CLIMATE CHANGE: EVALUATION OF ECOLOGICAL RESTORATION OF DELHI RIDGE USING REMOTE SENSING AND GIS TECHNOLOGIES

Madan Mohan
Jawaharlal Nehru University, India
Computer-Aided Cartographic Laboratory
Centre for the Study of Regional Development
School of Social Sciences-I
mdnmohan@jnuniv.ernet.in

Technical Commission – VII-1

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ABSTRACT

Over exploitation of land, forests, water and air and the failure to tackle the problem of ecological degradation have exposed humanity to the threat of climate change. The atmospheric pollution is increasing, largely because of human activity. Climatic importance is becoming clear, and heightens rather than reduces our concern about anthropogenic climate change. Delhi Ridge forest cover has failed to meet reduction targets for greenhouse gases emission in the Delhi City due to constant concrete jungle sprawl over the periods. Direct aspects of reducing climate change include investment in technology to combat emissions; appropriate building and settlement design, fuel-efficient transportation; and reducing fossil-fuel inputs to industry, etc. Whereas, indirect possibilities include the adoption of landuse practices over Delhi Ridge that sequester high volumes of carbon e.g. afforestation, forest conservation and ecological restoration. Little action has been taken to limit greenhouse gases emission from fossil fuel consumption. Over the Delhi Ridge, there is less concern with ecological change, especially in the face of rapidly growing population of the Delhi City. It must be recognised that an almost all-human activity includes either directly or indirectly caused environmental pollution. However, the vulnerable input of climate change on Delhi Ridge includes ecological imbalance, deforestation and CO_2 effects etc. Although climate change has a wide range of adverse impacts on Delhi Ridge environment, a bigger threat come from other factors, such as population growth, land encroachments, quarrying/mining activities, urbanisation and industrialisation and social and political conditions.

1 INTRODUCTION

About 100 years ago, geographers, meteorologists and climatologist were concerned with the notion of climate variability, and anthropogenic climate change due, for instance, to deforestation and reforestation. Remote Sensing (RS) and Geographical Information System (GIS) have been used to form the basis for cost-effective technologies for broad scale evaluation of many environmental monitoring problems including landuse and land condition assessment (Kontees et al., 1993 and Wharton, 1987) and ecological restoration, including foresty management (Skidmore, 1989 and Behn and Campbell, 1992). Physical surface temperature (ST) is one of the most important environmental parameters used in determing the exchange of energy and matter between the surface of the earth and the lower layer of the atmosphere. A continuous measurement of this parameter is likely to yield information about suspected climate change. At regional scale, the only way to determine ST is by using satellite data (Gupta et al., 1997). Studies emphasize solar variation as a force or driver for climate change. One of the solar forcing variable is the climate with the measurement and modeling of the temperature, rainfall, etc. (Hoyt, 1996). The analysis of historical land surface temperature (LST) provides evidence for climate change (Cane, 1997). Forest cover is another the most important biophysical parameters used for monitoring climate change. Vegetation regulates energy exchange between the earth surface and atmosphere's lower layer. Changes in vegetation cover regulate long-term climatic changes at the micro-region level. So, it is essential to monitor vegetation cover over the periods of time to assess environmental conditions especially in case of the micro-region like Delhi Ridge, which is functioning as a green lung for the Delhi City. There is a rapid increase in the level of air pollution due to the rapid expansion of the urban and industrial activities. These processes have resulted in the expansion of built-up areas on the one hand and large scale quarry and deforestation activities particularly over south of the Delhi Ridge on the other hand. So, the settlement expansion and land encroachment all over the Delhi Ridge is noticed as a recent phenomenon resulted due to the high population pressure in the Delhi City. However, it is observed that all-over Delhi Ridge there has not been much change in the vegetation cover with the exception of the potential reforested areas where dense vegetation cover has found been increased over the periods.

Rapid population growth and urbanisation are expected to further increase in the Delhi's population by 2010. The atmospheric pollution in Delhi environment is increasing, largely because of diverse human activities. The City is at risk to the impacts of climate change, including accelerated global warming. In contrast to historical precedent, a proactive approach is to be recommended towards ecological hazards and changing levels of risk with time. Low-cost measures to maintain or increase future flexibility of response to climate change need to be identified and implemented as part of an integrated approach to environment management (Nicholis and Bronson, 1998) for the Delhi Ridge. The Delhi's population, one of the principal divers of Delhi Ridge environmental stress, during the 90 years period has grown by about 24.68 per cent per year since 1901. Other trend includes increases in atmospheric CO_2 and ozone depletion. Now, at micro-regional level attention is focused as never before on climate change problems. A number of steps being taken by the government of Delhi to promote non-conventional energy sources. The use of such sources is not gaining ground as expected in Delhi, due to high initial costs; concerted efforts are needed to achieve this goal. The use of non-conventional sources could reduce... energy-related CO_2 emissions 11.8 per cent below 1988-89 levels by the year 2005-2006 (Maji, 1995). However, to sustain economic growth, energy systems must increase economic productivity and competitiveness, put more people to work, and reduce environmental degradation. At the beginning of the new millennium, state-of-the-art energy systems are in transition from liquid oil to (gaseous) methane/natural gas. This new "Age of Energy Gases" will and with totally clean hydrogen, using basically the same infrastructure as natural gas (Hefner, 1995) help in ecological restoration of the Delhi Ridge. However, the scientists are working to quantify the relationship between population and emissions of greenhouse gases. Their modeling indicates that population may be a key variable for stabilizing atmospheric CO_2 in the long term, and that the CO_2 target chosen will affect the extent to which population policies help meet the goal. Based on land surface temperatures, and on the deforestation, concludes that the more recent warming is best explained by the effect of greenhouse gases. The primary evidence for this interpretation is the dominance of the deforestation over Delhi Ridge since the beginning of the 20th Century. Although climate change may have a wide range of adverse impacts on water, forest resources, a bigger threat may come from other factors, such as population growth, technology, economic, social and political conditions (Ott, 1997). However, Delhi's population continues to grow rapidly and changes in urban and industrial development ensue disruption of ecological system.

2 OBJECTIVES

The main objectives of the study are as follows:

(i) to examine changes in the ecological and climatological scenarios;
(ii) to assess impacts of the direct and indirect aspects of environment change; and
(iii) to explore suitable strategies for ecodevelopment.

So, by ascertaining the above objectives, suitable control measures are to be suggested to minimise the adverse impact of climate change, in order to chalk out a suitable ecological restoration plan. Thus, this study discusses the climate change risks associated with ecological system, forest depletion, and species loss. Unlike most ecological studies of climate change, this one takes into account not only the external effects of fossil fuel combustion, but also the exhaustibility of natural forest resources, especially in relation to the existence of non-polluting technologies options. However, this study combines information on climate change from the Remote Sensing and GIS databases to draw conclusions that could not be obtained from the analysis of the historical records alone.

3 DATABASE AND METHODOLOGY

Images used in the present study are acquired for the two different periods of time for their comparative analysis. The Delhi Ridge is covered by the Indian Remote Sensing (IRS) satellite under the path number 96 and row number 56. The satellite remote sensing data of IRS for LISS (linear imaging self scanning) and PAN (panchromatic) sensors, which are providing excellent images with 24-m and 5.8-m spatial resolution respectively, have been used in the present study. The mutlispectral sensors (IRS LISS-III) take into account the variability in reflection patterns caused due to the structural, biochemical and biophysical characters of different vegetation surfaces, over a wide range of electromagnetic spectrum. So, the delineation of different landuse patterns, vegetation types and crown densities has become easier. Several vegetation indices have been used to enhance spectral vegetation characteristics from the visible and near-infrared regions of electromagnetic spectrum (Tucker, 1979 and Jackson, 1983). These indices are usually correlated to some biological parameters, such as biomass or leaf area index (LAI). These also minimise to some extent the effect of scene illumination, surface slope, and data acquisition geometry that affect the spectral response of sensor bands. In this context, the remote sensing data have been successfully used to monitor vegetation cover patterns (Defries and Townshend, 1994) and over geographical regions (Tucker, 1979 and 1986), mostly through the use of the Normalised Difference Vegetation Index (NDVI). It is defined as an algebraic expression of corrected reflectance from the red and near-infrared (NIR) bands. Typically, various calibrations and corrections are made to the NIR and Red bands data prior to these data being used to calculate NDVI. The NDVI values are then composited to minimise the effects of cloud cover (Holben, 1986). So, the NDVI is the most commonly used vegetation index and is obtained using the following equation:

$$NDVI = \frac{(a2-a1)}{a2+a1} \qquad (1)$$

Where a1 and a2 are the reflectance values measured by bands of the data. For instance, NIR is the spectral response in the near-infrared (band 2) and Red is the spectral response in the visible (band 1). The band 1 and 2 used to generate vegetation, soil and shade fraction images, which represent the proportion values of each component within the pixels. The resultant NDVI has been interpreted as a measure of vegetation vigour; i.e. high value indicates pixels that are dominated by high proportions of green biomass. Non-vegetated surfaces, such as cloud tops, water and bare soil/land topography do not exhibit this response. While dead or stressed vegetation show NDVIs of decreasing magnitude. So, the reflectance was then used to calculate the normalised difference vegetation index (NDVI). Nevertheless, there is yet no perfect vegetation index, but NDVI is the most universally accepted and most frequently used index (Tucker, 1979). It is usually applied for quantitative estimation of vegetation cover. However, in the present study the near-infrared and red bands have been taken into account to compute Normalised Difference Vegetation Index (NDVI). On the basis of this index, the quantification of estimation of vegetation cover has been worked out for the study area. While using the ratio of NIR and R bands, NDVI were computed for both the years 1989 and 1999. Theoretically, the NDVI values ranges between –1 and +1; and a value of +1 is unobtainable as it would only be reached when the entire pixel surface consisted of substance that totally absorbed visible and red light. However, the data summary of the NDVI results is presented in the Table 4 for the Delhi Ridge. The ground truth verification were carried out by field visits, landuse maps, Survey of India toposheets, Forest maps etc. The image processing was done using IDRISI (Version 2.0/ Windows) software. Geo-referencing and editing were carried out in PC-ARC/INFO and ARCVIEW in windows environment.

4 STUDY AREA

Delhi Ridge is located in the heart of the Delhi City has been selected for the present study. The geographical coordinates i.e. the latitudinal and longitudinal extent of the study area is given in the Table 1. The geographical features of the study area reveals that the entire ridge is rocky and undulated with partially flat plain.

Coordinate Labels	*Latitude*	*Longitude*
Lower Left Bottom	**$28^0$22’30’’ N**	**$77^0$00’00’’ E**
Upper Left Top	**$28^0$45’00’’ N**	**$77^0$00’00’’ E**
Lower Right Bottom	**$28^0$22’30’’ N**	**$77^0$15’00’’ E**
Upper Right Top	**$28^0$45’00’’ N**	**$77^0$15’00’’ E**

Table 1. Geographical Coordinates of the Study Area

The 32 kms. long Delhi Ridge is an inseparable part of Delhi City. The Delhi Ridge spread over an area 7,777 hectares is a continuation of the Aravalli’s, which extends into Delhi from Haryana at the Tughlaqabad-Bhatti mines—Dera-Mandi axis moving northwards covering areas of the Asola Wildlife Sanctuary, parts of Delhi Cantonment and Lutyens Zone terminating at Delhi University covering the Kamla Nehru Ridge. However, sources point out that from the original area of the ridge which was 15,046 hectares — the total area has come down to 7,777 hectares (Chopra, 1976 and Thapliyal, 1987). The Aravalli Hills belong to the most ancient mountain chain not only in India but in the world as well. The hills came into existence at the close of the Dharwar Era. Basal quartzite, conglomerates, shales, slates, phyllities and the gneisses comprise Aravalli Hills (Wadia, 1976). The ridge achieves a height of 318 meters near Bhatti, which is probably the highest point. A number of small rivulets drain this hilly region. A semi-arid climate prevails in the region throughout the year.

Naturalists and ridge lovers have found a wide spectrum of plant species here. There are the native ones like the Babul (Acacia Arabica) and Ber (Jujube). There are the exotic varieties of Vilayti Kikar (Acacia) and Neem (Margosa Tree). Amaltash, Palash, Flame of the forest and an orchid species bring vibrant colours to the forest during different seasons (Chopra, 1992). However, the geographers and environmentalists feel quite strongly that it is high time to save the ridge... from us. A close examination of the ridge revealed that it is a wonderful slice of nature. It is a repository of the Delhi's future and a sobering reminder of what Delhi might have looked a few decades ago till it was run over by wheels and concrete (Bhatt, 1986). More than 200 species of birds have been spotted in this tropical thorn forest. Earlier, their number was 300 and more (Dahiya and Krivov, 1999). It is having about 70 species of butterflies and large varieties of animals and insects. Unbelievable as it might seem, the forest even housed lions, tigers and leopards some 70 years ago.

5 PRESSURE OF POPULATION ON ENVIRONMENT

Delhi's Population, one of the principal drivers of the environmental stress has grown by 9.01 million as against 0.41 million persons in 1901 to 9.42 million persons in 1991. In other words, the Delhi's population during the 90 years period has grown by about 24.68 per cent per year since 1901. Whereas the population growth for Delhi portrays a rising trend all through during 1901-51. There was not much change in Delhi's population during 1901-11 as it grew by just 1.98 per cent. The decade 1911-21 witnessed an increase by 18.03 per cent, whereas the population increased only marginally from 0.41 million in 1901. This increase may be mainly attributed to the shifting of capital from Calcutta to Delhi in 1912. The growth of population during 1921-31 and 1931-41 was 30.26 per cent and 44.27 per cent respectively. The partitioning of the country resulted in huge influx of displaced persons. The 1951 Census recorded a growth rate of 90 per cent for the decade 1941-51. During 1951-61, the growth rate fell to 52.44 per cent. During the next period, it is again showed ascending trend, although marginally. Such growing tendency in population was due to the multiplication and intensification of services during the post-independence era. During 1971-81 decade, the population recorded a growth rate of 53 per cent. The main factors responsible for unabated growth of population in the Delhi are the expansion of commerce and trade; and the growing industrialisation, particularly, in the field of small-scale industries during the last three decades. In 1981-91 period, the growth rate of population was 51.45 per cent. Such decline in population growth was resultant due to decline in urban growth rate of 46.87 per cent in 1981-91 in comparison to the previous decade 1971-81 growth rate of 58.16 per cent. However, since Delhi has remained a capital of the country for centuries and a hub of all social and economic activities, it has always been attracting in-migrants. This has resulted in excessive growth of its population, which is not due to natural increase alone, but more because of large-scale in-migration. On account of this, the capital city of Delhi is densely populated. It has recorded a growing density of population since 1921. At the time of partition of the country in 1947, Delhi attracted gigantic and unprecedented mass immigration of displaced persons. The highest density of population of 6,352 persons per sq. kms was recorded during 1991 Census which is the highest among all the States and Union Territories of the country, India. Within Delhi itself, great variations in the density of population can be marked. Apart from this, the share of rural population is less than one-tenth of the total population with the continuous shifting of the ratio in favour of urban population. In 1901, Delhi had almost an equal distribution of population in the rural and urban areas. In 1981, the share of urban population was 92.73 per cent, which slightly declined to 89.93 per cent in 1991. Thus, the most striking characteristic of the population of Delhi is the predominance of in-migrants.

6 ECOLOGICAL CONSEQUENCES OF QUARRYING AND INDUSTRIALISATION

The quartzite rocks largely forming of the Delhi Ridge are exposed in many localities in Delhi and form a useful source of road metal and building materials. The rocks had been extensively quarried at Pharganj, Kalkaji, Jhandewalan, Rohtak Road, and Mehrauli, Lado Sarai and other places. The Delhi Ridge is scoured with quarries. A large quantity of 'Badarpur sand/quartzite' is quarried on a vary large-scale in Bhatti group of mines (around 12 quarrying pits) by the Delhi State Industrial Development Corporation (DSIDC) and subsequently by a separately formed organisation designated as the Delhi State Mineral Development Corporation (DSMDC) since 1983. Likewise, the quarrying operation is still conducted in the Dera-Mandi and Jonapur, Ghattorni, Rajokri, Tajpur and Gujiriwalla in Bhatti group of mines by the private contractors/cooperative societies. The air pollution main sources are such as the dust particles and fuel smoke. The dust created by transportation, loading and unloading of waste, drilling and blasting has appreciable impact on the inhabitants and the plants. This has been possible to conclude on the basis of the field survey and the interviews conducted by the researcher, that the human body, houses, the utensils and the water pots carry heavy deposits of dust particles. While working in and around the quarrying areas, the workers are compelled to inhale the dust particles. So, in the area, many persons have been reported to be suffering from the dust-prone diseases such as silicosis and tuberculosis, and this shows that there is an appreciable effect of dust. Due to heavy transportation in the area, the exhaust gases pollute the environment badly. Besides this, the rapid industrialisation, high volumes of traffic and thermal power plants have further aggravated the air pollution in Delhi. The permissible limit of the air pollution for human beings to inhale is 250 ppm. Whereas in Delhi residential areas, it is generally 400 to 500 ppm. and in the industrial areas it is as high as 900 ppm. that is almost equal to the pollution level at the ITO bridge, in New Delhi where it is reported to be at the level of 1000 ppm. The smoke-emitting furnaces and refractories and vehicles plying on the roads cause most of the air pollution. For instance, the Thermal Power Plant's fly-ash emission continues to precipitate the air pollution in many areas over Delhi.

The Delhi Ridge had a thin vegetation cover prior to quarrying activities, but now due to the quarrying, the vegetation is almost negligible in the area. Due to the deposition of the dust particles on the photosynthetically active parts of the plants, the growth of vegetation has been considerably reduced. As to the fauna, due to the disturbance created by the quarrying activities, particularly after the second half of the present century, the deer's, wild-cows, lions, jackals, foxes etc., which used to be there in this area, are practically not seen there now. Consequently, the large-scale quarrying and the removal of natural vegetation have laid the land bare. The sensitive local flora also shares the brunt of the solid suspensions. Strong wind spreads the fine stone dust almost over a kilometer around a pit, depositing it on a leaf and causing their premature fall. So, the Delhi Ridge is getting sick due to the air pollution by the smoke-belching chimneys of factories, the chemical and mineral industries with scant regard for environment. Despite the master plan and the NCR (National Capital Region) plan, the Delhi is fast growing haphazardly in terms of population and industries. So, the implication of quarrying over the Delhi Ridge are not that severe as are usually associated with the open-cast quarrying, but even considering certain parameters, the impact is appreciable. The conjunctive study of the imagery and SOI (Survey of India) toposheet 53 H / 2 and 53 H / 3 suggest that the ecological degradation over Delhi Ridge has been caused by extensive human activities whether productive or consumptive. The huge debris deposition and mineral rock extraction at Bhatti and Gujraiwala and Dera-Mandi and Jonapur etc. quarrying sites over south of the Delhi Ridge have also been evidenced which supports the observation made from imagery.

7 RESULTS ANALYSES AND DISCUSSION

7.1 LANDUSE AND BIODIVERSITY CHARACTERISATION

Delhi Ridge is needed an immediate evaluation of the ecological landuse patterns. Sustainable management of natural resources is the basic need of the hour, for long term benefits and resource availability. In recent years, there has been indiscriminate destruction of habitats leading to the extinction of several species over the Delhi Ridge. The ridge, being one of the mega centres of biodiversity, has major responsibility towards conservation efforts. When viewed from the point of view of demand and availability of resources, whether agricultural or forest lands, it needs to prioritize utilisation of resources. The study envisages characterising biodiversity at landscape level, using various ecological parameters such as the physiographic divisions, geographical area, built-up area, vegetation cover, vacant land and exposed rocks and water body etc., are used to generate information for Delhi Ridge. Field data with respect to species richness, ecosystem uniqueness, biological values etc. is supplemented with available collectoral data, to arrive at biological richness of the forest types.

Remote sensing (RS) and GIS (Geographic Information System) as monitoring techniques can play an important role in assessing the quality and quantity of vegetation cover as well as increase in the so-called development activities over the Delhi Ridge. While keeping this point in view, the satellite and the Survey of India (SOI) maps have also been taken into consideration to find out the main landuse patterns for Delhi Ridge, which are presented in the Table 2.

Sl. No.	*Physiographic Divisions*	*Area(1) (in hect.)*	*Area(2) (in hect.)*	*Built-up Area*	*Vegetation Cover*	*Vacant Land & Expo. Rocks*
1.	Northern Ridge	87	82	8.05	51.25	22.70
2.	Central Ridge	864	829	76.78	392.10	357.42
3.	South-Central Ridge	626	604	68.42	199.12	335.58
4.	Southern Ridge	6200	6161	39.20	840.97	5274.52
	Delhi Ridge	***7,777***	***7,676***	***192.45***	***1483.44***	***5990.22***

Notes: (1) *D.D.A., 1987. Master Plan for Delhi: Perspective 2001. Delhi Development Authority, pp. 37.*
(2) S.O.I., 1976. DELHI, HARYANA. Topographical Sheet No. 53 H / 2 & 3, Scale 1: 50,000.

Table 2. Landuse Patterns by Physiographic Divisions.

A forest supports different species of flora and fauna. A forest destroyed once is gone forever. The British's planted trees after very deep and detailed study of the Delhi Ridge area and its environment. So, the Delhi Ridge forest should not be treated as an isolated pocket of forest. It is an important component of the Aravalli range and should be treated in totality. In the present scenario it is not possible to protect and conserve the entire Delhi Ridge without popular people's movement.

7.2 FOREST VEGETATION MAPPING

The computed NDVI statistics is compiled and given in the Table 3 for the two different periods. During 1989, a degree of variation is observed in the distribution of maximum NDVI values as compared to 1999. The value of NDVI does not exceed 0.5809 in any of the years under study area. The highest value of NDVI is 0.5809 observed in 1999, which has increased from 0.4608 in 1998. This increasing tendency indicates that the vegetation cover has increased over the periods over southern ridge. Almost similar condition of vegetation cover has also been found for the other divisions of the Delhi Ridge as is clearly evidenced by the Table 3 below:

Sl. No.	***Physiographic Divisions***	***NDVI Min.***		***NDVI Max.***		***Mean***		***S.D.***	
		1989	***1999***	***1989***	***1999***	***1989***	***1999***	***1989***	***1999***
1.	**Northern R.**	-0.1563	-0.4869	0.3489	0.3940	0.0042	0.0020	0.0802	0.1365
2.	**Central R.**	-0.0539	-0.6410	0.3012	0.3519	0.0032	0.0015	0.0792	0.1180
3.	**S-Central R.**	-.01211	-0.5235	0.2946	0.4920	0.0053	0.0025	0.0650	0.1291
3.	**Southern R.**	-0.1892	-0.7601	0.4608	0.5809	0.0067	0.0032	0.0950	0.1431

Table 3. NDVI Statistics by Physiographic Divisions.

The repetitive capability of satellite remote sensing is much more useful in such areas and studies. The satellite image is prepared after super-imposing False Colour Composite (FCC) having 5.8-meter spatial resolution of the panchromatic image and having 24-m spatial resolution of the LISS image. This type of hybrid image has got double advantage; firstly it gives 5.8-m ground resolution for better interpretability while FCC is useful for sharp delineation of boundaries between built-up area and vegetation covered area. FCC is also very useful in identification of different types of vegetation cover. The difference in area is inevitable because no clear boundary is defined. On the satellite images only the edge of vegetation is taken as boundary. As shown in Table 4, the vegetation is classified based on the NDVI values such as the no vegetation means that the land is rocky and barren whereas the scattered vegetation means that there are only some kind of scrubs. While sparse vegetation is the open forest or degrade tree vegetation. Trees are sparsely distributed interspersed by shrubs and grass. The dense vegetation means that there is closed forest where crown density is high or dense forest.

The vegetation cover over the Delhi Ridge has marginally been increased from 18.79 per cent in 1989 to 19.67 per cent in 1999. Among the Delhi Ridge divisions, the Northern Ridge has the highest vegetation covered area of 62.27 per cent. Whereas the Central Ridge covered with the vegetation of 47.02 per cent. The South-Central and Southern Ridges were covered with the vegetation of 32.67 per cent and 13.31 per cent respectively. The sparse and dense vegetation covers have grown to 9.23 per cent and 7.0 per cent over the Delhi Ridge. The plantation of trees under the different forestry plans has been taken place over the Delhi Ridge. Besides this, the Central Ridge recorded an increase in the scattered and sparse vegetation of 19.28 per cent and 13.48 per cent respectively during 1989-99. Similarly, over the South-Central Ridge, the sparse and dense vegetation covers increased to 10.88 per cent and 8.89 per cent. Over the Southern Ridge, the sparse and dense vegetation increased to 6.10 per cent and 8.59 per cent. The imagery interpretation indicates that there are areas with some darkest shade, which represents the highest concentration of vegetation. In 1999, the dense vegetation was located in the five major locations over of the Delhi Ridge. Out of these, three of them such as the Hauz Khas and Deer Park (Forest) is located over the Central Ridge while the Asola Wild Life Sanctuary is located over the Southern Ridge. These come under the protected forests. Whereas the rest of two locations such as the Jawaharlal Nehru University (JNU) and north of Vasant Inter-Continental Hotel are covered with the dense vegetation. Both these areas are lying over the South-Central Ridge. These are unprotected forest cover areas. The sparse and dense vegetation occupied nearly 0.757 sq. km. and 0.152 sq. km. area over the South-Central Ridge. These are located nearby the densely vegetated areas. The surroundings of JNU and Deer Park and the adjoining areas were covered with the scattered vegetation in 1989 which becomes dense in 1999. Besides this, it is interesting to point out that about 6.452 sq. km. of the Southern Ridge's total geographical area registered less than 0.075 but greater than 0 NDVI value as is evidenced by the Table 4. These values indicate that there are scattered low and medium scrubs in rocky outcrops of the Southern Ridge which most of the times grow wildly. The built-up area of both Kishangarh village and Vasant Kunj, which are the newly planned inhabited areas over the Southern Ridge, has taken place primarily in the scattered vegetation covered areas.

Sl. No.	Physiographic Divisions	No Veg.		Scattered Veg.		Sparse Veg.		Dense Veg.	
		Less than 1		0 to 0.075		0.075 to 0.1		More than 0.1	
		1989	1999	1989	1999	1989	1999	1989	1999
1.	***Northern R.***	0.3098	0.2998	0.2219	0.2001	0.1896	0.1901	0.0999	0.1021
	Change (89-99)		-0.0100		-0.0217		0.0005		0.0022
	% Change		-3.23		-9.81		0.26		2.24
2.	***Central R.***	4.0721	3.9568	2.0923	2.4956	1.3826	1.5689	0.1398	0.1498
	Change (89-99)		-0.1153		0.4033		0.1864		0.0100
	% Change		-2.83		19.28		13.48		7.15
3.	***S-Central R.***	4.2200	4.1901	1.2257	1.1126	0.6826	0.7569	0.1399	0.1523
	Change (89-99)		-0.0299		-0.1131		0.0742		0.0124
	% Change		-0.71		-9.23		10.88		8.89
4.	***Southern R.***	53.7421	53.2426	6.4421	6.4526	1.6896	1.7926	0.1196	0.1298
	Change (89-99)		-0.4995		0.0104		0.1030		0.0103
	% Change		-0.93		0.16		6.10		8.59
	DELHI R.	62.3441	61.6894	9.9820	10.2609	3.9444	4.3085	0.4991	0.5341
	Change (89-99)		-0.6547		0.2789		0.3641		0.0349
	% Change		-1.05		2.79		9.23		7.00

Table 4. Landuse Classification Based on NDVI Statistics.

However, it is noteworthy to point out that over the southern ridge the tree plantation took place under the different forestry plan to generate the vegetation cover by the government and private agencies such as the Delhi Development Authority (DDA), Delhi Forest Department and Quarry Owners (Cooperative Societies) etc. So, there is found a marginally decrease in the no vegetation covered area of 0.93 per cent during 1989-99 over the Southern Ridge. Besides this, a large proportion of the northern ridge covered with the vegetation. There is found an increase in dense vegetation cover of 2.24 per cent during 1989-99. There has not been much change in the built-up area excepting some pockets over the Northern Ridge and the surroundings. Whereas the sparse vegetation recorded no significant change in their proportion. It is important to point out that there is found a decrease in the scattered vegetation cover of 9.81 per cent which indicates that the vegetation has been removed extensively over the period. The land encroachment is one of the major causes responsible for decrease in vegetation covered areas. So, widespread deforestation and land encroachment activities have been responsible for the fragile ecological system degradation over the Delhi Ridge. However, conservation and sustainable utilisation of forests need information on the location, rate and type of change in the vegetation cover, as well as an understanding of the human activities in order to avoid the possible climate change problem.

7.3 ECOLOGICAL RESTORATION

In order to study the Delhi Ridge ecological restoration, the detailed analysis of the IRS imagery has revealed the presence of a dark/block patch along the southern ridge, which has been interpreted as big holes. Careful examination of this particular feature in term of its location, shape, size, association, its tapering nature towards upstream etc. proved to the presence of an artificial lake formed by the DDA. The lake is about 1.82 km. long and 243-m wide, covering an area of about 0.39 sq. km (39 hectares) as revealed from satellite data. However, the volume of water existing in the lake can be utilise for the nearby residential localities such as the Mahipalpur, Vasant Kunj and Mehrauli. However, the Delhi Ridge with its large stretch of land in the central part of the Delhi State is currently prone to the ecological degradation. Remote sensing satellite data are being actively used in developing early climate change systems, effective ecological plans, ecological damage assessment and other mitigation plans. The development of forest cover all over the ridge, as a carbon dioxide absorbing zone is also considered important, to reduce the ecological damages caused by wide spread land encroachment and deforestation. As a part of the ecological restoration program, the Forest Department and Delhi State Govt., have envisaged ecological development of shelter belts all over the Delhi Ridge. The forest belt development is essential, to be planned at 0.5 km and 5 km stretch for forest cover. Towards this, it is required to analyze the vegetation and land cover conditions for identifying suitable areas to develop New Forest shelter belts and improve the existing ones as presented in the foregoing discussion. The air and dust pollution can be controlled by way of laying the green barriers and undertaking plantation. Use of properly maintained vehicles could reduce the air pollution due to the exhaust gases emitting from them. Enough care should be taken for the flora and fauna management. It must be made mandatory for the leaseholders to grow plants in and around the leased areas. A scheme of developing the green barriers to be jointly undertaken by the quarry owners (Cooperative Societies) and the government should be launched as already undertaken by the DDA for the Bhatti group of mines. Such a scheme of undertaking plantation will not only help minimise the land degradation but will also improve the ecosystem in the quarrying areas. Since the fauna is inter-related with the flora, no extra efforts as such are required in this direction.

8 CONCLUSIONS AND SUGGESTIONS FOR THE FUTURE

The statistics on landuse and vegetation were extracted for all the 4 divisions for the Delhi ridge is useful in planning and development, at three different phases such as the (i) selection of new areas for plantation belt development (degraded forests, rocky & barren lands); (ii) improvement of existing forest belts (ridge plantations, mixed plantations.); (iii) conservation of vegetation zones (dense forests and forests). The distribution of the classes pertaining to these three different planning categories will help in prioritizing the division-wise activities. Within each division, it is envisaged that the participation of the local people and the govt. is essential for the successful establishment of forest belts. Therefore, for all the Delhi Ridge divisions, the areas were identified on the basis of vegetation maps and digital landuse layers, which were developed in GIS. This has facilitated in developing buffer area around forest for each division for assessing the availability of suitable areas for plantation. This kind of integrated forest planning is possible with the use of high-resolution Delhi Ridge vegetation maps generated from IRS LISS-III and PAN merged data. So, much of the Delhi Ridge area having already disappeared, the priority is to save whatever is left behind right now. It will also be desirable to declare the ridge area as a national park under the Wildlife Protection Act. 1972, just as it was done in the case of “Van Vihar” in Bhopal and “Borivilli National Park” in Mumbai. Both these areas are now ‘protected areas’ and are flourishing. The Delhi ridge’s upkeep should be given to a special unit created in the Forest Department. This wing should comprise of specialists like Forest Ecologist, Environmentalist, Forester and Horticulturist. The boundaries of the Delhi Ridge must be defined and demarcated with the help of modern survey techniques like Remote Sensing and GIS and should be mapped and notified. No further infringement of the Delhi Ridge should be permitted. It should be maintained in its pristine glory. Encroachers must be severely punished, under Forest law, by imposing penalty as well as imprisonment. Politicians must be kept away from the Delhi Ridge affairs and enlightened citizens must form a conservation group on the lines of GREEN PEACE to monitor the activities in and around the Delhi Ridge. However, “let us save ecology from development no doubt but at the same time, let us save development from ecology as well” (Mohan, 1992 and 2000).

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