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The comparative vegetation cover assessment of the greater Bangalore using high resolution satellite imagery

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Abstract

Bangalore is experiencing unprecedented urbanization in recent times due to concentrated developmental activity resulted in the increased population and consequent pressure on infrastructure and natural resources, which ultimately gives rise to plethora of serious challenges like climate change, green house effect and frequent flooding of low lying areas. Urban forests or urban vegetation is an integral part of this urban structure providing a lattice of green in an otherwise artificial landscape. "The value of an urban forest is equal to the net benefits that members of society obtain from it" (McPherson et al. 1997). In the present study vegetation distribution across 8 zones of Bangalore Metro area is assessed by NDVI and TNDVI transformed 2005 Quick Bird imagery. Both NDVI and TNDVI, a biophysical variables clearly unravel the pattern of vegetation distribution across different zones of Bangalore metro. Among the different zones high NDVI value was observed in Byatarayanapur followed by West. The zones in outskirts of the metro area once characterized by thick plantations and forest cover now shows phenomenal decrease in vegetation. The zones in central metro area once famous for parks, gardens and plenty of avenue trees mainly responsible for calling Bangalore as "garden city" is metamorphosized into concrete jungle. Urbanization is happening at a very fast rate and at the cost of agricultural land and plantation in the outskirts of metro, which is described as National Natural Resource Census (NRC) hot spot areas for further studies and monitoring. Urban sprawl is observed as 9% and around 177 km2 of agricultural land has been converted into built up area in the last 5 to 6 years. The Zone-wise assessment of vegetation distribution using high resolution satellite imagery can illustrate how urban vegetation cover and its associated benefits vary across the Bangalore Metro and this data can be used to compare urban vegetation cover estimates among zones.

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Introduction

Vegetation monitoring presents valuable information for understanding the natural and man-made environments through quantifying vegetation cover from local to global scales at a given point of time or over a continuous period. It is critical to obtain current status of vegetation cover in order to initiate vegetation protection and restoration programs (Egbert *et al.,* 2002; He *et al* 2005). Urban vegetation is an essential component of "green infrastructure", which plays a significant role in one's judgment for urban Quality of Place (QOP) and is one of the important implication areas of urban image classification techniques. Urban green areas have considerable ecological benefits that serve to sustain human and environmental health (Che Lam et al. 2005; Myeong, Nowak and Duggin 2006; Peng et al. 2008). Bangalore once green city of India is experiencing unprecedented urbanization in recent times due to concentrated developmental activity resulting in the increased population and consequent pressure on natural resources particularly vegetation and aquatic ecosystem which are showing great decrease in both quality and quantity. The current study on the vegetation pattern across eight zones of Greater Bangalore (BBMP) using NDVI and TNDVI transformed 2005 Quick Bird imagery is very significant as urban forestry literature on the study area is very scarce and limited. Both NDVI and TNDVI are biophysical variables commonly used for assessing urban vegetation cover and they also minimize the effect of soil brightness, environmental effects, soil color, moisture and shadow as these are major complex mixture of vegetated areas which interfere in the vegetation response. The NDVI and TNDVI transformed images are grey scale continuous data sets. The vegetation cover is depicted as varying level of brighter patches and the shift towards darker regions of the grey is due to the presence of built ups and water bodies. The primary goal of this research is to determine which of the two common vegetation indices is most accurate in this study area and for these types of biotic communities (tropical with a dry-deciduous forest dominated landscape). The vegetation pattern showed lot of variation across different zones, depending in part on the location and size of the zones, population density, development intensity and surrounding natural vegetation cover. In the NDVI transformed image, high percentage of vegetation cover was observed in Bommanahalli and lowest in South zone, while in TNDVI, high percentage was observed in Byatarayanapura and lowest in West. Water areas are more obscured in TNDVI image and are depicted as vegetative areas in some places. The vegetation cover is depicted in a more concise manner in NDVI transformed image than in TNDVI. Hence in the current research, NDVI can be considered as best vegetation indices for assessing the vegetation cover across different zones of Bangalore and this could provide the basis for developing urban forest inventories which is lacking in the present study area. The main objective of the study is to determine which of the two common vegetation indices is most accurate in the vegetation assessment and to illustrate how urban vegetation cover and its associated benefits vary across the different zones of Greater Bangalore.

Material and methods

Study area

Bruhat Bangalore Mahanagara Palike (BBMP) is situated in the heart of Deccan plateau in peninsular India to the South-Eastern corner of Karnataka State between latitude parallels of 12°39'00" N & 13°1'00" N and longitude meridians of 77°22'00" E and 77°52'00" E at an average elevation of 900 mts above mean sea level and has an area of 800 Km2 and supports 80 lakh population. Administratively BBMP is divided into 8 Zones (Byatarayanapura, Mahadevapura, Bommanahalli, R.R nagar, Dasarahalli, West, South and East zone).

Data products

The present study is carried out using the 2005 Quick Bird imagery and Survey of India Toposheets of scale 1:50000; Erdas 9.2 and ArcGis 9.2 were used for image processing and GIS analysis respectively.

Methods

Methodology is based on the combination of techniques to extract information from Remote sensing (RS) data.

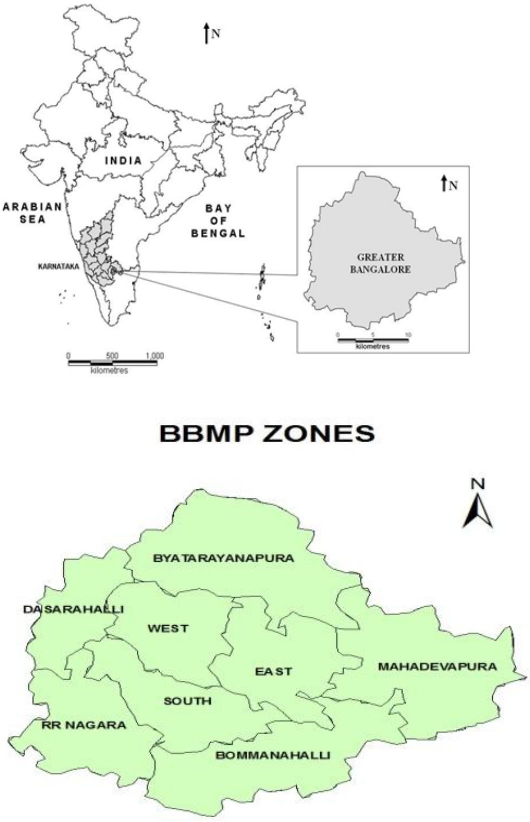


Fig. 1. Study area_BBMP (Greater Bangalore) and BBMP Zones.

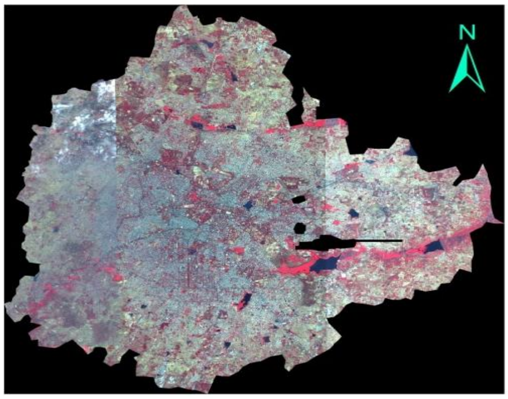
Creation of base layer

Base layers like district boundary and zonal boundaries were created using SOI toposheet of scale 1:50000.

Georeferencing of RS data

The Quickbird satellite data was geocorrected with 20 ground control points and projected to UTM coordinate system with WGS 84 as datum.

The Normalized Difference Vegetation Index (NDVI) and Transformed Normalized Difference Vegetation Index(TNDVI)



FCC Quick Bird_Bangalore

spectral data into a single image band which represents vegetation distribution was computed using standard algorithm

NDVI = (NIR – R) / (NIR + R)

TNDVI= Sqrt ((NIR– R /NIR+ R) + 0.5)

NDVI- RGB False color composite(FCC)

The NDVI-RGB FCC of vegetation was developed to display and quantify vegetation change.

One way anova

One way anova was applied to compare TNDVI and NDVI mean values of 8 zones of Bangalore Metro.

Scatter plot

was constructed to find the correlation between TNDVI and NDVI, Vegetation Percentage and Population Density of different zones of BBMP.

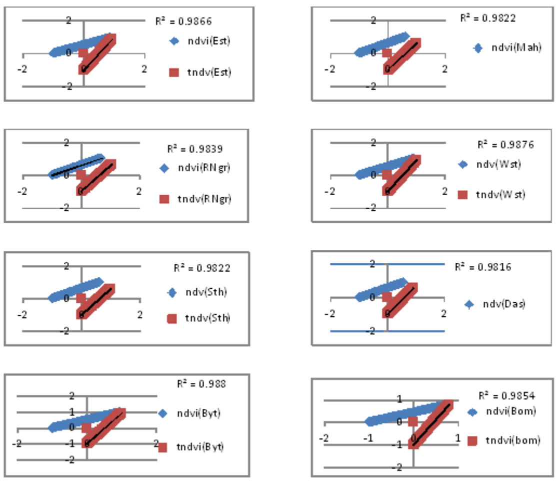


Fig. 5. *Scatterplots of TNDVI vs. NDVI for eight zones of BBMP.*

Results and discussion

In the present study Quick Bird image of 2005 of Bangalore Metro is taken for comparative vegetation assessment using NDVI and TNDVI indices. The FCC (False Color Composition) of the study area (Fig. 2) is prepared using 4, 3, 2 bands of the Quick Bird.

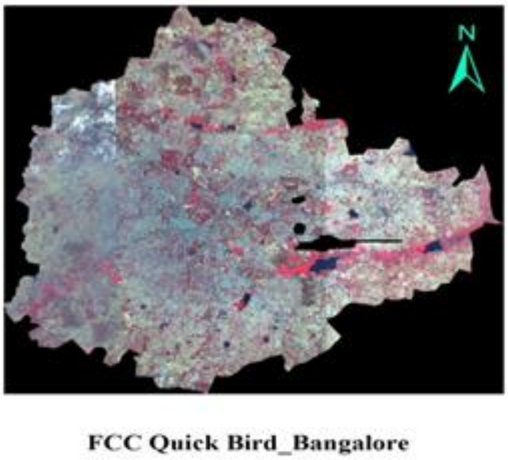


Fig. 2. *FCC of Study area_BBMP.*

Normalized Difference Vegetation Index (NDVI) and Transformed Normal Difference Vegetation Index(TNDVI) have proven to possess an extremely wide range of applications in measuring urban vegetation cover (Brown et al. 1993; Evans, Zhu and Winterberger 1993; Loveland et al. 1991; Townshend, Justice and Skole 1994). The NDVI/TNDVI transformed image is classified into 5 different classes based on NDVI/TNDVI values, which varies between -1 and +1 for NDVI and between 0 and 1 for TNDVI and are given pseudo color in varying shades of green (vegetation) and Red(water). The five classes were identified as Water, Impervious surfaces, Soil, Sparse Vegetation and Dense Vegetation. In Fig III & IV dark red pixels indicates water bodies, light red shows built ups and impermeable surfaces, yellow pixels indicates bare soil and fallow lands, green pixels represents the vegetation areas. Dense vegetation shows up very strongly in the imagery and areas with little or no vegetation can be clearly identified (Wilson et al. 2003; Wilson, Brother and Marcano 2000).

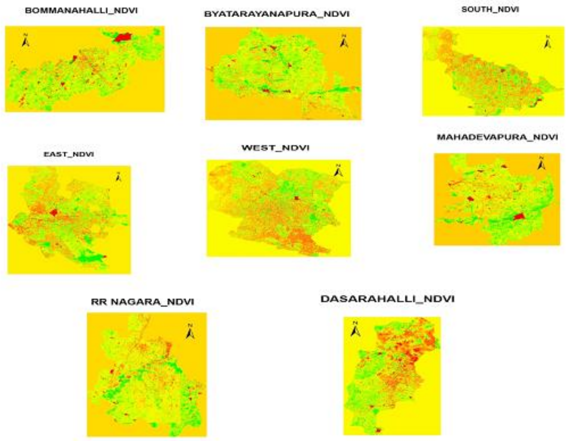


Fig. 3. NDVI image of BBMP Zones. Red colored pixels indicate a reduction in vegetative reflectance, while Green colored pixels indicate an increase in vegetative reflectance.

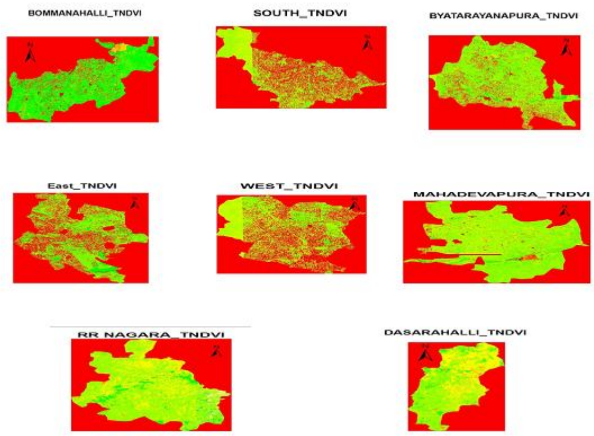


Fig. 4. TNDVI image of BBMP Zones. Red colored pixels indicate a reduction in vegetative reflectance, while Green colored pixels indicate an increase in vegetative reflectance.

A closer look at the values of NDVI by land use category (Table I) indicates continuous decrease in NDVI as we move from dense vegetated area to non vegetation area like built ups and water bodies. The NDVI values in the above table follows the same trend as it is observed by Briggs et al. 1997. In dense vegetation category comprising mainly grass and trees (parks, forest and plantations) mean NDVI values varies between 0.387 and 0.606. Scrub vegetation are categorized as sparse vegetation. Soil class represents open fields and fallow lands. The buildings, roads and other concrete structures are brought under impervious surface class. Water, a good absorber of near-infrared radiation shows the lowest NDVI mean, which range between -0.651 to -0. 582 for different zones.

Visual analysis of the scatter plots (Fig. 6A.) to determine the correlation between the percentage of vegetation and impervious surfaces of eight zones of BBMP showed significant linear relationship.

We can also observe (Fig. 6B.) a negative correlation between vegetation percentage and population density and a positive correlation between % impervious surfaces and population density. This clearly shows that increasing urbanization has negative effect on vegetation of the area which is showing marked decrease, especially in the outskirts of the city.

In the pie chart of NDVI image (Fig. 7.), Percentage Vegetation cover across different zones vary from 40.66% in "Bommanahalli" followed by 38.28 % in "RR Nagar" to 19.9 % in south Zone. The Vegetation cover shows large scale depletion in South zone and West zone once famous for large green areas in the form of number of parks, avenue trees, trees in residential areas and a famous Lalbagh Botanical Garden in "South zone" and Golf Course and Indian Institute of Science campus in West zone comprising mainly old big trees. Large number of developmental works like ring roads, road widening and construction of sub-ways have taken heavy toll on vegetation in these areas (about 300 old big trees, which once used to line streets of Bangalore are cut for this projects-BBMP Report on Urban forestry).

In the pie chart of TNDVI image (Fig. 7.), percentage vegetation cover across different zones vary from 39.53 % in "Bommanahalli" zone to 17.34 % in "Byatarayanapura" Zone. The high percentage of vegetation in "Bommanahalli" zone is mainly attributed to the presence of state forest, plenty of plantation areas and parks which is in line with the observation made by Nowak et al. 1996.

Dense vegetations are generally restricted to zones in the outskirts of the metro, while built up is dominant in zones of the central metro area like West, East and South zones. The large extent of vegetation cover is replaced by rapid expansion of built up area especially in the outskirts of the city. The Urbanisation process increased in 2000 to 2006 indicating higher entropy value, as the distribution of built up during 2000-2006 was more dispersed than in 1973 or 1992 (Ramachandra and Uttam Kumar 2009).

The present study comprising different zones help to show the zonal variation in vegetation picture and urbanization of the Bangalore in a much more elaborated manner and further this data can be used to compare vegetation cover estimates among zones as observed by Jain et al (2011). Vegetation cover can serve as an indicator of the extent to which trees and forests are providing critical services to local residents.

The percentage vegetation cover shows gradual increase as we move from inner boundary to outskirts of the city. In recognition of the importance of urban forestry, the U.S. Conference of Mayors recently conducted an urban forestry survey of 135 U.S. cities with populations of 30,000 or more. Their final report (City Policy Associates 2008) recognizes "the invaluable role of urban forests in the protection of public health and the reduction of harmful greenhouse gases".

The validation of results shows that the vegetation cover is depicted in a much more concise way by NDVI transformed Quick bird imagery than TNDVI. Lillesand and Kiefer (2000) and Quackenbush et al. (1999) observed that NDVI helps in compensating for image variations caused by changing illumination conditions and surface slope and therefore could be used to mitigate the shadow effect of high-spatial resolution imagery and to improve the classification of vegetated areas. NDVI is also used as an ecological indicator to successfully monitor temporal and spatial variation in vegetation density as well as the health and viability of plant cover (Fung and Siu 2000; Jiang et al. 2008; Wang, Price and Rich 2001; Weng, Lu and Schubring 2004). The literature on vegetation of Bangalore is very scarce and limited. A comprehensive study on urban forests of Bangalore was made by Sudha and Ravindranath (2000) found 374 species in the different land-use categories. Species richness was found highest in parks (291 species) followed by residential areas (164), institutions (126), temples (107) and commercial areas. Similar study carried out by Nagendra and Gopal (2010) showed that density of street trees in Bangalore is lower than many other Asian cities, but the species diversity is high. There is a greater need to improve documentation and synthesize available information on urban forestry of Bangalore. The present study is an important step in this direction where in the NDVI/TNDVI estimation of vegetation cover gives broader picture of the vegetation of the area, which could be used as a basis for developing urban vegetation cover inventories covering several hundred square kilo meters and in establishing automatic system for inventory updates and vegetation monitoring.

Table 1. NDVI for various land uses in eight zones of BBMP

Zones	Water	Impermeable surface	Soil	Sparse Vegetation	Dense Vegetation
	NDVI Mean±SD	NDVI Mean±SD	NDVI Mean±SD	NDVI Mean±SD	NDVI Mean±SD
BYATARAYANAPURA	-0.650± 0.202	-0.147± 0.090	0.049± 0.025	0.161± 0.041	0.606± 0.217
BOMMANA HALLI	-0.651 0.203	-0.142± 0.091	0.063± 0.029	0.158± 0.027	0.578± 0.217
DASARAHALLI	-0.592± 0.228	-0.102± 0.056	0.029± 0.022	0.125± 0.034	0.387± 0.118
WEST	-0.651± 0.203	-0.142± 0.091	0.063± 0.029	0.158± 0.027	0.578± 0.217
SOUTH	-0.634± 0.210	-0.131± 0.082	0.072± 0.037	0.202± 0.039	0.536± 0.155
MAHADEVPUR	-0.592± 0.234	-0.105± 0.048	0.058± 0.048	0.185± 0.026	0.425± 0.114
EAST	-0.620± 0.221	--0.122± 0.068	0.068± 0.043	0.192± 0.030	0.558± 0.182
RR NAGAR	-0.582± 0.238	-0.101± 0.041	0.014± 0.027	0.111± 0.029	0.432± 0.158

Table 2. TNDVI for various land uses in eight zones of BBMP:

Zones	Water	Impermeable surface	Soil	Sparse Vegetation	Dense Vegetation
	TNDVI Mean±SD	TNDVI Mean±SD	TNDVI Mean±SD	TNDVI Mean±SD	TNDVI Mean±SD
BOMMANAHALLI	0.185± 0.106	0.420± 0.029	0.485± 0.008	0.520± 0.012	0.666± 0.071
BYATARAYANAPURA	0.165± 0.096	0.378± 0.028	0.440± 0.008	0.479± 0.014	0.612± 0.063
DASARAHALLI	0.285± 0.164	0.617± 0.028	0.708± 0.025	0.774± 0.013	0.854± 0.033
WEST	0.276± 0.159	0.619± 0.039	0.742± 0.032	0.820± 0.013	0.930± 0.051
SOUTH	0.268± 0.155	0.610± 0.043	0.737± 0.031	0.845± 0.032	0.951± 0.030
MAHADEVPUR	0.296± 0.177	0.638± 0.033	0.743± 0.028	0.827± 0.020	0.926± 0.037
EAST	0.206± 0.119	0.470± 0.034	0.570± 0.024	0.631± 0.011	0.791± 0.082
RR NAGAR	0.203± 0.119	0.491± 0.048	0.614± 0.024	0.688± 0.019	0.885± 0.095

Table 3. Anova depicting difference in NDVI among eight zones of metro at 95 % (p<0.05)

	DF	F-value	p-value(<0.05)
Variance in NDVI between Zones	7	4.722505	2.84
Variance in NDVI Within Zones	2040		
Total	2047		

Table 4. Anova depicting difference in TNDVI among eight zones of metro at 95 % (p<0.05)

	DF	F-value	p-value(<0.05)
Variance in TNDVI between Zones	7	11.79706	8.412
Variance in TNDVI Within Zones	2039		
Total	2046		

Summary and conclusion

In the current study, NDVI/TNDVI indices are taken for assessing the vegetation cover of BBMP in different zones of Bangalore using 2005 quick bird imagery and is supplemented by ancillary data sources, which provide information on the land use history as characterized by high population growth and rapid urbanization. The variation in NDVI/TNDVI values across different zones were estimated using single factor one way anova which did not show much significance. A strong linear relationship was observed between percentage of vegetation and impervious surfaces of different zones. The validation of results according to ground truth revealed that NDVI is best tool for monitoring vegetation cover in urban environment by Quick Bird data set. This is due to the fact that the near-infrared reflectance (Band 4 in quick Bird) that is closely related to the physical structure of healthy leaves. The efficiency of NDVI in detecting the changes was proven by many earlier researchers (Lyon et al. 1998; Rose and Christopher 1999). The present study shows importance of satellite imagery in supporting urban vegetation cover and a similar reference was made by Maik Netzband and Carsten Jurgens (2010), where they have observed urban remote sensing as a useful tool for cross scale urban planning and urban ecological research.

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