IMPACT OF ANTHROPOGENIC ACTIVITIES ON LAND USE AND LAND COVER CHANGES – IN AND AROUND DELHI RIDGE

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DECLARATION

I declare that the dissertation entitled "**Impact of Anthropogenic Activities on Land Use and Land Cover Changes – in and around Delhi Ridge**" submitted by me for the award of the degree of **Master of Philosophy** of Jawaharlal Nehru University is my own work. The dissertation has not been submitted for any other degree of this University or any other university.

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CERTIFICATE

We recommend that this dissertation be placed before the examiners for evaluation.

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Dedicated

To

My

Beloved Parents

Contents

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New Delhi ***Yasodha. K***

29th July, 2009

List of Tables

List of Figures

List of Graphs

List of Plates

Abbreviations

A.D	Anno Domini
BIS	Bureau of Indian Standards
BOD	Biological Oxygen Demand
CGWB	Central Groundwater Commission
CNG	Compressed Natural Gas
CO	Carbon Monoxide
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CPWD	Central Public Works Department
DDA	Delhi Development Authority
DEM	Digital Elevation Model
DIT	Delhi Improvement Trust
DO	Dissolved Oxygen
DPCC	Delhi Pollution Control Committee
DSIDC	Delhi State Industrial Development Corporation
DSMDC	Delhi State Mineral Development Corporation
EIA	Environmental Impact Assessment
ENVIS	Environmental Information System
ERDAS	Software
FC	Feacal Coliform
GIS	Geographic Information System
GSI	Geological Survey of India
GWQS	Groundwater Quality Series
IARI	Indian Agriculture Research Institute
IMD	Indian Meteorological Department

ISI	Indian Standards Institution
LU/LCC	Land-use and land-cover change
MCD	Municipal Corporation of Delhi
MPD	Master Plan for Delhi
MSW	Municipal Solid Waste
N.C.T	National Capital Territory
NAAQS	National Ambient Air quality Standards
NDMC	New Delhi Municipal Council
NNE- SSW	North-North East – South-South West
NRCD	National River Conservation Directorate
RMB	Ridge Management Board
RSPM	Respirable Suspended Particle Matter
SDI	Spatial Data Infrastructure
SOI	Survey of India
SPM	Suspended Particle Matter
SPOT	Satellite Pour l'Observation de la Terre
TC	Total Coliform
TDS	Total Dissolved Salts
WNW-ESE	West North West-East South East
WQI	Water Quality Index
WTP	Waste Treatment Plant
WWF	World Wide Fund

Chapter I

Chapter I

Introduction

Geomorphic setting of a region is an expression of prevailing geology; climate; erosion; depositional processes at work on them and their evolution over time. Today the surface of the earth is undergoing a profound transformation as the result of human activities. Man act as dominant force on earth's physical and biological system and alter his environment to suit himself. These Anthropogenic forces are the sum total of all human activities and modify the landforms at global or regional or local. Modification of landforms by man means of mining and quarrying; deforestation; introduction of exotic plants and animals; use of agricultural machineries; building; use of tracks and roads etc and overgrazing of pastures have all singly and in combination profoundly altered landforms and causes accelerated erosion and deposition (Richard H. Bryant; 1986).

Urban areas are particularly modified landforms under anthropogenic activities. Human activities typically superimpose a layer of artificial composition and structure on urban geomorphologic landforms not only in terms of invasion of land area but also change in land use; reduced infiltration and base flow; flooding; river shifting; water logging; slope instability; modification of natural channels; ground subsidence etc. Identification; monitoring and analysis of contemporary geomorphological processes as well as man made land use changes in urban area are gaining momentum.

The man-made cities have been carved on the land of wildlife (non-domesticated animals, uncultivated plants and micro-organisms). The habitat of wildlife (natural home of wildlife), it means has been destroyed for making the urban habitation, roads, offices, institutions and commercial areas etc. Urbanization leads to change of land use, primarily from natural ecosystem to cities.

There is an unequal urban growth which is taking place all over the world but the rate of urbanization is very fast in the developing countries especially in Asia. In 1800

A.D, only 3% of the world's population lived in urban centers but this figure reached to 14% in 1900 and in 2000, about 47% (2.8 billion) people were living in urban areas. The process of urbanization in India gained momentum with the start of industrial revolution way back in 1970s followed by globalization in 1990s. Forests were cleared, grasslands ploughed or grazed, wetlands drained and croplands encroached upon under the influence of expanding cities, yet never as fast as in the last decade (Rahman, 2007).

In India there are 35 metropolitan cities (2001) compared to 23 in 1991 (census of India; 1991 and 2001); Delhi (13.78 million); Mumbai (13.22 million) and Chennai (6.42 million). As urban population increases demand of land area for various urban activities also increases. These land encroachments in terms of clearing forest; grass land overgrazing; draining wetlands; quarrying and mining for minerals and rocks all affects urban geomorphology and environment. Every action has its reaction. Flooding in metropolitan cities is a known example of it (Mumbai; Chennai; Delhi floods in recent years) due to reduced infiltration; channel shifting etc. Delhi one of the most urbanized state in India is witnessing sharp increase in population faces shrinking of rural area with authorized and unauthorized settlements especially in urban fringe. The deleterious influence of urban anthropogenic activity on hydrology and geomorphology in terms of occupation of water bodies; paleochannel; nallas etc with settlements or sewage drains changed the city ecology.

In other words, the reservoirs of energy in terms of fuel and food/fodder, oxygen, fiber, fertilizer, water and climatic stability etc. gets lost to cities. This also leads to floods and consequential losses, pollution and unrest. Since top fertile living part of earth's crust i.e. soil in cities enjoys very thin vegetation cover, it remains naked for erosion to wind and storm rainwater. The soil surface is otherwise also relatively compact, so the rainwater percolates less leading to lesser groundwater recharge. Because of the reasons of (a) compactness of the soil in cities, (b) more of concrete city surface (because of roads and buildings) and (c) scarcity of ground cover by vegetation, the availability of surface area for seepage of rain water is reduced tremendously. Resultantly, the water table hardly gets recharged or replenished. Due to lack of enough moisture in the surface cooling effect diminishes and aggravates the problem of maintaining adequate vegetation for sustaining the environment for urban dweller. Because of development of cities, the habitat of wildlife gets destroyed. As a result, the wildlife goes to the edges or outskirts of the urban areas and consequently, weak species get lost/vanish leading to loss of diversity. This biodiversity (variation and in the types of plants, animals and microbes) loss is a matter of worry for the whole world.

The Delhi Ridge with 7.78 sq km of land, forming only 6 per cent of the land mass of Delhi, is the lung of the city. It helps in maintaining the oxygen-carbon dioxide balance, purifying air, reducing noise levels, regulating temperature and preserving biodiversity. Impact of anthropogenic activities on its surrounding area is dramatic. Land use change and over exploitation of groundwater has reduced the water table in ridge areas of Aravalli quartzite terrain of Delhi. Despite the government notification of 1994 (which declared the ridge as a reserved forest), and the Supreme Court ruling of 1995 in this regard, Ridge is still under encroachments, pollution activities and urbanization activities which are deteriorating its ecology. It is therefore a matter of concern to study the impact of anthropogenic activities in and around this important geomorphic feature to conserve and sustain its uniqueness for our future generation.

1.1 Statement of the Problem

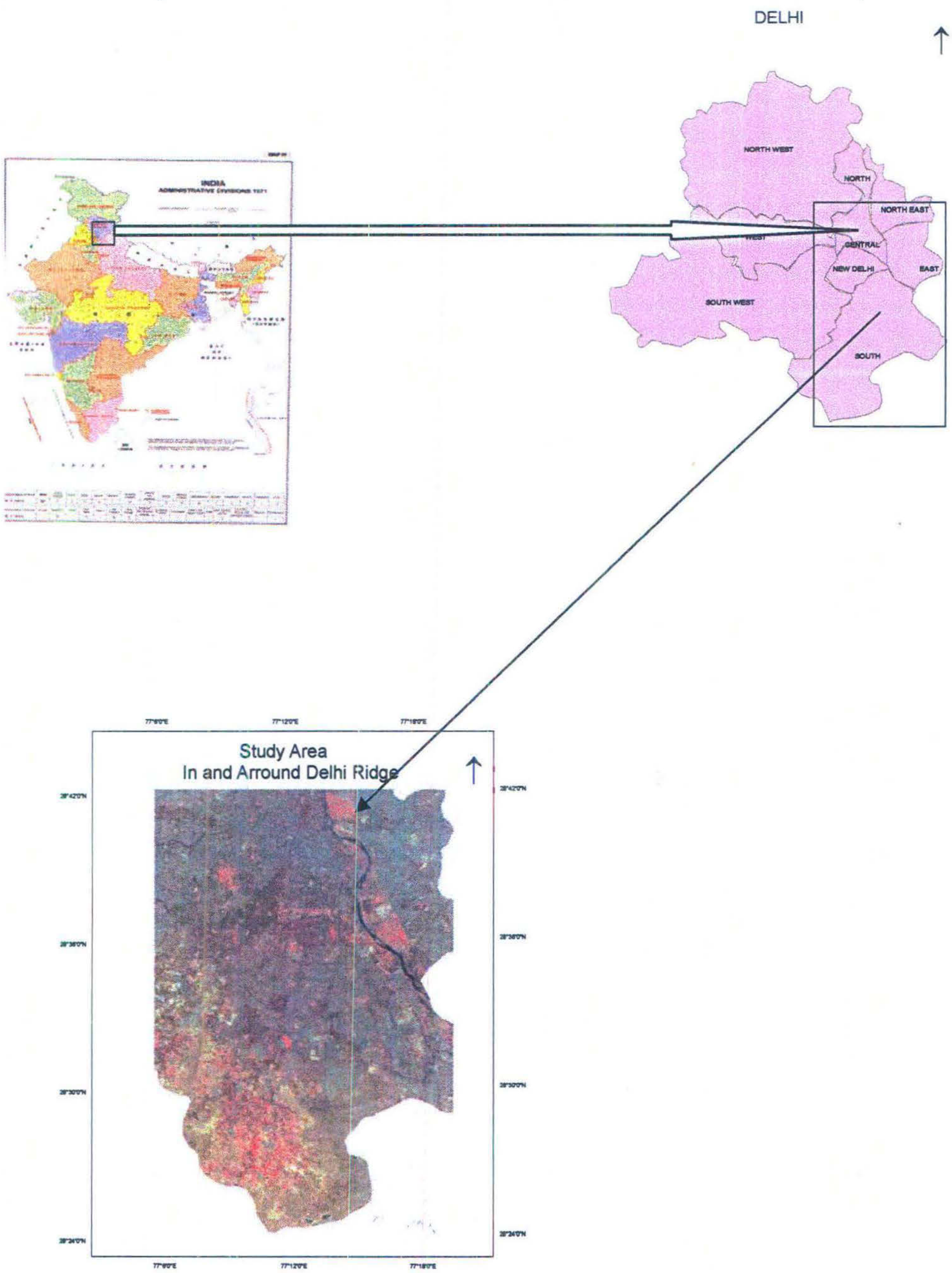
Delhi, the capital city of India is among the oldest historical living cities of the world with around 20,000 archeological remnants and ruins. Delhi had been built by different rulers in geographical parts with erecting monuments at different locations. Those structures invariably involved a huge amount of stones to be stocked and piled up. Masonry developed in great details during these times and forts demanded a continuous workforce of sculptors who gave shapes to stones for posterity. Stones of special size for sculptures and forts had to be sourced by employing a huge workforce of miners. This impacted the mountain range of Aravalli a great deal and mountain landscape underwent a significant change (Dr. Madan Mohan 2002). 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 Delhi Ridge spread over an area of 7.78 sq km 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 to parts of Delhi Cantonment and Lutyens Zone terminating at Delhi University covering the Kamla Nehru Ridge(Thapliyal, U.P., 1987).

However, sources point out that from the original area of the ridge which was 15.05 sq km— the total area has come down to 7.78 sq. km (Dr. Madan Mohan 2002). The quartzite rocks largely forming the ridge are exposed in many localities in Delhi and constitute a useful source of road metal and building construction materials. Land use change and over exploitation of groundwater has reduced the water table in ridge areas of Aravalli quartzite terrain of Delhi, India. Fluctuation in water level in this area has been noticed since several years. Further changes in these features may lead to lowering down of the water level which may even lead to land subsidence due to increased effective geostatic pressure.

The rocks had been extensively quarried at Pharaganj, Kalkaji, Jhandewalan, Rohtak Road, Mehrauli, Lado Sarai and other places. The Delhi Ridge is scorched 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 organization designated as the Delhi State Mineral Development Corporation (DSMDC) since 1983. Though quarrying activities are banned by the Supreme Court of India the ecological impacts left out are still continuing.

Land use, land cover changes in the eastern part of the study area which is under Yamuna plain is also immense where cultivated areas have been taken away by built-ups. Pollution, water table reduction, biodiversity losses and other ecological impacts makes this study very important.

1.2 Study Area



Delhi, the capital city of India is located between the 28° 24' 17" and 28° 53' 00" N latitudes and 76° 45' 30" and 77 ° 21' 30" E longitudes and it spreads over an area of 1,463 km^2. It is situated on Aravali quartzite rage of Rajasthan. The Delhi region in northern India is bounded by the Gangetic alluvial plain in the north and east, the Thar Desert in the west, and Aravalli hill ranges to the south.

The study area which is situated between $77^0$18'E and $77^0$60'E longitude and 28^0 24' N and $28^0$42' N latitude. This Delhi ridge region which is the northernmost extension of Aravalli relict mountain system consists of quartzite rocks and extends from southern parts of the territory to western bank of Yamuna for about 35 kilometers. The alluvial formations overlying the quartizitic bedrock have on either side of the ridge. The Yamuna flood plain contains a distinct river deposit. The nearly closed Chattarpur alluvial basin covering an area of about 48 sq.km is occupied by alluvium derived from the adjacent quartzite ridge. The study area can be divided into

- Alluvial plain on eastern and western sides of the ridge
- Yamuna flood plain deposits
- Isolated and nearly closed Chattarpur alluvial basin
- NNE- SSW trending Quartzitic Ridge.

The area of the study – the Delhi Ridge – is situated in the northern Aravallis which starts in Rajasthan- the north-western part of India and ends here. In the geographical sense, the Delhi Ridge is the continuation of oldest mountain chain of the Aravallis. The Delhi Ridge is the culminating spur of the Mewat branch of the Aravallis, constitutes the most significant physiographic features in Delhi cosmopolis. Almost entire Aravalli Hills have been out-cropped since long back (Wadia, 1976). It enters Delhi from the south and extends like a "lean but wiry finger straight to the Yamuna" in a north-easterly direction; skirting the north-west and west. The northern most tip of the rock exposure of the Northern Ridge is at Wazirabad; overall bedding surface is seen tending NNE-SSW. The rock exposure shows to be slightly widening towards south and is widest at its southern-most tip.

The western undulatory terrain has fluvio-alluvial material of older geologically, at places with aeolian mounds are found in the western part of the ridge. Eastern active floodplain is of old and newer alluvium fertile in nature but occupied by built-ups now. Southern upland area with strike ridges, dissected hills, badland with rills and man made mines. The northern and eastern areas are adjacent to ridge largely occupied by older alluvium (Sub-recent in age).

As the oldest part of the city founded in the part of the study area, it's with many historical monuments along with recent developments. Increased population led to demand for land for housing and sprawl of the city. Urbanization as well as industrialization leads pollution. Abandoned stone quarries exist near the southern boundary of the zone area. All these anthropogenic activities are depleting and deteriorating the ecology of this region.

1.3 Geology and Geomorphology

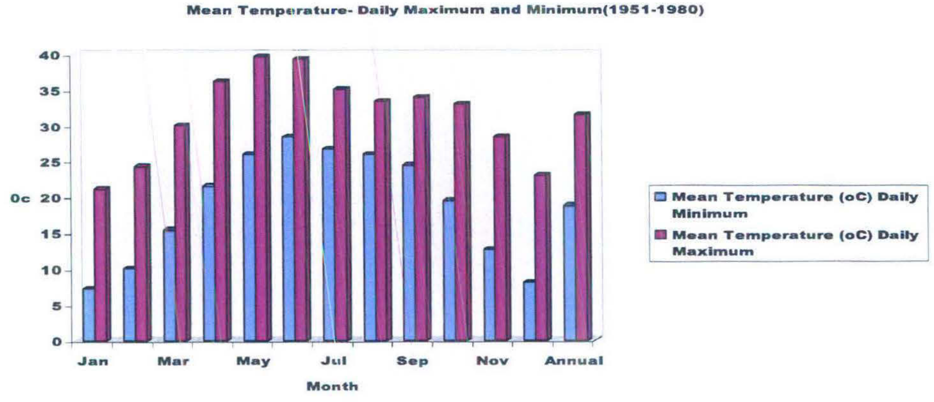
Geologically, the rocky upland area comprises quartzites with intercalations of schistphyllite, belonging to the Delhi Supergroup (Proterozoic); the whole assemblage is intruded by younger pegmatiteand quartz veins (Heron 1953). The rocks in the central part extend as a NE–SW-trending ridge (known as the Delhi Ridge or the Delhi Shahabad Ridge) up to Wazirabad in the NE.

The area can be divided into four major geomorphological domains, each characterized by its distinguishing parameters: 1. Northern Ridge- the Northern Ridge spreads over an area of about 0.87 sq km between Civil Line and Delhi University; 2. Central Ridge- The Central Ridge covering an area of 8.69 sq km extends from Karol Bagh and Mandir Marg upto Dhaula Kuan in the south Delhi; 3. South-Central Ridge- The South-Central ridge spreads over a very large area of 6.26 sq km while covering the Mahipalpur-JNU area which around Mehruali is divided into two parts by Mehrauli and Kishangarh villages. Mining and quarrying activities, especially in the south-central ridge, have also resulted in shrinking of ridge areas, concerning enormous loss to its biodiversity; 4. Southern Ridge- The Southern Ridge spread over an area of 62.00 sq km is by far the largest part of Delhi Ridge. The Southern Ridge is mainly situated in Mehrauli tahsil. Another ecologically important location, the Asola Wildlife sanctuary, was established in 1991 to enhance the protection and conservation of the ridge flora and fauna diversity.

1.4 Climate

The climatic regime of the region falls under the semi arid type, as influenced by the considerable distance of the city from the sea and prevalence of continental winds during major portion of the year. It has four well defined seasons namely winter, summer and monsoon season. The cold season begins at the end of November, and extends to March and winters are usually cold and night temperatures often fall to 7.3^{0}C during the period between December and February. This is followed by hot summer starting from March to till June. It is characterized by extreme dry conditions associated very high mean temperature of 40^{0}C in May (Graph: 1.1) and even it goes up to 44^{0}C-45^{0}C degree in June. The average annual temperature recorded in Delhi is 31.5° C based on the records over the period of 70 years maintained by the Meteorological Department. . The monsoon season starting from June extends up to end of September. Rest is transition season. It also experiences rains primarily during monsoon season.

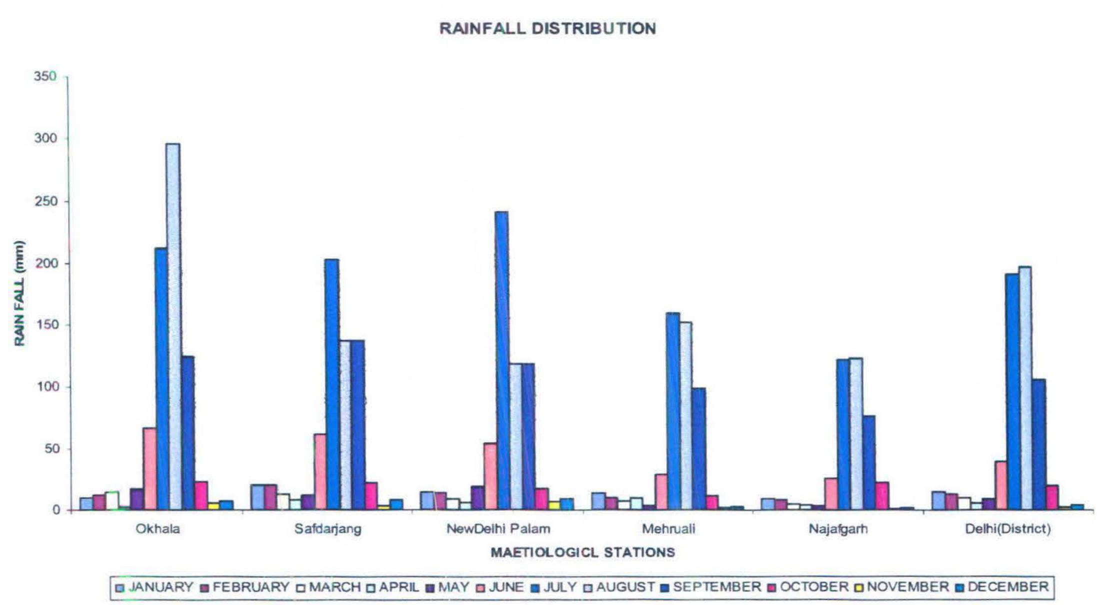
Graph: 1.1



Source: IMD

Winds are generally light during the post monsoon and winter months. They are stronger during the summer. Except during the monsoon months winds are predominantly from the westerly or north westerly in direction and be more northerly in afternoons (Census of India- Regional Divisions of India- a Cartographic Analysis; page number 28). In the monsoon season wind direction is Easterly and South-Easterly. About 87% of the annual rainfall is received during the monsoon months June to September. On an average, rain of 2.5 mm or more falls on 27 days in a year. Of these, 21.4 days are during monsoon months. For design considerations, rainfall intensity of 20 to 30 mm which generally occurs in one hour duration has to be taken into account. **The normal annual average rainfall is 714.6mm.** Records of rainfall for 5 stations located in and adjoining these two districts are available for sufficiently long period. The details of the rainfall are given below

Graph: 1.2 Monthly Rainfall Distribution



Source: *www.raiwaterharvesting.org*

The rainfall increases from south west to north east and isolated squalls also take place. The isohyet of 600mm surrounds the Yamuna Khaddar in the eastern part and in the western part is surrounded by isohyet of 300mm.

1.5 Vegetation and Biodiversity

Delhi has a much larger green cover than any of the other metropolitan city in the country, and could well be called a "Green City". However, the green cover is not uniformly distributed as some parts have considerable greenery than the others. Totally forest and tree cover of N.C.T is 268sq km as per the latest report by Ministry of Environment and Forest. Out of 268 sq km 170sq km (11.5% of total geographical area of the U.T) is under forest and remaining is under tree cover covering 98 sq km and 6.6% of the total geographical area. Over all state has 18.1% of its area under forest and tree cover. The district wise forest cover of Delhi is given below.

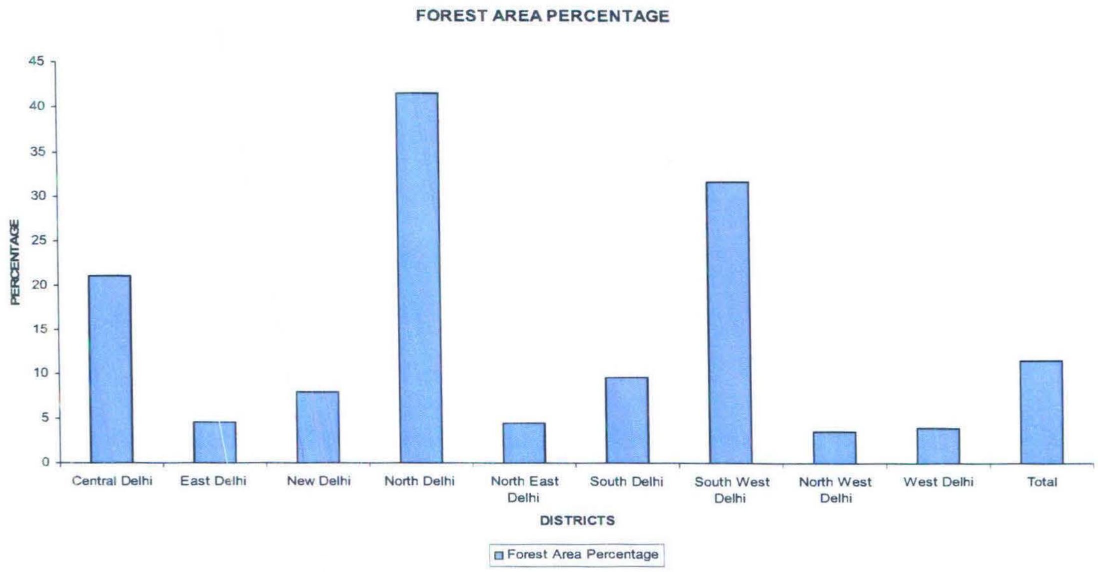
Table: 1.1 District Wise Forest Cover of Delhi (2003-04)

District Forest of	Geographic Area(sq km)	Forest Cover (ha)	Forest Area Percentage
Central Delhi	0.25	0.05	21
East Delhi	0.64	0.03	04.61
New Delhi	0.35	0.047	07.94
North Delhi	0.59	0.14	41.66
North East Delhi	0.60	0.02	04.48
South Delhi	2.50	0.41	09.66
South West Delhi	4.21	0.79	31.6
North West Delhi	4.40	0.15	03.51
West Delhi	1.3	0.05	03.91
Total	14.83	1.70	11.46

Source: State of Forest Report 2003, Forest Survey of India, Dehradun

The New Delhi and South Districts are greener when compared to other Districts. It's mainly because of the presence of the Rashtrapathi bhavan area and ridge region.

Graph: 1.3 District wise Forest Area Percentage



Source: State of Forest Report 2003, Forest Survey of India, Dehradun

Table: 1.2

Tree and forest cover in Delhi (N.C.T)		
Area	**Area (sq kms)**	**Per cent of total geographical area**
Geographical area	1,483	100
Forest cover	170	11.5
Tree cover	98	6.6
Forest & Tree cover	268	18.1

Source: Ministry of Environment and Forests (2005)

Apart from ridge protected area District Parks, City Parks, Community Parks etc. cover large area. In addition to this, a large chunk of green area is provided in the form of

Neighborhood Parks / Tot lots in the gross residential use zones, plantations / greens in large campuses like President's Estate, JNU, IARI, Delhi University, plantations along drains and roadside plantations. In addition to above, two Bio-diversity parks are under development by the DDA.

Biodiversity

Delhi Ridge is an important natural resource of this region which is rich in biodiversity in terms of rich diversity of plant as well as animal species. The ridges and hillsides of the national capital territory abound in thorny trees, such as acacias, as well as seasonal herbaceous species. It has over 120 species of plants. Climate of this region decides it biosphere. As rainfall decreases from east to west floral and fauna composition also differs between east and west i.e. river ecosystem and ridge and semi arid western side ecosystem. The sissoo (shisham; *Dalbergia sissoo*) tree, which yields a dark brown and durable timber, is commonly found in the plains. Riverine vegetation, consisting of weeds and grass, occurs on the banks of the Yamuna. New Delhi is known for its flowering shade trees, such as the neem (*Azadirachta indica*; a drought-resistant tree with a pale yellow fruit), jaman (*Syzygium cumini*; a tree with an edible grapelike fruit), mango, pipal (*Ficus religiosa*; a fig tree), and sissoo. It also is known for its flowering plants, which include a large number of multicoloured seasonals: chrysanthemums, phlox, violas, and verbenas. In spite of this, Ridge has *Prosopis Juliflora*, a weed colonising the native vegetation.

Among the Capitals in the world, Delhi hosts the largest number of resident and migratory birds after Nairobi. This is mainly due to three different habitats – the Aravalli belt, northern scrub forest and the Yamuna plain which attracts the aquatic habitat. This diversity helps in attracting birds of different habited loving. The animal life of the national capital territory, like its plant life, is quite diverse According to the Zoological Survey of India; Delhi has 32 species of mammals, 25 species of reptiles, 434 species of birds. There are 1787 species, 585 species of vertebrate and 1202 species of invertebrates. Among carnivorous animals are leopards, hyenas, foxes, wolves, and jackals, which inhabit the ravine lands and hilly ridges. Wild boars are sometimes spotted along the banks of the Yamuna. Monkeys are found in the city, especially around some of the temples and historical ruins. Birdlife is profuse; year-round species include pigeons, sparrows, kites, parrots, partridges, bush quail, and, on the ridges, peafowl. The lakes around the city attract seasonal species. Fish are plentiful in the Yamuna, and an occasional crocodile also may be found there. However, altered land use pattern of Delhi Ridge has led to disappearance, displacement or dispersal of many species.

In 1940 there were 300 species of birds in Delhi but by 1990s the number had gone down to 200. Among mammals, fox, hare, pig, blackbuck, chinkara, jackal, nilgai, hogdeer, laeopard cat, wolf, hyena, porcupine, cheetal and wild boar were present in the Ridge about a century back, but today higher mammals have almost vanished. The ridge serves as a sink for many pollutants, air purifier and supplier of oxygen. Delhi Ridge, therefore, needs to be conserved and developed by developing it into multistoried forest vegetation as well as faunal diversity which are threat mainly due to anthropogenic activities (www.vikipedia.com & http://www.dda.org.in/greens/biodiv).

1.6 Literature Review

To understand the urban geomorphological features, land use, land cover classes and their changes over a period of time due to impact of anthropogenic forces on them, the literatures are discussed in five different headings as - Anthropogenic forces on geomorphology and urban land use; mining and quarrying activities and impact; impact on hydrology and water bodies; ecological and environmental impact and GIS and Remote Sensing in urban land use and impact studies.

1.6.1 Anthropogenic Forces on Urban Land Use and Geomorphology

Urban geomorphology is the study of landforms; and their related processes; materials and hazards in ways that are beneficial to planning; development and management of urbanized area. The urban geomorphological studies are useful in identifying resources that are under threat and to study the geomorphological hazards posed on the human community due to their misuse or over usage. Land is always in a constant flux of continual change due to transformation resulting from either natural processes or human activities.

Fellmann, Getis, & Getis, (1992). Explains, no modern landscape evolution theory can leave the human factor out of consideration. Human interventions may be direct or indirect, deliberate or accidental, but undoubtedly influence natural geomorphic processes all over the Earth's surface. The interaction of people and their environment was determined not only by landscape, but the culture of the people. Permanent settlements soon developed due to the discovery of agriculture and several important locations for farming and trade emerged as cultural hearths and when development goes on problems related to it increased. Natural forests converted into parks for leisure and water bodies also became for same purpose in urban areas.

R.U.Cooke; D.Brunsden; J.C.Doornkamp and D.K.C.Jones, (1982). The Los Angeles metropolitan – the study area has encountered a range of geomorphological problems due to its rapid expansion. City expanded onto plains where they are vulnerable to floods and debris from mountains); it also expanded into mountains (where it is vulnerable slope failures) and along costal plains (slope stability and costal process problem) prevails. They say, active adjustment of the stream channel and channel bank erosion is the dominant adjustment, but aggradations also occur in urban geomorphology due to human activities. Change following urbanization is an increase in bed particle size due to the addition of particles of anthropogenic origin.

Margaret E Marker, (2003). Inherent landscape sensitivity becomes manifest when change reaches critical thresholds triggered either by extreme climatic events or by cumulative human impact or when both act in tandem. The Knysna Basin, South Africa - a southern Cape catchment, drains into the Knysna estuary is under Landscape sensitivity is high and thresholds are easily exceeded, leading to rapid and irreversible change. It is under threat from increasing population and burgeoning development. As per author, the estuary is already under threat from tourism-driven developments, from urban expansion and land-use changes in the catchments. Storm water runoff has increased in volume and peak flows carry suspended sediment into the estuary and threatens fresh water inflow. Waste water disposal brings in chemical and biological pollutants. Environmental deterioration is most visible in and adjacent to the estuary. Development, to be welcomed as a contribution to the local economy, must be managed to minimize impacts for environmental sustainability.

Hariklia Skilodimou, George Livaditis, George Bathrellos, Efthimia Verikiou-Papaspiridakou, (2003). Authors say geologic and geomorphologic conditions facilitate the flood phenomena at the broad region of Glyfada and Voula. Flooding of the region is very likely to happen because the water carries huge quantities of materials and water from the streams to the low and coastal areas. Furthermore, human intervention has caused the situation to become more complicated by wetlands and the lagoon have been dried up and covered by buildings without considering the specific conditions of the area. The stream channels have been diverted, filled in and covered by man- made structures, too. The urbanization and the road construction of the area modify the permeability and increase the volume and the velocity of the water flow during intense rainfall.

Leopold, (1973). As per his analysis, the transition of a watershed from the natural, forested state to a predominantly urban condition encompasses removal of vegetation and canopy, compaction of soils, creation of impervious surfaces, and alteration of natural drainage networks. These actions result in increased surface runoff and changes to sediment budgets. These changes, in turn, induce a geomorphic response, commonly resulting in enlarged, unstable channels.

K. N. Joshi & C. R. Suthar, (2002). Cities are becoming hub of almost all human activities. Be it job opportunities for unemployed, educational facilities for learners, availability of health services for the sick, economic upliftment, assured base of large consumers of agro-products reaching from rural sectors, cities have always attracted human beings. This has resulted in ever-growing size of cities, squeezing open spaces available within the city and has started exerting pressure on resources. The main factors affecting the urban fringe land transformation are growth of industrial, commercial and institutional activities as per the author.

Dr. Madan Mohan (2002). The hills came into existence at the close of the Dharwar Era. Basal quartzite, conglomerates, shales, slates, phyllities and the gneisses comprise the Delhi Ridge spreads over an area of 77.77 sq km but originally it was 150.46 sq km. This is because of the encroachment and destruction by human activities like mining and quarrying, deforestation etc which is having changes in the drainage system and adds pollution in the geographic environment.

1.6.2 Mining Activities and Impact

P. K. Haff (2001). Says, residual slopes receiving uncompacted over bank in mining and quarrying sites after excavation can change their stability condition both extensively and rapidly. The groundwater level and their quality also degraded. Stripping of vegetation from a hillslope may be done in one or a few days by directed human action, but the now-denuded hill responds to the removal of vegetation on a time-scale determined by its own dynamics, which, in the simplest case, is independent of the human disturbance time-scale. The hillslope erodes at a rate that depends on factors such as slope, rainfall frequency and intensity, and soil characteristics.

Felinks, Birgit1, Pilarski, Monika & Wiegleb, Gerhard1 (1998). Indirect effects of human activity may also introduce harmful changes in landscape system. In mining area after the mining activities were finished no amelioration and only local leveling took place; compression of the top soil was performed with the help of various methods in order to prevent landslides. These measures cause disturbances of the original relief and landscape morphology after dumping. Ground water lowering and alteration of vegetation in the area are also effects of mining are the areas discussed by the author.

MINENVIS December 2002 & March (2003). The newsletters from ENVIS says In the Aravalli Hills, a large number of mining activities, operation of stone crushers and pulverizes, deforestation and unplanned construction activities are causing environmental degradation. These mines are usually located in clusters in remote mineral rich districts / areas where living standards is lower and understanding of people towards environmental impacts is also poor. In the past, mine operators took no note of environmental damage.

The small mines (< 5 hectares) and the mining of 'minor minerals' which are small individually but have damaging characteristics when in clusters e.g. the mines of granite, marble, slates, quartzite etc. (falling under minor minerals) are no less damaging than the others, especially when the processing is taken into consideration. The mining activities in the region results in disturbance of land surface, altering drainage pattern and land use, besides the pollution problems.

S. A. Azad Dr. Ashish Mittal Prasar (2006). After independence new construction was planned and in 1950s mining started in and around Anand Parvat (near the present New Delhi Railway Station) and the motive was mining and razing down the hills and building the city. Initially, what was an the automatic phenomenon of shifting the quarry and crushing sites as the land grab was over in the area, now the relocation of all the mining activities was under the veil of preventing the pollution and environmental protection. The builders grabbed the land that was vacated when the polluting crushers and mining got relocated and many hotels and high-rise buildings came up on it.

1.6.3 Impact on Hydrology and Water Bodies

As the urban population grows older and internal congestion increases, changes in the utilization of land inevitably occur along with simultaneous changes in the social and economic structure. Water movement (hydrology); Stream channel shape and function (fluvial geomorphology); Water quality and Habitat are the most areas affect by human activities in urban area.

Grable J. L. and Harden Carol P. (2006). As the runoff increases due to little infiltration in built up area peak level discharges are noticed. In an urbanizing catchment, changes to the physical characteristics of the land surface alter the local hydrology and the size and quantity of sediment delivered to the stream .This sequence of changes has been shown to trigger complex responses by the stream system, including adjustments in channel morphology.

Saumitra Mukherjee, (2008). Humans transform the land for different activities based on their needs and quantifiable information on these dominating activities is necessary to develop future plans. Soil properties and land use patterns are major contributing factors to the hydromorphogeology of a particular area. Remote sensing data are helpful in the studies changes in land use patterns. Extraction of groundwater from non-potential aquifer may lead to land subsidence and destruction of vegetation in surrounding areas and Groundwater level-his study in Aravalli ridge in Delhi explains it.

Kumar, Pushpam et al, (2002). He explains that to maintain the ground water recharge potential of the floodplains, it is imperative to prevent any fresh civic structures to come up in floodplain areas as fresh ground water resources present in the floodplain and connected aquifers in the city are replenished annually due to the floodplains in Delhi. Any human activity impairing the water recharge function of the floodplain ecosystem will create problems not only for the present but future generation too.

Joshi K. N. & Suthar C. R. , (2002). Author explains that important impact of urbanization is noticed on the natural hydrological system of the city. As the urban areas spread the natural hydrological features like rivers, nallah, water bodies comes in the heart of the city. They are subjected to encroachment by the people. This results in either completely or partly block of the system. Hence this process on one hand breaks the hydrological system and on other hand creates a permanent recurrent flood damage zone in the city area.

Ramachandraiah Sheela Prasad C. (2004). With urbanization proceeds, the biological needs like water increase. As the local water resources like rivers, lakes and groundwater get increasingly polluted, the highly urbanized areas are forced to seek water from ever greater distances and expense. Hyderabad growth encroached into vacant lands and water bodies due to the increasing pressure on land for housing and other activities. Water channels that used to carry floodwaters from one lake to the next in a catchment area have also been encroached by private and government agencies. . It is estimated that there were 932 tanks in 1973 in and around Hyderabad which came down to 834 in 1996. Consequently the area under water bodies got reduced from 118 to110 sq km.

May 15; Hindu(2005) In Delhi there were around 800 lakes; ponds and other surface water bodies which are come to around 600 in number now. In 2001, the MCD had identified 177 water bodies in the Capital but this figure was challenged since an earlier report had identified 355. Finally, an independent body was set up by the court which has identified 794. Of this, at present, 629 water bodies exist officially in Delhi which is being revived by various agencies. It's a dangerous touch of exotica that is chocking the city's green lung. A recent stock taking of the growing weed population in the reserved green area of the Capital revealed that American weeds are rapidly becoming naturalized in the Ridge as undergrowth choking native vegetation and fast working their way to becoming the dominant species in the forest.

Times of India, (Sep 8, 2008). Three water bodies in JNU, which were mentioned in the 2002 list, did not find a place in the current list. Water bodies like wells, small lakes, marshlands and depressions are constantly being used to dump the garbage of the city because of the rapidly shrinking landfills in the Capital. They explain that with the constant dumping, the water gets contaminated with heavy pollutants and which can be harmful for the human beings.

Gupta Kokil, (2006). The author explains importance of water bodies as, those have been the prime determinant of location and growth of settlements. Water bodies were especially created to conserve rainwater to serve during dry seasons. Once valued & protected, today the water bodies in urban areas exist as "wasted" precious land prone to encroachment and waste disposal. In Delhi alone, about 800 water bodies have been identified from the revenue records & surveys. Most of these have either been reclaimed for urban development or are in threatened state of survival. With the growing stress on available urban water resources and increasing techno-economic- political difficulties in identifying and developing new sources, he says that it would be a relevant venture to look at the feasibility of reviving the urban water bodies.

Kapil Narula, Frank Wendland, Bhujanga Rao D.D and Bansal N.K., (2000). An assessment of water resources development in the Yamuna river basin, out of 80 districts in the basin, at present 20 districts face high water stress caused either due to depletion in water quantity or deterioration in water quality. A water development scenario examining the prospects for water sustainability by the year 2025 says the number of water-stressed districts will rise to approximately 40.

Soni Vikram , (2007). Any tampering with the river and its floodplains would be an unmitigated disaster. It means the loss of an incredible water resource. But with support of governments, this is happening in Delhi, with huge developments like Delhi Secretariat, Akshardham, etc. already built and with the Global and Commonwealth Games village and metro depots are going on. Building on the floodplains, in a water-starved city, is the destroying their own habitat.

1.6.4 Impact on Ecology and Environment

de Blois et al and Domon (2001). Urban people use the environment through consumption of food, energy, water, land and goods more than the level of replenishment / recycle / replacement, thus in turn, pollute it more. This adversely affects the lives of the urbanites. Habitat Loss; Deforestation; Soil erosion; Water loss; Biodiversity loss and Ecological disruption are some of the destructive impacts. In less than two centuries large parts of the territory went under crop land before coming back to the forest area in Godmanchester – Canada. The changes were not uniform as well as not because of natural processes but mainly due to socio-economic for specific resources.

Amjed S. Almas a, Rahim a C. A., Butt b M. J., Tayyab I. Shah (2006). Urbanization, the conversion of other types of land to uses associated with growth of populations and economy, is a main type of land use and land cover change in human history. The urban centers in Pakistan are characterized by haphazard growth, congestion, pollution and unplanned expansion, including settlements along major national highways adjacent to metropolitan areas. This has put increasing burden on an already inadequate infrastructure and contributed to environmental problems. Lahore is the second largest city of Pakistan. Here Urbanization is taking place at a striking rate with inadequate development of the requisite infrastructure. Such sprawl gives rise to the congestion, pollution and commuting time issues and encroachment of land. The metropolitan expansion, based on growth direction and distance from the city centre, was observed for a period of about thirty years.

Joshi K. N. (2002). The rapid increase of urban population and the urbanization leads to an ever increasing demand on the urban environment. The unplanned expansion of cities and encroachments by people for various purposes pose serious problems to the environment and the people living in the area. Therefore it is very much necessary to monitor the land use and its changes in periodical frame in Jaipur.

Rahman, (2006). Scientific management to control this kind of an environmental degradation would need comprehensive information on varying scale of forest cover type, resource component, land use practices and administrative details in the format of national geospatial data frame. Remote sensing based database should finally help the effort of saving forest resources in megalaya, (Indira Gandhi Conservation Monitoring Centre 2005, WWF). Much attention was paid to measuring human impact on nature, e.g. detecting area and extension of large scale forest decline or deforestation. To house such a large migrant people city has to expand. The rate of expansion is very fast, unplanned, uncontrolled and most of them are illegal.

Bhupesh Mangla (1988). Once known as the 'Garden City', Delhi is presently reeling under an alarming rate of environmental pollution which may earn it the dubious distinction of being one of the most polluted cities in the world. The air is affected by smoke from vehicles, factories and power stations, the water by sewage and industrial effluents and the green environs by unplanned urbanization. Areas with vehicular traffic are most affected.

Vikash Talyan, R.P. Dahiya, T.R. Sreekrishnan, (2008). With an ever increasing population and a rapid pace of urbanization, the effects of poor waste management practices on human health and the environment have never been more pronounced. Present policy and infrastructure are inadequate in dealing with the enormous quantity of MSW generated by the city of Delhi. With an almost 3-fold increase in MSW generation by 2021, the situation may reach critical proportions. More such initiatives need to be taken towards educating people about correct practices of solid waste disposal. Initiatives taken by policy makers never yield results unless matched by proper implementation at every level.

Suresh Jain & Mukesh Khare, (2007). In the past, major causes of environmental degradation in mega cities have occurred 'sequentially' rather than 'simultaneously.' Presently, mega cities are suffering intense pressure of a combination of different driving forces e.g. motorization, industrialization and an increase in urban population density. Air pollution at traffic intersections and urban roadways in Delhi is critical and the problem has reached threatening dimensions. Even with the introduction of advanced emissions control technology and application of CNG, motor vehicles remain the dominant sources of urban air pollution.

The Hindu, (Feb 01, 2008) R. S. Gupta and B. L. Vohra (Ridge Monitoring Committee) said, a proper demarcation of the forest area has not been carried out as a result of which Mandi and Jaunpur villages have seen a thorough infringement of the forest boundary. There are issues of unauthorised constructions and, in a glaring example; settlements have come up under a high-tension cable in the Vasant Kunj area.

Chaturvedi M. K., Bassin J. K., (2009). Bore well in Nehru Camp pumping station, the bore well in Sanjay Gandhi pumping station, and the WTP in Haiderpur using the WQI and classification based on NSF WQI as an indicator of the drinking water quality and compare the quality of water supply sources and quality analysis for Temperature, TDS, Turbidity and pH shows Nehru Camp and Sanjay Gandhi samples to be treated before usage where as Haiderpur sample is good.

1.6.5 GIS and Remote Sensing and Urban Geomorphologic Studies

Remote sensing is the science and art of obtaining information about an object, area or phenomena through the analysis of data acquired by a device that is not in contact with the object, area, or phenomena under investigation. The data analysis process involves examining the data using various image processing techniques by a digital computer. Its application in the field of urban geomorphology studies is of great prominence. Urban development monitoring and mapping are necessary to make effective policy for development of unplanned areas as well to protect the vulnerable areas from over and misuse. But monitoring and mapping requires reliable data at regular intervals. In momentum of urban growth Remote sensing techniques and GIS tools have become important in management of urban environment.

Chaudhary B. S., Saroha G. P. and Yadav Manoj (2008), says as land resources being finite imply more judicious use of land resources to meet the ever-increasing demands. The unsustainable and unplanned exploitation of land resources is the major reason for degradation of our environment. The main issue is to bring a balance between economic development and conservation of resources, which is possible by proper inventory, and management of these resources on periodic basis. Recent technologies of Remote Sensing (RS) and Geographic Information System (GIS) have made it feasible and cost effective. The expansion of Gurgaon City is immense due to increasing population and Industrial/ Infrastructural development pressure of National Capital.

Rajeshwari (2006). Author recognizes, Remote sensing as an effective technology for the monitoring and mapping the urban growth and environmental change. The main advantage of satellite remote sensing is its repetitive and synoptic coverage that is very much useful for the study of urban area and to create information base on land use, land cover distribution, urban change detection, monitoring urban growth and urban environmental impact assessment in any study of urban landscape. The two components of urban ecology can be perceived: (i) the natural environment comprising location, physical structure, and (ii) the created environment comprising of buildings, streets, civic amenities and social facilities which are important under urban geomorphological studies. Satellite images enable us to better understand some of the intrinsic components of urban ecosystems and the interactions within whole urban environment.

Tayyebi, A., Delavar M.R., Saeedi S. , Amini J. and Alinia H., (2008). Geographical Information System (GIS) provides up-to-date spatial information for the detection of change and the spatial pattern of an attribute along with strategic modeling and mapping solutions. They have taken two historical Landsat imageries of Tehran Metropolitan Area with twenty year time interval and user-selected socio-economic and environmental variables analysis has been done. It has revealed that the land use change in this region for this time period is concentrated along west of the city. The land use change pattern to the south of the metropolitan area is also substantial but more dispersed as per this analysis.

Amjed S. Almasa, C. A. Rahim a, M. J. Butt b, Tayyab I. Shah (2006). Exploitation of Remote Sensing and GIS techniques for studying the metropolitan expansion and land use/ land cover classification of cities where urbanization is taking place at a striking rate with inadequate development of the requisite infrastructure. Lahore second largest city in Pakistan in a period of about thirty years urban metropolitan expansion, based on growth direction and distance from the city centre, was observed using Remote Sensing and GIS technique. Resultantly, remote sensing and GIS techniques were found very efficient and effective for studying the complex metropolitan growth patterns along with the classification of urban features in to prominent categories.

Rindfuss et al. (2003). Integrated geo-spatial technology i.e. remote sensing (RS), geographic information system (GIS) can contribute substantially in a more supplementary fashion to some of the interactive operations that should become an asset for assessing, understandings, mapping utility. By utilizing remote sensing data and implementing GIS mapping techniques, change detection over a period of time of the urban areas can be monitored and mapped for specific developmental projects. Creating linkages between remote sensing data and socio economic data obtained on the ground from household surveys has been recognized as one of the major challenges of land use/land cover change studies.

Gupta, Kokil (2006). Mapping of water bodies using GIS and analyze the impact of urban development, current status and scope of rejuvenation on the basis of the available data can be done. Spatial analysis at city level and zonal level conducted using map of water bodies generated in GIS to analysis its status. Other attribute and spatial data can be over laid to study the areas of suitability for development as well as conservation. This technique is useful in conservation of water bodies in urban area

Mishra, J.K.; Aarthi, (1994). The research is basically to analyze the components influencing geomorphological processes especially in estimation of sediment transfer process in urban geomorphology of Delhi by the researchers. Several parameters like terrain and vegetation features are defined and taken into consideration. The study shows the spurt in urbanization in the study area. These developments reduced forest and water availability in the river Yamuna. Satellite data from SPOT and Indian Remote Sensing Satellite (IRS-1B) from 1987 to 1992 have been combined with rainfall data and ground truth to assess both the spatial and the temporal changes shows, forest cover is constantly declining with the most severe depletion occurring in northeast Delhi. However, due to increase in rains over the past few years, the forest and the vegetation covers in 1992 have increased.

Saumitra Mukherjee, (2008). Remote sensing data are helpful in the studies changes in land use patterns, which are located in the recharge areas of elevated parts of Aravalli hill region- region situated on a low relief hill, northwest of Mehrauli and southwest of Hauz Khas in South Delhi, India. Satellite data products inferred Land use, Geological, Hydromorphogeological and ecological information. Urban development monitoring and mapping are necessary to make effective policy for development of unplanned areas. But monitoring and mapping requires reliable data at regular intervals. Humans transform the land for different activities based on their needs and quantifiable information on these dominating activities is necessary to develop future plans

1.7 Objectives

- Preparation of geomorphological map of the study area to understand various geomorphological units.
- Different years land use land cover map preparation to identify the changes in land use and land cover in the study area.
- Analysis of the effects of the land use land cover changes on Geo- environment of the study area.

1.8 Data Source

1.8.1 Primary Data

Primary data is collected using through short field visits and observation of various land use land cover classes and different geomorphological units.

1.8.2 Secondary Data

- Survey of India Toposheet:

Dated 1975 (53H/2; 53H/3; 53H/6) & 2000 (H43 X2; 43 X3; H43 X6 and H43 X7)

- Satellite imageries of different years
    1. LANDSAT imageries
       MSS - Path/Row 157/040, 08-03-1977
       TM - Path/Row 147/040, 18-05-1989
       ETM - Path/Row 146/040, 13-09-1999
    2. IRS P6 LISS III imagery 12-02-2006

- Published map & Data
    1. Delhi Geology and Geomorphology Map by Geological Survey of India, 2000
    2. Climatic Data
    3. State Economic Survey, Statistical Abstract
    4. State of Forest Report by FSI, Ministry of Environment and Forest
    5. Water Quality- (Surface and Groundwater) Data by CPCB, DPCC
    6. Groundwater Data by CGWB
    7. Air Quality Data and Solid Waste Data by CPCB, DPCC

1.9 Methodology

- Quantitative and qualitative data collection, Remote Sensing and GIS environment.
- Visual interpretation of Toposheets and Satellite Imageries to identify and interpret different land class features and various Geomorphological units.
- Generation of base map of the study area using SOI Toposheets of 1976 and 2000 to understand various Land Use and Land Cover classes.
- Slope map, and Digital Elevation Model preparation to understand the geomorphology of the study area.
- Generation of drainage map to understand the hydrogeomorphological system of the study area with the help of Survey of India Toposheet and DEM.
- Land Use and Land Cover of different years-1977, 1987, 1999 and 2006 supervised classification is been carried out and analysed.
- The changing scenario in Land Use and Land Cover during last three decades has been studied based on the Change Detection Map prepared in ERDAS and GIS environment using classified images
- Performing Groundwater Quantity and Quality analysis and interpretation
- Analyzing Surface Water Quality trend at two sample points in River Yamuna and Interpretation based on existing secondary data.

- Air Quality trend and Solid Waste management have been analysis and interpretation from existing secondary data

Pre-Field Work

1. Preparation of
   - Geomorphology Map
   - Land Use/ Land Cover Map of different years
   - Water Bodies Map
   - Soil Map
   - Quarry and Mining area Map

2. Base Map preparation using Toposheet

Field and Post - Field investigation

- Confirmation of earlier interpreted Land Use and Land Cover Classes, Geomorphological Units with the help of existing literature survey.
- Preparation of final map after the modification of pre-field maps and corrections

1.10 Organization of the Study

Chapter I

This chapter is the preliminary introductory one deal with about the study and its importance. This briefly discusses about the study area and literature study related to the study. This also covers the objectives of the study, methodology, primary and secondary data sources as well the organization of these study materials.

Chapter II

The second chapter- deals about geology and geomorphology of the study area broadly. Geological origin and land form evolution along with the human influences are discussed. The study areas four distinct geomorphological units- Older Alluvium, Newer

Alluvium, Ridge and its four units and Nearly isolated Chattarpur basin in the middle of the South and South Central Ridges are discussed. Apart from this Slope, DEM, Soil, Drainage system in the study area are explained.

Chapter III

The third chapter deals with the Land Use and Land Cover of the study area and the changes in these classes over the period of three decade i.e. from 1977 to 2006. In the first part historical evolution of the city is discussed briefly. Land Use and Land Cover Classification of the four periods 1977, 1987, 1999 and 2006 have been done separately then Change detection has been carried out for 1977 and 2006 classified image as well as for 1999 and 2006 to study long term as well as short period changes. Five classes- Built-up area, Vegetation, Cultivated Land, Barren and Exposed Land and Water Bodies are discussed separately to show the changes in each category over period of time.

Chapter IV

This chapter analyses various anthropogenic activity causes for the changes in land use of the study area. The area analyzed are causes in the ridge region ecological changes- has been discussed under impact of mining in this particular area, land encroachment in various parts and vegetation cover changes. This also includes the conservation activities by the government. Ecological damages in the Yamuna flood plain area which falls under the study area also discussed in this part. In the following part of the study activities on groundwater impacts are dealt as quantitative changes and qualitative change analysis. Surface water quality analysis also been done for two sample points in Yamuna River. Apart from this air quality, as well as solid waste statuses also discussed in this chapter.

Chapter V

The last chapter is the concluding remark which brings out the discussion, based on the analysis made from the previous chapters. Thus this chapter throws light on the results and discussion made in the study.

Chapter II

Chapter II

Geology and Geomorphology of the Study Area

Geomorphology and geology are the science and study of Earth and its composition, structure, physical properties, dynamics, and history and the processes by which they are formed, moved, and changed and it also includes the scientific study of landforms, the history of their formation, and examination of their constituent materia and processes that shape them. The landscape is built up through tectonic uplift and volcanism. Denudation occurs by erosion and mass wasting, which produces sediment that is transported and deposited elsewhere within the landscape or off the coast. Landscapes are also lowered by subsidence, either due to tectonics or physical changes in underlying sedimentary deposits. These processes are each influenced differently by climate, ecology, and human activities where they evolve in response to a combination of natural and anthropogenic processes. Its important to understand why landscapes look the way they do to understand landform history and dynamics, and predict future changes through a combination of field observation , remote sensing, GIS and statistical data interpretation.

The geology of India started with the geological evolution of rest of the Earth i.e. 4.57 Ga (billion years ago). India has a diverse geology. Different regions in India contain rocks of all types belonging to different geologic periods. The Indian sub-continent was once part of the supercontinent of Pangaea and it was attached to Madagascar and southern Africa on the south west coast, and Australia along the east coast in 160 Ma during the Jurassic Period, rifting caused Pangaea to break apart into two supercontinents namely, Gondwana (to the south) and Laurasia (to the north). The Indian sub-continent remained attached to Gondwana, until the supercontinent began to rift apart about in the early Cretaceous, about 125 Ma (Briggs, John C.,2003).

The Indian Plate then drifted northward toward the Eurasian Plate, at a pace that is the fastest movement of any known plate. It is generally believed that the Indian plate separated from Madagascar about 90 Ma , however some biogeographical and geological evidence suggests that the connection between Madagascar and Africa was retained at the time when the Indian plate collided with the Eurasian Plate about 50 Ma (Briggs, John C.,2003). This orogeny, which is continuing today, is related to closure of the Tethys Ocean. The closure of this ocean which created the Alps in Europe, and the Caucasus range in western Asia, created Himalaya Mountains and the Tibetan Plateau in South Asia. The earliest phase of tectonic evolution was marked by the cooling and solidification of the upper crust of the earth surface in the Archaean era (prior to 2.5 billion years) which is represented by the exposure of gneisses and granites especially on the Peninsula. These form the core of the Indian sub-continent and the Aravalli ridge relief.

National Capital Territory – Delhi occupies a nodal position on the sub- continent and has the honour of being the capital of India. This is a part of Southern Haryana Plain which is surrounded by Haryana state in north, south and west and Uttar Pradesh in eastern side falling $28^{0}25'$ and $28^{0}53'$ North Latitudes and $76^{0}50'$ and $77^{0}22'$ East Longitudes . Physiographically the NCT is characterised by Piedmont Plain , Old Flood Plain, Yamuna Kadhar(newer alluvium) and the Aravalli Ridge. The physiographic divisions are mainly influenced by river Yamuna and Aravalli range. The study area falling in $77^{0}6'$ and $77^{0}20'$ East Longitude and $28^{0}42'$ and $28^{0}24'$ North Latitude covers 620 sq Km in and arround Delhi ridge region gains prime importance due to the breach, invasion and occupation of this important geomorphological features and for the protection of the same.

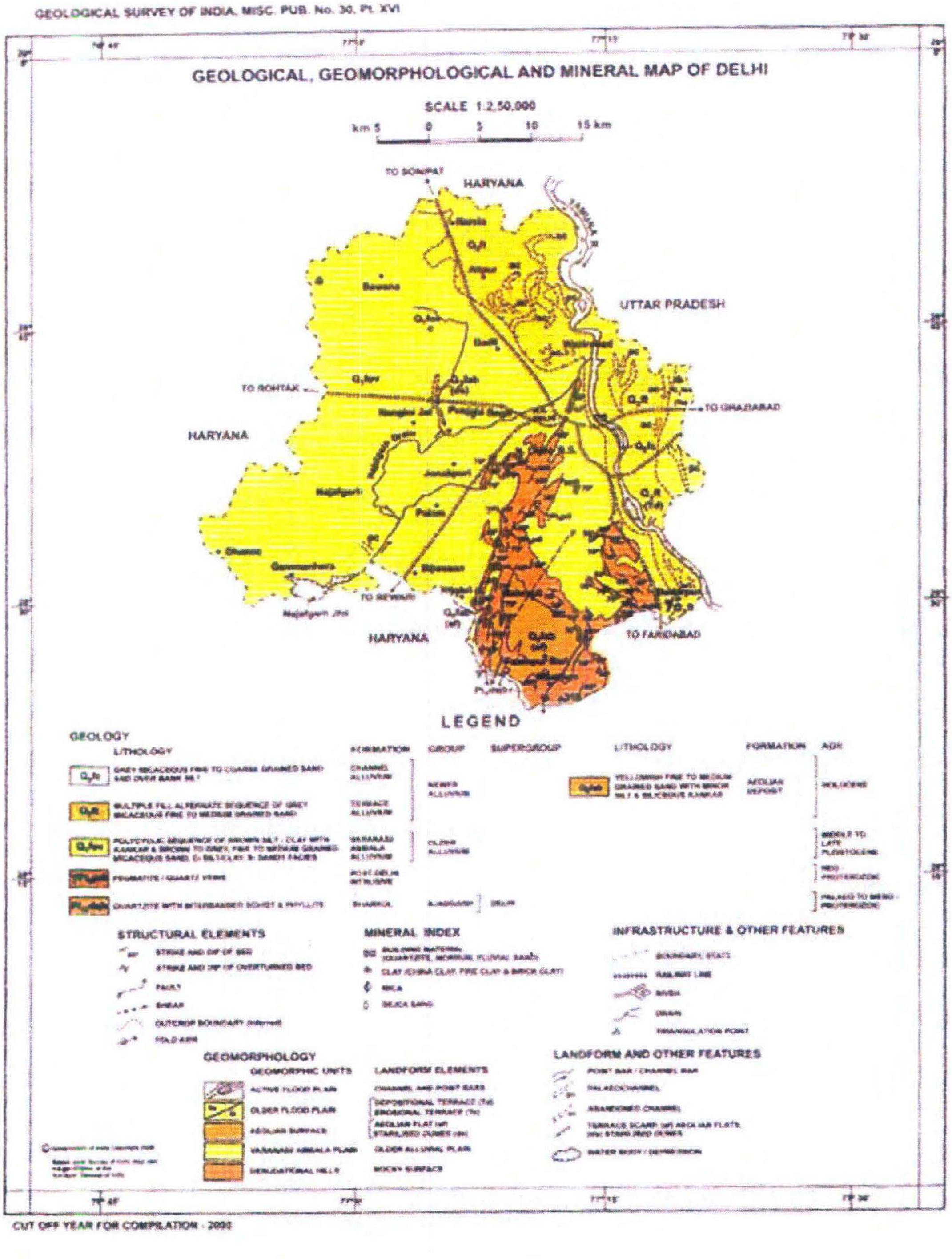
2.1 Geology of the Region

Geologically India is divided into three regions, viz., Peninsular region; Extra peninsular region and Indo-Gangetic plain. Peninsular region is one of the oldest land masses of the earth and is dominated by senile topography made up off Archaean super group- Gneisses and Schists comprising pre- Cambrian era rock structures. They are the fundamental or basement complex formed as plutonic intrusions having well defined foliated structures. Archaean super group covers two- thirds of the peninsular region and number of isolated outcrops extending from north of Vadodara to a long distance along the Aravalli.

This Peninsula region is occupied by the Dharwar system which is also pre-Cambrian era rock structures extends up to the Aravalli of Rajasthan between Jaipur and Palanpur. Cuddapah super group next to the orogeny of Archaean and Dharwar system containing unfossiliferous clay, slates, quartzite, sandstones and limestones were deposited in great synclinal basins which occupy major portion of Andhra Pradesh, Orissa and the main axis of Aravalli from Delhi to Idar in Gujarat. Peninsula region is also occupied by Vindhyan supre group, Gondwana, Cretaceous (Deccan Trap formation) systems also. Extra peninsular on the other hand presents the most youthful relief of the earth in the form of the Himalayas. Indo-Gangetic plain presents the flat, featureless and monotonous topography. The Indian Peninsula has not undergone marine submergence since the Cambrian period and is not much affected by tectonic forces. But the Extra-Peninsula region has its origin in the Tethys Sea which is weak and flexible portion of the earth crust prone to tectonic forces (D.R.Kullar, 2005).

The Aravalli region forming the northwestern part of the Bundelkhand represents a classic record of the Precambrian supra-crustals. The metasediments along with concordant and discordant intrusive and extrusive phases corresponding to three geological cycles have been designated as the Bhilwara, the Aravalli and the Delhi Supergroups. It extends approximately 500 kilometres from its northern end to isolated hills and rocky ridges into Haryana, ending near Delhi. Aravalli and Delhi Supergroups exhibit a mature topography where the physiography has faithfully depicted the major structures of area. The study area which covers Yamuna flood plain in the east, Aravalli-delhi subgroup from south to north and north east and the western alluvial palin. The bedrock topography in Delhi is undulating in nature with several humps and depressions. The Aravalli Range is the remnant of an early Proterozoic orogen called the Aravali-Delhi orogen that joined the two older segments that make up the Indian orogeny.

Figure: 2.1



The Alwar quartzite of Delhi system exposed in the area belong to Pre- Cambrian age. The quartzite are pinkish to grey in colour, hard, compact, highly jointed, fractured and weathered. These occur with inter beds of mica- schist's and are intruded locally by pegmatite's and quart veins. The silt and sand fractions of these sediments were mostly quartz, which indicate the sediments were developed under medium to high weathering intensities for a long period of time. The clay fraction was mainly kaolinite; quartz, feldspar, mica, kaolinite, illite, chlorite and calcite are present in all the parts of the study region. Quartzite are ferruginous and gritty types on weathering and subsequent disintegration give rise to coarse sand (Badarpur sands). Chemical weathering of deer horizons is also common. Few important mega lineaments - major fault zones or the zones of intense granitic activity also present here Saumitra Mukherjee (2008). The strike of these rocks varies north east - south - west to north northeast – south southeast with steep dips towards south east and east except for some local variations due to folding.

Plate: 2.1

Weathered Granites

The prominent joint sets are strike joints, bedding joints and dip joints. Some of these are oblique to the regional strike of rocks and support drainage running in diagonally opposite direction within the same lineament, indicating thereby upheavals subsequent to the lineament formation. The lineaments fall broadly in two sets which are correlatable to the two major phases of Delhi orogeny. The lineaments of the first set trend NE-SW and are more prominent: than the NW-SE and WNW-ESE running lineaments. The major lineaments together with other regional lineaments depict appreciable geomorphological expressions and significant geological evidences. Delhi region has a long seismic history being affected by earthquakes of local origin as well as these on Himalayan origin. Based on the tectonic map of the region prepared by Srivastav and Roy(1982), this region is characterized by several dominant feature such as the Delhi - Hardwar ridge, the Aravalli - Delhi fold, the Sdohna fault, the Mathura fault and the Moradabad fault.

Table: 2.1 Stratigraphic Sequence of the Area

Geological unit	Series	Characteristics
Present and sub recent (Pleistocene)	Younger Alluvium	Yamuna river bed sand and other sediment deposits in the stream bed i.e. channel alluvium and terrace alluvium
	Older Alluvium	Polycyclic sequence comprising of brown silt, clay with kankar beds, sand of fine to medium grained.
Post Delhi intrusive and Delhi Super Group (Pre- Cambrian)	Alwar series	Quartz Quartzites, grayish, bluish and pinkish in color, fine to coarse grained veins and Pegmatites.
Aeolian deposit	Holocene–recent series	Yellowish fine to medium grained sand with minor silt and siliceous kankar

Source: Geological Survey of India Misc. Pub. No 30, Pt. XVI (2000).

2.2 Geomorphology of the Region

Geomorphology of India can be divided into five major division viz., The Himalayan Mountains, The Great Plain, The Peninsular Plateau, The Coastal Plain and The Islands. The Himalayas consists of the youngest and loftiest mountains of the world extending over 2400 km which are recent in orogeny. The Great Plains are aggradational plain formed by deposition of three major rivers viz., the Indus, the Ganga and Brahmaputra. The Coastal Plains are narrow strip between the edges of the Peninsular Plateau and the coastline covering about six thousand kilometers and the Islands comprises of the Andaman and Nicobar island group in Bay of Bengal and the Lakhshadweep island group in Arabian Sea. Regarding Peninsular Plateau is concerned in the north it runs along the Aravalli range up to Delhi and parallel to the Ganga and Yamuna plain from west to east and flanked by Western and Eastern ghats.

The Aravalli Range one of the major physiographic elements of Peninsular India running from south - west to north – east for 800 km between Delhi and Palanpru near Ahmedabad in Gujarat . The Aravalli represent the relict of the world's oldest mountain formed as a result of folding close to the Archean era marking north east as Delhi ridge but it suppose to continue up to Haridwar buried under the alluvium of the Great Plains (D.R.Kullar, 2005).

Geomorphologically, the study region is characterised by mature topography with more or less flat-topped mountain ridges, inselberg surfaces and vast stretches of plains. The Union Territory of Delhi consists of flat and level plains interrupted by cluster of sand dunes and a long continuous chain of rocky ridges. The sand dunes are of varying dimensions and in general trend northeast – southwest where the study area finds it in the south western part and more or less fixed in this area which supports vegetation. The study area is located at the northern end of the Aravalli Mountains and it is almost fully surrounded by Gangetic alluvium. An extension of the Aravalli Hills enters Delhi region from the South, spreads out into a rocky table- land and runs in a northeasterly direction across the Delhi State (Sett, 1964).

The Delhi ridge which is the northernmost extension of Aravalli Mountain consists of quartzite rocks and extends from southern parts of the territory to western bank of Yamuna for about 35 kilometers. The alluvial formations overlying the quartizitic bedrock have different nature on either side of the ridge. The Yamuna flood plain contains a distinct river deposit. The nearly closed Chattarpur alluvial basin is occupied by alluvium derived from the adjacent quartzite ridge. The geomorphology map of the study region has been prepared with the help of SRTM data (2003), SOI Toposheets and existing literatures. The different geomorphological units of the study area (Figure 2.2) are,

1. Yamuna River major unit and micro units of Streams and nallas, Lakes and swamps.
2. Quartzitic Ridge trending in NNE-SSW.
3. Older Alluvial plain on eastern and western sides of the ridge and buried pediments
4. Yamuna flood plain deposits in the eastern region.
5. Chattarpur alluvial basin which is isolated and nearly closed.
6. Isolated hillocks

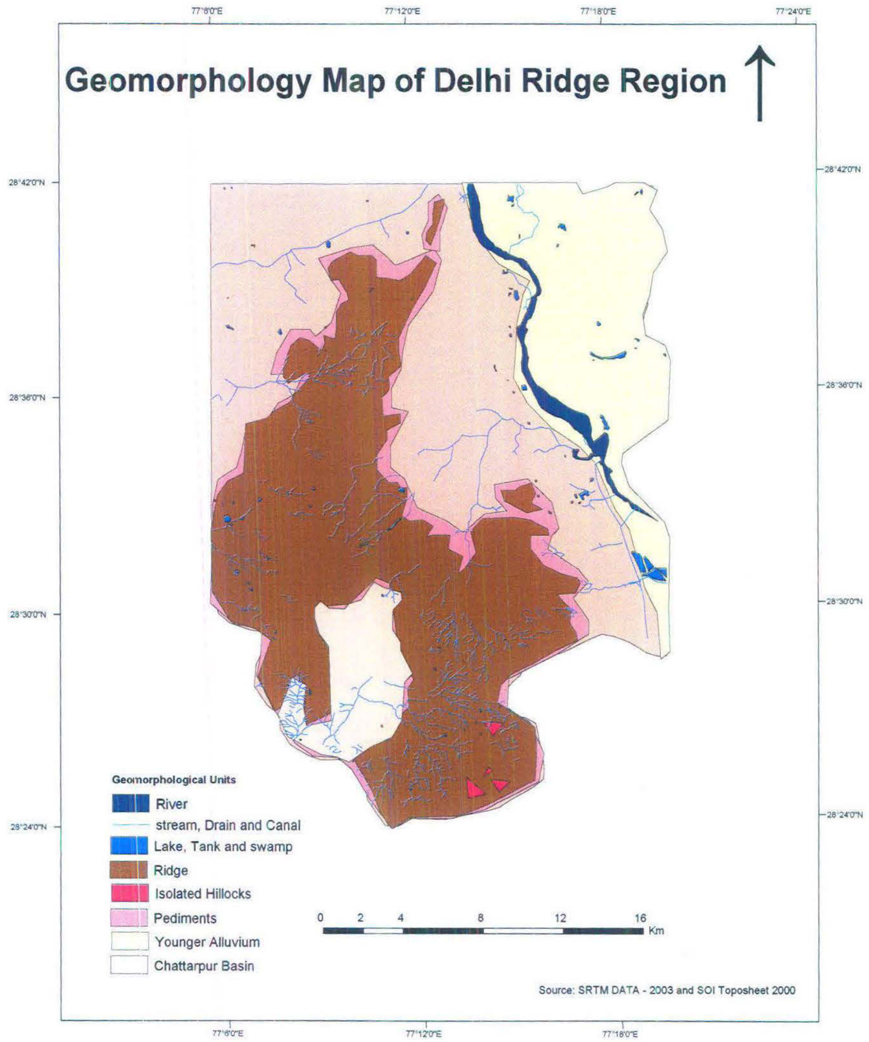
The terrain is generally flat in north and North West part of the study area and NNE-SSW trending Delhi ridge in the central portion of the region with river. Thus the study area can be divided into three major geomorphological units i.e., Delhi ridge, older alluvium (Pleistocene) and newer alluvium (Holocene)

2.2.1 The Ridge

The exposed ancient Aravali (Pre-Cambrian) mountain ranges extending NE in this area the Aravalis might have extended as far as up to the Himalayas. It reaches near the bank of river Yamuna at Wazirabad village then runs parallel to the river encircling the walled city and extends towards the weatern part of the city. In the southern part the ridge runs further towards the Qutab and Mehrauli where it throws out numerous branches and some extends towards Gurgaon district and the highest spur is located in the Tuglakabad Fort.

The region is surrounded in the north and east by Indo-Gangetic plains, in the west by the extension of the great Indian Thar desert and in the south by the continuation of Aravali ranges. The exposed rock outcrops in Delhi are mainly quartzites of the Alwar series. The Alwar quartzites are the basement rocks exposed in the area and belong to the Pre-Cambrian age. These are composed mainly of quartzite with inter beds of mica schist and are intruded locally by pegmatite and quartz veins (Krishnan, 1982). The quartzite inter bedded with mica schist belonging to the Delhi Super Group, unconformably overlain by unconsolidated Quaternary to recent sediments. The rocks of the Delhi quartzite have undergone multiple folding and different phases of metamorphism.

Figure: 2.2



The quartzite are white, pale grey or pinkish purple in color and mottled with brown and red depending up on the amount of iron oxide present. These quartzites occur in the central and southern part of the area while the Quaternary sediments comprising older and newer alluvium cover the rest of the area.

The strike of the quartzites varies from NE-SW to NNE-SSW with steep slips towards the east and south east direction. Three sets of joints are common in Delhi quartzites. Of these two sets are almost vertical and one is horizontal. One of the vertical joints trends north - south while the other is at right angle to it. The north south joints are more in number than the other two sets. The effects of weathering are more pronounced along the joint plains. The weathering of pegmatite gives rise to clay which is available in many areas of the Delhi. The detailed geological map of Delhi gives the geological successions of the Delhi region (Naqvi and Roger, 1986).

Tors and spheroids are commonly exposed features on the ridge. Massive quartzite has been fractured and joint systems have developed due to compressive forces related to folding, as well as due to uplift in this region (Tyagi, 1980). Gullies or open gull structures as described by Robinson and Williams (1994) for some European sandstones, small-scale caves up to few metres in size and pits are also observed on the Delhi ridge (Jayant K. Tripathi and V. Rajamani ;2003).

The ridge can be divided physiographically into four, namely Northern, Central, South Central and Southern based on their presence. This is not a continuum as various intervening stretches have, over a period of time, been brought under urbanisation - for example the Central Ridge area was planned as an integral part of New Delhi, at the time of the development of New Delhi as the Capital in the early part of the twentieth century.

The Master Plan of Delhi - 2001 identified the Regional Park into four parts as below:

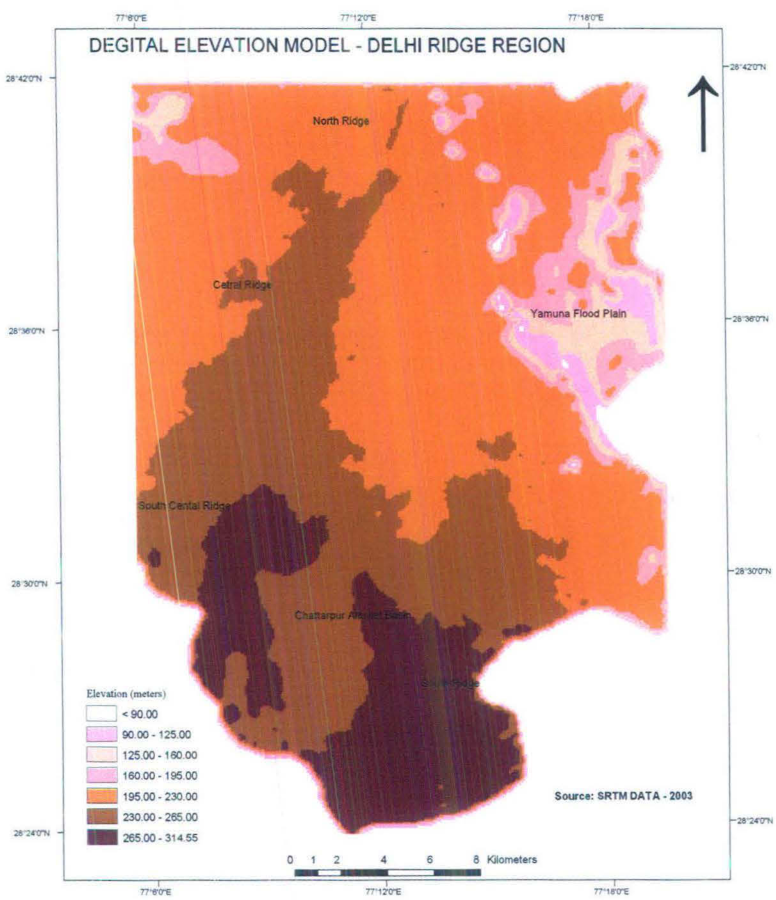
1. Northern Ridge 0.87 sq km
2. Central Ridge 8.64 sq km
3. South Central Ridge 6.26 sq km
4. Southern Ridge 62.00 sq km

Subject to verification, the area of Regional Park is 77.77 sq km. Part of this has been notified as Reserve Forest under the Indian Forest Act, 1927 vide

Notification dated 24.5.94 and 02.04.96. the DEM (Figure:2.3) also shows four different pockets of the ridge.

Plate: 2.2 Weathered Tor Structures

Figure: 2.3



Physiographic Divisions of Ridge

Northern ridge

The northern most tip of the rock exposure of the Northern Ridge is at Wazirabad in north Delhi. Overall bedding surface is seen tending NNE-SSW and dipping east at about 53° to 60° angles (Figure: 2.1 Geology and Geomorphology and Mineral Map of Delhi, 2000). This rock exposure shows to be slightly widening towards south. South of it, the rock is exposed at the railway crossing; but further south it is all covered up. The fact reveals that there is a somewhat 'S' shaped drag with subsequent with a shrink in the middle part of the ridge may be shear plane (Figure: 2.3). The rock here is reddish brown to bluish grey in colour with massive in look is isolated from other parts of ridge with built up.

Central Ridge

The Central Ridge covering an area of 8.64 sq km extends from Karol Bagh and Mandir Marg upto Dhaula Kuan in the south Delhi. The central ridge notified area being 9.17 sq km by the 1913. The balance of 0.48 sq km is unaccounted for the developmental i.e. for the built up and infrastructure purpose those areas have been taken. Karol bagh in north and Dhaulakuan in the south are marking its limits. Its surrounding parts are under rapid urbanization now.

South-Central Ridge

The South-Central ridge spreads over a large area of 6.26 sq km covering the Mahipalpur-JNU area and area around Mehruali. It is divided into two parts by Mehrauli and Kishangarh villages (Figure: 2.3). Mining and quarrying activities, especially in the south-central ridge, as well as occupation of commercial complexes and illegal construction works resulted in shrinking of ridge areas, concerning enormous loss to its biodiversity.

Southern Ridge

The Southern Ridge spread covers a large area of 62.00 sq km is by far the largest part of Delhi Ridge. The Southern Ridge is mainly situated in Mehrauli tahsil and the Asola Wildlife sanctuary, was established in 1991 an ecologically important location to enhance the protection and conservation of the ridge flora and fauna diversity is also located in this ridge area.

2.2.2 The Plain

The Alwar series and the post Delhi intrusives are covered by the quaternary deposits in the form of aeolian and alluvial deposits. The alluvial deposits belong to the Pleistocene period, i.e., older alluvial deposits and of recent age i.e., newer alluvium. These alluvial plains present in both the sides of the ridge as older one and newer one along the river- both the sides.

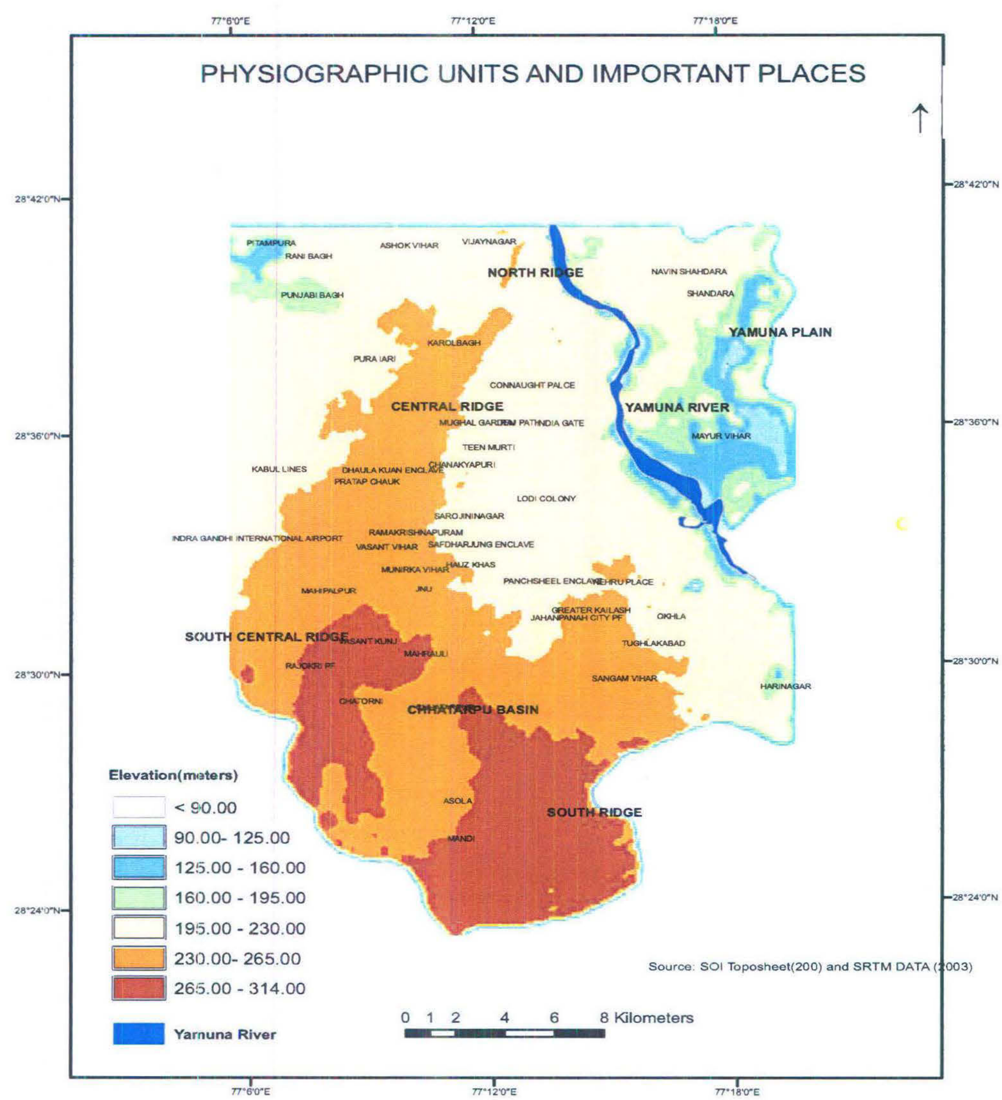
Older alluvium

The older alluvium occurs extensively in the western part of the Delhi region. Older alluvium deposits consists of mostly inter bedded lenticular and inter fingering deposits of clay, silt and sand along with kankar. In the central part of the Delhi the older alluvium deposits are associated with kankar which are resulted from the weathering of the exposed Delhi quartzite. In the Chattarpur basin (Figure: 2.3), the alluvium has been derived from the weathering of the surrounding quartzites and subsequent transportation and deposition as well as aeolian deposited. This is closed by the quartzite ridge in both the sides.

Yamuna Flood Plain

Yamuna River flows toward south direction in the eastern side of the study area from Wazirabad Barrage to Okla Barrage (Figure: 2.2). Most rivers in India have a variable flow which peaks, during the monsoon, when the river runs its banks and widens considerably, depositing water and silt on the wide floodplains. Floodplains have a soil constitution of silt and sand that is highly porous – it is this soil type that defines the boundary of the flood plains. They present and sub recent origin geologically in Pleistocene period representing younger Alluvium or Khaddar containing sand and other sediment deposits in the stream bed. This alluvial plain is highly productive in agricultural terms because of new sediments brought by the river but now this is under sever threat due to excessive urbanization and related consequences live river flooding.

Figure: 2.4



Apart from the above discussed major geomorphological units, features like isolated hillocks in the southern part of the ridge, buried pediments in the vicinity of the ridge area are also important features(Figure:2.2)

2.3 Slope and Drainage

The general slope of the land is towards the centre of the basin from the surrounding ridge. The Yamuna River flowing in a southerly direction in the eastern part of the Union Territory of Delhi is the only perennial river in the area. Eastern and western Yamuna canals and Agra canal are the three major canals which originate from the Jamuna River with Bawana, Rajpur and Lampur distributaries. Auchandi, Budhanpur, Sultanpur Mundka, Mongolpur, Nahari, Dhansa and Surkhpur are some of important minors. The Agra canal originates from Okhla, about 12 km South of Delhi.

The newer alluvium- kadhar occurs mainly on the eastern part of the region and extends from north to south east of the study area. These alluvial deposits were laid down to the east of Delhi ridge extending to the western side of river Yamuna. The Ganda nala which is tributary of Najafgarh drain falls in the western part of the study area and the Najafgarh drainjoins the Yamuna River in the northern part of the study area. Eastern Yamuna Canal and Hindan Cut Canal originating from Uttar Pradesh join Yamuna River in its left hand. The length of the river in the NCT of Delhi is 48 kms from Palla in the North to Okhla in the South, with a total river bed/flood plane area of around 97 sq kms, which is about 7 percent of the total area of Delhi. A little over 50 percent of the river lies North of Wazirabad and the rest, around 22 kms., to its South, in the Urban area of Delhi.

Apart from being the main sources of water supply for Delhi, it is one of the major sources of ground water recharge. However, over the years, rapid urbanization, encroachments on the river banks, over exploitation of natural resources/water, and serious deficiencies and backlog in sanitation and waste water management services, have resulted in the dwindling of water flow in the river and extremely high levels of pollution.

As far as the slope of the study area is concerned it ranges from 0-0.25 to more than 25 degree. This high variation is due to the presence of two different geomorphological feature- Elevated Ridge and Low level plain as well Yamuna River. The figure: 2.6 show the slope of the area, where nearly flat i.e. 0-0.25 degree of slope parts present in both the sides of the ridge as well as in the Chattarpur Aeolian plain.

Figure: 2.5

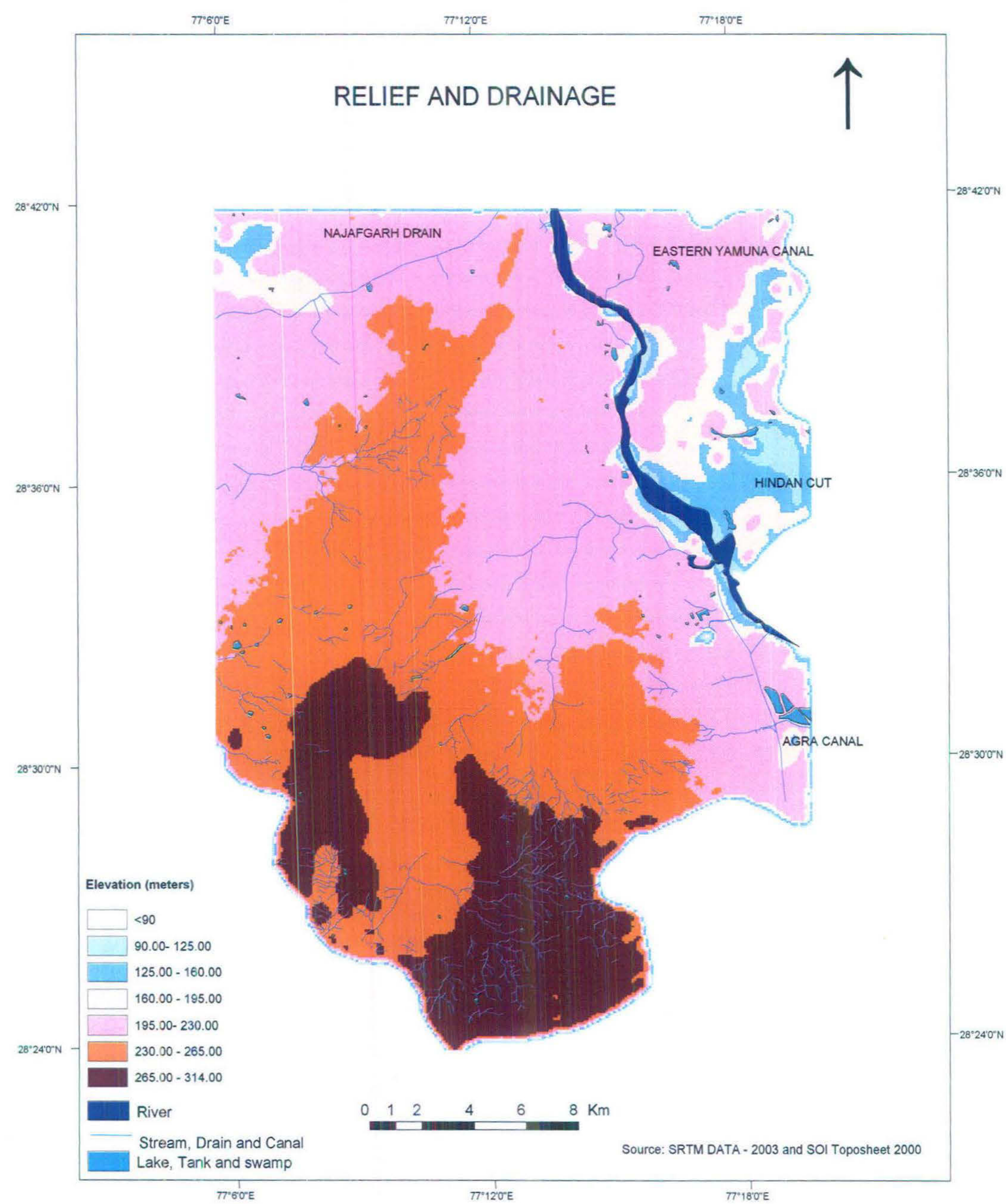
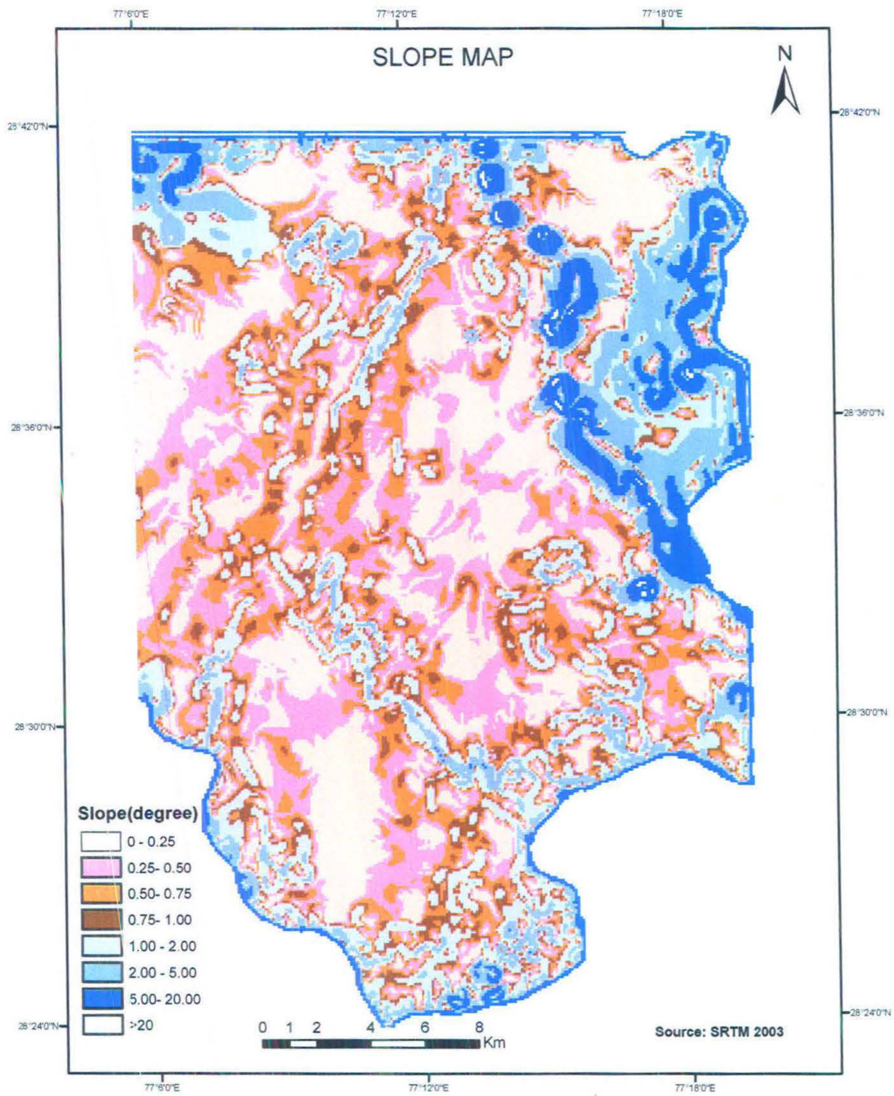


Figure: 2.6



The isolated hilly area in the southern part is also showing more than 20 degree of slope apart from the Yamuna flood plain and Yamuna river area. In the flood plain area the slope is towards the south and Eastern side which shows the vulnerability of flooding in these parts if Yamuna over flows. In the Okla area also slope is steep and it shows the wetland in this part. Most of the area occupied by flat slope and elevated areas have high slope.

2.4 Soil

The soils of the Delhi area are mostly light with subordinate amount of medium texture soils. The light texture soils are represented by sandy, loamy, sand and sany loam; whereas medium texture soils are represented by loam silty loam. The soils of the study area can be divided into four important categories according to traditional soil classification and depicted viz;

- Calcareous, silty and clay loam(fine loam)
- Mixed calcareous, silty, clay and sandy loam (course to fine loam)
- Sand, silt and calcareous (coarse loamy)
- Rocky Aravalli ridge and dissected land

The soils of the study region are generally influenced by river Yamuna, the Aravalli ridge and the winds from the south western direction. Clay content generally varies from place to place and salinity is a great problem in the soils of this region. The structure is mainly grained or weakly developed granular in nature. These are sandy loam in texture becoming slightly heavier in depth. The soils in these formations have medium to coarse grained sands with flakes of mica in abundance. The thickness of the alluvium both on eastern and western sides of the ridge is varying and it is thicker in western side.

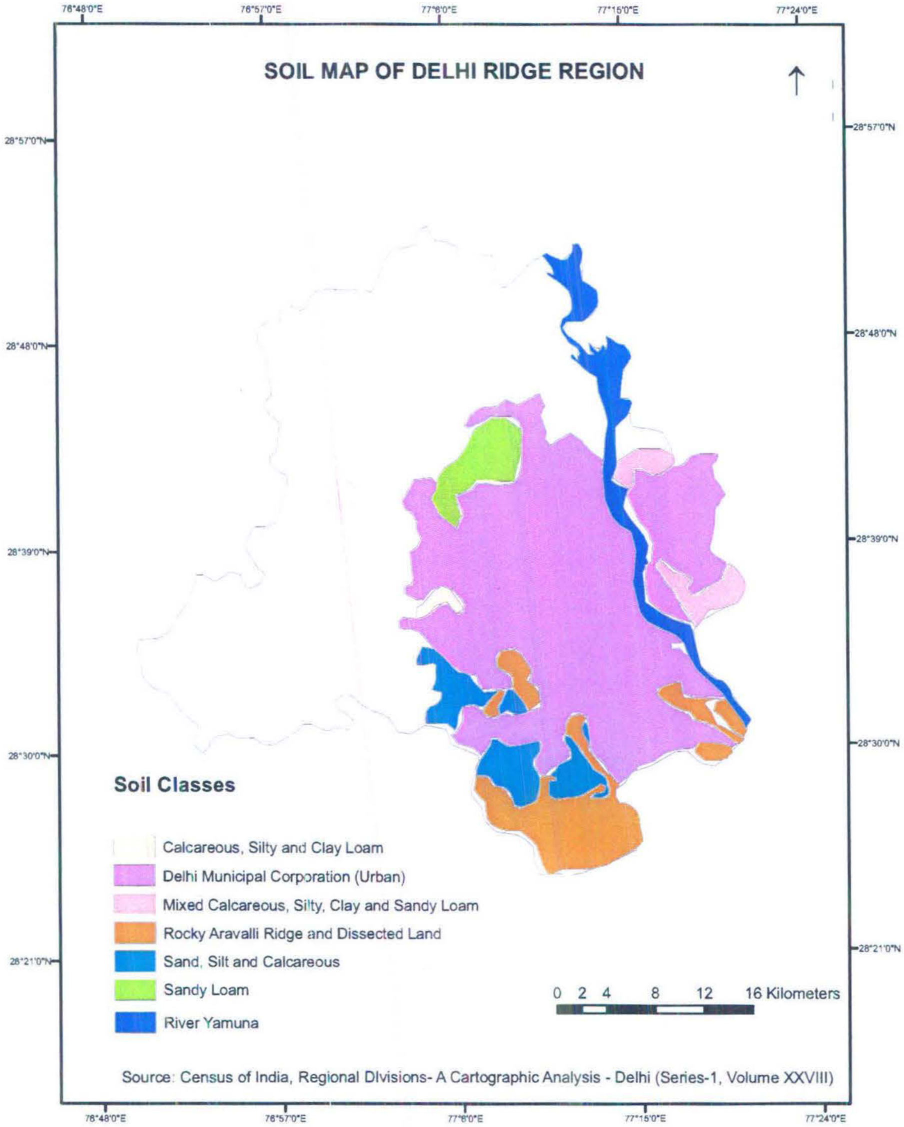
The older alluvium comprises silt, clay with minor lenticular fine sand and kankar beds. The newer alluvium mainly consists of unoxidised sands, silt and clay occurring in the older and active flood plains of Yamuna River. The nature of bedrock topography is rendered uneven due to existence of sub surface ridges. Thickness of alluvium overlying the quartzites increases away from the outcrops. In the city block, west of the ridge, the alluvium thickness increases away from the ridge to 300m or more. East of the ridge, in the area upto river Yamuna, the alluvium thickness is comparatively less to about 165 m east of river Yamuna. For example parts of city and Shahdara blocks, the thickness of alluvium ranges from 48 to 240 m (www.rainwaterharvesting.org). The thickness of the alluvium, both on the eastern and western side of the ridge, is variable, but it is generally larger to the West of the ridge (GSI, 1997).

The southern part of the study area and the ridge running areas are formed of quartzite or sand stone and the alluvium brought by small streams. The north western part of the study area is occupied by sandy loam soil made up of alluvium with saline efflorescence and in the west central region a patch of calcareous, silty, clay and loam soil presents which is of old flood plain. Yamuna kadhar present in the eastern part of the study area is geologically alluvium of recent origin coccupied by flood plain. Soils are coarse to fine loamy i.e. calcareous, silt, clay and loam in the profile depth. Water table is high and generally soils are fertile and high yield crops can be grown in this part.

In the southern part of the study region Aravalli outcrops which is predominantly rocky with undulating relief and slopes of various steepness. The outcrop is culminating spur of the Aravalli Range. The region is fairly dissected and number of flanking spurs also present in this region which adds complexity to the region. Soils of this region are shallow to moderately deep with strong brown colour and alluvium also present in this region. Soils are modified to some extent by the Aeolian deposits. The texture of the soil varies from sandy loam to loam, due to uneven topography the soils are subjected to erosion at various points deep gullies are formed and water table in this region is very low which is a major problem.

In the Chattarpur basin of Mehrauli block, the alluvial thickness varies from a few metres near the periphery to 115m around Satbari bund. In the Vasant Kunj area the first Layer of clay and kankar extends to depth of 12m .This is followed by layer of kankar and silt from 12 to 25m below ground level. This is again underlain by layer of clay and kankar which extends even beyond 40m. The Mandi area the first Layer of clay and kankar extends to depth of 8m l. This is followed by weathered and fractured quartzites.

Figure: 2.7



In Mandi the occurrence of fresh water in alluvium formation is upto a depth of 30m to 60m. Below that level saline or brackish water occurs. In other parts like in the Hamdard area the first Layer of clay and kankar extends to depth of 8m. This is followed by a layer of kankar and silt upto 20m; this is under laid by weathered and fractured quartzites. In the Rajender nagar area the first Layer of clay and kankar extends to depth of 4m.. This is followed by quartzite formation. The fractured and jointed layers of the formation act as water bearing formation (*www.rainwaterharvesting.com)*.

Chapter III

Chapter III

Land Use and Land Cover Changes in and arround Delhi Ridge

Resources are physical or virtual entities with limited availability used by human beings to earn a living. Among these resources natural resources are derived from the environment. Natural resources provide the base on which the edifice of development is raised. Its use depends upon the type of economy, the level of technology and preferences of the culture of a given society. The importance of natural resources is more critical to societies which are at a relatively and life style to the settings of nature. The sustainable use of natural resources to attain high levels of human development has become imperative (Planning Commission).

Many of these natural resources are essential for our survival while others are used for satisfying our wants. There is tremendous pressure on these resources due to increasing population. To meet the demands of large population means the need for more food production, more requirement of energy, more water requirement, better civic amenities for a reasonable quality of urban life, more infrastructure development to sustain increasing pressure and increased per-capita expenditure for maintaining quality of life.

Land resources - finite natural resources imply more judicious use to meet the ever increasing demands. The most important natural resource, upon which all human activity is based since time immemorial, is land. The utilization of land depends upon physical factors like topography, soil and climate as well as human factors such as the density of population, duration of occupation of the area and technical levels of the people (D.R. Khullar 2005).

Man's inexorable progress towards development has, however, considerably damaged our land resource base. The unsustainable and unplanned exploitation of land resources is the major reason for degradation of our environment. Unprecedented population pressures and demands of society on scarce land, water and biological resources and the increasing degradation of these resources is affecting the stability and resilience of our ecosystems and the environment as a whole. Globally the expansion of human settlements and infrastructure, intensification of agriculture, and expansion of settlement putting agriculture into marginal areas and fragile ecosystems especially in urban area emphasizes the need for integrated planning and management of land resources.

Land use is a more complicated term. Land cover refers to the physical and biological cover over the surface of land, including water, vegetation, bare soil, and/or artificial structures. Natural scientists define land use in terms of syndromes of human activities such as agriculture, forestry and building construction that alter land surface processes including biogeochemistry, hydrology and biodiversity. Social scientists and land managers define land use more broadly to include the social and economic purposes and contexts for and within which lands are managed (or left unmanaged), such as subsistence versus commercial agriculture, rented vs. owned, or private vs. public land. While land cover may be observed directly in the field or by remote sensing, observations of land use and its changes generally require the integration of natural and social scientific methods (expert knowledge, interviews with land managers) to determine which human activities are occurring in different parts of the landscape, even when land cover appears to be the same.

Land-use and land-cover change (LU/LCC); also known as land change is a general term for the human modification of Earth's terrestrial surface. Though humans have been modifying land to obtain food and other essentials for thousands of years, current rates, extents and intensities of LU/LC Changes are far greater than ever in history, driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales. These changes encompass the greatest environmental concerns of human populations today, including climate change, biodiversity loss and the pollution of water, soils and air. Monitoring and mediating the negative consequences of LULCC while sustaining the production of essential resources has therefore become a major priority of researchers and policymakers around the world. Delhi's unprecedented rate and scale of urbanization over the last few decades has placed enormous stress on the natural resources of the city. In comparison to the urbanization rate in the last 50 years, the rate of environmental degradation has grown at a much higher rate (City Development Plan Delhi, Department of Urban Development, Govt. of Delhi October 2006).

The environmental degradation in terms of the loss of green cover, loss of biodiversity and aesthetics; increasing air pollution, surface and ground water pollution; loss of water bodies, receding water table, high incidence of diseases and mortality are faced by the city. Most of the 916 lakes, ponds and reservoirs reported to have existed in city have been depleted (City Development Plan Delhi) and continued degradation of the river Yamuna due to the dumping of untreated effluents into its waters is other important issue.

Unsustainable extraction of ground water, Weak management of natural resources, leading to degradation of the ridge, the river and surface water bodies are some of the Issues related to the status of city environment degradation. The main issue is to bring a balance between urban development and conservation of resources, which is possible by proper inventory, and management of these resources on periodic basis. In this context study of the land use and land cover changes in the Delhi ridge region gets importance. Recent technologies of Remote Sensing (RS) and Geographic Information System (GIS) have made it feasible and cost effective. Present study deals with RS and GIS based monitoring of land use/ land cover changes in Delhi Ridge region.

3.1 Historical Evolution of the Region

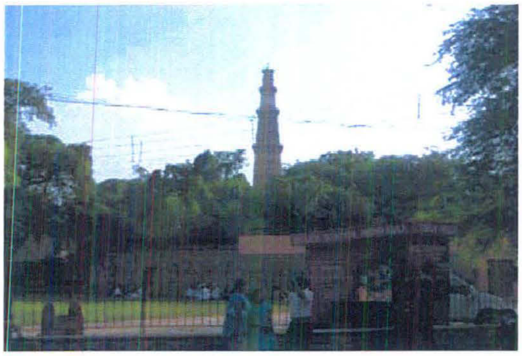
"The city, as one finds it in history, is the point of maximum concentration for the power and culture of a community. It is the place where the diffused rays of many separate beams of life fall into focus, with gains in both social effectiveness and significance. The city is the form and symbol of an integrated social relationship: it is the seat of the temple, the market, the hall of justice, the academy of learning. Here in the city the goods of a civilization are multiplied and many folded; here is where human experience is transformed into viable signs, symbols, patterns of conduct, and systems of order. Here is where the issues of civilization are focused; here, too, ritual passes on occasion into the active drama of a fully differentiated and self-conscious society" (Louis Mumford, *The Culture of Cities,* 1938).

The growth and urbanization of a city can be of historical, induced and spontaneous. Delhi city's evolution is a mixture of historical based on cultural and traditional village based; induced in the way of urban planning in recent years especially from Master Plan period i.e. since 1961 onwards and spontaneous because of natural growth of population and migration from different parts of the country. Urban development in Delhi is linked to four different periods. These periods are pre-colonial (before 1911), pre-independence (1911-1947)-British period, post independence (1947-1961) and Master Plan period (1961-1981) and recent developments based on master plan. Pre-colonial period as already stated was based on traditions, cultures and religious lifestyles promoted by invaders mainly Mughal rulers placed their seat in Delhi.

The history of the evolution of the city starts from Mahabharata was the town Indraprashta has come down to us from this oldest Delhi. The seven cities Lal Kot, Jahanpanah, Siri, Tughlaqabad, Firozabad, Purana Qila, Shahjanabad and others founded. During slave dynasty of Qutub-ud-din- Aibak and his successor Iltutmish built buildings and monuments - Qutb Minar is the earliest monument left by them. The Tughlah dynasty's remains Tughlaqabad the third town of delhi was found by Ghiyaz-ud-din Tughlaq and Firoz Shah Tughlaq founded Firozabad and group of buildings in Hauz Khas area. Sikandar Lodi built Lodi garden and the tombs there and where Sher Shah's Purana Qila also marks important place is the evolution of the city and these areas are commonly called as Old Delhi in general.

The greater Mughal rulers specifically Shah Jahan finds unique place in the history of the city foundation. Though he built beautiful monuments in Agra his ten years of work for town development with Red Fort on the bank of Yamuna which received name-Shahjanabad in later days is a marvelous work. In later days this area has been known as Delhi in general.

Plate: 3.1 Qutb Minar



Pre-independence was related to migration of the British from Calcutta to Delhi. The British built New Delhi south of Shahjahanabad, and shifted the capital city from Calcutta in 1912. Raisina Hill is a prime area in Edwin Lutyens' New Delhi, housing India's most important government buildings. The Rashtrapati Bhavan, India's Presidential palace, flanked by the Secretariat building housing the Indian Prime Minister's Office and several other important ministries. Other important buildings and structures situated near the Raisina Hill includes the Parliament of India, the Rajpath, the Vijay Chowk and the India Gate.

The capital city of India, after independence, has grown in size and density - engulfing all the ancient sites, and overflowing across the Yamuna and the Northern Ridge. Post -independence was based on migration from partitioned West Pakistan. Master Plan Period refers to temporary migration from rural areas in search of employment. The fields of power changed and Delhi underwent marked physical changes due to profound social, economic, and political restructuring.

The increase in Delhi's population from 4.1 million in 1911 to14.37 in 2000 is the highest in the world. Major increase during the master plan period has been in last two decades from 5.2 million to 13.4 million (Source: Delhi 1999 Fact Sheet). The urbanization of Delhi dates back to the beginning of the 20th Century. In 1901, 52.76%

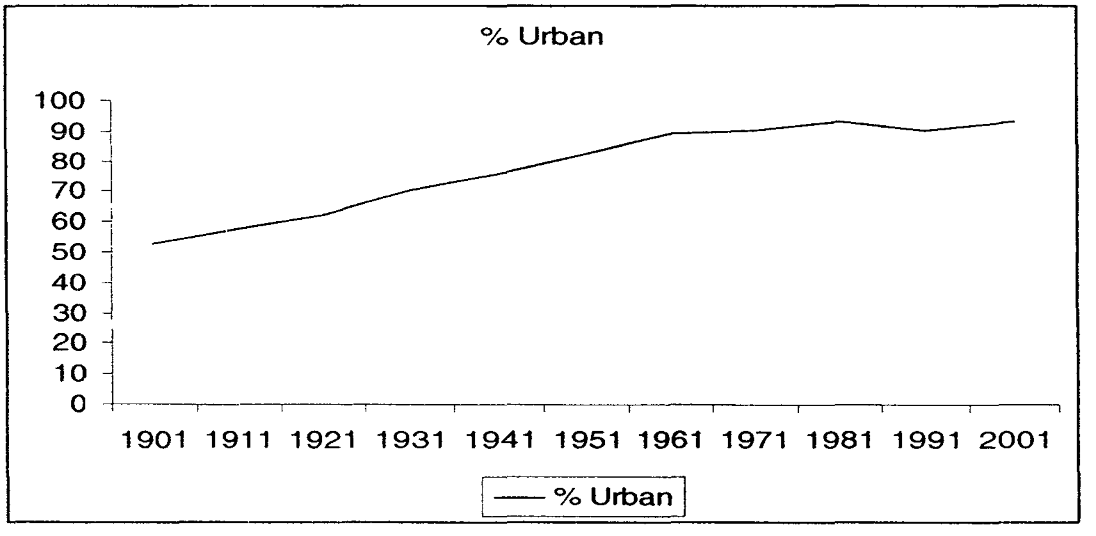
of the population of Delhi was urban. The urban area in Delhi territory has increased from 22% in 1961 to 62.5% of the total area in 2001. The rapid urbanization of Delhi has resulted in sharp increase in the density of population. In 1901, the density was 274 persons per square km, this increased to 1176 persons per sq. km. in 1951 and 9294 persons per sq. km. in 2001 (Census2001). This rapidity coincides with the rapid changes in the land use and land cover of the city also.

Table 3.1: Trend of Urbanization in Delhi 1901-2001

Census Year	Population	Urban	% Urban	Annual Exponential Growth Rate	Decennial Growth %
1901	405819	214115	52.76	-	-
1911	413851	237944	57.50	1.1	11.13
1921	488452	304420	62.32	2.5	27.94
1931	636246	447442	70.33	3.9	46.98
1941	917939	695686	75.79	4.4	55.48
1951	1744072	1437134	82.40	7.3	106.58
1961	2658612	2359408	88.75	5.0	64.17
1971	4065698	3647023	89.68	4.4	54.57
1981	6220406	5768200	92.73	4.6	58.16
1991	9420644	8471625	89.93	3.8	46.87
2001	13782976	12819761	93.01	4.1	51.33

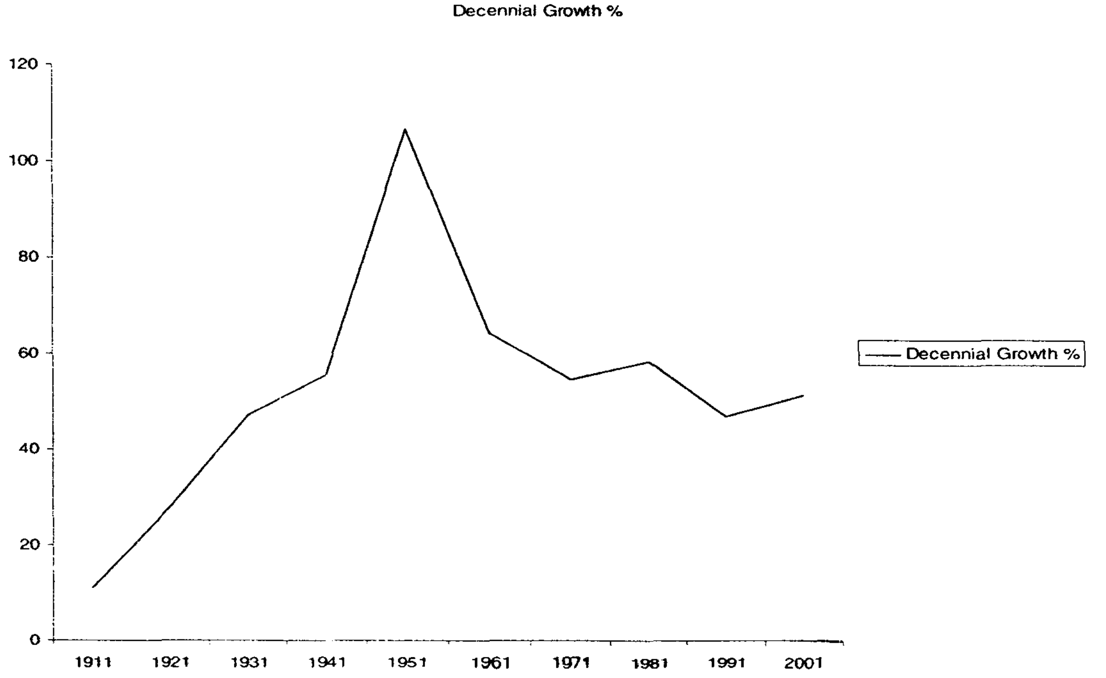
Source: Economic Survey of Delhi 2001-02

Graph: 3.1 Urbanization Trend – Delhi (1901-2001)



Source: Economic Survey of Delhi 2001-02.

Graph: 3.2 Decennial Population Growth- Delhi



Source: Economic Survey of Delhi 2001-02.

The era of urban planning in Delhi commenced in 1824, when a Town Duties Committee was constituted by the British, for the development of the Cantonment, Khyber Pass, the Ridge area and the Civil Lines. Therefore, urban development picked up in Delhi with the composition of the first Municipal Committee of Delhi in 1883. The Municipal Building byelaws were first made operational in Sadar Baazar, Subzi Mandi and other suburbs. The Delhi Improvement Trust (DIT) was contributed in March 1937. In addition to manage the acquired land, Najul Land, DIT was also assigned the job of rehabilitation of the households to be shifted from slums and substandard areas.

On December 30, 1957, Delhi Development Authority (DDA) was set up under the Delhi Development Act, 1957 as a successor to DIT for the planned development of Delhi. DDA prepared a Master Plan for Delhi (MPD), which was published in 1962. The MPD envisaged development of 447.70 sq km of urban area by 1981 for urban population of 46 lakhs. Subsequently, development of an additional 40.00 sq km of urban area at Patpar Ganj, Sarita Vihar and Vasant Kunj was added in the target of the first MPD. The first MPD (1961-81) was reviewed and amended for its extension for another 20 years by DDA and published in 1990. This amended MPD (second MPD 2001) envisaged acquisition of 200.00 sq km of land for urban area extension of Delhi by 2001 making a target for development of 687.sq km urban area.

DDA has subsequently proposed to develop 838.04 sq km of land as urban area within the framework of MPD 2001. This includes 33.60 sq km area for urban development along National Highways, 1996 ha of Dwarka Ph II and 97.00 sq km of Yamuna River bed. DDA has reviewed the provisions of the MPD 2001 and the actual development of urban area in Delhi to date with a view to revise the MPD with reference to the target period for 2001. Now MPD 2021 is in operation.

Urbanization is characterized by rural to urban land conversion. Urban planners and policy-makers desire scientifically based assessments on the short and long-term effects of these rural to urban land conversion activities. The effects of this process, however, are difficult to describe and even more difficult to adequately understand because of an extreme range of differences in the patterns and rates of urbanization, patterns of density, and the stages of urbanization in different environmental contexts. One strategy to better understand urbanization has been to characterize and quantify land cover change, particularly rapid urban growth, through satellite remote sensing.

Although historically aerial photography has been the basis for mapping land use/land cover in a region (Donnay et al. 2001), more recently multispectral satellite imagery has been used to classify urban land use/land cover. The advantage of using satellite imagery is that data can be collected and analyzed at time intervals more frequently, and with less cost and less subjective interpretation than with aerial photographs due to the higher information content of multi spectral data. In this study, we present the results of classifying land use/land cover change for a small region of New Delhi- the region covering 620 square kilometer in and around Delhi ridge area is taken for the analysis as this ecologically sensitive region which is important for the survival of the city which is under peril due to rapid urbanization and other human induced changes like quarrying, groundwater depletion, pollution etc.

3.2 Land Use and Land Cover Changes

Urban land cover / land use changes are very dynamic in nature and have to be monitored at regular intervals for sustainable environment development. Remote Sensing data is very useful because of its synoptic view, repetitive coverage and real time data acquisition. The digital data in form of satellite imageries, therefore, enable to accurately compute various land cover / land use categories and helps in maintaining the spatial data infrastructure (SDI) which is very essential for monitoring urban expansion and change detections studies. In other words, the remote sensing satellite data of different years and multi-spectral means to provide spatial and temporal information for land cover / land use at different levels for various aspects as built-up land, agricultural land, forests, wastelands and water bodies etc. So, the land cover / land use maps prepared using different years data provides different levels of spatial information which are used in change detection studies (Burrough, 1986). The study area covers area of 620 sq km which includes whole of New Delhi, Central Delhi, East Delhi, South Delhi and parts of South West Delhi, North West Delhi, West Delhi and North East Delhi. The urban land cover / land use patterns has been found change in the study region- in and around the Delhi Ridge over the periods. Similarly, there has been existed diverse urban land cover / land use patterns.

The Land Use and Land Cover changes study over a period of three decades from 1977 to 2006 using satellite imageries of LANDSAT-TM 1977, 1989 and LANDSAT ETM 1999 and IRS P6 LISS III imagery of 2006 has been carried out through supervised classification method in ERDAS 8.4. The various Land Use maps of different years have been prepared from that.

Data Base

Year	Sensor	Date
1977	MSS	08-03-1977
1989	TM	18-05-1989
1999	ETM	13-09-1999
2006	LISSIII	12-03-2006

The change detection has been prepared for 1977 to1999 and also for 1999 to 2006 to identify the changes in land use and land cover in 30 yrs period as well as the recent years in land use and land cover changes with the help of ERDAS and Arc GIS 9 softwares and interpreted various land use classes and changes over time.

Satellite imagery interpretation key

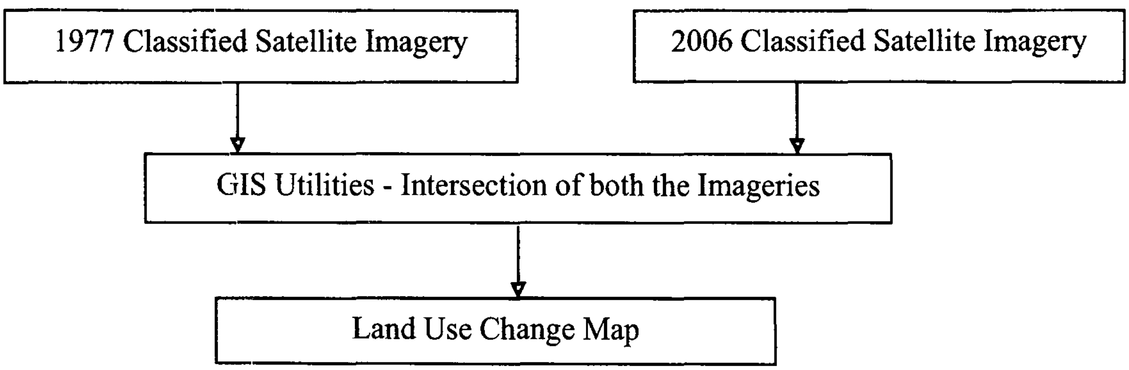
Sr. No.	Land Uses	FCC 432
1	Dense Vegetation	Dark Red
2	Sparse Vegetation	Faint Red
3	Agricultural Land	Very Light Pinkish
4	Barren Land	Dirty White
5	Water Bodies	Black
6	Settlement	Bluish-grey to Steel-grey

Source: Modified after Prakash and Gupta (1998).

Based on the image interpretation key given above the supervised classification of the images have been done. This gives the picture of rapid urbanization in this study area.

The Land Use Change operation from the GIS software allows two thematic images in vector forms of different years to be compared. By comparing two simple classified images were fed into the process and different classes intersection has been run. No change areas have been identified with the one class going to the same and changed areas were identified with one class going to different class. The change tables (which are shown in the tables 3.4 &3.5) are prepared.

Flow Chart of Change Detection Map Preparation



Base map (2000) has been prepared using the Toposheets- H43 X2, H43 X3, H43 X6 and H43 X7 which covers the study area(77^{0}18'E and 77^{0}6'E longitude, 28^{0} 24' N and 28^{0}42' N latitude). Based on this, Built-Up Area, Vegetation, Cultivated Land, Barren and Exposed Land and River and other Water Bodies are the five classes have been taken as a major land use classes.

Graph: 3.3 and the Graph 3.4 to 3.7 are showing that the percentages of different land use classes have changed significantly. The built-up area has been increased very significantly from 26.82% of the total 623 sq km i.e. 167.21 in 1977 to 49.65 % i.e. 308.10 sq km in 2006. This is because of the rapid urbanization in recent urbanization as well as the historical developments during Mughals in Old Delhi area and British settlements in New Delhi and their later period expansions.

Regarding the Vegetation Class it has been decreased in the 1980's and 90's but now the area under vegetation has started to show increasing trend. The percentage to total area was 30.03% during 1977 and has declined to 28.16% in 1989 and 21.21% in 1999 but slightly increased to 22.49% in 2006 (Graph: 3.3). The afforestation and tree planting activities by the Delhi Government for Green Delhi is started to show the positive developments. But this is depicting the degradation of the lung of the city that is the Ridge area which is unique and precious for the survival of the city and its biodiversity.

The total cultivated area was 120.32 sq. km i.e. 19.30 % in 1977 but it went down to just 28.16 sq km i.e. just 4.6 % in 2006 which is very drastic and the cultivated area are concerned, almost totally are going to vanish under built-ups in future .

In this regard Barren and exposed land shows increasing trend up to 1999 and in 2006 it again shows decreasing trend because of land occupation under construction. The land area conversion from cultivated to plots and built-ups and left as uncultivated land as well as waste lands are the reasons for this increasing trend in barren land and decrease in cultivated land. This class covers large area because areas like airports (Indira Gandhi Internatioanl and Safdhar Jung Domestic) - quite significant in size, exposed rocky outfits which are barren have also been taken with in this class.

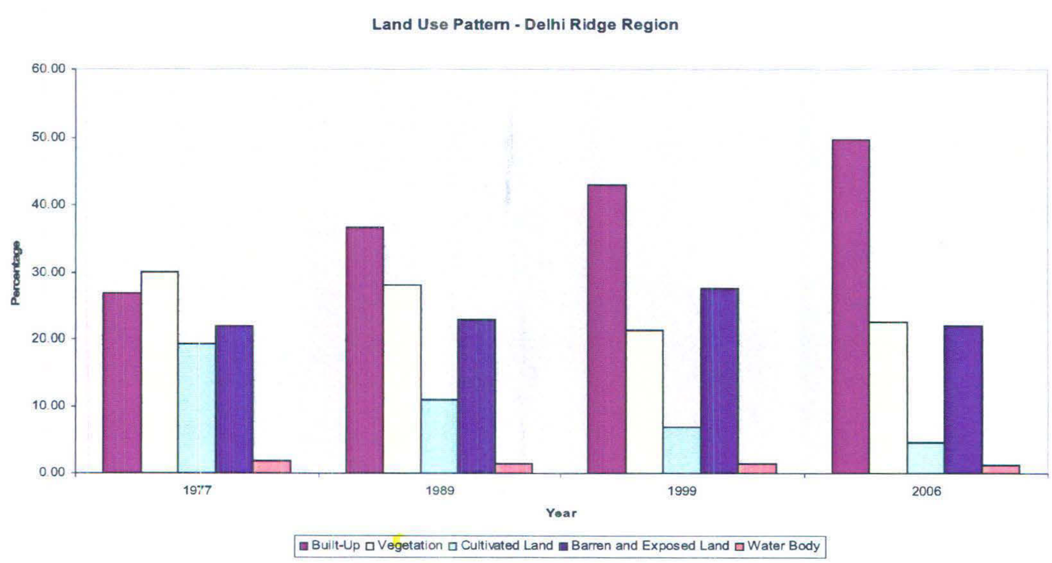
The river class shows decreasing area from 11.57 sq km Km^2 in 1977 to 7.74 sq km in 2006. Though the percentage decrease to total area is minimal, total water body area decrease is due to encroachment of the river banks and near by area as well as occupation of many of the dry and wet tanks, ponds in the city area are quite significant.

Table: 3.2 Land Use Classes - Percentage to Total Area

Land Use Classes	1977		1989		1999		2006	
	Area(sq km)	%	Area(sq km)	%	Area(sq km)	%	Area(sq km)	%
Built-up Area	167.2	26.82	226.86	36.62	267.14	42.99	308.1	49.65
Vegetation	187.25	30.03	174.47	28.16	131.81	21.21	139.59	22.49
Cultivated Area	120.32	19.30	67.37	10.87	42.16	6.79	28.59	4.61
Barren and Exposed Land	137.11	21.99	142.41	22.99	171.28	27.56	136.55	22.00
Water Bodies	11.57	1.86	8.45	1.36	9.01	1.45	7.74	1.25
Total	623.45	100	620.00	100	621.4	100.00	620.57	100.00

Source: Land Use Class Maps of 1977 (LANDSAT: 8-3-1977), 1989 (LANDSAT: 18-5-89), 1999 (LANDSAT: 22-10-1999) & 2006 (IRS P6: 12-02-2006) Satellite Imageries.

Graph: 3.3



Source: Land Use Class Maps of 1977 (LANDSAT: 8-3-1977), 1989 (LANDSAT: 18-5-89), 1999 (LANDSAT: 22-10-1999) & 2006 (IRS P6: 12-02-2006) Satellite Imageries.

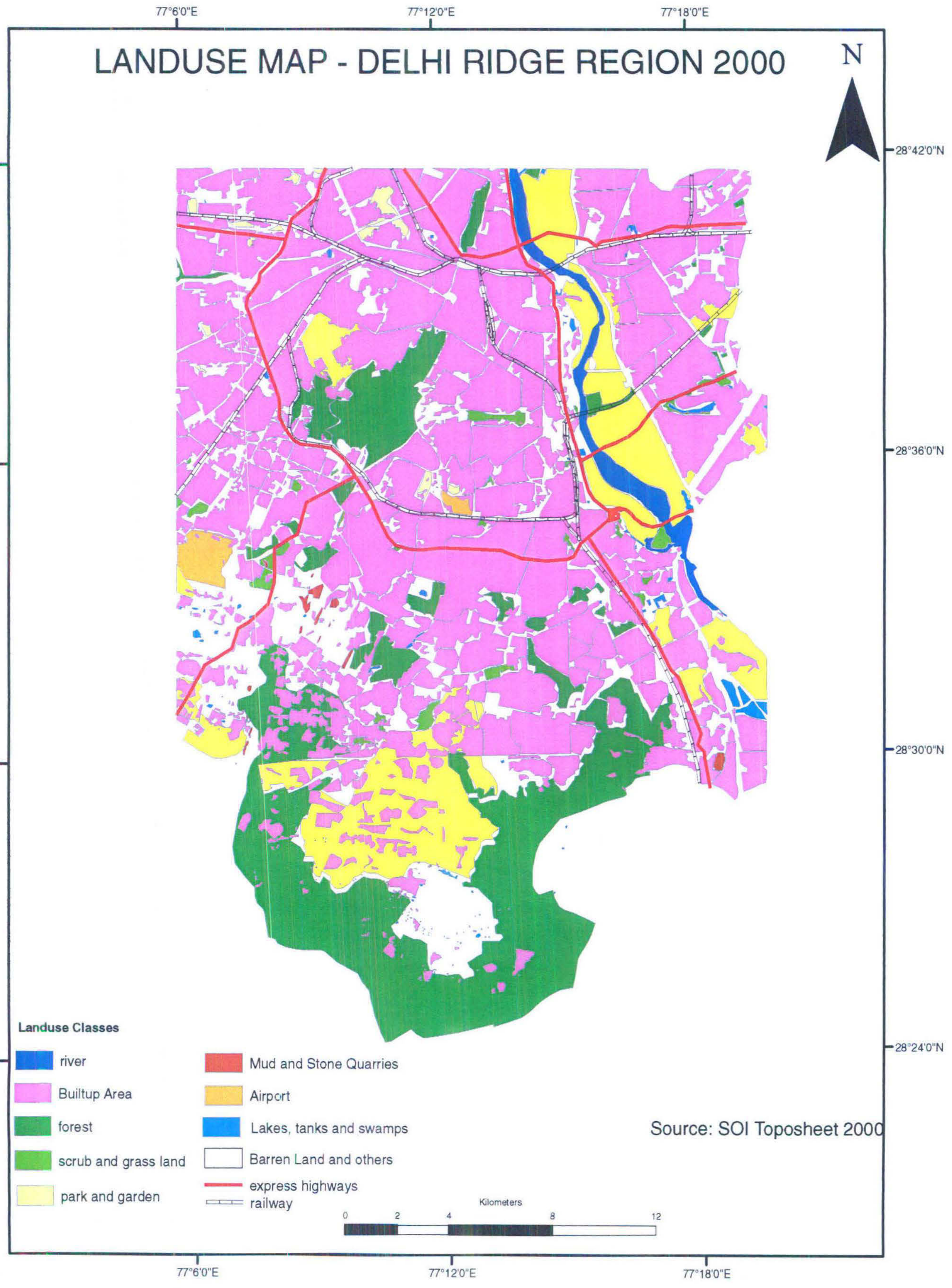

LANDUSE MAP - DELHI RIDGE REGION 2000
N
77°6'0"E
77°12'0"E
77°18'0"E
28°42'0"N
28°36'0"N
28°30'0"N
28°24'0"N
Landuse Classes
river
Builtup Area
forest
scrub and grass land
park and garden
Mud and Stone Quarries
Airport
Lakes, tanks and swamps
Barren Land and others
express highways
railway
Kilometers
0
2
4
8
12
Source: SOI Toposheet 2000

Figure: 3.1

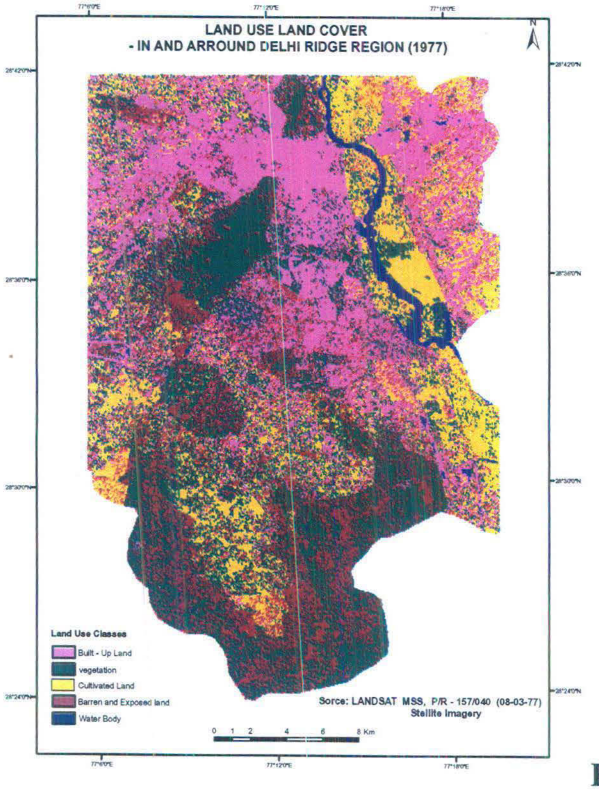


Figure:3.2

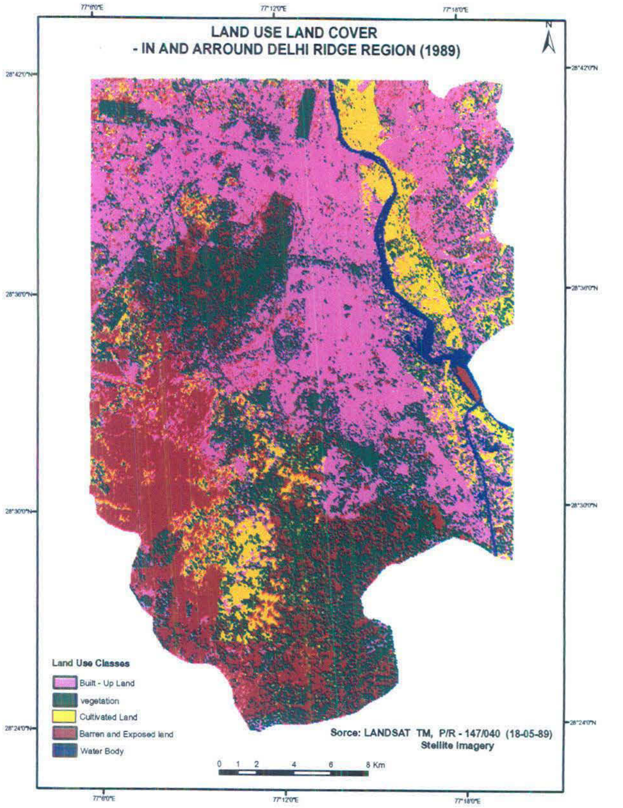


Figure: 3.3

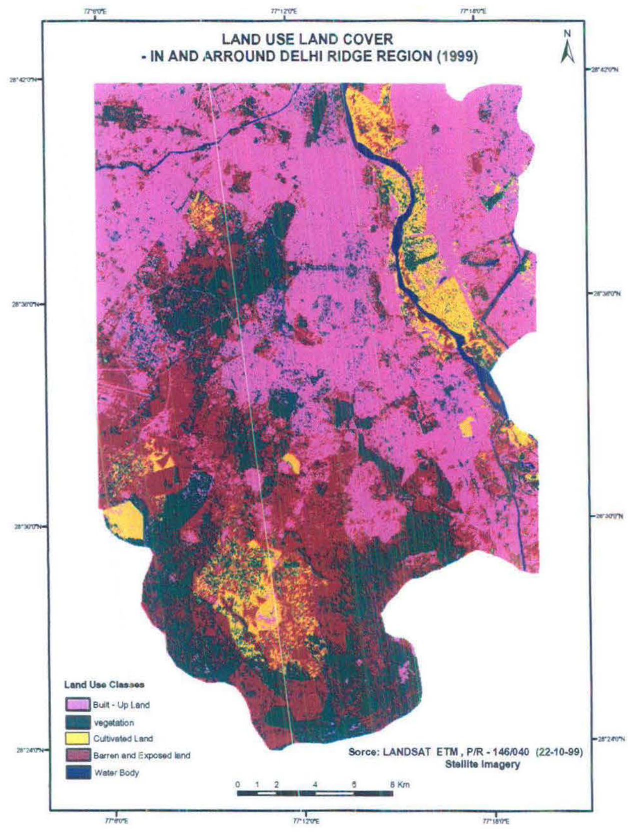


Figure: 3.4

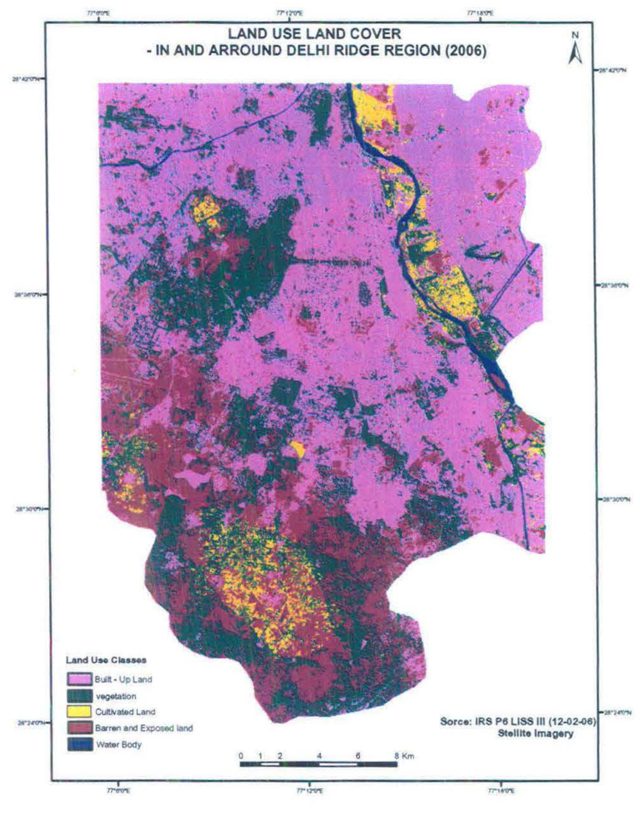
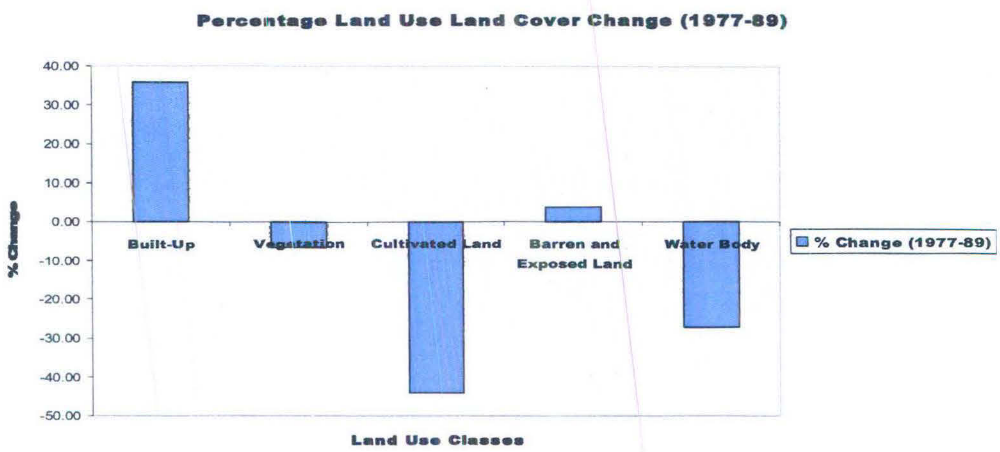


Table: 3.3 Land Use Changes in Area (Sq. Km) and Percentage Change

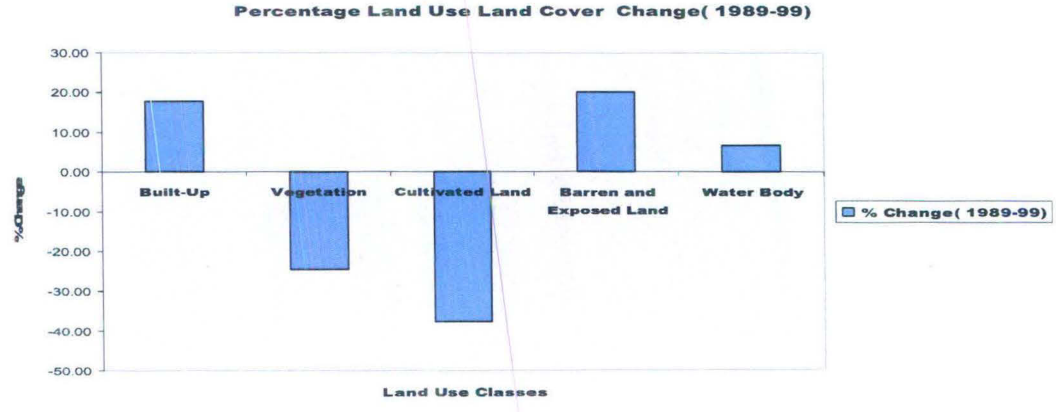
Land Use Classes	1977-1989		1989-1999		1999-2006		1977-2006	
	Increase/ Decrease in Area (sq km)	% Change	Increase/ Decrease in Area (sq km)	% Change	Increase/ Decrease in Area (sq km)	% Change	Increase/ Decrease in Area(sq km)	% Change
Built-up Area	59.66	35.68	40.28	17.76	40.96	15.33	140.9	84.3
Vegetation	-12.78	-6.83	-42.66	-24.45	7.78	5.90	-47.7	-25.5
Cultivated Land	-52.95	-44.01	-25.21	-37.42	-13.57	-32.19	-91.7	-76.2
Barren and Exposed Land	5.30	3.87	28.87	20.27	-34.73	-20.28	-0.6	-0.4
Water Bodies	-3.12	-26.97	0.56	6.63	-1.27	-14.10	-3.8	-33.1

Source: Source: Land Use Class Maps of 1977 (LANDSAT: 8-3-1977), 1989 (LANDSAT: 18-5-89), 1999 (LANDSAT: 22-10-1999) & 2006 (IRS P6: 12-02-2006) Satellite Imageries

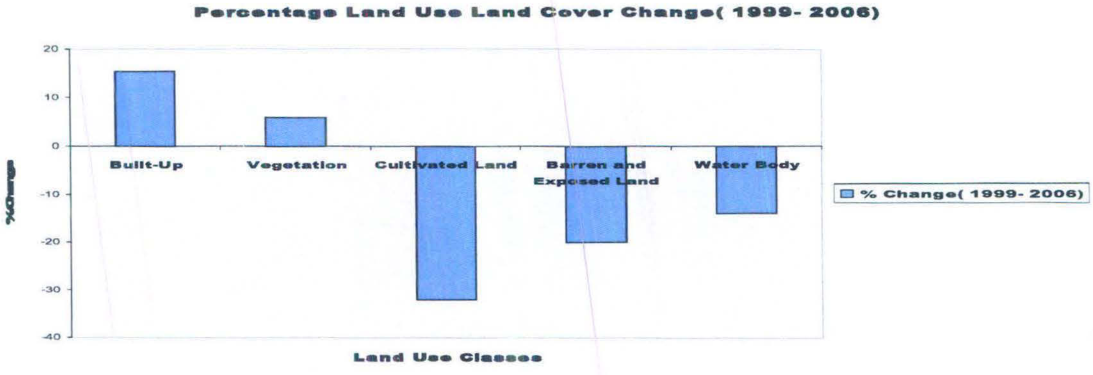
Graph: 3.4



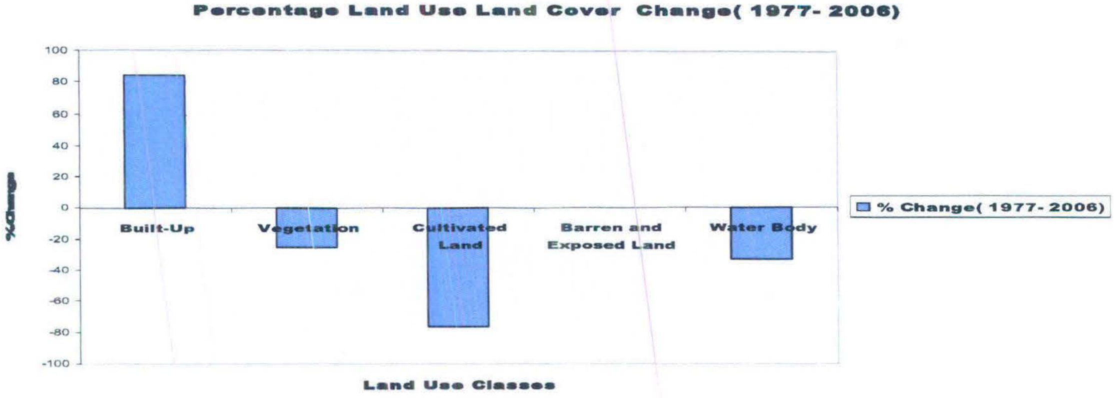
Graph: 3.5



Graph 3.6

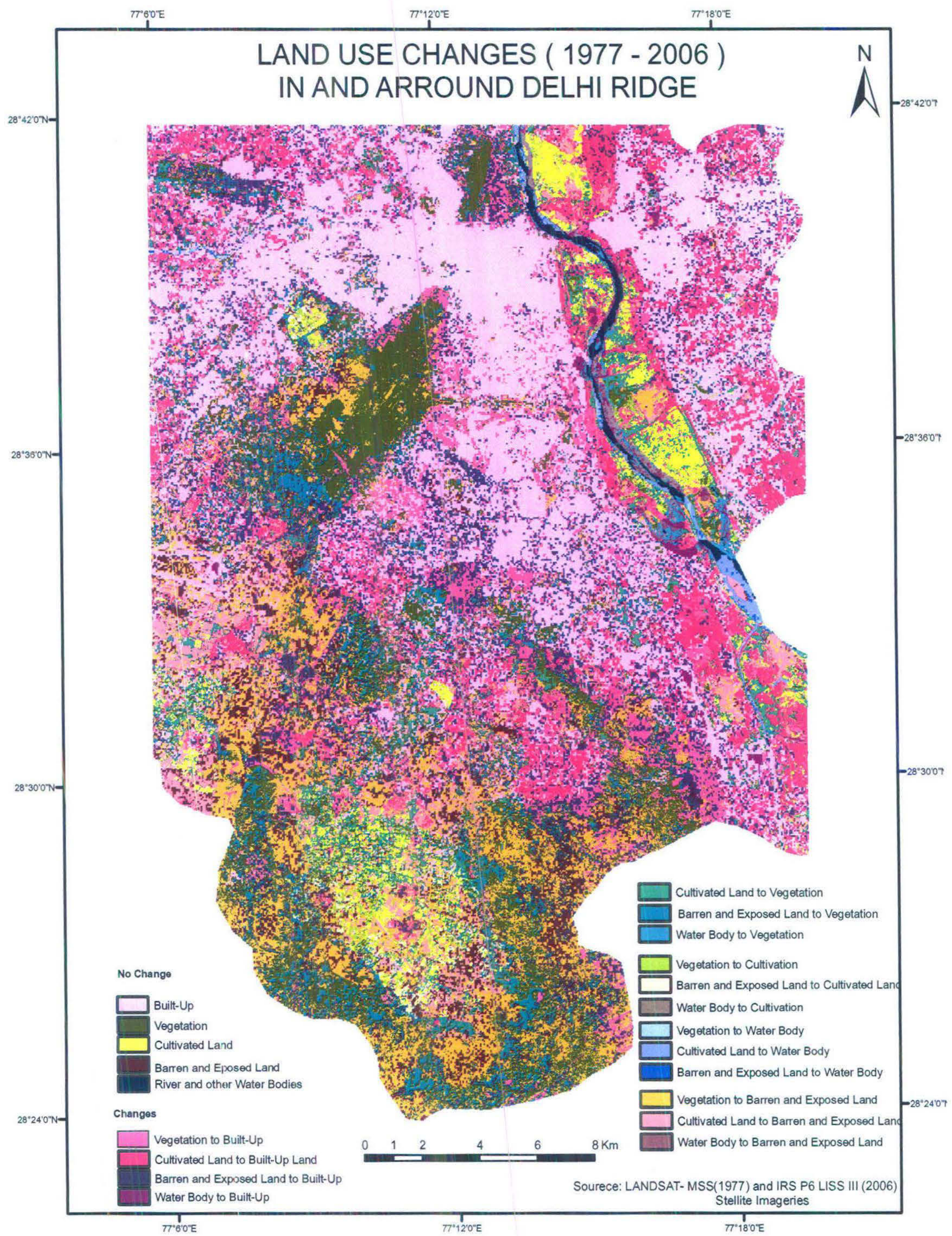


Graph: 3.7



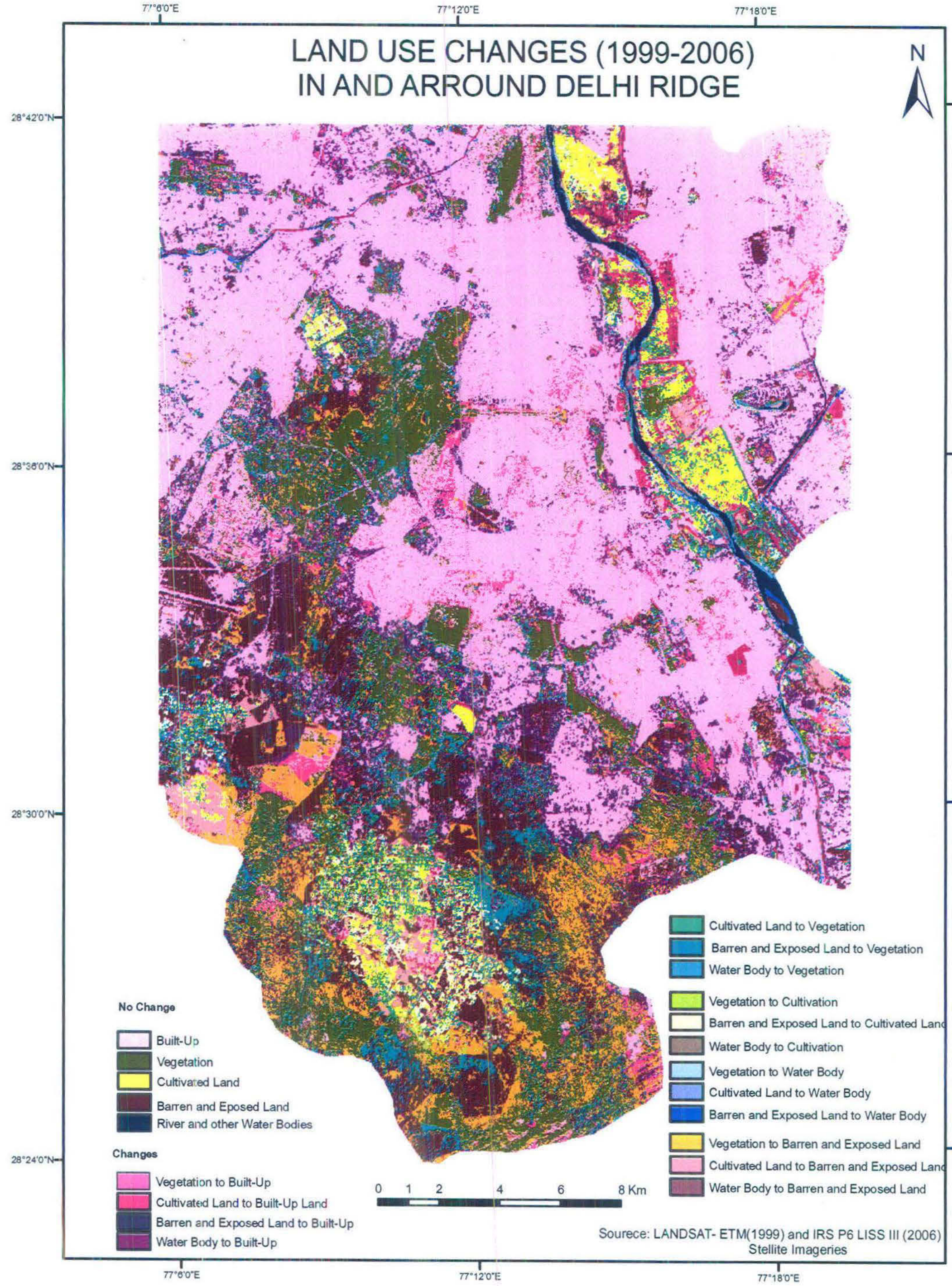
Source: Table: 3.2, Land Use Changes in Area (Sq. Km) and Percentage Change.

Figure: 3.5



LAND USE CHANGES (1977 - 2006)
IN AND ARROUND DELHI RIDGE
N
77°6'0"E
77°12'0"E
77°18'0"E
28°42'0"N
28°36'0"N
28°30'0"N
28°24'0"N
No Change
Built-Up
Vegetation
Cultivated Land
Barren and Eposed Land
River and other Water Bodies
Changes
Vegetation to Built-Up
Cultivated Land to Built-Up Land
Barren and Exposed Land to Built-Up
Water Body to Built-Up
Cultivated Land to Vegetation
Barren and Exposed Land to Vegetation
Water Body to Vegetation
Vegetation to Cultivation
Barren and Exposed Land to Cultivated Land
Water Body to Cultivation
Vegetation to Water Body
Cultivated Land to Water Body
Barren and Exposed Land to Water Body
Vegetation to Barren and Exposed Land
Cultivated Land to Barren and Exposed Land
Water Body to Barren and Exposed Land
0 1 2 4 6 8 Km
Sourece: LANDSAT- MSS(1977) and IRS P6 LISS III (2006)
Stellite Imageries

Figure: 3.6



LAND USE CHANGES (1999-2006)
IN AND ARROUND DELHI RIDGE
N
77°6'0"E
77°12'0"E
77°18'0"E
28°42'0"N
28°36'0"N
28°30'0"N
28°24'0"N
No Change
Built-Up
Vegetation
Cultivated Land
Barren and Eposed Land
River and other Water Bodies
Changes
Vegetation to Built-Up
Cultivated Land to Built-Up Land
Barren and Exposed Land to Built-Up
Water Body to Built-Up
Cultivated Land to Vegetation
Barren and Exposed Land to Vegetation
Water Body to Vegetation
Vegetation to Cultivation
Barren and Exposed Land to Cultivated Land
Water Body to Cultivation
Vegetation to Water Body
Cultivated Land to Water Body
Barren and Exposed Land to Water Body
Vegetation to Barren and Exposed Land
Cultivated Land to Barren and Exposed Land
Water Body to Barren and Exposed Land
0 1 2 4 6 8 Km
Sourece: LANDSAT- ETM(1999) and IRS P6 LISS III (2006)
Stellite Imageries

Table: 3.4

Class wise Land Use Change (1977 to 2006)- sq. km						
Land Use Classes	Built-up Area	Vegetation	Cultivated Area	Barren and Exposed Land	Water Bodies	Total (1977)
Built-up Area	166.46	0.02	0.01	0.01	0.00	166.50
Vegetation	42.98	79.62	5.85	57.31	0.57	186.34
Cultivated Area	55.44	19.63	16.59	25.46	2.16	119.28
Barren and Exposed Land	41.48	37.83	4.36	52.63	0.45	136.74
Water Bodies	1.73	2.45	1.78	1.06	4.546	11.57
Total (2006)	308.10	139.55	28.59	136.46	7.73	620.43

Source: Change Detection Map Using Classified Imageries of 03-08-1977 - Path/Row 157/040 & IRS P6 LISS III imagery 12-02-2006.

Table: 3.5

Class wise Land Use Change (1999 to 2006)- sq. km						
Land Use Classes	Built-up Area	Vegetation	Cultivated Area	Barren and Exposed Land	Water Bodies	Total (1977)
Built-up Area	266.60	0.01	0.00	0.01	0.00	266.62
Vegetation	3.77	105.79	3.88	17.82	0.38	131.64
Cultivated Area	6.16	8.43	15.44	11.46	0.59	42.08
Barren and Exposed Land	31.03	24.07	8.56	106.63	0.79	171.08
Water Bodies	0.54	1.23	0.71	0.53	5.97	8.98
Total (2006)	308.10	139.53	28.59	136.45	7.74	620.41

Source: Change Detection Map Using Classified Imageries of 22-10-1999 - Path/Row 146/040 & IRS P6 LISS III imagery 12-02-2006.

3.2.1 Cultivated Land

Delhi is primarily a City State and has limited land under Agriculture and shrinking fast due to rapid urbanization, industrialization and land use for other non-agriculture purposes, the total cropped are has continuously been declining.

Very few people depend on this occupation. The degree of urbanization in this territory is very high as a result the total cultivable area decreased rapidly. The cultivable area decreased from 1170.00 sq Km in 1971 to 740.00 sq Km in 1999 (Table: 3.6) as far as whole Delhi is concerned. Major food crops are wheat, bajra, jowar and maize. However, emphasis has now shifted from food crops to vegetables, fruits, diary, poultry farming etc. as these is more remunerative than food crops in the territory (Census of India: 2000). The position over the last decade in respect of availability of land for cultivation is as under:

Table: 3.6 Total Agriculture Area of N.C.T (1990-91 – 2005- 06)

Year	Total Cropped Area in Sq. Km
1990-91	**762.39**
2000-01	**528.16**
2005-06	**386.57**

Source: Dept. Of Agriculture, Govt. of N.C.T. Of Delhi

The main urban agricultural area in the core area of the city of Delhi is the floodplain along the Yamuna River. This lays importance but diminishing agricultural areas. The satellite image also clearly depicts the wide extent of agricultural land use in and especially considerable level tracts of land happen to be in the Yamuna River bed part where the cultivated areas are now going under the urban land use.

The North East, East and some parts of Southern districts are by and large formed by the plain area. The River Yamuna is flowing all along its eastern side. It has formed a flood plain area. The tract of land all along the Yamuna River is made up off newer alluvium known as 'Khadar'. In the low lying flood plain newer alluvium is found deposited due to recent floods. The soil in the flood plain area retains adequate moisture even after the rainy season and is particularly good for cultivation. Demographic and economic expansion of cities, through processes such as migration and industrialization, tend to be accompanied by spatial expansion, resulting in encroachments. At the same time, areas that were earlier distant from the city and rural in character will subsequently start falling within the cities' reach or "band of influence".

Within the boundaries of the National Capital Territory of Delhi (Delhi NCT) there are both urban and more 'rural' areas. Beside this, as the land area availability for the urban expansion is almost saturated in the city, now the expansion towards the periphery and south where the fertile farming region of Chattarpur cultivated area and rocky vegetated ridge regions are going under construction in the name of farm houses and other built-ups. This kind of change is seen in the cultivation dominated area in the South Eastern and Northern part of the study area. The important factor which may have been largely responsible for the urban sprawl in the South Eastern part of the study area is dispersal of urban settlements and industries from Delhi to Okla and its surrounding parts.

Over all cultivated area has come down to 42 sq Km in 1999 which was 120 sq Km in 1977. The reduction is mainly due to conversion of cultivable land into built-up area. The land use table: 3.2 and 3.3 show that the cultivable land of 55 sq Km has been occupied by built up area in 2006. Though this conversion is less in 1999 to 2000 it significant as nearly 6 sq Kms of cultivable land especially in the yamuna flood plain region, Chattarpur area and Okla region have come under urban settlements. Next important factor for this land use change is conversion of cultivable land into plots for sale which are grouped under fourth class i.e. barren, exposed and others where these uncultivated lands are calculated. Some areas of (11.46sq Km) to barren and cultivable waste land (others) category and to area occupied under water bodies and river (0.59 sq Km) have gone from 1999 to 2006.

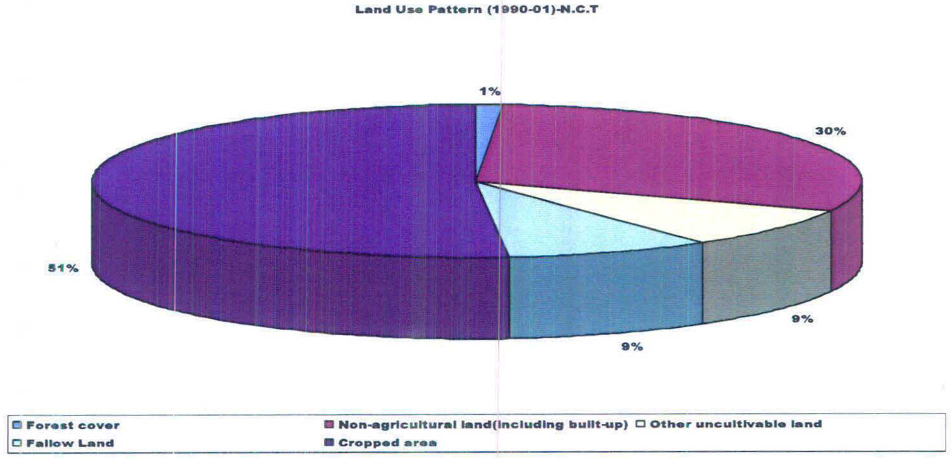
In last seven years cultivated land to barren, exposed land category was high i.e. 11.46sq Km. area went to vegetation is next high from 1977 to 2006 because of shift to horticulture farming and tree plantation in the areas of cultivated land. Apart from this cultivated area gained areas from water bodies as areas near by river bank are occupied for cultivation. Barren land of 4.4 sq km has come under cultivation. That may be because of cultivable waste land are conversion to cultivated one in 2006. But the activities of taking away of cultivated land into buildings and other developments show negative impact on the cultivated land cover in this region. The facts of the whole N.C.T also reveals the same (Table: 3.7&Figure: 3.8, 3.9). Total ecological system of the study area is been changed due to urbanization process. Though urban spread due to increasing population is inevitable, steps to be taken to control unauthorized occupation and illegal encroachments on these cultivated areas is necessary.

Table: 3.7

Changing pattern of land use in NCT (1990-91 -2003-04)				
Land use	**1990-91**	**%**	**2003-04**	**%**
Total area	1,483	100	1,483	100
Rural area (rounded off)	798	53	558	38
Urban area (rounded off)	685	47	925	62
Forest cover	16	1.08	170	11.46
Built-up area (as per IRS IC LISS III Satellite data)	488	32.9	702	47.34
Non-agricultural land (including built-up area)	448	40.26	597	40.26
Other uncultivable land	129	7.48	111	7.48
Fallow Land	128	12.81	190	12.81
Cropped area	762	27.98	415	27.98

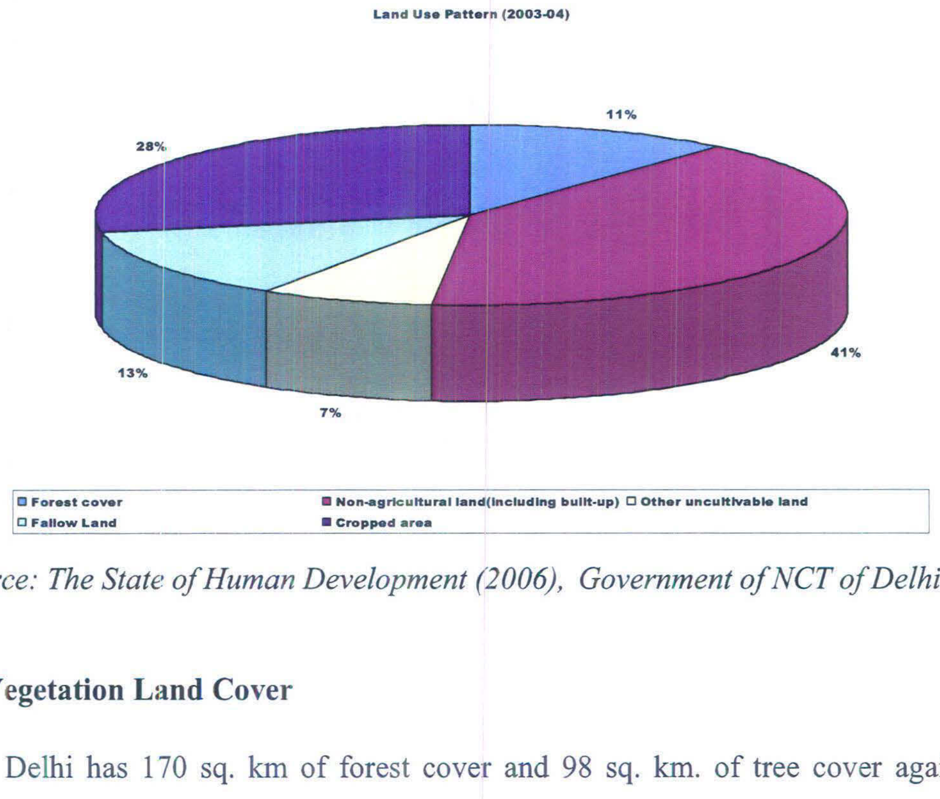
Source: The State of Human Development (2006), Government of NCT of Delhi.

Graph: 3.8



Source: The State of Human Development (2006), Government of NCT of Delhi

Graph: 3.9



Source: The State of Human Development (2006), Government of NCT of Delhi.

3.2.2 Vegetation Land Cover

Delhi has 170 sq. km of forest cover and 98 sq. km. of tree cover against the geographical area of1483 sq. km, representing only 18.1% of total land area of the city. Forest cover has been changed due to rapid expansion of the urban and industrial activities. The settlement expansion and land encroachment all over the Delhi Ridge is noticed as an important phenomenon resulted due to the high population pressure in the Delhi. These processes have resulted in the expansion of built-up areas on the one hand

and large scale quarry and deforestation activities particularly over the Southern Ridge on the other hand.

All these activities resulted in reduction of vegetation cover in this region. Among the Delhi Ridge divisions, the Northern Ridge has the highest vegetation covered area of 62.27 per cent while the Central Delhi accounts for 41.66 percent cover to its geographical area. The South-Central and Southern Ridges were covered with the vegetation of 40.61 ha is percent in the South District. Apart from this sparse and dense vegetation covers are seen in many parts of the study area.

The analysis shows that over all vegetation in the study area has decreased from 187.25 sq Km in 1977 to 132 sq Km in 1999 but it has increased to 140 sq Km in 2006. The decrease in the vegetation (25.5% reduction from 1977 to 2006) is due to clearance for the built-up and left over as waste land. Vegetation to barren land category is also high, showing deforestation activities. Widespread deforestation and land encroachment activities have been responsible for the fragile ecological system degradation over the Delhi Ridge and leads to imbalance in the ecosystem.

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 Government have envisaged ecological development of shelter belts all over the Delhi Ridge. In recent days Delhi Govt is taking steps to increase vegetation in the metro to meet out impacts of global warming because of man made emissions. These cut trees are now tried to be planted under the different forestry plans has been taken place over the Delhi Ridge. Hauz Khas and the Deer Park (Forest) located over the Central Ridge and the Asola Wild Life Sanctuary on the Southern Ridge is important protected greenest areas Table: 3.8 show the protected forests area in different parts of the ridges and their managing authorities.

Table: 3.8: Proposed Reserved Forests

S. No.	Name	Area(sq km)	Managing Agencies
1	Northern Ridge	0.87	DDA, MCD & Forest Deptt.
2	Central Ridge	8.64	Deptt, DDA, Army, CPWD, NDMC, MCD
3	South Central Ridge	6.26	DDA
4	Nanakpura South Central	0.07	DDA
5	Southen Ridge	62.00	Forest, DDA, Sports Authority of India
TOTAL		77.84	

Source: GREENING DELHI ACTION PLAN 2005-2006 Govt. of NCT of Delhi Notification No.F.10. (42)-I/PA/DCF/93/2012-17 (I0 dated 24.05.1994).

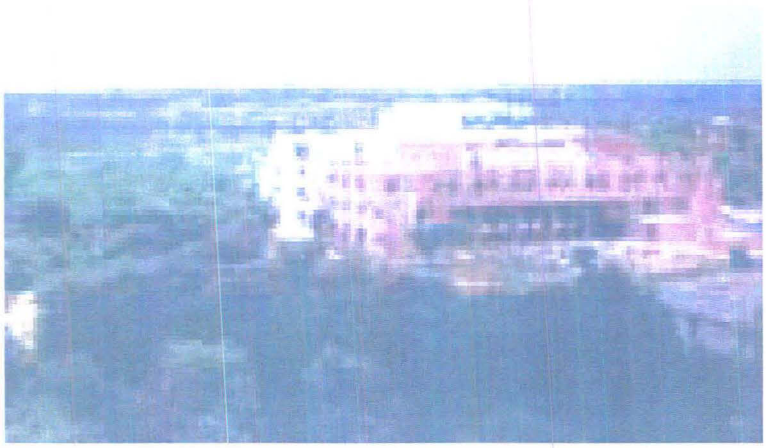
Apart from this Razokri Protected covering 2.43 sq km, Hauzrani City Forest 0.29 sq km are also important area protected under forest department. Other than this some areas like Vasant Vihar Distt. Park of 0.08 sq km, Dhaula Kuan Complex Defence Land of 0.81 sq km, Nehru University afforestation of 0.81 sq km, Garhi Mandu 1.21 sq km, Anand Vihar 0.13 sq km are also under protected forest list under D.D.A. Though these areas have been put under protected and reserved forest list vegetation cover has come down. Due to recent steps to protect, conserve and afforest and planting new trees in various places now the over all vegetation cover is in increasing trend. This is been established by the study (Graph:3.3) as well as for the data for N.C.T also explains the same(Figure: 3.10)

Table: 3.9: Increasing Trend of Forest and Tree Cover of N.C.T (1993-2003)

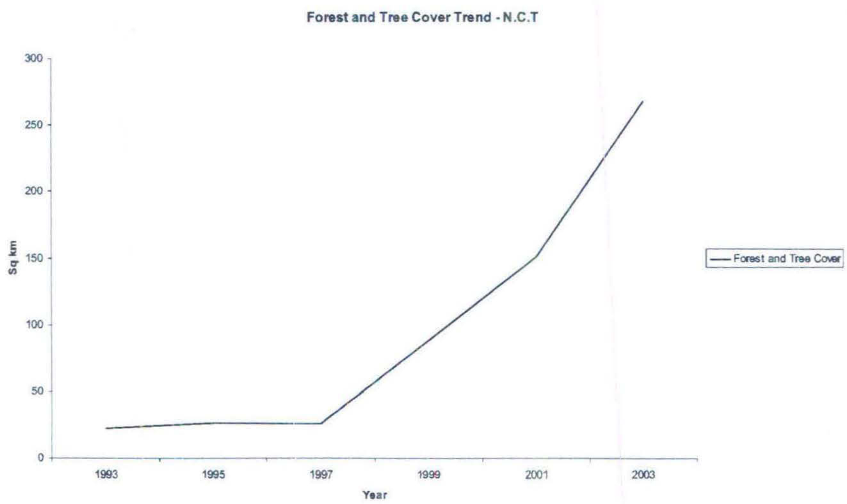
Assessment Year	Forest & Tree Cover (sq. km)	% of Geographical Area
1993	22	1.48
1995	26	1.75
1997	26	1.75
1999	88	5.93
2001	151	10.2
2003	268	18.1

Source: Economic Survey of Delhi, 2005-2006

Plate: 3.2 Restored green cover by reforestation



Graph: 3.10



Source: Economic Survey of Delhi, 2005-2006

3.2.3 Built-up Land

3.2.3.1 Urban Residential Complexes

Urban area of total N.C.T has increased from 326.54 sq km in 1961 to 591.90 sq km in 1981, 700.23 sq km in 1991 and 924.68 sq km in 2001. This urban area was 22% in 1961, 40% in 1981 and 47% in 1991 and 62% in 2001 of the total area. In the study area the urbanization has increased nearly three fold from 166.5 sq Km in 1977 to 266.62 sq Km in 1999 and 308 sq Km in 2006 and area under built-up has increased from 26% to

49% of the total area (Table: 3.2 & 3.3). The sprawl is very rapid and detrimental to other classes. If we the population of the place its growth is high. In the study area districts- North East, East, South are having high decadal growth rate > 40%, North district also shows significant growth of 13%. Only Central shows negative growth rate.

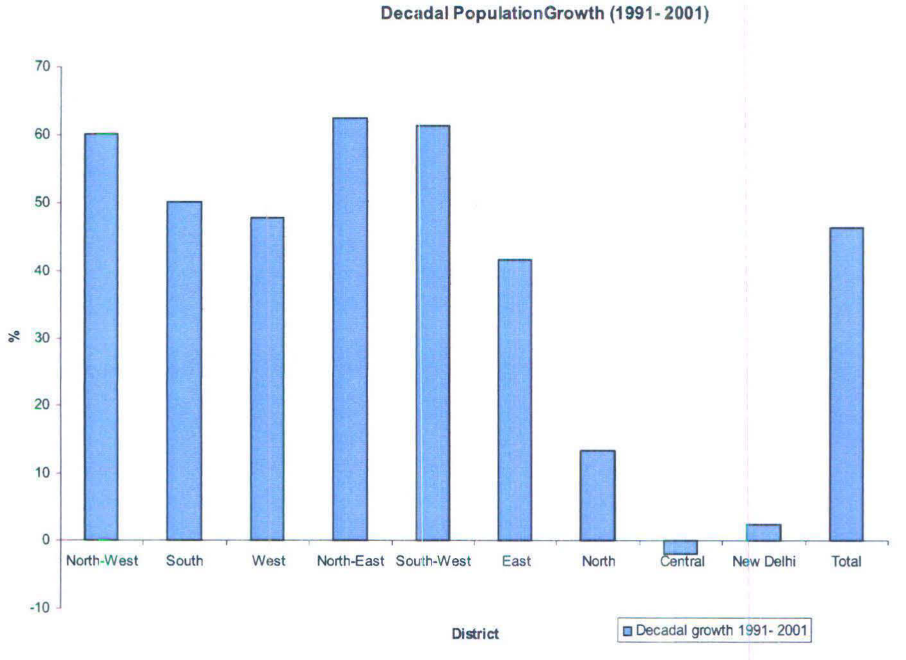
The density of population was 1,966 in 1981 which increased to 6352 persons per sq. km. in 1991. Furthermore, it was increased to 9340 persons per sq. km. in 2001. The decadal growth of population is also high where North West, South, North East and South West districts show more than 50% in decadal growth and over all it was 46% (Table: 3.10 & Graph:3.11). This rapidity in the urban area increase is due to increase in the population pressure on land requirement. This urbanization has taken away the land available for cultivation and also the uncultivated land as well as barren and left over land. The most affected part due to this uncontrolled urban sprawl is the cultivated areas of East, North East and South districts and the ridge region.

Table: 3.10 District-wise area and population of N.C.T during 1991 & 2001

District	Area (sq km)	% Area to total area of State	1991	2001	Decadal growth 1991- 2001
			Density (pers/sq km)	Density (pers./sq. km)	
North-West	440	29.7	4042	6502	60.12
South	250	16.9	6012	9068	50.27
West	129	8.7	11116	16503	47.81
North-East	60	4.05	18088	29468	62.52
South-West	420	28.3	2583	4169	61.29
East	64	4.31	15986	22868	41.61
North	60	4.05	11471	13246	13.30
Central	25	1.68	26261	25855	-1.91
New Delhi	35	2.36	4791	5117	2.47
Total	1483	100.00	6352	9340	46.31

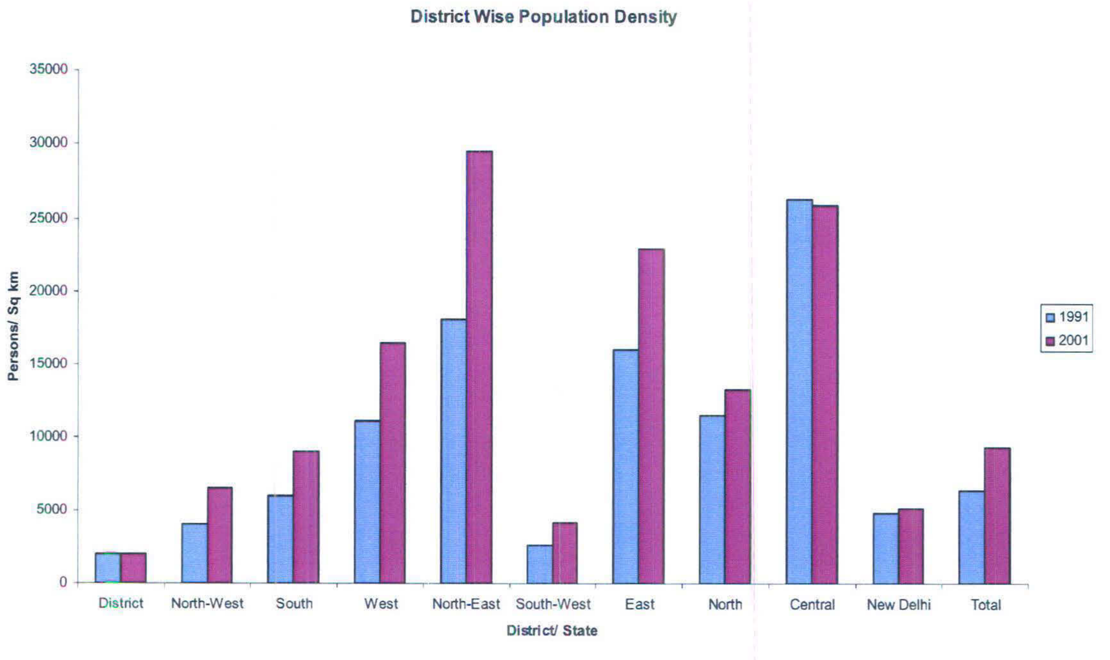
Source: Census of India 1991 & 2001

Graph: 3.11



Source: Census of India 1991 and 2001.

Graph: 3.12



Source: Census of India 1991 and 2001.

3.2.3.2 Industrial Complexes

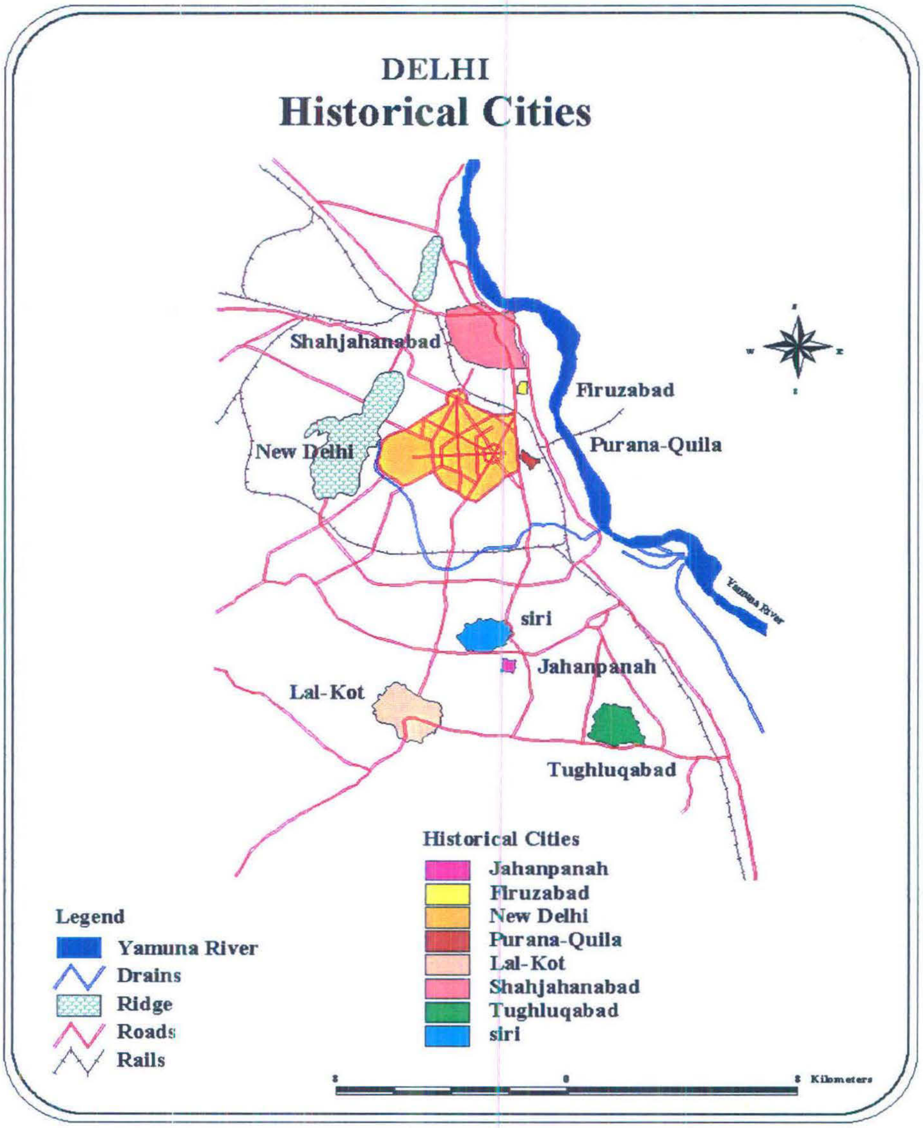
Out of 1.3 lakhs industrial units in Delhi, only around 25000-30,000 are located in planned industrial areas. The existing industrial estates are Bawana; Narela; Badali; Mangolpuri; Okhla; Patparganj and Shahdara. In these Okhla; Patparganj and Shahdara, vishwanagar areas were developed in the 70s and over the years have deteriorated considerably in terms of physical infrastructure falls in the study area. Land allocated by the Government of Delhi for the industrial areas in the study areas are, Okhla Industrial Area 1241 acres and Shahdara Industrial Area 3832 acres (source: Source: Compiled from Master Plan of Delhi-1961-81). Garbage is littered on the roads and overflows out of the dustbins in these industrial complex regions. The collection system is unreliable and the areas are occupied by slum dwellers also (source: Land Management & Urban Growth,Dept. of Urban Development, Govt. of Delhi). The industrial area stimulated urbanization has been visually seen in these areas where housing and other built-ups are coming up at the expense of cultivated and vegetated land.

3.2.3.3 Historical Buildings and Monuments

There are found a number of historical buildings and monuments which are in ruins in different part of the study area. Delhi is one of the greatest historical centre in the world. It is one of the oldest capitals in the world, having two world heritage sites- Qutb Minar and Humayun's Tomb. Delhi was built and rebuilt seven times on different sites through out the history within a triangular area of about 142.20 sq. kms lying between the last ridge of the Aravalli Range and the River Yamuna.The slave dynasty back (**Madan Mohan** http://www.isprs.org/congresses/istanbul2004). Qutb Minar, Tughlaqabad ruins, Lal Kot in the south delhi , Hauzkas village area, Tomar city of Lal-Kot to Siri, Jahanpanah and Firuzabad of the Sultans and then Purana-Qila and Shahjahanabad of the Mughals.

New Delhi built by the Britishers in pre-independence period expanded into many folds in the post independence period. The ancient historical cities and cultural heritage sites have been are now surrounded by concrete and some areas are occupied by slum people also. The cange in land use pattern in these areas with ever growing residential complexes and pollution created by human beings are posing severe danger to these historical monuments. Protection and conservation of these monuments and heritage sites are important to say our history to future generations.

Figure: 3.7



Source: Madan Mohan http://www.isprs.org/congresses/istanbul2004

3.2.3.4 Transport Network and Other Infrastructures

Delhi is well connected by roads with all parts of India. The road length in 2000-01 was 28,508 km. The city has the largest number of vehicles and its road traffic is highest in the country. It has three inter-state bus terminuses - ISBT at Kashmere Gate, Sarai Kale Khan and Anand Vihar and number of fly-overs to decongest the traffic. Delhi was opened to railway traffic on 1st January, 1867 and Delhi-Ambala-Kalka railway was opened on March 1, 1891. Now city has railway connection with all parts of India. Three important railway stations in the city are Delhi Junction, New Delhi Railway Station and Nizamuddin Railway station. In 2000-01 the total length of railway tracks were about 200 km (Census of India: 2001- overview Delhi).

Capital of the country is well connected by Air service to different parts of the country and the world. The city has three airports, Indira Gandhi International Airport (for international flights), Palam Airport (to handle the domestic flights) and Safdarjung Airport (for training purpose). All these three ways of transportation networks are becoming congested due to increasing demand and supply gap. Due to increased CO_2 and CO emissions cities temperature has increased in recent years. To meet out the increasing temperature and other pollution with increasing population sustainability in usage of various natural resources of the city is important.

3.2.4 Water Bodies – River and Lakes and Tanks

The perennial River Yamuna flows all along the eastern side of the region and various fresh water bodies present in the Delhi region. Population pressure exerts various types of pressure on the urban ecosystem specially the forest patches and freshwater bodies. The excessive demographic pressure alters the land use pattern and invariably destroys the capability of existing land use pattern to perform ecological functions-immensely beneficial to the society but hidden from the eyes of city planners (Kumar et al 2002; Kumar and Aggarwal, 2003). The numbers of these water bodies have come down and there areas are occupied by garbage dumps and illegal constructions. Sanjay lake Myur Vihar is an important one. Recently Hauzkas lake is been renewed by the Govt of Delhi. The land use classes analysis shows that water body level is shrinking from 11.57 sq km in 1977 to 9.00 sq km in 1999 and it has come down to 7.7 sq km in the 2006. These changes are due to vanishing lakes and ponds as well as shrinking water level in Yamuna.

3.2.5 Barren, Exposed and Waste Land

Barren and Exposed Land class in the study shows nearly 22% of the total area of study. It is because of the presence of the rocky exposed land and barren land in this region. Now these areas are being converted into buildings.

This analysis is trying to put forth the land use changes in this ecologically fragile region. As we have seen almost all the geomorphologically and ecologically important features of the city i.e. Yamuna River ecosystem region, Aravalli Ridge area and Older alluvium part comes in the study area and all these parts are under severe threat due to human induced land use changes as their land use changes are very rapid with the urbanization process of the city. The various human activities responsible for the land use changes and their impacts are dealt in the coming chapter.

Chapter IV

Chapter IV

Anthropogenic Causes for Land Use and Land Cover Changes

Human beings originated in the wild then emerged as hunters and gatherers, later people whose livelihood depended on the plants and animals of the land provided enough food for everyone. The population spread over most of the earth and grew immensely. Population growth required a more productive means of obtaining food. Agriculture was discovered as a more productive method of subsistence than gathering. The interaction of people and their environment was determined not only by landscape, but the culture of the people. As human lifestyles evolved, tribes and societies formed centers for trade and other activities. Permanent settlements soon developed due to the discovery of agriculture, farmers could no longer roam freely about the landscape, but rather had to stay in restricted areas in order to tend to their crops. Several important locations for farming and trade emerged as cultural hearths. These areas were the centers of cultural development (Fellmann, Getis, & Getis, 1992).

Technological innovations allowed many humans to become detached from the workings of the earth. The domestication of plants and animals also marked a change from the land influencing people to the people influencing the land. A consequence of the forming of cultural hearths was the founding of cities (Fellmann, Getis, & Getis, 1992). Societies needed land on which to live, and the better land was contested by rival societies. Cities became key areas for economic and cultural activity because of their central location and concentrated population (Fellmann, Getis, & Getis, 1992). Delhi grew into large city though more cities were founded earlier too (Kolkata & Chennai). Modern trends of urbanization were welcomed as signs of cultural advancement. Forests and other natural features were often cleared for this purpose including agricultural land.

Since the location provided a unique ecological security as well as a vantage point over the plains of the Punjab in earlier years it has been chosen for the seat of the empires. British also found this as secured place for their rule and placed them in Raisina

Hill near the bank of Yamuna which is fertile and Ridge gave them protection from west. After the independence the population growth with demand of land for settlement also increased. As the Delhi population has grown and become more urbanized, the problems related to the development also started to surface.

Like the rest of the developing world's cities, the Delhi now has an overwhelmingly non-farm population residing in cities, suburbs, and towns and villages. Surrounding urban areas is a classical frontier of rapid land-use and land cover change. Urban impacts go beyond the land uses and land covers for settlement and infrastructure; they also involve the mining for building materials, the disposal of wastes, the creation of parks and water supply reservoirs, and the introduction of pollutants in air, water, and soil by various human activities. Delhi with its large green spaces, gardens, trees and forests has now become a polluted city. Usage of land for providing housing and other infrastructure services like water supply, drainage, roads plus social infrastructure such as clinics, hospitals, schools, police and fire stations etc. has subtracted land use for agriculture and vegetation.

Today's Delhi has to see it in a context of both its changing land uses, as well as it being the capital of one of the fastest changing countries in the world. The city is attracting foreign and Indian Govt. investments more for housing as well as better infrastructure development. The trend in Delhi and especially the study area has undeniably been one of residential dispersal and increased settlement densities as population increases have been chronologically over layered by events and outcomes of great historical importance through the ages. Over exploitation of natural resources - land, forests, water and air lead to ecological degradation. The major human activities which changed land use changes are stone and lime mining, deforestation and encroachment on the ecologically rich as well as fragile Delhi Super Groups ridge, brick kiln activities, rapid ground water extraction and exploitation, vanishing water bodies-tanks and other air, water, solid waste, air and water pollutions due to over usage of hydro-carbon fuels and improper, untreated waste disposals. These impacts of anthropogenic activities on the study area are immense.

The Ridge is the unique ecological feature with semi arid vegetation. As an important geomorphologic feature, it acts as the surface water divide and source of recharging groundwater table. It's important to study the causes of land use changes in this area and their impact on the ecology of this region. The river another important geomorphologic unit and network of ponds, lakes and canals found in this region are also ecologically important. As sewage drains joins with Yamuna River make it more polluted as it are already polluted with the industrial and other toxic effluents and its changing course during monsoon floods and fertile alluvial soil on its banks as the site for cultivation establishes importance of this study. The river area is shrinking recent years owing to their catchments are being built upon. The Yamuna flood plain as well the river catchments are filled and built upon and it is very rapid in the last and present decades its from1980's.

4.1 Ecological impact

Current globalization processes, industrialization, technological development and economic growth are occurring at increasingly variable rates. Understanding the interaction between human activities and urban ecosystem requires a fresh look.

Natural landscapes in urban areas are important for many reasons. First of all, the presence of trees and parks contributes to citizens well being. As Ridge and the forest present in it, Park, Open scrub land offer many things that an urban terrain cannot provide. These include open spaces, natural vegetation and wildlife, and the natural feeling and relaxation from the fast paced city lifestyle. Rather, people feel more at peace within the parks of the city and outside the city in the countryside itself when he is having lot of work pressure these days. A need for a natural environment that cannot be satisfied by wholly man made surroundings is surfacing highly in todays city society. Not only the recent developments are not suitable for the resotoration of these ecologically important area but also destroy their elegance and effective role in combating raising pollution and global warming. The study areas two important micro ecosystems are Delhi Ridge and the Yamuna river ecosystems. The impact of human activies on these ecosystems and changing land use in these areas are very deleterious and fast in nature where they totally take away the true nature of the system to a man made one.

4.1.1 Impact on Ridge

All-human activities both direct or indirect cause environmental pollution and detrimental impact on ecology. Vulnerable impact of land use change on Delhi Ridge includes ecological imbalance, deforestation, quarrying/mining activities, urbanization and land encroachment, and industrialization. The area of the Ridge is not in continuous as it was in last centuries , in fact four relatively small pockets of forest are meant as Ridge now (Figure: 4.1 & Fgure:3.4). The name urban development and population growth have eaten away this majestic protective feature and it is a silent victim of the short sighted urban developers. The discontinuous four pockets ridge areas also shrinking since they are cut and developed at many points.

The Ridge Forest land in Delhi, earlier shown as Regional Park measuring 77.77 sq km in the Master Plan of Delhi 2001, was notified under section 4 of the Indian Forest Act, 1927, vide Notification No F.10 (42) - 1/PA/DCF/93/2012-17(I) dated 24th May, 1994.

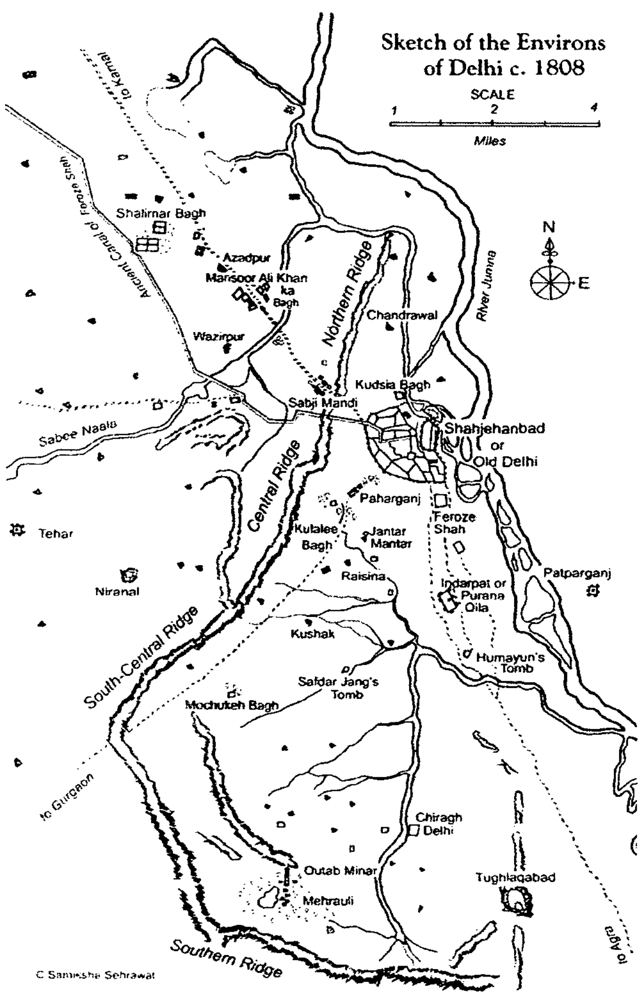
Regarding the Northern Ridge when it was first declared a reserved forest in 1942 by British its area was listed as 1.5046 sq km but the present notification list of the government of NCT states it is 0.87 sq km (Rapid EIA Of proposed Comptroller & Auditor General of India, developed by Central Public Works Department New Delhi, 2004). The balance of 0.6346 sq km has been encroached it means. These encroachment activities have started during the Mughal period itself as these areas were used as woodland and hunting activities and now the advanced level of encroachments are done in the name of urban infrastructure developments.

Table: 4.1 Ridge area during notification and Loss

Ridge Name	Area During Notification	Area(2005) Sq km	Loss
Northern Ridge	150.46(1942)	0.87	63.46
Central Ridge	917.47 (1913)	8.6963	47.84
South Central Ridge	- (1948)	6.2698	-
Southern Ridge	- (1948)	62.0049	-

Source: Rapid EIA Of proposed Comptroller & Auditor General of India, developed by Central Public Works Department New Delhi, 2004

Figure: 4.1



Source: *http://journals.cambridge.org*

The central ridge is been encroached more for the construction of roads as well as other built-up points. Central Ridge, the notified area being 9.1747 sq km but the net area available is only 8.69 sq km now (Rapid EIA Of proposed Comptroller & Auditor General of India, developed by Central Public Works Department New Delhi, 2004).

Police camp, hospitals, petrolpump stations, road, schools, talkatora complex, army camp, Buddha Jayanthi park, army school, housing, Mahavir Jayanthi park are some of the points occupied with in the zone of the ridge region. Several paths ,cremation ground, park had been constructed, water body had been covered up, dumping of debris in the notified area of the Central Ridge by DDA. Delhi High Court took serious view of the abuse of the notified Central Ridge and directed the DDA to ensure that "the Ridge is maintained as Ridge only" in 2004 (www.rainwaterharvesting.com).

As far as South Central and Southern ridge part are concerned now they under severe ubuse. These areas are affected severly by quarrying and mining activities though it has been banned by Government of N.C.T . Other human cuase for land use changes and ecological degradation in this part are illegal land encroachments and other infrastructure developments like builiding bridges, Metro rail link etc. Depleting groundwater table is another concern. Conversion of farming land into farm lands and creation of parks and other man made recreation spots in the place of natural vegetation and massive ridge are visible here.

Although as reported by the Deptt of Forests there has been an overall increase in the forest cover in the last 10 years, degradation of the forests in some pockets of the city has increased. An ecologically important location, the Asola Wildlife sanctuary, was established to protect and conserve the city's biodiversity. However, this sanctuary is again under threat with the proposed scientific land fill at the Bhatti Mines. Sanjay Van the densest part of the Delhi ridge is degraded by contruction of road, housing, dumping of garbage as well as brick klins and most devastating mud and stone quarries (Indian Express – Newsline, 27/12/2005).

Plate: 4.1

Metro Rail bridge connection on ridge- Mehrauli area of South Central Ridge.

The Ridge Management Board (RMB), comprising government officials and environmental activists, was set up in 1995 to check encroachments and ensure afforestation and preservation in the area. The survey was carried out in the forest region from Qutub Institutional Area, extending up to Vasant Kunj on one side and Mehrauli on the other by RMB. The southern part of the Ridge area is spread across 62.00 sq km of which 15.77 hectares fall within urban limits.. The respiratory problems like silicosis are very common in these stone mining areas (Indian Express – Newsline, 27/12/2005).

If we see following recent announcement we can understand the real factor in this Delhi ridge area. Around 0.20 sq km of Ridge area has been diverted under Forest (Conservation) Act, 1980 for infrastructure projects after seeking approval of the Hon'ble Supreme Court as per details given below:

Name of Project/ extent of forest land diverted Under Forest (Conservation) Act, 1980.

- Relocation of Petrol Pump due to Dhaula Kuan Flyover Project 0.001 sq km,
- Construction of Dhaula Kuan Flyover Project, .0035 sq km
- Construction of Diaphragm Wall for underground Rly Line of Delhi Metro Rail Corporation 0.0038 sq km
- Upgradation of Talkatora Stadium of NDMC .0011 sq km
- Construction of Bridge over Neela Hauz of PWD .001 sq km
- Construction of Qutub Minar-Gurgaon Corridor of DMRC .0056 sq km
- Upgradation of S.P. Mukherjee Swimming Pool Complex of CPWD 0.0015 sq km
- Construction of Airport Link Express of DMRC.006 sq km.

(Source: Government of N.C.T of Delhi, Department of Forests and Wild Life, 10 December, 2008)

Quarry and Minining

Apart from these kind of encroachment activities ridge is affected by quarrying and minining activities. Mining and quarrying activities have degraded especially the South-Central Ridge and Southern ridge parts along with the construction activities. These activities have started in this region when new built ups came itself. After independence stone quarries were set up in North-East of the city i.e. Anand Parbat. Then the sites were shifted to Timarpur and Chandrawal near ISBT and Kashmiri Gate in North and enough exploitation had done up to 1970s. After shut downing quarries at Anand Parbat, operations started near the suburb of Dhaula Kuan in the ridge area had begun. Later years their presence extended from East to West including Tajpur, Badarpur, Lal Kuan, Lakadpur, Anangpur, Surajkund, Kusum Pahadi, Rajokri and Bhati Mines (SA Azad, 2007).

Based on the map prepared using Survey of India Toposheets of 2000 (H43 X2, H43 X3, H43 X6 and H43 X7) and 1975 (53 H/2, 53 H/3 and 53 H/6) analysis has been done to study the changes in the mining and quarrying area (Figure:4.2&4.3). It shows an increase of area under these activities form 1.87 Sq Km in 1975 to 5.23 Sq km in 2000. Number of sites also increased. New areas like Chandan Hula, Raipur Khurd, Mandi had come up (Figure:4.2 &4.3). . This increase in area as well as their number of presence had severe impact on the ecology of this region.

The mining activities in the region results in disturbance of land surface, land use changes and pollution problems. Subsidence of land, mine fires, destruction of vegetation, generation of wind blow dust etc are some of the problems in these mining areas. Damages are caused due to unscientific mining by Private mine owners .With the human population on the increase, their demand from the forest has correspondingly gone up but they are cut down in these mining areas. The drainage system of this region has been changed as left over mining parts becoming new depressions and now filled with rain water during monsoon. And these areas are now habitat of various trees of natural as well as planted by Government.

In the past, mine operators took no note of environmental damage. In fact they were not even conscious about it. The attitude of mining community is to ignore the environmental concerns. In majority of the cases, the environmental concerns are ignored for making quick profits.

Figure:4.2

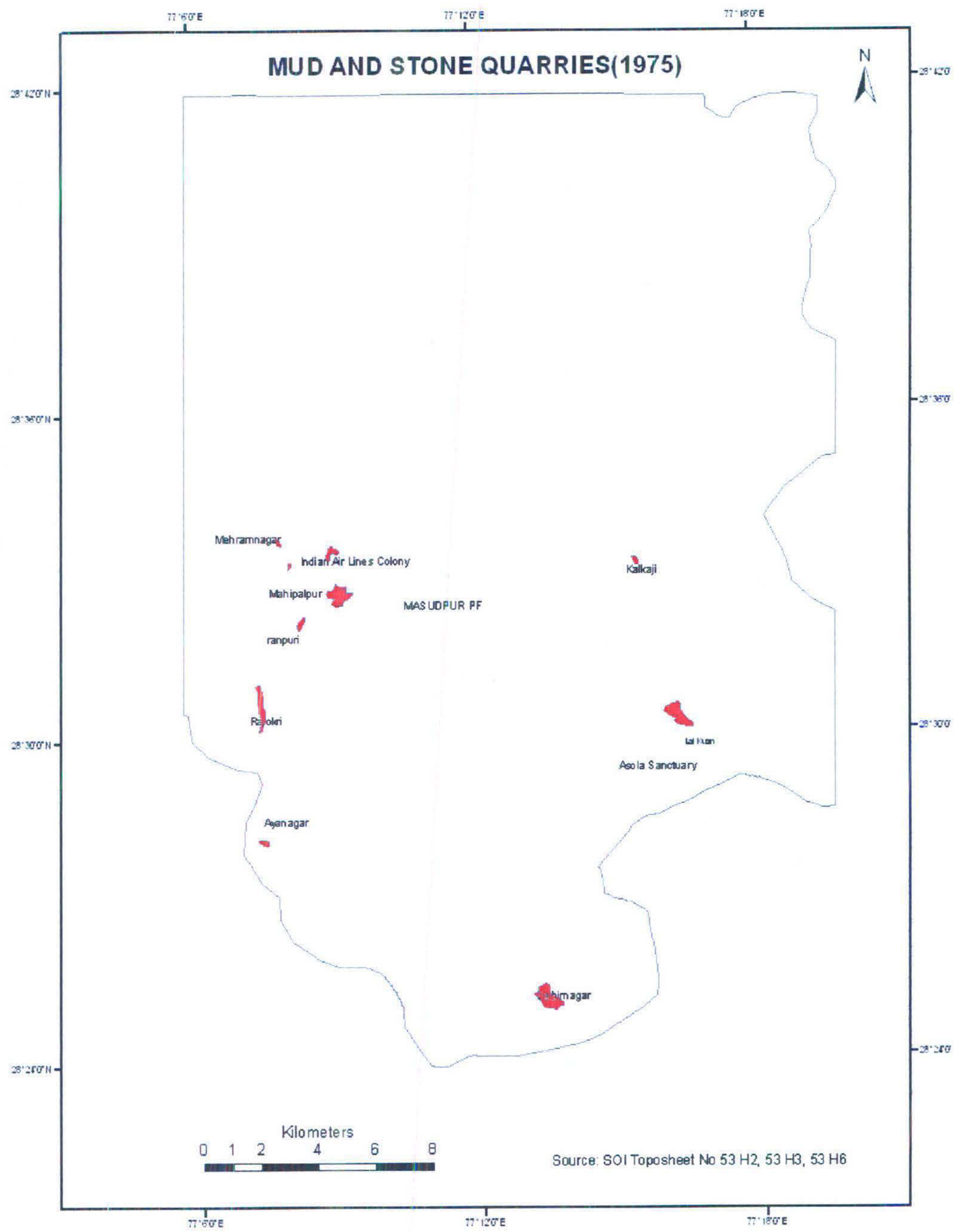
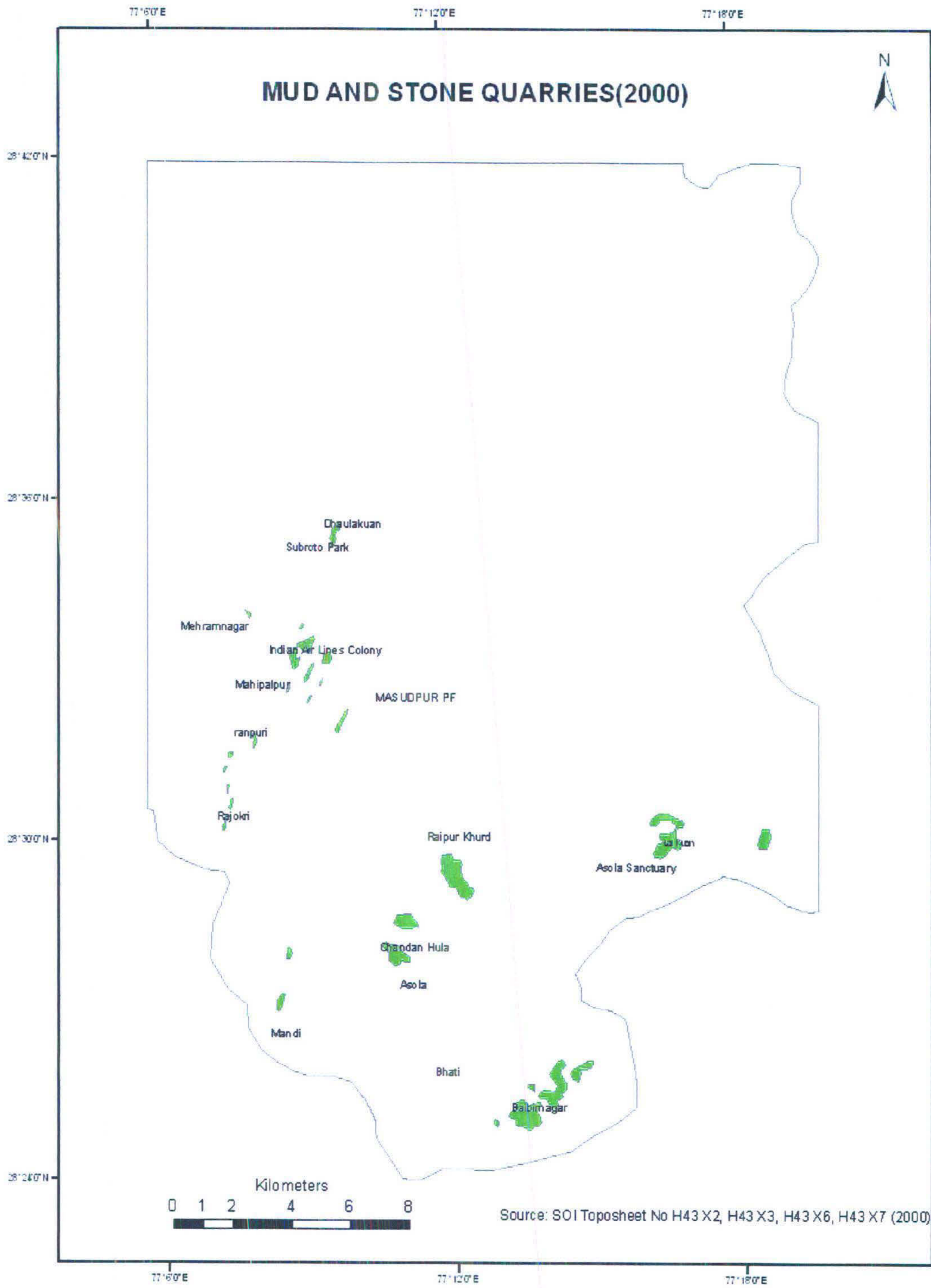

MUD AND STONE QUARRIES(1975)
N
Mehramnagar
Indian Air Lines Colony
Kalkaji
Mahipalpur
MASUDPUR PF
ranpuri
Asola Sanctuary
Ayanagar
Kilometers
0 1 2 4 6 8
Source: SOI Toposheet No 53 H2, 53 H3, 53 H6

Figure: 4.3


MUD AND STONE QUARRIES(2000)
N
Dhaulakuan
Subroto Park
Mehramnagar
Indian Air Lines Colony
Mahipalpur
MASUDPUR PF
Rajokri
Raipur Khurd
Asola Sanctuary
Chandan Hula
Asola
Mandi
Bhati
Balbimagar
Kilometers
0 1 2 4 6 8
Source: SOI Toposheet No H43 X2, H43 X3, H43 X6, H43 X7 (2000)

Though quarrying activities are banned in the state now still illegal activities are going on. More over the left out parts once under quarrying are just left out as such now and those areas have become ground for the waste and garbage disposal as well as stone wastes remains creating ecological imbalance. The air pollution and related respiratory diseases like silicosis as well as the ground water recharge limitation due to quarrying are some other problems. Cut off trees to be planted in those left over areas. To check illegal quarrying and mining activities strict legal enforcements are to be established.

The degradation, misuse and insensitive treatment of the ridge and its forest cover in Delhi sums up the threat to not only the environment but to the overall sustainability of the city. The Ridge area of Delhi has degraded tremendously due to by roads, buildings, traffic and garbage dumping, lopping of trees and grazing by livestock. Mining and quarrying activities in the past have degraded the South-Central Ridge causing enormous loss to biodiversity. Although as reported by the Dept of Forests there has been an overall increase in the forest cover in the last 10 years, degradation of the forests in some pockets of the city has increased. Government of Delhi is taking steps to restore Asola and Bhatti Mine area through planting trees and arresting quarrying and mining activities and this area has been announced as sanctuary also.

Major steps taken by Government to restore ecology of this ridge region are creation of Asola Wildlife Sanctuary in South ridge and proposed Aravalli Biodiversity Park in the South Central ridge area.

An ecologically important location, the Asola Wildlife Sanctuary, was established in 1992 to protect and conserve the city's flora and fauna. However, this sanctuary is again under threat with the proposed scientific land fill at the Bhatti Mines. The Delhi Ridge was once inhabited by leopards, deers, antelopes, wolves, jackals, hog deer, etc which have vanished over time (City Environment Profile JNURM, Dept. of Urban Development, Govt. of Delhi). Some of the important species found are mongoose, small Indian civet, small Indian mongoose, jungle cat, flying fox, porcupine, palm squirrel, spiny tailed lizards, Rufus tailed hare and monitor lizards. Major birds at Asola Wildlife

Sanctuary are bee-eaters, cormorants, egrets, grebes, falcons, partridges, quail, peafowl, lapwings, sandpipers, woodpeckers, doves, parakeets, cuckoos, owls, nightjars, barbets, swallows and shrikes etc.

The area surrounding the proposed biodiversity park (Aravalli Biodiversity Park) is situated in Vasant Kunj area. This is dominated by the moist deciduous forest community merges with luxuriant *Acacia* dominated forest community with species such as *Aegle marmelos, Prosopis cinerari, Tendu, Haldu, Mahua), Mitragyna parviflora (Ken) and Sapindus laurifolius (Soapnut, Reetha) under a canopy of Prosopis juliflora (Vilayati kikar)* and *Cordia garaf* interspersed with grass patches (http://www.dda.org.in/greens/biodiv/aravalli-biodiversity-park.html). This imitative should be implemented at full swing. J.N.U, Nicholas Ranges and Jaunpur which are not under the ridge area notification also to been taken into it as per many committees recommendation and ecology of the ridge should be preserved.

4.1.2 Impact on Yamuna Flood Plain

The flood plains of river Yamuna in Delhi are ecologically important geomorphologically unit. Recharge ground waters (aquifers) through flood waters seepage and this area is habitat for many fauna and flora. This flood plain is critically threatened by encroachment and pollution. From Wazirabad to Okla barrage it covers 22 Km length. All along the bank of the river recent urban developments in both the sides are very fast. The rapid infrastructure developments for up coming Common Wealth Games 2010 shows with increased number of new shopping malls, various complexes. The transportation infrastructures like Delhi Metro connection, National Highway are consuming this fragile zone in the name of development.

Figure 4.4

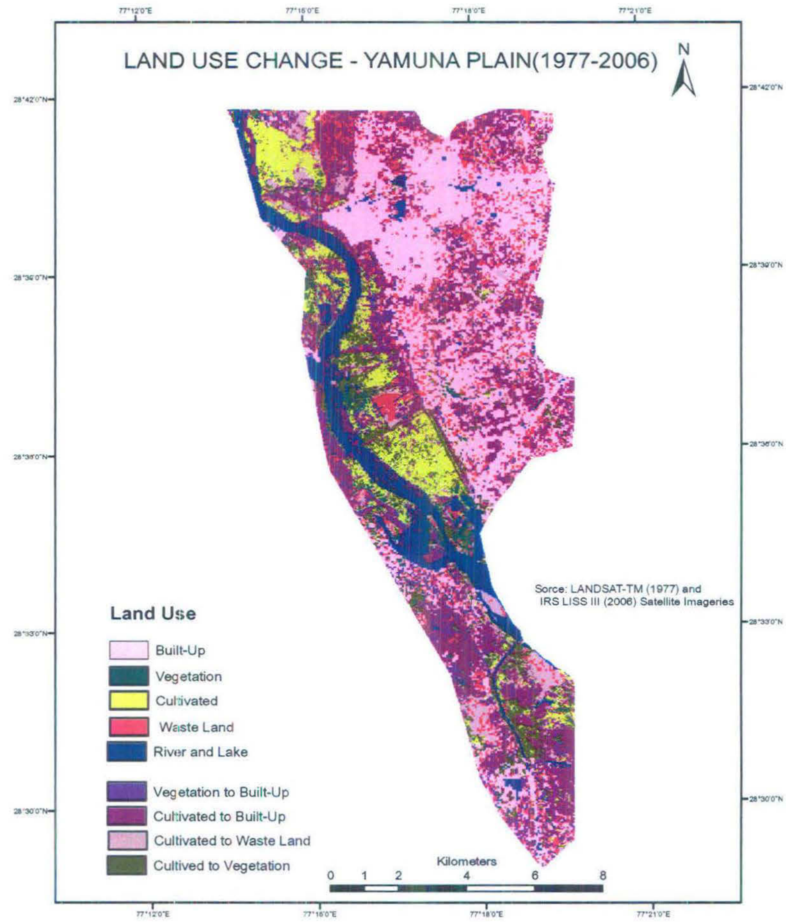


Figure: 4.4 –shows how the flood plain area has been taken under the built-ups. This land use change has severe impact on the ecology of this part by means of pollution, reduction in ground water level, disappearance and becoming vulnerable list of many organisms. Some of this parts- pollution and ground water depletion are discussed in later part of this chapter.

From the land use change analysis of this study place only newer flood plain area is left out as cultivated region. But that also encroached in areas like Shahdara, Kaithwara, Gandhinagar, Akshardham, Mayur Vihar etc. Almost whole older flood plain parts as well as abandon channels (figure: 2.1- Geology and Geomorphology map of Delhi) are under built-up now.

By studying the DEM (Figure: 2.3) we can understand that South Central and Southern part of this plain region are under the elevation of 90- 125m - flood plain zone but man occupied this natural features with constructions. The riverbed slope towards the water channel i.e. river Yamuna. (Figure: 2.6). But residential and industrial activities have occupied on the riverbed. As the slope is increasing towards river south and eastern part of the plain region these areas are more prone to flooding. 'Environmental Management Plan for Rejuvenation of River Yamuna in NCT, 2005' of NEERI recommends in Sub Zone 05 (where the DMRC Yamuna Metro complex today stands) only nurseries and low impact parks, botanical gardens, picnic spot, mini sport complex etc can only locate. Soil which is having high porosity due to presence of coarse to fine loamy i.e. calcareous, silt, clay and sandy loam (Figure: 2.7). Water table is high and generally soils are fertile and high yield crops can be grown in this part. But now these parts are going under constructions i.e. concrete with no water absorbing, holding or percolating structures.

There are few steps taken by Government in consideration of ecological importance of this region. They are Yamuna Biodiversity Park initiative and Pollution control actions.

"Yamuna Biodiversity Park"- is presently spread over an area of approximately 457 acres near Wazirabad village on the flat alluvial plains of the Yamuna. Though this part is not falling under the study area it's important to mention here while discussion ecology of this region. Plantation is designed on the basis of the structure and composition of the forest ecosystem found in its natural environment. These ecosystems are: Subtropical mixed evergreen forest ecosystem dominated by *Toona ciliata, Dalbergia latifolia,_Trewia nudiflora, Artocarpus lakoocha,_Dillenia indica,_Barleria cristata, Vigna capensis* etc. Moist tropical deciduous forest ecosystem with Teak as a dominant species, Tropical dry decuduous forest ecosystem with Sal as a dominant species, Tropical thorn forest with *Acacia sp, Prosopis cinerarias* dominant species and Scrub jungle dominated by *Acacia catechu, A. Senegal, Euphorbia neriifolia.* This area is prominent for migratory as well as native birds (http://www.dda.org.in/greens/biodiv/yamuna-biodiversity-park.html). This initiative is a welcome one and has to be implemented at right way.

To tackle the pollution problem in river Yamuna Action Plan Phase I was implemented in April 1993 with the aim of pollution abatement and water quality improvement of river Yamuna by the National River Conservation Directorate (NRCD), Ministry of Environment and Forests. In this 22 km falling under Delhi also comes under this action plan. Yamuna Action Plan Phase II commenced from December 2004 to implement schemes which have visible and tangible impact on the immediate improvement of water quality of the river. This project is implemented with the assistance of Japan Bank for International Cooperation- JBIC (Source: Government of NCT of Delhi, Department of Urban Development). Though many initiatives are taken by government agencies, due to uncontrolled growth of urban sprawl and population growth, pollution created by human activities, danger posed to this ecosystem is large. Apart from this as urbanized areas under this flood plain zone, they are more vulnerable to flood during heavy showers and flash floods in the drains and river especially the low lying flood plains. Parts like Wazirabad, Shahdra in the east bank and Mukherjee Nagar, Nirankari Colony, Geeta Colony, Shastry Park, Yamuna Bazzar and Red Fort area , Okla area in the west bank are more prone (Taranjot Kaur Gadhok 2000 http://www.gisdevelopment.net/application/natural_hazards/floods).

4.2 Ground Water Depletion

The study region is hydrogeologically part of Alwar quartzite and aeolian and alluvial plain- both older and newer deposits. The ground water availability in Delhi is controlled by the hydrogeological formations characterized by the presence of alluvial formation and quartzitic hard rocks. The rock formation is widely varied with variation in land formation like ridge areas. It is traversing across the city and is quite significant to control the occurrence as well as movement of groundwater. In shallow aquifers, the groundwater occurs under phreatic confined condition. Contrarily, it is in semiconfined to confined conditions in deep aquifers. Delhi receives 81 MGD water from groundwater sources (Table: 4.2).The shallow aquifers contain saline water and the depth varies from 5 to 10 m. The deeper aquifers vary from 20 to 50 m. A decline in water table of 4 m has been observed in Delhi for last few decades (Groundwater Quality Series: GWQS/

10/2007-2008, Status of Groundwater Quality in India -Part-II, Central Pollution Control Board ,Ministry OF Environment and Forests).

Table: 4.2 Sources of water for Delhi

S.No	Source	Quantity (MGD)
1	Yamuna	210
2	Ganga	100
3	Bhakra Storage	240
4	Total(Surface)	550
5	Ranney and Tube wells	81
Total		**631**

Source: Economic survey of Delhi, 2001-02.

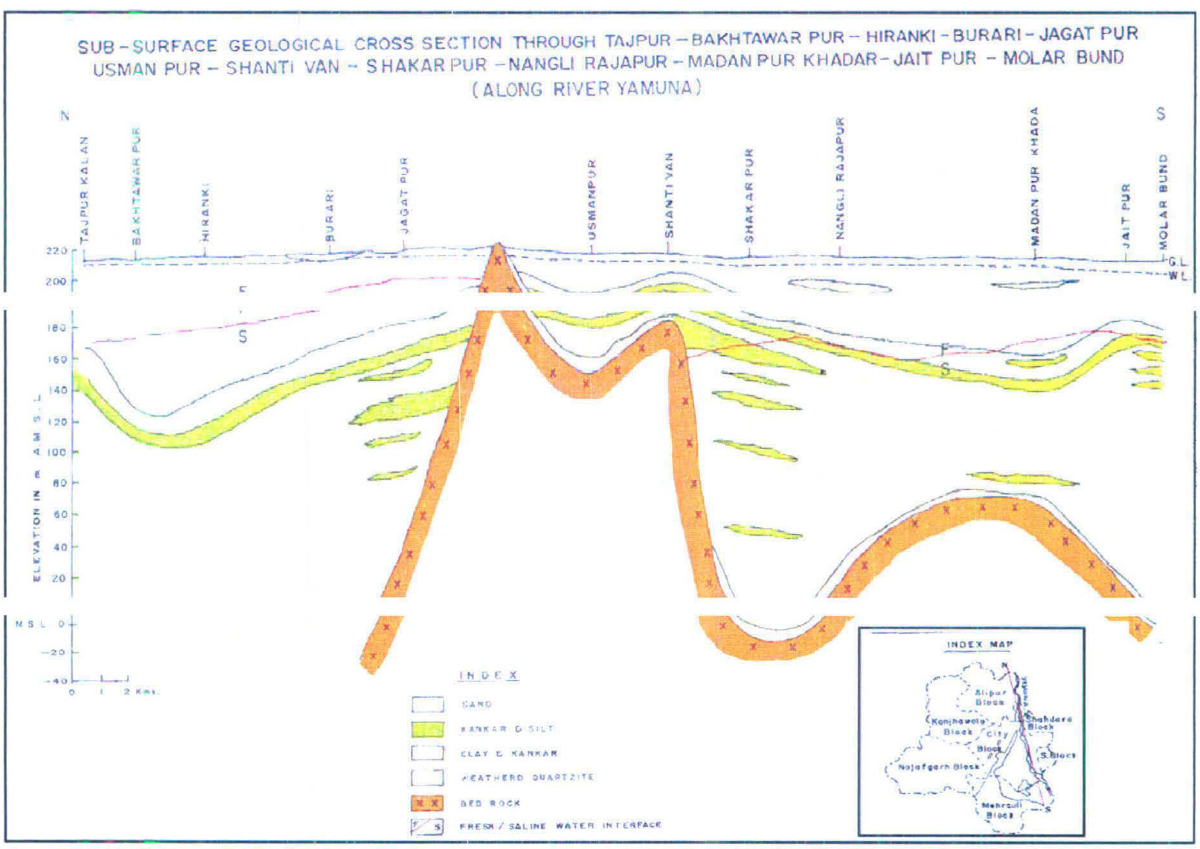
Yamuna River is a perennial river flowing through the eastern part of the territory. The occurrence of fresh groundwater in Delhi is mostly restricted to the Yamuna flood plain, the quartzitic ridge, Chhatarpur Basin – are the three important hydrogeomorphological features of this region.

4.2.1 The Yamuna Flood Plain

The Yamuna flood plain of Delhi is the most promising area with regards to fresh groundwater resource potential. The flood plain of Yamuna has fresh water acquifer at the lower level than that of the quartzitic area. The thickness of the younger alluvium varies from nearly 70 m in the northern part of the flood plain to nearly 30–40 m in the southern part of the flood plain. In areas close to surface exposure of hard rocks, the depth to basement is at a shallower level, and the thickness of the overlying alluvium is reduced –can be seen in the sub-surface geological map shown below.

The fresh groundwater in the Yamuna flood plain is mostly restricted to younger alluvium, while saline groundwater is mostly restricted to clay predominant older alluvium. The depth to the fresh/saline interface in the groundwater is found at the deepest level in the northern part at approximately 70 m below ground level (m bgl) in the Palla area while it is shallower in the southern part (Shashank Shekhar & R. K. Prasad, 2008). Palaeochannels and abandoned channels (figure: 2.1) are abandoned course of rivers or streams and can be served as excellent ground water storage and recharge locations. Division of some of the monsoon flows into these channels greatly replenishes the declining water table for subsequent use. But now these channels are under construction (figure: 4.4)

But DDA has taken areas under this plain for construction activities; in spite of being protected as a recharge zone in the Masterplan and by the Groundwater Authority (The CGWA notified the Yamuna floodplains as protected for groundwater management on 2 September 2000). The porosity of the aquifer is severely affected which leads to less infiltration also and ultimately aquifer recharge is affected much.



Vikram Soni, A. K. Gosain, P. S. Datta and Diwan Singh, 2009, *Source: Central Ground Water Board Yamuna Profile.*

4.2.2 Quartzitic Ridge and Chattarpur Basin

Quartzitic Ridge, rising above the surrounding plains acts as a groundwater divide between the western and eastern parts of Delhi. The alluvial formations overlying the quartizitic bedrock on either side of the ridge are piedmont formations. The nearly closed Chattarpur alluvial basin is occupied by alluvium derived from the adjacent quartzite ridge. Quartzite rocks have limited source of availability ground water confining largely to fracture planes and the weathered zone/mantle. Figure: 2.1 show the presence of fault zone running NE- SW. More over Aravalli hills are highly fractured, jointed and weathered making it the major recharge zone for the surrounding areas. They have cracks from 2 billion years of natural history. These are potential groundwater zones in quartzite dominated area. This recharges 80% of the rain falling on it. All rainfed aquifers surrounding the ridge are an incredible resource for pure water and must be preserved by protecting their recharge zones (Vikram Soni, 2007)

Figure: 4.22 Of this chapter show drainage system in this area particularly streams originating from ridge flowing in to various small water bodies as well as to low elevated areas like Chattarpur basin. The older alluvium in the Chattarpur basin consists of predominantly sand with subordinate silt, clay and kankar having good water holding capacity and infiltration will also be high. . But thickness of alluvium is highly variable because of presence of sub surface ridges and faults (www.rainwaterharvestin.org). These sources of runoff during monsoon –the streams and other water bodies are seasonal in nature mostly. They help for augmenting the groundwater resources. But now water bodies – nallas, drains and other small streams and tanks, ponds etc are under severe threat due to land encroachment activities and affect groundwater recharge also.

The study area is experiencing increasing pressure to meet demand for its water resources. Growing urbanization, improvements in living standards, exploding population are just some of the contributing factors. The large-scale extraction of groundwater is a result of this widening gap between the demand and supply of water. Quality is also deteriorating these days. Increasing demand in agriculture and industrial sectors as well as domestic needs for the ever growing population and change in cropping patters in order to raise cash crops in certain areas have increased the demand for water. Due to failure of monsoon in some years as well as inadequacy of surface water availability puts stress on ground water extraction during drought periods especially leads to unplanned withdrawal from subsoil aquifer.

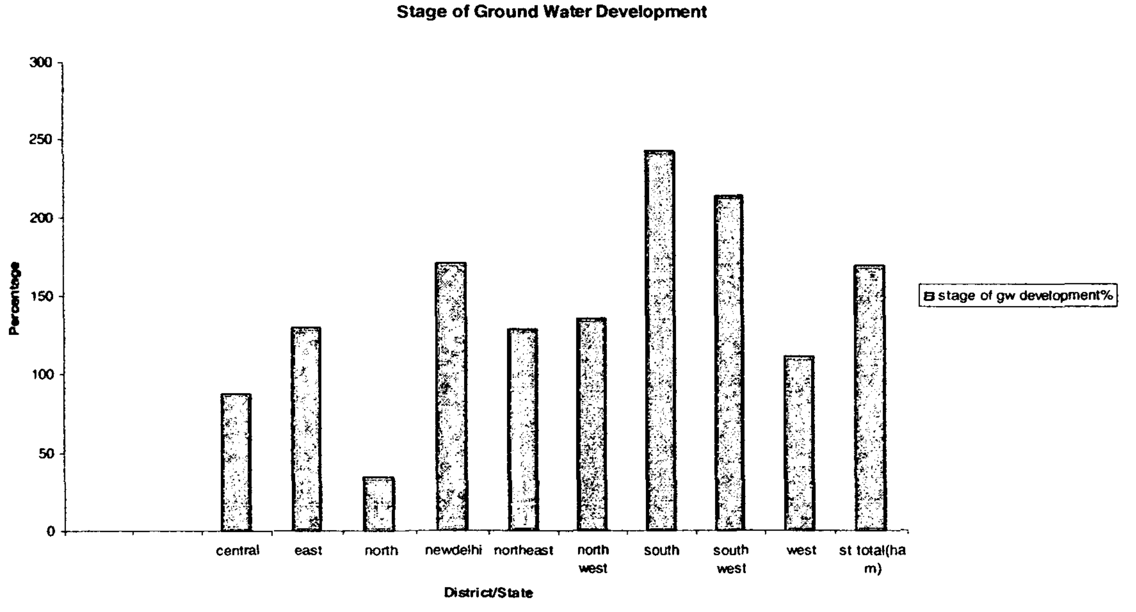
The stage of ground water development in the UT is 170% which falls under over exploitation category i.e. is more than 100 % (Graph: 4.1). Table: 4.3 explain the stage of development of ground water in different districts of the area. The districts, East; North East; South; New Delhi and South West which are falling under study area have more than 100% of groundwater development and have been categorized as over exploited. Only two districts Central and North are categorized as safe. If we see the usage of these exploited ground water its highly for domestic purpose which gives glimpse of increasing dependency on ground water for domestic purpose. In the whole state and North Eastern as well as Eastern districts and South district were once agriculture was dominant but now increased urbanization changed ground water demand for domestic purpose (Graph: 4.2 & 4.3).

Table: 4.3 District wise Stage of Groundwater Development & Categorization

District/State	Stage of Ground Water Development (%)	Categorization
Central	88	Safe
East	130	Over- Exploitation
North	35	Safe
New Delhi	171	Over- Exploitation
Noth East	129	Over- Exploitation
North West	136	Over- Exploitation
South	243	Over- Exploitation
South West	214	Over- Exploitation
West	112	Over- Exploitation
Total	170	

Source: Central Ground Water Board (2004).

Graph: 4.1



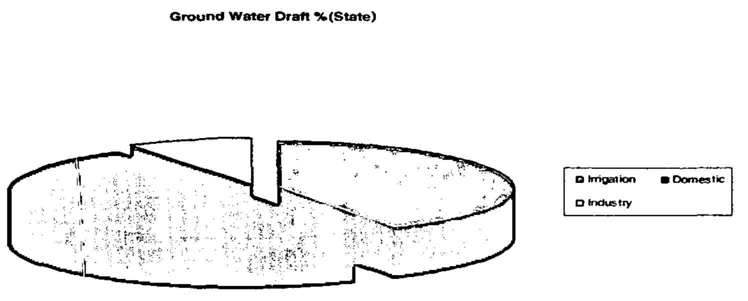
Source: Central Ground Water Board (2004)

Data

District/State	Stage of gw development%
central	88
east	130
north	35
newdelhi	171
northeast	129
north west	136
south	243
south west	214
west	112
st total(ha m)	170

Source: Central Ground Water Board (2004

Graph: 4.2



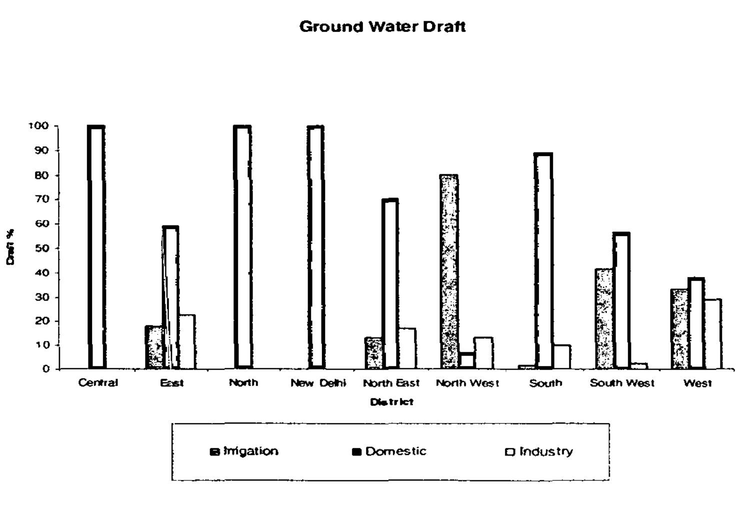
Source: Central Ground Water Board (2004)

Data

Groundwater Draft (State)		
Irrigation	Domestic	Industry
41.72	49.31	8.97

Source: Central Ground Water Board (2004)

Graph: 4.3



Source: Central Ground Water Board (2004).

Data

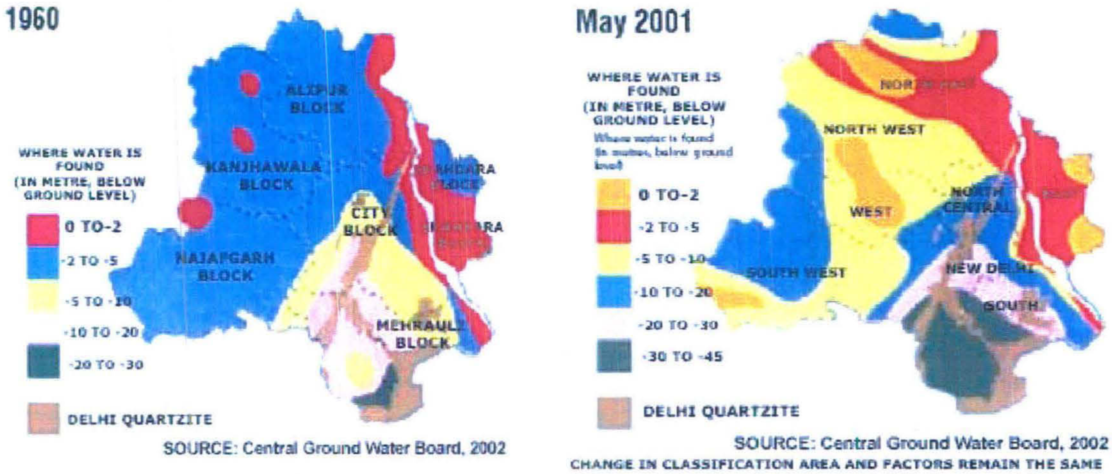
District/State	Irrigation	Domestic	Industry
Central	0	100	0
East	18.02	59.14	22.72
North	0	100	0
New Delhi	0	100	0
North East	13.01	70.34	16.74
North West	80.14	6.72	13.14
South	1.31	89.03	9.66
South West	41.24	56.65	2.11
West	33.09	38.08	28.80
Total	41.72	49.31	8.97

Source: Central Ground Water Board (2004)

The human induced land use changes exploits natural resources rapidly. This kind of situation is mainly because of over exploitation of the resource as well as the reduced infiltration of surface runoff during rainy season due to conversion of percolating soils into concretes and buildings.

Figure: 4.8 shows the reduction of ground water level especially in the study area of South Delhi from -5 to -10 and -10 to -20 meter in parts of chattarpur region in 1960 has gone down to -30 to -45 meters below ground water level in 2002. Other than this area around the ridge both east and western sides are showing decreasing ground water level from -2 to -5 meter below ground, down to -5 meter to -10 meter below ground level in 2002 which are alarming(Figure: 4.5)

Figure:4.5

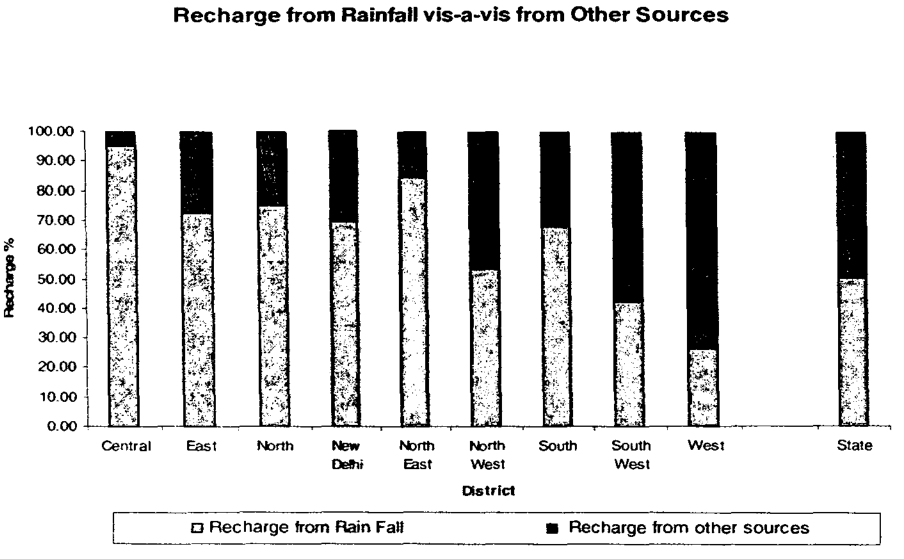


Source: *www.rainwaterharvesting.org*

Ground water collects in the aquifers over thousands of years through infiltration and ground water flow recharge. A particular amount of ground water is replenished regularly through rainwater infiltration. Sustainable use of ground water means withdrawal of ground water at a rate at which it is replenished through recharge. Faster withdrawal rates would lead to fall in water table and finally depletion of ground water (*www.rainwaterharvesting.org)*.

Dattaa 1996) carried out isotopic investigations to assess the natural recharge in the NCT Delhi and found levels of recharge lower than 5% in most of the area. In the urban centre, recharge was lower than 3%. The following graph (Graph: 4.4) shows district wise ground water replenishment during monsoon as well as non-monsoon rainfall period as well other sources. Districts Central, East, North, New Delhi, North East and South are showing more than 50% of annual replenish of groundwater through rainfall during monsoon as well as non-monsoon period. Because of urbanization soils are covered with concretes and percolation level is also decreased. Both the over exploitation as well as decreased percolation and infiltration of surface water has reduced ground water availability in the study area.

Graph: 4.4



Source: Central Ground Water Board (2004)

Data:

District/State	Recharge from Rain Fall	Recharge from other sources
Central	95.19	4.81
East	72.33	27.83
North	74.91	25.09
New Delhi	69.49	30.82
North East	84.68	15.43
North West	53.37	46.63
South	67.68	32.32
South West	42.40	57.60
West	26.64	73.33
State	50.64	49.36

Source: Central Ground Water Board (2004)

Mining and quarrying activities, construction works, deforestation etc. affects the ground water availability in this part. As well as pumping of ground water during mining of Silica sand affects ground water regime of surrounding area(CGWB). Dewatering of mines, results in decline in ground water levels and also reduction in discharge in the surrounding wells. Drainage pattern of the area has been modified due to haphazard mining and dumping of waste material which has bearing on natural path of ground water flow in the area (ENVIS, Centre of Mining Environment, Newsletter 2002&2003). The human induced ground water depletion and reduced recharges are dangerous for future sustainability. Even after so much pressure by the Supreme Court illegal mining prevalent at the Aravalli hills of Faridabad and Gurgaon (N.C.R) area the quarries are still running un-affected (www.faridabadguide.com, 24 March 2009). This kind of on going illegal activities to be stopped immediately to protect invaluable natural resources- ridge virginity, ecology and ground water resource where it has aquifer connectivity. Apart from this ground water quality deterioration due to increased pollution is also to be concerned.

4.3 Groundwater Quality

Pollutants are being added to the groundwater system through human activities and natural processes. The quality of groundwater depends on a large number of individual hydrological, physical, chemical and biological factors and interaction of ground water with various materials in geologic strata. The problem of groundwater pollution in several parts of the country has become so acute that unless urgent steps for abatement are taken, groundwater resources may be damaged (Central Pollution Control Board). Delhi metro is one of the most polluted cities in India.

Climate in this region falls under semi arid category. Due to high evaporation and less rainfall inland salinity problem is prevalent in this part. More over increased groundwater with drawl accompanied with unscientific methods of surface water irrigation and excessive usage of fertilizers also lead to the quality deterioration. Industrial water pollution, polluted drains with domestic as well as sewage water, landfills also contributes for this.

The Bureau of Indian Standards (BIS) earlier known as Indian Standards Institution (ISI) has laid down the standard specifications for drinking water (BIS, 1991). The national water quality standards describe essential and desirable characteristics required to be evaluated to assess suitability of water for drinking purpose.

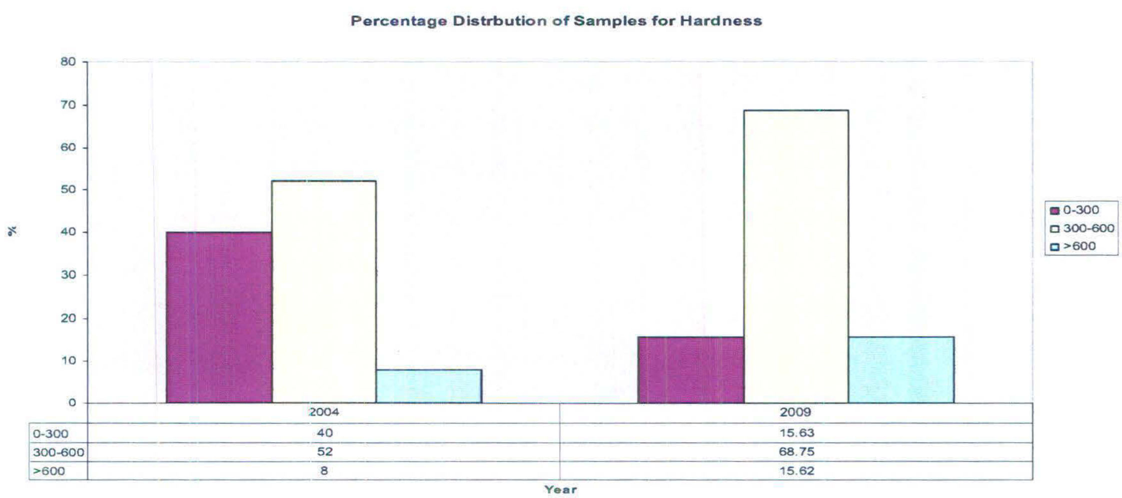
Trend in the ground water quality of Delhi region has been taken for the analysis. The Central Pollution Control Board – Groundwater Quality Series: GWQS/ 10/2007-2008, Status of Groundwater Quality IN India- Part II of 2004(Pre-Monsoon) and Report by Delhi No: DPCC/W/GM/09-10/034-067 of May 2009 have been taken.

Table: 4.4: ***Drinking Water Standards***

pH	TDS	Cl	Hardness	Ca	Zn	Fe
6.5-8.5	500	250	300	75	5	0.3

Source: DPCC Units in mg/l except pH

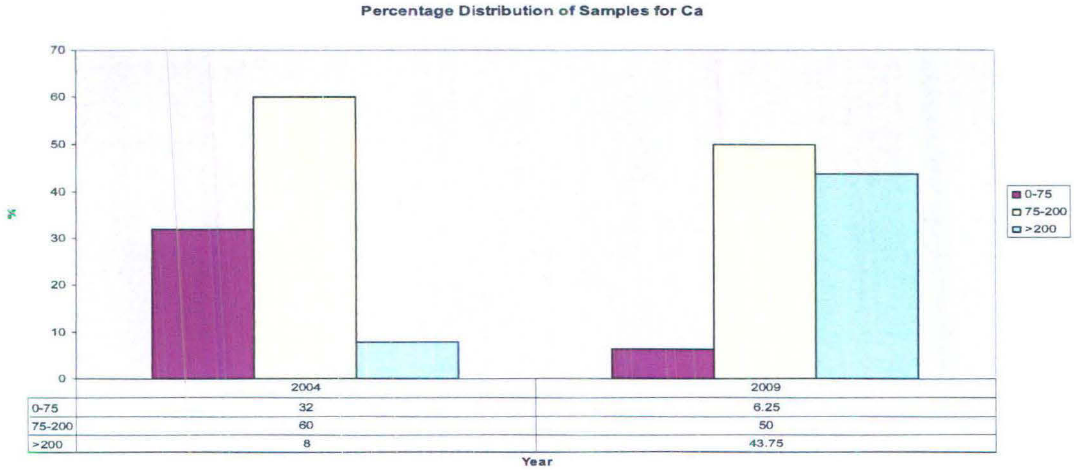
Graph: 4.5



Source: CPCB (2004) & DPCC (2009).

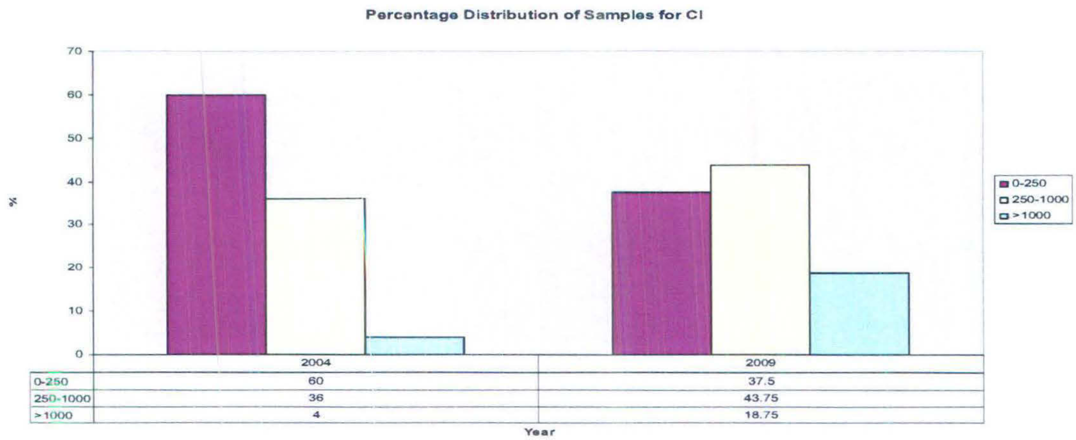
Quality Water in terms of CaCO3, Ca as Ca, F, Cl and SO4 mineral presence are compared between these two years. The Graph: 4.5 to 4.9 show the changes in the presence of the above mentioned minerals between pre-monsoon level in 2004 and 2009 before monsoon that i.e. May.

Graph: 4.6



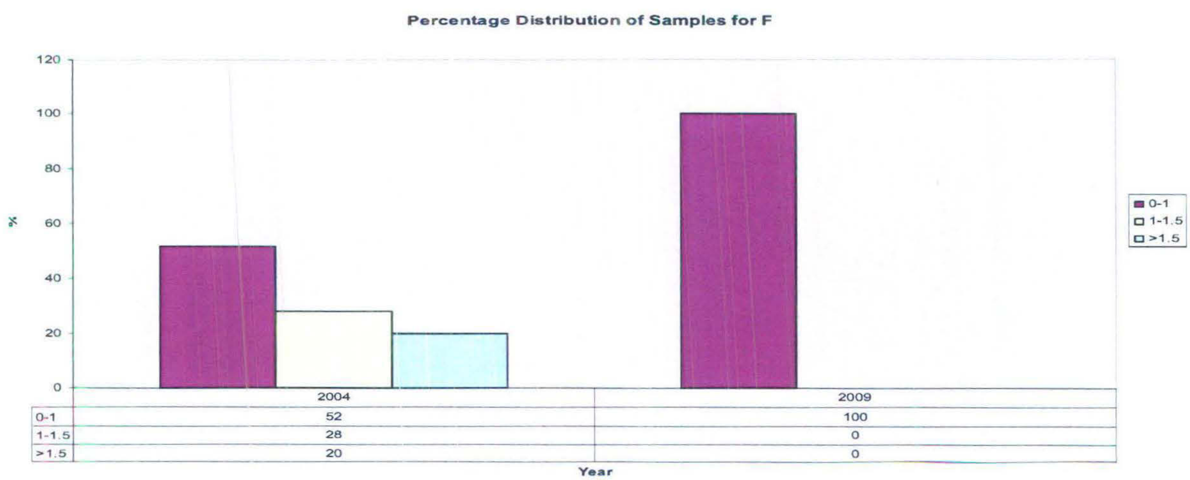
Source: CPCB (2004) & DPCC (2009).

Graph:4.7



Source: CPCB (2004) & DPCC (2009).

Graph: 4.8

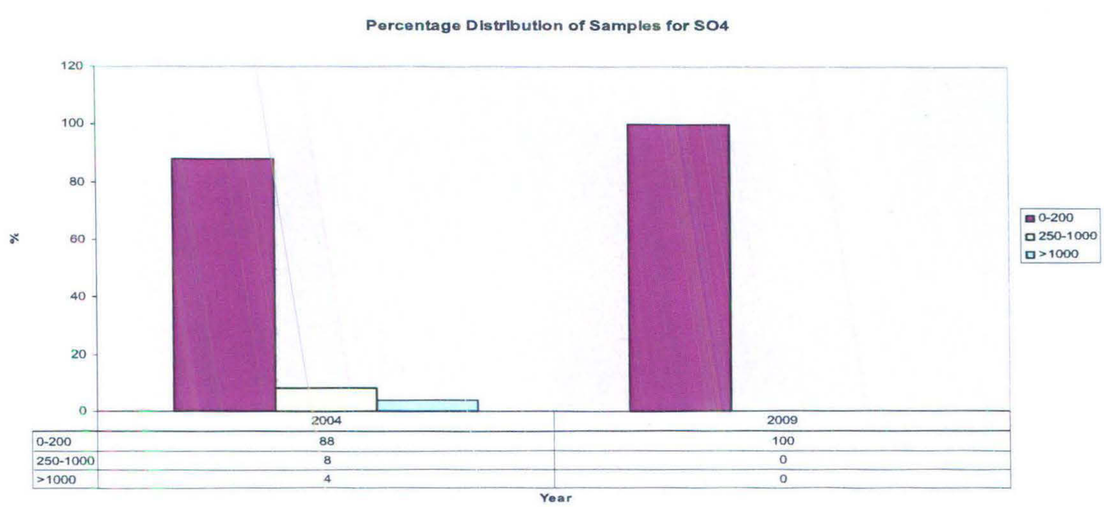


Source: CPCB (2004) & DPCC (2009).

Analysis clearly explains the quality of the Groundwater is deteriorating fast. 300 mg/l is the permissible level of Hardness. In 2004 40% of the samples were under this limit but in 2009 only 15.5% are under this category rest are under beyond permissible level for drinking. As far as Ca presence is concerned 75mg/l is the permissible limit but the samples falling in this category has come down from 30% in 2004 to 6.25% in 2009 and >200 category shows significance increase. For Cl 250mg/l is the permissible limit.

In this also the percentage distribution of samples in this limit are decreasing. 250-1000mg/l has maximum samples of 43.75% and > 1000mg/l has nearly 19% which is showing decreasing water quality. As far as SO4 and F are concerned their level is with in the permissible limit of 200mg/l

Graph: 4.9



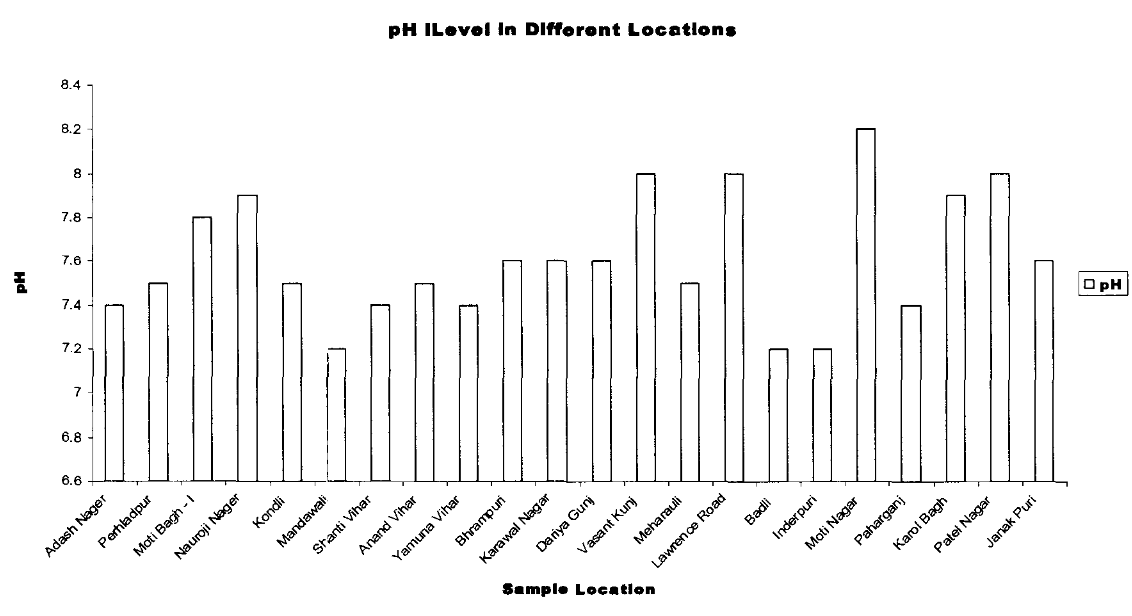
Source: CPCB (2004) & DPCC (2009).

If we see the samples of May 2009 we can understand the quality deterioration of ground water in the study area. pH of the samples show that it's alkaline in nature i.e.>7.00. Graph: 4.10 shows all the samples are showing TDS with more than permissible limit of 500mg/l (Inderpuri>11000mg/l), (Graph: 4.11). Regarding Cl samples like Motibagh, Ymuna Vihar, Kandli, and Anan Vihar are under permissible limit but Inderpuri, Perhladpur are showing very high values.

Waste water from drains and nallas are one of the major sources of groundwater pollution in the city. Industrial areas are affected due to the effluents having highly contaminating minerals. Solid waste from industrial units is being dumped near the factories, and is subjected to reaction with percolating rainwater and reaches the groundwater level and picks up a large amount of dissolved constituents and reaches the aquifer system and contaminates the groundwater. For example the industrial areas like Inderpuri, Perhladpur are noted with high level of TDS. Regarding CaCO3 and Ca showing higher level than permissible except few parts- Paharganj, Dariganj, Mehrauli and Lawrence road in CaCO3 (Graph: 4.13& 4.14). Fe content in the study area samples is high. This is mainly man made. The wastes in various forms with iron content are leached down and enter into to the subsoil aquifer. Zn content is in permissible limit(Graph:4.16 &4.15)

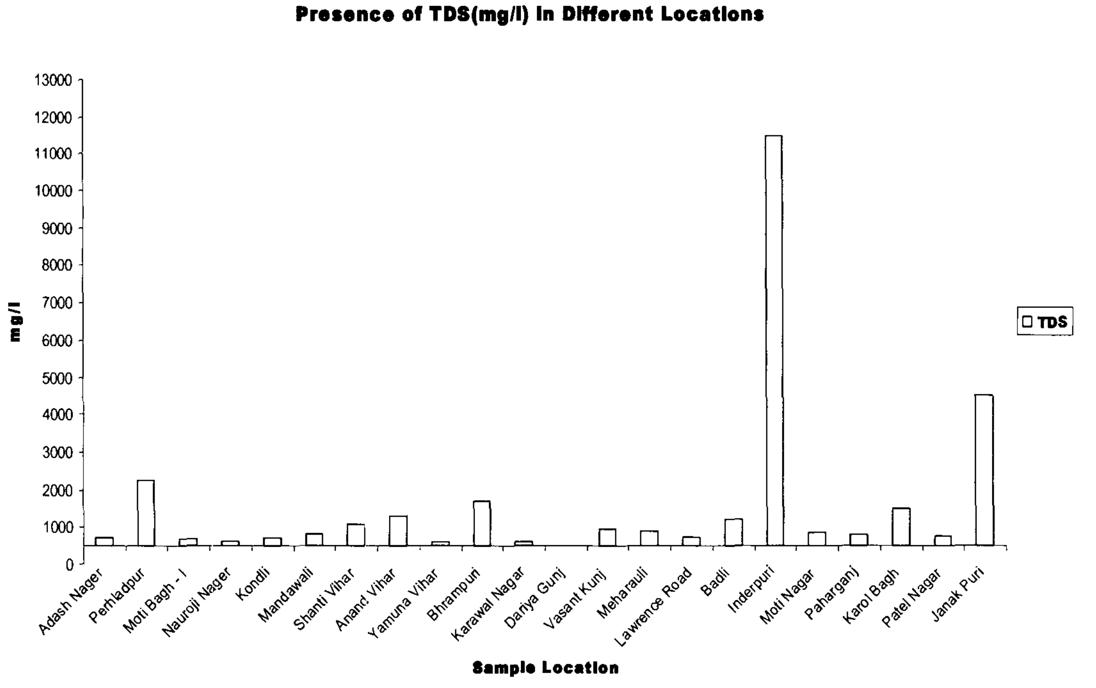
Apart from this major sources of contamination and deterioration of groundwater are lechates from landfills. Solid wastes dumped in the landfills are not decomposed properly and not disposed. Because of that wastes remaining there for long and the minerals are leaching down and contaminates highly. Area near by the existing landfills- Okla, Gazipur and Banswala have high contaminated ground water.

Graph:4.10



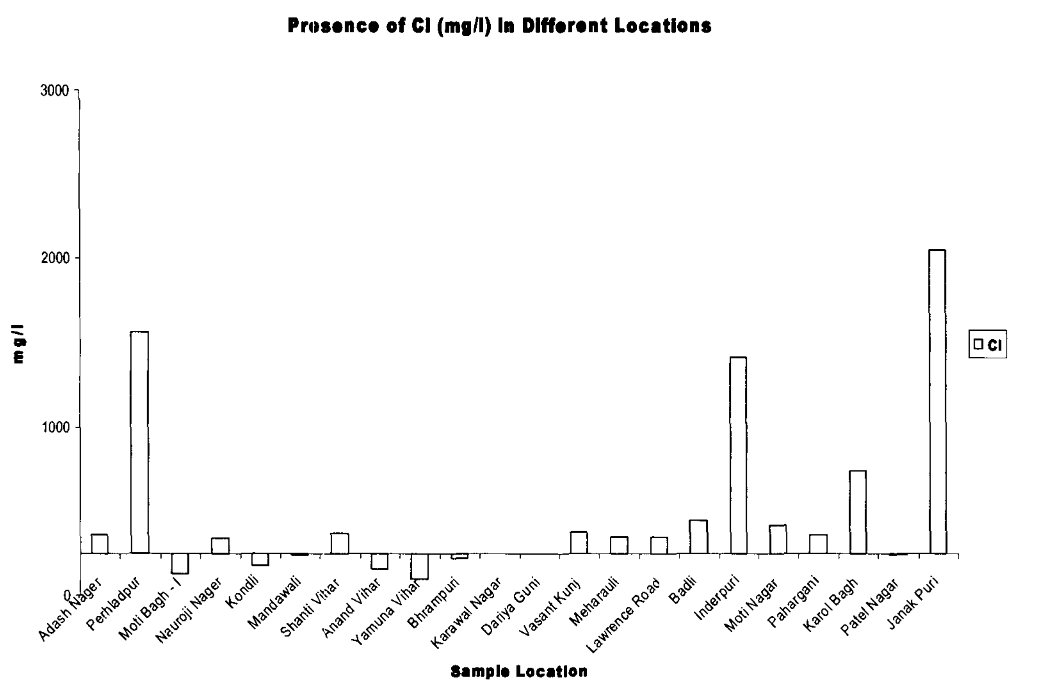
Source: CPCB (2004) & DPCC (2009).

Graph: 4.11



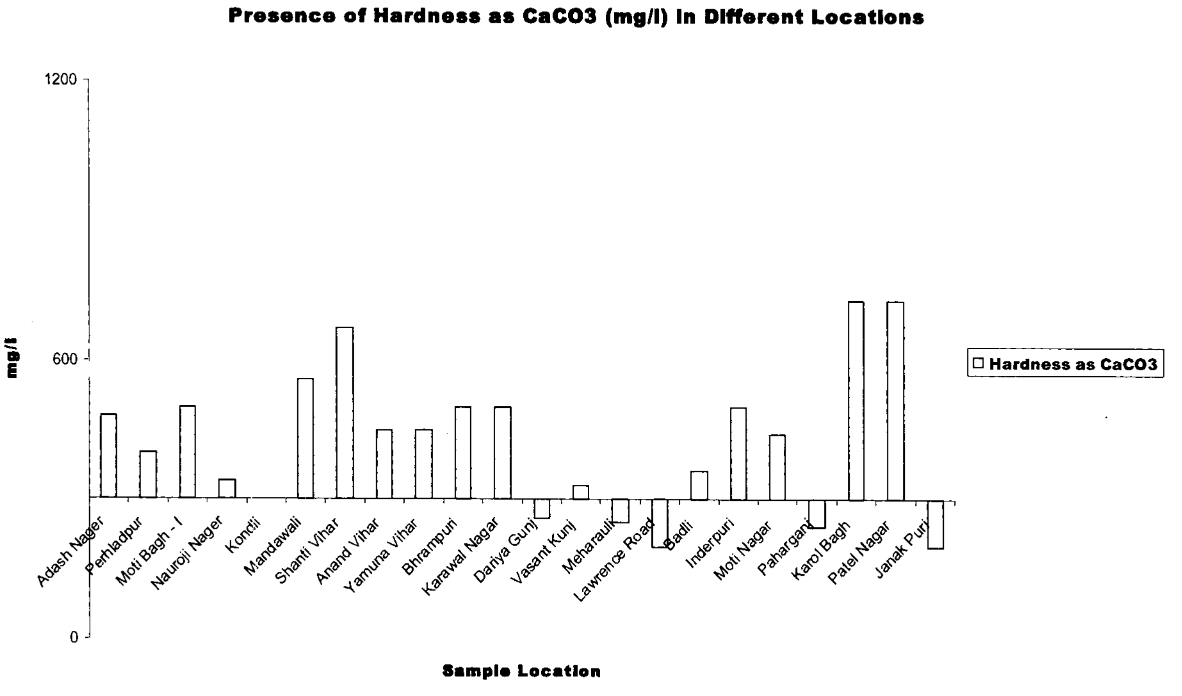
Source: CPCB (2004) & DPCC (2009).

Graph: 4.12



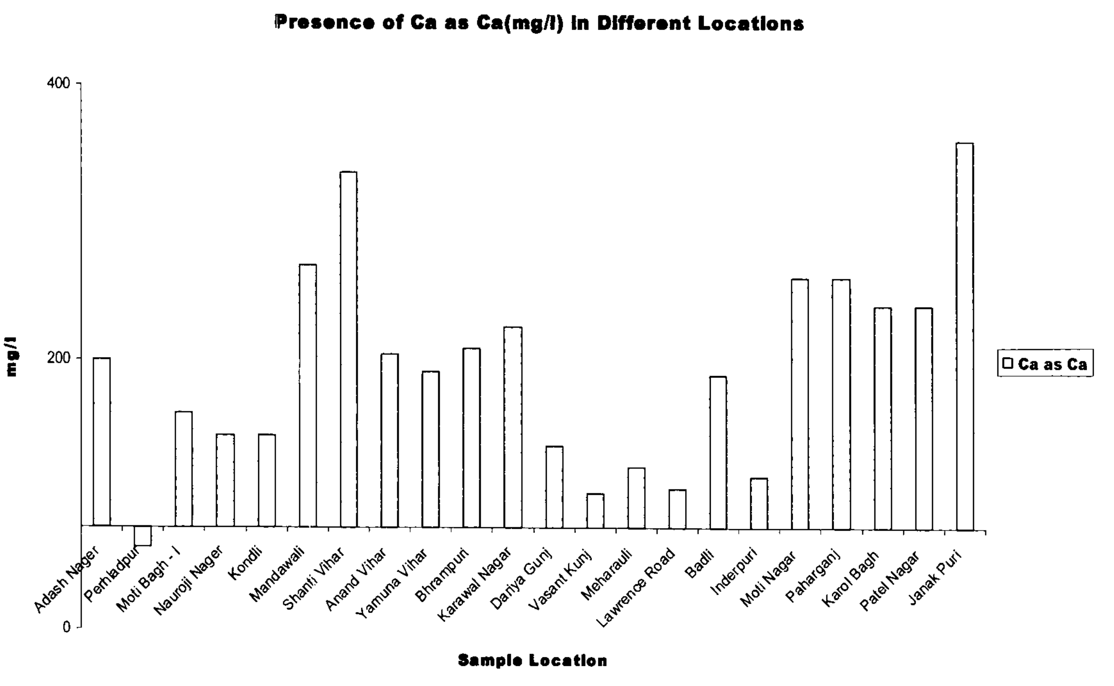
Source: DPCC (2009).

Graph: 4.13



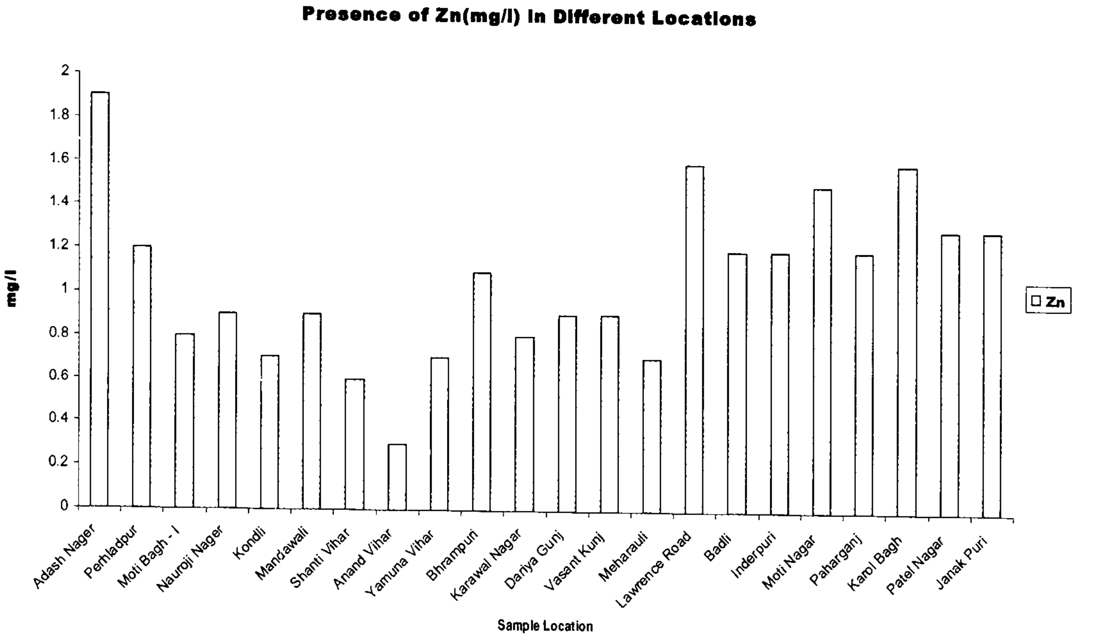
Source: DPCC (2009).

Graph:4.14



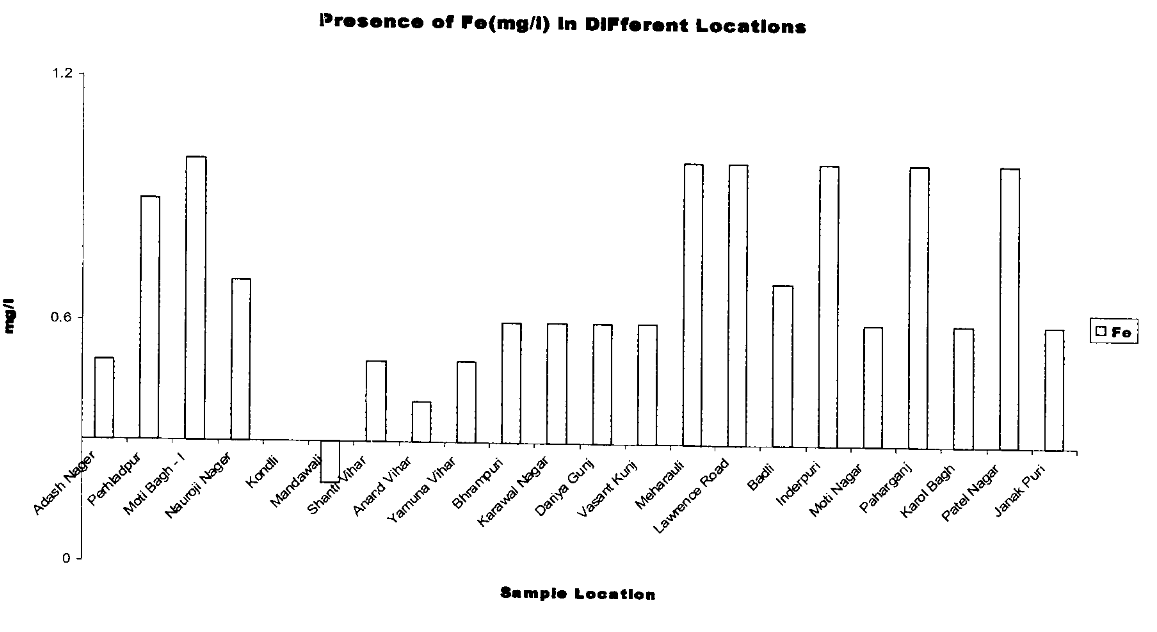
Source: DPCC (2009).

Graph:



Source: DPCC (2009).

Graph: 4.16



Source: DPCC (2009).

Data

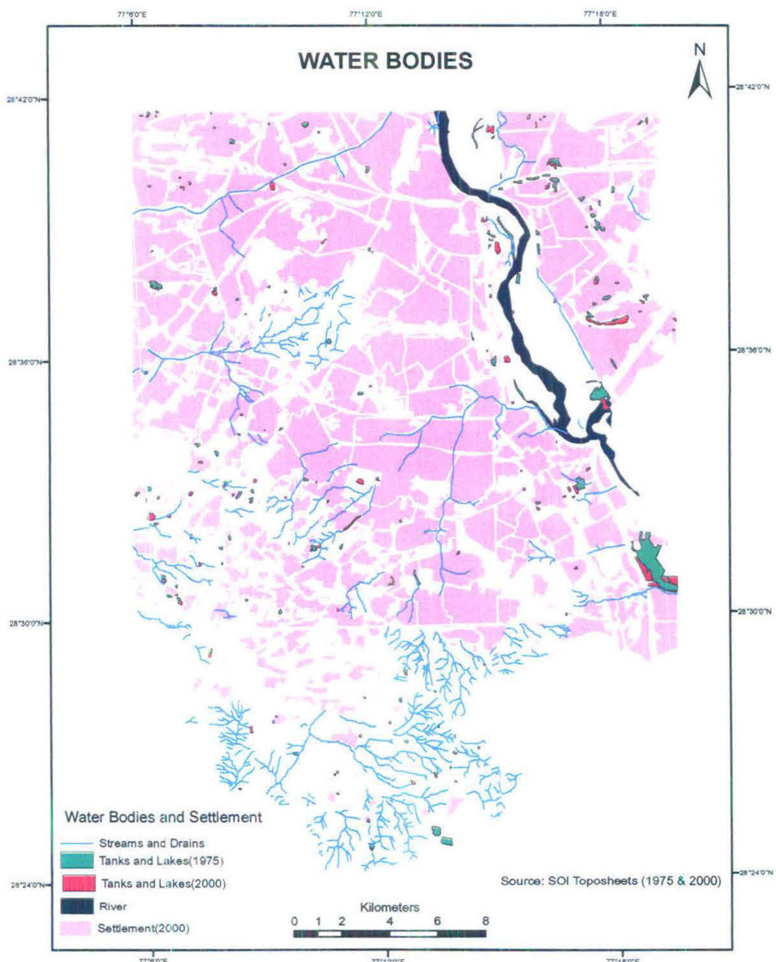
Samples	pH	TDS	Cl	CaCO3	Ca	Zn	Fe
Adash Nager	7.4	730	360	480	200	1.9	0.5
Perhladpur	7.5	2240	1570	400	60	1.2	0.9
Moti Bagh - I	7.8	680	130	500	160	0.8	1
Nauroji Nager	7.9	630	340	340	144	0.9	0.7
Kondli	7.5	710	180	300	144	0.7	0.3
Mandawali	7.2	800	240	560	268	0.9	0.2
Shanti Vihar	7.4	1090	370	670	336	0.6	0.5
Anand Vihar	7.5	1290	160	450	204	0.3	0.4
Yamuna Vihar	7.4	590	100	450	192	0.7	0.5
Bhrampuri	7.6	1690	220	500	208	1.1	0.6
Karawal Nagar	7.6	600	250	500	224	0.8	0.6
Dariya Gunj	7.6	490	250	260	136	0.9	0.6
Vasant Kunj	8	950	380	330	100	0.9	0.6
Meharauli	7.5	870	350	250	120	0.7	1
Lawrence Road	8	710	350	200	104	1.6	1
Badli	7.2	1220	450	360	188	1.2	0.7
Inderpuri	7.2	11470	1420	500	112	1.2	1
Moti Nagar	8.2	850	420	440	260	1.5	0.6
Paharganj	7.4	770	360	240	260	1.2	1
Karol Bagh	7.9	1490	740	730	240	1.6	0.6
Patel Nagar	8	760	240	730	240	1.3	1
Janak Puri	7.6	4510	2050	200	360	1.3	0.6

Source: DPCC (2009). Units in mg/l except pH

4.4 Surface Water Bodies

Water is one of the prime determinants of the carrying capacity of settlements and the sustainability of urban communities for its survival. As we have seen already there were more 600 water bodies' lakes, ponds, and tanks in the N.C.T area which are important sources of ground water recharge as well as surface water sources. But now this number has come down. Water bodies like wells, small lakes, marshlands, nallas, tanks and depressions are constantly being used to dump the garbage of the city because of the rapidly shrinking landfills in the Capital. With the constant dumping, the water gets contaminated with heavy pollutants and which can be harmful for the human beings

Figure: 4.5



In the study area number of these tanks and small lakes number have decreased from more than 120 to around 85 in the time period from 1975 to 2000. This is great loss to the water availability for the city where demand is increasing day by day. Apart from number decrease these water bodies are heavily polluted due to waste dumping.

Based on the petition filed by TAPAS NGO regarding water bodies' encroachment by Government and private parties in Delhi High Court hearing still goes on. So far arguments reveal that "natural water bodies that exist in Vasant Kunj - Neela Kunj and Prasad Nagar areas would vanish if not taken care" (H.C Delhi).H.C also questioned and asked the Govt of N.C.T -DDA to file a reply as to why 39 other water bodies were converted into public parks or encroached upon by vested interests and prohibited the State government from carrying on any further construction on two water bodies in the capital. Another example of human ocuupation on these natural features- Three landfill sites at Ghazipur (East Delhi), Bhalswa (North), and Okhla (South East) are operational at present, though these will soon get filled. "Too much land is being consumed accompanied by increasing danger of ground and surface water contamination" (May 16, 2004 The Hindu). Taking stock of the status of the marsh areas of Jahangirpuri in North Delhi and the Mayapuri Lake DDA's plan for constructions as per Master Plan 2021 are also under scrutiny.

Plate: 4.2

Bridge Construction over Water Body near Vasant Kunj, opposite to ICGEB

By viewing the Figure: 4.5 we can understand that the streams coming from Delhi ridge which is playing as water divide for the catchments of rainwater falling within the

N.C.T boundary recharges ground water as well as plays vital role in surface water availability. These streams and nallas along with the small lakes and tanks are going under human encroachments like dumping grounds, concrete structures like roads, shopping malls and other public and private buildings. These encroachments should be checked and cleared off. Apart from encroachments pollution of these water bodies due to domestic and industrial effluents are alarming.

"Water bodies in areas including Ghitorni, Nangal Dewat, Qutab Ki Boili, Mithapur and Rajpur Khurd are constantly being polluted and are examples of heavy contamination of water due to dumping and this is only the tip of the ice-berg," explains head of the non-government organisation TAPAS, Vinod Kumar Jain, who has compiled a report of the condition of ground water contamination due to dumping (The Hindu May 16, 2004).

4.5 Surface Water Pollution

The River Yamuna, which provides Delhi's water, contains high levels of raw sewage and industrial waste - and is getting worse every year. Pollution of the river level increases significantly. The growth in sewage treatment capacity has not kept pace with the increase in population and waste.

Table: 4.5: Water Quality Trend in Yamuna (1999-2005)

Year	pH		COD		BOD		DO	
	Nizammudin Bridge	Agra Canal	Nizammudin Bridge	Agra Canal	Nizammudin Bridge	Agra Canal	Nizammudin Bridge	Agra Canal
1999	7.74	7.76	50.5	41	11.5	8.5	1	1.3
2000	7.6	7.58	57.5	41.5	18	10	1	1.9
2001	7.29	7.32	60.5	46	21	13.5	1.5	1.1
2002	7.12	7.17	62	43.5	22.5	12.5	0.65	1.05
2003	7.39	7.48	65.5	50	22	13	0.95	0.85
2004	7.44	7.58	80	65.5	26	18	0	0.25
2005	7.47	7.43	45	47.5	16.5	14.5	1.15	0.75

BOD, COD, DO = mg/l

Year	Faecal Coliform		Total Coliform	
	Nizammudin Bridge	Agra Canal	Nizammudin Bridge	Agra Canal
1999	1781206	1150247.5	20825834	4938854
2000	1754318	844318	10830834	8097500
2001	1218875	389334	21748959	15448625
2002	479250	98750	7244167	2972083.5
2003	18685250	8972208	105830000	39892625
2004	15414791.5	2120833.5	70781250	9353333
2005	2905800	1105000	24605000	13345833.5

Feacal Coliform& Total Coliform = MPN/100 ml

Source: CPCB

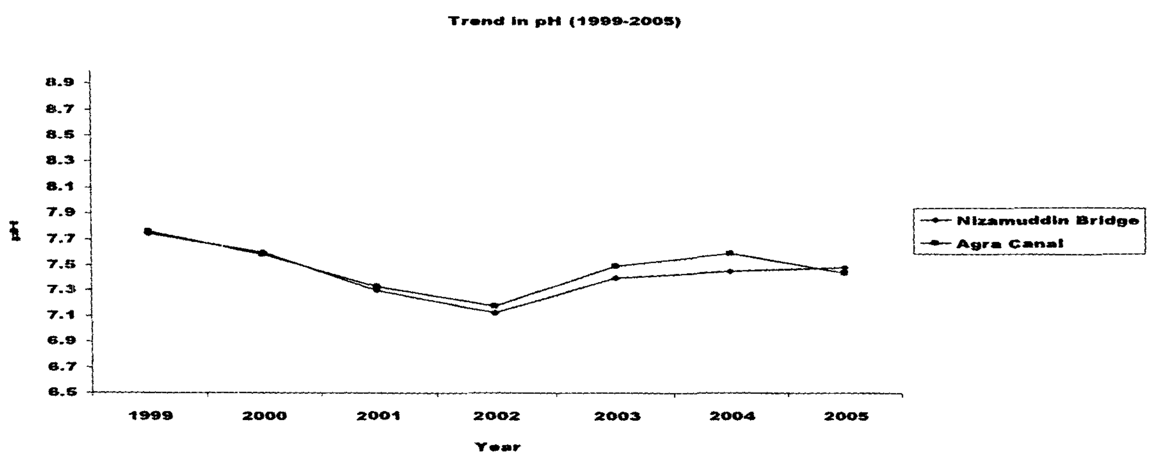
Table: 4.6: Designated Best Uses of Water

Designated Best Use	Class	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	1.Total Coliforms Organism MPN/100ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C, 2mg/l or less
Outdoor bathing (Organized)	B	1.Total Coliforms Organism MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C, 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	1. Total Coliforms Organism MPN/100ml shall be 5000 or less 2. pH between 6 and 9 3. Dissolved Oxygen 4mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C, 3mg/l or less
Propagation of Wild life and Fisheries	D	1. pH between 6.5 and 8.5 2. Dissolved Oxygen 4mg/l or more 3. Free Ammonia (as N) 4. Biochemical Oxygen Demand 5 days 20 °C, 2mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	1. pH between 6.0 and 8.5 2. Electrical Conductivity at 25 °C micro mhos/cm, maximum 2250 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2mg/l
	Below-E	Not meeting any of the A, B, C, D & E criteria

Source: CPCB

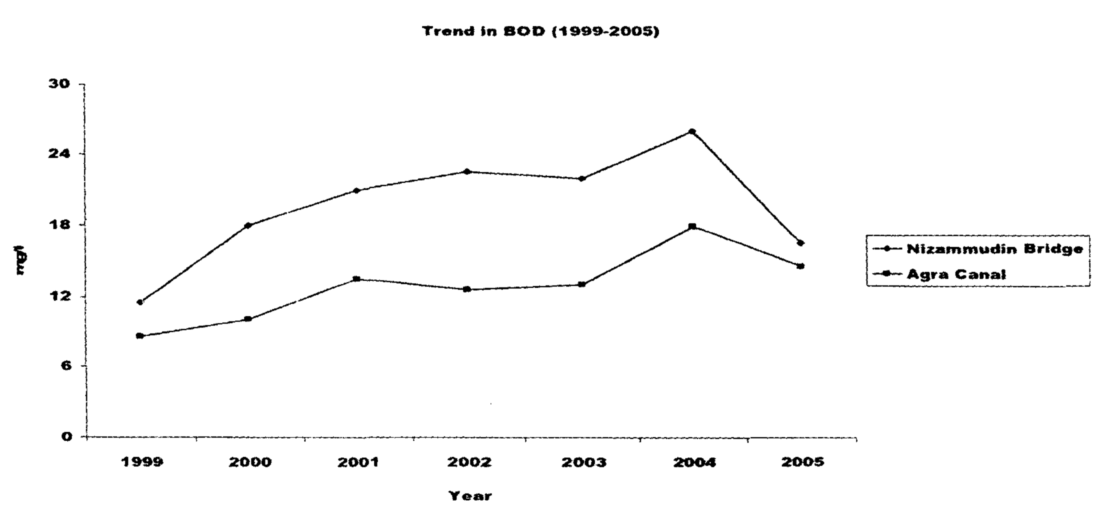
Delhi impounds all its water at Wazirabad, where the dammed up river practically ceases to exist; what flows subsequently is only sewage and waste from Delhi's 22 drains. Nizamuddin Bridge, Okla Barrage of Agra Canal area also feeds polluted drain water into the river. There is just no water available to dilute this waste. Pollution levels in the Yamuna have risen. Apart from this lake, ponds etc. have become dumping grounds. The quality analysis at Nizamuddin Bridge and Agra canal shows,

Graph: 4.17



Source: CPCB

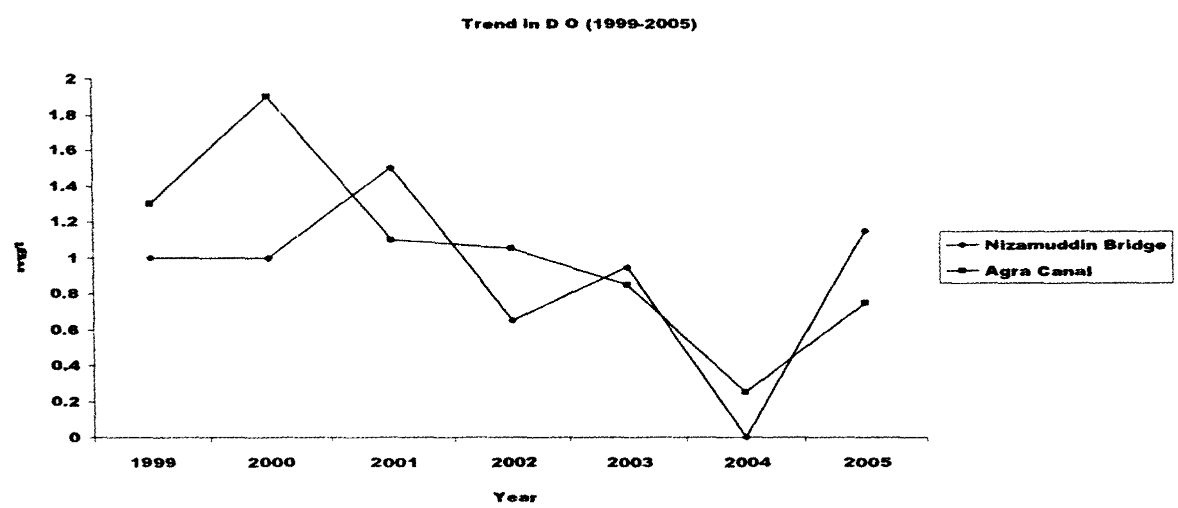
Graph:4.18



Source: CPCB

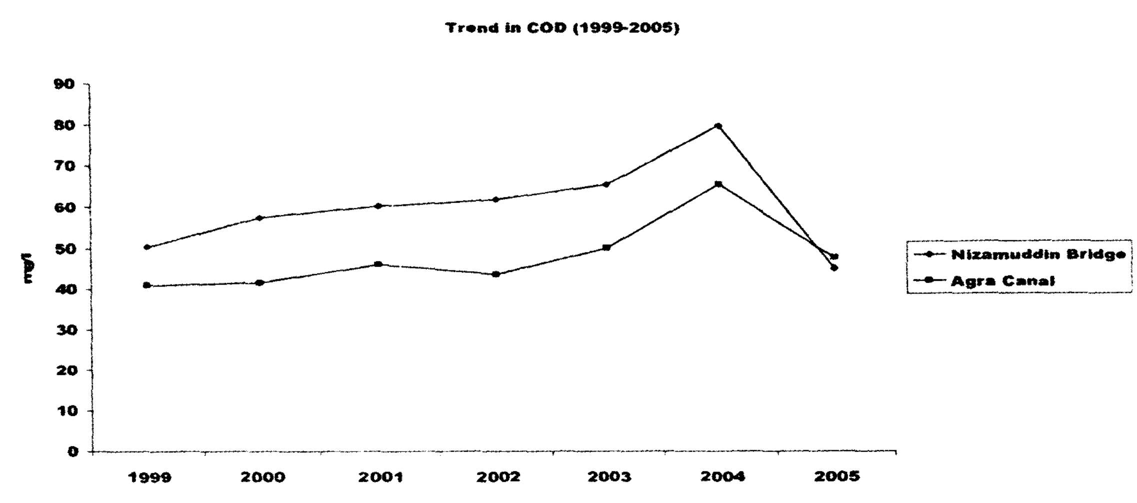
pH level in both the sample places show alkaline condition. It was increasing till 2004 then started to show decreasing trend in 2005. Regarding BOD it's important in the quality of water because of showing oxygen demand for the organism in it. 3mg/l is the limit for the usable water but polluted samples show more than 6mg/l. this is because of more of microbial polulation and other organic pollution. DO should meet the requirement especially if it used of acquatic organisms to live as well as for drinking. This level is very poor in the two samples and over period of time reached zero level in 2004 where the minimum should be 4mg/l or more for surface water.

Graph:4.19



Source: CPCB

Graph: 4.20



Source: CPCB

As far as COD is concerned it was increasing in trend upto 2004 and then shows decreasing in 2005. Faecal coliform and Total Coliform no/ 100ml also very high in both the samples as polluted drains are meeting in these points with the river (Graph: 4.17 to 20).

Plate: 4.3

The unsupported and polluted water body on the Delhi Ridge in the Delhi University area, Malka Ganj(22 June 2008, The Hindu)

4.6 Air Pollution

Apart from the impact of land use changes directly on the ecology of the region environmental pollutions are caused indirectly. These pollutions are Air, Water, Solid Waste pollutions as well as Noise pollution. The changed highly urbanized society is facing the pollution at alarming level. Vehicular in number and fuel consumptions are at peak level of usage and emission of hydro-carbon gases like CO2, CO, SO2, Nitrogen Oxides goes up creating urban air which is not suitable to live.

The city suffers from all the health related problems caused by a polluted atmosphere. High occurrence of respiratory infections, heart problems, sickness from water and vector-born diseases and other diseases because of exposure to pollutants and inappropriate disposal practices of municipal solid waste have become the way of life in the city. Poor living conditions, constant exposure to the pollutants, untreated wastes has resulted in high incidence of diseases like diarrhea, hepatitis, dengue and others. Though various measures are taken by Govt. to tackle these problems increased complications in management of large population and pollutions lead to the situation more critical.

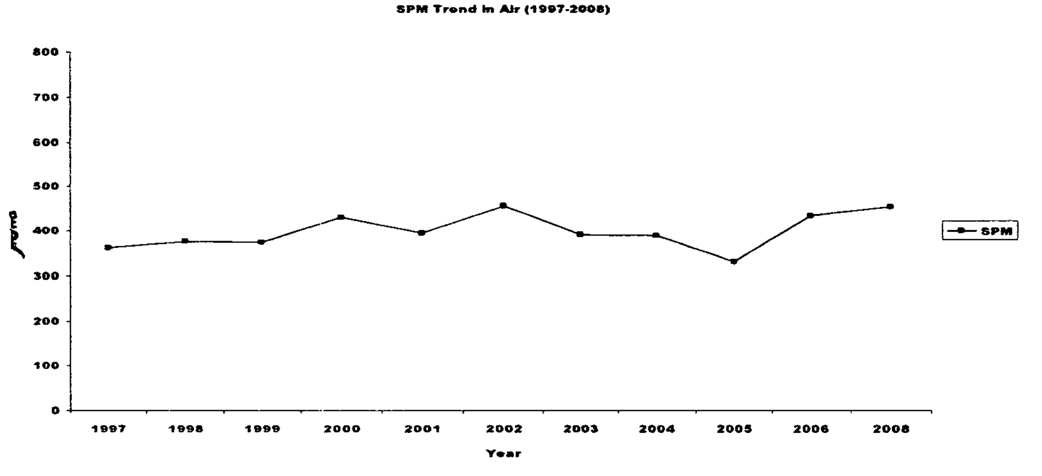
Concentration of various pollutants in the ambient air is showing a declining trend, which is evident from the following statement. It is also noted with concern that there has been some reversal in pollution level of certain elements of air quality which have increased level in 2006. This is being watched so that pollution does not get increased.

Table: 4.7 Trend of Air Polluting Gases and Particles in Delhi

Year	SO2(µg/m3)	NOx (µg/m3)	CO(µg/m3)	SPM(µg/m3)	RSPM(µg/m3)
1997	19	45	4810.00	362	-
1998	21	42	5450.00	377	-
1999	19	40	4241.00	375	-
2000	18	42	4686.00	430	-
2001	14	42	4183.00	394	149
2002	11	46	3258.00	455	192
2003	10	56	2831.00	390	169
2004	9.00	57	2581.00	389	164
2005	9.00	49	2541.00	331	139
2006	10.15	55.9	2531.00	433	174
2008	11.56	52.83	996.88	452.25	235.22

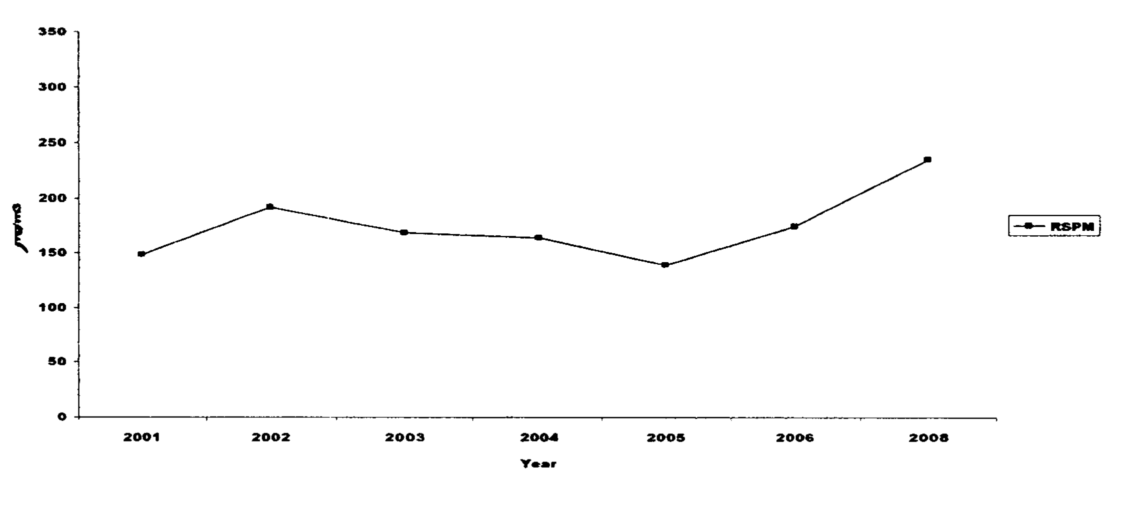
Source: Department of Environment, GNCTD, Economic Survey of Delhi, (2007-2008) & DPCC

Graph: 4.21



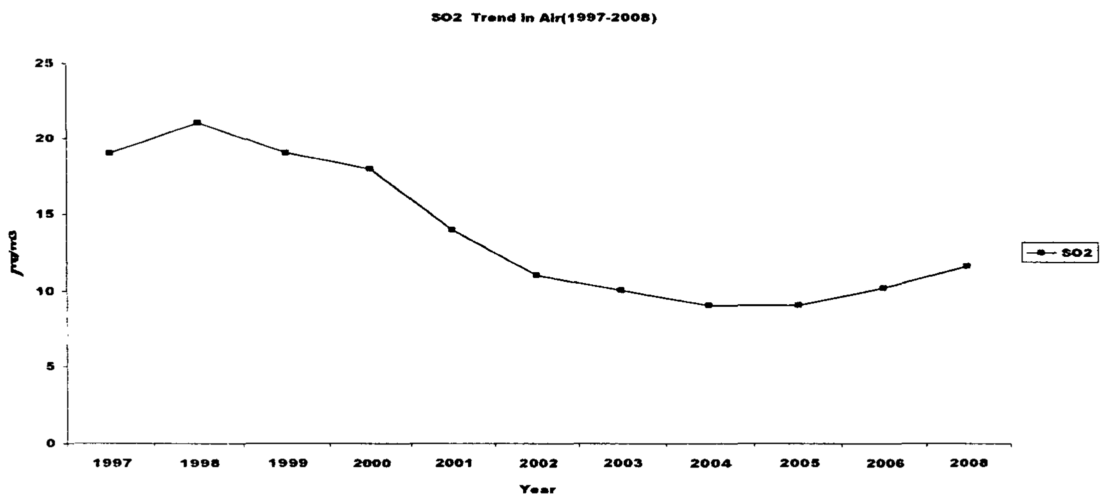
Source: Department of Environment, GNCTD, Economic Survey of Delhi, (2007-2008) & DPCC

Graph:4.22



Source: Department of Environment, GNCTD, Economic Survey of Delhi, (2007-2008) & DPCC

Graph: 4.23



Source: Department of Environment, GNCTD, Economic Survey of Delhi, (2007-2008) & DPCC

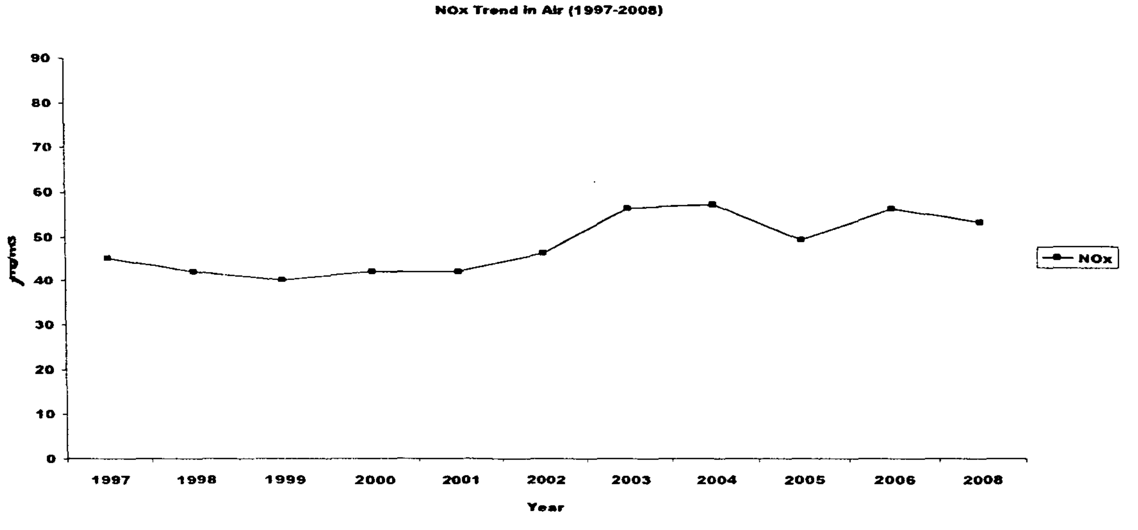
Trend of SPM was oscillating in between 300-400 µg/m³ started to increase > 400 µg/m³ more than the permissible limit. Regarding RSPM it showed decreasing trend till 2005 and again started to increase still above 150 of limit in industrial area. SO2 also shows same kind of trend where the decrease up to 2005 and under the permissible limit. NOx is also increases but CO is showing decreasing trend which is very important as its one of the main green house gases. So totally Delhi's air is polluted with all excessive contaminating gases (Graph: 4.21 to 4.25)

Table: 4.8 National Ambient Air quality Standards (NAAQS)

POLLUTANTS	Time Weighted Average	Concentration of Ambient Air			
		Industrial Area	Residential Rural and other area	Sensitive area	Method of Measurement
Sulphur Dioxide (SO_2)	Annual Average	80µg/m³	60µg/m³	15µg/m³	Improved west and Gacke Method
	24 hours	120µg/m³	80µg/m³	30µg/m³	Ultraviolet fluorescence
Oxides of Nitrogen (NO_2)	Annual Average	80µg/m³	60µg/m³	15µg/m³	Jacab Hochheister modified (Na-Arsentire method
	24 hours	120µg/m³	80µg/m³	30µg/m³	Gas Phase Chemilumine Scene
Suspended Particulate Matter (SPM)	Annual Average	360µg/m³	140µg/m³	70µg/m³	High Volume sampling (average flow rate not less than 1.1 m³/minute)
	24 hours	500µg/m³	200µg/m³	100µg/m³	
Respirable Particulate Matter (size Less than 10µm) RPM	Annual Average	120µg/m³	60µg/m³	50µg/m³	Respirable particulate matter sampler
	24 hours	150µg/m³	100µg/m³	75µg/m³	
Lead as Pb	Annual Average	1.0µg/m³	0.75µg/m³	0.50µg/m³	AAS method after sampling using EPM 2000 or equivalent filter paper
	24 hours	1.5µg/m³	1.0µg/m³	0.75µg/m³	
Carbon Monoxide	8 hours	5.0mg/m³	2.0mg/m³	1.0mg/m³	Non disbersive infrared spectroscopy
	1 hour	10.0mg/m³	4.0mg/m³	2.0mg/m³	
Annual Average : Annual Arithmetic Mean of minimum 104 measurements in a year taken twice a week 24-hourly at uniform interval 24 Hours Average : 24-hourly/8-hourly values should be met 98% of the time in a year. However 2% of the time, it may exceeded but not two consecutive days.					

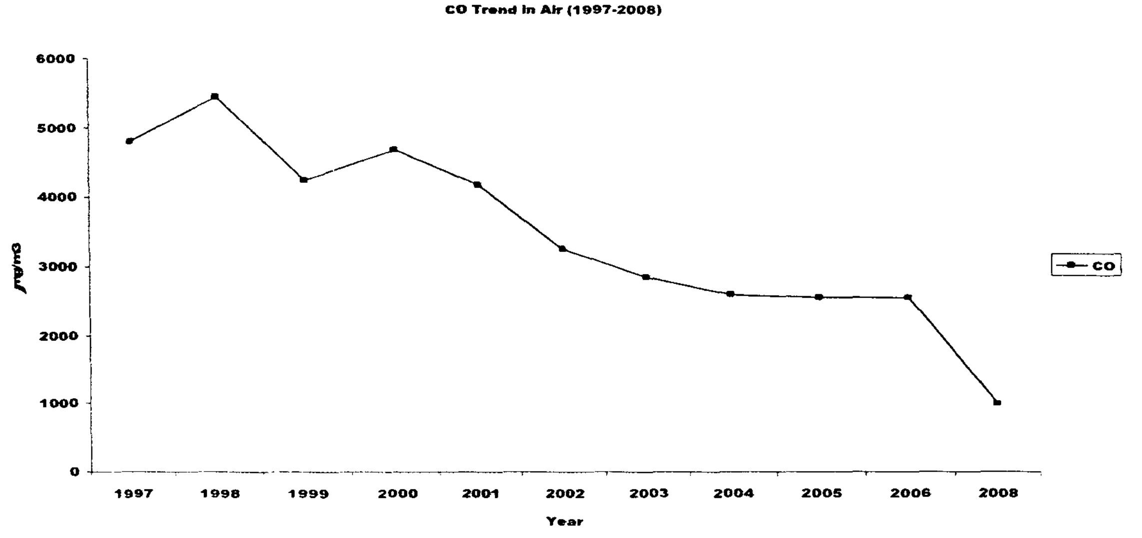
Source: CPCB.

Graph: 4.24



Source: Department of Environment, GNCTD, Economic Survey of Delhi, (2007-2008) & DPCC

Graph: 4.25



Source: Department of Environment, GNCTD, Economic Survey of Delhi, (2007-2008) & DPCC

4.7 Solid Waste

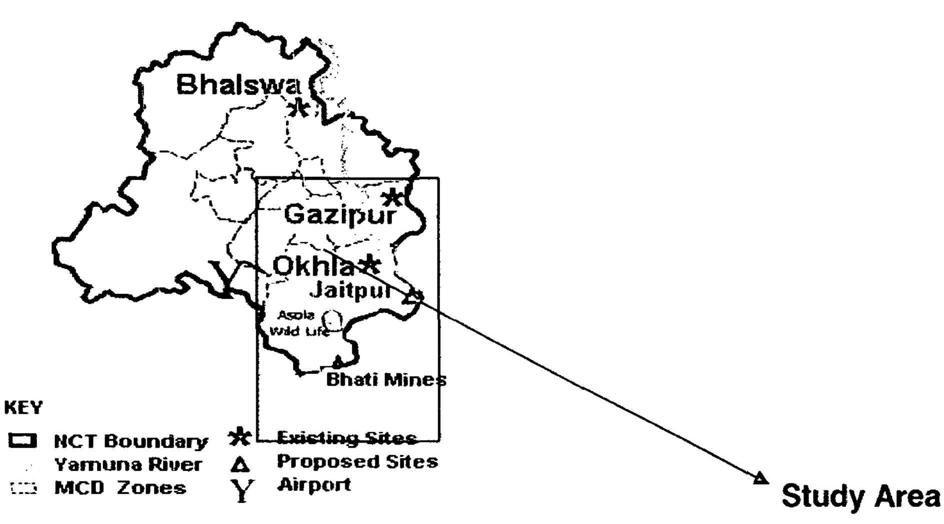
Latest estimates indicate that about 6500-7000 M. Tones of Solid waste is being generated each day in Delhi at present. In addition, industrial hazardous and non-hazardous waste, such as fly ash from power plants, is also generated. MCD and NDMC could manage to clear about 5500 M. (Economic Survey of Delhi, 2007-2008).

Table 4.9: Municipal Solid Wastes

Agency	Area (Sq. Km)	Population (Million)	Waste Generation (MT/Day)	Landfill (MT/Day)	Composting (MT/Day)
MCD	1399	13.8	7000	5500-6000	350-400
NDMC	42.8	4.5	250	170	80
Delhi Cantonment Board	43	0.13	60	60	0

Source: DPCC.

Existing Sanitary Land Fill Sites: (3)	Proposed sites:
Ghazipur (70Acres),	Jaitpur (26 Acres)
Okhla (56Acres),	Bawana (150 Acres)- Bhatti Mines
Bhlasawa (40Acres)	



Rise of tones of garbage generated each day resulting in accumulation of garbage in the city area. With the increase in the number of hospitals and nursing homes in Delhi, hospital waste has become another area of concern and Small Nursing Homes, Clinics and Dispensaries are disposing off the waste through operator facilities but are not so efficient. Construction debris, industrial waste slaughter house waste, electronic waste etc. are also to be concerned. Waste from different parts of the city is transported to three landfill sites, located at Gazipur, Bhalaswa and Okhla and these existing landfills (dump-sites) are almost full they need to be closed immediately. Treatment of wastes is almost non-existent. Apart from this these wastes are responsible for the contamination and pollution of surface as well as ground water in those regions. Thus various human activities – encroachment, mining, pollution etc. have severely affected the geo-environment of the study area. These changed land uses have serious impact on the ecology of the region and poses threat to its survival.

Chapter V

Chapter V

Conclusion

The dynamics of population expansion and its effects on the land cover features is obvious. There is tremendous pressure on the natural resources due to increasing population. To meet the demands of large population, the need for more of food production, energy, water requirement, better civic amenities for a reasonable quality of urban life and better infrastructure development goes up day by day which in turn put pressure on the natural resources.

These pressures make urban areas as modified landforms under anthropogenic activities. Human activities typically superimpose a layer of artificial composition and structure on urban geomorphologic landforms not only in terms of invasion of land area but also change in land use; increased usage of resources as well as release of various level of pollution into the urban geo-environment. The pressures are dealt in the third and fourth chapters of this dissertation work confirm the detrimental effect of anthropogenic activities. The changed land forms are mainly to accommodate the ever growing population due to natural as well as more of migration where environmental aspect is nullified.

Urbanization, the conversion of other types of land to uses associated with growth of populations and economy, is a main type of land use and land cover change in human history. This study of land use land cover change in and around the Aravalli of Delhi i.e. Delhi Super group system shows the negative impact of the anthropogenic activities. The analysis confirms the encroachment of ridge and Yamuna plain geomorophic units by the government as well as private parties.

As far as the land use changes of this region is concerned, has originated very long back in Indian history. The known history explains us that Indraprasta –earliest Delhi during Mahabharatha period grew with Indian culture and heredity had come under the rule of many kingdoms in later years. Mughals were the founding pillars of the Islamic heritage sites of this city ruled majestically and left over remains explaining their glory still. British rule also had taken the privilege of building new architects like Edwin Lutyens' house. After independence Indian government buildings took the chance into its hand. Yes its important to have better infrastructre facilities for the betterment of the people as well as for nation. But that development should not eat away the ecologically and physiologically very much important features like 'The Delhi Super Group System'- which is termed as the 'lung of the city'.

If we see the land use and land cover changes in the chapter three explains changes over a period of time which is drastic human made one. Urbanization has negative impact on the study area as the area under forest cover decreased till 1990's and due to government measures now started to increase. As far as the - the area under settlement/ built-up has increased three times with in three decades. This change has taken agricultural/ cultivated land, forest and tree vegetation, barren land and even the water badies into its stomach. Still its going on at very high speed than ever to meet the need of upcoming commomwealth games as well as the housing and other infrastructure need in this city. For example, if we take cultivated land category, the total cultivated area was 120.32 Km^2 i.e. 19.30 % in 1977 but it went down to just 28.16 Km^2 i.e. just 4.6 % in 2006 which is very drastic.

If we see where these lands have gone- the change table show that 55.44 sq km has gone under built-up area category and the vegetation depletion also not less as it is 43 sq km of the vegetation category in 1977 gone under built-up in 2006 class. 41.48 sq km of barren and exposed land and 1.73 sq km of water bodies of 1977 also occupied by built-up land. This shows how the ridge area as well as the Yamuna plain areas is going under peril. Though base map have been prepared for the 1975 and 2000 to make use for supervised land use classification, the study is based on the satellite images of different resolution as well as of low resolution ones results may not be very accurate. More over the month of the satellite imageries also different so the reflectance from the various classes may also have differences between imageries.

In the fourth chapter various human activity causes for the land use changes have been discussed. The River Yamuna is flowing all along its eastern side. It has formed a flood plain area. The tract of land all along the Yamuna River is made up off newer alluvium known as 'Khadar'. In the low lying flood plain newer alluvium is found deposited due to recent floods. The soil in the flood plain area retains adequate moisture even after the rainy season and is particularly good for cultivation. Demographic and economic expansion of cities, through processes such as migration and industrialization, tend to be accompanied by spatial expansion, resulting in encroachments. These encroachments affects infiltration of water to sub surface aquifer for groundwater to get it recharged. More over vegetables and fruit crops occupies major part than the other cereal corps these days in the Yamuna bank.

The paleaochannels and abandoned channels in the older alluvium area of Yamuna plain are encroachment now. The concrete structures won't allow water to percolate. More over as this area is under the seismic zone V and it is quite well known that tall buildings founded on deep alluvial deposits can be vulnerable to even long-distance earthquakes due to resonance effects. As per this buildings in the Yamuna plain and in the Aurobindo marg-Hauz Khas area where the depth of the bedrocks are very deep and very much vulnerable for earthquake. Apart from this, illegal settlements are very common in railway lands, Yamuna Pustha area, near by industrial areas etc. though many steps have been taken by the Government of Delhi by rehabilitation still it is continuing.

Road and other transport networks like railway, metro infrastructures are good for the development of the city. But happen in some areas like tunneling of the rock system, cutting and evacuating those areas and also building bridges on these majesties will be harmful one which affects the virginity of the ridge ecosystem itself. Already many animals like fox, deer's, and hyena have vanished and in the long run we many loose even monkeys and pigeons which are common in this city now. Another important deteriorating activity in the ridge region is the Mining and Quarrying activities. As per the analysis done the area has increased from 1.87 Sq Km in 1975 to 5.23 Sq km in 2000.

Though it has been banned by the Honorable Supreme Court of India inside the Delhi boundary still quarrying on in just adjacent side of Bhatti mine area in Haryana, which is also to be banned. Government of Delhi is rejuvenating the left out mining area by tree plantations which shows out as the increased vegetation cover in the city recent years. These initiatives to be promoted further to augment its out come.

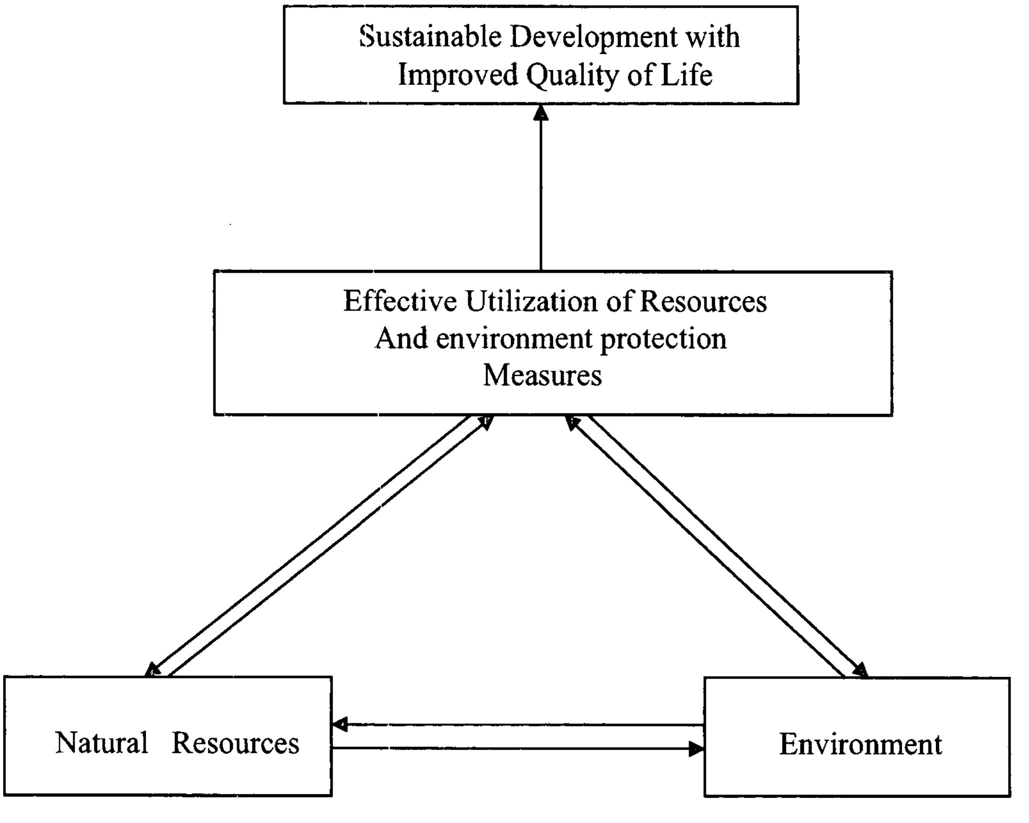
Apart from the human encroachments on the ridge region, the study area is affected by the pollution due to the result of the increasing population related emissions and creation of wastes. The study reveals the increasing pollution in the area, like deteriorating ground water as well as the surface water quality. Though two year data wont give clear picture of increasing pollution, with the available data I have analyzed the ground water quality of pre-monsoon 2004 data with 2009 before monsoon data(May 2009) to have recent picture.

Categories Hardness, TDS and Ca are showing increasing between 2004 and 2009. As per the 2009 data for different samples are considered industrial areas like Inderpuri, Perhladpur are noted with high level of TDS, $CaCO_3$, Ca and Fe are showing higher level than permissible in the industrial and garbage dumping landfill areas due to leachate as well as pollution due to pollution due to drains in that area and industrial effluents. The two sample sites –Nizammudin Bridge and Agra Canal of the Yamuna River (surface water quality analysis) also reveals the increase in pollution. BOD, COD levels are higher than permissible limit and DO has come down even to Zero in 2004 and FC and TC are much more above the limit as drains are meeting in this sample point.

Air pollution is also high. Trend of SPM, RSPM are above permissible limit. SO_2 also shows same kind of trend where the decrease up to 2005 and under the permissible limit. NOx is also increases but CO is showing decreasing trend which is very important as its one of the main green house gases. Apart from this important pollution comes from solid water created ever day by every house hold, industry, offices etc. already the working three land fills at Okla, Bhalaswa and Gazipur are about to fill. So Government is finding sites for the new lanfills, in that proposal Bhatti mine area is also there as per some reports which is very sensitive issue in the environmental pollution and encroachment aspects.

The harmful aspects of the development sides are seen in the urban environmental studies. Though the economic and infrastructure developments are severely criticized they are important for the over all growth. But these developmental activities should also include the conservation aspect also into it for the future generation. Here the sustainability arises. Sustainable use of resources for the betterment of present as well as for the future generation is important to have healthy, quality life.

As this region is meant for the greenish vegetation which works as lung for whole city by absorbing the polluting gases and regulating energy exchange between the earth surfaces and atmosphere's lower layer. Changes in vegetation cover regulate long-term climatic changes at the micro-region level. It's important to make this lung to be functional for long as our future generations also have their rights to live.



Sustainable resource management, by means of effective utilization of the available resouces and mainataining that for the future generation can give this. By means of protecting and tree planting in the barren areas, mining and quarrying parts as well as water harvesting through roof tops, check dams and riviving natural water bodies under human encroachments etc can help for this. Proper pollution management as well as reduction by means of efficient utilization can protect and conserve our precious natural resources for long.

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