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CRITICAL ANALYSIS OF VEGETATION DESTRUCTION IN THE NCT OF DELHI

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Abstract: Vegetation destruction is the outcome of the fast pace of urbanization and industrialization at the global level. Similar is the case of NCT of Delhi, where developmental processes have resulted in vegetation destruction. Both 'Open forest' and 'Dense forest' have under gone massive destruction due to the expansion of grey infrastructure and consequently, resulting in the shrinkage of 'Carbon Sink' in the NCT of Delhi. The present research study attempts to analyze trends and patterns of vegetation destruction in the NCT of Delhi during the period 1987-2006 by using the Geographical Remote Sensing (GIS) and Remote Sensing. The present research study is based on the remote sensing data of Landsat-7 (TM), Landsat-7 (ETM+) and IRS-P6 LISS III of 1987, 1999 and 2006 respectively. The data interpretation and analysis of vegetation destruction in the NCT of Delhi helps in understanding the changes in land cover, causes of vegetation destructionand impact of vegetation destruction on micro-climate.

Keywords: Vegetation, Vegetation Destruction,Urbanization, Carbon Sink.

Introduction

The people of Delhi, today would react with surprise and disbelief it they would be told that urban Delhi was once forested and inhabited by a variety of wildlife. The biotic and abiotic factors, governing the type of vegetation in Delhi are rather adverse. The area is characterized by long periods of water deficit coupled with high temperature. These characteristics give the region a semi-arid climate. The vegetation of Delhi comprises nearly 1000 species of flowering plants belonging to some 120 families (Khot, 1986). Sixty percent of species are either indigenous or naturalized and the remaining introduced. There is no endemic. More than 50 percent of the indigenous vegetation represents the tropical species. The vegetation destruction in the NCT of Delhi is the result of pressure of developmental processes to meet the demands of increasing population. The large tracts of forest area and cultivable land were encroached by the process of urbanization and industrialization. Vegetation destruction in the NCT of Delhi have adverse impact on the air quality, temperature regulation and other micro-climatic phenomenon.

The present research study makes an attempt to identify the spatial-temporal changes in vegetation destruction in the study area. Further, the basic purpose of the present research study is to promote ecological understanding regarding the importance of vegetation among the urban dwellers of the study area.

Objectives of the Study

The objectives of the present research study are as follows:

* To Critically analyze the trends and patterns of vegetation destruction during the period 1987-2006 in the NCT of Delhi.

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* To examine the causes of vegetation destruction during the 1987-2006 in the NCT of Delhi.

Methodology

The land use and land cover of the NCT of Delhi was carried out from satellite data of Landsat – To calculate the 'Rate of Change Per Year', we will use the following formula (Chebet, C. 2013):

$$R = \frac{Y - X}{T}$$

Where,

R = rate of change.

Y = the area (km^2) of the study area in the final year.

X = the area (km^2) of the study area in the initial year.

T = the time difference in years

Further, the use of software like ERDAS Imagine ver. 9.1 and ArcGIS ver. 9.1 is involved in the present research study.

Study Area

The present research study has been carried out on the NCT of Delhi, the capital city of India located between the 28° 24´17″ N to 28° 53´00″ N latitudes and 76° 45´30″ E to 72° 21´30″ E longitudes. The NCT of Delhi is situated near the western bank of river Yamuna which spreads over an area of around 1,483 km2 is surrounded by the Himalayas in the North and the Aravalli in the South-west (Figure 1). The hottest months are May and June with temperatures touching 48°C, whereas, the lowest falls to about 5°C at the end of December-January. The monsoon season lasts from July to September with maximum rainfall in the month of July (around 300 mm). The total population of Delhi was nearly 0.4 million in 1901, which increased slowly and reached 1.74 million in 1951 (4.35 times in Century) and reached 13.78 million in 2001 implying about 34.45 times increase in one century.

7 (TM), Landsat – 7 (ETM+) and IRS – P6 LISS III for the three different time periods 1987, 1999 and 2006. The data for the present research study has been obtained from the Global Land Cover Facility (GLCF) and National Remote Sensing Agency (NRSA), Hyderabad, India.

Land Use and Land Cover Changes During 1987-2006

The study area has an area of 148304.49 ha. Table1 contains the data showing the land use/land cover categories occupying major share includes built-up area (24.98%), waste land (20.34%), cultivable land (16.87%), open forest (17.65%). The land use/land cover categories occupying moderate share includes plantations (8.42%) and Dense forest (5.14%). The land use and land cover categories occupying minor share includes road/rail network (2.44%) and river/water body (4.16%).

During 1999, the land use/land cover category of urban built-up (Figure 2) experienced tremendous increase from 24.98% (1987) to 41.25% (1999). Though, the category of dense forest also experienced the slight increase from 5.14% (1987 to 6.74% (1999). The other categories experiencing the slight decline includes Open forest [17.65% (1987) &11.05% (1999)], plantations [8.42% (1987) & 7.82% (1999)], cultivable area [16.87% (1987) & 13.32% (1999)], road rail network [2.44% (1987) & 1.43% (1999)], river/water body [4.16% (1987) & 1.65% (1999)], waste land [20.34% (1987) & 16.74% (1999)].

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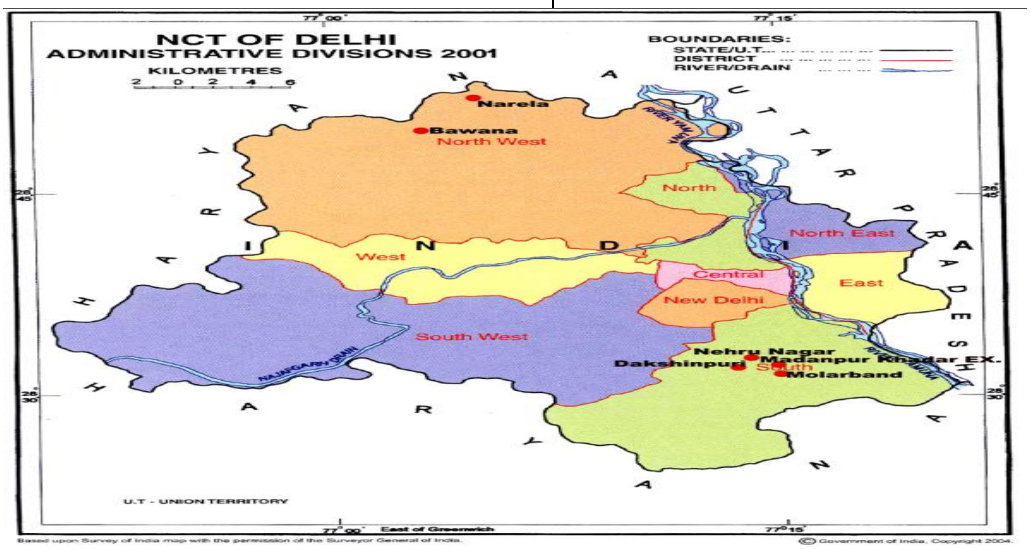

During 2006, the land use and land cover categories experiencing drastic increase includes road/rail (Figure 2) network [1.43% (1999) & 4.90% (2006)] and waste land [16.74% (1999) & 20.78% (2006)]. Unlike the previous year of 1999, the urban built-up experienced only slight increase that is from 41.25% (1999) to 42.58% (2006) along with the Open forest [11.05% (1999) & 11.21% (2006)]. The other categories which experienced the decline includes Dense forest [6.74% (1999) & 3.89% (2006)], plantations [7.82% (1999) & 5.28% (2006)], cultivable area [13.32% (1999) & 9.78% (2006)] and river/water body [1.65% (1999) & 1.52%(2006)]

Figure 1
Location Map of Study Area

Figure 2
Land Use and Land Cover Maps (1987-2006), NCT of Delhi, India

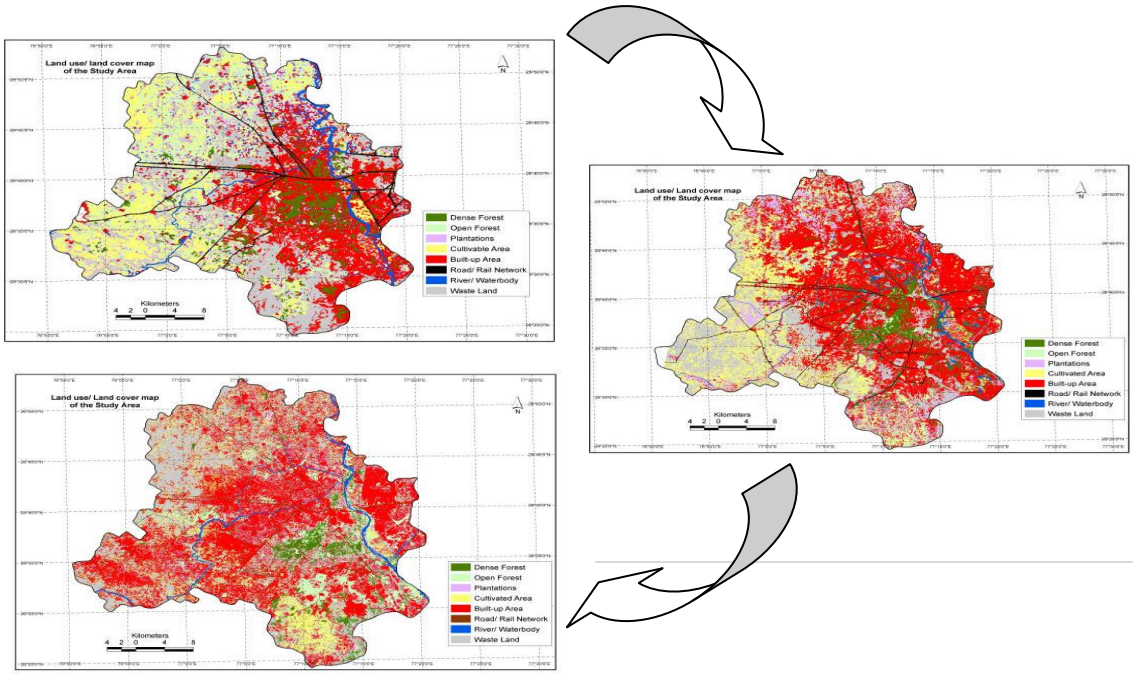

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Table 1
Area under Different Land Use and Land Cover Changes, 1987-2006, NCT of Delhi, India

Land Use/Land Cover Categories	1987 Area (ha)	%age	1999 Area (ha)	%age	2006 Area (ha)	%age
Dense Forest	7622.62	5.14	9960.34	6.74	5768.87	3.89
Open Forest	26174.95	17.65	16329.70	11.05	16718.24	11.27
Plantations	12486.86	8.42	11556.40	7.82	7835.07	5.28
Cultivable Area	25018.21	16.87	19684.31	13.32	14503.74	9.78
Built-Up Area	37045.34	24.98	60959.29	41.25	63146.14	42.58
Road/Rail Network	3618.52	2.44	2113.26	1.43	7261.53	4.90
River/Waterbody	6169.28	4.16	2438.37	1.65	2254.16	1.52
Waste Land	30164.22	20.34	24738.39	16.74	30816.74	20.78
Total	**148304.49**		**147780.06**		**148300.00**	

Source: Compiled by Author and Calculated from Satellite Images

Loss of Forest Cover and Cultivable Land During 1987-2006

The vegetation destruction during the period 1987-2006 have shown highly variable trends and patterns both in the category of forest cover and the cultivable area.

The area of crops rose in the forest and grazing lands or areas open for grazing within the forests should remain included under the forest area. It is an area notified for forestry boundary, predominantly with trees and other vegetation capable of producing either timber and other forest produce. Approximately, 11,000 ha. of forest lands (Open forest and Dense forest) were lost during the study period. Moreover, the NCT of Delhi is covered with open forest rather than the dense forest, therefore, conversion of open forest to other land uses was more prevalent. The land area under the Dense forest increased from 5.14% (1987) to 6.74% (1999) but in the year 2006, the land area under the dense forest decreased to 3.89% (Table 2, Table 3, Table 4). The discussion over the land use/land cover changes shows that there was an increase of 2337.72 ha. of land under the category of dense forest during the year 1999 but the increased demand of land for grey infrastructure resulted in the loss of 4191.47 ha. land. Open forest being more vulnerable experienced large scale of decrease from 17.65% (1987) to 11.05% (1999) with slight increase of 0.22% in the year 2006.

The cultivable/agricultural land is defined as the land primarily used for farming and production of food crops. It includes the land under irrigation and rain-fed crops, which are growing under different season in different farming activities. During 19 years, an area of around 10,000 ha. of agricultural lands was lost to built-up areas and road infrastructure. These agricultural lands were prominently spread in the north-western and western part of the NCT of Delhi up to 1987. The agricultural land in the NCT of Delhi have declined considerably during the study period. The agricultural land decreased to 13.32% (1999) from 16.87% (1987) and in the year 2006, the land area under agriculture was reduced to the 9.78% (2006) from 13.32% (1999). Near about 5333.9 ha of land was lost during 1987-2006 & 5180.57 ha. of land was lost during 1999-2006 (Table 2, Table 3, Table 4).

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Table 2
Difference in Area and Increase/Decrease in Forest Area & Cultivated Area, 1987-99, NCT of Delhi, India

Land Use Categories	1987 Area	%Age	1999 Area	%Age	Difference Area	%Age
Forest (Dense & Open)	33797.57	22.79	26290.04	17.79	-7507.53	-5.00
Cultivated Area	25018.21	16.87	19684.31	13.32	-5333.90	-3.55

Source: Calculated and Compiled by the Author
Note: Positive sign (+) indicates while the Negative sign (-) indicates decrease in area

Table 3
Difference in Area and Increase/Decrease in Forest Area & Cultivated Area, 1999-2006, NCT of Delhi, India

Land Use Categories	1999 Area	%Age	2006 Area	%Age	Difference Area	%Age
Forest (Dense & Open)	26290.04	17.79	22487.11	15.16	-3802.93	-2.63
Cultivated Area	19684.31	13.32	14503.74	9.78	-5180.57	-3.54

Source: Calculated and Compiled by the Author
Note: Positive sign (+) indicates while the Negative sign (-) indicates decrease in area.

Table 4
Difference in Area and Increase/Decrease in Forest Area & Cultivated Area, 1987-2006, NCT of Delhi, India

Land Use Categories	1987 Area	%Age	2006 Area	%Age	Difference Area	%Age
Forest (Dense & Open)	33797.57	22.79	22487.11	15.16	-11310.46	-7.63
Cultivated Area	25018.21	16.87	14503.74	9.78	-10514.47	-7.09

Source: Calculated and Compiled by the Author
Note: Positive sign (+) indicates while the Negative sign (-) indicates decrease in area

Rate of Change of Vegetation Destruction During 1987-2006

The Table 5 contains the calculated data of 'Rate of Change' of land use and land cover for the period 1987-2006 in the NCT of Delhi. During the period of 19years'vegetation destruction shows the negative rate of change. Forest (both open and dense forest), Plantations, Cultivable area shows the values of -595, -245, -553 respectively during the period 1987-2006.Now, the largest loss is faced by the forest cover (both open and dense forest) followed by the cultivable land and lastly, plantation areas which got encroached by the built-up expansion. The negative change in the forest land and the cultivable land shows that these two categories of land use/land cover experienced the loss of land and this loss of land took place due to the developmental activities involved in the built-up area and road/rail network.

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Table 5
'Rate of Change' of Land Use/Land Cover, 1987-2006, NCT of Delhi, India

Sl.No.	Land Use/Land Cover	1987-1999 Area (ha)	1999-2006 Area (ha)	1987-2006 Area (ha)	$R = \frac{Y - X}{T}$
1	Forest	-7507.53	-3802.93	-11310.46	-595.29 ~ -595
2	Plantations	-930.46	-3721.33	-4651.79	-244.83 ~ -245
3	Cultivable Area	-5333.90	-5180.57	-10514.47	-553.39 ~ -553
4	Built-up Area	+23913.95	+2186.85	+26100.80	+1373.72 ~ +1374
5	Road/Rail Network	-1505.26	+5142.27	+3643.01	+191.42 ~ +191
6	River/Waterbody	-3730.91	-184.21	-3915.12	-206.05 ~ - 206
7	Waste Land	-5425.83	+6078.35	+652.52	+34.34 ~ +34

Source: Calculated and Compiled by the Author
Note: Positive sign (+) indicates an increase while the Negative sign (-) indicates decrease in area.

Delhi Ridge: A Special Case of Vegetation Destruction

The Delhi Ridge and its neighboring hilly tracts represent the characteristic natural flora of the state, which is a tropical thorny secondary forest commonly known as arid open scrub forest (Maheshwari 1963). Such forests are widely distributed in the arid and semi-arid zones of the earth where the total annual rainfall ranges from 50-100 mm. The Delhi ridge is divided into four major sections (Table 6) viz. Northern Ridge or Old Delhi Ridge extending between civil lines and Delhi university, Central Ridge or New Delhi Ridge extending between Karol bagh and Dhaula Kuan, South Central Ridge extending from Mehrauli, covers JNU in middle course and ends at Mahipalpur and the Southern Ridge stretching from outside city to the Gurugram (earlier Gurgaon).

Table 6
Delhi Ridge and its Sub-Divisions in the NCT of Delhi, 2015

Sl. No.	Sub-Divisions	Range	Area (Ha.)
1	Northern Ridge or Old Delhi Ridge	Civil Lines to Delhi University	87
2	Central or New Delhi Ridge	Between Karol Bagh and Dhaula Kuan	869
3	South Central Ridge	Mehrauli-JNU-Mahipalpur	626
4	Southern Ridge	Outside City Limits up to Gurgaon	6200
	Total		7782

Source: Botanical Survey of India, Government of India, 2014-15

The tress comprising the perennial vegetation of the ridge are both indigenous as well as introduced (Table 7). The chief indigenous species are Acacia, leucophloea, A. modesta, A senegal, A arabica, A catechu, Butea monosperma, Anogeissus pendula, Cordia dichotoma, C. rothii, Tecomela undulata, Zizyphus mauritiana etc. (Maheshwari, 1963). The most important exotic species of the ridge is Prosopis juliflora, native of the arid regions of Mexico and Central America introduced in 1877. Other successfully introduced tress are Azadirachta indica, Feronia limonia, Dalbergia sissoo, Casia fistula, Albizzia lebbeck, Prosopis glandulosa etc. (Maheshwari, 1963). The thorny shrubs occur in widely spaced clumps supporting several twiners and climbers. Of these Capparis sepiaria is very common and abundant., growing alone or associated with

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Grewia tenax, Securinega lucophyrus, Carissa spinarum, Flacourtia indica etc.

Table 7
Dominant Species of Delhi Ridge, NCT of Delhi, 2015

Sl. No.	Sub-Divisions of Ridge	Name of the Dominant Species
1	Northern Ridge or Old Delhi Ridge	Acacia nilotica, Prosopis juliflora, Albizzia lebbeck, Casia fistula, Ergthrina variegate, Cariesa spinarum, Secuinega varosa, Zizyphus nummularia, Grewia tenax.
2	Central or New Delhi Ridge	Prosopis juliflora, Acacia nilotica, Butea Monosperma, Acacia levcopwoea, Casia fistula, Diospyros cordifolice, Azadirachta indica, Dalbergia siesoo, Ehretia laevia
3	South Central Ridge	Cariesa spinarum, Lantana indica, Zizyphus nummularia, Prosopis juliflora, Leptadaenia reticulate, Ricinus communis, Securinega virosa
4	Southern Ridge	Prosopis juliflora, Acacia spp, Zizyphus spp, Butea monosperma, Azadirachta indica, Dalbergia sisoo, Calotropis procera, Achyranthes aspera.

Source: Botanical Survey of India, Government of India, 2014-15

Out of four existing pockets of Delhi Ridge only two i.e. Northern Ridge and Central Ridge have substantial vegetal cover. Even here, most of the green areas have been transformed from natural and semi-wild scrub land into artificial landscape gardens which is not suitable for ecosystem stability. Western portion of the Northern Ridge is under severe biotic pressure while eastern flank is comparatively less disturbed. Some portion of the Central Ridge have good forest cover (with crown density >40%). Besides it has the only surving native floral elements like Diospyros montana, Cardia dichotom, Cardia rothii, Ehretia laevis, Grewia tenax, Capparis sepiavia etc. The habitat destruction in the Central Ridge has been mainly due to government establishments.

The South-Central Ridge has also been more or less completely denuded due to incessant quarrying and construction work. The main green belts, which have survived within this human onslaught, are the still thickly forested. 'San jay Van' behind Qutub hotel and certain green patches adjacent to Ayanagar and Rajokri. Southern ridge is also suffering from severe degree of degradation. Quartzite mining is taking place in the Haryana part of the ridge, while it has now stopped in Delhi. The Southern Ridge is also occupied by some colonies like DLF, Qutub enclave, Ansal Sushant Lok, Palam Vihar, Garden Estate City etc. North eastern portion of the southern ridge has been declared as Asola-Bhati Wildlife Sanctuary.

A marked change is induced by the monsoon when the ridge wears a new clock of green and the whole ground becomes carpeted with a variety of herbs which cover the surface with a vivid green. These plants complete their life history in three to four months after the rains. They help in increasing the humus content of the soil and extending the vegetation to barren areas. In areas where the soil consists of gravel or a thin superficial mantle of soil over the rock, Oropetium thomaeum forms a dense tufted growth, in association with Riccia sp. and moss. All these form a pioneer plant community on the parent rock. As the soil dries up, Riccia sp. dies leaving black patches after which this grass is seen in a fruiting condition either alone or associated with Cyperus triceps, Melanocenchris jacquemonti etc.

In the arid and semi-arid regions, soil moisture is the main limiting factor for plant growth (Champion and Seth, 1968). Such regions do not favor luxuriant vegetation and thus are more susceptible to biotic influences. Grazing

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and fire tends to compact and harden the soil, make it less absorptive of moisture and finally more liable to erosion. Grazing and fire results in slow regeneration and growth of dicot species, which finally results in a marked reduction in the number of species (Aggarwala, 1985; Daubenmire, 1968; Ramakrishnan and Ram, 1988). Depending on the mode of degradation, fire or grazing, the vegetation shows two types of deterioration. One towards the Savanna type where fires are important, stimulating grass growth. On the other hand, the heavy browsing leads to a scrub and thicket type of degradation wherein the palatable species disappear leaving behind thorny elements (Purl et al., 1983). Different animals show different kinds of grazing behaviors. For example, goats and sheep graze upon the vegetation and thus remove it right up to the ground level which leads to complete loss of vegetal cover and is catastrophic, while cows browse upon the vegetation, the camels feed upon the tree top vegetation and are less deleterious than sheep and goats.

Depending upon the intensity and variety of factors, different stages of degradation of natural vegetation are seen. Often such degraded lands are immediately invaded by the exotic weedy species or efforts are made to restore by using alien species. In Delhi growing urbanization has led to almost complete destruction of the ranges and only a couple of areas have been protected. The southern part of these ranges is highly degraded due to intensive and extensive quarrying. The rapid regrowth of vegetation in Delhi ridge is prevented by excessive grazing and fires, the result is a progressive deterioration in the character of vegetation. This is also accompanied by drier conditions of environment, ecological retrogression and sometimes culminates in almost complete sterility of land (Aggarwala, 1985).

The protected area of the ridge is comparatively less degraded and it only bears the near natural flora of the state, which is an arid open scrub forest. This may be due to comparatively well-developed nutrient rich soil. As the site is protected and has less of biotic influences the area also has comparatively higher regeneration. Shankar (1983) concluded that protection of degraded vegetation through enclosure on the deserted habitats invariably led to improvement of the grass cover as well as the regeneration of the shrubs. While in the degraded area the species composition has changed and a mixed flora made up of weeds and weedy plants are noted. This characteristic ruderal flora occurs in open places, where the soil is disturbed (Maheshwari, 1963). Grasses form the dominant vegetation at most of the degraded sites.

The possible reasons for the predominance of grasses may be fire, cutting and grazing. Fire may contribute in a shift to community structure from perennials to annual (Hopkins et al., 1948; Reynold and Bonning, 1956; West, 1965; Daubenrnire, 1968) and from dicot species to grasses (Cook, 1939; Humburg, 1958; Sharrow and Wright, 1977; Scott, 1971). The possible reason for the presence of perennial species (such as Saccharum spontaneum) in infertile soils is because of the well-developed underground rhizomes that help in regeneration after perturbation. Cutting of grass could possibly be another reason. Dabadghao and Shankarnarayan (1973) pointed out that Saccharum spontaneum predominates under the influence of burning and cutting. Like fire, grazing also favours the growth of grasses and impedes the regeneration of both native and exotic species.

Conclusion

The urbanization process in the NCT of Delhi have resulted in the expansion of grey infrastructure and loss of biodiversity. The developmental processes involving the

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conversion/degradation of landscapes led to the ever-increasing loss of vegetation. Unwise clearing of green plants has introduced the process of destabilization of Natural ecosystem and this can be justified by the extreme level of micro-climatic changes in the NCT of Delhi. Green plants act as carbon sink and occupy very important place in the ecosystem because of its higher biomass and its capability to convert solar energy into food energy, then serving a basis of energy flow in an ecosystem.Attention is needed for the preservation and conservation of vegetation to maintain ecological balance and ecosystem equilibrium to ensure the survival of urban dwellers in the NCT of Delhi.

References

E. Lopez, G. Bocco, M. Mendoza and E. Duhau, "Predicting Land Cover and Land Use Change in the Urban Fringe a Case in Morelia City, Mexico," Landscape and Urban Planning, Vol. 55, No. 4, 2001, pp. 271-285.

M. Mohan, Lalit Dagar and B. R. Gurjar, "Preparation and Validation of Gridded Emission Inventory of Criteria Air Pollutants and Identification of Emission Hotspots for Megacity Delhi," Environmental Monitoring and Assessment, Vol. 130, 2007, pp. 323-339. doi:10.1007/s10661-006-9400-9

M. Netzband and A. Rahman, "Urban Remote Sensing for a Fast-Growing Megacity: Delhi, India," SPIE Inter- National Society Advancing an Interdisciplinary Approach to the Science and Application of Light, Berlin, Germany, 2007. http://spie.org/x17987.xml

T. V. Ramchandra and U. Kumar, "GRDSS for Land Use, Land Cover Dynamics Analysis," Proceedings of the FOSS/GRASS Users Conference, Bangkok, Thailand, 2004.

M. K. Ridd and J. J. Liu, "A Comparison of Four Algo- rithms for Change Detection in an Urban Environment," Remote Sensing of Environment, Vol. 63, 1998, pp. 95- 100. doi:10.1016/S0034-4257(97)00112-0

G. H. Rosenfield and K. Fitzpatirck-Lins, "A Coefficient of Agreement as a Measure of Thematic Classification Accuracy," Photogrammetric Engineering & Remote Sensing, Vol. 52, No. 2, 1986, pp. 223-227.

P. Roudgarmi, M. Monavari, J. Feghhi, J. Nouri and N. Khorasani, "Environmental Impact Prediction Using Remote Sensing Images," Journal of Zhejiang University Science A, Vol. 9, No. 3, 2008, pp. 381-390. doi:10.1631/jzus.A072222

D. A. Stow and D. M. Chen, "Sensitivity of Multi-Temporal NOAA AVHRR Data of an Urbanizing Region to Land Use/Cover Changes and Misregistration," Remote Sensing of Environment, Vol. 80, 2002, pp. 297-307. doi:10.1016/S0034-4257(01)00311-X

H. S. Sudhira and T. V. Ramachandra, "Characterizing Urban Sprawl from Remote Sensing Data and Using Landscape Metrics," 10th International Conference on Computers in Urban Planning and Urban Management, PR Brazil, 2007. http://eprints.iisc.ernet.in/11834/

B. L. Turner, "Local Faces, Global Flows: The Role of Land Use and Land Cover in Global Environmental Change," Land Degradation and Development, Vol. 5, 1994, pp. 71-78. doi:10.1002/ldr.3400050204

R. Verma, K. Sangeeta Kumari and R. K.Tiwary, "Application of Remote Sensing and GIS Technique for Efficient Urban Planning in India," Geomatrix Conference Proceedings, IIT Bombay, 2009.
http://www.csre.iitb.ac.in/~csre/conf/wp-content/uploads/ fullpapers/OS4/OS4_13.pdf

Paper ID: UGC 48846-824

Q. Weng, "A Remote Sensing-GIS Evaluation of Urban Expansion and Its Impact on Surface Temperature in the Zhujiang Delta, China," International Journal of Remote Sensing, Vol. 22, No. 10, 2001, 1999-2014.

C. Weber and A. Puissant, "Urbanization Pressure and Modeling of Urban Growth: Example of the Tunis Metropolitan Area," Remote Sensing of Environment, Vol. 86, 2003, pp. 341-352. doi:10.1016/S0034-4257(03)00077-4