LAND DEGRADATION AND LAND USE / LAND COVER CHANGES OF ARAVALLI HILL REGION OF NATIONAL CAPITAL REGION DELHI

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MASTER OF PHILOSOPHY

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DECLARATION

I, SATYENDRA PRATAP, hereby declare that the dissertation entitled **"LAND DEGRADATION AND LAND USE / LAND COVER CHANGES OF ARAVALLI HILL REGION OF NATIONAL CAPITAL REGION DELHI"** submitted by me for the award of the degree of **MASTER OF PHILOSOPHY** is my bonafide work and that it has not been submitted so far in part or in full, for any degree or diploma of this university or any other university.

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CERTIFICATE

It is hereby recommended that the dissertation may be placed before the examiners for evaluation.

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Satyendra Pratap

DEDICATED

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CHAPTER – I

INTRODUCTION

Mountain and hill ranges are known for their distinct relief, geology, climate, and other natural features. Rich mineral and natural resources are also more profound in mountains and hills. High altitude and tough terrain of hill and mountain regions have not only restricted man to invade but gave challenges to triumph in terms of access to these resources. But growing population and new paradigms of economic development are now encouraging people to use and exploit natural resources at any cost. These processes have led to environmental losses, disasters and degradation. Long term results of these are found in land use and land cover changes. These are linked to human influences on natural environment through their activities.

Human beings have been altering environment throughout time since they inhabited the earth. Moreover, some activities of human beings have resulted due to increase in number of people and successive technological revolution including the invention of wheel, domestication of plants and animals, and industrial revolution. Despite large changes in environment in the past, evidence suggests that very large population, rapid rate of population growth and rapid rate of technological change constitute adaptation and enhancing the rate of changes.

Human beings have been seen as transforming and active agents on earth surface since the beginning of human civilization. They were closely dependent on their surrounding for subsistence and livelihood. Earlier people were fully involved with nature for food and subsistence through hunting and gathering. It is also seen that at beginning, nature was transforming human life in many ways. Human beings were

scared of nature due to natural calamities and they believed that natural environment is responsible for their own development and they cannot do anything against will of nature. But later on, human beings with their innovative skills and natural succession were able to develop themselves. They developed tools and technical knowledge through their innovative skills to overcome natural calamities.

It was the result of growing human capabilities through technological advancement that helped human beings to make life easy and made it possible to alter several environmental aspects. But in other ways, this technology also increased the rate of exploitation of natural environment.

Human beings started carrying out several activities those are altering natural environment at alarming rate. Emergence of materialism and consumerism encouraged people to exploit more natural resources. Growing population, increasing urbanization and industrialization are posed major threats to natural environment[1]. Opening of world economy under globalization processes through growing demand for trade and subsistence are also making man more exploitative and competitive.

Biologists have estimated that human activities are causing extinction of earth species at an exponential rate of 0.1 to 1.0 per cent per year causing an irreversible loss of earth's biodiversity. In various part of the world, forests, grasslands, wetlands, and topsoil continue to disappear or getting degraded as human ecological foot print spreads exponentially across the globe[2].

Ultimately all terrestrial life depends upon natural resources of earth. Food for human subsistence is primarily derived from land, either through agriculture or livestock rearing with a smaller contribution from aquatic environment. The relationship between man and environment is complex with various interacting social, economic and traditional systems. It had undoubtedly led to immense alteration and transformation of

our environment. Land use / land cover changes and land degradation are the outcomes of human intervention on natural environment.

1.1 LAND USE / LAND COVER CHANGES

Land-use change, as distinct from land-cover change is usually due to human activities. People extract resources from land in order to satisfy their needs for food, water, habitation, energy, mobility, or recreation[3]. Humans also use land to satisfy their aesthetic and spiritual needs or to meet political and military ambitions. Land-use activities usually modify land cover, but sometimes people also reserve land for parks where they try to minimize human interference so that a nearly natural land cover can remain or redevelop.

It is important to define the terms "land use" and "land cover" to comprehend the role of changes in land cover. These terms for denoting transformation of land from natural into managed ecosystems are primarily utilized by geographers, economists, anthropologists, and planners and they imply use of land for specific human purposes. Land use is defined as "the human activity associated with a specific piece of land" or "it is the purpose of human activity on land"[4].

Land use and land cover seems to be similar terms but they differ methodologically. It has been argued from ecological and bio-geographical point of view that natural vegetation are demarcated under land cover, while agricultural croplands, built-up areas and man-made associated land are demarcated under the category of land use. Land cover is also defined as observed bio-physical cover of earth's surface. Such an observation can be made by human eye, aerial photographs, satellite sensors, or simply existing maps[5]. Land use can be considered as a reflection on the degree of human activities directly related to land and the use of its resources or

having an impact on it. The term land use cover relates to the type of feature present on the surface of earth. The term land use relates to human activities or economic functions associated with a specific piece of land.[4]

In some cases, it is not possible to determine functional aspects from biological aspects. For instance, the use of land for nomadic or extensive grazing will frequently be based on a land cover of unimproved grassland, although this is an inference which requires field checking. In many other cases, one biophysical category may correspond to a large number of functional categories. Areas of grass may, for example, correspond to a lawn in an urban environment, an airport runway, a sown meadow or even rough pasture.

Anthropogenic activities are related to land use change of land cover through utilization and perhaps loss of primitive natural resources. Now many of land use operations lead to change in land cover resulting in environmental degradation, which is the consequence of interactions between natural environment and anthropogenic activities on earth surface.

1.2 ENVIRONMENTAL DEGRADATION

Word degradation coming from Latin derivation implies reduced to a lower rank, the rank is in relation to actual or possible uses, and reduction implies a problem for those who use the land. Land degradation occurs when natural and human induced processes decrease the ability of land to support crops, livestock, or wild species in future. One type of land degradation is characterized as soil erosion. Land degradation is a widespread phenomenon of the environment which is result of human actions. A wide range of human activities can trigger or exacerbate land degradation.

Human induced degradation occurs when land is poorly managed or where

natural forces are so powerful that there is no means of management those can check its progress. Heavy anthropogenic pressures are changing natural composition, structure and cause degradation of land. Land degradation affects environment in several ways because every biological factor as even human beings are directly associated with land. Biotic organisms as primary producers directly make their food from water and carbon dioxide in presence of sunlight and necessary soil nutrients. This is how food chain is initiated and it is further sustained through higher order trophic levels.

Blaikie and Brookfield[5] have suggested land is degraded when "its suffers a loss of intrinsic qualities or a decline in its capabilities. It is therefore, best viewed as a result of forces or product of an equation, in which both human and natural forces find a place, that equation being:

Net Degradation = {(Natural Degradation Process + Human Interference) – (Natural Reproduction + Restorative Management)}.

Factors affected by the land degradation are mainly:

- Physical- soil, water, air.
- Biotic- Includes plants, animals, human beings.
- Socio-economic - Land degradation has far reaching ill effects on the social and economic well-being of people.

1.3 CAUSES OF ENVIRONMENTAL DEGRADATION AND LAND USE CHANGES

Population increase: Increase in total population creates a demand for more land which further leads to land cover changes and degradation.

Urbanization: Similarly a rise in urban population creates demand for more land for several purposes such as housing, infrastructure etc. An increase in build-up areas

irretrievably results in land cover changes and degradation.

Inappropriate land use: can lead to soil degradation. Bad farming techniques such as excessive use of chemical fertilizers, over irrigation etc. are often responsible for land degradation. Leaving fields bare, ploughing these in correctly causes severe soil erosion.

Over cultivate happens when a farmer does not allow a piece of land to recover in between plantings, thus exhausting the soil. Left unchecked this can eventually lead to land degradation as the land is being used in a way which is unsustainable.

Overgrazing is when more animals than a piece of land can support are allowed to graze in that area. This can cause serious damage to land. When too many animals are allowed to graze on a piece of land they eat the plants that hold soil in place.

Pollution is also an important factor in causing environmental degradation. Soil and land can be damaged as a result of waste products and pollutants being deposited and left in it. When rubbish from factories, mines and households are dumped in natural environment it pollutes the land and leaves its toxins within the soil.

Poverty is a contributing factor to land degradation as it forces millions of people to overuse resources in order to survive. Poor people often do not have access to good land, leaving them dependent on fragile areas and resources. It may mean that they have no other choice other than to use what resources are available to them, even if it results in degradation of land.

Mining is another anthropogenic factor that affects environment of ecosystem. It may damage, soil cover, water bodies, local biodiversity.

Other anthropogenic *factors*, such as construction and manufacturing create pollution and lead to land use changes and environmental degradation. Use of chemicals and fertilizers, over irrigation also result in to several associated problems of land degradation.

1.4 STUDY AREA

Aravalli Hills are believed to have good forest cover and rich wildlife. Presently, this ecosystem has come under severe stress due to excessive demand of fuel, fodder, construction, industry and extensive mining. Aravalli hills extend into National Capital Territory Delhi and areas around it have become ecologically fragile. This has resulted in extensive land degradation, land use changes, soil erosion, silting up of river channels and reservoirs, and lowering of ground water table.

Aravallis form distinctive and ancient hills of peninsular India. It is also one of the oldest geological formations. Heavily eroded and exposed outcrops of granite, limestone, marble, slate, quartzite and other minerals make it very prone to degradation. Many running anthropogenic activities in the region have resulted in disturbance of land causing deforestation, altering ecology, drainage and land use, besides adding pollution and other problems.

Growing human population, construction, industrialization and growing urban centres are gradually lowering bio-capacity of region. This requires more land to use, which is coming through deforestation and from others biological fertile zone[8]. Human settlements, other build-up areas, agricultural expansion have increased demand of forested and other land which has led to degradation. In of population concentration, urbanization, industrialization, mining and allied activities are more prone to degradation.

1.4.1 LOCATION

Aravalli hill region of NCR cover a part of National Capital Region. Its latitudinal extent is from 27° north to 29° north and longitudinal extant is from 76° east to 77.6°

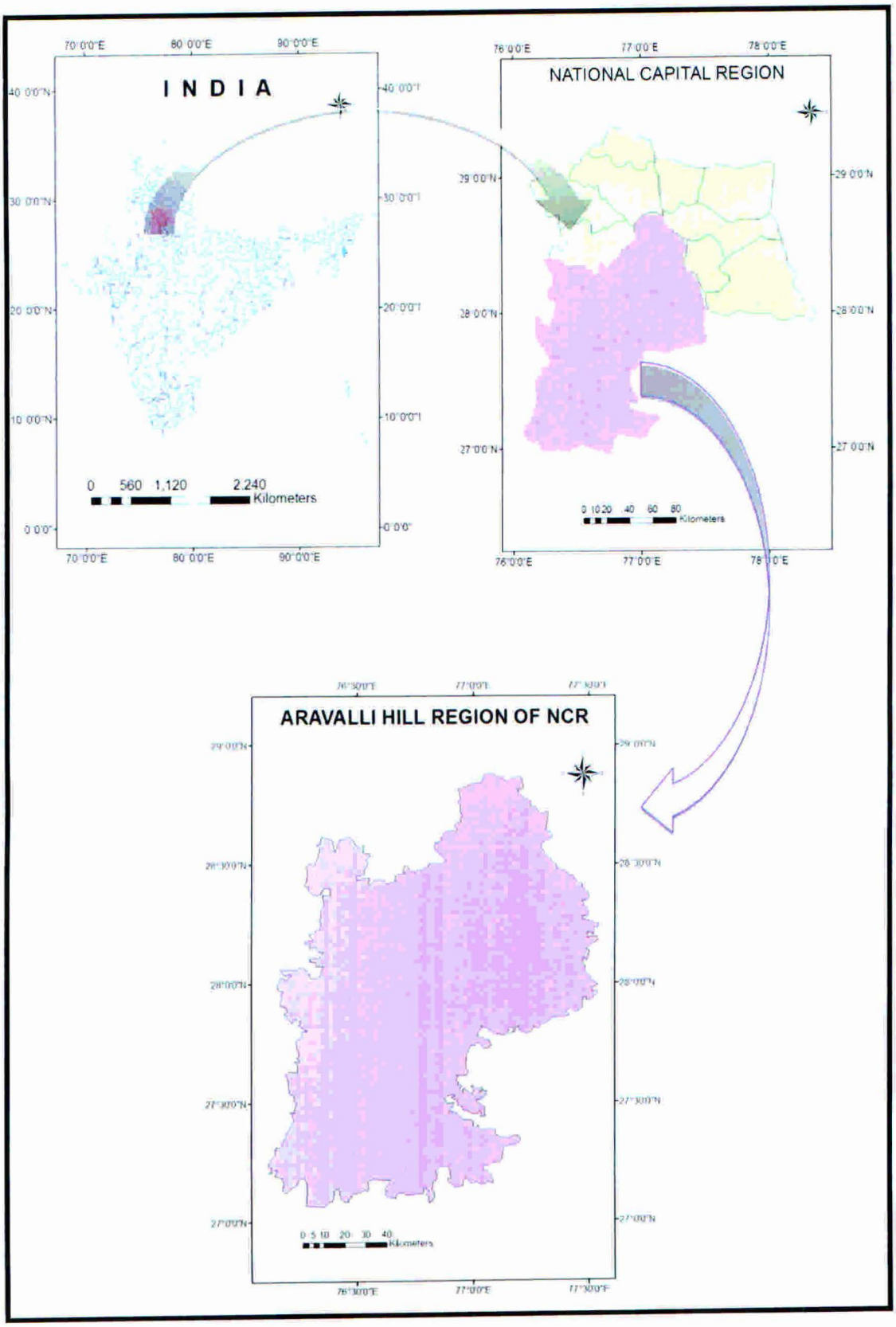

Figure 1.1 Study area

east. The region comprises four district of Haryana namely Gurgaon, Faridabad, Rewari and Mewat, one district of Rajasthan that is Alwar and National Capital Territory (NCT) of Delhi as sown in figure 1.1.

1.5 LITERATURE REVIEW

Human beings and their activities, land use / land cover changes and land degradation are positively correlated. Anthropogenic activities put stress on natural environment with varied intensities. From the time of evolution of Homo-sapience's, human beings have always been remained in close relationship with nature. This relationship was also exploitative in nature. But since the days of Socrates, people have been debating about earth's carrying capacity and importance of other organism. Plato, Malthus and many other scholars have long predicted that if population growth continued at its present rate, the planet would become over populated and earth's resources would not be able to sustain human population. With consequence of these several views came in favour of environment to sustain it. In religious texts Buddhism and Jainism also favoured environment for sustainability of human life. They taught the lesson of Ahimsa, to save and life of other organism[5].

Aravalli hills are, known for their rich natural resources but suffer not even strong human interference. Several activities of human beings are registering in degradation of hills at faster rate. There is hardly any study attempted to capture losses of rich natural environment of Aravalli hill region in NCR. These have been reviewed below:

1.5.1 Studies on Human Activities and Environment

Human beings affect their environments in several ways. There are number of studies on this aspect.

Sing C. Chew[5], in his study "*World Ecological Degradation*" has tried to look into major causes of ecological degradation since beginning of human civilization. He argues that main causes for world ecological degradation were accumulation of surplus and wealth, population growth, urbanization, industrialization. Those have severe consequence for nature.

Narrottam Gaan[6], in his study, has explained the impact of environmental degradation on society. With illustrations from India and Bangladesh, he has explained environmental degradation or scarcity of resources takes in terms of land, water, forest, and biodiversity. These have been interacting with burgeoning population growth. Effects of environment on economy and political life of people have resulted in economic decline, growing weakening and incapability of states to meet their needs. Economic decline may further exacerbate the existing domestic problems and differences will impel conflicts. These conflicts may take the form of intra-state, groups vs. groups and people vs. people depending on the dimension and magnitude of the social effects. He founds that the main causes of environmental degradation lead to social problem in a region.

William D. Solecki's[7] Study examined human–environment interactions and effects of ecological degradation. He has also presented a plan for ecological restoration at regional scale. In interaction mechanisms he has taken note of land use, direct resource utilization, pollution, basic needs, quality of life and environmental ethics. In control systems he has looked at governmental regimes, legal institutions, resource management. He has also studied societal context regarding demographic aspects, social structure and economic conditions. All the above factors have been in seen for environmental degradation. This primary objective was to determine the role of each of these components in the process of environmental change for period of 1845 to 1995.

Kuheli Dutt,[8] in her paper examined environment-income relationship in the context of Environmental Kuznets Curve. It shows that as per capita income increases, environmental quality initially worsens but with continued increases in income, environmental quality starts improving, giving rise to an inverted U shaped curve. She also looked possible role of other factors playing their role in environmental degradation. She says that governance, political institutions, socio-economic conditions and education influence environment and income relationship. She has compared some countries. She argues that better governance; stronger political institutions, better socio-economic conditions and greater investment in education causes less environmental degradation.

Ahluwalia S. k.[9], has argued that population pressure, skewed land resource distribution, in appropriate land tenure, small land holdings and poor infrastructure exacerbate pressure on environment. This leads to soil erosion and land degradation.

Chadwick, A.[10,] has discussed social and economic impacts in UK environmental impact assessment. He has provided information on the extent, scope, balance and quality of socio-economic impact treatment. He has tried prove through several socio-economic effects can also generate important biophysical or environmental impacts.

Kumar, Neeraj,[11] has looked at Population and Economic Growth as Drivers of Future Land Use in India. His work presents a perspective on challenges facing India in terms of population and economic growth and future land use patterns. He argues that in a developing country like India, future land use patterns are likely to be decided by in population growth and economy in next few generations. Agriculture and land use are so interdependent that change in one would have effect on the other. He has discussed the present status of India's population and current state of land and food availability.

He has made projections of demand and supply of land and food grains up to 2050. He also attempted to see whether land and food supply would be able to keep pace with increasing population and economic growth.

1.5.2 Studies on Land Use and Land Cover Change

Several studies have been carried out on land use / land cover changes. Temporal analysis on land use and land cover is very useful in monitoring land use / land cover changes. Analysis of rate of changes in land use helps in gauging intensity of human activities and resultant stress on environment.

Gerhard K. Heili[12], Has identified five anthropogenic factors as major determinants of land use changes in China these are:

- The continuing increase in population.
- Rural-to-urban migration and the emergence of urban agglomerates.
- Accelerated economic modernization and industrialization.
- Changes in diets and life styles among people, and
- Changing economic and political arrangements and institutions.

He explains that land use and land cover changes are fully influenced by institutional arrangements done by strong government of China. New liberalization and modernization policies of China, which came in late 70s spread across eastern provinces and resulted in urbanization, industrialization and increase in income of people this led to rural urban migration. An increase in income has also altered consumption pattern and life style of people.

Chen S. & Rao[13] said that remote sensing and Geographic information Science technologies can be productively used to detect and quantify changes in landscape and consequential environmental impacts. Present report has applied remotely sensed data to examine urban land and changes in modern times. It shows varying degree of different

patterns of urban expansion and development which could be associated with specific environmental factors.

Prakasam[14] studied land use and land cover changes in Kodaikanal region of Western Ghats in Tamilnadu to observe changes over during a span of 40 years from 1969 to 2008. He used Landsat data and performed supervised classification. He found that 70% of the region was covered by forest in 1969 and it decreased to 33% in 2008. Built-up area has also increased from 3% to 21%. It is showing that the region is affected by rapid urbanization which in turn leads to adverse environmental effects for bio-diversity of Kodaikanal.

Samant and Subramanyam[15] have used Landsat TM imageries to study land use changes in Mumbai, India. They carried out the study using land use maps for 1925 and 1967 and compared them with Landsat imageries of 1994 to quantify changes spanning from 1925 to 1994. They found a remarkable increase in build-up area by around 300 per cent and reduction in forest area by around 50 per cent, They concluded that this happened to cope up with increasing urban population.

Zubair Ayodeji Opeyemi, [16] has used remote sensing and GIS technique to find out land use and land cover changes in Ilorin, Nigeria. He has taken Landsat images of 1972, 1986 and 2001 and has used un- supervised classification method. He classified land in five classes namely farmland, wasteland, forest, build-up area and water bodies. He demonstrated that farmland declined by 7 per cent during 1972 to 1986 while the build-up land increased by 8%. Decline in farmland was recognized as transition from farming to urban activities with the creation of Kwara state and Ilorin becoming capital city. Augmentation in build-up land was attributed to rapid urbanization and redevelopment projects as a result of state creation.

1.5.3 Studies on Land Degradation

Botha & fouche[17] have done land degradation assessment for rural areas of South Africa in they used vegetation indices like soil adjusted vegetation index (SAVI). These indices give an indication of a general decline in vegetation environment at regional level. They have also used time series data to assess temporal land degradation. By using SAVI they revealed that land degradation is taking place in rural areas of South Africa.

Chen S. & Rao P[22], in there paper assessed land degradation of northeast China. They have calculated Normalized Difference Vegetation Index (NDVI) and Kappa Statistics[18] to estimate degradation of north-east China province. They also compared the results of land degradation analysis through comparison of temporal land degraded images.

Dregne[19] has analysed land degradation pattern across world by review of literature. He found that there is little good research data available to estimate land damage. He has attempted to analyse global information sources and draw tentative conclusions on on-site and off-site impacts of land degradation. Satellite imagery with higher resolution, offers the promise of filling part of data gaps. He also looked at different forms of land degradation and their causes.

Chopra, & Gulati, S.C.[20] studied environmental degradation and population movements. They have looked at the role of property rights by examining the linkages with environmental degradation. They found out that deforestation and land degradation occurred due to mobility of population. They found out that deforestation and degradation occurred due to mobility of population. Their study is based on assumption that migration is largely a consequence of push factors and it leads to land degradation.

Quiggin, [21] in his paper argued that expansion of agriculture into new regions

has often resulted in land degradation. Central point is that opening up of new areas will be undertaken by those with optimistic expectations about the productive capacity of new lands and new technologies. Therefore, it will be associated with overexploitation. He has explained that the main reason behind land degradation is the process of land development which involves selection of pioneers with optimistic expectations about the robustness and carrying capacity of new land.

Nina Nikolic. et al,[22] argued in their paper that "barren hill" has been a keyword for land degradation in the uplands of Vietnam for a decade. To estimate the degradation process of barren land, they have performed primary survey and found that degradation process of barren hills is very fast due to sparse vegetation and unconsolidated soil. They also found that barren lands are continued to be cyclically generated by the predominant land use system.

Zhang, Kefeng et al,[23] have studied land resource degradation of China. They had tried to calculate extent, intensity and economic impact of land degradation. They identified, defined and classified land resource degradation on the basis of two time period data. They also analysed dynamic changes in degradation and rehabilitation processes.

1.5.4 Studies on Study Area

Planning Board report[24] on environmental problem of Aravalli has also accepted environmental degradation. The report shows that lot of construction, waste deposition, deforestation mining and other activities are causing environmental degradation in Aravallis. It reveals that a large number of unplanned construction and urban areas extension have led to several environmental problems in the region. Extension of build-up area is a dominant factor which altered the cultivated areas and land use pattern of the region.

Khanna[25], in this paper looked into emerging problems, prospects and potentialities of National Capital Region. He provided an operational framework for sustainable development through estimating carrying-capacity of the region. His estimation on supportive and assimilative capacity of the NCR has enabled identification of operational constraints in planning for socio-economic development and to achieve equitable quality of life while minimizing environmental degradation. His investigation is based on comprehensive scanning of resources and their potential to support economic activities, optimal allocation of resources, and optimal use of assimilative capacity. Equitable quality of life as sustainability criteria ensures end-use approach in developmental planning.

Paul F. Robbins, [26] studied the Kumbhalgarh Wildlife Sanctuary of Rajasthan. He revealed that Land cover changes in protected areas are often related with human activities, especially illicit extraction, but the direction and spatial distribution of such effects and their drivers are poorly understood. He analyses and explains spatial distribution of vegetation change in Kumbhalgarh Wildlife Sanctuary in Aravalli range of Rajasthan. He found that anthropogenic factors are overruling over natural factors in land use changes of Kumbhalgarh Wildlife Sanctuary.

NCRPB[27] has done macro level study for National capital Region for preparing plan for 2021. The board looked at overall natural and socio-economic features of the region and evaluated and examined all indicators for future management and sustainability.

Chandrasekhar Bhuiyan[28] has worked on the Aravalli range ground water table fluctuations and varying infiltration due to rough and hard terrain of the range. He looked into the relationship between the terrain of Aravalli and hydrological factors.

Saif-ud-Din[29] studied, Aravalli-Delhi fold belt lithology by using the thematic

mapping (TM) data, and he has divided Aravalli Delhi belt into several litho-units.

M. Zafar-ul Islam and Asad R. Rahmani[30], have been anthropogenic influence on the biodiversity of Thar Desert and associated problem were also examined by the authors.

1.6 OBJECTIVES OF STUDIES

Human beings are the most transforming agents on earth surface and closely dependent on earth for their subsistence. Natural resource rich regions are not away from greedy hands of human population. Moreover increasing population is demanding more natural resources for consumptive purposes. Major processes of human civilization such as urbanization, industrialization, mining and quarrying and all other extraction of resources from nature are keeping Earth under ever increasing stress[25].

Aravalli Hills with rich natural resources are not immune to human interference. Growth centres like as Delhi in National Capital Region is now putting more pressure on these resources and gradually this region is becoming ecologically more vulnerable. Keeping in mind consequences of human activities and resultant land degradation in the region, following objectives have been set for the study.

- To understand environment, population and resources base of Aravalli hill region of NCR.
- To study Land use / land cover changes in Aravalli hill region of NCR.
- To examine level of land degradation in hill region of Aravalli in NCR.
- To analyse anthropogenic impacts which are responsible for land use / land cover changes and land degradation in the region.

1.7 RESEARCH QUESTIONS:

Keeping the above in mind and to fulfil research objectives an attempt has been made to answer following questions.

- What is the natural environment and resource base of the region?
- What are the demographic features of the region?
- What is land use pattern of the region and how is it changing over a period of time?
- What is the extant of land degradation in the region?
- Is rapid population increase in NCR, with urbanization putting pressure on the environment of Aravalli hill region of NCR?

1.8 DATA SOURCES

The present study is based on the secondary sources which are given below.

- Primary Census Abstracts & District Census Handbooks, Census of India, Government of India for 1971, 1981, 1991, 2001, 2011. Data have been use to see demographic features of the study area.
- Satellite data from Global Land Cover Facilities in form of Multi spectral Scanner (MSS), Enhanced thematic mapper (ETM+) for the time period of 1977, 1999, 2006 has been use to see the temporal land use and land cover changes in the study area.
- Thematic Map (District Planning Map) of districts Published by National Atlas and Thematic Mapping Organization, Kolkata has been used to delineate the boundary of study area.
- Thematic Map of Land use, Published by National Atlas and Thematic

Mapping Organization, Kolkata were used for the reference in classification of images.

- District-Wise Land Use Data, Special Data Dissemination Standard Division, Directorate of Economics & Statistics, Ministry of Agriculture, Govt. of India, New Delhi to see the land use / land cover of the study area under different land use categories.
- For climatic information of study areas Indian Meteorological Department, Government of India, rainfall and temperature data has been used.
- Report on forest cover data has been taken from Forest Survey of India, Ministry of Environment and Forest, Government of India.

1.9 METHODOLOGY

To fulfil the requirements of the present study, a number of statistical techniques have been used. The methods vary from the simple averages to regression analysis. With the help of the above techniques, demographic data related to growth rate, population density, sex ratio etc. has been shown. With the help of Arc view Geographical Information System maps have been prepared to show environmental setting, population and resources base of Aravalli hill region of National Capital Region. Remote sensing multi-layer satellite data has been used to understand land use and land cover changes different period of time and has been used for the preparation of land use land cover maps. ERDAS image and Arc view (GIS) software have been used in processing of remote sensing multilayer data for spatial and land use / land cover analysis. Normalized difference Vegetation Index (NDVI) has been prepared for land degradation analysis by using remote sensing (red and infra-red band) satellite data.

Temporal changes of land use / land cover and land degradation has been shown with the help of thematic map.

Apart from these techniques, several other indicators have been used in analysis as given below.

Projection of population has been done for period of forty year, from the base population of Census of India for the time period of 1971, 1981, 1991, 2001 and 2011. In order to estimate the population following method has been used:

$$r = \log\left(\frac{Pt}{P(t-1)}\right)\frac{1}{n} * 100$$

$$Pn = P(t-1) * e \text{ ^} rn$$

Where:

r = rate of change

Pt = latest population census

$P\ (t\text{-}1)$ = previous year census

n = difference in two census period

Pn=projected population

$e^{r\,n}$ = exponential growth rate

Physiological density has been calculated to see pressure on cultivated land due to population increase and finally cropping intensity has been calculated to see pressure on land across periods of time due to increase in population in the study area.

1.10 ORGANIZATION OF MATERIALS

First chapter is on general introduction about the theme and study area, purpose and objectives, research questions, database and methodology which has been adopted for analysing the data.

To look at the land use / land cover and environmental degradation, it is

important to know existing natural resource base of a region. Second Chapter entitled "environment, population and resources" has been developed to understand natural resources of study area. This chapter has been done by looking on natural elements such as geology, physiography, soil, drainage, climate, natural vegetation, mineral resources and demographic features of the study areas.

Third Chapter has deals with land use / land cover changes in Aravalli hills region in NCR. Land use / land cover has been classified and its changes have been analysed over a particular time period.

Fourth chapter is entitled as "land degradation in Aravalli hill region of NCR. There, an attempt has been made to look at level and trends of land degradation and wasteland under different categories. It has also been attempted to see correlation among degradation categories.

Fifth chapter is entitled anthropogenic impact on Land use / land cover changes and environmental degradation of the region. Here, it is focused on the level and pattern of anthropogenic impact and population as important factor which are responsible for land use / land cover changes in the region.

Last chapter presents "summary of conclusion" of the study.

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CHAPTER-II

ENVIRONMENT, POPULATION AND RESOURCES

Physiography, climate, drainage and natural vegetation are the main components of physical environment of any region and these play a significant role in human life. Natural environment also has great impact on human settlements and their functions. It not only affects settlements and human activities but also social and cultural aspects of a region.

Environment provides resource endowment to a region. Geologically rich areas have potential to use more mineral resources, and this can directly and indirectly support many human activities. More drainage density and well-developed drainage network can make an area rich in water resources. Such areas have probability to support primary activities. Good climatic conditions and rich fertile soil can support a region with increasing agriculture productivity and by enhancing associated economic activities. Rich vegetation cover is important for providing raw material to industries and in enriching environment.

All the above-mentioned elements of natural setting greatly affect human activities and in turn may get affected by human activities. This shows close interaction and interrelationship between natural setting and human population. In the light of above, it is important to comprehend the natural environment and population of Aravalli Hills of National Capital Region (NCR) in terms of the following:

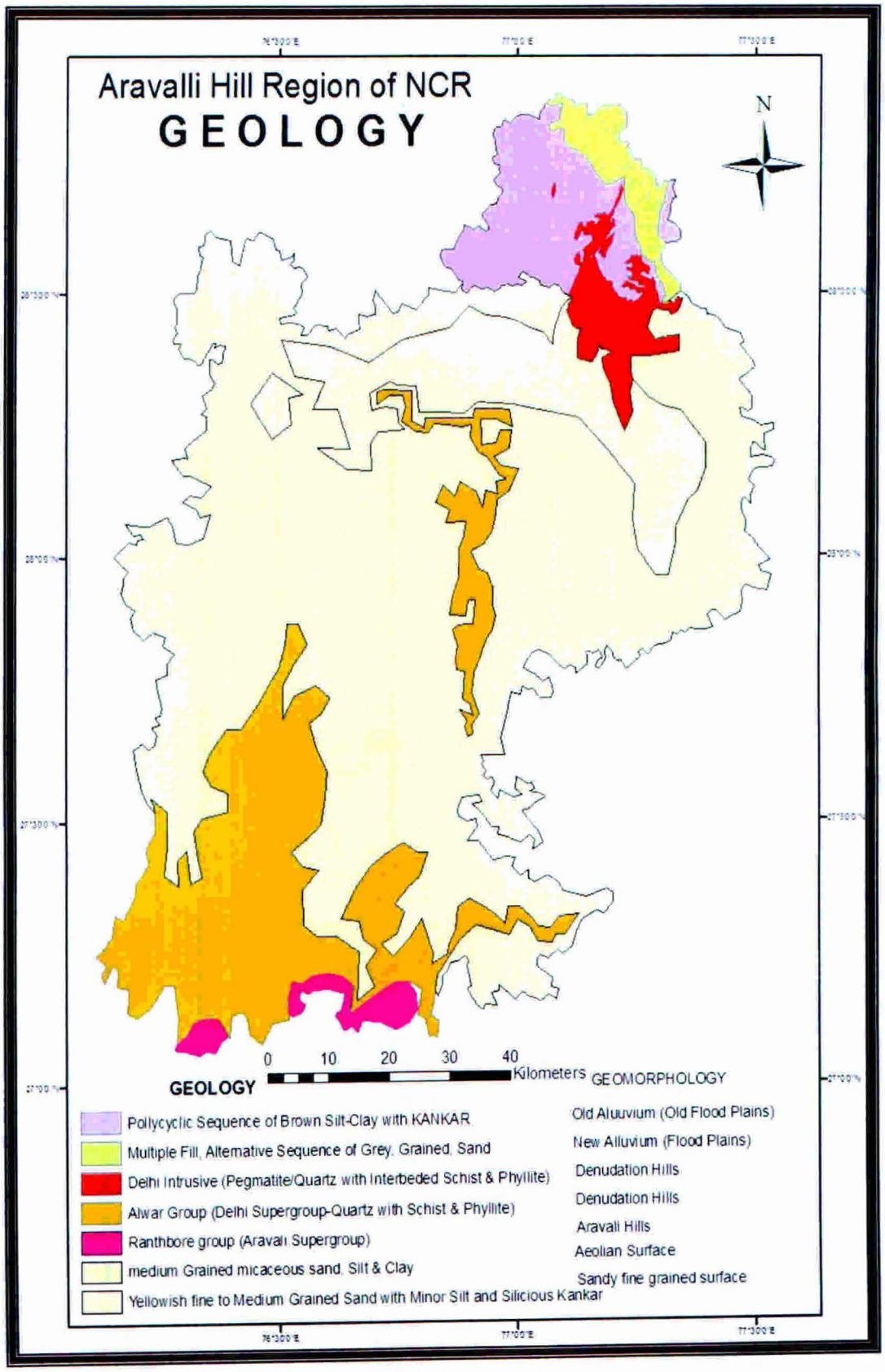
- Geology: as it provides information about lithology and surface features, which affect water and mineral resources of a region.
- Physiography: to have an idea about nature of terrain and landforms because landforms and human activities affect each other.

- Drainage: It helps in comprehending water resources.
- Climate: has a significant impact on human beings and their activities.
- Soil: is an important determinant of vegetation and affects agriculture.
- Vegetation: to get idea about forest and pastures.
- Population: as many of its features can give an idea about anthropogenic activities and level of pressure on natural environment. It also helps in understanding the man - nature relationship. Environment of Aravalli in NCR has been significantly affected by anthropogenic activities.

2.1 GEOLOGY

Aravalli range is the oldest stable part of the earth's crust and geologically known as Aravalli Craton[1]. This Craton occupies north-eastern part of the Indian shield which has undergone varied geological processes and tectonic events since 3500 million years[2]. The Aravalli Craton is bound by Himalayas in the north, Phanerozoic Cambay Graben in south-west, Proterozoic Vindhyan basin and much younger Deccan Trap in east. It mainly covered in many parts by recent alluvium particularly in north.

Aravalli hill region of NCR is situated on the Banded Gneiss Complex and is represented by Aravalli Super group and Delhi Super group of rocks[3]. Geology map (Map 2.1) of Aravalli hill of NCR shows it has the very diverse nature of rock structure. For instance, there is a polycyclic sequence of brown silt-clay to *Kankar* rock surface in north-western part of Delhi. This was formed by low fertile, old alluvium soil. The north east Aravalli region along the river is of multiple fill with alternative sequences of gray grained sand. Grained and sandy surface has been formed by fluvial deposition process. This is a geologically of recent development and also known as new alluvium or *Khader,* formed by flood of the river. There are areas along Yamuna river in the west


Aravalli Hill Region of NCR
GEOLOGY
N
0 10 20 30 40
Kilometers
GEOLOGY
Polycyclic Sequence of Brown Silt-Clay with KANKAR
Multiple Fill, Alternative Sequence of Grey, Grained, Sand
Delhi Intrusive (Pegmatite/Quartz with Interbeded Schist & Phyllite)
Alwar Group (Delhi Supergroup-Quartz with Schist & Phyllite)
Ranthbore group (Aravali Supergroup)
medium Grained micaceous sand, Silt & Clay
Yellowish fine to Medium Grained Sand with Minor Silt and Silicious Kankar
GEOMORPHOLOGY
Old Aluuvium (Old Flood Plains)
New Alluvium (Flood Plains)
Denudation Hills
Denudation Hills
Aravali Hills
Aeolian Surface
Sandy fine grained surface

Map 2. 1

of Delhi those form flood plain multiple fill alternative sequence of grey grained and sand forming fertile soil.

Offshoots, rocky and stony surface of Aravalli are found in the south and south-west district of Delhi and parts of Gurgaon and Faridabad. These are made up of igneous and metamorphic rocks. Geologically known as Delhi intrusive, are formed of pegmatite, quartz with inter bedded schist and Phyllite. Along the boundary of Gurgaon and Faridabad there is Delhi super group of rocks formed by quartz with schist and Phyllite. Geographically, these are characterised by features of denuded hills and are known as out crops of Aravalli. These outcrops of Aravalli are rich in mineral resources. There is Aravalli Super group of rocks in south of Alwar, locally known as Ranthambhore group. This sub group of Aravalli forms a stable structure of igneous rock and is found in southern part of Alwar district. There are medium-grained micaceous sand, silt and clay formed by Aeolian process in mid part of Aravalli of NCR lying in Faridabad, Mewat, Rewari and north Alwar.

Geologically Aravalli hill region in NCR is composed of the oldest structure of rocks. Rocks of Aravalli are igneous in the form of pegmatite, quartz with inter-bedded schist and Phyllite. These are very prone to weathering and degradation. Denudated hills, grained sand with minor silt, siliceous and Kankar and hilly areas of Aravalli forms rocky wasteland and rocky sheet surface. Rocky wastelands and rocky sheets are affected by continuous disintegration and erosion, which leads to land degradation.

Map number 2.1 shows that Aravalli hill are geologically very diverse. These are relict of one of the oldest mountain systems of the world. These heavily denuded hills have now attained near stability and are counted among the most stable parts of earth's surface.

Due to their old geological age, the hills have experienced several tectonic

activities and geological processes which led to changes in morphology.

2.2 PHYSIOGRAPHY

Physiography of Aravalli Hills in NCR represents mature topography with plains, low linear ridges and isolated hillocks. Aravalli hills extend north eastward from Gujarat, passing through Rajasthan, Haryana and up to Delhi. These are designated as Delhi Ridge in Delhi and Alwar ridge in Alwar.

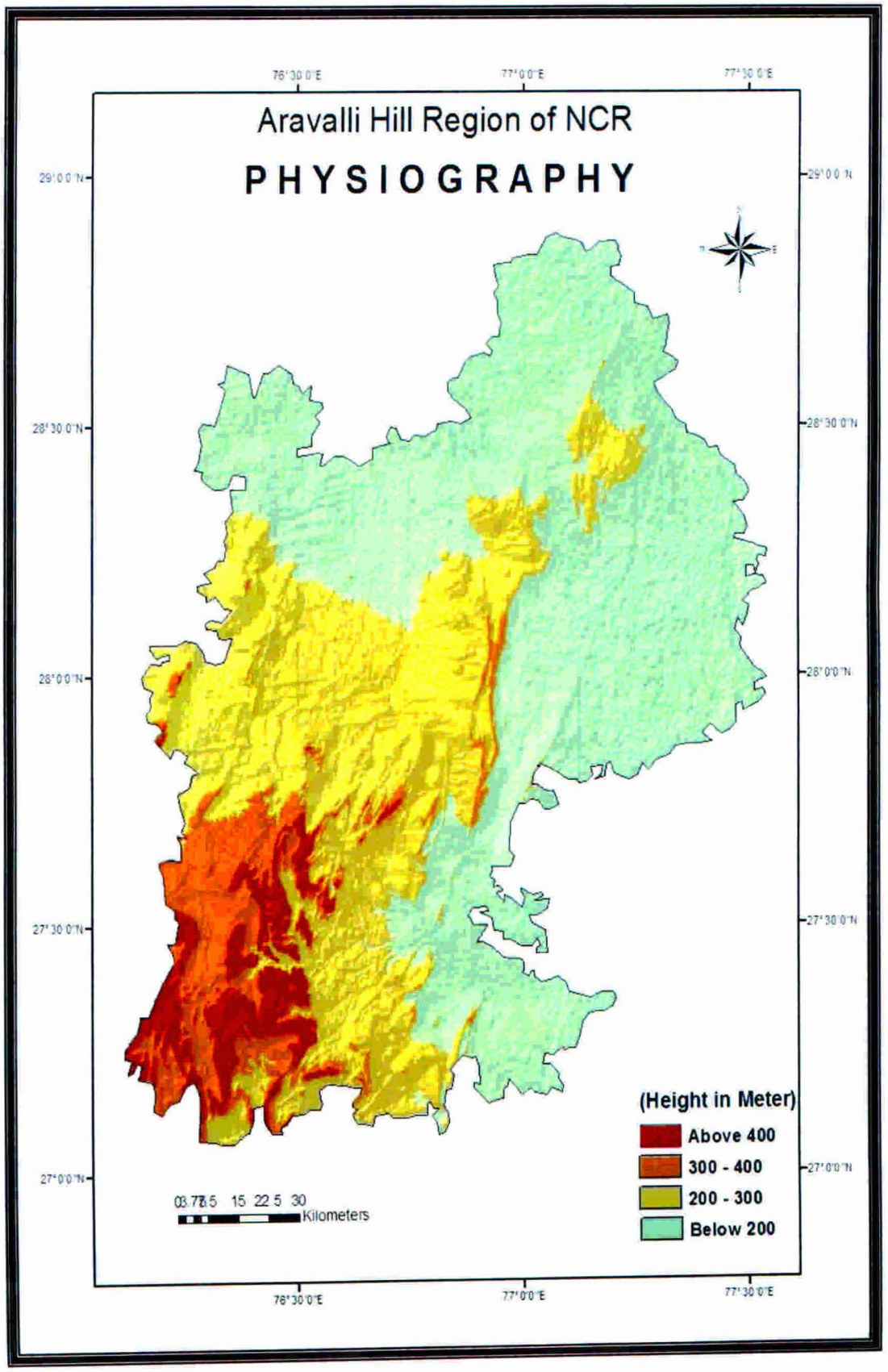
Aravalli hills occupy northern part of Rajasthan, south-eastern part of Haryana and south central part of Delhi and extend up to the west bank of Yamuna River as seen near Okhla in south Delhi and Wazirabad in the northeast. General elevation of plains around the hills varies between below 200 m above mean sea level and ridges rise from 200 to 700 m above mean sea level.

The physiography of the Aravalli hill region has three parts (Map 2.2). Areas below 200 meters are known as old and new plain. Area between 200 to 300 meters is composed of denuded hills, offshoots and outcrops of Aravalli and rocky and sheet wastelands. Areas with an elevation of around 300-700 meters come in Alwar districts and along the boundary of Gurgaon and Faridabad. That has forest (Map 2.5).

In general, as per their appearance (Map 2.2), Aravalli Hill region of NCR can be further divided into two different physiography units as:

- Alluvial flood plain and old flood plain that is 200 m above mean sea level.
- Hilly rocky, Ridges and off shoots of Aravalli that are visible above 200 m above mean sea level.

Low altitude Yamuna, Sahibi and others river flood plains provide an excellent scope for agriculture, as it is covered by fertile alluvial soil brought by rivers.


Aravalli Hill Region of NCR
PHYSIOGRAPHY
76°30'0"E
77°0'0"E
77°30'0"E
29°0'0"N
28°30'0"N
28°0'0"N
27°30'0"N
27°0'0"N
(Height in Meter)
Above 400
300 - 400
200 - 300
Below 200
Kilometers

Map 2. 2

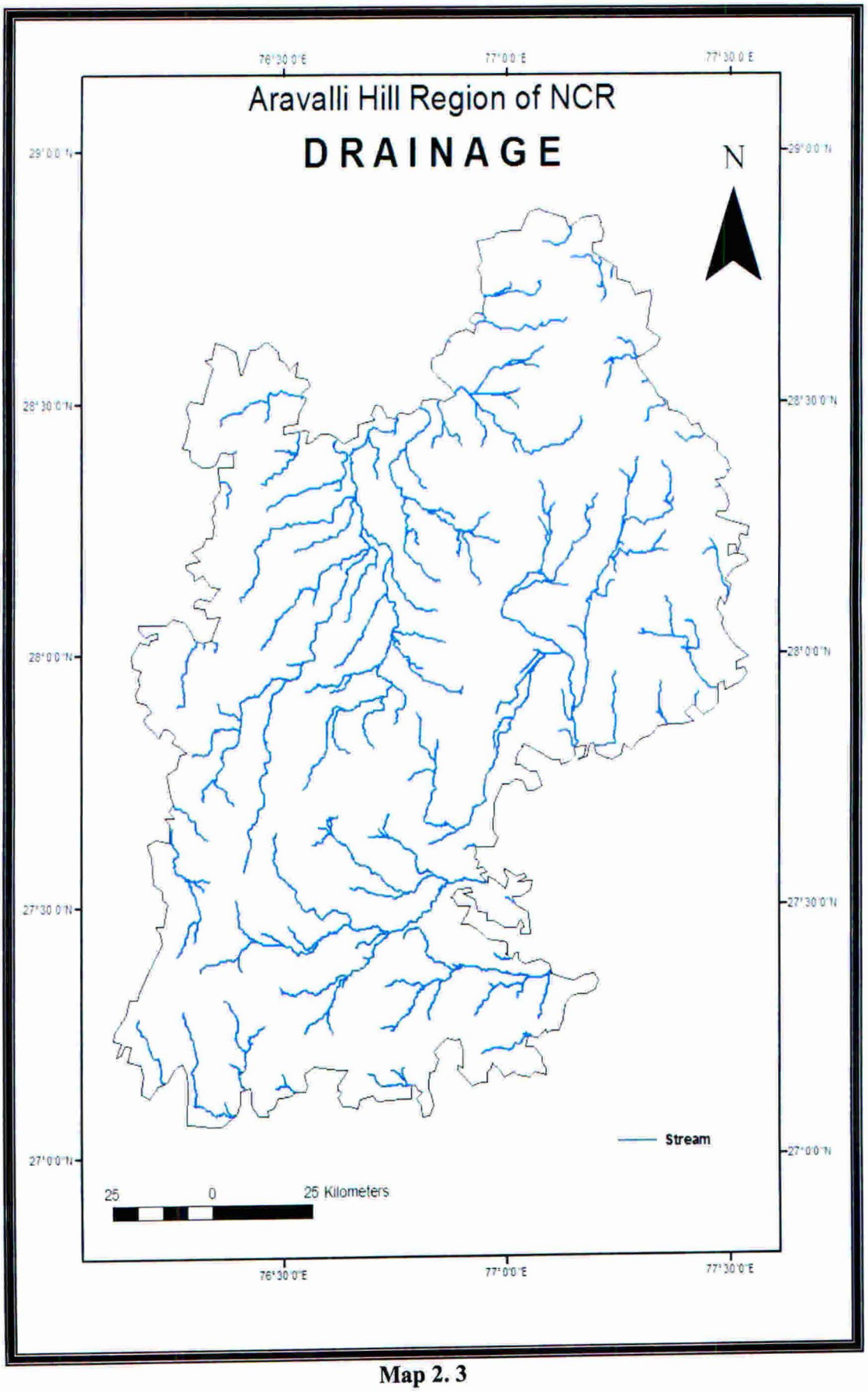
Old flood plain, locally known as Bangar, is dry and less fertile. This area is spread between new-flood plain and rocky surface of Aravalli. Area towards west of ridge representing Older Alluvial Plain is mostly covered by sand dunes and has a westerly slope. Older Alluvium mainly comprises yellowish brown, occasionally white micaceous, medium to fine sand, silt, silty-clay, clay and Kankar. Kankar occurs both in the form of bedded deposits and as sporadic nodular lenses. Area under old and new flood plains has lower elevation of around 200 Meters.

Ridge or rocky areas of Aravalli hill in NCR, reaches up to height of 700 meters. The rocky surface represents structurally controlled rectilinear ridges and isolated hillocks comprising of rocks of Aravalli- Alwar-Delhi Super group (Map 2.1) and isolated hills mostly occur in northern part of Rajasthan, Southeast Haryana and south and south-western part of Delhi.

Sand dunes, barren low hills and outcrops are other features of Aravalli in NCR. Rocky barren land and its outcrops are seen in the west in Rewari and North West Alwar districts. Flat topped prominent and precipitous hills of the Aravalli range enclosing fertile valleys and high table lands are seen in the south-west region. Rest of the region comprises plain below 200 m (Map 2.2) with general slope from north- east to south and south-west.

2.3 DRAINAGE

Drainage is an important element of physical environment. Main drainage of Aravalli in NCR is Yamuna and Sahabi river. These flow along eastern and south western boundary of Aravalli hill region of National Capital Region in Delhi. Other main rivers in the extension of Aravalli are Sahibi, Sota and Utaagan River. Which flow west to east. Apart from these, there are several other seasonal streams (Map 2.3).


Aravalli Hill Region of NCR
DRAINAGE
N
76°30'0"E
77°0'0"E
77°30'0"E
29°0'0"N
28°30'0"N
28°0'0"N
27°30'0"N
27°0'0"N
Stream
25 0 25 Kilometers

Map 2. 3

Apart from rivers, there are several canals and drains in the region. Some of these provide drinking and irrigation water in NCR region. These include Agra canal, and Hindan cut in the southwest, eastern Yamuna canal, in the west. There is Najafgarh drain in the west joining western Yamuna canal. Dariyapur drain also joins Yamuna river towards north-west.

In addition, Najafgarh drain joins Ganda Nala and Mungashpur drain in south-west. There is Li Nala in Gurgaon district. Gurgaon canal runs in Faridabad and Gurgaon. Sahabi river drains in Rewari district. Gaunchhi drain is found in Mewat. There is a Ruparel river flow west to east in Alwar district. Utangan and Banganga flow in south. These emerge from hills of Alwar Aravalli and flow towards Southeast in the district. There is Santa river flowing in north Alwar district (Map 2.3).

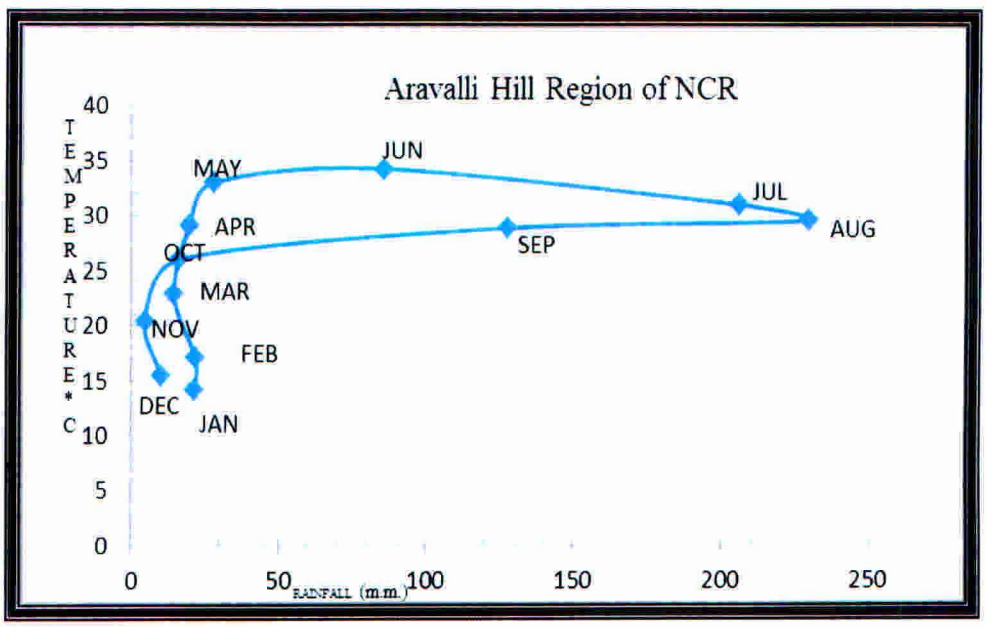
2.4 CLIMATE

Climate is the product of interrelation between the various forces of atmosphere. Precipitation and temperature are the most important elements of climate influencing the physical and socio-cultural aspects of a region.

Climate of Aravalli hill region of NCR in general is subtropical monsoon type marked with seasonality. It is quiet varied and gets effected by weather of nearby hills and plain areas. Delhi experiences extreme of weather in all seasons with very hot summer and cold winter. Climatic conditions are of semi-arid type. Weather registers seasonal changes, hot and dry summer, cold and dry winter and muggy monsoon seasons are very irritating.

Summers in Delhi begin from April and end in June. Temperature slightly falls in the month of July and August to 29 ^{o}C and above (Figure 2.1). Weather of Aravalli in NCR is very hot and dry in summer months with temperature soaring up to 45^{o} C.

However, mean monthly temperature of the region is around 35 °C (Figure 2.3). It is highest in June. Rainy season in July and August provides some relief from heat. Sudden muggy weather in the months of July and August makes life uncomfortable with high humidity and high temperature.



Note: Base on average rainfall and temperature of four stations of Aravalli region of NCR.

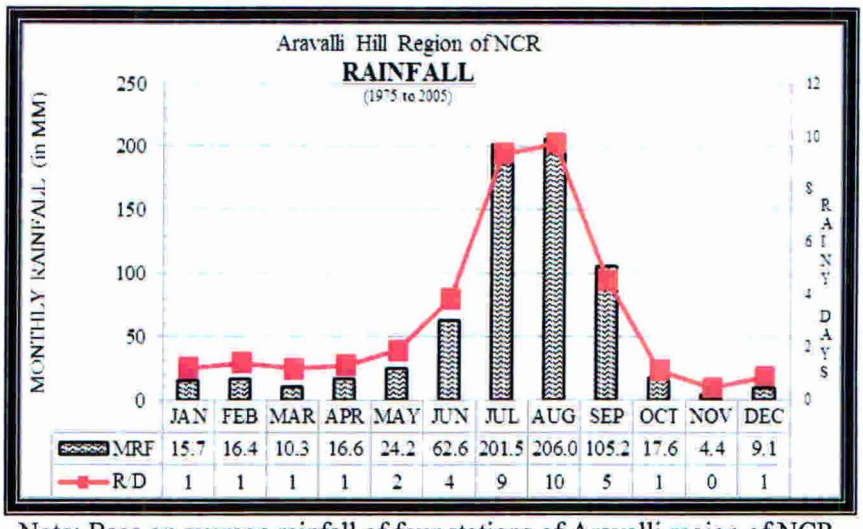
Figure 2. 1

However, rainy season ends in September after heavy rainfall in July and August. Mean monthly temperature of the region is around 12 °C in January. Winter months are characterised by a dip in minimum temperature often reaching 5 °C or less (Figure 2.1). This low temperature in winter month also makes human life uncomfortable.

2.3.1 Rainfall

The region has a short rainy season. That extends from July to September. That is the result of an outburst of monsoon. Month of September sees end of monsoon season and it is reasonably pleasant. About 77 per cent of annual rainfall is received during

monsoon months from June to September. On an average 27 rainy days are recorded in a year. More than 7 rainy days occur in a month during monsoon season. The months of August and July account for maximum rainfall of above 200 mm with more than nine rainy days in a month. Lowest rainfall is observed in the month of November and December below 10 mm. The region does not witness much of rainfall except June, July, August and September (Figure 2.2).



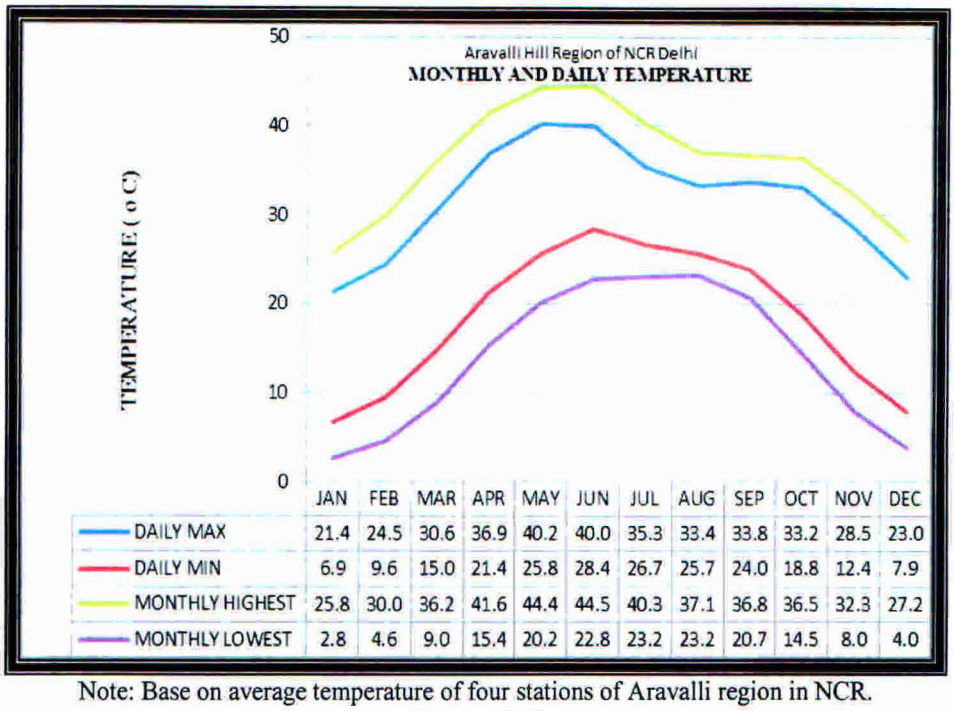
Note: Base on average rainfall of four stations of Aravalli region of NCR.

Figure 2. 2

It can also be observed from figure 2.2 that Aravalli hill region of NCR has a short rainy season. Rainy season is mainly continued monsoonal months. This region remains dry in other months. It creates harsh conditions for growth of vegetation.

2.4.2 Temperature

Aravalli hill region in NCR is known for its bitterly cold winter and hot dry summer. Temperature fluctuations in the region are very high. In summer, Maximum daily temperature may go above 44 °C. May and June have high average daily maximum temperature that goes up to 40°C. In contrast, winter season is dry and cold, the daily average minimum temperature reported around 7°C or less. Lowest temperature is around 3°C in the month of December and January (Figure 2.3).



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DAILY MAX	21.4	24.5	30.6	36.9	40.2	40.0	35.3	33.4	33.8	33.2	28.5	23.0
DAILY MIN	6.9	9.6	15.0	21.4	25.8	28.4	26.7	25.7	24.0	18.8	12.4	7.9
MONTHLY HIGHEST	25.8	30.0	36.2	41.6	44.4	44.5	40.3	37.1	36.8	36.5	32.3	27.2
MONTHLY LOWEST	2.8	4.6	9.0	15.4	20.2	22.8	23.2	23.2	20.7	14.5	8.0	4.0

Note: Base on average temperature of four stations of Aravalli region in NCR.

Figure 2. 3

2.8 SOIL

Soil of Aravalli region in NCR varies considerably as it has developed under different geological conditions (Map 2.1). Soil of Aravalli NCR can be broadly classified into seven categories by co-relating the taxonomical classification provided by NBSS and LUP (ICAR) [4]

The classification is as follows shown in Map 2.4.

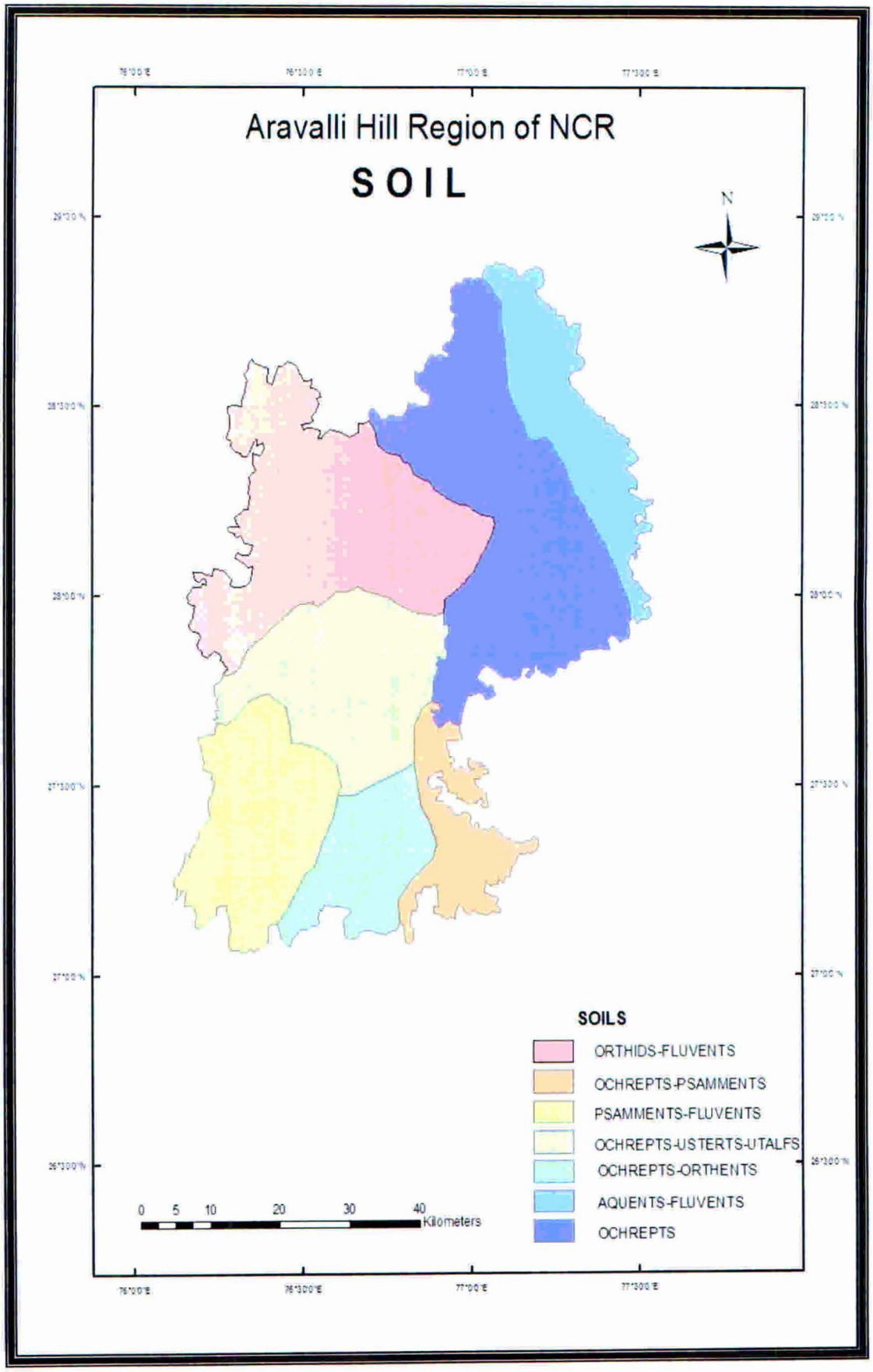
- ORTHIDS-FLUVENTS- Fluvial- Aeolian Plains: Sandy soils with loamy surfaces. Soil erosion is marginal with high moisture and water retention capacity.
- OCHREPTS –PSAMMENTS- Shallow black, brown and alluvial sandy soil: Soil has developed by an alluvium process of river.
- PSAMMENTS- FLUVENTS- Sandy and new alluvial soil: in area surrounding of ridges of Aravalli in NCR. This has developed by rivers, coming from the hills of Aravalli like Sota, Banganga and Sahabi. Due to

rocky surface of hills no infiltration occurs that results in high runoff to erode surface, and that have deposits sandy and alluvial soil. This soil is found in southern district of Alwar, western part of Gurgaon and eastern part of Faridabad.

- OCHREPTS-USTERTS-UTALFS- Aravalli Pediments- shallow black, brown, coarse loamy soil with loamy surface and deep black soil that has low infiltration and high runoff. This soil is found on ridges of Aravalli.
- OCHREPTS-ORTHENTS - Old alluvial plains: loamy soil eroded surface and less fertile soil with slight salinity and water logging surface.
- AQUENTS-FLUVENTS - Active alluvial plains: are found along with the flood plain Yamuna river. This soil is more fertile compared to other. It suffers from water logging problem.
- OCHREPTS- shallow black, brown and alluvial soil of the northern region: soil of flood plains is round along riverine tracts and is characterized by highly stratified river deposits subjected to seasonal inundation. This soil is coarse loamy in texture and of good quality with sub-soil water. It is of recent origin and is composed of mostly stratified layers.

According to soil, characteristics as given by NBSS & LUP, distribution of soil cover of NCR Aravalli has been shown in Map 2.4. But looking at their regional characteristic, soil of Aravalli can also be clubbed into three groups as given below.

- Khadar - New alluvium (AQUENTS-FLUVENTS):
- Bhanger-old Alluvium soil (OCHREPTS)
- Kohi Soil-Rocky areas (OCHREPTS-USTERTS-UTALFS):


Aravalli Hill Region of NCR
SOIL
N
SOILS
ORTHIDS-FLUVENTS
OCHREPTS-PSAMMENTS
PSAMMENTS-FLUVENTS
OCHREPTS-USTERTS-UTALFS
OCHREPTS-ORTHENTS
AQUENTS-FLUVENTS
OCHREPTS
0 5 10 20 30 40
Kilometers

Map 2. 4

a) Khadar - New alluvium (AQUENTS-FLUVENTS): The soil is of recent origin found in flood plain along rivers. This soil shows a distinct stratification. It is usually silt to sandy loam in texture and contain less clay. Khadar is found in Shahdara, along flood plain of Yamuna. It is also found along riverine tract of sahibi where it is characterised by highly stratified river deposits. Here the soil is sandy, coarse and loamy in texture and moderately drained and has good capacity to retain plant nutrients.

b) Bhanger-old Alluvial soil (OCHREPTS): It occurs in western part of Delhi, Gurgaon and Faridabad districts. Its area in Delhi lies in Narela, Najafgarh, and part of Rewari, Gurgaon and western part of Faridabad districts. Rewari district has sandy to loamy sand soil on undulating topography; with low water table. This soil is generally fertile with high moisture content but patches of saline alkaline soil is also founds in the area. Faridabad district is mostly covered with of old alluvial soil.

d) Kohi Soil- Rocky areas (OCHREPTS-USTERTS-UTALFS): Rocky areas of the Aravalli Hills are prone to high surface runoff and severe erosion is observed mostly in south western and northern part of the region. Delhi ridge and Alwar ridge are composed of quartzite or sandstone where soil texture varies from sandy loam to clay loam. Due to the uneven topography, structure and texture of landforms, soil is subjected to a high rate of erosion and weathering. Gurgaon district has mostly rocky surfaces of Aravalli hills except in some areas, which have sandy loam to coarse loam texture of soil. Here soil is very deep with coarse loam and severely eroded and has slightly saline. Aravalli pediments cover Alwar district. Here it moderately deep, undifferentiated and has rocky area of Aravalli. It is subjected to high surface runoff and severe erosion.

2.9. MINERAL RESOURCES

Understanding of mineral resources of a region is very important as mineral resource rich regions are very prone to land use and land cover changes and environment degradation. Aravalli is a rich from the mineral resource point of view. It has considerable deposits of resources mentioned below:

- Barytes
- Feldspar
- Quartzite
- Copper
- Clay
- Calcite
- Building Stone
- Limestone

The Aravalli hill region is an important mineral resource region having an almost monopoly in the mining of non-ferrous minerals like Zinc, copper, Lead and Silver. It has large reserves of ferrous minerals such as Iron-ore and Manganese. Non-metallic minerals such as Dolomite, Calcite, Emerald, Feldspar, Garnet, Mica, Phosphate, Magnetite and building stones like Marble, Limestone etc.

Major mineral deposits of Aravalli hill region are China clay with a reserve of 7.54 million tonnes occurring mainly in Delhi and Gurgaon, and Quartz with 15-32 million tonnes occurring mainly in Faridabad and Gurgaon. Copper is found in Alwar district with a reserve of 0.31 million tonnes. Major mineral deposits in Alwar are Barytes, Quartz, Calcite, Soapstone, Copper, China clay and Silica sand[5].

Minor mineral deposits found are Asbestos, Feldspar, Fire clay, Soap stone and Quartz. China clay (kaolin), Silica sand and Fire lay deposits also occur in Faridabad district. Gurgaon contributes Silica and Kaolin. Occurrence of Slate deposits is reported

from Rewari district.

2.11 NATURAL VEGETATION

Because of pressure of population, urbanization, industrialization and extensive cultivation, very little natural vegetation has been left in Aravallis. The forest cover of the region is of 'tropical thorn type' ranging from open shunted forests to xerophyte bushes occurring in both plains and hills.

The forest is mainly 'dry deciduous type' with dominant tree types being Kikar and Dhak. Faridabad, Mewat and Gurgaon districts account the least amount of forest cover of total geographical areas. Forest cover is mostly seen as forest in the region. The other tree cover is mainly in the form of orchards in plains. Owning to low rainfall and gravelly substratum of Delhi, the upper strata of soil cannot support any dense perennial vegetation.

Natural vegetation of Aravalli NCR has been seen by dividing the region into four divisions by the NCRPB.

These are:

- Special Protected Areas - National Parks, Sanctuaries and Forests.
- Hilly Vegetation Areas - Shrubs and bushes on rocky surface of Aravalli.
- River Side Vegetation Area – green vegetation surrounding river banks.
- Habitations - Open spaces in urban areas, agricultural lands and parks.

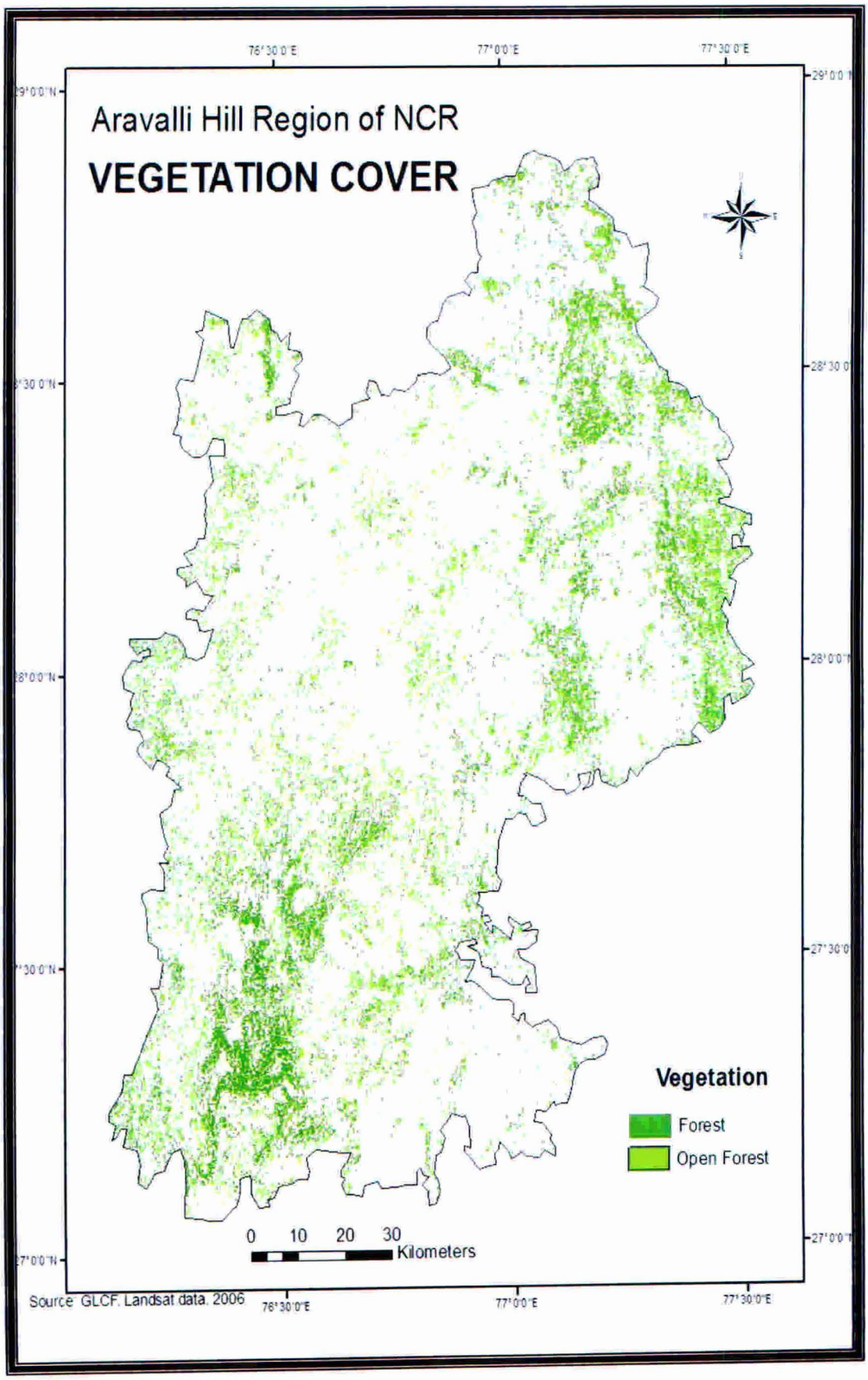
Table 2.1 shows 826 km^2 areas of this region is under forest. It accounts for 5 per cent of total geographical area. Maximum proportion of forest cover is found in districts of New Delhi and South Delhi of around 47 per cent and 31 per cent respectively. Lowest forest cover is found in Rewari, Alwar and northwest Delhi. It is 3

per cent of the total geographical area of these districts. Maximum forest cover in terms of total geographical areas has been observed in districts of Alwar, Gurgaon, Faridabad and South Delhi. Alwar district accounts for largest area under forest cover in Aravalli hill region of NCR. Most of natural vegetation of the region is concentrated in denuded hills.

Table 2. 1

Aravalli Hill Region of NCR VEGETATION COVER				
District	**Geographical Area**	**Total forest**	**% forest Cover**	**% Scrub**
Central Delhi	25	5.05	20	0.0
East Delhi	64	2.99	5	0.0
North-East Delhi	60	3.59	6	0.0
North-West Delhi	440	16.41	3	0.0
New Delhi	35	16.31	47	0.0
North Delhi	59	4.81	8	0.0
South-west Delhi	421	42.45	10	0.0
South Delhi	250	78.64	31	0.3
West Delhi	129	6.33	5	0.0
Alwar	8481	276	3	2.6
Faridabad	2151	93	4	0.9
Gurgaon	2766	229	8	1.8
Rewari	1745	51	3	0.2
NCR	**16626**	**825.6**	**5**	**1.8**
Source: Forest survey of India 2007 (Areas in sq. Km)				

Aravalli hill region of NCR contains around 1.8 per cent areas under scrub cover. Table 2.1 shows maximum areas under scrub is in Alwar district. Very small scrub areas are found in Gurgaon, Gurgaon, Faridabad, and Rewari districts. Delhi does not have of any area under scrubland. It can be said that due to nature of human activities and different forms of land use / land cover practices the area does not have scrub land. Moreover, most of the forest cover in Delhi is also the result of special efforts made by different agencies.


Aravalli Hill Region of NCR
VEGETATION COVER
76°30'0"E
77°0'0"E
77°30'0"E
29°0'0"N
28°30'0"N
28°0'0"N
27°30'0"N
27°0'0"N
Vegetation
Forest
Open Forest
0 10 20 30
Kilometers
Source: GLCF, Landsat data, 2006

Map 2. 5

Map 2.5 shows that maximum concentration of vegetation cover is either in the hill or along the riverside. It can be seen from the map 2.5 hills of Aravalli in south Alwar, Gurgaon and Faridabad, south and south-western parts of Delhi account for highest vegetation concentration. Apart from these others vegetation covered areas are along the riversides along the north eastern boundary of the region.

Maps of vegetation, drainage, physiography and soil show strong interrelation among these. Rich vegetation cover is found on Alwar hills or other denuded hills of Aravalli at higher altitude. Apart from higher areas, most of vegetation cover is along Yamuna, Sahibi, and Sota rivers in north east, south west and south Delhi. Vegetation cover is also seen either along rivers system of Sahibi and Gurgaon canal or on the hills of Aravalli in Gurgaon districts.

Sparse vegetation covers is observed in areas under open forest, bushes, pasture along human habitation in both urban and rural settlements. Some rich vegetation cover may be in the form of community forest, horticulture, floriculture, sericulture and plantation along the roads and railways. Urban-area vegetation cover may be seen either in open spaces, community parks, botanic gardens or along road, railway and canals in the region.

2.12 POPULATION

Distribution of population in Aravalli hill region of NCR is very diverse. Urban areas of the region account for highest concentration of population (Table 2.2). These include fully urbanized districts of Delhi, Gurgaon and Faridabad also have more concentration of population compared to other districts of the region. Alwar district had the lowest density. It appears that as we go away from Delhi, the population concentration trends to decline.

Aravalli NCR Region had a total population of 257 lakh of which 77 per cent

was in urban areas in 2011. Alwar district had highest rural population with total population of 37 lakh people and 82 per cent of them living in rural areas.

Table 2. 2

POPULATION OF ARAVALLI HILL REGION IN NCR							
District	Population (in lakh)	% population	Geographical Area (in km sq.)	% Urban population	Population Density	Sex Ratio	Literacy Rate
Central Delhi	5.8	2.3	25	100	23147	892	87.6
East Delhi	17.1	6.7	64	100	26683	883	88.75
New Delhi	1.3	0.5	35	100	3820	871	89.38
North Delhi	8.8	3.4	59	98	14973	811	86.81
North East Delhi	22.4	8.7	60	99	37346	886	82.8
North West Delhi	36.5	14.2	440	94	8298	862	84.66
South Delhi	27.3	10.6	250	100	10935	859	82
South West Delhi	22.9	8.9	421	94	5445	836	87
West Delhi	25.3	9.8	129	100	19625	876	88.81
Mewat	10.9	4.2	1510	11	721	906	56.14
Rewari	9	3.5	1745	15	562	898	82.23
Faridabad	18	7.0	2151	79	2298	871	83.04
Gurgaon	15.1	5.9	2766	69	1241	853	84.44
Alwar	36.7	14.3	8481	18	438	894	71.68
NCR Aravalli	257		18136	77	11109	871	82.52
Sources: Provisional Population Total, Census of India, 2011							

Most districts of Delhi do not have rural population except North Delhi, Northeast Delhi, North west Delhi and South west Delhi. Here again the share of rural population was very low. Gurgaon and Faridabad is highly urbanized district with 69 per cent and 79 per cent urban population respectively in 2011. These districts are also very densely populated. Population density of an Aravalli hill region is very high of 11109 people per Km^2. Higher population density is found in north east Delhi, East Delhi and central Delhi of more than 20 thousand persons per km^2. Districts with large rural population have low density in the region.

Sex ratio of Aravalli in NCR is not balanced. These were 871 females per 1000 males in 2011(Table 2.2). Sex ratio is low across districts and in both rural as well as urban areas in the region. Some imbalance in sex ratio could be due to male selective in-migration to urban centres. But this alone cannot explain low sex ratio figures in all districts including less urbanised districts. It requires further in depth study to find reasons of this.

Literacy scenario is quite good in Aravalli hill region of NCR with 82.52 per cent literacy. Only too districts namely Alwar and Mewat had less than 80 per cent literate population. In fact Mewat district had the lowest literacy with 56.14 per cent literate people in the region. These two districts are relatively less urbanised. As expected, more urbanized districts of Delhi and its adjoining districts have higher literacy.

It may be concluded that Aravalli region of NCR has very varied environment in terms of physiography, drainage and soils. It has semi-arid monsoonal continental type of climate. Vegetation cover is restricted to only a few pockets. The region has high population with very density. In fact, the capital city of Delhi located within the region has strong influence on all aspects of physical environment as well as on human resources.

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CHAPTER-III

LAND USE / LAND COVER CHANGES IN ARAVALLI HILL REGION OF NCR

Land is an important natural resource on which all biotic and abiotic activities :ake place. Land contains bio-diversity and provides carrying capacity to all species iving on earth. Human beings are greatly dependent on land, using it as a source of ıatural resources in order to fulfil their needs. As such, land based resources may be :onsidered amongst the most important natural gifts available to human beings. Some of he major uses of lands include for habitation, as a source of energy through ınderground resources like coal, natural gas or oil, for locating industrial ventures, as a nedium for agriculture, for forestry and as grazing land etc.

Increasing human population and their economic activities have raised pressure ɔn available land resources over the years. Land resources are limited and some ıuthorities have created an adverse impact on these. In particular, intensification of ıgriculture and expansion of urbanization have led to land use changes at a rapid rate ınd over exploitation and degradation of land resources. Along with anthropogenic ımpacts, these are natural phenomena such as volcanic activity, landslides, avalanches, ınd floods, etc., which also affect land resources and lead to land cover changes.

Land resource planning is crucial for sustainable use of natural resources and ɔlanning is not possible without knowing existing resources. It is important to look at :xisting natural resources and their utilization pattern for land and other natural resource management. It is also important to see utilization trends of land resources across time. Information on the rate and kind of changes in the use of land resources is essential for

proper management and planning. This can help in putting checks and balances and conserve natural resources. It is in this light that knowledge of land use and land cover is important.

It is necessary to understand and quantify the processes of landscape change to ensure a sustainable management of natural resources. Patterns of landscape modifications and changes are the results of complex interactions between physical, biological and social forces[1]. Here biological and social forces are related to anthropogenic factors. Information on land use and land cover is useful for assessing the impact on soil degradation, desertification, changes in water quality and components of hydrologic cycle, and possible change in micro and meso-climate of a region. One needs to monitor and characterise spatial patterns of land-use / land-cover changes.

Urban expansion and increase in human activities due to population increase and other factors are changing the natural environment of Aravalli hill region of NCR. Urban centres are to keep pace with growing population, and their expanding economic activities need more land. This results in the processe of acquisition of surrounding land to keep pace with urban expansion. It has resulted in drastic changes in land use / land cover and the landscape of Aravalli hill region of NCR. The present study has been done to monitor and detect the level and pattern of land use / land cover changes in the region.

Changes detected from different temporal images usually reflect both natural and human activity impacts. Aravalli hills because of location in NCR are especially susceptible to environmental degradation due to high growth of population and urbanization. Thus, monitoring the land use / land cover changes using multi temporal remotely sensed Landsat images provide an idea about the rate and magnitude of changes over space and time.

Table 3. 1

Landsat data have used in land use / land cover change				
MSS (1975 - 1977)				
I.D.	WRS: Path/Row	Acq.Data	Datasat	Producer
020-864	1:157/040	March, 1977	MSS	Earth sat
020-865	1:157/041	March, 1977	MSS	Earth sat
020-875	1:158/040	March, 1975	MSS	Earth sat
020-76	1:158/041	March, 1975	MSS	Earth sat
ETM+ (1999-2000)				
I.D.	WRS: Path/Row	Acq. Data	Data sat	Producer
038-809	2:146/040	October, 1999	ETM+	Earth sat
038-857	2:147/040	September, 1999	ETM+	Earth sat
038-810	2:146/041	October, 1999	ETM+	Earth sat
038-858	2:147/041	September, 2000	ETM+	Earth sat
ETM+ (2006)				
I.D.	WRS: Path/Row	Acq. Data	Data sat	Producer
251- 946	2:147/042	September,2006	ETM+	Earth sat
251- 945	2:147/041	September,2006	ETM+	Earth sat
251- 944	2:147/040	September,2006	ETM+	Earth sat
251- 895	2:146/042	September,2006	ETM+	Earth sat
Source: Global land cover facilities, Landsat data, 1977, 1999, 2006.				

Remotely sensed multi-layer data have been used in classification of land use / land cover. Traditional classification of algorithms, supervised classification and unsupervised classification, have been used in land use classification of the images.

For processing of Landsat data following methods have been used.

- Digital data processing
- Visual interpretation
- Verification of the data through other secondary sources.

Landsat data collected for three time periods of 1977, 1999 and 2006 has been used in land use / land cover analysis. Digital image processing facilitated by computer implemented statistics algorithms enabled maximum spatial resolution of the data at a high degree of manipulation. This was done with the help of ERDAS 9.1 and Arc View 9.3 software.

An attempt has been made to reduce error in image classification. Classification processes used logical reasoning through appropriate knowledge of the study area and

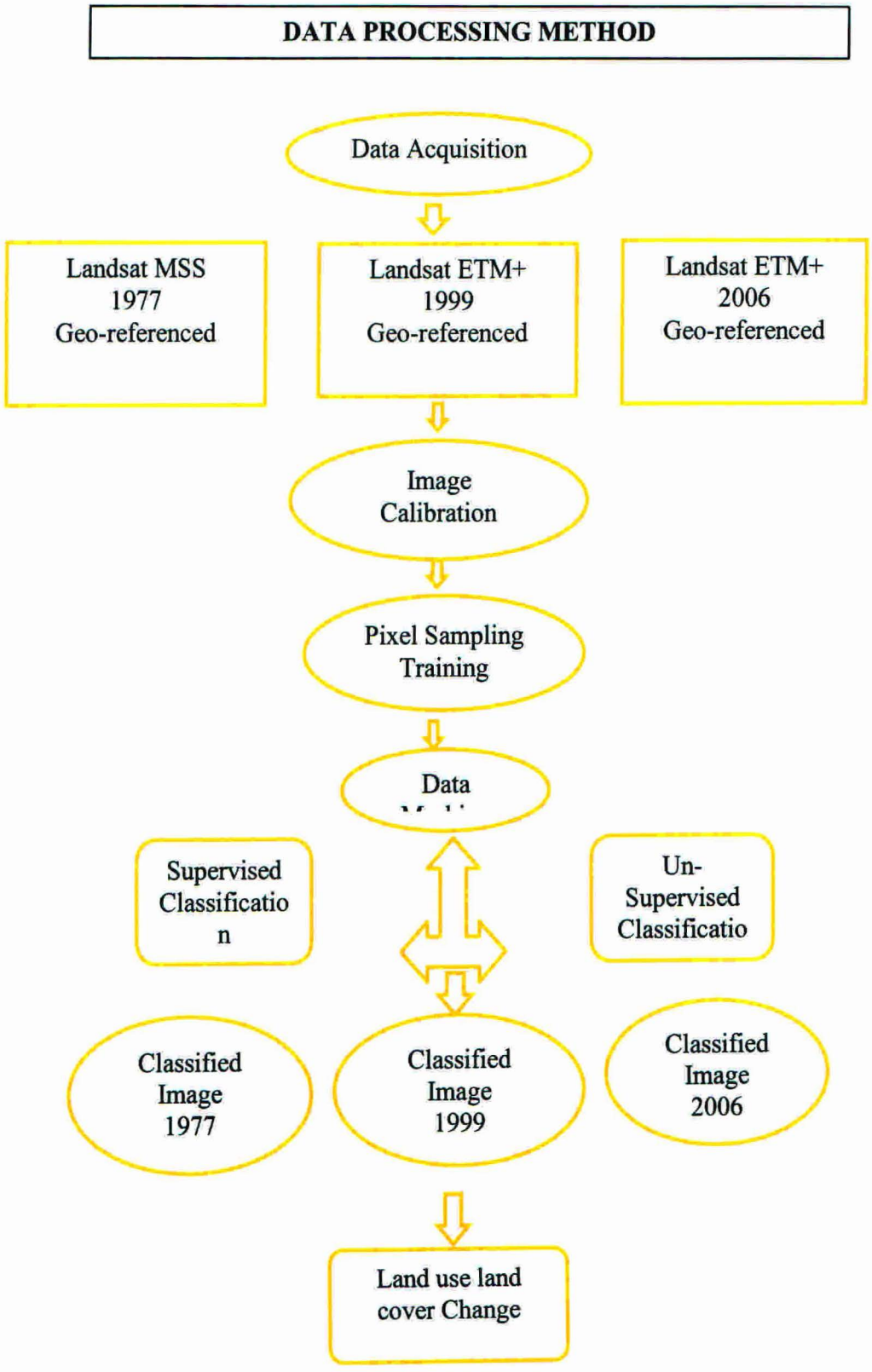

DATA PROCESSING METHOD
Data Acquisition
Landsat MSS
1977
Geo-referenced
Landsat ETM+
1999
Geo-referenced
Landsat ETM+
2006
Geo-referenced
Image
Calibration
Pixel Sampling
Training
Data
Supervised
Classificatio
n
Un-
Supervised
Classificatio
Classified
Image
1977
Classified
Image
1999
Classified
Image
2006
Land use land
cover Change

Figure 3.1

Table 3.2 National land use land cover classification system

S.N.	LEVEL I	LEVEL II	LEVEL III
1	Build-up Area	Build-up(Urban)	Residential Industrial
		Build-up (Rural)	Commercial Transportation Recreational
2	Agricultural Land	Crop land	Kharif
			Rabi
			Zaid
		Fallow	Current Fallow
		Plantation	Tea, Coffee, Rubber, Horticulture, Floriculture, farm Forestry, social Forestry
3	Forest	Evergreen	Dense Forest
		Deciduous Forest	Open forest
		Grass land Forest Plantation	Degraded forest
4	Grass Land and Grazing Land	Grasslands Manmade Grasslands	Moist Dry Pasture Grassland with tree cover
5	Waste land	Salt Affected Gullies ravines Scrub land Sandy Area Barren Rocky Stony	Saline Alkaline Shallow Land with Scrub and land without Scrub Barren land Rocky land
6	Wet land	Inland wet land	Oxbow Meander Marshy Swampy Water logged
7	Water Bodies	River System Lakes Ponds Canal Reservoirs Drain	Stream Lake Pond Canal Drain

ground truth of sample area using photo elements like texture, tone, colour, size and pattern aided by secondary sources. For cross checking and ground conformation of the satellite image classification, secondary sources such as the Survey of India; Topographic sheets, National Atlas and Thematic Mapping Organization (NATMO) land use / land cover maps of National Capital Region and USGS: Earth explorer maps have been used.

3.1 LAND USE / LAND COVER OF ARAVALLI HILL REGION IN NCR

Land use classification can be defined as "the process of defining land use classes on the basis of selected diagnostic criteria by using methods provided by National Land use classification system[2]. Eight land use and land cover classes were developed to map remotely sensed Landsat data for 1977, 1999 and 2006. It was classified using image differencing and image classification methods.

Land has been categories into eight major land use / land cover classes:

1. Agricultural Land
2. Build-up Areas
3. Dense forest
4. Open forest
5. Degraded forest
6. Barren Land
7. Pasture Land
8. Water Bodies

Map 3.1

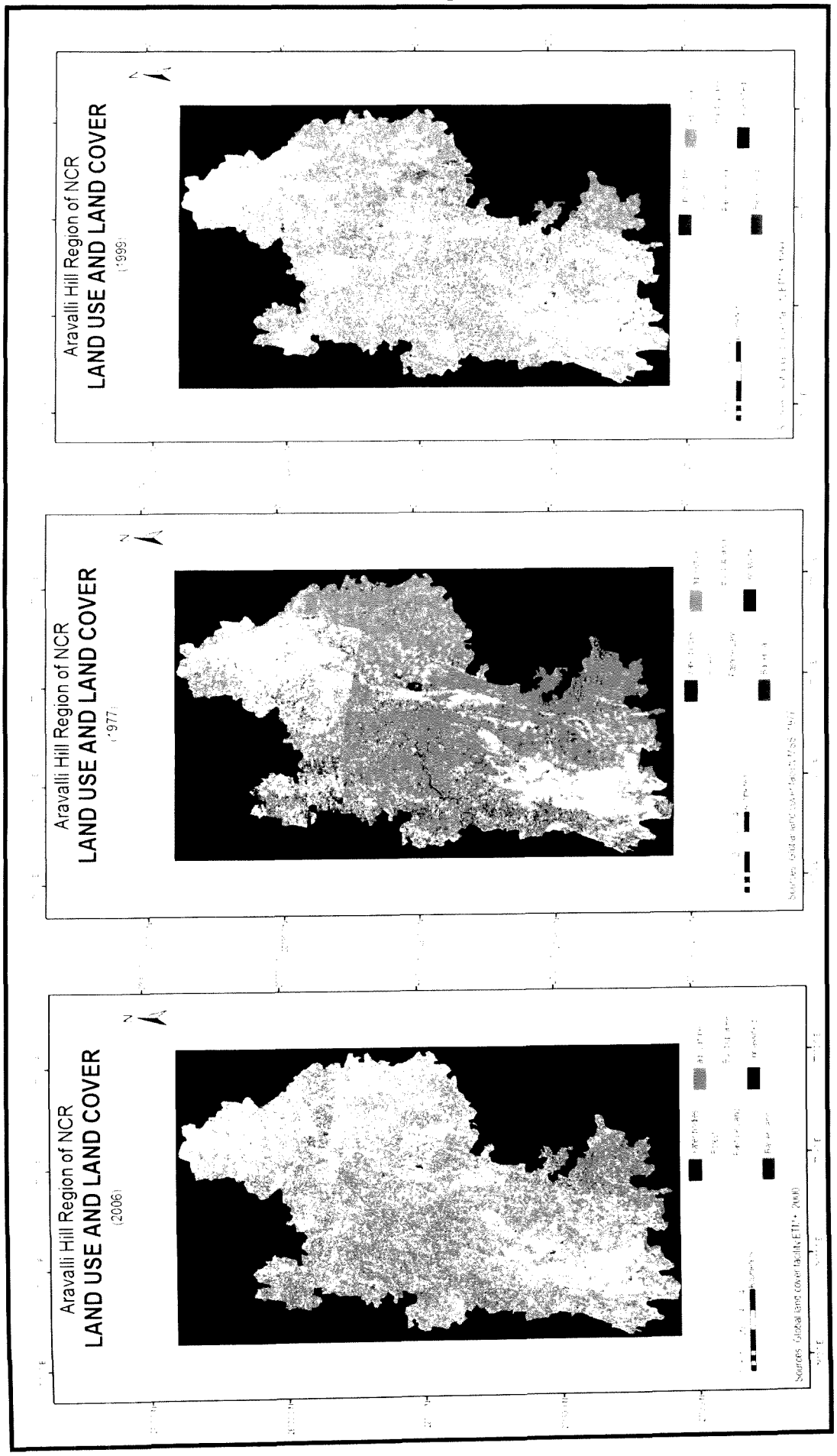

Aravalli Hill Region of NCR
LAND USE AND LAND COVER
(2006)
Aravalli Hill Region of NCR
LAND USE AND LAND COVER
(1977)
Aravalli Hill Region of NCR
LAND USE AND LAND COVER
(1999)

Table 3.3

Land use / land cover of Aravalli hill region of NCR

Classes	Area (in Hec) 1977	Area (in Hec) 1999	Area (in Hec) 2006
Agriculture	950807 (56.9)	813452 (48.6)	756663 (45.3)
Barren land	167190 (10.0)	113125 (6.7)	80735 (4.8)
Build-up area	137568 (8.23)	233077 (13.9)	307578 (18.4)
Dense forest	52363 (3.13)	36763 (2.2)	27399 (1.63)
Open Forest	98085 (5.8)	151355 (9.05)	153680 (9.2)
Degraded Forest	88349 (5.28)	211916 (12.6)	199871 (11.9)
Pasture	148830 (8.9)	95965 (5.7)	127617 (7.6)
Water Bodies	27697 (1.6)	15240 (0.9)	17345 (1.0)
Total	**1670888 (100)**	**1670892 (100)**	**1670889 (100)**

Source: Landsat image, Global Land Cover Facilities, (1977-2006).
Note: Figures in parenthesis pertain to percentages.

3.1.1 Agriculture land

Agricultural land is the area which is broadly defined as land used primarily for the production of food grains, vegetable, fruits and fibre. In the present study, agriculture land has been classified on the basis of ground truth of sample area using photo elements like texture, tone, colour, size and pattern aided by secondary sources. In the classification of agriculture land, canopy cover and growing season of cropland differentiated from the Landsat image. It has been done with the help of secondary sources.

Agriculture is an important activity in rural areas of Aravalli hill region of NCR. Importance of agriculture can be visualized by the fact that more than 52 per cent people of India are still involved in the agriculture and allied activities. Rural people of Aravalli hill region of NCR are mainly dependent on cultivation for their livelihood.

Scholars argue that in densely populated countries like India there is not much scope of further expansion of agricultural land. In fact, there has been a decline in crop

area due to construction on prime agricultural land on account of urban expansion, industrialization and other related activities.

Table 3.3 shows agricultural land covered around 950807 hectares i.e. 56.9 per cent of the total land of Aravalli hill region of NCR in 1977. Areas under the agricultural land have been consistently declining from 1977 to 2006. Areas covered by agricultural land in 1999 were 813452 hectares i.e. 48.6 per cent of total geographical areas of the region. It shrunk to 756663 hectares and covered 45.3 present of total area in 2006. There was a 12 per cent loss of agricultural land during 1977 to 2006. This consistent decline seems to be either due to the spread of built-up area or increase in forest.

Most agricultural land of the region is found close to water bodies like rivers, canal, drains, ponds and lakes. Eastern, south-eastern and north-western parts of Aravalli hill region of NCR comprise agricultural land experiencing change over time. Most of the changes in agriculture land use have been seen around urban centres of Delhi, Gurgaon, Faridabad and Alwar. It seems that this land is being brought build-up area and open forest (Map 3.1).

Lot of expansion of other land uses in Aravalli hill region of NCR can be attributed to decline of agricultural land. There is positive increase in build-up area. Land under other categories does not show much linkage with loss of Agriculture land. So it can be said that most of land under agriculture is going to build-up area.

Mainly real estate business seems to be responsible for decreasing agricultural land. This land is being used to provide residences, business places, industrial buildings, roads and railways etc. for the growing urban population. Most of the expansion is happening at the cost of agricultural and barren land and that is why this area is registering changes in land use across the period of study.

Growing demand of infrastructure and construction of infrastructure in NCR may be seen as one of the factors which have led to creating pressure on agriculture land. Constructions of infrastructure as roads, railways, canals to cop up with growing demand of population not only put pressure on agricultural land but are also degrading land. The Government of India, keeping in mind existing problem of over concentration of population in the region, has brought new areas under National Capital Territory. This has created new possibilities of further expansion of build-up area. New land has come under the ambit of urbanization process through this process.

3.1.2 Build-up areas

Built-up area constitutes of areas of intensive use with much of land covered by structures. Included in this category are cities, town, villages, and strip development along highways, power transmission lines and communication facilities and land under shopping centres, industrial and commercial complexes and institutions. These may, in some cases, be isolated from urban areas[3]. This includes all land occupied by buildings, roads and railways or under water, rivers and canals, and other land put to uses other than agriculture.

Many build-up structures look bright in intensity in the Landsat image. Appearance of an image based on colour and texture has been used in the classification of build-up area from the images.

The built-up area registered major increase during 1977 to 2006 in the study areas. This change in build-up area of the region got accelerated due to urban expansion caused by urban population increase. Industrialization may be seen as a significant contributor to build-up area of the region. This also promoted growth of the service sector in urban centres.

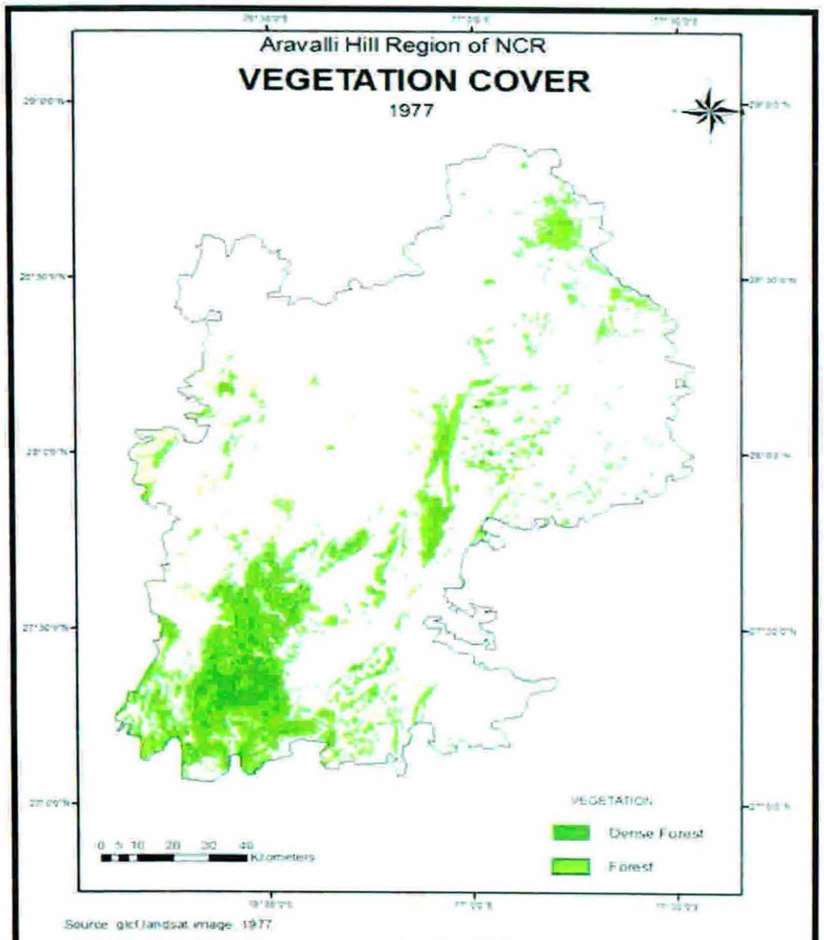
Build-up areas were estimated to be around 137568 hectares i.e. 8.2 per cent of

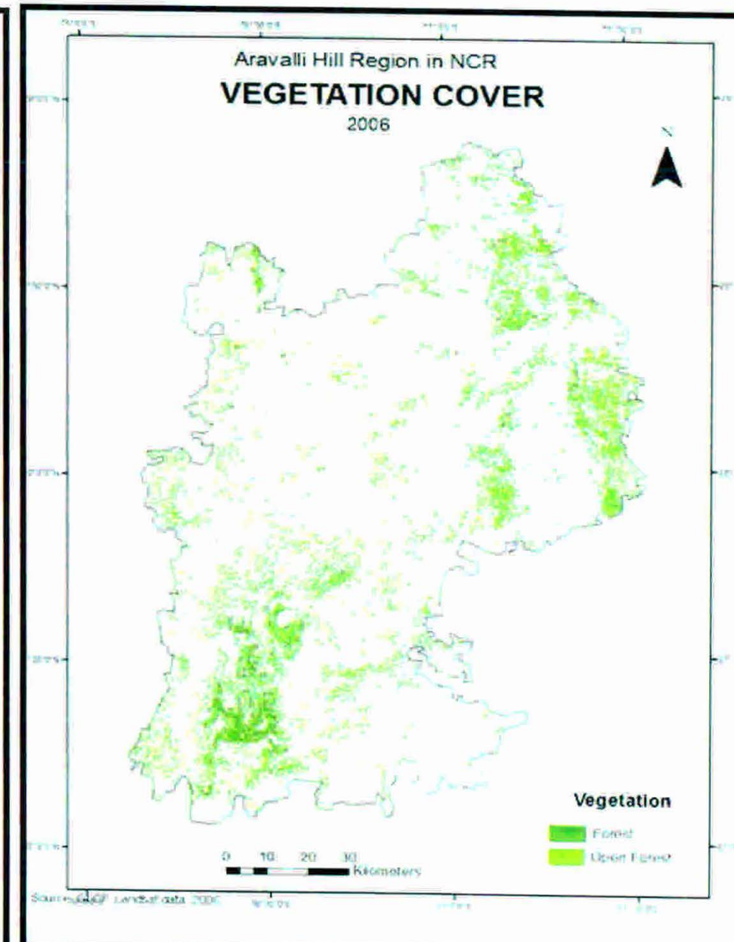
the total areas of Aravalli hill region of NCR in 1977. It consistently increased at a rapid rate and accounted for 233077 hectares that is 13.9 present of the total geographical area of the region in 1999. This further increased to 307578 hectares amounting to 18.4 per cent of the total area in 2006. Thus, a net 10 per cent increase is seen from 1977 to 2006 in the region. It can be observed from Table 3.3 and Map 3.1 that the area under build-up category is continuously increasing. Most of the build-up areas are clearly visible in and around urban centres. This seems to be because more increase in urban population. Most of this land has gone for construction of residential houses and infrastructure and to support other associated business of urban centres. Thus, it is found that the rapid growth in population and growing residential and commercial activity to be the major cause of increase in build-up area in Aravalli hill region of NCR.

3.1.3 Forest land:

A Forest land comprises land under dense forest, open forest and degraded forest. Forest land has been classified from the images on the basis of ground truth of sample area using photo elements like texture, tone, colour, size and pattern aided by secondary sources. Further, division of forest land has been done in to the categories of dense, open and degraded forest. It is based on the appearance in the image. Appearance as dark in colour and size has been taken as dense forest. Moderate colour distribution is for open forest and light colour with fragmented distribution of the degraded forest. Colour tone, texture, size and pattern have been taken as important indicators in the demarcation of forest categories. It has been done with the help of secondary information about the land use of the study areas.

CHANGES IN FOREST COVER ACROSS THE PERIOD OF TIME





Map 3.2

Dense forest is found in hill area of Aravalli and in ecologically protected areas. Area under open forest is located along riverside, canals, railway lines and roads. It is spread randomly in between build-up area and around water bodies and barren land. Degraded forest has is in plain areas around human settlements.

Net forest land is consistently increasing in Aravalli hill region of NCR. Government initiatives have done well by initiating afforestation programme to overcome the problem of deforestation and vegetation loss. Data shows that areas under the dense forest have been continuously deceasing since 1977 to 2006 i.e. Map 3.2. It can be observed that dense forest covered area of 52363 hectares of land in 1977. It accounted for 3.13 per cent of the total area. It came down to 36763 hectare i.e. 2.2 per cent of total area in 1999. It further declined to 27399 hectares in 2006. It meant that only 1.63 per cent of total land was covered with dense forest in 2006 (Table 3.3).

This shows a continuous decrease in dense forest of the region. As opposed to this, open forest has shown an increase in Aravalli hill region of NCR since 1977. It can be said that forest land is more vulnerable due to expansion of built-up area in the region. An increase in the total and urban population of NCR demands more land for their activities such as for residential use, industries, roads, railways and other infrastructure. Demand of land for industries is creating more pressure in the region. This seems to degrade and deforest the dense forest of the region.

It has been observed that area under open forest category has increased significantly. Land under open forest in 1977 was around 5.8 per cent of the total geographical areas of the region and rose to 9 per cent in 1999. It means that it gained more than 3 per cent land during 1977 to 1999. Open forest cover was more or less same in 1999 to 2006. Total area under open forest was 980856 hectares in 1977. The figure went to 151355 hectares in 1999 that was 9 percentages of the total geographical

areas of Aravalli in NCR. Areas under open forest category increased to 153680 hectares in 2006 that is 9.2 per cent of the total area (Table 3.3). Increase in forest cover seems to be because of afforestation along roads, railways and canals and in many other degraded areas. Most of the open forest cover is visible in and around urban centres (Map 3.2). That is the result of site beatification in urban centres and along roads and railways under afforestation programme. There are some contributors to the increase in area of open forest. Reclamation and afforestation programme of National Capital Region Planning Board seems to be the main contributor to this.

An area of 88349 hectares i.e. 5.3 per cent of the total land was counted under degraded forest cover in 1977. It rose to 211916 hectares in 1999 accounting for 12.6 per cent of the total area. It experienced a slight decline in 2006 and area under it came down to 11.9 per cent. Some of it could the land which earlier had dense forest. Rise in degraded forest could be the result of anthropogenic impact. It could be due to growing demand of land by rising population especially in of urban centres.

Thus it can be observed from the given table that forest area is under stress. Although there is an afforestation programme for regenerating forest yet dense forest has suffered. Recent afforestation and plantation programme is an important factor for increase in area under open forest. An effort has been made to plant trees on barren area, hilly tracts and plain area. Fencing of some hills has also been done to regenerate degraded forest cover.

3.1.4 Barren land

Barren land is the land with limited ability to support vegetation cover. In general, wasteland is classified as land without scrub, barren, rocky or stony waste or sheet area. This category also includes area such as dry land, salt flats, bare exposed rocks, strip mines, quarries, and gravel pits. All non-vegetated barren lands have been

included in this category for study. Land which cannot be brought under cultivation except at a very exorbitant cost is classified as un-culturable land whether such land is in some isolated pockets.

Barren land has also shown a decline in Aravalli hill region of NCR. Table 3.3 shows that it accounted for 10 per cent of total land with an area of 167190 hectares in 1977. It came down 113125 hectares i.e. 6.7 per cent in 1999. It further declined to 80735 hectares i.e. 4.8 per cent in 2006. There was a net decline of 5 per cent in barren land in the region during 1977 to 2006.

Area under barren land seems to be quite high in terms of total area. This may be because of geology and terrain of metamorphic rocks of Aravalli hills. Most of the barren land of Aravalli Hill region of NCR come under rocky and areas. It is not possible to bring these bare areas under vegetation.

3.1.5 **Pasture and grazing land**

This includes all grazing land in the form pasture and meadows. This has all been classified under the category of pasture land. Village common grazing land is also included under this. Pasture land has been defined as land where potential natural vegetation is predominantly grasses, herbs, or shrubs and where there is grazing activity of livestock.

Pasture areas were reported to be around 148830 hectare i.e. 8.9 per cent of the total land in Aravalli hill region of National Capital Region in 1977. But area under this category reduced to 95965 hectares that was 5.7 per cent of the total area. Pasture lands covered an area of 127167 hectares of land accounting for 7.6 per cent area of the region in 2006.

Pastures have got significantly reduced around bigger urban centres but are still found in and around villages especially in the southern part of the region.

3.1.6 Water bodies

Water bodies include land under rivers, streams, canals, lakes, reservoirs, ponds and other water submerged area. Area under permanent wetland or flooded, submerged by water is also considered as area under water bodies.

Most of the water bodies of the region are in the form of rivers, canals, drains, Nalas, ponds and lakes. Amongst there are some seasonal natural drains and rivers. These do not contain much water flow in a year.

Increasing urbanization and industrialization are putting pressure on water bodies by creating more demand of water for use. Pollution and waste dumped around water bodies are significant factors in loss of water bodies. Population increase and rising demand for irrigation are also putting lot of stress on water bodies. Over exploitation of water resources leads to depletion of water table. Cultivation on alluvial soil in close proximity to water bodies also put pressure on water bodies and may cause loss of water bodies. At places, even land is reclaimed from water bodies.

Water bodies covered around was around 1.6 per cent of the total area in 1977. It included land under rivers, canals, lakes, ponds, reservoirs and other open water bodies in the region. But it came down to around 0.9 per cent in 1999 and remains the same in 2006.

Table 3.3 shows that total land under water bodies was 27697 hectares in 1977. It fell down to 15240 hectares in 1999 and slightly rose to 17345 hectares in 2006. It meant net loss of 10352 hectares during 1977 to 2006. This is big loss for a very densely populated like NCR as these water bodies are the source of water and for recreation. These also provide habitat to aquatic flora and fauna. Many water bodies of NCR have become excessively polluted due to heavy discharge of toxic industrial waste and sewage. Some of the water bodies have become unfit for aquatic life.

The above discussion of land use/ land cover changes shows a drastic change in the landscape of Aravalli hill region of NCR over the last four decades. The region is under heavy pressure of urbanization. The study shows that the important changes in Aravalli hill region of NCR. Increase in build-up area and decrease in Agriculture and barren land have been seen as major land use changes in the hill region of NCR. Apart from these, changes have been seen in other land use categories. Area under dense forest has come down. However, significant increase is witnessed in area under open forest. Area under degraded forest is also increasing. Area under pasture show slight reduction while water bodies are stressed due to pressure of population increase.

Expanding build-up area and open forest land has come from conversion of agricultural and barren lands and some from dense forest. Increases in the intensity of urbanization, expansion of rural and urban settlements and infrastructure network have modified the natural environment of Aravalli hill region of NCR.

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CHAPTER – IV

LAND DEGRADATION IN ARAVALLI HILL REGION OF NCR

Land is the upper layer of the earth's crust. It is made up of soil, rocks, water, and other elements of inorganic matter and biota. It also contains man-made landscape and biophysical processes. Loss of its 'usefulness for human beings' is considered as degradation. This is generally considered to be synonymous with soil degradation[1]. Food and Agricultural Organisation defines land degradation as 'a process which lowers the current and potential capacity of soil to produce,[2] while Millennium Ecosystem Assessment (MEA) defines it as 'the reduction in the capacity of the land to perform ecosystem goods, functions and services that support society and development'[4].

Desertification has been considered as a synonymous of land degradation in arid regions in several studies. Arid and semi-arid regions of the world are variably affected by soil salinization and alkalization. Saline and sodic soil cover about 10% of the total arable land and it is found in over 100 countries. According to an estimate, 10 million hectares of irrigated land are abandoned yearly as a consequence of adverse effects of irrigation, mainly secondary salinization and sodification[5].

Land degradation has also been defined as deterioration of physical and chemical properties of soil as a result of environmental changes. Land degradation is a global issue and it has been linked with climate change and loss of biodiversity, but its extent and severity are not exactly known and there is also little knowledge of its immediate effects.

Presently, some discussion is going on about the issue of competition for land resources. Due to ever-growing human population, land under build-up area and food

crops peaked at the end of last century, and there is a growing requirement of land for production of food grains and biofuel. This puts land degradation on the global agenda as an economic, political and environmental problem, and gives a new focus on the significance of land-use change studies.

Intergovernmental Panel on Climate Change (IPCC) argues that "climate change will drive certain types of land degradation by more extreme weather events and a likely increase in total area affected by it. At the same time, land degradation interacts with atmospheric processes and may drive climatic change through increasing greenhouse gas emissions and reducing nitrogen fixation in soils and biomass[3].

Land resources are under tremendous pressure with the growing needs of development and exploding population. Advent of modern age and newer forces, exacerbated by short-term gain driven motives often lead to over-exploitation of natural resources which includes depletion of soil fertility, degradation of land resources and the natural environment.

India occupies 2.4 per cent of the global geographical area and has 16 per cent of the human population and 15 per cent of livestock. This scenario has necessitated proper demarcation of productive and non-productive lands, particularly wasteland that could be treated and reclaimed for productive use[6]. Rapid increase in number of industries, population, intensive agriculture, over irrigation lead to environmental degradation through soil erosion water pollution, soil salinization, alkalization and water logging etc. In order to increase biomass production and restore environmental health, preventive and curative measures need to be employed for rehabilitation of wasteland and degraded land. Information on nature, extent, severity and dynamics of degradation is vital in this endeavour.

Estimation of land degradation in India ranges from 30 million to 175 million hectares. There are also variations in figures of wasteland and degraded land mainly due to lack of mutually agreed definitions of various classes of wastelands, variations in the database used, and methodologies adopted for deriving information on wastelands[7].

Management of natural resources in the wake of the ever increasing demand for food, fuel and fodder pose complex problems for the country's growth and development. Strategies for solving such complex problem lie in understanding the potential of land resources and designing appropriate plans to overcome these, while meeting the basic needs of the nation. There is a pressing need for repeatable and spatially explicit measures to check degradation because its occurrence affects food security, local economic development and natural resource conservation strategies.

Land degradation processes may be categorized as biological, physical or chemical. Each of these may have natural or human induced causes, called as factors or agents or catalysts of the above mentioned processes. Land degradation is mainly human induced but there are also natural or environmental processes which affect degradation. Many studies have focused on human induced land or soil degradation. Most common perspective on land degradation is what farmers see happening on their land in terms of symptoms such as soil erosion and increase in PH value of soil etc.[8]. Land degradation has been mainly seen as the outcome of economic processes due to overuse of natural resources. It is important to see available data sets and findings of recent research on land degradation to measure and monitor long and short term changes in the land degradation.

Land degradation may be assessed qualitatively or quantitatively. The first approach, using expert opinion, may be able to look at several processes those are

usually considered the consequences or symptoms of degradation. These may be related to fertility, biomass or vegetation health. This can be measured by looking at the land use and land cover changes in terms of vegetation cover and non-vegetation cover as has been discussed in the previous chapter. Quantitative approach uses proxy measures like spectral reflectance. It is done by quantifying the information about land resources or degraded land by measuring particular areas.

Land degradation is also measured by looking at vegetation cover because most land-degradation processes adversely affect it. Vegetation dynamics are relatively easier to quantify using remote sensing. It has been widely adopted as an indicator of land degradation at regional and global scales.

Land degradation is one of the most pressing problems of environment. Area of Aravalli hill region of NCR has a semi-arid climate which is highly vulnerable to degradation, salinization and even desertification. It has undergone significant environmental degradation over the past decades, which implies not only climate related changes, but also human induced alterations. Human changes are mainly linked to urbanization, industrialization, overgrazing and agricultural intensification.

4.1 DEGRADED LAND AND WASTE LANDS IN ARAVALLI HILL REGION OF NCR

Wasteland refers to degraded land that is currently un-utilised or underutilized. As stated earlier, it is the outcome of human and natural factors. Over exploitation and lack of management of land resources lead to environmental degradation while overuse of chemical fertilizers, pesticides and irrigation intensify the rate of degradation. As

mentioned above, natural factors are also at times responsible for land degradation.

Table- 4. 1

Wasteland & Degraded land in the NCR Aravalli Region

Wastelands and Land Degradation in Aravalli Hills Region in NCR (Areas in Km^2)					
	Waste & Degraded Land	**2000**	**2003**	**2006**	**2009**
1	Gullies & Ravinous land	268	390	132	93
2	Scrublands	1063	1923	988	987
3	Waterlogged and Marshy land	54	11	21	17
4	Land affected by Salinity & Alkalinity	48	40	22	21
6	Underutilised & Degraded notified Forest land	1058	937	196	150
7	Degraded Pastures & Grazing land	70	111	102	97
8	Degraded land under Plantation Crop	33	41	25	18
9	Sandy Area	92	1	1	1
10	Mining Wastelands	20	23	11	11
10	Industrial Wastelands	0	3	1	1
11	Barren Rocky, Stone Waste & Sheet Rock Area	354	811	303	258
	Total Wasteland & Degraded	**3059**	**4291**	**1802**	**1653**
	Total Geographical Area	16287	16287	16287	16287
	Percentage of Geographical Area	**14**	**26**	**11**	**10**

Sources: wasteland Atlas of India, Department of land Resources, Ministry of Rural Development.(2000-09)

Wasteland Atlas of India and Land sat data have been used in order to estimate and measure degraded land in the Aravalli hills of NCR area. It has been observed from the data that, due to increasing anthropogenic factors like increase in population, urban

population and build-up area, the land under gullies & ravinous land, scrublands, and barren rocky and sheet rock area is decreasing at a fast rate.

Waterlogged and marshy lands have also decreased. Salinization is also decreasing in the region. Waterlogging and marshy land is the result of over irrigation and accumulated water in the rivers and canals. Waterlogging and salinization and alkalinity are directly related to each other. That is why a decrease in water logging may be led to reduction of land affected by salinity and alkalinity. Besides, some such land may have gone to build up area. The degraded notified forest and degraded land under plantation crop land are also decreasing in the region. Even area under degraded pasture land is increasing during 2000 to 2009. Industrial wasteland has increased while mining waste land reduced in the region in this period. Environmental consciousness, afforestation work done by NGOs and the government are behind the success in terms of increase in forest cover and reduction of degraded forest areas in the Aravalli hill region of NCR.

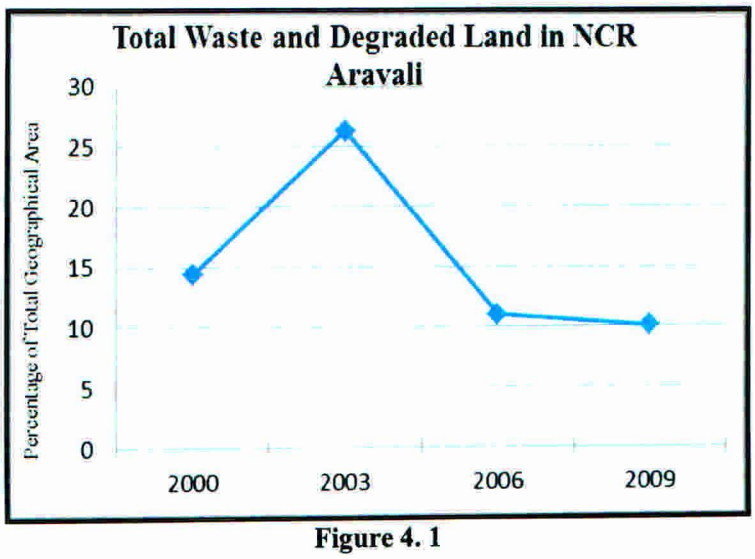


Figure 4. 1

Reduction in terms of absolute areas under different wasteland categories is quite impressive. Area under waste and degraded land categories was 14 per cent of the

total geographical area in 2000. It was highest i.e. 26 per cent in 2003. Area under wastelands accounted for 11 per cent and 10 per cent in 2006 and 2009 respectively.

Wasteland and degraded land has been categorised and classified by the Indian Remote Sensing Agency. Data for four point of time i.e. for 2000, 2003, 2006 and 2009 has been used in the present study. Eleven waste and degraded land classes have been made use of for Aravalli hill region of NCR. These have been interpreted and examined to find the condition of land degradation and wasteland in the region. In Fact, good news is that wasteland and degraded land in the region has come down from 3059 km^2 in 2000 to 1653 km^2 in 2009 registering a net decline of per cent. Table 4.1 shows that land under all categories of wasteland has come down except under industrial wasteland where it increased marginally.

Category-wise discussion of wasteland is as given below;

4.1.1 Gullied and Ravinous Land

Gullies and ravinous land are formed by erosion of landforms by flowing water. The intricate network of gullies is referred to as ravines. It is characterized by undulating topography, loose and sandy to sandy loam soil. Increased gully erosion and ravine formation results in increased runoff at peak discharge for any given watershed.

Gullied and ravinous land shows significant decline during 2000 to 2009. It is of 175 km^2. Decline is wasteland of area under gullies and ravinous land seems to be linked to anthropogenic activities. Increase in population and urbanization seems to have led people to occupy this undulating land. An expansion of urban area with more build-up area is creating direct and indirect pressure on remaining land. This may be one of the major factors responsible for the loss of gullies and ravinous land in Aravalli hill region of NCR.

Figure 4.2 shows that Alwar district for highest concentration of area under gullies and ravinous land. It is because Alwar has lot of gully area. It was observed that area under gullies and ravines land is continuously decreasing from 2003 onward. Highest area under gullied land was 390 km^2 in 2003. It has observed from figure 4.2, area under gullies & ravinous land was 268 km^2 in 2000. It increased in 2003 and then started falling with figure of 132 km^2 and 92.9 km^2 in 2006 and 2009 respectively.

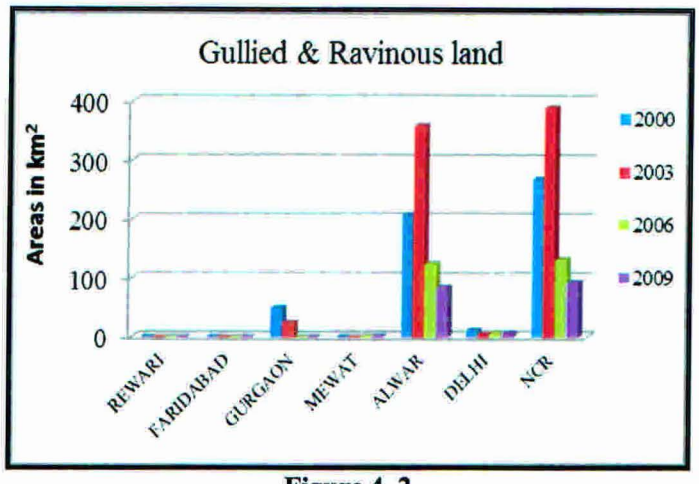


Figure 4. 2

It has been observed that highest concentration of gullied and ravinous land been is in Alwar and Gurgaon districts. Alwar was accounting maximum areas under this categories covering 350 km2 in 2003. It came down to 80 km^2 in 2009. Even in Gurgaon shows significant decline of gullied and ravinous land during 2000 to 2003 and now there is no land under this category. Thus, one can say that there is net decline gullied and ravinous land in Aravalli hill region of NCR.

Loss of ravine land may alter natural environment in the region. It seems to be the outcomes of human intervention on natural environment. It is mainly due growing population which creates demand of land for build-up area, industrial purposes, and for construction of infrastructure and commercial purposes.

4.1.2 Scrub land

Scrub land is characterised by scattered vegetation. Scrubland is generally prone to degradation due to lack of vegetation. Less vegetation on land lead to erosion. Scrub land is mostly found in arid and semi-arid environment. Such lands generally occupy higher locations. Ravines provide more favourable conditions for scrubland and that is why its concentration is seen in rugged areas. It was found land with dense scrub is more resistant to erosion as compared to land with open scrub or without it. Area under shallow and skeletal soil of scrubland is prone to erosion and degradation.

Scrubland accounted for 1063 km^2 in 2000. It went to 1923 km^2 in 2003. Then, it decreased to 988 km^2 and 987 km^2 in 2006 and 2009 respectively. There is total of 76 km^2 reduction in scrubland during 2000 to 2009. Decrease in scrubland observed in Aravalli region of NCR appears to be the result of mainly human intervention due to construction.

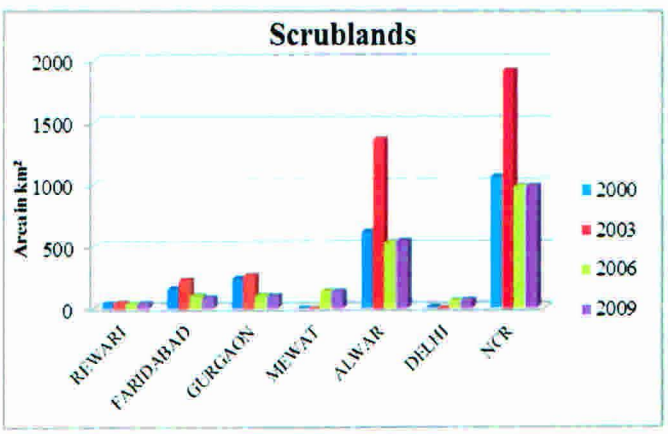


Figure 4. 3

Uplands with rugged topography are more favourable for scrub especially in semi-arid and arid areas. Alwar accounts for highest land under scrub. More arid climate and ruggedly with sandy soil in Alwar district are promoting good condition for scrubland. Figure 4.3 show that Alwar had 1367 km^2 area under scrubland. It has now come down to 547 km^2. As mentioned earlier, Alwar district also has highest area under

gullies and ravines. There is decline in scrubland in all areas of the region.

4.1.3 Waterlogged & Marshy Land

Waterlogging occurs when water table reaches the surface. It is closely associated with salinization and /or sodification. Wetland are seen where water is stagnant for most part a year and it saturates soil pores. Water logging creates marshy condition on land. Land is notified as permanent or non-permanent waterlogged area. Non-permanent water logged area is also classified as seasonal or non- seasonal water logged area.

If waterlogging conditions prevail for most part of a year, then it leads to formation of permanent marshy land. Often, it has been observed that waterlogged areas are found around water bodies like rivers, and canals, and in low lying surfaces.

Problem of human induced water logging in India is more common in canal command areas due to surface irrigation. That is also the result of over irrigation, often carried out without adequate provision of drainage resulting in rise of water table. Some are around Yamuna river suffering from water logging and marshy conditions. Faridabad, Mewat and Delhi have more water logged area of Aravalli hill region of NCR region. Yamuna, Shabi and other rivers are largely responsible for water logging of Aravalli in NCR areas.

Problem of seasonal water logging is also seen during monsoon months from July to September. Permanent water logging surface has been observed on the bank of rivers and in over irrigated areas of Faridabad and Mewat. It may be mentioned that Faridabad and Mewat districts have many quarries. Though quarrying has been banned in some areas but it still illegally going on. Quarrying has led to formation of many depression where waterlogging is seen.

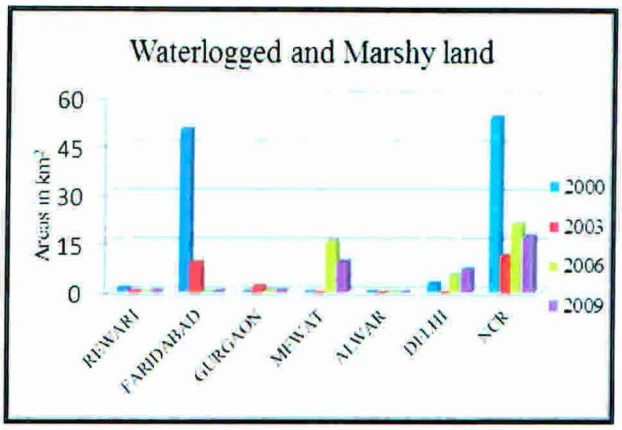


Figure 4. 4

Water logging problem in Delhi is found along rivers and streams. Area of Najafgarh and north-eastern part of Delhi has maximum area under waterlogging. At places permanently water logging has created marshy conditions along river bed. There is net decline in waterlogging and marshy land in 2009. Still land under waterlogging and marshy land covered 17 km^2 areas in 2009. Faridabad district had maximum area under this category in 2000. But now it has come down and waterlogging and marshy land presently found Mewat and Delhi.

4.1.4 Land affected by salinity & Alkalinity

Salinity is defined in terms of dissolved inorganic ions and molecules. Soil salinity is generally measured by determining electrical conductivity of soil solution. Land affected by salinity and alkalinity have excess soluble salts (saline) or high exchangeable sodium. Salinity is caused due to capillary movement of water during extreme weather conditions leaving salt encrustation on surface.

Salinity and Alkalinity exerts negative and direct effects on crop yield by two ways: (a) reducing the ability of plant roots to absorb water, due to increased soil osmotic potential, or (b) the direct effects of saline ions, resulting in either toxicity or

nutrient imbalances.

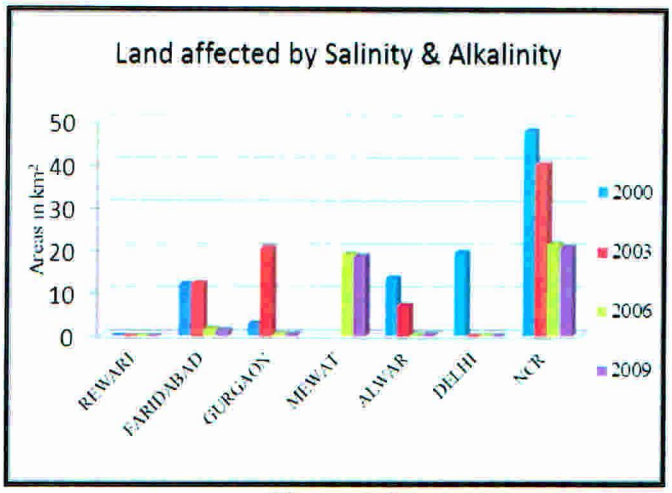


Figure 4. 5

Over irrigation, high runoff, high infiltration of water, use of chemicals and chemical fertilizers are main causes of salinity and alkalinity. Extension of canal irrigation is associated with widespread water logging and salinity problem in irrigated areas. Water logging and marshy land provides suitable conditions for salinity and alkalinity.

There is net decline in land affected by salinity and alkalinity in the region. Decline in waterlogging and marshy land may seem to be one of major causes of decline of land affected by salinity and alkalinity. Given figure 4.5 shows that in spite of decline still around 20 km^2 under this category.

Mewat had the largest area suffering from salinity and alkanity in 2009. Over irrigation of agriculture land and areas lying around Yamuna river and its canals is more vulnerable to alkalisation and Salinization.

4.1.5 Under Utilized Degraded Notified Forest Land – Scrub Dominated

Land with than 20 per cent vegetation cover is classified as degraded forest by

Indian Remote Sensing Agency. This land is generally confined to fringe areas of notified forest.

This generally an area of formerly forest land severely impacted by intensive or repeated disturbance such as mining, fire or overgrazing and with inhibited or delayed forest re-growth. This includes barren area, grassland, brush land, and scrubland. Former forest land is also severely damaged by excessive harvesting of wood and/or non-wood forest products and poor management.

Degraded and notified forest land is also continuously decreasing from 2000 to 2009. Area under this category was around 1058 km ^{2} in 2000 and it subsequently went down to 937 km^2, 196 km^2 and 151 km^2 respectively in 2003, 2006, and 2009. Loss of areas under notified degraded forest land in Aravalli hill region of NCR was to the time of 907 km^2 during 2000 to 2009.

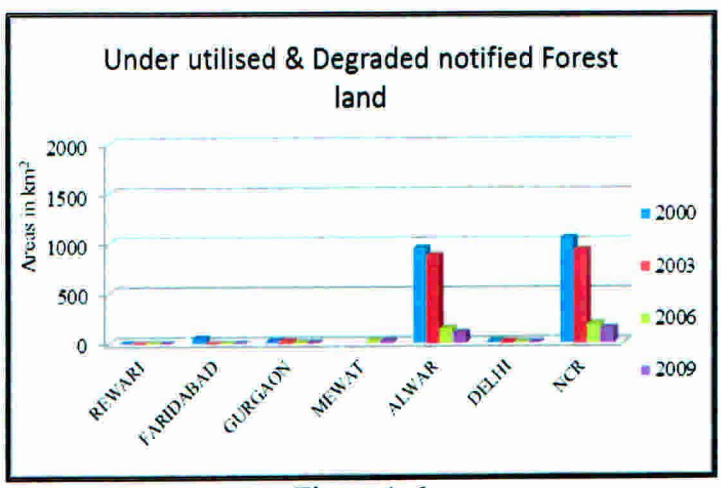


Figure 4. 6

Increase in forest cover by reclamation of degraded forest with afforestation may seem to be major cause for reduction in notified degraded forest cover. Reclamations of degraded land under afforestation programme, wasteland restoration programme and

other rain fed area improvement programme are probably responsible for the decline of degraded forest land of Aravalli in NCR Area.

Highest degraded forest cover was seen in Alwar district in 2000 and 2003 but this area went down in 2006 and 2009. Although sharp reduction in degraded forest has been seen in Alwar district. But still area under degraded forest is significant covering an area of around 108 km^2 in Alwar district. There is no degraded forest cover in Faridabad and Rewari districts.

4.1.6 Degraded pastures & grazing land

Degraded pasture and grazing land comes under non-forest area. It is under permanent pastures or meadows. Such land gets degraded by lack of proper soil and

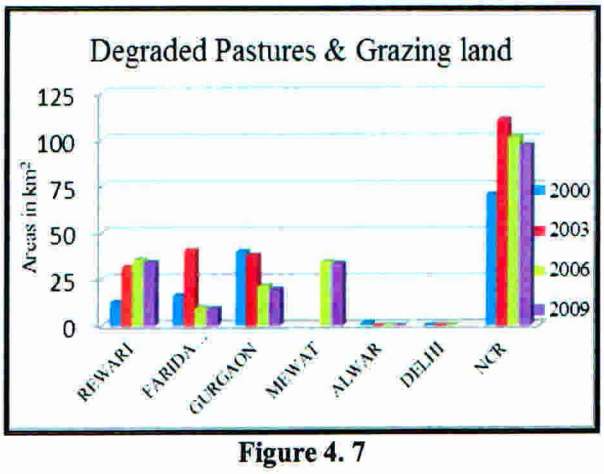


Figure 4. 7

water conservation measures. The loss of pasture land is also by overgrazing and expansion of build-up area in pasture land. An area under degraded pasture and grazing land is decreasing in the region from 2003 to 2009. Total area under degraded pasture and grazing land experienced net loss of 17 km^2 from 2000 to 2009 (Table 4.7).

Degradation of pasture and grazing land is the outcome of human interference in

pasture land where land reclaimed or for others commercial use. Activities like construction and industries. Are putting pressure on pasture and grazing land. Most of the degraded pasture land is found in Rewari and Mewat districts. This land more than doubled in Rewari district since 2000. Area under degraded pasture and grazing land was more 30 km^2 in 2006 and 2009 in Mewat district. Expansion of urban centres may be one of major factors causing decline in area under degraded pasture and grazing land of Aravalli in NCR.

5 Degraded land under plantation crop

Degraded land has been brought under plantation crops after reclamation and is located outside notified forest area which comes under the degraded land. Around 1 per cent of region notified as degraded land is under plantation crops. There was around 50 per cent reduction in this category from 2000 to 2009 in Aravalli region of NCR.

District wise observations show no land under the degraded land under plantation crops in Delhi and Alwar. Such areas have been reclaimed with afforestation in Delhi and no degraded area has been put under plantation crops in Alwar district.

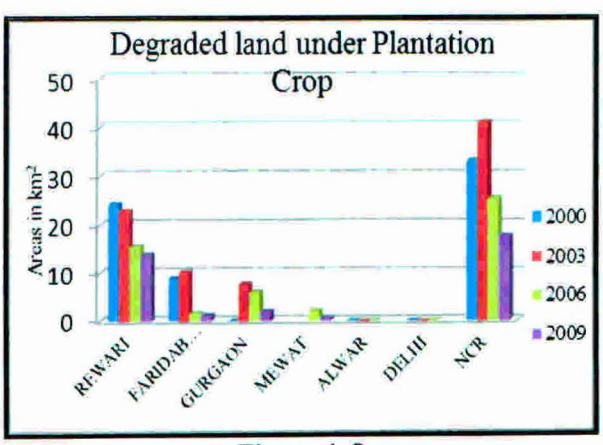


Figure 4. 8

Rewari and Faridabad districts have larger area under plantation crops followed

by Gurgaon. In all about 40 km^2 area is under degraded land under plantation crops. Area under degraded land used for plantation crop is decreasing in all of districts due to reclamation through afforestation.

4.1.8 Sandy Areas

This category refers to land with accumulation of sand found in riverine or inland area. Sand is drier area and riverbeds in Aravalli Region. Sandy area is low in organic matter and water holding capacity and vulnerable to strong winds. Sand gets accumulated in flood plain of rivers as sand, sheets or sand bars. It is called riverine sand. It also includes inland sand which accumulates along abandoned river courses or gets deposited by wind action.

Sandy area of Aravalli region in NCR has shown a declining trend since 2000. Area under sand covered 92 km^2 areas in 2000. Then it has come down to less than 1 km^2 in 2009. Reduction of sand affected area is due reclamation of land. This has led to continuous reduction in total sand affected area of the region.

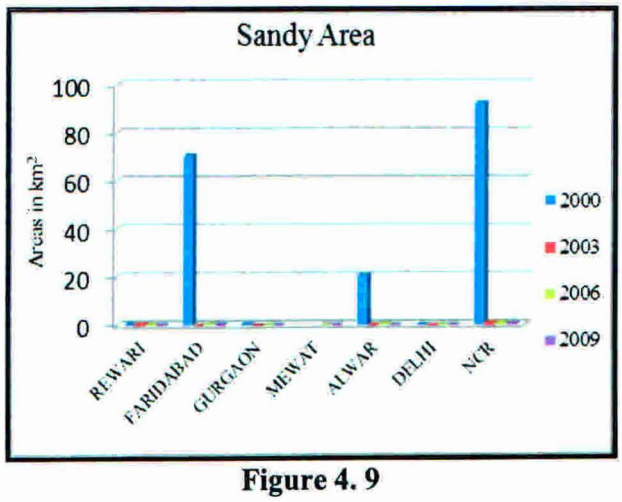


Figure 4. 9

Faridabad and Alwar had huge area under sand to extent 70 km^2 and 20 km^2 respectively in 2000. This may be because of their location, closer to desert pocket of

Rajasthan and absence of regulation. Faridabad sand is mainly of riverine type that of Alwar is deposited by Aeolian process. However, most of sandy area has been reclaimed either irrigation or has come under other use.

4.1.9 Mining wastelands

Mining wasteland is land where mined waste debris gets accumulated, or land gets degraded with extraction of minerals. This category includes mine & quarry areas subject to removal of different earth material, both surface and sub-surface by manual and mechanized operations. Commercial quarrying and mechanical operations result in creation of mine dumps as well as large screed area. It includes surface rocks and stone quarries, sand and gravel pits, soil excavation for brick etc.

Land degradation is the inevitable result of any form of mining, particularly open cast mining, which thoroughly disturbs physical, chemical, and biological elements of soil and alters landscape. Area under mining waste of the Aravalli hill region of NCR accounted for 10.8 km^2 in 2009. It comprises 23.4 km^2 in 2003. It shows that there is a net decline in mining land in the region.

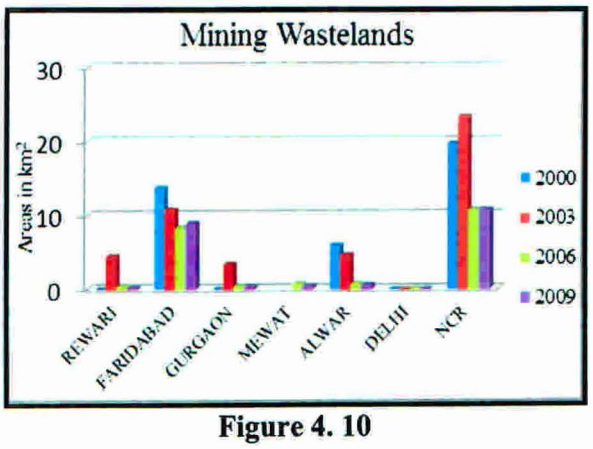


Figure 4. 10

Faridabad and Alwar are most mine affected districts of Aravalli in NCR. Faridabad had 13.7 km^2 and Alwar had about 6 km^2 area in this land category in 2000.

No other part of the region had mining wasteland in 2000. Mining wasteland expanded to four districts with Rewari and Gurgaon also registering land under mining wasteland in 2003. Subsequently, land under mining wasteland declined in all part of the region. It needs to be mentioned that hilly parts Faridabad, Alwar and Gurgaon districts were the main source of construction material like Building stone, Bajari and red granular material called Badherpur Bajari. There is lot of opposition to quarrying in these areas in recent times as it adversely affects ecosystem of Aravalli hills. Mining and quarrying activities has been banned in some areas. Unfortunately, illegal quarrying is still going on in a few pockets.

4.1.10 Industrial wastelands

This area has storage dump of industrial raw material or slag /effluents or waste material or quarried / mixed debris from earth's surface.

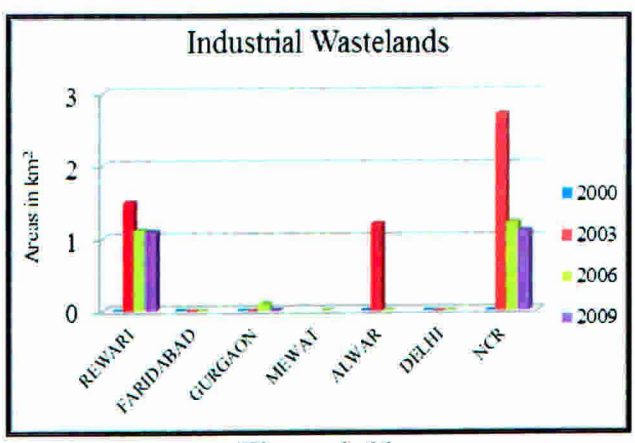


Figure 4. 11

Dumping of industrial waste and pollutants creates industrial wasteland. Figure 4.11 shows small area under industrial wasteland in 2000. There were 3 km^2 lands under industrial wasteland in 2003. It came down to about 1 km^2 in 2006 and 2009. It shows that area under industrial waste land is under control in the region. Highest industrial wasteland was seen in Rewari and Alwar districts in 2003.

4.1.11 **Barren Rocky Area**

These are rock outcrops of varying lithology and often barren and devoid of soil and vegetative cover. These occur amidst hill-forest as openings or as isolated outcrops on plateau and plains. Barren rocky areas occur on steep isolated hillocks or hill slopes, crests, plateau and eroded plains associated with barren and exposed rocky, stony wastes, lateritic out-crops, mining and quarrying sites.

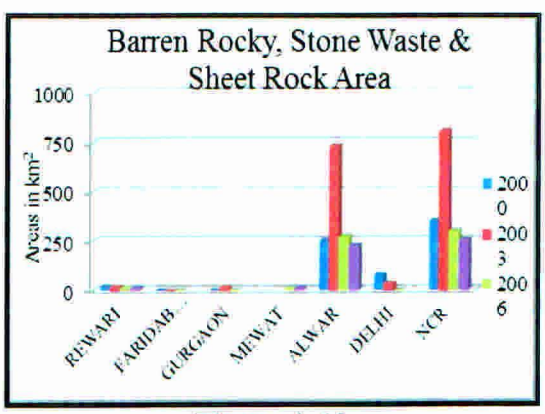


Figure 4. 12

Rocky and stony area covered 3059 km^2 area in 2000. Area under barren rocky and stone waste is continuously decreasing at a faster rate in the region. In 2003, 2006 and 2009 areas under this category was 4291km^2 1802 km^2 and 1653 km^2 respectively. There are around 2500 km^2 losses of barren land under rocky, stony and sheet rock found in 2003 to 2009. Decrease in areas under waste and rocky land categories may be observed due to natural process and anthropogenic activities.

Erosion of rocks by wind and water and weathering of rocks are the two natural processes which have created rocky surface of Aravalli in NCR. Anthropogenic factors have also contributed to the emergence of rocky area in Aravalli in NCR. Need of building stone, rocks, boulders are for are under for construction which may cause rocky wastelands.

Three districts of Aravalli region of NCR areas had rocky and stony land in 2009. These are Alwar, Rewari and Mewat. Land under this category was 258 km^2 in the region in 2009. Highest land under Barren rocky was in 2003 when it measured 811 km^2. Afterwards land under this category started declining. Most of the barren rocky area covering 228 km^2 is found in Alwar district. Absence of this land in Delhi and adjoining districts is because such land has been put under other uses.

4.2 ASSESSMENT OF LAND DEGRADATION THROUGH REMOTELY SENSED DATA:

Presently remote sensing techniques have been used to monitor and map land cover changes between two time periods. Normalized Different Vegetation Index (NDVI) is an important technique used for vegetation cover analysis. It is also a good indicator to assess vegetation vigour of the cover and is a method to estimate and analyse land degradation.

4.2.1 **Normalized Difference Vegetation Index (NDVI):**

NDVI is an index which has been developed to estimate vegetation cover and its vigour. It is also most widely used technique in land degradation analysis. NDVI is software generated value which works on the basic logic of temperature emitted from an object. For calculation of NDVI the software takes the basic algebraic structure of a spectral index in the form of a ratio between two spectral bands Red Band (R) and Near Infrared (NIR). This index is calculated by subtracting Red Band from NIR Band, and dividing by the sum of Red band from NIR Band as given below:

$$NDVI = \frac{(NIR - R)}{(\mathrm{NIR} + \mathrm{R})}$$

Calculations of NDVI for a given pixel always result in a number that range from minus one to plus one (-1 to +1) value. Absence of green leaves gives a value close to zero, either in positive or negative. A value of Zero, close to zero or negative means no vegetation cover i.e. non-vegetated area. Value close to plus one (+1) indicates highest possible density and vigour of green leaves and vegetation cover i.e. rich vegetated areas. For wetland, water bodies, build-up area, wasteland and barren land NDVI value are found close to zero or negative. But for vegetated region and rich vegetation areas, value is non-negative and may go close to plus one (+1). Using this method, vegetation and non-vegetation surface can be delineated. It is possible to measure the rate of changes and total change in land degradation by comparison of two time period data.

Table 4. 2

Land degradation in the Aravalli hill region of NCR

(25 September 1999 and 23 September 2006)						
	1999			2006		
Land use	Areas in Hec.	% Area	NDVI Value	Areas in Hec.	% Area	NDVI Value
Built-up Areas	233526	14.2	-0.34 to -0.18	278100	16.7	0.12 to 0.2
Barren / Fallow land	644415	39.1	-0.18 to -0.01	612893	36.7	0.2 to 0.36
Water Bodies	2260	0.1	-0.5 to -0.3	4775	0.3	0 .01 to 0.10
Agricultural cropland	625885	38	0.01 to 0.22	704462	42.2	0.37 to 0.74
Dense Vegetation	141967	8.6	0.22 to 0.57	69698	4.2	0 .75 to 0.89
Source: GLCF Landsat data, September, 1999 and 2006.						

NDVI is used to transform multi-spectral data into a single image band to represent vegetation distribution. NDVI value also indicates the extent of green

vegetation. Pixel with a higher NDVI value indicates more green vegetation and good vegetation health. NDVI values are highly related to rangeland production and vegetation abundance or vegetation cover in any region. That's why it is widely used and is an efficient and objective tool to monitor vegetation condition and changes in vegetation cover.

NDVI method has been used with the help of remotely sensed data to determine the health of vegetation cover of Aravalli in NCR for 1999 and 2006.

NDVI value are found to be in the range of -0.479 to 0.571 having a mean value of 0.045 and standard deviation is 0.302 for September 1999 and in the range of 0.007 to 0.895 having a mean value of 0.451 and standard value of 0.261 for September 25, 2006. Higher standard deviation and mean value implies higher vegetation density. Low positive value shows very less vegetation cover and very less positive value and negative value shows areas without vegetation cover.

Higher NDVI values represented in Map 4.1 as *brighter areas* show vegetated rich area. Alwar ridge, Delhi ridge, protected forest areas and other forest areas are in very good health with rich vegetation cover. Medium NDVI values represented in *gray colour to bright colour* in Map 4.1 have been observed over cropland and paddy crop mainly dominated in the season and pasture lands of Aravallis. Low NDVI values shown in *grey colour to black colour* include Build-up area, barren land, and fallow land and water bodies. Major urban centres and village centre have fallen in this category.

On map 4.2 bright to black colour representation of NDVI data in the range of -1 to +1 has been shown with the help of thematic mapping. This shows rich vegetation cover in hilly areas of Aravalli in NCR and along water bodies like rivers, streams,

canal, ponds and lakes. South-western part of Alwar district shows dense vegetation cover both in 1999 as well as 2006. Some vegetation cover is also seen along the boundary of Mewat and Gurgaon. South-eastern part of Delhi also shows significant vegetation cover. Significant changes are observed from the maps related to increase in urban area and cropland due to urban expansion and decline in dense forest area during 1999 to 2006.

Estimated value of NDVI reveals that build-up area was around 14.2 per cent in 1999, which rose to 16.7 per cent in 2006 (Table 4.2). The change accounts for a net 2.5 per cent i.e. 44574 hectares land coming under this category in the region. Area under water bodies was 2260 hectares i.e. 0.1 per cent in 1999 which increased to 4775 hectares accounting for 0.3 per cent in 2006. Area under barren, fallow land shows a reduction from 39 per cent in 1999 by 37 per cent in 2006. NDVI estimates that around 38 per cent area was under agriculture in 1999. It rose by 4 per cent to 42.2 per cent in 2006. There is however a decline in area under dense vegetation.

It can be concluded from the discussion that there is significant increase in build-up area in Aravalli hill region of NCR. Barren land and fallow land that is non-vegetated or very less vegetated area has declined due to population increase and urban expansion. Area under agriculture has has gone up but overall decline in vegetation cover is seen.

Table 4.3 shows the mean and standard deviation values of NDVI. High mean and S.D. values show rich vegetation cover while a low and negative value shows less vegetation and non-vegetation cover. That is areas under water bodies, build-up area, barren land fallow land or areas under very less vegetation cover.

Table 4.3 shows higher Mean and S.D. values for highly vegetated and rich

vegetated areas such as forest and agricultural land cover. While a low value and negative value and have been found for barren land, fallow land, and Build-up area and water bodies.

Table- 4. 3

Statistics of Normalized Difference Vegetation Index (NDVI), Sep 1999 and 2006				
Land use / Land cover	September 23, 1999		September 23, 2006	
	NDVI		NDVI	
	Mean	SD	Mean	SD
Vegetation	0.394	0.102	0.823	0.045
Agricultural Cropland	0.109	0.064	0.557	0.111
Barren / Fallow land	-0.096	0.052	0.29	0.045
Built-up Areas	-0.266	0.047	0.163	0.031
Water Bodies	-0.411	0.038	0.058	0.033

NDVI values have been further divided into vegetation and non-vegetation categories. As the values near +1 i.e. close to one show high concentrations of vegetation cover while a near -1and close to zero value shows the non-vegetation cover.

Areas under vegetated and non-vegetated categories have been shown in figure 4.12.

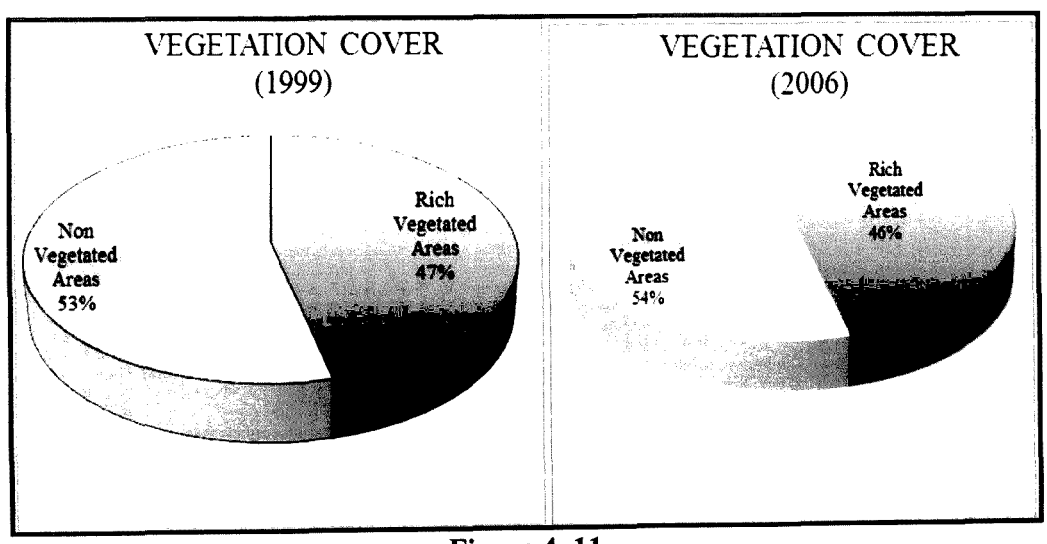
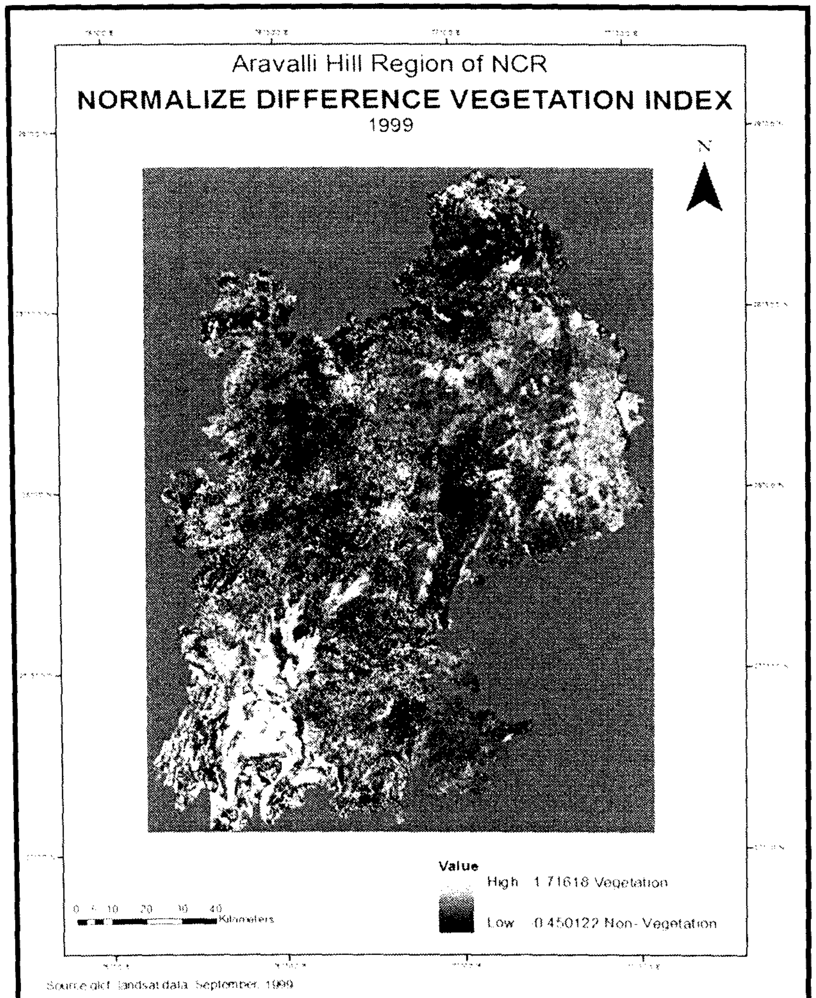
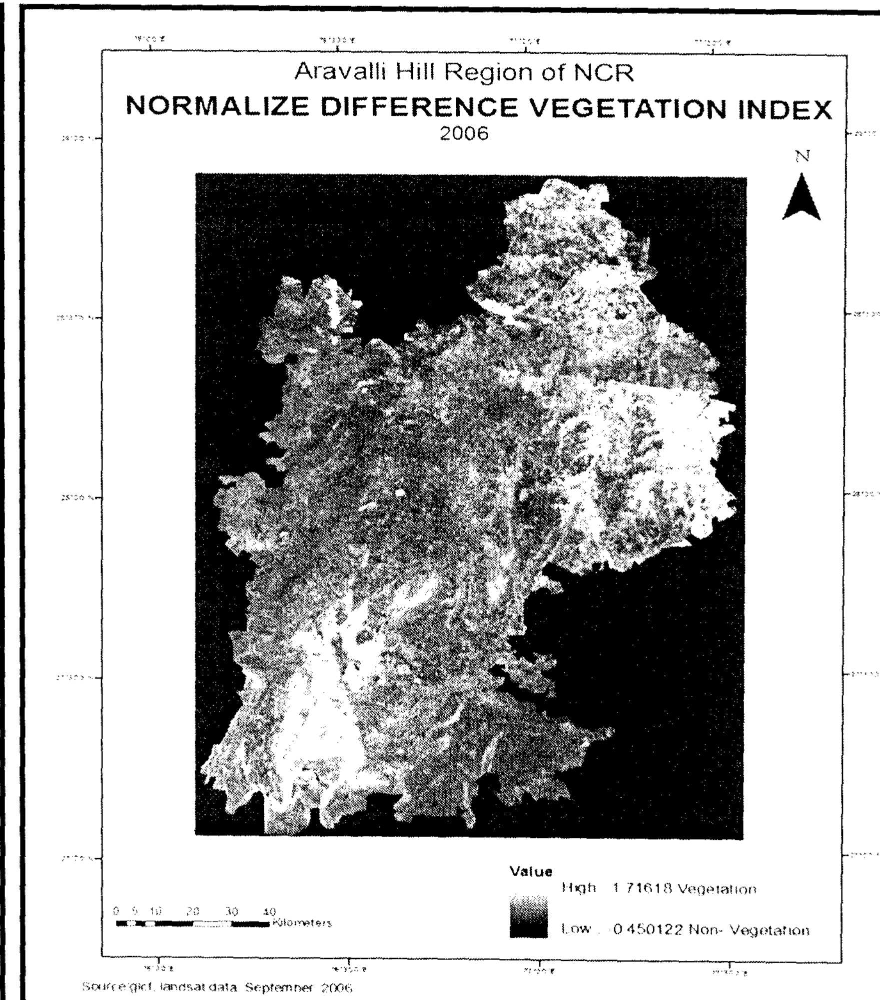
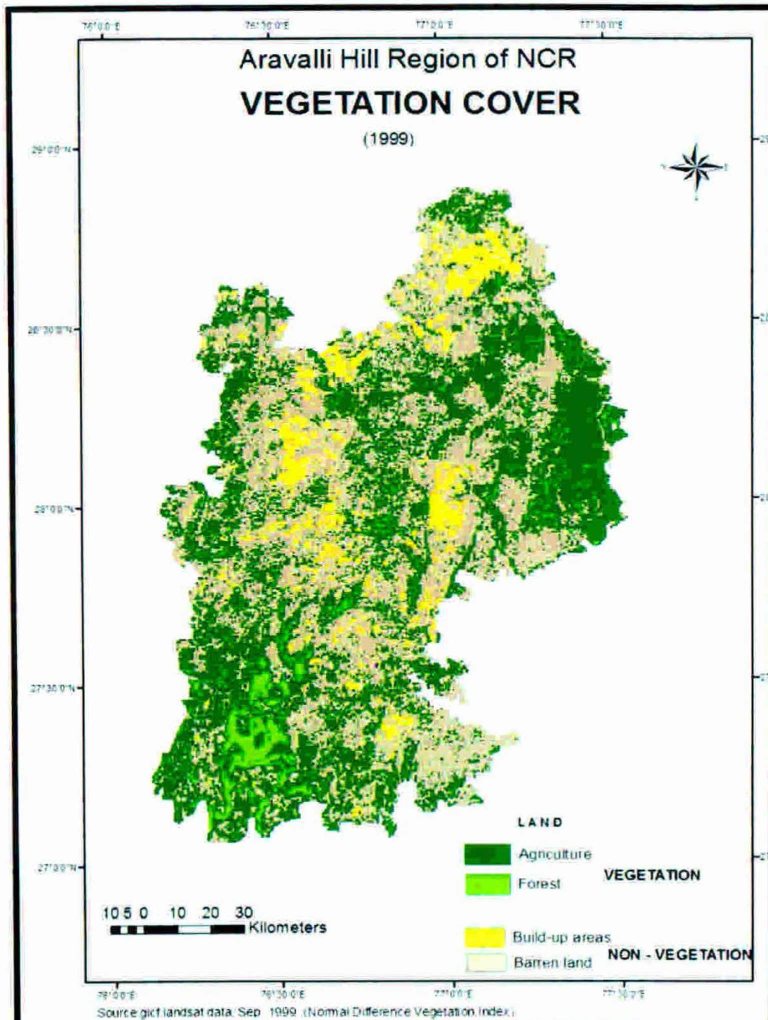


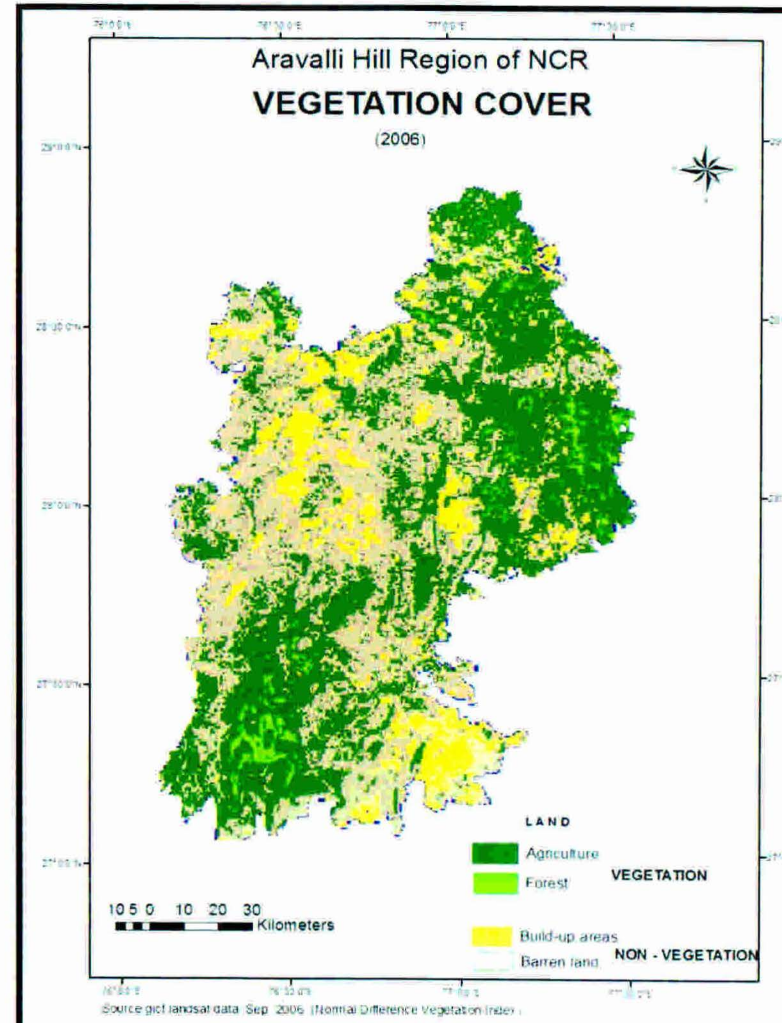
Figure 4. 11


Aravalli Hill Region of NCR
NORMALIZE DIFFERENCE VEGETATION INDEX
1999
N
Value
High 1.71618 Vegetation
Low 0.450122 Non- Vegetation
0 5 10 20 30 40
Kilometers
Source gicf landsat data September 1999


Aravalli Hill Region of NCR
NORMALIZE DIFFERENCE VEGETATION INDEX
2006
N
Value
High 1.71618 Vegetation
Low 0.450122 Non- Vegetation
0 5 10 20 30 40
Kilometers
Source gicf landsat data September 2006

Map 4.1


Aravalli Hill Region of NCR
VEGETATION COVER
(1999)
LAND
Agriculture
Forest
VEGETATION
Build-up areas
Barren land
NON - VEGETATION
10 5 0 10 20 30
Kilometers
Source glcf landsat data Sep 1999 (Normal Difference Vegetation Index)


Aravalli Hill Region of NCR
VEGETATION COVER
(2006)
LAND
Agriculture
Forest
VEGETATION
Build-up areas
Barren land
NON - VEGETATION
10 5 0 10 20 30
Kilometers
Source glcf landsat data Sep 2006 (Normal Difference Vegetation Index)

Map 4.2

Area under vegetated and non-vegetated category in 1999 was 47 per cent and 53 per cent respectively. While area under vegetated cover accounted for 46 per cent and non-vegetated cover 54 per cent of the total areas in 2006. Therefore, there is 1 per cent net loss of vegetation cover found during 1999 to 2006.

It can be concluded that land degradation processes are going on the Aravalli hill region of NCR. Though wasteland and degraded land has decreased significantly but still some area is found under this category. The change in wasteland and degraded land seems to be directly linked to anthropogenic activities and government interventions. Most of the barren land counted as area under gullies and ravinous land, scrubland, water logging, salinity and alkalinity have declined probably due to human intervention. Expansion of build-up area may be an important cause for loss of degraded land. Non-agriculture activities are more dominant for land use change in the region.

NDVI value shows a significant increase in build-up area, water bodies and cropland. As opposed to this, there is loss of dense vegetation cover and increase in non-vegetated land. NDVI observations it show net one per cent decline in vegetation cover in the region.

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CHAPTER- V

ANTHROPOGENIC IMPACT ON LAND USE / LAND COVER AND ENVIRONMENTAL DEGRADATION

The term anthropogenic pertains to an effect or object resulting from human activity. Human beings are active agents on earth surface. Human activities such as social, political and economic put stress on land, which result in land, cover changes and degradation. Land use is also an outcome of human activities. Growing population pressure is changing land use patterns of earth and transforming limited land resources from one form to another.

Man as producer, consumer and decision maker has a significant role in shaping the pattern of land utilization over time. There are different forms of land uses in Aravalli hill region of NCR. All this can be clubbed into two parts; these are area not available for cultivation and area available for cultivation.

In the present study, it is important to discuss changes in land use caused by human activities. To see impact of anthropogenic activities on land use and land cover of Aravali hill in NCR, it is also important to look at the existing land use / land cover and changes caused due human activities. An attempt has been made to look at this is a cause - effect relationship between rising population and different land uses in the region.

5.1. POPULATION GROWTH

Population of Aravalli in NCR almost tripled over the period of last 40 years. It exceeded 25.72 in 2011 million compared to 7.16 million in 1971 (Figure 5.1) Its

compound annual growth rate has been of 3.4 per cent during 1971 to 2008 (Table 5.2). A divide has been seen in urban and rural population. Figure 5.1 shows that urban population growth is much higher in the region compared to rural areas. There is higher compound annual growth rate in urban areas at 3.9 per cent while the figure for rural areas is 2.3 per cent. Even total rural population growth much smaller than urban population. Stagnant population growth has been seen in rural areas while there is exponential population growth in urban areas. Urban population of Aravalli in NCR was 4.1 million in 1971which rose to 19.81 million in 2011. While in rural areas, it was 3.1million in 1971 and 5.91 million in 2011 (figure 5.1). There is a decline in decadal rate of population growth. Still an increase in total population is seen in the region. Urban population is growing faster than the growth rate of total population.

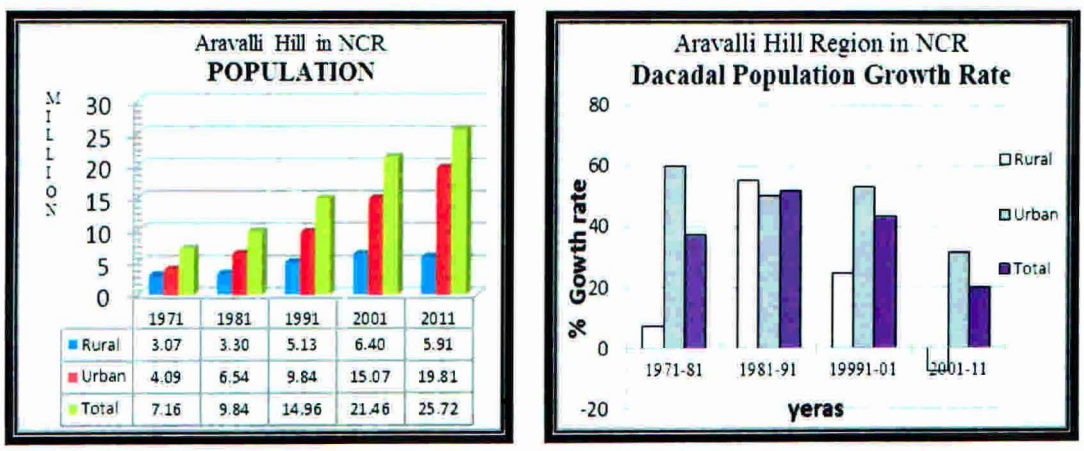

Figure 5. 1

Increasing level of urbanization is caused either by higher natural growth of urban population or migration of rural population towards cities[1]. Exponential population growth in urban areas may be observed because of rural-urban mobility of population and concentration of more population in urban centres. High population growth in urban areas has also been observed because of incorporation of some rural areas into urban areas to reduce the burden of population pressure in urban areas. Rural

areas are showing reduction in total numbers and in growth. This reduction may be observed because of shrinkage of rural areas and mobility of rural people to urban centres. Population in rural areas fell from 6.4 million in 2001 to 5.9 million in 2011 (Figure 5.1).

It is also clear from above estimation that population of urban areas is growing very fast and it has led to increase in population concentration in the region. Due to increasing pressure of population in urban centres, these have reached overpopulation stage and that is creating pressure on existing land resources.

5.2. ANTHROPOGENIC EFFECT ON LAND USE LAND COVER CHANGES

Increase in human population is directly linked to an increase in the size of settlements and build-up area at the cost of other natural resource. Impact on cities and the resident population gets amplified significantly by rural to urban migration. It adds its own pressure, and is expected to increase significantly in coming decades. Present increase in infrastructure of urban centres due to population increase has a significant anthropogenic impact on Aravalli region of NCR. Apart from urban settlements, many other pressures have led to transformation of land resources in hills of Aravalli. Most common classifications of environmental impacts of anthropogenic activities are made based on a particular activity and source. These are urbanization, agriculture, industry and mining etc. Some of also add pollutants and make other interventions.

Series of human activities are taking place in hills of Aravalli in NCR. These include construction, land reclamation and expansion into barren and agriculture land, mixed mining and demolition waste deposition or alterations indirectly induced by anthropogenic activities such as land erosion, groundwater or soil salinization etc.

An attempt has been made to see the linkages between population and natural environment to assess human impact. It has been tried to see as to how human impact leads to land use, land cover changes and degradation in Aravalli hill region of NCR. To assess the impact following environmental aspects have been looked at:

5.3. POPULATION AND FOREST

Time series data from 1971 to 2008 (Table 5.2) show that area under forest is increasing. Increase in forest cover has been observed at compound annual growth rate 3.54 per cent since 1971 to 2008. It shows that area under forest categories was almost stagnant until 1987 and experienced some decline in some years. It was around 30 to 40 thousand hectares. It was seen that the region had very small forest cover, which was even below the national standard. It has been mentioned in NCRPB report that, "NCR has a very poor forest cover."[2] Due to government initiatives forest cover increased significantly after 1990s. It was done through reclamation of barren land, pasture land and other non-cultivable wasteland. To arrest undesirable growth in the green zone and, to ensure orderly and compact urban development, a controlled green belt was proposed all around the expected developable areas. Development was restricted or strictly controlled in this green belt[3]. Development of green buffer zones along major transport corridors and intensive afforestation programme has been undertaken in fallow and barren wasteland to increase forest cover of the region.

Forest cover was not good in 1970s and 80s. NCRPB report stated that the situation of forest in the region was very poor with reference to National Forest Policy[3]. Major initiatives of the government to increase vegetation cover were to increase forest cover in forms of protected areas, reserved areas and through community and social forestry on all those land, which were not fit for agricultural use.

The main targets of the operation were:

- To afforest and vegetate barren land, rocky area, culturable wasteland etc. So that forest or vegetation cover is raised at least to 10 per cent of land area.
- To intensify forest cover by planting suitable species in sparsely forested zones and denuded areas, and
- To identify alternate sources of energy for fuel, and to find methods of increasing efficiency of social or community forest.

These steps were taken in a phased and planned manner so that afforestation and vegetation could be sustained and stabilised over time. All these development initiatives taken by the government led to increase in forest cover of Aravalli in NCR. Forest covers reached 87 thousand hectares registering around 2.5 times increase in forest cover during 1971 to 2008

Coefficient of variation has been calculated to capture variations in forest cover in the region from 1971 to 2008. It shows 43 per cent variability in this period (Table 5.2). It means consistency in the increase of forest cover.

5.4. POPULATION AND BUILD-UP AREA

Human beings create settlements for living and undertaking many activities for their survival. Increase in population leads to increase in households and construction of more. Increase in population has been seen as major cause of expansion of rural and urban settlements and increasing build-up area.

Urban centres are seen to be more prone to concentration of build-up area. This is the result of concentration of houses and creation of infrastructure etc. Nature of economic activity may be an important factor for increase in build-up area in a region. Generally, secondary and tertiary activities separate urban centres from rural areas. Rural areas are dominated by primary activities, which are fully dependent on land

resources.

Urban centres need more land to accommodate people due to diverse nature of economic activities and high concentration of population. Additional land requirement is met through conversion of agricultural land, barren land and non-cultivated land into build-up areas.

Urban centres have concentration of more buildings compared to rural areas. This is because of the nature of activities carried out in cities and towns. This is directly related to increase in population both in rural and urban areas.

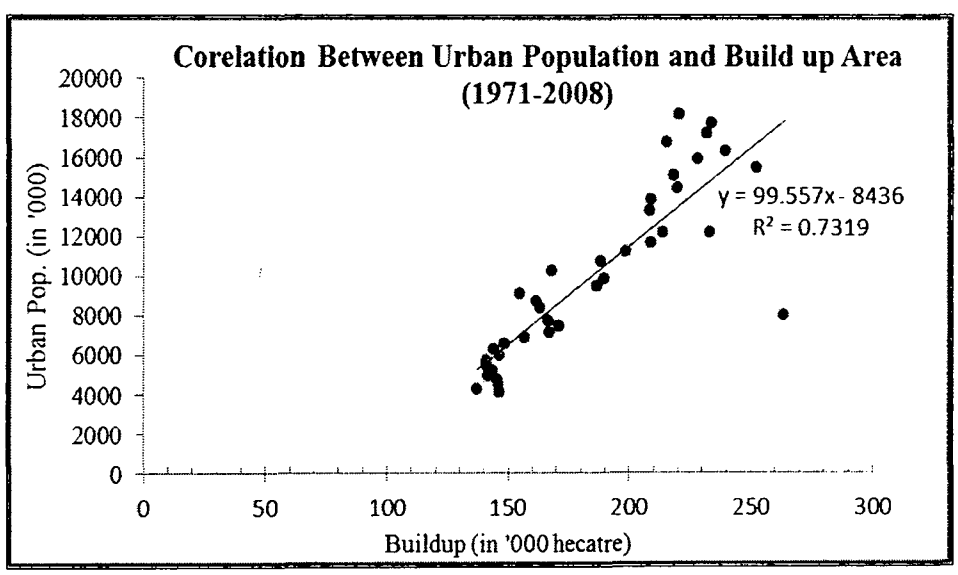

Figure 5. 2

An increase in build-up area of Aravalli hill region of NCR has been seen during 1971 to 2006. Table 5.2 shows 1.64 per cent compound annual growth rate of build-up area in this period. The increase in build-up area was highest in 1990s and 2000s. This may be because of economic liberalization of Indian economy in 1990s. This opened ways to many multinational companies and private entrepreneurs to set up industries and offices in the region[4]. This initiative of government may have indirectly boosted labour force mobility from rural to urban areas.

Population increase and higher urban population growth seem to be main factor for increase in build-up area. It has also been observed that urban areas account for much more concentration of build-up area than rural areas. Above discussion shows population increase to be one of the main factors for build-up area in urban centres. Growing urban population need land for housing, infrastructure and work place etc. An attempt has been made to see cause effect relationship between the size of urban population and build-up area during 1971 to 2008 (Figure 5.2).Positive and strong correlation has been found between these. Figure 5.2 shows coefficient of determination with value of 0.73.

5.6. POPULATION AND BARREN LAND

Barren land in Aravalli hill region in NCR is shrinking at a compound annual growth rate of -1.2 per cent during 1971 to 2008. Increasing pressure of population may be one of the major factors for loss of barren land. There has been reduction of around 56 thousand hectare in barren land in last 37 years (Table 5.2).

It may be assumed that increasing population need more land for other uses. If supply from another source of land is not possible, they may or use non-fertile or barren land. Therefore, barren land is one of recent sources to meet growing demand of land.

With population and physiological density increasing in the study area, more pressure is coming on existing land resources. Figure 5.5 shows shrinkage of barren land during 1971 to 2008.

It may be also argued that barren land may not be going only to build-up or cultivated areas. There is also demand of barren land to increase forest cover of Aravalli in NCR. There was an increase in forest cover by afforestation programme on barren land and other fallow land from 1990 onward. An attempt was made to vegetate barren

land, rocky area and culturable wasteland etc., so that forest or vegetation covers increases by at least by 10 per cent of the land area.[3]

Coefficient of variation has also been calculated to estimate and observe the variations in proportion of barren land from 1971 to 2008. Table 5.2 makes it clear that co-efficient of variation is 14 per cent. This shows higher reduction in barren land in this period.

5.7. POPULATION AND PASTURE LAND

Decline in pasture and grazing land is seen in Aravalli hill region of NCR since 1971. to 2008. Shrinkage in pasture and grazing has been accounted for with annual compound growth rate of -1.45 per cent (Table 5.2). In terms of total area, It experienced a loss of around 23 thousand hectares of land under pastures from 1971 to 2008 (Figure 5.3 & Table 5.2). Reduction in land under pasture and grazing land is seen in most of the years. However most land in this category was lost in 1970s. It can be seen from above figure that higher decline in pasture land was also in 1990s. This may be linked to green revolution in India, because districts of Haryana initiated green revolution. Mechanization and irrigation facilities may have helped in bringing some grazing land under plough. However, some pastures may have been lost to industry and to other uses, which started in 1970s.

Conversion of pasture land in forest category has been observed due to increase in hills of Aravalli in NCR. Therefore, to see the cause and effect relationship between population and pasture land 37 years data have been collected. Rural population data have been taken, under the hypothesis that often pasture land is transformed for cultivation or generally rural people may have more livestock population and these may affect pasture land.

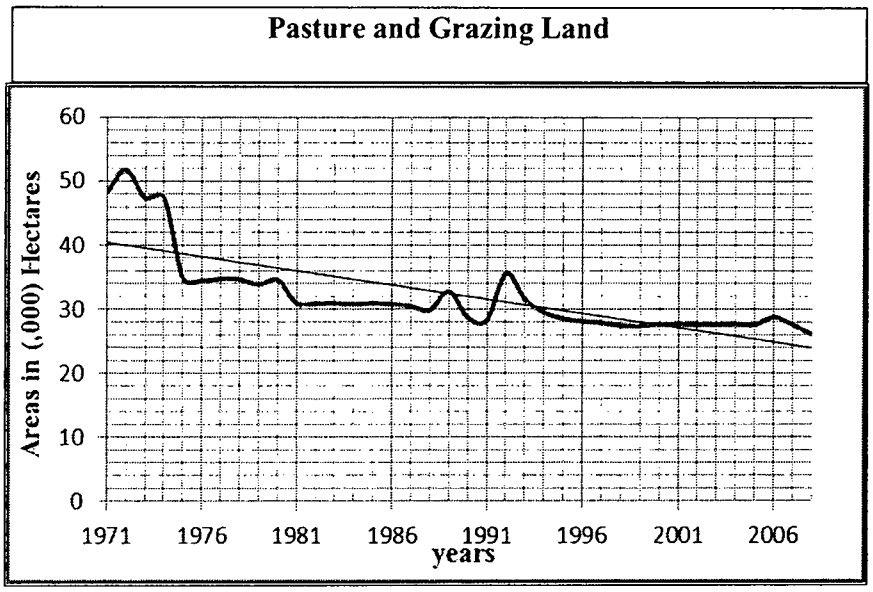

Figure 5. 3

Negative correlation has been observed between population and pasture land. It means that increase in population have led to decline in pasture (Figure 5.4).

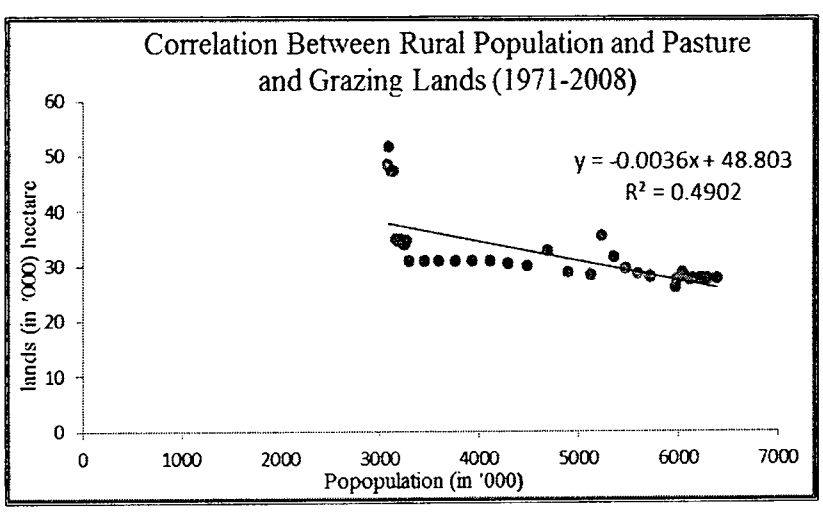

Figure 5. 4

Coefficient of variation has been calculated to estimate changes in pasture land of time period, to see percentage of variation in declining pasture land. About 21 per cent deviation from the mean has been observed. The given table shows that annual

compound rate is -1.45 (Table 5.2).

5.8 POPULATION AND AGRICULTURE

Agriculture and population are closely from time immemorial. This has led to rapid changes at various levels. World is facing a dilemma where population is growing while agricultural land is shrinking. The situation reveals that with present days exploding population and ever increasing levels of scientific and technological research, developers are mobilizing un-cultivated land resource for use. Demand for more land for cultivation is also increasing in Aravalli hill region of NCR. This has put stress on existing land resources.

5.8.1. Net Cultivated Areas (NCA)

Net cultivated areas in NCR have been more or less constant during these past few decades. There is a small increase in net cultivated area with compound annual growth rate of 0.14 per cent. This is very small compared to the compound annual growth of population at 3.54 per cent (Table 5.2). Net sown area has been slightly increased since 1990s with a few fluctuations. Physiological density has also been calculated to see pressure on land resources and to observe available cultivated land for people of the region.

One is aware that food availability in NCR is not dependent on local land resources only. However, rising population on cultivated land has implication on existing cultivated area. Physiological density in the region was 600 persons per cultivated km^2 in 1971, which rose to 2600 persons in 2006. It was seen that physiological density has increased subsequently this is putting excessive pressure on limited cultivated land.

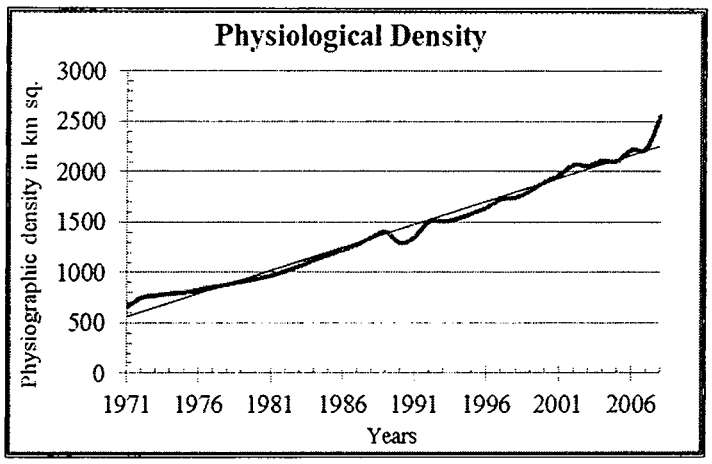

Figure 5. 5

Along with rapid increase in population, per capita total cultivated area is also declining. Deforestation is also related to increase in physiologic density. Figure 5.5 shows continuous linear growth across in all years except 1987 to 1992.

5.8.2. Areas Sown More than Once:

Increase in population pressure and improvement in agriculture technology made it possible to increase area sown more than once. To keep pace between population increase and food production, new technology and mechanization have been brought in. Increase in irrigation facilities and fertilizer improved land fertility, which helped in using land sown more than once.

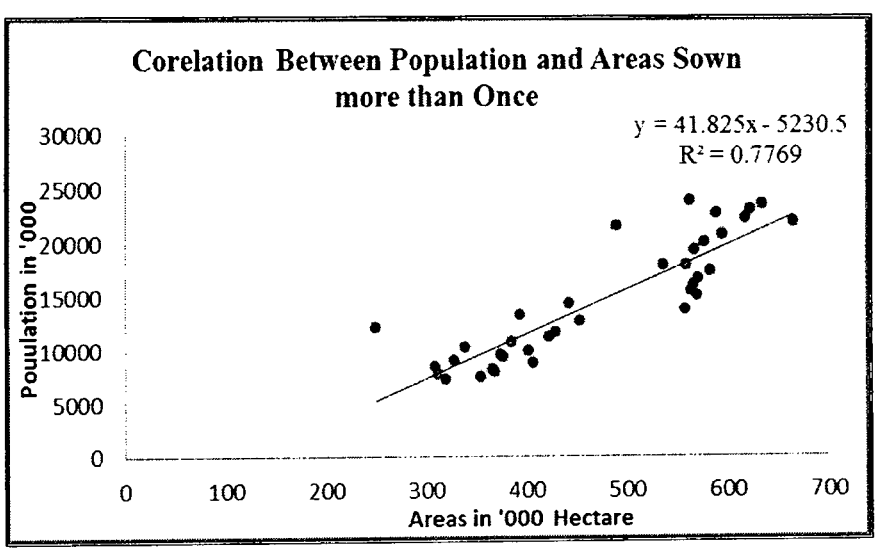

Figure 5. 6

Rising population, raise demand for agricultural products. This is especially seen in the case of perishable goods like vegetables, flower, etc. as these cannot he easily brought from far off places. If there is more demand for agriculture products due to increasing in population, then farmers will even try to increase their income by raising more crops on the same land.

The figure 5.6 shows that population pressure may directly or indirectly linked to areas sown more than once. A positive and strong correlation between these two was found with R^2 value of 0.78. Coefficient of variation has also been calculated for areas sown more than once. It shows a consistency in increase in area sown more than once with is deviation from mean of 21 per cent (Table 5.2).

5.8.3. Total Area Not Available for Cultivation (ANAC):-

Areas under forest, build-up area, and barren and un cultivable land form total area not available for cultivation. Under which forest land and build up area are growing at faster rate in Aravalli hill region of NCR while barren land is shrinking.

It has been found that in build-up area, forest land and barren land are growing at a compound annual growth rate of 3.5 per cent and 1.60 per cent and -1.2 per cent. These together formed land not available for cultivation which is increasing at a compound annual growth rate of 0.87 per cent from 1971 to 2008 (Figure 5.7). Although areas under forest cover and build-up are main factors for increase in area not available for cultivation but this is putting pressure on cultivable land. Increase in areas not available for cultivation may lead to pressure on land under other categories.

Trend line of Figure 5.7, shows that land under forest and build-up areas are increasing at steady growth rate while barren land is declining during 1971 to 1990. This resulted in steady growth in total area not available for cultivation (ANAC).

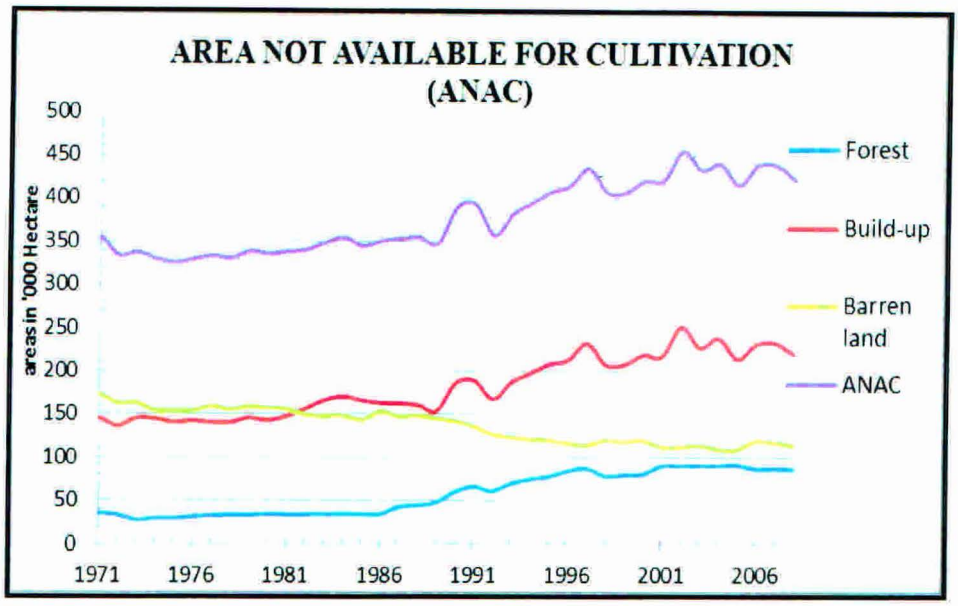

Figure 5. 7

Increase in build-up area may be observed because of new liberalization and privatization policies of government of India to promote industrialization and other activities. Increase in labour mobility, migration from rural to urban areas have been found significant contributors in increase in urban population found coming up of new building including houses. This contributed a lot to the expansion of urban centres. An increase in forest cover is because of new afforestation policy of National Capital Region Planning Board (NCRPB). These both initiatives are responsible for increase in areas not available for cultivation in the NCR.

5.8.4. Cultivable land and Areas not Available for Cultivation:

It is seen in figure 5.10 that area not available for cultivation (ANAC) is increasing but total cultivable land (CL) comprising of land under miscellaneous tree crops, net sown areas, and fallow, current fallow land is decreasing.

As stated earlier, build-up area and forest, expansion is very high and this seems to be calming land from other categories including cultivable land in the region of NCR. That is responsible for increase in area under not available for cultivation. Growth of urbanization and increase in population in urban areas is creating demand for more land

to be brought under build-up areas at the cost of cultivable land.

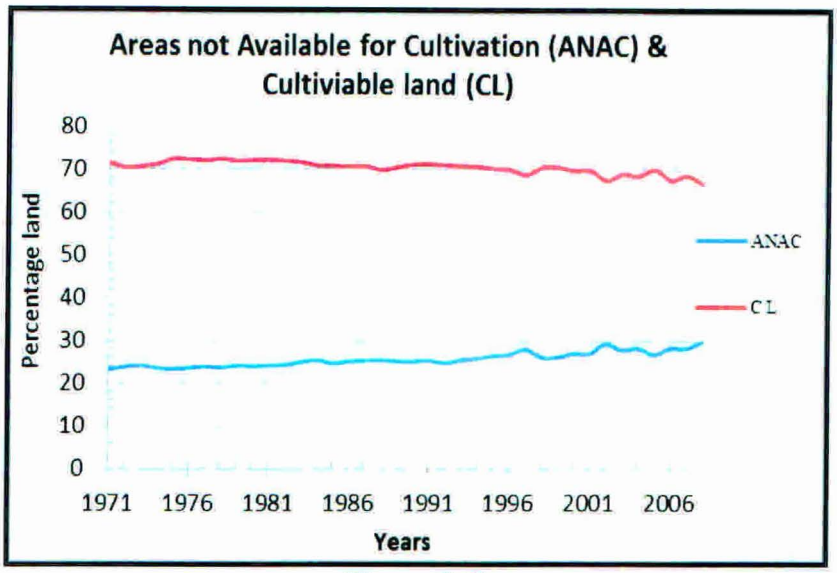

Figure 5. 8

Figure 5.8 shows a decline in cultivable land and rise in areas not available for cultivation in the region. Expansion of land not available for the cultivation from 1990s onward has been because of two reasons. First, is because of increase in land under forest and secondly due to increase in population and population density. This increase may be linked expansion, of settlements creation of infrastructure such as bridge, roads, railways, and canal. Strong negative correlation has been found between area not available for cultivation and cultivable land. Coefficient of determinant with is R^2 value of was 0.85 per cent found between both indicators (Figure 5.9). It means that increase in ANAC has led to decline in cultivable land.

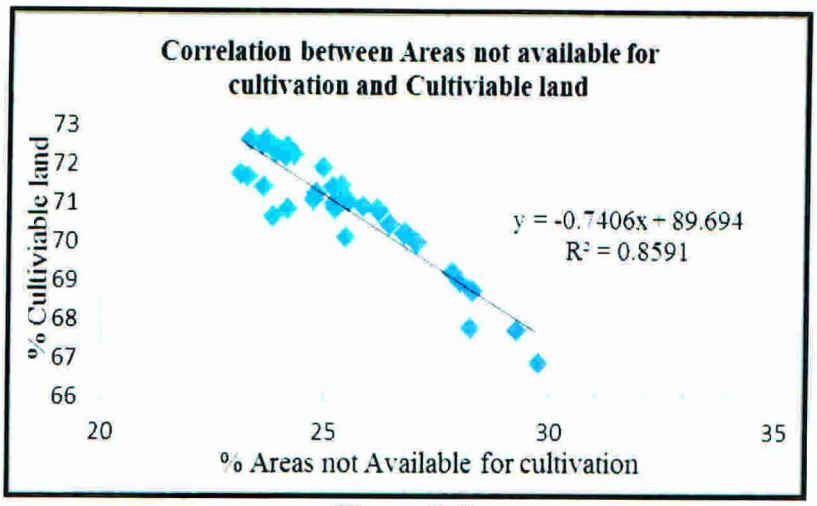

Figure 5. 9

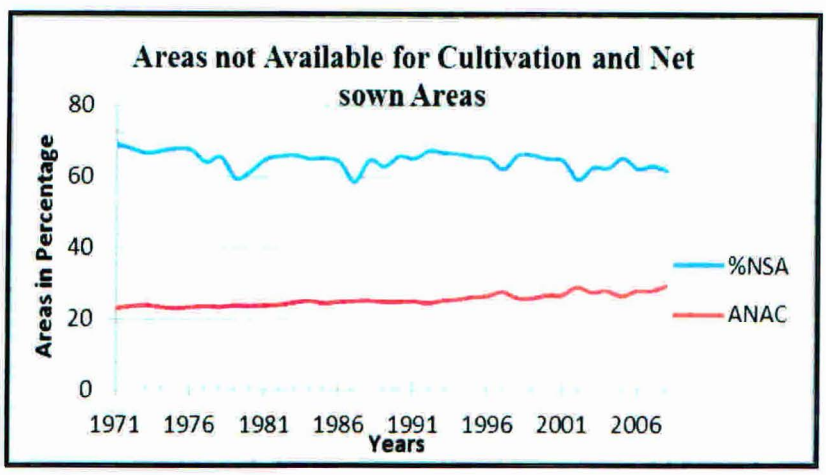

Figure 5. 10

Increase in ANAC has led to decrease in cultivable land (figure 5.8). Increase in area not available for cultivation is also putting pressure on net sown of area. There has been a constant, increase in ANAC since 1970s with decline in net sown area (Figure 5.10).

There is a weak negative correlation with co-efficient of determinant with r^2 value is found 0.29 (figure 5.11). It shows that net sown area and land not available for cultivation are negatively correlated to each other. It means expansion of build-up areas is creating pressure on Net sown area.

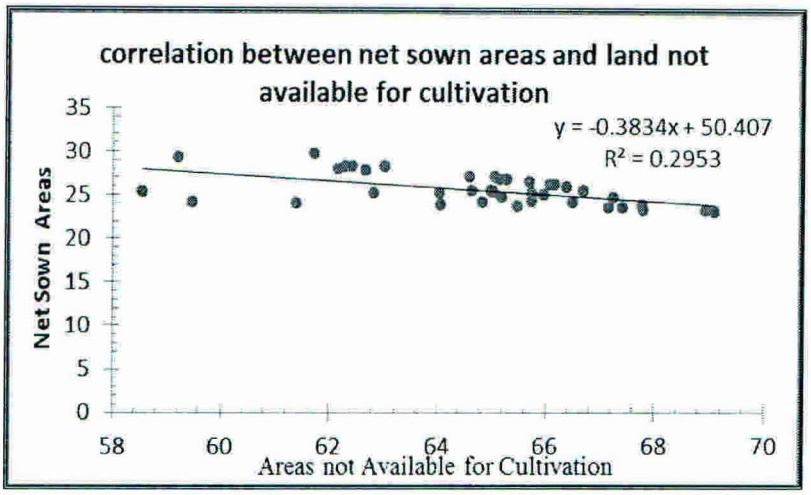

Figure 5. 11

Therefore, although there is demand of land for build-up areas but there is also demand of land for cultivation and other use. So it may say that increase in area not available for cultivation i.e. areas under forest, build-up, and barren land decreases the net sown areas at slow rate. From figure 5.10 and 5.11 it has been found that increase in ANAC decreasing net sown area at slow rate and expanding towards land under other category i.e. pasture land, land under miscellaneous tree crops, and barren rocky, and stony surface. That is the reason seems to be weak correlation between the net sown areas and land not available for cultivation.

5.9. RELATIONSHIP BETWEEN POPULATION AND LAND USE / LAND COVER:

Correlation matrix has been calculated to show cross linkages between population and land use and land cover under different categories. That is presented in Table 5.1. Land use / land cover indices and population change over time from 1971 to 2008 has been shown. A bivariate correlation analysis, using on SPSS statistics software has been done. It shows remarkable relationship between population and land use / land

cover.

Positive and strong correlations have been found between increase in build- up area and total population, rural and urban population increase. It can be said that increase in population has led to increase in build-up area. New land has been used for housing and infrastructure as roads, railways and canals, etc.

Strong negative correlations have been found between barren land, population, and forest land and build up area. Correlation is significant at 1 per cent level. It can be seen from the correlation matrix that increases in population either rural or urban, forest land and build-up area resulted in loss of barren land.

There is negative correlation between pasture and population, forest land, build-up area. It can be argued from the values given in table 5.1 that increase in rural or urban population, area under forest cover, or build-up area have led to loss of pasture land. It can also be argued that increasing population will demand more dairy products and that may lead to rise in livestock population. Increase in livestock population may result in overgrazing causing harm to pastures. Increase in forest cover may also be at the cost of pasture land in the region. Increase in build-up area may require more land for habitation and settlements and that may result in more loss of pasture land.

However, positive and significant correlation has been found between pasture and barren land. It shows that increase or decrease in barren land except hard, rocky, rocky sheet barren land may increase or decrease the pasture cover.

Net Areas Sown is positively correlated with population increase, forest cover, and build-up area. Increase in population may demand more land for cultivation. Non-significant negative correlation has been seen between net areas sown and barren and pasture land.

Table 5.1

Correlation Matrix - Land use / Land cover Change and Degradation

	Total Population	Rural Population	Urban population	Forest Land	Build-up areas	Barren land	Pasture land	Areas sown more than once	land not available for cultivation	Total Cropped Areas	Net Areas Sown
Total Population	1										
Rural Population	.969**	1									
Urban population	.998**	.953**	1								
Forest Land	.963**	.975**	.951**	1							
Build-up areas	.864**	.857**	.858**	.834**	1						
Barren land	-.731**	-.743**	-.722**	-.683**	-.922**	1					
Pasture land	-.712**	-.700**	-.710**	-.638**	-.654**	.612**	1				
Areas sown more than once	.877**	.889**	.865**	.899**	.774**	-.679**	-.589**	1			
land not available for cultivation	.948**	.942**	.940**	.969**	.886**	-.681**	-.630**	.857**	1		
Total Cropped Areas	.776**	.820**	.757**	.843**	.695**	-.589**	-.465**	.954**	.802**	1	
Net Areas Sown	.409*	.507**	.379*	.553**	.378*	-0.285	-0.108	.665**	.514**	.849**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Strong, positive and significant correlation has been found between area sown more than once, population. Growth, forest land and build-up area. Table 5.1 shows that increase in total population may demand more land for cultivation. However, availability of land is limited and no more land can be brought under plough. There may be a possibility of raising production with improvement in technology. Technology may reduce crop-growing period or improve irrigation and other facilities. This may improve land quality, which may be able to grow more crops on same land. Areas sown more than once is also linked and positively correlated with forest land and build up area. Increase in forest and build-up area in Aravalli in NCR may put more pressure on cultivated land. Positive and significant correlation is seen between areas sown more than once and net sown area. Increase in areas sown more than once cannot be above a certain level. There will be need of more lands for cultivation through expansion of net areas sown.

Land not available for cultivation is positively correlated with population increase, forestland, build–up area, and areas sown more than once. Increase in population may indirectly and directly increase land not available for cultivation with increasing settlements and physical infrastructure etc. This will lead to increase in land not available for cultivation. Increase in forest cover, build-up area also led to increase land not available for cultivation. Increase in area not available for cultivation may raise cropping intensity.

There is positive correlation between total cropped area and population. Increase in population is rising of more land under crop cover to increase agriculture production. Increase in total cropped area is directly linked with improvement in irrigation and fertilizer use etc.

In may be concluded from above discussion that anthropogenic

activities are significantly leading to loss of natural environment and bring land use changes in the region. Increase in population has enlarged settlements, with higher construction, manufacturing and other activities. Lot of increase is seen in build-up area, forest land, and decrease in pasture land, barren land and net sown area. An increase in build-up areas is gradually eating in to natural environment. It requires more land for a use that is coming from either barren land, pasture land or agricultural land.

Table 5.2
GROWTH OF POPULATION AND LAND USE LAND COVER CHANGE

Years	Forest		Build-up Areas		Barren land		Pasture	
	Areas*	Change^	Areas*	Change^	Areas*	Change^	Areas*	Change^
1971	35.5		146.8		173.4		48.3	
1972	33.6	-5.1	137.2	-6.5	163.4	-5.8	51.7	7.1
1973	27.8	-17.3	146.3	6.6	163.7	0.2	47.4	-8.4
1974	29.4	5.6	145.8	-0.3	155.1	-5.3	47.3	-0.1
1975	29.3	-0.5	141.7	-2.8	155.2	0.1	34.8	-26.4
1976	31.5	7.7	143.6	1.3	154.9	-0.2	34.5	-1
1977	32.8	4	141.5	-1.5	159.8	3.2	34.7	0.7
1978	33.2	1.4	141.4	0	156.4	-2.1	34.6	-0.2
1979	33.1	-0.5	146.7	3.7	159.5	1.9	33.8	-2.4
1980	34.3	3.5	144	-1.8	158.2	-0.8	34.5	2.1
1981	33.7	-1.5	148.5	3.1	157	-0.8	30.9	-10.6
1982	33.8	0.2	157.2	5.9	150.1	-4.4	30.9	-0.1
1983	33.7	-0.1	167.1	6.3	148.4	-1.1	30.9	0.2
1984	34.6	2.4	171.4	2.6	149.2	0.5	30.8	-0.5
1985	34.2	-1	167	-2.6	144.1	-3.4	31.0	0.6
1986	34	-0.7	163.9	5	153.7	0.7	30.8	-0.7
1987	42.4	24.8	163.4	-3.1	148.2	3.6	30.5	-1
1988	44.6	5.2	161.8	-1	149.2	0.7	29.9	-2
1989	47.7	7	154.9	-4.3	146	-2.1	32.8	9.7
1990	60	25.7	187.2	20.9	143	-2.1	28.7	-12.3
1991	66.3	10.5	190.1	1.6	137	-4.2	28.3	-1.6
1992	61.1	-7.9	168.4	-11.4	128	-6.6	35.6	25.8
1993	69.9	14.4	188.5	11.9	124.4	-2.9	31.5	-11.4
1994	74.9	7.2	198.7	5.4	121.8	-2.1	29.5	-6.4
1995	77.9	4	209.3	5.4	121.2	-0.5	28.5	-3.2
1996	84.2	8.1	214	2.2	117.1	-3.4	28.1	-1.6
1997	87.5	3.9	233.2	9	115.1	-1.7	27.9	-0.7
1998	78.7	-10	208.5	-10.6	120.7	4.9	27.4	-1.5
1999	79.9	1.5	208.9	0.2	119.2	-1.2	27.5	0.1
2000	80.8	1.2	220	5.3	120.6	1.1	27.6	0.5
2001	90.5	11.9	218.6	-0.6	112.9	-6.3	27.6	0.1
2002	90.8	0.4	252.4	15.5	113.1	0.2	27.7	0.2
2003	91	0.2	228.4	-9.5	114.9	1.5	27.6	-0.2
2004	91	0	239.5	4.9	110.6	-3.7	27.7	0.3
2005	91.6	0.7	215.3	-10.1	110	-0.5	27.6	-0.5
2006	87.3	-4.7	232.4	8	120.3	9.3	28.8	4.4
2007	87.4	0.2	234.2	0.8	118.1	-1.8	27.6	-4.1
2008	86.8	-0.7	221.1	-5.6	115.1	-2.5	26.1	-0.02
Compound Annual Changes		**3.54**		**1.6**		**-1.2**		**-1.45**
C. V.	43		19		14		21	

Table 5.2 (cont.)

Years	Net Areas Sown		Total Cropped Areas		Areas Sown More than Once		Cultivable Land	
	Areas*	Change ^	Areas*	Change^	Areas*	Change^	Areas*	Change^
1971	1054.2		1469.5		415.3		1095.8	0.0
1972	950.6	-0.1	1271.0	-0.1	320.4	-22.8	990.9	-0.1
1973	929.8	0.0	1294.1	0.0	355.3	10.9	990.7	0.0
1974	939.4	0.0	1253.1	0.0	313.8	-11.7	999.0	0.0
1975	948.4	0.0	1317.8	0.1	369.4	17.7	1015.9	0.0
1976	943.2	0.0	1310.5	0.0	367.3	-0.6	1014.6	0.0
1977	896.4	-0.1	1205.5	-0.1	309.1	-15.8	1011.6	0.0
1978	916.0	0.0	1303.1	0.1	407.1	31.7	1016.3	0.0
1979	837.0	-0.1	1165.7	-0.1	328.7	-19.3	1015.9	0.0
1980	862.5	0.0	1239.6	0.1	377.0	14.7	1016.8	0.0
1981	911.2	0.1	1286.6	0.0	375.5	-0.4	1017.9	0.0
1982	923.8	0.0	1326.6	0.0	402.7	7.3	1015.0	0.0
1983	923.5	0.0	1347.9	0.0	339.6	-15.7	1006.3	0.0
1984	907.9	0.0	1293.5	0.0	385.5	13.5	993.2	0.0
1985	910.6	0.0	1333.8	0.0	423.2	9.8	992.8	0.0
1986	894.5	0.0	1324.5	0.0	430.0	1.6	991.4	0.0
1987	817.9	-0.1	1068.3	-0.2	250.3	-41.8	991.7	0.0
1988	903.1	0.1	1357.0	0.3	453.8	81.3	979.3	0.0
1989	869.0	0.0	1262.7	-0.1	393.7	-13.3	979.8	0.0
1990	1020.2	0.2	1578.6	0.3	558.5	41.9	1108.2	0.1
1991	1009.4	0.0	1452.6	-0.1	443.3	-20.6	1108.5	0.0
1992	970.3	0.0	1543.9	0.1	570.5	28.7	1027.8	-0.1
1993	1001.0	0.0	1567.3	0.0	564.9	-1.0	1066.0	0.0
1994	1015.6	0.0	1582.7	0.0	566.4	0.3	1084.8	0.0
1995	1015.0	0.0	1587.0	0.0	571.7	0.9	1087.9	0.0
1996	1011.0	0.0	1594.5	0.0	583.2	2.0	1089.3	0.0
1997	967.2	0.0	1503.9	-0.1	536.6	-8.0	1072.5	0.0
1998	1031.6	0.1	1590.8	0.1	559.2	4.2	1104.3	0.0
1999	1030.2	0.0	1598.1	0.0	568.0	1.6	1103.5	0.0
2000	1014.3	0.0	1591.2	0.0	576.9	1.6	1091.0	0.0
2001	1007.1	0.0	1602.0	0.0	594.8	3.1	1090.7	0.0
2002	923.3	-0.1	1413.3	-0.1	490.0	-17.6	1055.8	0.0
2003	977.4	0.1	1642.4	0.2	665.0	35.7	1078.9	0.0
2004	973.6	0.0	1591.7	0.0	618.1	-7.1	1071.8	0.0
2005	1016.5	0.0	1605.5	0.0	589.0	-4.7	1093.5	0.0
2006	970.0	-0.1	1593.2	0.0	623.2	5.8	1055.3	0.0
2007	981.4	0.0	1616.0	0.0	634.6	1.8	1071.0	0.0
2008	877.5	-0.1	1440.5	-0.1	563.0	-11.3	950.6	-0.1
Compound Annual Changes		**0.14**		**0.69**		**1.83**		**0.16**
C.V.	6		11		**24**		4	

Table 5.2 (cont.)

Years	Land not Available for Cultivation		Total Un-Cultivated Land		Total		Rural		Urban	
	Areas*	Change^	Areas*	Change^	Population"	Changes^	Population"	Changes^	Population"	Changes^
1971	355.7		91.5		7.16		3.07		4.09	
1972	334.3	-0.06	91.9	0.4	7.40	0.032	3.10	0.01	4.29	0.05
1973	337.9	0.01	82.5	-10.2	7.63	0.032	3.12	0.01	4.49	0.05
1974	330.3	-0.02	87.8	6.4	7.88	0.032	3.14	0.01	4.71	0.05
1975	326.2	-0.01	76	-13.4	8.13	0.032	3.16	0.01	4.94	0.05
1976	329.9	0.01	75.1	-1.3	8.40	0.032	3.19	0.01	5.17	0.05
1977	334	0.01	81.1	8	8.67	0.032	3.21	0.01	5.42	0.05
1978	331.1	-0.01	80.5	-0.7	8.95	0.032	3.23	0.01	5.68	0.05
1979	339.3	0.02	87.5	8.6	9.24	0.032	3.25	0.01	5.96	0.05
1980	336.4	-0.01	92	5.1	9.53	0.032	3.28	0.01	6.24	0.05
1981	339.1	0.01	87.7	-4.6	9.84	0.043	3.30	0.05	6.54	0.04
1982	341.1	0.01	81	-7.7	10.26	0.043	3.45	0.05	6.81	0.04
1983	349.3	0.02	82.5	1.9	10.70	0.043	3.60	0.05	7.10	0.04
1984	355.2	0.02	78.8	-4.4	11.16	0.043	3.77	0.05	7.39	0.04
1985	345.4	-0.03	79.5	0.8	11.64	0.043	3.94	0.05	7.70	0.04
1986	351.6	0.02	82.2	3.4	12.14	0.043	4.11	0.05	8.02	0.04
1987	353.9	0.01	89.7	9.1	12.65	0.043	4.30	0.05	8.36	0.04
1988	355.6	0	82.4	-8.1	13.20	0.043	4.49	0.05	8.70	0.04
1989	348.6	-0.02	85.1	3.3	13.76	0.043	4.69	0.05	9.07	0.04
1990	390.2	0.12	75.5	-11.4	14.35	0.043	4.91	0.05	9.44	0.04
1991	393.5	0.01	75	-0.6	14.96	0.037	5.13	0.02	9.84	0.04
1992	357.5	-0.09	89.2	18.9	15.51	0.037	5.24	0.02	10.27	0.04
1993	382.7	0.07	78.6	-11.9	16.08	0.037	5.36	0.02	10.71	0.04
1994	395.4	0.03	73.9	-6	16.67	0.037	5.48	0.02	11.18	0.04
1995	408.4	0.03	72	-2.5	17.29	0.037	5.60	0.02	11.67	0.04
1996	415.2	0.02	86.6	20.2	17.92	0.037	5.73	0.02	12.17	0.04
1997	435.8	0.05	82	-5.3	18.58	0.037	5.85	0.02	12.70	0.04
1998	408	-0.06	68	-17	19.26	0.037	5.99	0.02	13.26	0.04
1999	408.1	0	69.2	1.7	19.97	0.037	6.12	0.02	13.84	0.04
2000	421.4	0.03	70.2	1.4	20.70	0.037	6.26	0.02	14.44	0.04
2001	422	0	101.1	44.1	21.46	0.018	6.40	-0.01	15.07	0.03
2002	456.4	0.08	77.4	-23.5	21.84	0.018	6.31	-0.01	15.46	0.03
2003	434.2	-0.05	74.8	-3.4	22.23	0.018	6.23	-0.01	15.88	0.03
2004	441.1	0.02	74.1	-0.9	22.63	0.018	6.16	-0.01	16.30	0.03
2005	416.9	-0.05	74.3	0.3	23.04	0.018	6.10	-0.01	16.75	0.03
2006	439.9	0.06	90.8	22.1	23.46	0.018	6.05	-0.01	17.21	0.03
2007	439.8	0	78.3	-13.8	23.89	0.018	6.01	-0.01	17.69	0.03
2008	423.1	-0.04	79.3	1.4	24.33	0.018	5.97	-0.01	18.18	0.03
Compound Annual Changes		**0.87**		**-0.3**		**3.4**		**2.32**		**3.88**
C.V.	**11**		**9**		**38**		**27**		**44**	

Source: Indian Agriculture Statistics Vol. II. District-wise- (1971-2008)

*Areas in '000 hectare

^ Changes in Percentage

" Population in Million

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CHAPTER-VI

SUMMARY AND CONCLUSION

Aravalli hill region of NCR, where hills and offshoots of Aravalli range are seen comes under administrative area of National Capital region. This comprises four districts of Haryana namely Gurgaon, Faridabad, Rewari and Mewat and Alwar district of Rajasthan and Delhi.

Aravalli region of NCR has a very varied environment in terms of geology, physiography, drainage and soil. It has semi-arid monsoonal continental type of climate. It has ferrous and non-ferrous mineral resources. Vegetation cover is restricted to only a few pockets. Most of the forest cover is sparse as open forest and degraded type. The region has a high population density. In fact, the capital city of Delhi located within the region has a strong influence on all aspects of physical environment as well as on human resources.

Land use / land cover of Aravalli hill region in NCR has been categorized into eight classes with the help of satellite images. The categorization of land use patterns is as agricultural land, build-up area, densely forest area, forest area, open forest, barren land and water bodies.

Area under agricultural land has shown a significant and consistent decline from 1977 to 2006. Simultaneously, area under build-up category has been increasing at a fast rate. Area under forest cover has also shown an increase in the corresponding time period. A consistent increase in open forest and degraded forest cover has been observed. There has also been a decline in its dense forest and barren land cover. Pastures, grazing land and water bodies are also under pressure and have shown some decline in the region.

The significant land use / land cover changes have been observed in the region during 1977 to 2006. These have been brought about by various factors those seem to be mainly due to anthropogenic impact. Major factor of these are increasing population and urbanization. These factors have put a heavy stress on land resource of Aravalli hill region of NCR.

Land degradation is mainly the outcome of human activities on the earth's surface, but there are also natural or environmental processes influencing degradation processes. Land degradation is one of the most pressing problems in the region. As the area of Aravalli hill region of NCR has semi-arid climate, it is highly prone to degradation, salinization and desertification.

Wasteland and degraded land of Aravalli hill region of NCR are comprised of gullies and ravinous land, scrubland, waterlogged and marshy land, land affected by salinity and alkalinity, underutilized and degraded notified forest land, degraded forest land, degraded pasture and grazing land, land under plantation crops, sandy area, mining waste and industrial wasteland and barren rocky and stone waste area.

Total wasteland and degraded land in the region has come down registering a decline of around fifty per cent during 2000 to 2009. It has been found that area under gullies & ravinous land, scrubland, barren rocky and sheet rock area is decreasing at a relatively faster rate. On the other hand, waterlogged and marshy land has also decreased. Land affected by salinity and alkalinity is also declining in the region. Drastic decline has been seen in the area under degraded notified forest and sandy area. That is the result of afforestation programme and combating desertification programme in the region. In contrast, increase in degraded pasture and grazing land and industrial wasteland have been observed. That is outcome of the population and increase in the number of industries in the region. Mining and barren rocky stone wasteland are also

decreasing in Aravalli hill region of NCR.

Increasing anthropogenic factors like increase in population, urban population and build-up area have been seen as major factors for the increase in degraded pasture land and industrial wasteland. While reduction in degraded notified forest land, degraded land under plantation crops and sandy area is the result of greater environmental consciousness. Afforestation work done by NGOs and the government are behind the increase in open forest and reduction of degraded forest cover. Reduction of barren rocky wasteland is the outcome of human intrusion on barren land for his use. There is process found responsible for reduction in barren rocky area of Aravallis through construction and urban expansion etc.

Overall, there is a net decline in total waste and degraded land in Aravalli hill region of NCR. Most of the degraded land of the region comprises of area under barren rocky, stone waste, under gullied and ravinous land water logged and marshy land and land affected by salinity and alkalinity. Sandy areas and land under degraded notified forest cover are declining significantly. This has happened through afforestation in the region.

NDVI value shows one per cent loss of green vegetation cover during 1999 to 2006. That is the result of increase in non-vegetated area of the region. That loss of total vegetation cover has been seen due to decline in pasture land, dense forest and increase in area under degraded forest land. There is a significant rise in non-vegetated area in the region as a result of increase in build-up area, barren and fallow land. It seems that the increase in non-vegetated area of the region is also the result of an increase in human settlements and other build-up area.

Exponential growth of population may be seen as a significant contributor to the loss of cultivable land and increase in areas not available for cultivation. Increase has been seen in forest land and builds up area at the cost of pasture land, barren land and

net cultivated area. There is a significant positive correlation between increase in population and increase in build-up area. Negative correlation has been found between population increase and pasture land, barren land and net cultivated area. That led to increase in area sown more than once. It shows that Aravalli hill region in NCR is under tremendous pressure of growing population. It indicates that ever growing population is surpassing carrying capacity of the land. Increasing demand of land for construction and industry is met at the cost of barren land, pasture land and agriculture land.

It may be said that Aravalli hill region of NCR is showing significant land use / land cover changes and degradation. Land use changes have been found in buildup area, forest land, pasture land, agricultural land and barren land and water bodies. Highest increase have been found in build-up area, open forest and degraded forest land. Decline has been found in agricultural area, dense forest, pasture land and barren land.

Land degradation is also a major phenomenon of the region. Decline in gullies & ravinous land, scrubland, pasture and grazing land, barren rocky area and sandy area have been found. Area under degraded pasture land is increasing. NDVI it have shown significant decline in total vegetation cover during 1999 to 2006. It has been stated that observed increase in forest cover contributes very little to overall vegetation cover of the region. Decline in dense forest, pasture land, scrubland and other green vegetation covers are responsible for the reduction of total vegetation cover in the region.

Anthropogenic impact has been found to be a significant contributor for decline of area under natural vegetation and increase in the build-up areas of the region. This has led to land use land cover change and degradation in the region.

It can be concluded that further comprehensive micro analysis is needed at all levels to capture the holistic impact of these factors which are together responsible for the loss and degradation of Aravalli hill region of NCR.

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