. 2(C-1) PMC, CLASS - 1 (1999)

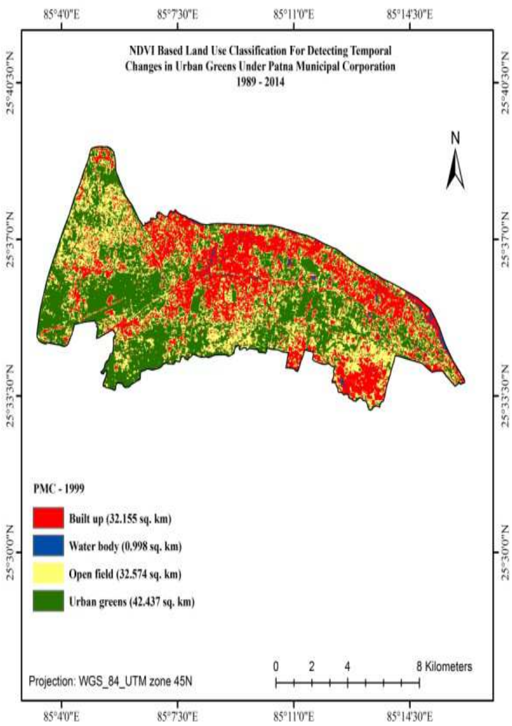


Fig. 2(C-1) PMC, CLASS -2 (1999)

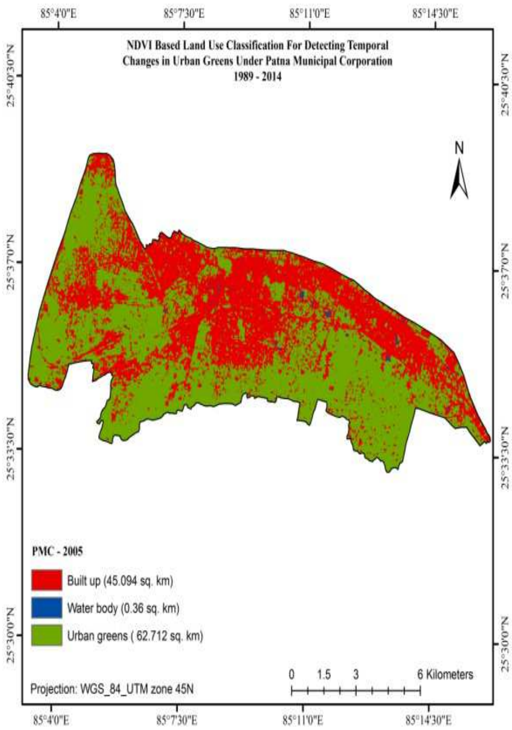


Fig. 2(D) PMC, CLASS - 1 (2005)

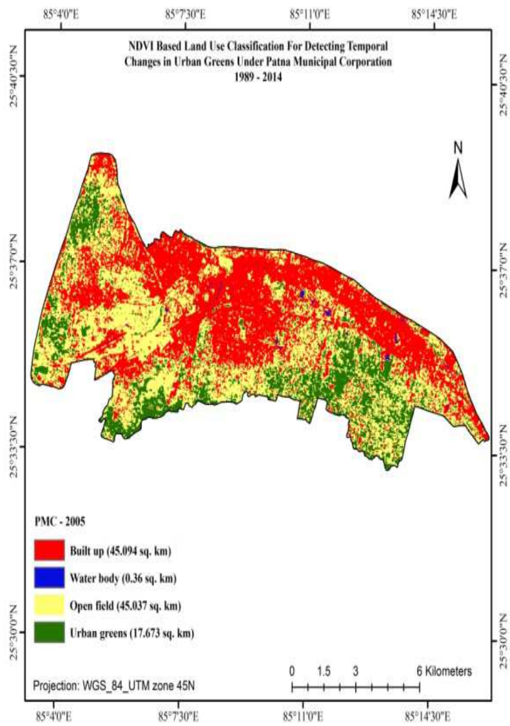


Fig. 2(D-1) PMC, CLASS - 2 (2005)

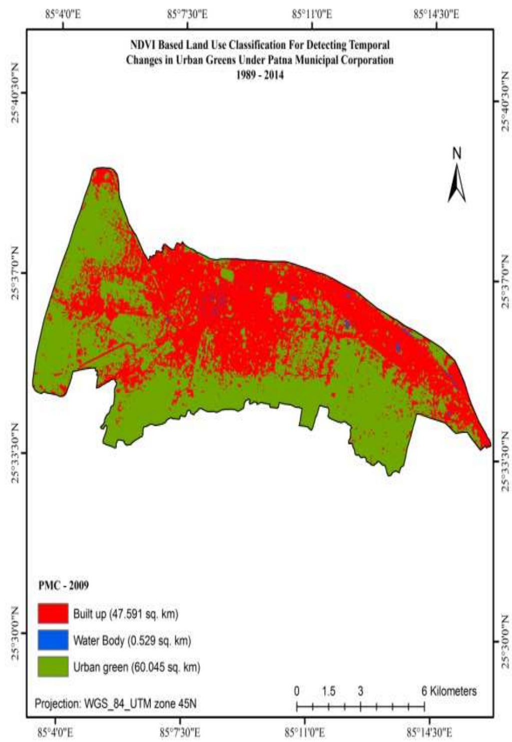


Fig. 2(E) PMC, CLASS - 1 (2009)

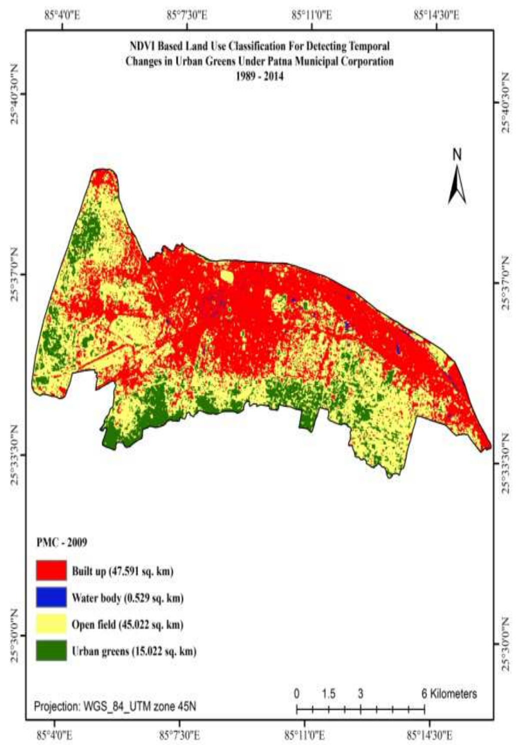


Fig. 2(E - 1) PMC, CLASS - 2 (2009)

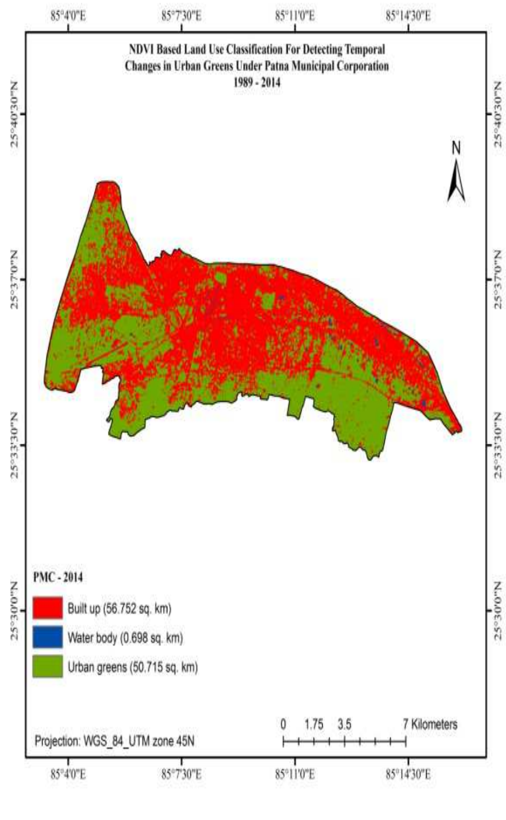


Fig. 2(F) PMC, CLASS - 1 (2014)

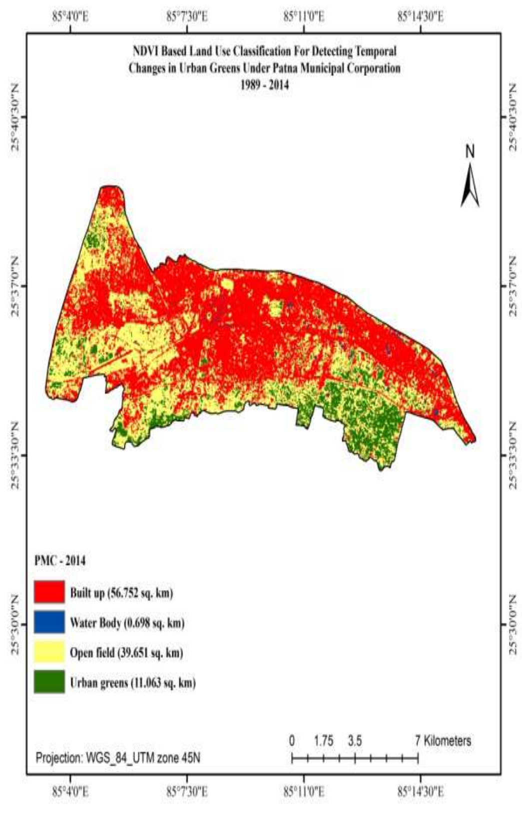


Fig. 2(F-1) PMC, CLASS - 2 (2014)

3.1. Built-up Area:

Both the CLASS-1 (classification that includes all the open spaces of a municipal / city area under urban greens) and CLASS -2 (Pixel based effective greenness classification which filters dry open fields from the actual green cover) shows the similar result for the Built-up area. With the rapid growth in urbanization Patna Municipal Corporation (PMC) has registered the maximum growth in Urban Built-up area. The present study shows that in 1989 the Built-up area under this urban zone was 20.041 km^2 which increased to 62.395 km^2 in 2014. The maximum rate of growth in this area was recorded between years 2005-2009. The Built-up area was 39.654 km^2 in 2005 which increased to 15.346 km^2 in just four years to cover a total area of 55.0 km^2.

3.2 Waterbody:

Here again both the CLASS -1 and CLASS -2 classifications show the similar results. The area under waterbody has shown fluctuations. In 1989 area under it was 0.485 km^2 which decreased slightly in 1993 to 0.356 km^2, again it increased to 0.998 km^2 in 1999 and then decreased to 0.424 km^2 in 2005. It increased in 2009 to 0.859 km^2 and then again shrunk to 0.673 km^2.

3.3 Open Field/Space:

According to the CLASS -1 classification and definition all the open spaces that fall in a municipal/city area comes under urban greens. But according to the CLASS -2 classification dry open spaces are separated from the pixel based green spaces. Here the result shows that these spaces have decreased over the years. In 1989 the dry open areas under the Patna Municipal Corporation area was 44.625 km^2, it was reduced to just 28.817 km^2 in 2014. The only exception year in between was 2005 where the open area increased comparing to its previous base year probably because the low rainfall in previous year monsoon.

3.4 Urban Greens:

The present paper mainly focuses on the urban greens of urban area. For the sustainable development of an urbanized city or a municipal area this vegetative part plays an important role. The growth of vegetation (urban greens) is more concerned with the simulation of physiological processes such as the analysis of photosynthesis, transpiration, respiration, distribution of dry matter among plant organs and water absorption by roots and carbohydrate assimilation in early literature (Dewit, et al., 1969). Later on, vegetation growth models were developed in order o examine the physiological processes and phenological events, their stages and environmental stress using Potential Evapo Transpiration based plant growth index, photosynthetic efficiency index for measurement of reproduction the green leaf biomass (Mc Call, et al., 2003) and Thornthwaite - based thermal efficiency index (Singh, et al., 2006). Recently, biophysical environment of vegetation and its growth have widely been parameterized by using remotely sensed data with various techniques of predicting green leaf biomass (Ashbindhu, et al., 1989), ground water potentials (Gupta, et al., 2008), rate of Potential Evapo-Transpiration (PET), Net Primary Productivity (NPP) and vegetation index (Ricotta, et al., 1999).

In general the area under urban greens has shown a inversely proportional relation with the urbanization trend of Patna municipal corporation area. The statistical analysis in table-3 shows that after 1993 the total area under urban greens has reduced more than one third of its original size which is very alarming for the city planners because the sustainability of a city is negatively affected by the reduction in its productive part. Going by the in trend [Figure 3(D) and Figure 3(E)] we can easily infer that the per capita urban green areas under Patna Municipal Corporation has definitely halved since 1989.

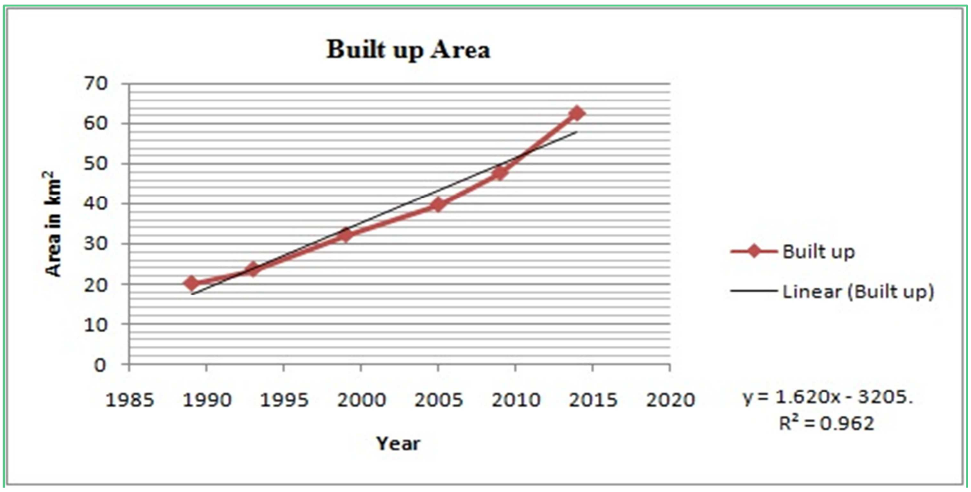


Fig. 3 (A) Correlation of Built-up area increase with Time (1989 -2014)

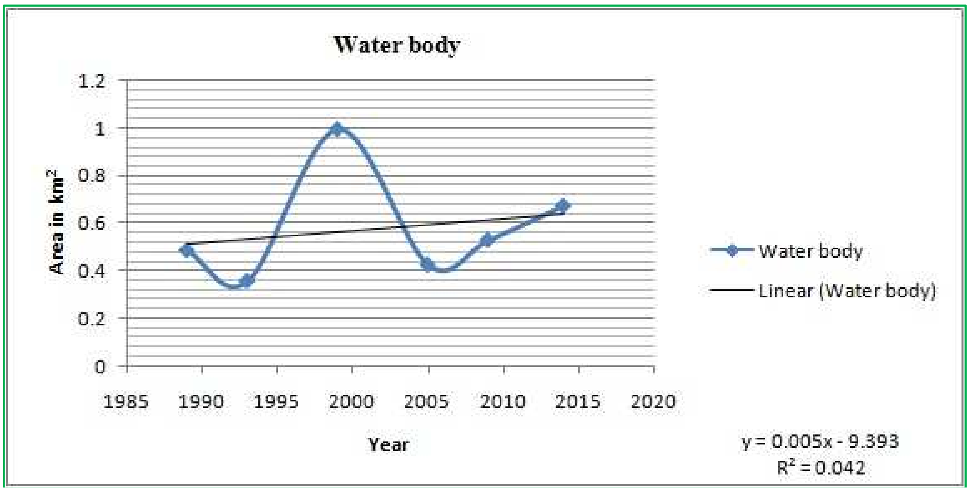


Fig. 3 (B) Waterbody area fluctuations over the years (1989 -2014)

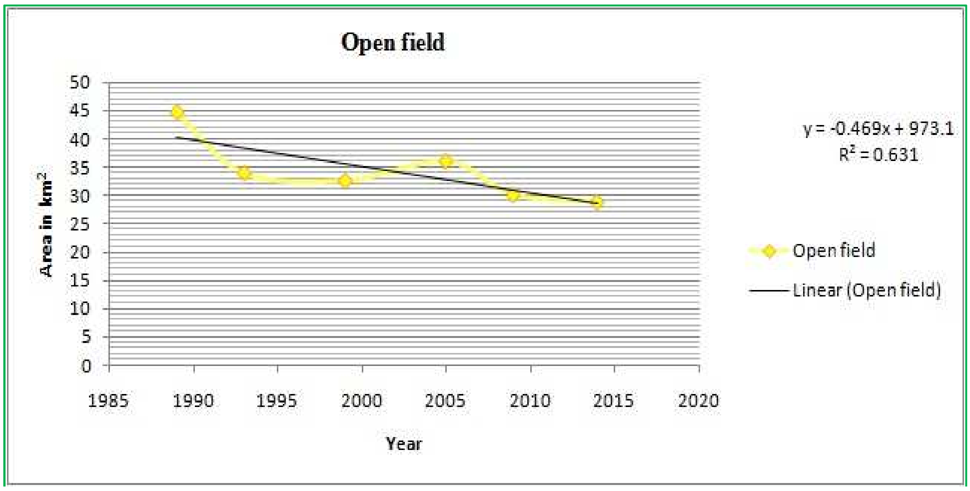


Fig. 3 (C) declining areas of Open spaces over the years (1989 -2014)

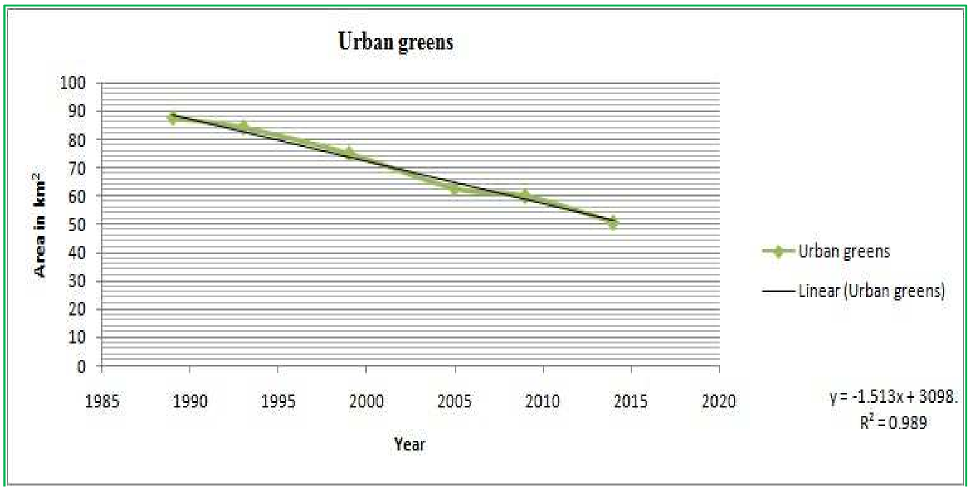


Fig. 3 (D) Class -1, Trend of declining Urban greens over the years (1989 -2014)

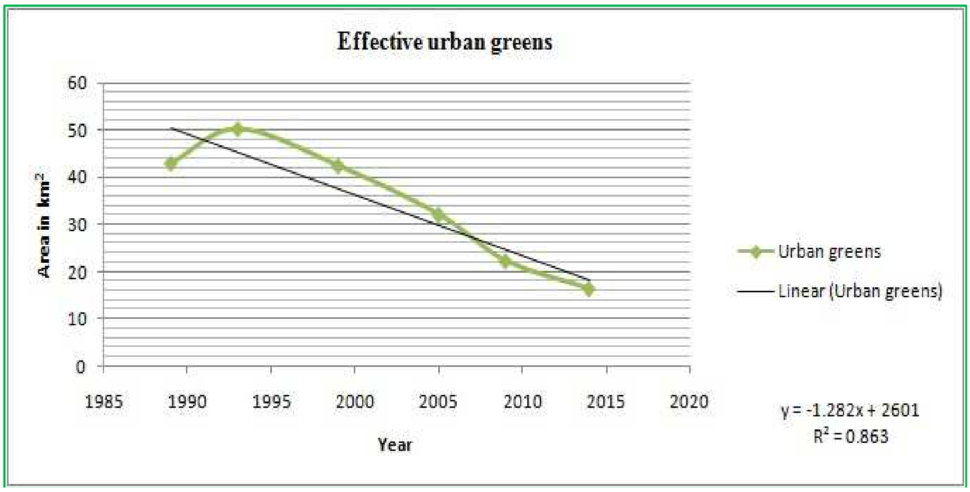


Fig. 3 (D - 1) CLASS - 2, Trend of declining Urban greens over the years (1989 -2014)

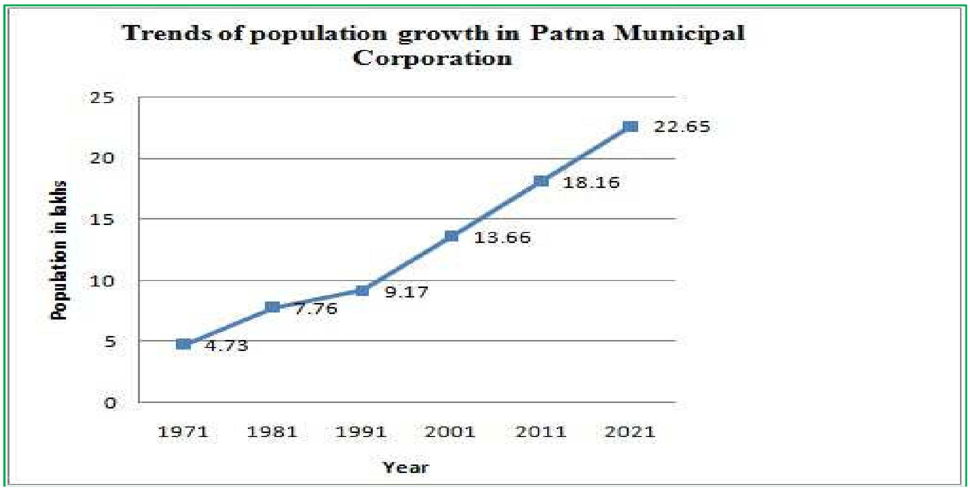


Fig. 3 (E) Government data and projection for population growth in PMC

4. Conclusions:

A strong interrelation between population growth, urbanization and decreasing urban greens has been established in the present assessment. The study reveals that the per capita effective urban greens (vegetative part of the urban area) have considerably reduced in last quarter century. Degeneration of effective urban greens will cause deterioration of healthy and aesthetic environment of the cities. Inhabitants will be confronted with the problems of air pollution and noise pollution. Consequently urban dwellers suffer from various kinds of pollutant induced diseases, deafness etc. Decline in quality of life will indirectly lead to malice-ridden urbanization. In India 35% of the population live in cities and the urban population has grown at a rapid pace during the last decade. Hence the land-man ratio in the cities is shrinking. This will have a profound effect on urban greens. The effective urban greens effectively reduce city air temperature by creating 'micro-climate'. The reduction in ' urban heat island' effect is directly related to plants which provide shade as well as cools the surrounding area by evapo - transpiration cooling. Urban greens including the tress act as important keystone species in denuded urban environments, and provide important support for urban wildlife (Krishen, 2006). With the declining greenery in Patna Municipal Corporation one can observe that flock of house sparrows; crows and other birds are not as visible as earlier days. The vegetative cover regulates the water cycle and intensity of erosion. Instead of seeping into the soil the rainwater drains away as the surface flow and causes considerable erosion, water logging and sedimentation along the Ghaats along the Ganga River. Lastly, the consequence of vanishing urban greens is causing 'urban stress' - a new approach to the ill effects of shrinking urban greens. The present paper has developed a new concept of ***per capita effective urban greens*** which can also be taken into consideration for the planning of a sustainable city or an urban area. This can be calculated by the following formula;

Per capita Effective Urban Greens =
Total Area under Effective Urban Greens / Population of the Area

Where a urban or a municipal area under urban greens can easily be calculated by remote sensing techniques using the above mentioned Normalized Difference Vegetation Index (NDVI) formula of equation one. Then a higher value of per capita urban green can be considered as more sustainable and healthy environment for living.

5.0 Acknowledgments:

The authors are thankful to Dr. Sudeepta Adhikari (Former Vice Chancellor of Patna University) and Dr. Ravi Kiran Sharma (Professor, Department of Geography, Patna University) for their kind support and making an understanding of technically new concept of "Urban Greens" in this study.

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