LAND USE/LAND COVER STUDIES IN A; PART OF NORTH- EASTERN PUNJAB BY USING MULTIDATE SATELLITE DATA

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CERTIFICATE

This research work embodied in this dissertation entitled **"Land Use/Land Cover Studies In A; Part of North- Eastern Punjab By Using Multidate Satellite Data"** has been carried out at the School of Environmental Sciences, Jawaharlal Nehru University New Delhi. This work is original and has not been submitted in part or full for any other degree or diploma in any other university/institution.

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New Delhi **Sudhir Kumar Singh**

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Preface

Uses of the land to humankind are multi-facet. As a source for primary production system, it serves as a store of water and nutrients required for plants and other living organisms. Proper use of land is essential to obtain the maximum benefit out of it. The proper use includes growing of suitable crops and plants, efficient soil and water conservation measures etc. The surface area alone cannot measure land as a resource, hence the types of soil, which is critical for productivity, underlying geology, topography, hydrology and plants and animal population also have to be considered. These attributes limit the extents of land available for various purposes. The growing population, industrialization and misuse and overexploitation of land resources have in effect increased the demand for land. Now with the development of remote sensing techniques and launching of new generation Indian Remote Sensing Satellite (IRS), the task been much easier. Remote sensing, in association with other conventional techniques, not only provides a minute coverage of the inaccessible areas but also helps collecting information about the subsurface characteristics, in very cost effective and time saving way. In the present study an attempt has been made to explore the, dynamic reasons for the change in land use/land cover and correlating the different data with the change in land use/land cover. This study consists of post image classification change detection by Landsat (1990) and IRS LISS III (2005) satellite data. It is the temporal study.

In this study the Chapter 1 gives the general introduction about the global issues related to change in land use/land cover, classification criteria, roles of remote sensing, geographic information system and global positioning system in the studies of change in land use/land cover, remote sensing based change analysis and soil erosion. Chapter 2 illustrates literature review done on brief introduction, land cover mapping, and soil loss in the siwalik and plain of the study area. A detailed account of location and extent of the study area, Phyisography, description about physical feature (siwalik and plains), climate (rainfall and temperature), description about soils of study area, land use/land cover of the present study area and land use pattern in the study area. Chapter 4 presents the objectives and scope for the present study. Chapter 5 describes the materials and methods for the present study. Chapter 6 elaborates the result and discussion. It presents the land use/land cover mapping, change detection by post classification methods and to find out the dynamic reasons for the change in land use/land cover of the study area.

Concluding remarks are listed in Chapter7 and some filed photographs are attached at the end of this dissertation before bibliography.

Sudhir Kumar Singh

July 28, 2007

‘O Mother Earth! Sacred are the hills, snowing mountains, and deep forests, be kind to us and bestow upon us happiness. May you continue supporting people of all races and nations!'

Atharva Veda

Chapter 1

Introduction

Chapter 1

INTRODUCTION

1.1 GENERAL

There is an unequal urban growth, which is taking place all over the world, but the rate of urbanization is very fast in the developing countries especially in Asia. In 1800 A.D, only 3% of the world's population lived in urban centers but this figure reached to 14% in 1900 and in 2002, about 47% (2.8 billion) people were living in urban areas. India no longer lives in villages and 79 million people were living in urban areas in 1961 but it went up to 285 million in 2001. In India and China alone, there are more than 170 urban areas with populations of over 750,000 inhabitants (United Nations Population Division, 2001). Statistics show that India's urban population is second largest in the world after China, and is higher than the total urban population of all countries put together barring China, USA and Russia. In 1991, there were 23 metropolitan cities in India, which increased to 35 in 2001 (Census of India, 1991 and 2001). There is a mass migration of people from rural to urban and also from smaller to bigger urban areas. The major cause anticipated for this is the high in-migration in search of better employment opportunities in these urban centers in comparison to neighboring states. As urban population increases, the demand of land for various urban activities also increases. The process of urbanization in India gained momentum with the start of industrial revolution way back in 1970s followed by globalization in 1990s. Forests were cleared, grasslands ploughed or grazed, wetlands drained and croplands encroached upon under the influence of expanding cities, yet never as fast as in the last decade (Rahman, 2007).

This explosive increase in the exponential form of 'Population Growth' has caused havoc for the human life in the city environment. Doubling and tripling of urban population practically in all major cities and towns and the consequent strain on the existing system manifested in an environmental chaos. Every major city of India faces the same proliferating problems of urban expansion, inadequate housing, poor transportation system, poor sewerage, erratic electric supply, insufficient water supplies etc. An increasing number of trucks, buses, cars, three-wheelers and motorcycles all spewing uncontrolled fumes, surge in sometimes-haphazard patterns over city streets jammed with jaywalking pedestrians, rickshaw and cattle. The phenomena of accelerated urbanization is the main culprit, wherein besides bringing higher standard of living has also brought problems of growth of dense and unplanned residential areas, environmental pollution, non-availability of services and amenities and solid waste generation and growth of slums.The level of pollution i.e. air, water and land has increased because of lack f poor environmental management. This has its direct impact on quality of urban environment, affecting efficiency of the people and their productivity in the overall socio-economic development. Each urban centre has a number of environmental problems with varying scale and scopes which are influenced by factors such as size of population and its density, climatic conditions, water resources and the flora and fauna in and around the urban centre (Hardoy et al., 1997). The state of urban environment all over India is deteriorating so fast that the sustainability of the cities is threatened. As the cities expand and population increases, the resources, which are limited, are shared. The lack of services such as water supply, sanitation, drainage of storm water, treatment and disposal of waste water, management of solid and hazardous wastes, supply of safe food, water and housing are all unable to keep pace with urban growth.

1.2 CLASSIFICATION CRITERIA

A land use and land cover classification system, which can effectively employ orbital, and high-altitude remote sensor data should meet the following criteria (Anderson, 1971):

1. The minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensor data should be at least 85 percent.
2. The accuracy of interpretation for the several categories should be about equal.
3. Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.
4. The classification system should be applicable over extensive areas.
5. The categorization should permit vegetation and other types of land cover to be used as surrogates for activity.

6. The classification system should be suitable for use with remote sensor data obtained at different times of the year.

7. Effective use of subcategories that can be obtained from ground surveys or from the use of larger scale or enhanced remote sensor data should be possible.

8. Aggregation of categories must be possible.

9. Comparison with future land use data should be possible.

10. Multiple uses of land should be recognized when possible.

Some of these criteria should apply to land use and land cover classification in general, but some of the criteria apply primarily to land use and land cover data interpreted from remote sensor data. It is hoped that, at the more generalized first and second levels, an accuracy in interpretation can be attained that will make the land use and land cover data comparable in quality to those obtained in other ways. For land use and land cover data needed for planning and management purposes, the accuracy of interpretation at the generalized first and second levels is satisfactory when the interpreter makes the correct interpretation 85 to 90 percent of the time. For regulation of land use activities or for tax assessment purposes, for example, greater accuracy usually will be required. Greater accuracy generally will be attained only at much higher cost. The accuracy of land use data obtained from remote sensor sources are comparable to that acquired by using enumeration techniques.

1.3 ROLE OF REMOTE SENSING, GIS AND GPS IN STUDIES OF LAND USE / LAND COVER

So in this context an integrated geo-spatial technology i.e. remote sensing (RS), geographic information system (GIS) and global positioning system (GPS) can contribute substantially in a more supplementary fashion to some of the interactive operations that should become an asset for assessing, understandings, mapping utility and service facility using GPS and solving complex urban and rural environmental issues. By utilizing remote sensing data and implementing GIS mapping techniques, change detection over a period of time of the urban and rural areas can be monitored and mapped for specific developmental projects. Creating linkages between remote sensing data and socio economic data obtained on the ground from household surveys has been recognized as one of the major challenges of land use/land cover change studies (Rindfuss et al. 2003). Satellite Remote Sensing, with its repetitive coverage together with multi-spectral (MSS) capabilities is a powerful tool to map and monitor the emerging changes in the urban core as well as in the peripheral areas of any urban areas. The loss of agricultural land because of rapid urbanization has been detected using remote sensing techniques in some cities of India i.e. Hyderabad, Madras and Nagpur (NRSA, 1994). The situation is severe in India due to unplanned growth of the cities in all directions. The spatial patterns of urban sprawl in all direction over different periods, can be systematically mapped, monitored and accurately assessed from remotely sensed data along with conventional ground data (Lata et. al., 2001).

Table 1. 1 Showing the land use/ land cover class and image characteristics

Land Use/ Land Cover	**Image Characteristics**
1. Settlements	Light gray clustering with particular patterns for the urban area. There may be brownish maroon patches for in between vegetation. For the rural settlements there occurs no particular patterns of such image characteristics.
2. Agriculture	Identify Rabi if the month of the data acquisition is January or February or march and color is brown red. For the Kahrif crops same charters tics in image occur if image data are acquired in the month of September, October, or November. B). Fallow land is identified by light gray color within cropped area (red color) C). Plantation occurs as brownish maroon patches.

3. Forest **A). Dense forest** **B). Degraded Forest** **C). Forest Blank** **D). Forest Plantation**	Dense forests are identified by dark red color patterns. In the case of degraded forest the dark color patterns contain small brown or white patches. The blanks in the forest show creamy patches in the dark red/ background. Dark red color sign of particular pattern identifies forest plantations.
4. Waste land **Muddy water logging, Clear water logging, temporary water logging, permanent water logging, marshy area water logging gullied land, land with scrub without scrub, sandy area**	Muddy water logging occurs as blackish or deep blue spots while dark/ bright blue patches identify clear water logging area. Comparing the image of rainy season and out of rainy season identifies temporary and permanent water logging. Marshy area is recognized as a sign of vegetation (red/ pink spots) in the water logged (brackish/ bright blue) area. Gullied land occurs white/ gray spot. The image of land with scrub contains white patches in the land area. Sandy area is classified as bright white coloration along the course of river.
5. Water bodies **A). River/ Stream** **B). Canal** **C). Lake/ Reservoirs** **D). Embankments**	River/ Stream is identified as long non-linear path colored with dark blue/ bright blue line in white background. Canals are identified as patterns along the river. Embankment occurs as light gray structure along the river.
6. Others	Grassland are identified as uneven appearance characterized by red (light to medium gray tones)

1.4 REMOTE SENSING BASED CHANGE ANALYSIS

There are several urban applications where satellite based remotely sensed data are being applied, namely, urban sprawl/ urban growth trends, mapping and monitoring land use/ land cover, urban change detection and updating, urban utility and infrastructure planning, urban land use zoning, urban environment and impact assessment, urban hydrology, urban management and modeling. Remote sensing techniques offer benefits in the field of land use/ land cover mapping and their change analysis. One of the major advantages of remote sensing systems is their capability for repetitive coverage, which is necessary for change detection studies at global and regional scales. Detection of changes in the land use/ land cover involves use of at least two period data sets. The changes in land use/ land cover due to natural and human activities can be observed using current and archived remotely sensed data. Land use/ land cover change is critically linked to natural and human influences on environment. With the availability of multi-sensor satellite data at very high spatial, spectral and temporal resolutions, it is now possible to prepare up-to-date and accurate land use/ land cover map in less time, at lower cost and with better accuracy. Keeping the above in view, the present work has been undertaken to prepare the multi-date land use/ land cover maps of study area from multi-sensor satellite data and to monitor the changes in various land use/ land cover classes using digital remote sensing techniques.

Change detection involves the use of multi-temporal datasets to derive land-cover changes between the dates of imaging. Types of change vary from short term to long term. Change detection procedures require data of the same or similar sensors. Influencing environmental factors should be considered in change detection procedures. Spatial and spectral resolution of recent satellite sensors gives high-quality satellite images. Remote sensing data having good spectral and spatial resolution are extremely useful for mapping land use and land cover. Areas surrounded by aquatic systems are important for their contribution to the hydrological cycle. Several image-processing techniques have been developed in the last three decades to process and analyze remote sensing images and extract meaningful information. Different land-cover types in an image can be classified using image-classification algorithms having spectral features. Methods based on spectral variations are robust when dealing with data captured at different times of the year.

Land cover is a fundamental parameter describing the Earth's surface. This parameter is a considerable variable that impacts on and links many parts of the human and physical environments. Remote sensing technique has ability to represent of land cover categories by means of classification process. With the availability of multispectral remotely sensed data in digital form and the developments in digital processing, remote sensing supplies a new prospective for land-cover and land-use analysis. Geographical Information Systems have already been used for assessing environmental problems, since they provides a flexible environment and a powerful tool for the manipulation and analysis of spatial information for land cover feature identification and the maps of all variables were combined to extract information to better understand analyzing (Weng, 2001). Satellite remote sensing, in conjunction with geographic information systems, has been widely applied and been recognized as a powerful and effective tool in analyzing land cover and land use categories. This study made use of remotely sensed data and GIS technologies; to evaluate qualitatively and quantitatively outcome of land cover and land use distribution. Obtained results were compared with each other, visualized and analyzed, in Geographic Information System.

Land-use/land-cover pattern is the result of anthropogenic interaction with the natural environment. Besides affecting the quality of life of the people living in the area, it also affects surface run-off as also erosion intensity that control the reservoir life. The inhabitants of the area traditionally maintained a large number of animals. Increasing restrictions upon forest resources in the previous decades have, however, led to substantial reduction in cattle headcount. This at the same time has increased human pressure upon land. Remote sensing techniques are particularly suited for providing reliable, up-to-date and comprehensive data on land-use/land-cover. Apart from the field investigations, IRS LISS III multispectral and Landsat data were used for preparing the land-use map of the area.

1.4.1 SOIL EROSION

Soil degradation by accelerated water and wind-induced erosion is a serious problem and will remain so during the 21st century, especially in developing countries of tropics and subtropics. Erosion is a natural geomorphic process occurring continually over the earth's surface. However, the acceleration of this process through anthropogenic perturbations can have severe impacts on soil and environmental quality.

Accelerated soil erosion has adverse economic and environmental impacts (Lal, 1998). Economic effects are due to loss of farm income due to on-site and off-site reduction in income and other losses with adverse impact on crop and animal production. The potential utility of remotely sensed data in the form of aerial photographs and satellite sensors data has been well recognized in mapping and assessing landscape attributes controlling soil erosion, such as Phyisography, soils, land use/land cover, relief, soil erosion pattern (e.g. Pande *et al.*, 1992). Remote Sensing can facilitate studying the factors enhancing the process, such as soil type, slope gradient, drainage, geology and land cover. Multi-temporal satellite images provide valuable information related to seasonal land use dynamics. Satellite data can be used for studying erosional features, such as gullies, rainfall interception by vegetation and vegetation cover factor.

1.4.2 CHANGE IN ARABLE LAND

Agriculture is important for the development of the human being and their environment. The agriculture growth of any country important for the sustainability of the society and environment. Now a day the change in land use/land cover is directly and indirectly affect the agriculture like the widening of road, construction of building, industrial setup, urbanization etc. Now there are so many methods for the estimation of the change in arable land. Recent technique like Remote Sensing is used for the regular, mapping, monitoring, and assessment of the crop yield.

1.4.3 CHANGE IN FOREST COVER

Forest is natural resource. Forest is required for the ecological balance in the ecosystem. In all over the world there is great decrease in natural forest. But now a day is some part there is also increase in the forest cover (plantation). The change in forest cover is due increase in agriculture field, deforestation for the urban area, and other developmental activities.

1.4.4 URBANIZATION

There is continuous increase in urban area around the world. Urbanization creates lots of changes in the environment like the loss of agriculture field, reduction of forest cover, in the impervious layer, drop in water level, change in air quality, loss of biodiversity. So there will be great need for human survival, by sustainable management of the resources. Human communities cannot exist in isolation, economically, socially or physically. They have to be inter-dependent for the mutual satisfaction of their requirement and also for meeting their basic needs. For meeting their basic needs, they are also dependent on the nature specially the immediate environment. Flux of population in urban territories due to migration from rural areas coupled with rapid growth in population has disturbed the ecological balance. This process hampers the socio economic sustainable development of any region. Expansion of suburban territory with encroachment in prime land is a matter of concern for all and in particular for the authorities associated with the urban planning and development.

Spatial distribution of land use/ land cover information and its changes is desirable for any planning, management and monitoring programmes at local, regional and national levels. This information not only provides a better understanding of land utilization aspects but also plays a vital role in the formulation of policies and program required for developmental planning. Planning means the assessment of future and making provisions for it. For ensuring sustainable development, it is necessary to monitor the ongoing changes in land use/land cover pattern over a period of time. Urban planning and development is a continuous process and involves planners, administrators, developers, investors and of course, the residents. In order to achieve sustainable urban planning and to check haphazard development, it is necessary that authorities associated with the urban development generate such planning models so that every bit of the available land is used in most rational and optimal way. This requires the present and past land use/land cover information of the area and pattern of changes with respect to urban settlements and other local resources like forest cover, biodiversity, agricultural field. The proper knowledge of the land use/land cover will help in maintaining the global issues like global warming, rise sea surface temp, increases the concentration of carbon dioxide etc. Remote Sensing and GIS is very important plays important role in the studies of land use/land cover mapping, monitoring and assessment.

Chapter 2

Literature review

Chapter 2

LITERATURE REVIEW

2.1 INTRODUCTION

Land is one of the important natural resources and as such it needs proper evaluation for sound planning and management (Singh & Roy, 1989). As human demands increase, sustainability of the land is in question. Better management of land involves identifying land use changes, understanding current land use patterns or features, and assessing economic and ecological benefits and costs that arise from land use practices, as well as finding alternatives. However, our management ability traditionally has been limited for two reasons: a). the difficulty in acquiring useful information over vast areas b). and the lack of a means to effectively process and analyze the acquired data (Campbell, 1987). Because of many factors associated with each feature under study, analysis and manipulation using manual methods are too costly, too time consuming or practically impossible (Aronoff, 1989). Remote sensing proved to be a cost effective tool for studying land use/land cover change (Jensen, 1996). Remote Sensing techniques can provide such information within short time at less cost and efforts (Gautam & Narayan, 1983; Gautam & Channaich, 1985). It also provides synoptic coverage of areas of interest and facilitates optimal monitoring capabilities. These features make remote sensing an optimal tool for this type of study (Alexander & Milazzo, 1973). Remote sensing provides data that are available in time series to study the dynamics of the area over long periods, which bridges monitoring gaps in understanding environmental change (Weng 2002, Parr et al.2003, Mukherjee, 1998, & Mukherjee, 2004). The inefficient usage of remote sensing in management actions resulted from the unadjusted accuracies of derived maps and information, but standardization in the process and reporting techniques has increased the reliance of satellite derived maps (Jensen 1996, Green et al. 2000, Lu et al 2003, Jansen & Gregorio 2004). Landsat satellites have been providing multispectral images of the earth continuously since the early 1970s. The Landsat and IRS satellite data have characteristic bands in the visible and in the near infrared part of the electromagnetic spectrum, which enable the estimation of land use/land cover patterns as well as change in land use/land cover. At the existing resolution of IRS-1A LISS-II data the identification and detection of the some of the land use classes for urban areas are not possible. This results in the merging of minor classes into the adjoining classes (Pathan et al., 1988). The areas falling just under the range of the resolution of the IRS-1A data required detailed ground survey for its correct delineation. Nowadays advance sensors as PAN and LISSIII provide more detailed coverage with vast capacity to measure spatial and temporal resolution at finer scale.

2.2 GLOBAL STUDIES OF LAND USE/LAND COVER CHANGE

The advanced technology like satellite remote sensing has played an important role in generating information about land use land cover (Botkin et al. 1984, Lent 1983 & Singh 1987). Food scarcity and continuous loss of agricultural lands are issues of global concern (Aboel Ghar, Shalaby, & Tateishi, 2004). Accurate and up-to-date land cover change information is necessary for understanding and assessing the environmental consequences of such changes (Giri, Zhu, & Reed, 2005). While remote sensing has the capability of capturing such changes, extracting the change information from satellite data requires effective and automated change detection techniques (Roy, Lewis, & Justice, 2002). Digital change detection is the process of determining and describing changes in land use/ land cover properties based on co-registered multi-temporal remote sensing data (Jaiswal, & Mukherjee, 1999). The basic premise in using remote sensing data for change detection is that the process can identify change between two or more dates that is uncharacteristic of normal variation. Numerous researchers have addressed the problem of accurately monitoring land use/ land cover change in a wide variety of environments (Chan, Chan, & Yeh, 2001; Muchoney & Haack, 1994; Singh, 1989). Ram and Kolarkar (1993) studied land use changes in arid areas in India by visual comparison of satellite imagery, maps and aerial photographs. There are many techniques available to detect and record differences (e.g. image differencing, ratios or correlation) and theses might be attributable to change (Singh, 1989; Stow, Chen, & Parrott, 1996; Yuan, Elvidge, & Lunetta, 1999). However, the simple detection of change is rarely sufficient in itself: information is generally required about the initial and final land cover or types or land uses, the ‘‘from-to’’ analysis (Khorram et al., 1999). Post-classification comparisons of derived thematic maps go beyond simple change detection and attempt to quantify the different types of change. The degree of success depends upon the reliability of the maps made by image classification. Broadly speaking, large-scale changes such as widespread logging or major urban development might be mapped reasonably easily. Whereas evolutionary changes such as erosion, succession, colonization or degradation, the boundaries may be indistinct and class-labels uncertain (Foody & Boyd, 1999; Khorram et al., 1999). Data on land use land cover patterns; their spatial distribution and changes are the prerequisites for-making development plans (Dhinwa et al. 1992). The loss of forest cover had been a matter of great concern through out the world and is mainly responsible for global environmental problems (Oza, 1992, Kushalapa, 1992 & Jaiswal et. al. 2002). A visual interpretation technique has been widely used for forest cover / land use pattern mapping (Anon, 1995 & Porwal et al. 1994).

Land cover is defined as that which one can observe on the surface of the earth (Di Gregorio & Jansen, 2000), whereas land use relates to the manner in which these biophysical assets are used by humans (Cihlar & Jansen, 2001), since use depends largely on the land characteristics (i.e. cover, form, position, substratum, etc.), there is a close relationship between land use/land cover observation does not automatically mean land-use definition because land cover and land use, though interrelated, are not identical. For each plot, i.e. a contiguous tract of land, individuals choose a land use type from which they expect to derive benefits, in the form of goods and services, considering their aims, available means, possible constraints and the given set of biophysical parameters. In addition, there are determining factors such as the institutional and cultural setting, the legal attributes of the plot (e.g. land tenure) and the broader socio-economic environment (Cihlar & Jansen, 2001). The land use choices made will vary in space and time and so will the resulting land cover. Understanding these land cover/land-use changes is regarded as crucial in understanding environmental change over the next decades in order to respond in a timely manner. Land use/land cover changes are one of four major environmental global problems, together with biodiversity, atmospheric composition, and climate change (Walker, Steffen, 1997 & Walker, 1998). The need for a better understanding of the land cover/land-use relationships and their changes has been the main incentive in establishing the joint international Geosphere-Biosphere Programme (IGBP) and International Human Dimensions Programmes (IHDP) land use /land cover change (LUCC) core project (Baulies, Canadell, 1998 & Turner et al., 1999). This project has recently endorsed the FAO/UNEP land cover classification system' (LCCS) methodology (Mc Connell & Moran, 2001). Attempts at compiling spatial land use information have been made, though not in a very systematic manner. They resulted, more often than not, in a mixture of land use/land cover (Jansen & Di Gregorio, 2002a). The main strategy in the past has been to design a land use classification or legend and to distinguish land use categories directly from remotely sensed images or other supporting data (Anderson et al., 1976; Kostrowicki, 1977; ECE-UN, 1989 & CEC, 1995). Land cover is based primarily on the spectral data content, while land use information benefits from aspects of the data such as pattern, shape, size, context, resolution, etc. (Lillesand & Kiefer, 2000). A skilled interpreter who is also known to the study area may efficiently extract this contextual information. The growing human and livestock populations and rainfall are exogenous factors influencing land use allocation (Stephenne & Lambin, 2001). The generation of fuelwood, food for subsistence household needs, cash crops for export, fallow, species protection and rangelands compete for the limited land resources. It should be noted that a land use does not necessarily concur with a single land cover type. The identified land cover classes are defined with LCCS that emphasizes the use of quantifiable criteria to build a class rather than class names (Di Gregorio & Jansen, 2000; Jansen & Di Gregorio, 2002a). Therefore, the resulting classes are based upon observable characteristics verified in a field survey that complements the preliminary interpretation. However, neither a comparable software application for land use, nor a widely accepted classification exists. The land use/land cover activities took place in parallel and thus cover the same timeframe.

2.3 CONCEPTUAL APPROACH FOR LAND USE /LAND COVER STUDIES

Though land use/ land covers are separate concepts, the two are also strongly related. Land cover can stand-alone but land-use in general cannot and must be inferred from land cover and patterns thereof. A relational land cover/land-use approach forms the conceptual framework upon which the method used in this study has been developed (Cihlar & Jansen, 2001). Land use is determined by biophysical, economic, institutional, cultural and legal factors. In the context of land evaluation (FAO, 1976,1984), possible land-uses are limited mainly by biophysical constraints such as climate, topography, soils and the geological substrate. The presence, type and characteristics of vegetative cover are important indicators of the climatic and edaphic conditions in the absence of (human) disturbances. Environmental conditions provide important constraints on possible land-use options but they are not always decisive. Sometimes the land cover is replaced by a land-use type that is only weakly hampered, if at all, by the natural environment (e.g. artificial structures such as roads, rail networks and buildings). Land use is also influenced by cultural factors such as agricultural practices: depending on locally prevailing customs different land-uses are practiced on the same type of village areas in southern Mali revealed that different land use options were preferred, depending on the showing that land management decision-making had changed from communal to individual land-use (Jansen & Diarra, 1989), an example of economically such as subsidies for sugarcane that have influenced land use in Brazil (Jansen, 1990) and the common agricultural policy of the European union that has affected land use /land cover patterns likewise.

If land cover is a result of land use, the land use /land cover relationship is generally easy to determine and tends to be strong. When human activity does not modify the appearance of the land cover, or modifies it in a way that is indistinguishable from changes by other land uses, the land use /land cover relationship is more difficult to establish (e.g., agroforestry practices or drinking water extraction in a forested area). When the modification of land cover is less profound, that is if a clear shift from one land cover type to another is absent, the type of land use is generally more difficult to infer and the reliability of the inference tends to be lower. The degree of land cover change resulting from a particular land use will depend on the local land-use practices. Land use practices change with time, by implication so may their relation to land cover and consequently the land use /land cover relationship (Cihlar & Jansen, 2001)

2.4 LAND COVER MAPPING STUDIES

Land cover mapping is one of the most successful applications to date for satellite based remote sensing. It is also a valuable activity since land cover information is essential for effective resource management and for developing sound policy on land utilization. These, in turn, are the mechanisms through which we hope to preserve environmental quality, and improve agricultural productivity and sustainability. Remote sensing has potential to supply accurate, objective, and up-to-date land cover mapping at a reasonable cost, particularly when required over extensive geographical regions. The traditional method of ground survey and inventory is, in comparison, both time-consuming and expensive. The research literature contains many examples of land cover mapping in a variety of landscapes and environments (Treitz et al. 1992, Civco 1993, & Mukherjee 1999). Soil salinity problems generally occur in arid and semiarid regions and reduce crop production at different levels (Mukherjee 1991). Salinity is also a major limiting factor for crop yield in poorly drained soils (Mikati, 1997; Gafni & Zohar, 2001; Rogers, 2002 & Patel et al., 2002). In some areas of the world where salinity is a major problem, it is rather difficult to monitor the required ground information in the areas affected by salinity (Gates et al., 2002). Multi-temporal analysis might be effective in detecting salt dynamics in a certain region and assessing the degree of damage on both crops and yield. The use of satellite imagery for monitoring salinity has proved feasible in large areas where salinity is already a serious problem (Su et al., 1989 & Metternicht, 2001). Despite some criticisms, remote sensing techniques have been shown to be a rapid and useful tool in monitoring and predicting salt-related crop productivity problems (Rahman et al., 1994; Alsaifi & Quari, 1996 & White, 1997). The integration of satellite imagery and geographic information system (GIS) has enabled new evaluation possibilities in agricultural areas.

Since dynamic crop simulation models are not perfect and have generally been developed and tested for application at the scale of homogeneous plots, there is an issue associated with the up scaling of model outputs linked with GIS. Decision makers usually need information at broader spatial scales where the assumption of a homogeneous environment does not hold and at higher system levels where different constraints operate (Hansen & Jones, 2000).

2.5 PREVIOUS STUDIES ON SOIL LOSS IN THE SIWALIK HILLS AND PLAIN OF RUPNAGAR

The knowledge of physiographic processes as portrayed on satellite imagery in the form of surfacial features provides enough traits to delineate soil boundaries. This technology has been employed successfully for soil mapping in different parts of the World (Westin and Freeze, 1976: Gastellu- Etchegorry et al., 1990 & Abd-El-Hay et. al., 1991) and in India (Sehgal et. al., 1988; Rao et. al., 1989 & Kudrat et. al., 1992). Information about the pedogenesis of soils in relation to physiography in Ropar Kandi tract is lacking Although, erosion in the NW Siwaliks is nearly a century old problems (Glover, 1946) but with the development of Chandigarh, there have been more adverse and pronounced effects on the vegetation of the adjoining Punjab – Haryana Siwalik Hills because of ever increasing demand for wood, fodder and construction materials. As a result, the process of soil erosion was accelerated. In certain areas of Morni Hills soil erosion has been extremely damaging. Heavy siltation of the famous Sukhna Lake even within two decades of its construction in 1958 attracted the attention of a number scientist. They studied the siltation problem and indirectly worked on soil erosion in the Siwalik catchment area of the Lake (Bansal & Mishra, 1982 & Grewal et al., 1990).

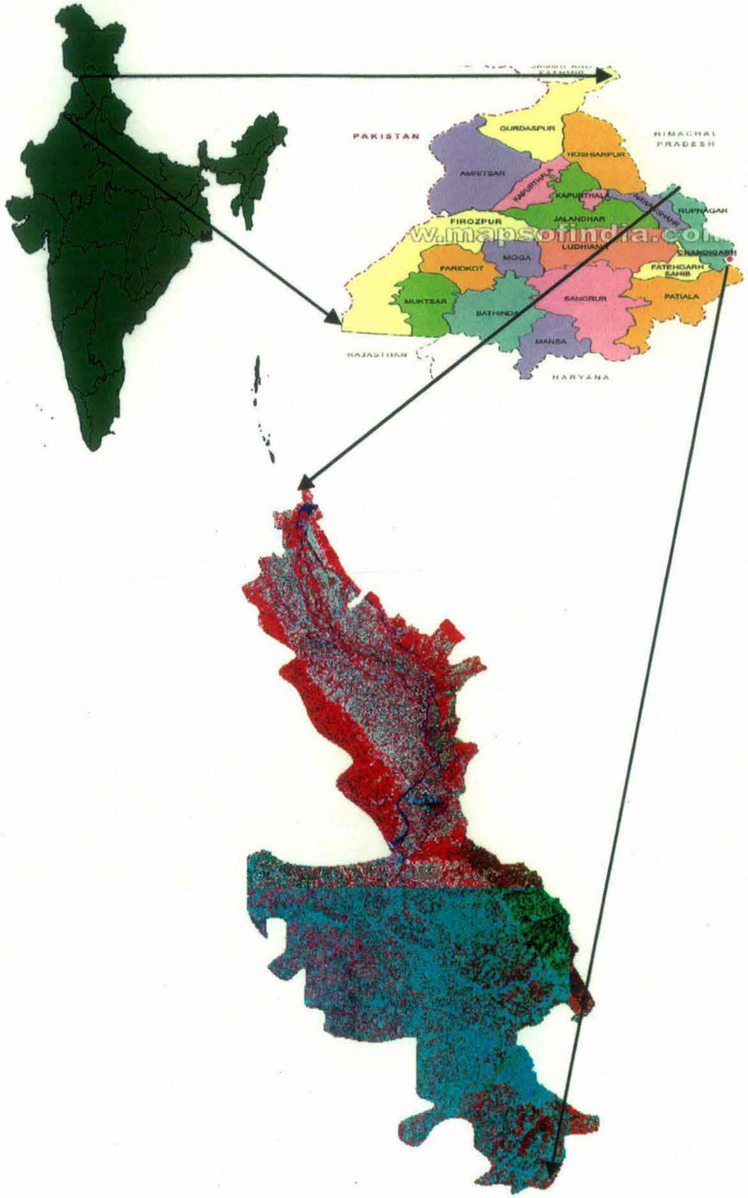
Now, the land degradation due to water induced soil erosion is a serious problem in Punjab-Haryana Siwalik region. Like several other regions of India, the Siwalik Hills experience severe erosion of more than 20 tonnes per hectare per year (Singh et al., 1990). Accepted average soil loss value of 80 tonnes per year has been reported from Siwalik region, this being a very high figure due to pinnacle erosion in this region although some of the ranges of Siwalik are vegetated too. The factors such as soil erodibility; steepness, length, aspect and shape of slope and vegetative cover have important influences on potential erosion hazard in submontane Punjab (Kukal et al., 1991). It has also been noted that slopes facing south, southwest and west have greater erosion hazard than those facing north-east because of more solar energy, greater aridity, less vegetation and dominantly concave slope. For the lower Siwalik Hills it has been found that vegetation cover is a more vital factor than slope steepness and length in determining actual erosion (Kukal et al., 1991). According to Singh (1996) Chandigarh-Morni Siwalik Hills have experienced high vicissitudes of environment and bio-degradation because of high anthropogenic pressures from the development in the capital city of Chandigarh and its satellite towns of SAS Nagar and Panchkula. Forest cover turns out to be the most significant factor while the geology of the hills, soil erosion and sedimentation are no less important. According to Singh (1992), the sedimentation of seasonal streams has brought about changes in their profiles. He worked out the longitudinal profiles of Manakpur, Sughrao, Jainti Devi Ki Rao, Budhki & Siswan streams flowing from Chandigarh Siwalik Hills on to the northern piedmont of Punjab plain near Chandigarh and noted that there is high degree of resemblance in the profiles of all these streams with upper, middle and lower courses and on the whole the profiles are planar or to some degree plano-convex. Due to siltation in the streambeds during rainy season the water over-flows the banks resulting in floods, which cause frequent inundation of the crop fields.

It has been observed by Singh (1994), that in the areas of the high erosion intensity in Siwalik Hills, the dominant vegetation is herbaceous in character. It is composed of grasses and herbaceous elements together with crown density of stunted trees below 10 per cent. Grasses are dominant with *Eulaliopsis binnata* being quite frequent. Areas of moderate erosion intensity are characterised by scrub vegetation with stunted trees and afforestation plantations of *Eucalyptus.* In high and moderate erosion intensity classes, it is the grazing pressure and the Eucalyptus water demand aided by semi-arid conditions that accelerate erosion of loose clayey - sandy soils. It may be pointed out that near Sukhomajri in the Siwalik Hills, about 70 per cent of rainfall of more than 1,200 mm per year (mostly received from July to September) used to be lost as run-off (working paper series No. 5 of Ford Foundation, New Delhi) till a stop to this wastage of water in Sukhomajri area in Chandigarh Siwalik Hills was ensured (Mittal et al., 1986). In Chandigarh Siwalik Hills there is alarmingly high rate of soil erosion in certain areas. According to Singh (1996) the soil loss of 367.5 tonnes/ha/year *i.e.* 2.45 cm of top layer per year from certain catchment areas is alarmingly high leading to voluminous depletion of organically rich soils.

Sustainable management of natural resources requires that ecological goods and services be used to meet current and future generations' needs by recognizing and adapting to the inevitable biophysical limitations and interdependences. For example, increasing the amount of land, water and nitrogen fertilizers for ever-increasing food consumption, which increases environmental degradation, leads to an unsustainable cycle. Environmental degradation makes it more difficult to meet our long-term basic human needs of food and clean water. Landscape analyses over long periods are essential for identification of such unsustainable trends. Multi-temporal high-resolution, remotely sensed data and geographic information systems (GIS) can be used to produce ecological inventories and monitor LULC changes at local, regional and global scales. In particular, the visible to short wave infrared (VSWIR) bands of Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM) data have been extensively used for surveys and analyses of forest and agricultural resources since the initiation of Landsat program in 1972, and by the IRS satellite data. The change in land use and land cover over space and time can be easily performed with the help of Remote Sensing and GIS. The change in land use/land cover had been identified with help of post classification analysis of image in this study (Jaiswal et.al. 2001).

Chapter 3

Study area



Rupnagar, study area

Chapter 3

STUDY AREA

3.1 INTRODUCTION

Land is a finite resource; yet in many regions of the world, population growth and demand for water and soil to provide food is increasing dramatically. The rapidly increasing population coupled with use of reductive approach in urban planning and developmental process has created lots of environmental impact in semiarid regions of Rupnagar district of State Punjab. The study area is district Rupnagar in State Punjab, India.

3.2 LOCATION AND EXTENT OF THE STUDY AREA

The area of Rupnagar is 2,117 Square Kilometer. District Rupnagar in Punjab State is part of the Kandi belt of the Himalayas and the alluvial plain of the river Sutlaj covering an area of 2680 sq. km. It is situated in northeastern part of the Punjab state lying between 30^0 34' to 31^0 26' N latitude and 76^0 17' to 76^0 52' E longitude.

3.3 PHYISOGRAPHY OF THE STUDY AREA

Physiographically there are main four units: Siwalik Hills, Valleys, Piedmont Plain and Alluvial flood plain. Siwalik hills have general slope ranging from 25 to 60 % and most of the hill area is under forests. The piedmont plain covers large area with slope 1 to 6 %, which is frequently intercepted by choes. This area is partly cultivated and partly under forests and wastelands. The alluvial flood plain is marked with the confluence of Sutlaj and Sirsa rivers with 1 to 3 % slope. Most of the area is under cultivation and is used for growing common agricultural crops.

3.3.1 PHYSICAL FEATURES

According to the geographical and physiographic point of view, the Punjab state divided into two regions: the Siwalik Hills and the Plain.

3.3.1.1 THE SIWALIKS

This region covers the outer range of the Siwalik Hills and is approximately 6 to 10 kilometers in width. Their height ranges between 400 and 700 meters above the sea level. It consists of conglomerates, clays, and silts all the character fluviatile deposits of rivers and streams. Different geologist has explained the origin of the Siwalik Hills differently. One view advanced is that the present Siwalik range is the flood plain of big river to whom pilgrims gave the name Indo-Brahm and Pascoe-Siwalik. According to another view the basin of deposition was a continuous lagoon or fore deep formed in front of the Himalayan range. The low range of Siwalik Hill separates the Himalayas from the plains. The Siwalik region covers the eastern most areas of the districts Rupnagar, the Hoshiarpur and the Gurdaspur and runs like a natural wall, northwest to southeast, separating the Sira and Una valleys of Himanchal Pradesh from the plain areas towards the west.

3.3.1.1. I. GEOLOGY OF SIWALIK

Broadly, the area can be subdivided into two distinct domains. Towards northeast rock sequence of the Himalayan Orogenic Belt is exposed, while the quaternary alluvial deposits of the Indo Gangetic Plains towards the North West region of the State, Punjab. The litho tectonic packets of the Himalayan Orogenic Belt are poorly metamorphosed Litho-Unit (F) C of the Tethyan sequence, high (F) F and low (F) FC grade assemblages of the central and other crystalline and lesser Himalayan belt, respectively along with granitoids and basic volcanics. The southern fringe of the Himalayan Belt is occupied by cover rocks of the frontal belt (F). Further south the quaternary cover is represented by alluvial fill along the foredeep (CF) and peritonic fills on attenuated continental crust (CPR) on northern and southern sides, respectively of the Delhi – Sagodha Ridge. Within the lesser Himalayan package the other important tectonic surface is the Vaikrita thrust

(VT). This lesser Himalayan belt is separated from the frontal belt (comprising the Siwalik sequence) by the main boundary thrust (MBT). The Ropar fault, occurring North West of Chandigarh is postulated to be the continuation of Sundergarh fault. A fault with similar trend and sense of the movement is identified in southeastern side of Chandigarh. The over all NW-SE trend of the Bouguer Gravity Anomaly is seen in most parts of the foredeep. In the southwestern tip of the area where basement is shallow a value of –10 to –20 m Gal is registered that decreases towards north to value as low as –230 m gal over the foothills. This steady fall in gravity is due to increase in foredeep sediment thickness, which is more than 3000 m near Hosiarpur –Chandigarh area. The accurate swing of contours over wide belt of Siwalik might represent shallow folds structures within the foothills. At the southwestern corner the relatively higher gravity, represented by closure of –20 to –30 m Gal, depicts the trend of the Delhi- Sargodha ridge.

3.3.1.2 THE PLAIN

The plain of Punjab is a part of Indo-Gangetic plain, which is synclinal basin, formed by the elevation of the Himalayas. One group of geologists hold this area to be afore deep formed in front of the stable peninsular India at a time when the Tethyan sediments were trust southwards and compressed against that stable block. Another group assumes the Indo-Gangetic plain to be the sites of a rift valley. The rivers of the region indicate that the plain is the result of recent deposition and these very rivers have formed the plain. The Punjab plain lies between 180 and 300 meters above sea level. It is the higher near Siwalik Hills but slopes away from them. The tract covering central Punjab ranges between 230 and 270 meters above sea level while western Bhtinda and Ferozepur districts lie below 230 meters above sea level. The land slopes from east to west. The gradient is much more in the east than in the west. The work of two important natural agents, which are wind and water, gives the contrasting structures in this area. The wind-dominated process occurs mostly in the western side of the region and the running water dominated process in the eastern side of the Siwalik range.

3.4 CLIMATE

The study area falls under semi arid (sub moist) and less hot zone of Punjab. It experiences two wet periods (mid December to mid February and mid June to mid September). The mean annual rainfall in the district is about 862 mm and major portion of it is received during the monsoon season with few showers during winter. The peak of the temperature (37.60^0 C) is observed during the month of June and January is the coldest month with mean monthly temperature falling to 7.10^0 C. As far as administrative set-up is concerned, the district consists of four tehsils, namely Rupnagar, Kharar, Mohali and Anandpur Sahib, and seven blocks Rupnagar, Chamkor Sahib, Morinda, Kharar, Majri, Nurpur Bedi and Anandpur Sahib. (Statistical abstract of Punjab: 2002)

3.4.1 TEMPERATURE

The subtropical latitudinal and continental location of Punjab makes the variation of temperature from month to month very high. Albeit the minimum air temperature rarely drops below 0° C, ground frost is common phenomenon in mid winter (Late December). The rise in temperature is gradual when the moisture content in the air is high from optimal level with the sky reaming overcast; the rise is however steep when the sky is clear and there is little moisture content in the air. The highest daytime temperature is recorded during the months of May and June, with the mean daily maximum temperature at about 40 °C and the mean minimum daily at about 25 °C. The lowest maximum temperature recorded during the month of January. When the sunrays are more oblique as compared to other months. The minimum temperature is lowest from December to February with about mean daily minimum 6 or 7 °C. The maximum numbers of days with the lowest night temperature are in the month of January. The highest minimum temperature is recorded in the month of June it is higher then the day temperature of December and January. The maximum numbers of days with such high night temperature are in the month of June. The annual range of temperature all over the district is around 21°C. The mean monthly range of temperature varies from 9°C in July to about 18°C in November. (Statistical abstract of Punjab: 2002).

3.4.2 RAINFALL

The amount of rainfall in the Punjab ranges between 250 mm and 1000 mm. The maximum precipitation near the Siwalik Hills and the minimum towards the desert in the west part of district due to high-pressure zone and also due to the subsidence of air. The 70 to 80 % of the total precipitation is concentrated during the three months of southwest monsoon winds and the rest precipitation (30 to 20 %) occurs in the winter due to western disturbance. There is very wide difference in the amount of rainfall experienced in east and west Punjab. Near the Siwalik Hills rainfall is over 1000 mm. The average annual rainfall in the district Rupnagar is 801.4 mm.

3.5 SOILS OF RUPNAGAR

The soil is a natural body of minerals and organic materials differentiated into horizons, which differ among themselves as well as from the underlying material in morphology, physical make-up, chemical composition and biological characteristics. There are many different classifications of soils of the Punjab by different sources. The simple texture based soil classification on the basis of the texture, the climate, and the topography and denudation process. The soils of the Rupnagar district in State Punjab have been classified into the following major types:

3.5.1 FLOOD PLAIN OR WET SOILS

These are the khaddar soils of the periodically flooded or old flood plain areas of various rivers, streams or choes of the state. They are found in the form of elongated belts on both side of the river channel such as those of the Satluj, the Ravi, the Beas, and the Ghagghar. They are pale to yellowish brown in color. The soils are well drained and very deep and they vary in texture and these have generally a low and irregular organic matter. Depending upon the source of alluvium, the soils are either calcareous or non calcareous. There is a wide belt of mature wet soils of old floodplain extending along the west bank of river the Satulaj from the Rupnagar to the Fazilka town in the southwest. These soils are called ustifluvent or Udi or Torripsamments in taxonomy classification. These soils are suitable for the cultivation of paddy, wheat, sugarcane and vegetables.

3.5.2 LOAMY SOILS

It is the most important, fertile and productive soil group of the state. Loamy soils have a large coverage in the western part of Rupnagar district. These soils cover nearly 25% area of the state. In taxonomy classification these are Ustochrepts of Ustic zone of Punjab. The soils become clayey towards northwest in Rupnagar and Gurdaspur districts. These are deep and fine-grained soils, which have developed under sub moist and cool to warm temperate climate. The pH value decreasing nears the surface from 8.0 to 7.8 in the B-horizon. Due to flooding by choes or rivulets and excessive irrigation the soils become partly salt affected or sodic in western Rupnagar and Amritsar district, southwestern Batala tehsil of Gurdaspur district. These soils intensively cultivated for wheat and paddy crops.

3.5.3 SANDY SOILS

These are arid soils of southwestern and south central Punjab covering the districts of Bhatinda, Mansa, southern parts of Ferozpur and Mukatsar district, larger parts of Sangrur, South-central parts of Patiala district and some parts of Ludhiana and Rupnagar district. These soils have developed under semiarid and warm to hot climatic conditions with rainfall ranging from 30 cm to 50 am. The soils are yellowish to grey color, the over all grey color reflects the deficiency of organic matter. The soil is poor in nitrogen, phosphorous and potash. The pH value ranges from 7.8 to 8.5. The soils are sandy loam to silt in mixture. They are dry and are called Calciorthids in classification. They have low to medium fertility but by artificial irrigation they become much more productive and are capable of producing cotton, citrus, oilseeds, and wheat and fodder crops.

3.5.4 KANDI SOILS

These types of soils are found in the areas of Gurdaspur, large parts of Hosiarpur, and Rupnagar districts. The soils have a sandy, sandy loam, silt loam and clay- silt to gravelly texture. The texture becomes coarser and rougher eastward the Siwalik Hills where, gravel, pebbles and conglomerates predominates. These have been deposited by numerous choes coming from Siwalik Hills. The soils are badly eroded and less productive and are less suitable from dry farming. (Source: Geography of Punjab By Manku, D.S).

3.6 LAND USE PATTERN

Land use pattern has undergone a tremendous transformation in the state due to change in agriculture cropping pattern, urbanization and industrialization. During the recent years, there has been an increase in the area put to non-agriculture uses, as expected, because as a result of increase in the development activities, more and more land is being used for industrial sites, housing, transport systems, recreational purposes, irrigation systems, etc. Punjab comes in the category of States where the proportion of lands under non-agricultural uses is higher than the all India average. The change in the land use pattern brings associated ecological changes in the state. Punjab is a small state with 50362 Sq. Km (5036200 ha) geographical area. The land is shared by the following activities: -

3.6.1 AGRICULTURE

The 85.5% of the total land is under agriculture activities and classified as net area sown. This percentage is about double of the average percentage of the country as whole (43%). The highest and lowest percentage of net area sown was for the district Mansa (93 %) and Rupnagar (58 %) respectively. The semi hill districts like Gurdaspur, Hosiarpur, Nawanshehar and Rupnagar have comparatively lower percentage of net area sown, which is 58% to 83 %. (Statistical abstract of Punjab: 2002).

3.6.2 FOREST

Forest area is very small in Punjab. It is 5.57% of the total area of the state. It is about one fourth of the average percentage for the country (20.7%). A large part of the forest lies in the district Hosiarpur (35.7%) and Rupnagar (16.8%), Gurdaspur (12.1%), Patiala

(5.0%), Amritsar (4.8%) and Nawanshehar (7.7%) district have each 5% to 12% of the forest area of the state. (Statistical abstract of Punjab: 2002).

3.6.3 LAND NOT AVAILABLE FOR CULTIVATION

This class of land includes absolutely barren and uncultivated land like mountains, deserts, swamps, and water bodies, etc. It also includes land covered by building, roads, railways, and water or otherwise appropriated for non-agriculture purposes. Such land from 8 % of the total area of the state. Amritsar, Ludhiana and Patiala districts have each more than 40,000 ha. of land under this class. Rupnagar, Sangrur, Moga, Bathinda and Kapurthala district have each 6 % to 10 % area of the state in this class.(Statistical abstract of Punjab: 2002).

3.6.4 OTHER UNCULTIVATED LAND

It is such a land, which is available for cultivation but due to one or the other reason has not been taken up for cultivation or abandoned later on. It includes culturable waste, permanent pastures, other grazing land and land under miscellaneous tree crops and groves. Under this category only very small area falls which is 0.6% of state's total geographical area. The area under this class declined from 55 thousand hectares to only 14 thousands hectares in 1994-95 but will increase to 31 thousand hectares in 2004-2005. (Statistical abstract of Punjab: 2002).

3.3.5 FALLOW LAND

It is the cultivable land, which after abandonment remains uncultivated over long period called "current fallow". Fallow land of the state has been decreasing over the years due to extension of cultivated land. It decreased from 3.13 lakh hectares in 1960-61 to meter 64 thousand hectares in 1995-96 and will be reduced upto 32 thousand hectares in 2004-2005. (Statistical abstract of Punjab: 2002) Local land use and land cover (LULC) changes ranging from losses of wetlands, productive lands and biodiversity to expansion of croplands at the expense of forests across the world are one of the most important human-induced disturbances that contribute to global environmental and climate change.

The worldwide trajectory of LULC changes over the last 300 years has been to decrease the area of forests and increase the area of agricultural lands. For the period 1850 to 2000, atmospheric CO2 concentrations increased by *ca.* 175 Pg C (*ca.* 85 ppmv) due to CO2 emissions from combustion of fossil fuels (275 Pg C) and LULC changes (155 Pg C). The annual terrestrial efflux of carbon (C) from LULC changes was estimated at 2.2 (±0.6) Pg C yr−1 in the 1990s. About 80% of all wetlands in some areas of Europe, and *ca.* 50% of all wetlands in the United States have been lost or destroyed. For example, more than 100 million ha of U.S.A. wetlands have been filled, tilled, or channeled. Globally, 1000 bird species, many dependent on aquatic habitats including wetlands, are on the verge of extinction. Agriculture in Mexico's Sonora desert, for example, has diminished 97% of the region's water resources, decreasing the migratory bird populations from 233,000 in 1970 to less than 100,000 recently.

The nearly complete destruction of the Aral Sea of 64,000 km2 in Central Asia, once the fourth largest inland sea in the world, is one of the most disastrous LULC changes. So there is great concern about our environment to protect it from the anthropogenic sources of pollution. The new and advance techniques like RS (Remote Sensing), GIS (Geographic Information System) and GPS (Global Positioning System) can simultaneously helps for the improvement of the environment.

Chapter 4

Objectives and scope

CHAPTER 4

OBJECTIVES AND SCOPE

4.1 INTRODUCTION

Land is the prime natural resource. So every developmental activity will affect the land use and the land cover. The change in land use and land cover is the global concern; because there is continuous decrease in forest cover, increase in the urban area, loss of arable land, change in water quality and change in climate. So there is a global need for the sustainable management of land use and land cover. The recent techniques provide up to date and cost effective methods for the mapping, assessment and monitoring of change in land use and land cover. Change in one from of land use will affect the other form of land use, like in crease in urban area leads loss of arable land or forest land and increase in agriculture field will leads to loss of wetland or forest land. So in urban area the increase in the impervious layer due to which less infiltration or reaching of ground water, this leads to a critical situation like drop in groundwater table. In forest area the deforestation the leads to the increase in soil erosion.

4.2 LAND USE/LAND COVER (GENRAL)

Comprehensive information on land use and land cover is the basic prerequisite for land resource evaluation, assessment, utilization and management. Today with the increasing population pressure on land and resulting changes in the land use pattern and processes, a considerable degree of land transformation and environmental deterioration is being witnessed. Therefore it is important to understand the cause and effect of the change through a scientific study. An analysis of mechanism land use changes plays an important role in forecasting environmental changes. As the population increase the infrastructure develop, and economy blooms in the study area and its vicinity.

Interaction between human activities in the landscape (land-use) and the movement of water vertically and horizontally through that landscape; action needed to avoid the negative eco-hydrological effects of such interactions (floods, pollution, desiccation, etc.) appropriate methods for environmental management to cope with such interactions. Two types of land-use activities that have a fundamental impact on livelihood and thus on the issues outlined above will also be addressed: land use dependent on drainage and flood protection, or, for example, dependent on limitations imposed by water on societal and biomass production. This type of land use is called "water-dependent" land use. Land Use, which has an impact on rainwater partitioning through soil and vegetation or impacts, related to the function of water as a carrier of solutes and silt in the landscape. This type of land use is called "water-impacting".

4.3 OBJECTIVES

Keeping in view, all the above-mentioned aspects, the present study has been made with an objective to: -

- To prepare the land use and land cover map of the study and observe the changes taken place in them over the past 15 years.
- Establish a link between the local geo-morphological activities and change in land use and land cover.
- Detect the geo-morphological changes occurring in the study area in terms of weathering, erosion and deposition.
- To prepare the digital soil map of the study area for the better management of the soil.
- Draw attention to the Applicability of the Remote Sensing, GIS and Ancillary Data for the study of change in the land use and land cover of the study area.

4.4 SCOPE

- The present study can be helpful in having a better understanding of the change in land use and land cover pattern for the sustainable management
- The mapping, assessment and monitoring of different land use and land cover will also help to adopt suitable land management techniques in order to improve the land use capability of the study area and conserve the ecosystem.

Chapter 5

Materials and methods

Chapter 5

MATERIALS AND METHODS

5.1 INTRODUCTION

A knowledge of land use and land cover is important for many planning and management activities concerned with the surface of the earth. Remote Sensing methods have been widely applied in mapping land surface features in urban and rural areas (Hack et al. 1997, Jenson & Cowen, 1999). With the availability of multispectral images in digital form and advances in digital processing and analysis, remote sensing has become a new prospective for the land use change detection. The characterization and classification of urban and rural areas has received attention since early Landsat program (Gordon, 1980, Forster, 1980, 1983, Jensen & Toll, 1982, Ridd et al., 1983, Moller-Jensen, 1990). The opportunity for urban growth and change in rural areas study is concurrently improved with the technology (Martin 1989, Fung & Zhang 1989, Gong & Howarth, 1990, Gong et al., 1992), allowing analysis for larger scales. The socio-economic, natural, technological and social processes are profoundly affected the evolving urban and rural spatial structure within which they operate.

5.2 LANDSAT SATELLITE DATA

National Aeronautics and Space Administration (NASA) of USA with the co-operation of the US Department of Interior planned the launching of a series of Earth Resources Technology Satellites (ERTS). A Thorn Delta Rocket launched ERTS-1 on July 23, 1972 and it operated until January 6, 1978. It represented the first unmanned satellite designed to acquire data about the earth resources on a systematic, repetitive, medium resolution multispectral basis. Subsequently, NASA renamed the ETRS programmed as Landsat programmed to distinguish it from the series of meteorological and oceanographic satellites that the USA launches later. ERTS-1 was later named as Landsat-1. There are three different types of sensors have been flown in various combinations on the missions. These are return Vidicon (RBV) camera system, the multispectral scanner (MSS) system and the Thematic Mapper (TM). Landsat images have found a large number of applications, such as, agriculture, botany, cartography, civil engineering, environmental monitoring, forestry, geography, geology, land resources analysis, land use planning oceanography, and water quality analysis.

5.2.1 CHARACTERISTICS OF LANDSAT SATELLITE AND THEIR SENSORS

Satellite Capabilities	
Particulars	Landsat 6,7
Altitude	705 Km
Orbit	Near-polar, Sun-synchronous
Inclination	98.2 degrees
Period	99 Minutes
Equatorial crossing time	0945 Hours
Repeat cycle	16 days
Swath width	185 Km
Data rate	84.9 MBPS

Sensor Capabilities					
Sensor	**Mission**	**Channel**	**Spectral spatial resolution (microns)**	**Spatial resolution**	**Radiometric resolution**
TM	**Landsat**	1	0.45-0.52	30 m	8 bits (255 levels)
		2	0.52-0.60	30 m	
		3	0.63-0.69	30 m	
		4	0.76-0.90	30 m	
		5	1.55-1.75	30 m	
		6	2.08-2.35	30 m	
		7	10.4-12.6	120 m	

5.3 INDIAN REMOTE SENSING SATELLITE (IRS)

IRS DATA

The IRS mission envisages the planning and implementation of a satellite-based remote sensing system for evaluating the natural resources. The principal components of the mission are: a three axis stabilized polar sun-synchronous satellite with multispectral sensors, a ground based data reception, recording and processing systems for the multispectral data, ground systems for the in orbit satellite control including the tracking network with the associated supporting systems, and hard ware and software elements for the generation of user oriented data products, data analysis and archival. The principal aim of the IRS mission is to use the satellite data in conjunction with supplementary/ complementary information from other sources for survey and management of natural resources in important areas, such as agriculture, geology and hydrology in association with user agencies. IRS series satellites are IRS IA, IB, IC, ID and IRS P4 apart from other satellites, which were launched by the government of India. The orbital and sensor characteristics of IRS IA and IB are the same and IRS IC and IRS ID have almost similar characteristics. IRS P4 is an oceanographic satellite. IRS has application potential in a wide range of disciplines such as management of agricultural resources, inventory of forest resources, geological mapping, estimation of water resources, study of coastal hydrodynamics and water quality surveying.

5.3.1 PARTICULARS OF INDIAN REMOTE SENSING SATELLITES (IRS) SERIES

Characteristics of satellite	
Orbit	Near polar sun synchronous
Altitude	904 Km
99.03 degrees	99.03 degrees
Equatorial crossing time	1000 hours
Repeat cycle	22 days
Eccentricity	0.002
Period	103 minutes

Sensor capabilities **Linear imagining scanning system: LISS**		
Number of LISS cameras	LRC (One)*	MRC (Two)**
Number of spectral bands	4	4
IFOV (Microrad)	80	40
Geometric resolution	72.5	36.25
Swath width	148 km	74 km
Radiometric resolution	7 bits	7 bits
Band to band	0.5	0.5
*Low resolution Camera ** Medium Resolution Camera		

5.4 SUPPLEMENTARY DATA USED

The following data has been acquired to supplement the Landsat and IRS data in the present study.

5.4.1 ANCILLARY DATA

- Survey of India topographic maps

Scale	**Survey of India Topographic sheets reference**
1:2,50,000	53 A and 53 B
1:50,000	53A/7,8,11 & 12 53B/6,9,10,13 & 14

- Climatic data of the study area from the Indian Meteorological Department
- Census record book and Handbook of Basic Statistics of the State Punjab for the year 1991 and 2004 respectively
- Previously published literatures of similar work on the study area
- District planning map.

5.4.2 FIELD DATA

- Land use / land cover of the study area
- Land forms and other geo-morphological information
- Soil and Water sample

5.4.3 LABORATORY DATA

- Visual interpretation of satellite data to prepare geo-morphological and land use/ land cover maps
- Physico-chemical study of soil sample
- Textural study of soil sample

5.5 WORK PLAN

The whole process of the study carried out during the present work can be broadly grouped under three stages, viz., Pre field stage, Field investigation Post field stage. The details of work under each stage are listed below:

5.5.1 PRE- FIELD STAGE

- Visual interpretation of satellite data and preparation of land use and land cover maps
- Interpretation of change in geomorphology
- Transfer of base map from the toposheets to the interpreted satellite maps
- Preparation of digital soil map

5.5.2 FIELD INVESTIGATION

- Field verification of interpreted maps
- Collection of additional field information on various themes
- Identification of types of forest
- Identification of types of urban settlement
- Collection of soil for the physico-chemical analysis of the samples for quality assessment

5.5.3 POST FIELD STAGE

- Finalization of interpreted maps incorporating field interpretation
- Physico-chemical study of soil
- Textural study of soil samples
- Compilation of the results

5.5.4 THE PREPROCESSING OF SATELLITE IMAGES

(1) The Landsat Data was for the year 1989 and 2000 of the study area was downloaded from www.landsat.com website.

a) The image at the scale of 1:50,000 was downloaded for spectral bands1 to 7.
b) Layer Stacking: The image was stacked for bands 1, 2, 3, and 4.
c) Mosaicking and Clipping: the individual tiles were mosaicked and then clipped with district boundary
d) Projection: Finally the image was re-projected from Universal Transverse Mercator to Lambert Conformal Conic projection, spheroid and datum Everest.

(2) The LISS-III image was obtained for the year 2005.

a) Satellite image from IRS -1C, LISS-III sensor, on a scale of 1:50000 (geo-coded) representing synoptic view of earth's surface at 25m x 25m ground resolution in three spectral bands have been procured. The details of the IRS data used to accomplish the study are given below.
b) Data product-Standard FCC (False Color Composite), bands 1, 2, and 3 in the range of (0.52 - 0.59 :m), (0.62 - 0.69 :m) and (0.77 - 0.86 :m) respectively.
c) Projection: The image was projected to Lambert Conformal Conic projection, spheroid and datum Everest.

5.6 LAND USE AND LAND COVER STUDIES

Land use and land cover studies mainly consist of mapping, assessment, monitoring and change detection of differ features in urban and rural area.

5.6.1 LAND USE AND LAND COVER MAPPING

The study area is selected for the mapping of land use and land cover studies. The land use and land cover map of 1990 has been prepared with help of the Landsat satellite image. Similarly, the land use and land cover map of 2005 has been prepared with the help of IRS-IC LISS III imagery of 2005. The map was visually interpreted based on image interpretation elements like tone, texture, association, pattern, location etc. The interpreted features have been verified with the help of a reconnaissance survey of the study area. A classification scheme was also prepare during fieldwork. Final interpretation key was prepared based on the field observation and it's relationship with the tone, texture, association, pattern, and location etc. Then the interpretation was finalized based on classification schemes and interpretation key. The table below which is for the interpretation of image. This key is used for the mapping of different types of land use and land cover classes.

Table 5.1 Interpretation key for Land Use and Land Cover Mapping

Serial Number	**Class Name**	**Tone**	**Texture**	**Location**	**Pattern**
1.	Dense forest	Dark Red	Smooth	Undulating hilly areas	Irregular
2.	Open forest	Light Red	Medium,	Hills and slopes	Irregular
3.	Plantation	Light Brown to dark Brown	Medium	Plain	Irregular to regular
4.	Low lying area	Dark Brown	Smooth	Low lying area, near river and ponds	Irregular
5.	Crop land	Yellowish Red	Smooth	Plain, hills	Irregular to regular
6.	Fallow land	Grey –White patches	Coarse	Plain, hills	Irregular
7.	Built up	Reddish Blue	Coarse	Pain, hills	Regular
8.	Barren land	Dark Grey	Smooth	Hills	Irregular
9.	Water body	Black	Smooth	Plain	Irregular to regular

5.6.2 IMAGE ENHANCEMENT AND VISUAL INTERPRETATION

5.6.2.1 INFORMATION EXTRACTION

5.6.2.1. I. VISUAL INTERPRETATION

The human eye is a power tool for the detecting subtle differences in the texture and recognizing characteristics shapes, patterns and feature associations. Automated classification technique cannot always take in to account the textural, contextual, pattern and shape information associated with the image features, which are essential for their recognition and differentiation. Simple texture measures can be derived from imagery and combined with the spectral information for classification of whatever type, is considerably poorer than that achievable by visual interpretation. This especially true in the interpretation of satellite imagery for the geological mapping. The mapping of land use/land cover depends upon the type of sensor.

5.6.2.1.II. CLASSIFICATION

In principal, classification techniques use the spectral, and some times also the spatial, properties of digital imagery in order to subdivide the imagery into meaningful classes of different cover types. Classification attempts to emulate the activity of the human interpreter, who sub divides imagery enhanced by a series of appropriate process into a series of classes, based on experience and on the requirements of the project. The human interpreter uses the color, texture and context in order to identify specific features and cover types. In theory, an automated classifier can examine many bands of data at the same time in totally objective fashion, at a speed thousands of many times faster than human interpretation. In practice, no computer based classification system is yet as accurate as an experienced visual interpreter, mainly because the three critical aspects of color, texture and context cannot be evaluated equally well by the most current image processing systems, and because the computer operates with a set of relatively inflexible rules, and can not, in most cases learn from its own mistakes.

Most common classifiers operates on the basis of "color" alone, in the sense that they operate n the individual pixel values at each wavelength. Each pixel is assigned to a class, feature or cover type based on its own spectral properties, without nay consideration of surrounding pixels. These "per-pixel" classifiers can be divided into two main groups, the supervised and unsupervised classifiers.

5.6.2.iii. UNSUPERVISED CLASSIFICATION

Unsupervised classification demeaned no prior knowledge of the image, but effects a sub division based on the intrinsic properties of the digital data. In principle, the digital values for each pixel at each wavelength are examined, and the image the sub divided into a per -set number of classes. Some image processing systems allow the user to select the number of classes, or the amount of spectral difference that there should be between classes, while others are less flexible. In practice, the initial clustering process to identify the main natural classes in the image usually examines a sample of the total number of pixels in order to save time. Once class statistics have been established, the user can normally select the number of classes required in the final image, based on tables and sometimes-graphical representation of the spectral distribution of the clusters. The final classification of the whole image into hen undertaken, normally using maximum likelihood techniques to assign each pixel to its most appropriate class. Provided that the process is reasonably rapid, it is often useful to carry out unsupervised classification of an image, in order to obtain an objective impression of main spectral types, before attempting any supervised classification. Some complex natural cover types, such as semi natural upland vegetation, may sub-divide better on the basis of unsupervised clustering due to the difficulty of defining reliable training areas for supervised classification.

5.6.2.iv. SUPERVISED CLASSIFICATION

Supervised classification depends on some prior knowledge of the area covered by the imagery to be classified. The operator interactively informs the system that a particular group of the pixels in the image represents a specific cover type on the ground, and the computer then searches for the pixels of similar spectral characteristics. The areas defined interactively area known as "training areas", and much has been written about techniques for selecting appropriate training areas, and about the amount and quality of "ground truth" required for satisfactory classification. The main essentials are that the training areas should be as homogenous as possible, and that it should be representative of the class, which the system is required to identify. Once a group of training areas defining the main cover types of interest in the specific study has been selected, then classification can proceed. Most image processing systems allow at least two types of supervised classification. A simple box or parallelepiped classifier defines the mean and range of the digital values for each class at each waveband, based on the training area and then classifies all pixels lying within these ranges as belonging to the class. Often only one class can be classified as a time, and there is inevitably considerable overlap between classes, unless the training areas are so homogenous as to be unrepresentative of real world surfaces. A more sophisticated method of classification uses statistical techniques to assign each pixel to a class. Minimum distance and maximum likelihood classifiers use such approaches, and can usually handle a large number of classes simultaneously. Some image processing systems allow interactive adjustment of probability levels in order to achieve an acceptable classification.

Classification techniques are widely used for the land cover mapping studies, but do not find wide application in geological mapping. Classification accuracies in lithological studies are usually very low, expect where vegetation is scare or absent and topography subdued. Although an experienced interpreter can often make a very precise geological interpretation of suitability-enhanced imagery, automated classification of the same imagery normally fails.

Accuracy is higher for the spectrally homogenous cover types displaying low intra-class variability. Classification can be improved by using multi-date imagery, but this is normally limited, in humid temperate climates, by data availability due to cloud cover. Unsupervised clustering is more appropriate in areas of complex semi natural vegetation, but good quality ground data is needed to interpret the results. Accuracy can be significantly improved by pre classification segmentation of imagery in order to exclude unwanted areas from the classification.

The goal of image enhancement is to improve the visual interpretability of an image by increasing the apparent distinction between the features. The process of visually interpreting digitally enhanced imagery attempts to optimize the complementary abilities of the human mind and the computer. The mind is excellent at interpreting spatial attributes on an image and is capable of identifying obscure or subtle features (Lillesand & Kiefer, 1994). Contrast stretching was applied on the two images and two false color composites (FCC) were produced. These FCC were visually interpreted using on screen digitizing in order to delineate land cover classes that could be easily interpreted such as urban & Sabkha. The process of visually interpreting digitally enhanced imagery attempts to optimize the complementary abilities of the human mind and the computer. The mind is excellent at interpreting spatial attributes on an image and is capable of identifying obscure or subtle features (Lillesand & Kiefer, 1994). Some classes were spectrally confused and could not be separated well by supervised classification and hence visual interpretation was required to separate them. The importance of water resources has increased with industrialization and growth of population, as these are needed for sustaining crop productivity, meeting the ever-increasing needs of the domestic, industrial and power sector. Land use/land cover pattern is the result of anthropogenic interaction with the natural environment. Land cover is a fundamental parameter describing the Earth's surface. This parameter is a considerable variable that impacts on and links many parts of the human and physical environments (Foody, 2002). Geographical Information Systems have already been used for assessing environmental problems, since they provides a flexible environment and a powerful tool for the manipulation and analysis of spatial information for land cover feature identification and the maps of all variables were combined to extract information to better understand analyzing (Weng, 2001). Satellite remote sensing, in conjunction with geographic information systems, has been widely applied and been recognized as a powerful and effective tool in analyzing land cover/use categories (Ehlers et al., 1990; Treitz et al., 1992; Harris & Ventura, 1995; Weng, 2001). The treatment of multidisciplinary data (i.e. from different sources, as well as covering different themes) is effectively done through the use of GIS (Goodchild & Gopal 1994), which, coupled with RS, can best facilitate the production of thematic maps (Star et al. 1997). The land cover change can easily be detected through analyzing the differences in the Normalized Difference Vegetation Index (NDVI) over a time interval, which also is a benefit of satellite imagery processing.

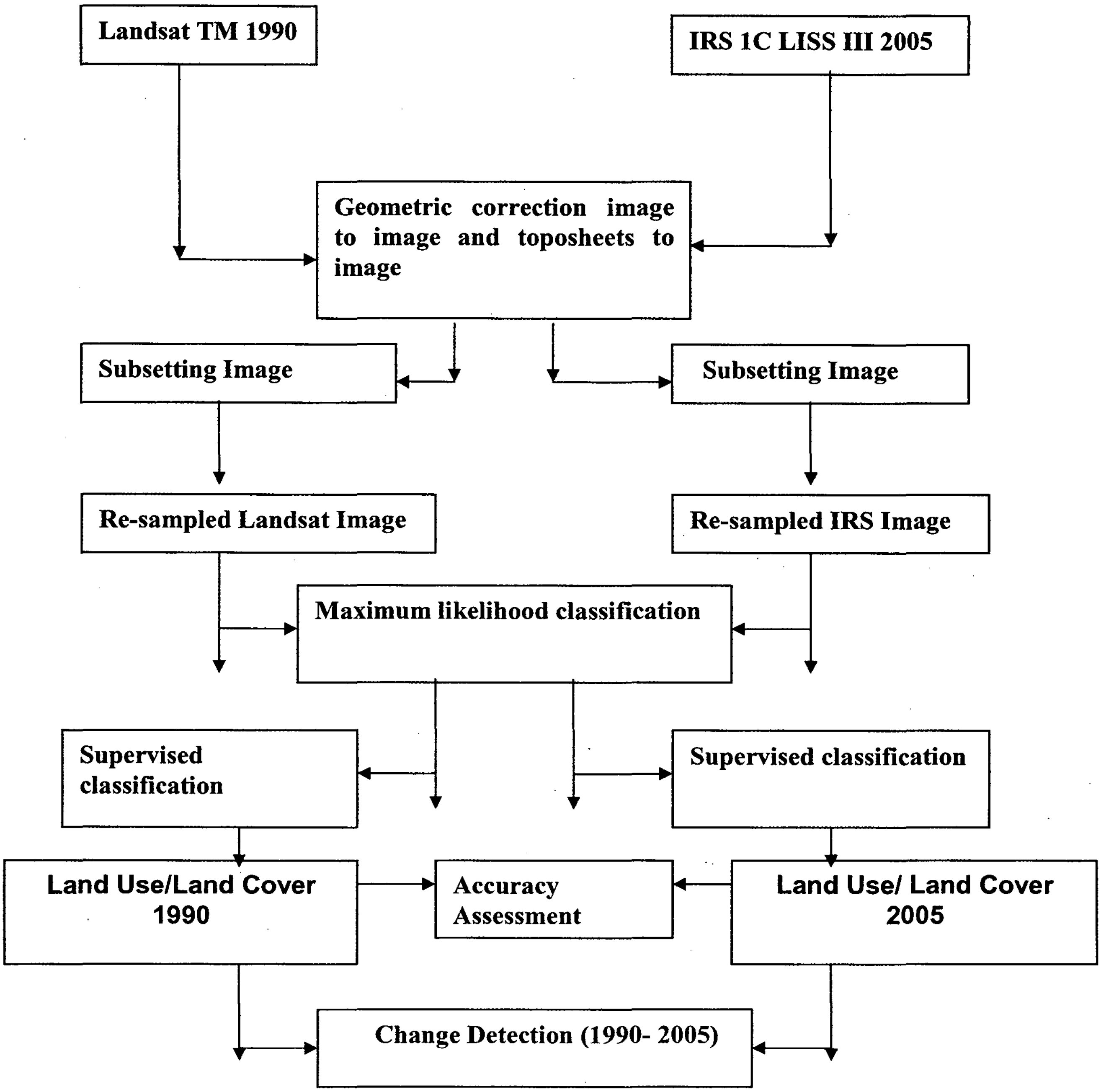
Over that period of time, if the green cover is reduced, as revealed through NDVI, then it is clear that environmental degradation has taken place (Jomaa & Khawlie 2002). Land cover is likely to be the single most important factor of change in all the river basins. It is well established that land use and land cover change has significant affects on many processes in basins, that include soil erosion (Douglas, 1983), global warming (Penner et al., 1992), impact on biodiversity (Chapin et al., 2000), and is expected to cause greater impact on human habitability than climate change (Skole, 1994).

5.6.3 METHODOLOGY FOR TEMPORAL LAND USE AND LAND COVER AND CHANGE DETECTION

The detection of change over time is one activity that can be performed more efficiently with digital remotely sensed imagery than by almost other means. The relative case with which different dates of satellite imagery, separated on times by days, months, or years, can be co-registered with each other, and the combination of quantitative measurements of surface reflectance at a number of wavelengths permits automated detection of change, the kinds of change of interest are extremely varied of change can also be determined by the change detection methods. Change detection can monitor the conversion of forestland into the agriculture and agriculture to urban and also soil erosion etc. There is a large range of methodologies reported for land cover change detection studies using satellite imagery (Pilon et al. 1988, Lo & Shipman 1990, Lu et al. 2003). Multi date image dataset should be geometrically and radiometrically corrected prior to the classification of the imagery. Comparing two independent land cover classifications identifies the environmental changes. Landsat and IRS 1C LISS III satellite image of 1990 and 2005 respectively have been used for generation of land use and land cover map. The satellite data was enhanced before classification using histogram equalization in ERDAS Imagine 8.7 for the better quality of the image and to achieve better classification accuracy. Further both satellite data were rectified a common Universal Traverse Mercator (UTM) projection and coordinate system on 1:50,000 scales. The data was resampled to a common spatial resolution of 23.5 m. Then classification was separately performed, the classified data was recoded and then ground truthing was done. Two land use/land cover maps were prepared from

i) Landsat TM 1990 and
ii) IRS LISS-III satellite data of 2005 thereafter changes in different land use /land cover was observed.

Flow chart of methodology for land use and land cover and change detection



5.7 SOIL MOISTURE STUDIES IN LAB

Soil moisture is a key variable in controlling in exchange of water and heat energy between the land surface and atmosphere through evaporation and transpiration. It plays an important role in the development of weather patterns and the production of precipitation (Clark & Arritt 1995, Fennessey & Shukla 1999). Remote Sensing plays important role for the measurement of soil moisture (Engman 1990). Microwave technology has demonstrated quantitative ability to estimate soil moisture physically for most ranges of vegetation cover (Njoku et al. 2002). Vegetation and land surface temperature have a complicated dependence on soil moisture. Careful analyses of data by Carlson et al. (1994) & Gillies et al. (1997) showed that there is a unique relationship among Soil moisture, NDVI, and Land surface temperature (LST) for a region.

In this study the soil moisture study done in situ and in the lab by conventional methods. The in situ soil moisture study was performed with the help of soil moisture meter, (Elico Private Limited, Hyderabad, India, Model DM 33). There is close relationship between in situ soil moisture studies and in soil moisture studies in the lab. In lab the soil sample first weighing, then sample had putted for over night oven dry at 60 degree centigrade. Then soil moisture % was calculated with the help equation:

$$\text{Soil moisture} = \frac{\text{Initial weight of soil sample in gram-Oven dry weight of soil sample in gram}}{\text{Initial weight of soil sample in gram}} \times 100$$

5.8 SOIL TEXTURE ANALYSIS

The texture of soil surfaces controls many important ecological, soil, and geomorphic processes in arid and semiarid soils, including infiltration, physical crusting pavement formation and erosion by wind and water. Texture can also strongly influence the distribution of plant and animal species in these regions. Fine textural soils are suitable for burrowing of animal (Andersen et al., 2000). Despite the importance of soil surface texture and it's relative ease of measurement using conventional field methods, soil maps are often produced at scales too coarse to adequately represents its spatial distribution and variability in ecological, soil or geomorphic models. Detail knowledge of soil surface texture would dramatically improve the ability to model wind erosion and water erosion in the soils where wind erosion is strongly controlled by surface grain size (Mahowald et al., 1999; Marticorena & Bergamitti, 1995: Okin, Murray, & Schlesinger, 2001). Remote sensing tools that can produce quantitative information on soil surface texture would be useful supplements to traditional soil maps for planning purposes. Such tools would also prove valuable in the emerging field of predictive soil mapping (Scull, Franklin, Chadwick, & McArthur, 2003). Several researchers have developed methods for mapping snow grain size using hyperspectral remote sensing (Green, Roberts, Dozier, & Painter, 2003: Nolin & Doziwer, 2000; Pinter et al., 2003) shown their utility in the study of snow hydrology (Molotch, Painter, & Dozier, 2003). Mineralogically, snow is much simpler than most soils. Other investigators demonstrated that the spectral reflectance of bare soils depends on the effective particle size (Baumgardner et al., 1985).

5.8.1 LABORATORY ANALYSIS OF SOIL SAMPLES

The size distributions of the field samples were measured using standard sieving techniques. The eight-stacked sieves were used (4.75, 2.36, 1.18, 0.6, 0.3, 0.15, 0.063 and 0.045 mm). An effective grain size, R_{eff} was calculated for each sample using (Liou, 1980).

In the present study there is post classification analysis for the change detection in land use/land cover in the given study area and preparation of various thematic maps for the resource management and sustainable planning. The better knowledge about the lad use/land cover at the local, regional, and global level will helpful for the human society. This study suggests the change in the land use/land cover in the rural and urban areas. There are different types of driving forces for the change in land use/land cover at the rural and urban areas. Some driving forces are common but there are some driving forces are different like the urbanization is high around the cities. So there is a need of integrated approach for the rural and urban land use/land cover change detection.

Chapter 6

Results and discussion

CHAPTER 6

RESULT AND DISCUSSION

6.1 URBAN OR BUILT-UP LAND

Urban or Built-up Land is comprised of areas of intensive use with much of the land covered by structures. Included in this category are cities, towns, villages, strip developments along highways, transportation, power, and communications facilities, and areas such as those occupied by mills, shopping centers, industrial and commercial complexes, and institutions that may, in some instances, be isolated from urban areas.

As development progresses, land having less intensive or nonconforming use may be located in the midst of urban or Built-up areas and will generally be included in this category. Agricultural land, forest, wetland, or water areas on the fringe of urban or Built-up areas will not be included except where they are surrounded and dominated by urban development.

6.2 INDUSTRIAL AREAS

Industrial areas include a wide array of land uses from light manufacturing to heavy manufacturing plants. Identification of light industries those focused on design, assembly, finishing, processing, and packaging of products can often be based on the type of building, parking, and shipping arrangements. Light industrial areas may be, but are not necessarily, directly in contact with urban areas; many are now found at airports or in relatively open country. Heavy industries use raw materials such as iron ore, timber, or coal. Included are steel mills, pulp and lumber mills, electric power generating stations, oil refineries and tank farms, chemical plants, and brick making plants. Uniform identification of all these diverse extractive uses is extremely difficult from remote sensor data alone.

6.3 CROP LAND/AGRICULTURAL LAND

Agricultural Land may be defined broadly as land used primarily for production of food and fiber. On high-altitude imagery, the chief indications of agricultural activity will be distinctive geometric field and road patterns on the landscape and the traces produced by livestock or mechanized equipment. However, pasture and other lands where such equipment is used infrequently may not show as well defined shapes as other areas. These distinctive geometric patterns are also characteristic of Urban or Built-up Lands because of street layout and development by blocks. Distinguishing between Agricultural and Urban or Built-up Lands ordinarily should be possible on the basis of urban-activity indicators and the associated concentration of population. The number of building complexes is smaller and the density of the road and highway network is much lower in Agricultural Land than in Urban or Built-up Land. Some urban land uses, such as parks and large cemeteries, however, may be mistaken for Agricultural Land, especially when they occur on the periphery of the urban areas.

6.4 FOREST LAND

Forest Lands have a tree-crown aerial density (crown closure percentage) of 10 percent or more, are stocked with trees capable of producing timber or other wood products, and exert an influence on the climate or water regime. Forest Land generally can be identified rather easily on high-altitude imagery, although the boundary between it and other categories of land may be difficult to delineate precisely. Lands from which trees have been removed to less than 10 percent crown closure but which have not been developed for other uses also are included. The pattern can sometimes be identified by the presence of cutting operations in the midst of a large expanse of forest.

6.5 WATER

The delineation of water areas depends on the scale of data presentation and the scale and resolution characteristics of the remote sensor data used for interpretation of land use and land cover. These frequently can be obtained from small-scale remote sensor data with considerable accuracy.

6.6 STREAMS AND CANALS

The Streams and Canals category includes rivers, creeks, canals, and other linear water bodies. Where the watercourse is interrupted by a control structure, the impounded area will be placed in the Reservoirs category.

6.7 IMPACTS OF LAND USE/ LAND COVER CHANGE ON ENVIRONMENT

As land use changes from forest to rural built-up lands, urban lands and subsistence agriculture, surface runoff increases while surface and groundwater quantity decreases and quality deteriorates. The effect is manifested in reduced natural recharge, reduced stream flow and elimination of wetlands. Currently, there is a steady recognition that surface and groundwater sources are declining. The change in land use also shows effect on the soil quality. The intensive agriculture increases the soil salinity and reduces the long-term soil fertility. The practice of continuous cultivation is impoverishing the soils. Sheet and rill erosion is observed when it rains and gullies are beginning to develop along some of the farm tracks. Deforestation and break down of the soil conservation structures which were established by the settler farmers has led to increased soil erosion and sedimentation in the river and water body.

6.8 EFFECT OF DYNAMIC GEOMORPHOLOGY ON THE LAND USE/LAND COVER

The dynamic geomorphology of the area is to a great extent responsible for the change in land use. The rivers, streams, and the wind also attribute the dynamics. The dynamism is evident by the presence of paleo- channels in the area. The changing course of rivers and streams combined with the micro tectonic activities such as rocks protuberances, lineament fabric etc., higher rainfall, high gradient, all these factors are responsible for the weathering and erosion of the hills. This leads to the mass wasting and erosion around the hilly area. The rivers carrying the sediments and deposited in the plains, the rivers also having the nature of shifting in the plains so there is always a great threat of flood in the low laying area.

6.9 EFFECT OF LAND USE CHANGE ON GEOMORPHOLOGY

The change in land use has also affected by the geomorphology of the study area. The urbanization of any area with its own set of advantages and problems. Environmental changes resulting from human activity like reclamation, deforestation and quarrying in the study area have led to problems like manssonal flooding. The drastic changes with drainage basins affect the channel parameters. The large percentage of impervious cover due to urban land use in the form of buildings and roads reduces the infiltration capacity in a drainage basin causing proportional in crease in the amount of surface run-off. The increase in run-off co-efficient coupled with the problems like deforestation due to urbanization has led to the problems like soil erosion, mass wasting in hilly areas. The increase in surface run-off has also triggered the erosion of rocks.

The geomorphology of the study area contains mostly alluvial plain. Other classes are as fallows

1. Denudational hill
2. Flood plain
3. Ox bow lake
4. Piedmont zone
5. River terraces
6. Water shed
7. Structural hills

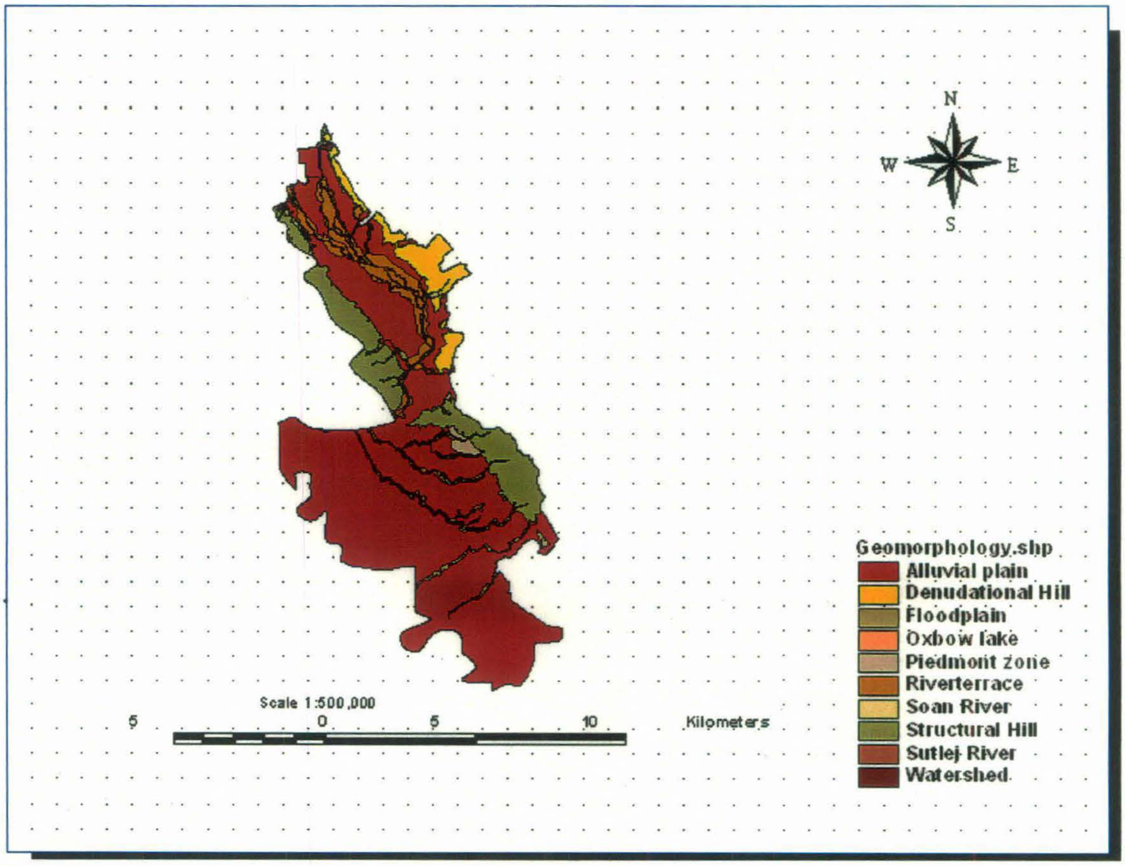


Figure 6.1 Showing the geomorphology of the study area.

6.10 EFFECT OF LAND USE/LAND COVER ON SOIL

Soil is important natural resource; the land use/land over of the area is also defined by the quality of soil. The quality of soil is changed by the anthropogenic and natural activities. The pH of some soil sample shows great variation in their ranges, maximum 8.9 at the sample site Rupx 12, and minimum 6.80 at the sample site Rupx 13. The pH of soil sample is also responsible for the crop yield. The best soil is slightly alkaline for the agriculture. Due excessive use of fertilizers also aggravates the soil salinity. For reclamation of saline by using the salt tolerant crop or lime for the improving soil quality. The electric conductivity varies from maximum 330 µs at the sampling site Rupx 8 and minimum 40 µs at the Rupx 13. The higher electrical conductivity shows the soil is better for the agriculture. The moisture content is important for the growth of plant and microorganism. The range of moisture in the soil sample vary form maximum 16.78 % at the soil sampling site Rupx 1 and minimum 0.86 % at the sampling site Rupx 13. The moisture content of soil can also important for the interpretation of the types of soil texture.

Serial Number	**Sample Number**	**pH**	**EC (µs)**	**Moisture %**
1.0	Rupx 1	8.50	160.00	16.78
2.0	Rupx 2	8.30	120.00	2.54
3.0	Rupx 3	8.30	220.00	13.10
4.0	Rupx 4	8.10	70.00	6.48
5.0	Rupx 5	8.70	230.00	1.68
6.0	Rupx 6	8.50	50.00	1.24
7.0	Rupx 7	8.00	60.00	10.08
8.0	Rupx 8	7.40	330.00	8.02
9.0	Rupx 9	8.20	50.00	4.20
10.0	Rupx 10	8.60	270.00	8.66
11.0	Rupx 11	8.30	60.00	1.62
12.0	Rupx 12	8.90	250.00	1.50
13.0	Rupx 13	6.80	40.00	0.86
14.0	Rupx 14	8.50	220.00	1.46
15.0	Rupx 15	8.20	60.00	1.23
16.0	Rupx 16	8.80	80.00	10.96
17.0	Rupx 17	8.40	190.00	11.84
18.0	Rupx 18	8.30	230.00	2.60
	Average	**8.27**	**149.44**	**5.83**
	Maximum	**8.90**	**330.00**	**16.78**
	Minimum	**6.80**	**40.00**	**0.86**
	Standard Deviation	**0.50**	**93.84**	**5.03**

Table 6.1 Physical parameters of soil

Sample Number	% of Gravel	% of Sand	% of Silt	% of Clay
Rupx 1	-----	95.63	4.25	0.11
Rupx 2	----	81.5	18.23	0.27
Rupx 3	0.8	95.98	3.1	0.11
Rupx 4	0.16	93.66	5.78	0.4
Rupx 5	-----	90.44	9.12	0.44
Rupx 6	26.29	70.87	2.57	0.26
Rupx 7	0.43	94.63	4.38	0.56
Rupx 8	-----	97.11	2.13	0.76
Rupx 9	0.21	88.24	10.51	1.04
Rupx 10	0.6	97.69	1.5	0.21
Rupx 11	0.6	94.52	4.59	0.29
Rupx 12	-----	90.49	9.2	0.31
Rupx 13	-----	95.96	3.84	0.2
Rupx 14	----	95.4	2.62	0.1
Rupx 15	-----	96.78	1.99	1.28
Rupx 16	-----	97.47	2.41	0.12
Rupx 17	-----	91.54	8.28	0.18
Rupx 18	-----	90.64	9.28	0.08

Table 6.2 Texture Analysis Results

6.11 SOIL TEXTURE

Analysis of surface effective particle diameter from field measurements indicates a decrease in particle size with increasing distance from the downwind edge of the abandoned field. The range of effective particle diameter (0.3-1.05mm) corresponds to a sensible geometric depth of 1-4 mm. Wind erosion impacts the texture of surface soils downwind of areas of active erosion by mantling the surface with material transported downwind by saltation. This observed pattern in effective grain size is due to the difference in the average length of saltation paths for particles based on mass differences. In saltation, particles move by a series of small hops and, while particles may experience approximately the same number of jumps, the longer saltation paths of smaller particles result in greater net movement downwind. For very small particles, liberated from the surface primarily by sandblasting, the path length becomes semi-infinite, resulting in suspension flux. The relatively large grain size observed inside the field is due to the relatively short transport distances of these large grains, transported from upwind within the field, and their inability to cross a wind barrier at the downwind edge of the field. Because grain size has an important influence of the albedo of soils the effect reported here should be apparent in other sites with different soil and vegetation characteristics. The ability to retrieve information on soil texture in arid and semiarid regions has a wide range of applications in ecological and geomorphologic science.

The soil map of the study area is showing the five types of soil classes which area as fallows.

1. Loamy sand
2. Sand
3. Sandy clay
4. Sandy clay loam
5. Sandy loam

Best soil for the agriculture sandy clay loam.

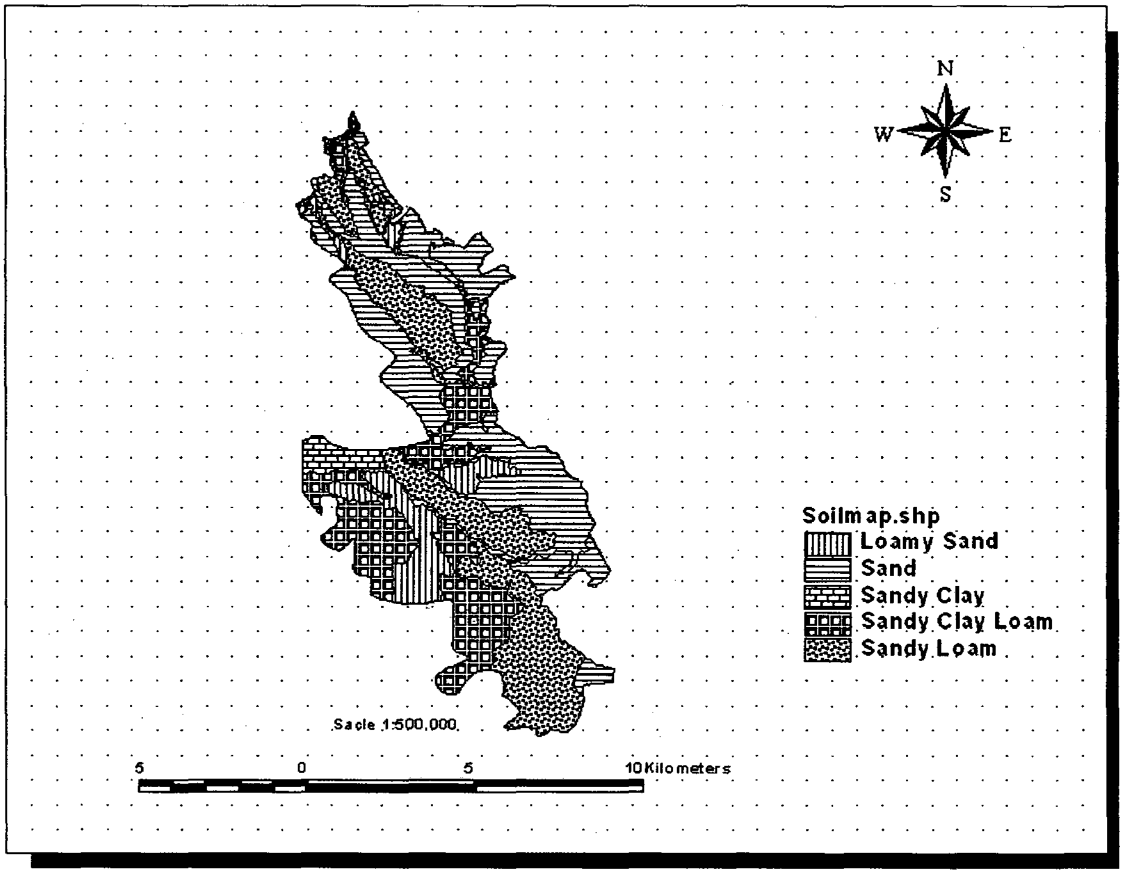


Figure 6.2 Showing the soil type in the study area. This is the soil map of the study area.

6.12 CHANGE IN FOREST COVER

Since deforestation precedes the establishment of much of the new agriculture in this region. Human activities do not measure exactly the same quantities unlike satellite-based measurements of deforestation rates, our estimates of agricultural activity depict changes in land use, rather than changes in land cover. In order to relate these changes to land-use patterns suggested by observations of deforestation, we needed to understand the relationship of changes in each category to the recorded loss of forest area during this period. Unlike the increase in planted pasture and cropland, losses in natural pasture were probably not closely related to deforestation activities. Though some natural pasture may have been converted to cropland.

Though forest area has decreased by 19.39 Km^2 of the study area but deforestation has resulted in decrease in forest density. Deforestation has arisen due four principal causes, often in relationship with each other; excessive felling of trees for timber, overgrazing, fire and clearance of land for cultivation. The total forestland and woodland has decreased from almost 384.34 Km^2 in 1990 to 364. 96 Km^{2}of the geographical area of in 2005, regardless of changes in forest quality (density of crown cover, composition etc.) Woodland has totally disappeared during this period and this is the major change noticed in this area. Woodlands are mainly shifted towards agricultural land and wasteland. Woodland area has converted into wasteland due to drought and non-survival of plantation. The woodland changed into agricultural land due to increase in population and far fulfilling ever-inversing demand for food, fiber, fodder and shelter. Rest of woodland has come under forestland as forest department has increased the forest boundary. The degraded forests now exist on the periphery of agricultural lands indicating human encroachment.

6.13 CHANGE IN AGRICULTURAL LAND

Agriculture land has been faced with great pressure from market forces of the residential development, and this study found that the development logic of economic interests has more competitive power than any thing else. At the urban fringe, complex areas of land cover changes were often found, including transformations from farmland to urban land uses. Particularly in the case of urban fringe monitoring, changes in land use from agricultural land to housing development were detected. In the study area, there was rapid urbanization and a significant loss of agricultural land to new development. The diminished amount of agricultural land caused by urbanization within the study area surrounding. In order to achieve the policy of dispersing the population of the study area, land use planners have sought high amenity areas for new residential land near the city.

A major factor responsible for the disappearance of forests has been the search of new agricultural land due to increasing population pressure and need to generate more income. The agricultural land has decreased from 727.16 sq. km. in year 1990 to 688.93 sq. km. in year 2005 at the cost of surrounding forestland and pastureland.. The change in agriculture field not observered same every where. Near the urban settlement there is tremendous pressure of conversion of agriculture land into the urban settlement. The agriculture land loss is also due to the widening of the road network.

6.14 CHANGE IN SETTLEMENT AREAS

Change in runoff characteristics induced by urbanization is important for understanding the effects of land use and cover change on earth surface hydrological processes. With urban land development, impermeable land surfaces enlarge rapidly, the capability of rainfall detention declines sharply and runoff coefficient increases. Urbanized land usually leads to a decrease in surface roughness; hard road and drainage system can greatly shorten the time of runoff influence. Therefore, urbanized area would become more susceptible to flood hazard under conditions of high precipitation intensity. Intensive human activities and land-use change have dramatically affected the regional water environment. Water shortage, flood hazards, and water pollution became more serious in the process of urbanization. A rapid urbanization process characterized by sharp decrease complicated. Soil antecedent moisture condition had important effects of runoff generation and flood process.

Rapid growth in population; and number of occupied residential houses has been reported from each village of the study area. This has inevitably caused changes in its main city centre Rupnagar. The urban area is found to be 50.94 sq. Km in the year 1990 and 111.69 Km^2 in the year 2005, in last 15 years. The main reason behind this is increase in population growth.

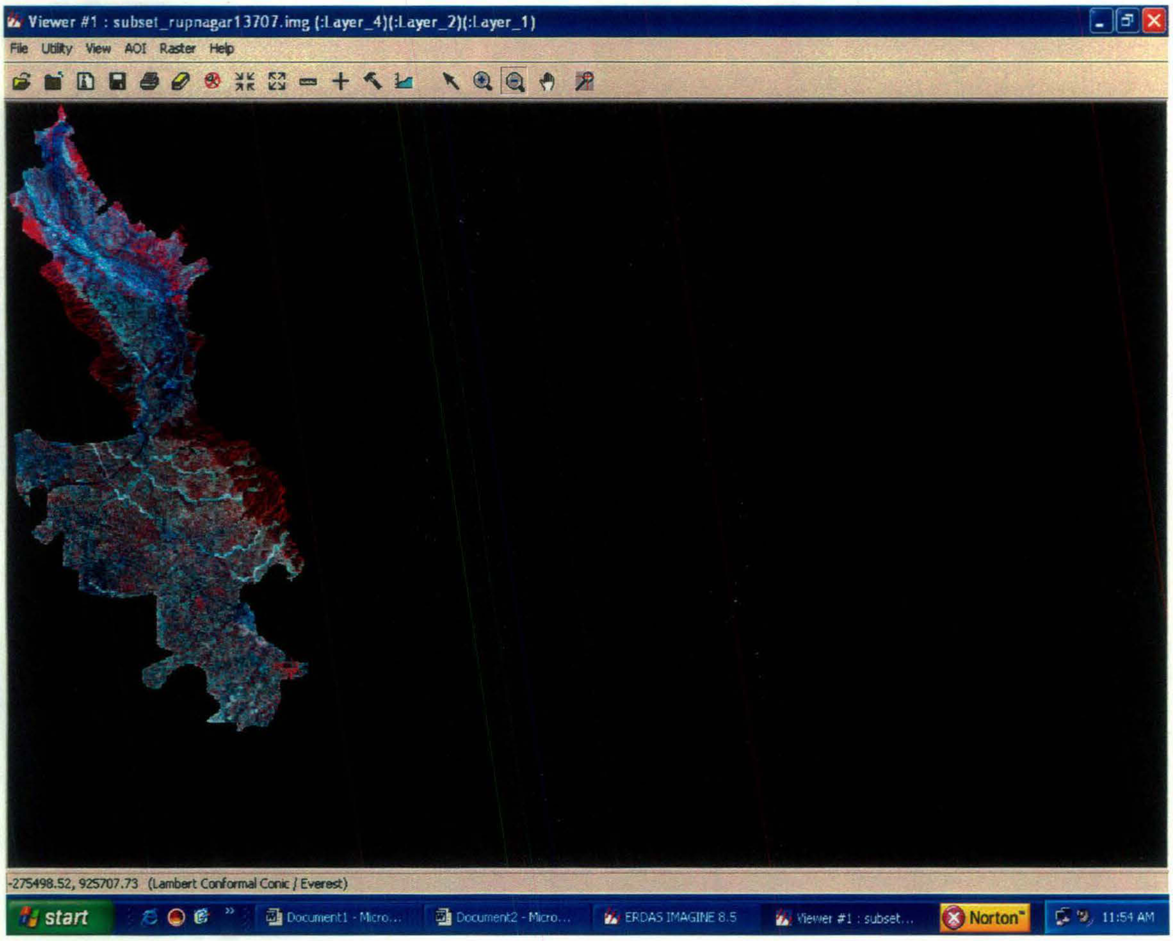
6.15 CHANGE IN WASTELAND AREAS

Significant increase was noticed in the area under wasteland. With increasing human and animal pressure on land, the intensive cultivation has extended even to areas under ecological stress leading to accelerated soil erosion and excessive land degradation.

6.16 CHANGE IN THE CROPLAND AREAS

The area under crop field in 1990 was 723.16 sq. Km and it had decreased upto the 688.93 sq. Km. The loss of the cropland is due to the urbanization and other developmental activities. The loss in the cropland area is directly related to the crop production.

Our estimates of total agriculture change in study area between 1990 and 2005 include cropland decreases, loss of natural pasture, and increase in planted pasture. In order to relate these changes to land-use patterns suggested by observations of deforestation, we needed to understand the relationship of changes in each category to the recorded loss of forest area during this period. Unlike the increase in planted pasture and cropland, losses in natural pasture were probably not closely related to deforestation activities. Given that abandoned natural pasture is extremely unlikely to support re-growing forest, it is inappropriate to include losses of this category in calculations of deforestation rates. Therefore, when estimating these rates, we focused strictly on the relationship between changes in cropland, planted pasture and deforestation. To estimate the change in cropland and planted pasture within the adjusted study area, we extracted the change in these quantities for all states.



-275498.52, 925707.73 (Lambert Conformal Conic / Everest)

Figure 6.3 Showing the FCC of the image of Landsat this is also a unclassified image of the year 1990 (Path 147, rows, 38 and 39).

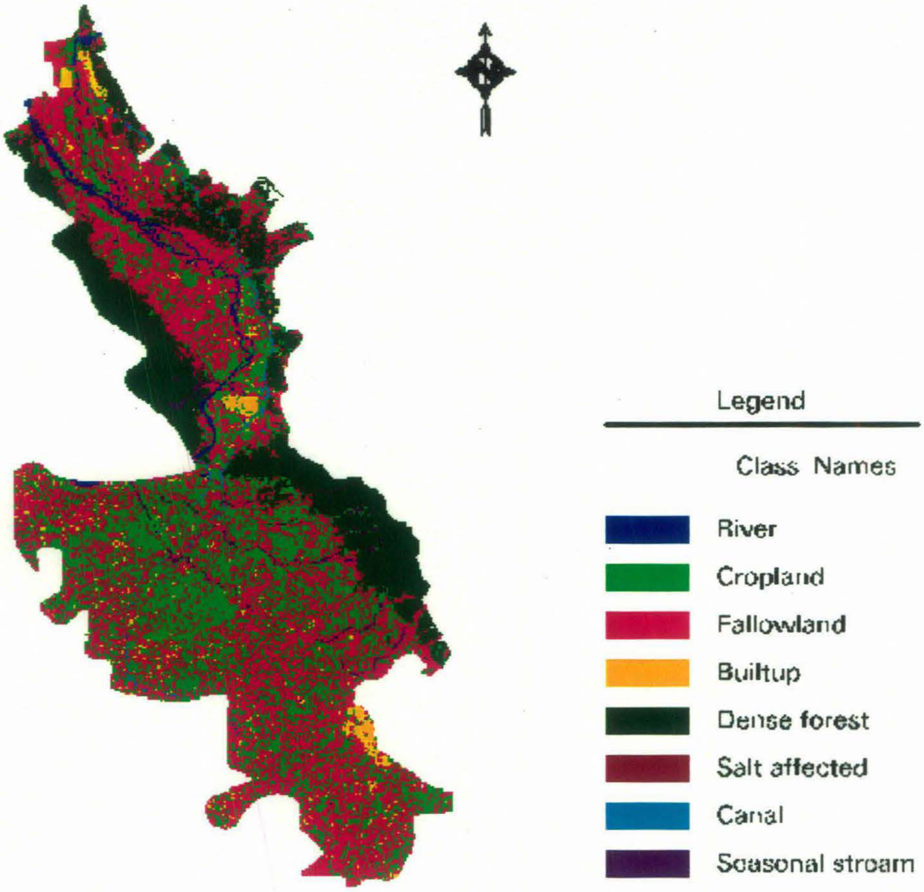
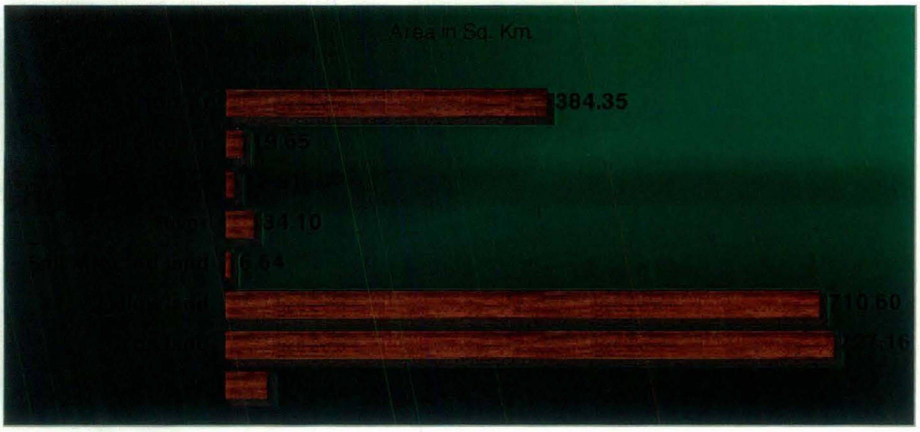
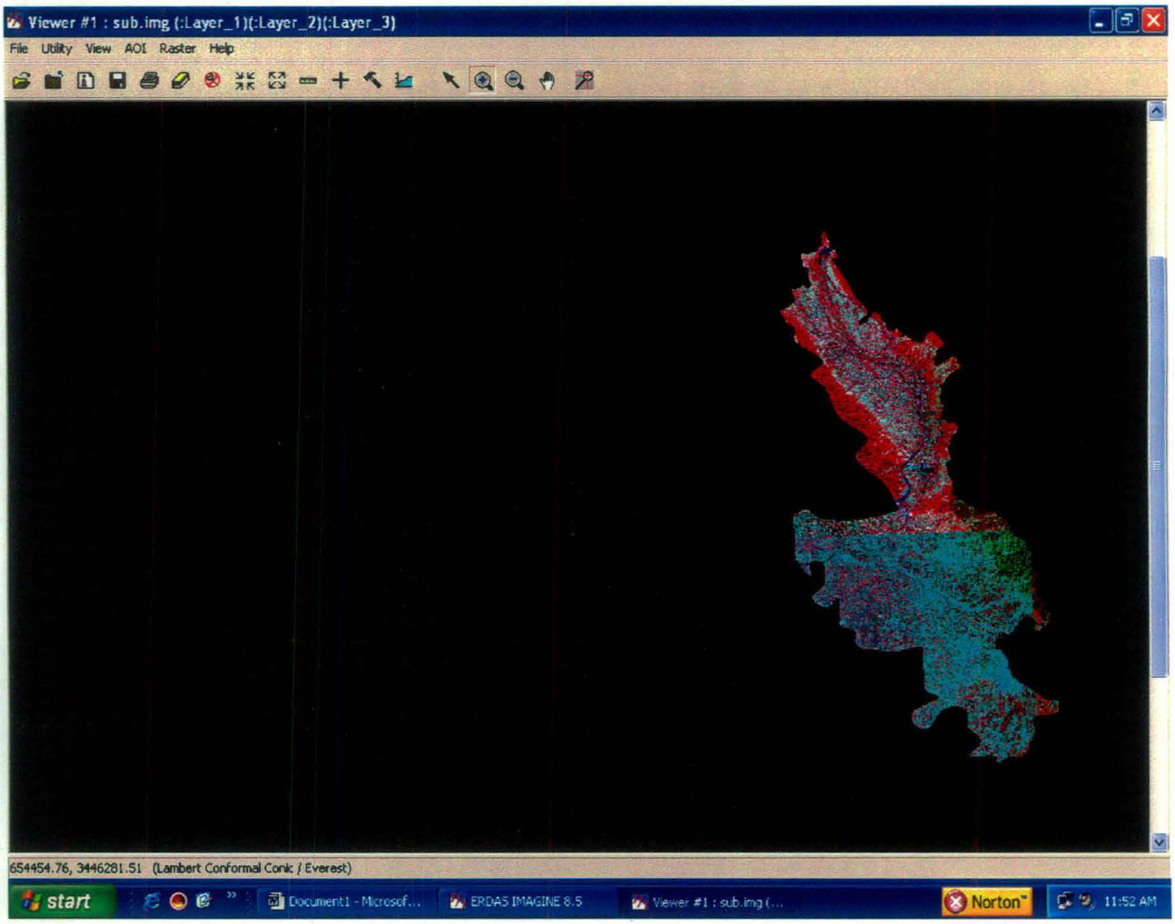


Figure 6.4 Unsupervised classified Landsat image of the year 1990, which is also containing the highest percentage of fallowland.



Graph 6.1 Showing the area of various classes in the classified image of year 1990, of the study area.



654454.76, 3446281.51 (Lambert Conformal Conic / Everest)

Figure 6.5 Showing the False color composite of IRS LISS III, image 2005.

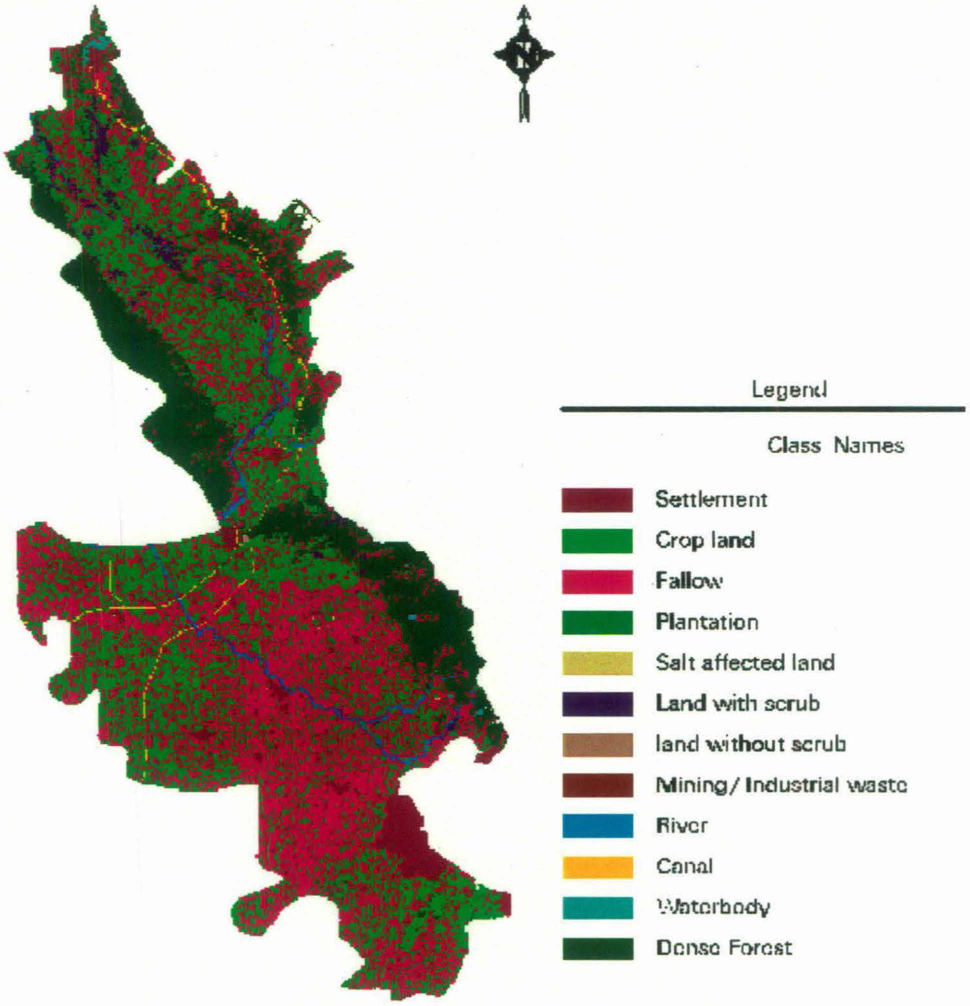
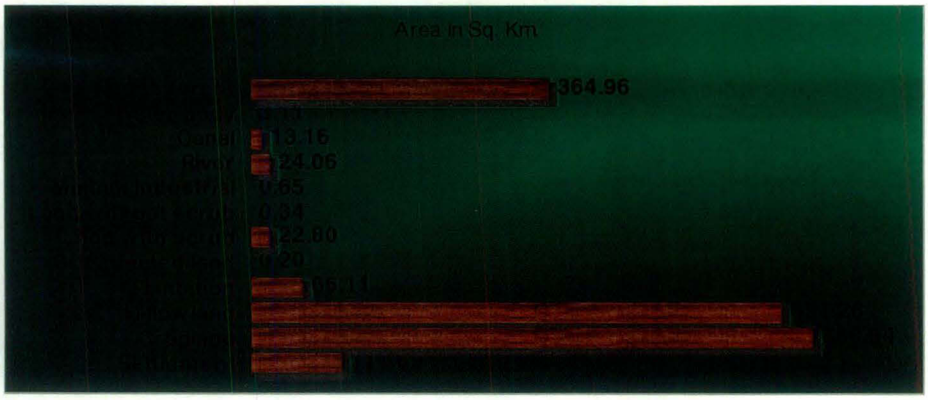
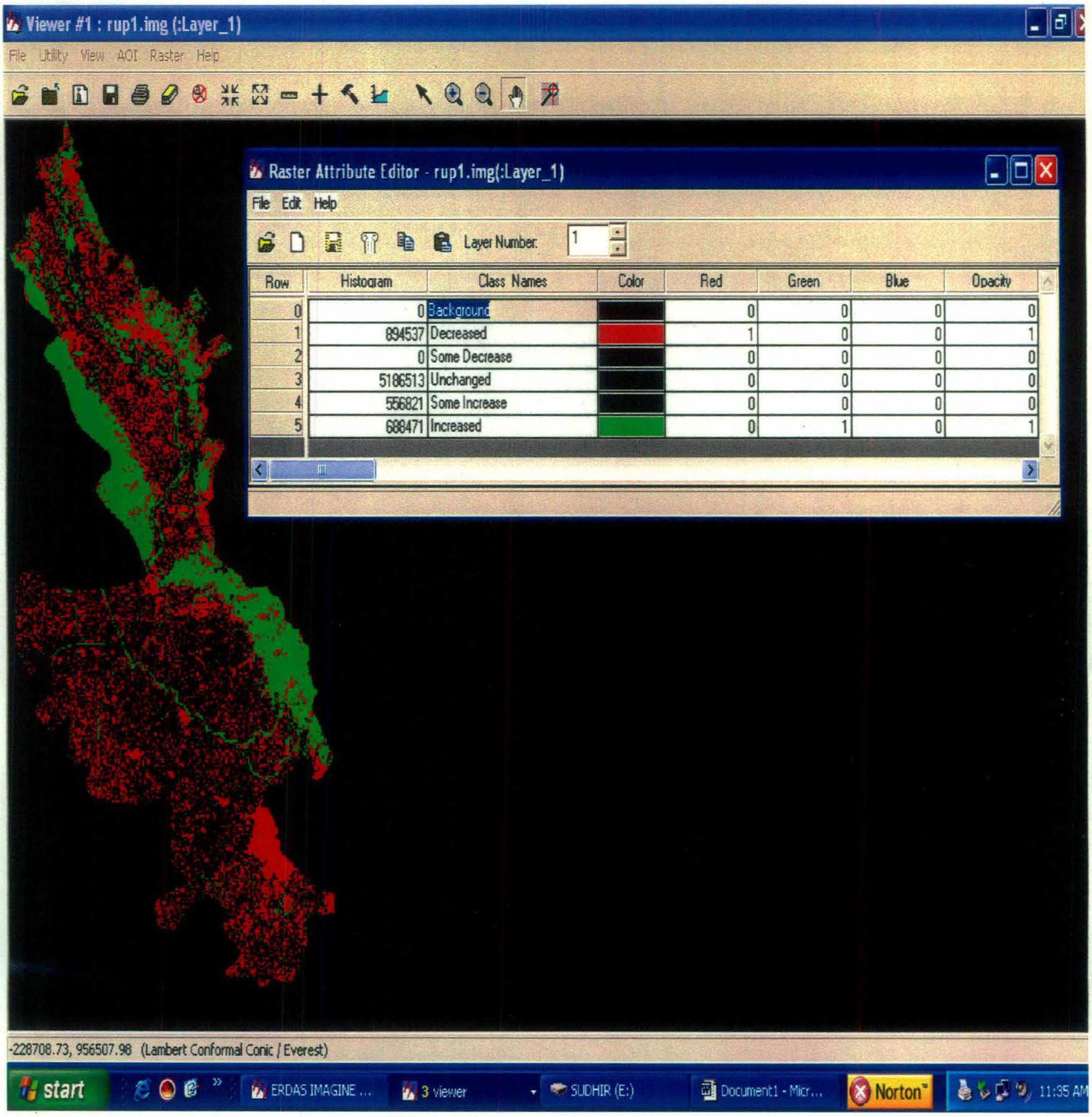


Figure 6.6 The unsupervised classified IRS LISS III image of 2005 showing various classes.



Graph 6.2 Showing the area of various classes in the classified image of year 2005, of the study area.



Row	Histogram	Class Names	Color	Red	Green	Blue	Opacity
0	0	Background	⬛	0	0	0	0
1	894537	Decreased	🟥	1	0	0	1
2	0	Some Decrease	⬛	0	0	0	0
3	5186513	Unchanged	⬛	0	0	0	0
4	556821	Some Increase	⬛	0	0	0	0
5	688471	Increased	🟩	0	1	0	1

-228708.73, 956507.98 (Lambert Conformal Conic / Everest)

Figure 6.7 Showing the change with help Landsat data, of 1990 and IRS IC LISS data of 2005, by the post classification analysis.

Class	**Area in Km^2**	**% of different classes in study area Km^2**
Built up	50.9478125	2.618396632
Crop land	727.1639375	37.37164584
Fallowland	710.6004375	36.52038628
Salt affected land	6.6421875	0.341366597
River	34.099	1.752473804
Canal	12.3101875	0.632666093
Seasonal Stream	19.6535625	1.010069311
Dense forest	384.346625	19.75299545
Total study area	1945.76375	100

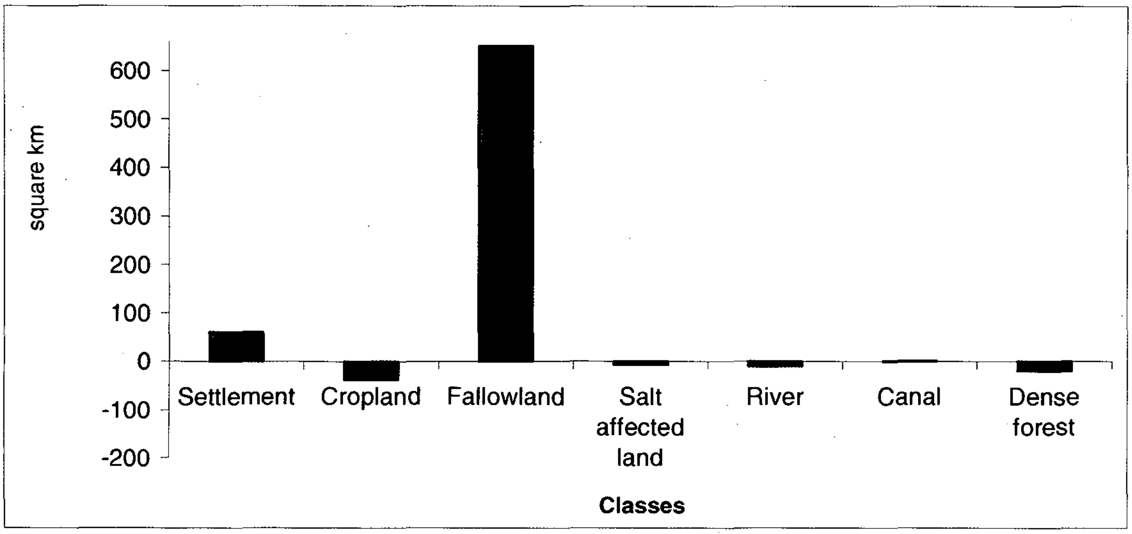
Table 6.3 The % of various classes in the study area as extracted from the Landsat data of year 1990.

Class	Area in Km^2	% of different classes in study area Km^2
Settlement	111.69125	5.738748321
Cropland	688.93625	35.39786463
Fallowland	651.260625	33.46207351
Plantation	65.108125	3.345285714
Salt affected land	0.201875	0.010372431
Land with scrub	22.7975	1.171346142
Land without scrub	0.335	0.017212456
Mining/ Industrial waste	0.64875	0.033333076
River	24.06	1.236213979
Canal	13.15875	0.676102689
Water body	3.105625	0.159568455
Dense forest	364.96125	18.7518786
Total study area	1946.265	100

Table 6.4 The % of various classes in the study area as extracted from the Landsat data of year 2005.

Class	Change in area of respective class
Settlement/ Built-up	60.74
Cropland	-38.23
Fallowland	-59.34
Plantation	--
Salt affected land	-6.44
Land with scrub	--
Land without scrub	--
Mining/ Industrial waste	--
River	-10.04
Canal	0.85
Water body	--
Seasonal Stream	--
Dense forest	-19.39

Table 6.5 The change in land use/ land cover classes during between 1990 and 2005.



Graph 6.3 Showing the change in different classes over the 15 years (1990-2005).

The study has shown the utility of satellite data for the studies of land use/land cover change detection. Based on the results obtained from the present study and the spatial distribution of features on the surface of earth, in the study area following conclusions are drawn.

- Landsat and IRS 1C LISS satellite data in association with other elements (like rainfall data, temperature, humidity and census data), and SOI toposheets can be effectively used in preparing various resource maps and land use/land cover maps with limited field checks. This is also very useful for geomorphologic studies.
- Loss of forest cover by analyzing the satellite image. The loss of forest cover was mainly due to increase in agricultural field and urban built up.
- The loss of agricultural field due to increase in urban built up and widening of road networks and other developmental activities.
- The area of rural built up is decreased in respect to increase in urban built up; this is due to migration of rural people to urban area.
- Micro-tectonic activities in the form of fault in Ropar area.
- Heavy downpour during monsoon months, which owing to steep gradient in hilly area, generates high surface runoff in terms of fast moving streams, hence eroding the hills and plain areas.

Remote Sensing techniques can provide such information within short time at less cost and efforts (Gautam & Narayan, 1983; Gautam & Channaich, 1985). It also provides synoptic coverage of areas of interest and facilitates optimal monitoring capabilities. These features make remote sensing an optimal tool for this type of study (Alexander & Milazzo, 1973). Remote sensing provides data that are available in time series to study the dynamics of the area over long periods, which bridges monitoring gaps in understanding environmental change (Weng 2002, Parr et al.2003, Mukherjee, 1998, & Mukherjee, 2004). The inefficient usage of remote sensing in management actions resulted from the unadjusted accuracies of derived maps and information, but standardization in the process and reporting techniques has increased the reliance of satellite derived maps (Jensen 1996, Green et al. 2000, Lu et al 2003, Jansen & Gregorio 2004). Landsat satellites have been providing multispectral images of the earth continuously since the early 1970s. The Landsat and IRS satellite data have characteristic bands in the visible and in the near infrared part of the electromagnetic spectrum, which enable the estimation of land use/land cover patterns as well as change in land use/land cover.

Chapter 7

Conclusion

CHAPTER 7

CONCLUSION

Understanding change in land use and land cover has been identified as a key research theme of the Large-scale Biosphere–Atmosphere because changes in the land surface can affect energy, water, carbon, and trace gas and nutrient cycles in the region. In recent years, a new set of satellite-based land-cover products has further augmented our understanding of the earth's surface. Efforts to understand the effects of land-cover conversion have indicated significant changes: in addition to large changes in biomass, conversion can affect hydrological and biogeochemical processes. An additional little-used source of land-use information is census data, which has recently been explored for its relationship to remotely sensed imagery. With the notable exception of a study of the correlation between deforestation rates and socioeconomic and demographic variables, soils, the pH, and EC in soils growing annual crops differed from soils supporting pasture and crop land perhaps because pastures are typically not cultivated. Perhaps the most compelling reason to monitor land-use change as well as land cover is the strong effect of land-use history on the state and fate of converted areas can mask strikingly different histories of intensity and duration of use. Re-growth rates also vary strongly by soil fertility. These effects illustrate the imperative for a spatially explicit time series of agricultural land use including representations of deforestation, farming practices, shifting cultivation patterns, and abandonment across the entirety. Such a time series would provide modelers with a baseline from which to make more educated assumptions about likely land-use histories and conditions in an area. Unfortunately, it does not appear possible to create such a land-use data set using only satellite data. Because they sense reflectance values, satellite products in the tropics are best suited to include only categories of land cover. Spatial resolution, explains the relationship between these snapshots of land use and deforestation rates, and investigates several areas witnessing dramatic change during the period.

The use of remotely sensed data showed that north-eastern had a significant change in land use/land cover over the last 15 years (1990-2005). The temporal images showed the pre-change and post-change cover types. The Landsat image of 1990 clearly showed rich vegetation cover, less built up. Deforestation, land fragmentation, cultivation of wetlands and rapid increase in human settlements have had negative impacts on water sources resulting in reduced stream flows and water shortages. The negative impact on the soil resources in terms of long-term soil fertility is also due to increase input of fertilizers and intensive irrigation by canal water and groundwater. The soil salinity increased in some areas. The loss of top surface soil (few cm), which is more productive, by the increase in the impervious layer, change in crop pattern, reduction of forest cover and change of grassland into the agriculture field.

Information from agricultural censuses can be integrated with satellite data to provide additional information that would otherwise not be available. This combination of satellite and census data allows analysis of the spatially explicit patterns of agricultural land uses within study area. Through an inspection of the relative changes in simple quantities between censuses, we have estimated changes in agricultural activities in a way that is consistent with satellite imagery and ground-based data sources. This integration of census and satellite information appears to hold promise for understanding the distribution and abundance of cropland and cattle pasture, whose land cover appears similar to natural systems in many areas. Satellite-based studies demonstrate the clear benefit of high spatial resolution and repeatability, and have formed the foundation for what we know about change in land use/land cover in the study area. Unfortunately, studies based on only satellite data are best suited and perhaps limited to analysis of land cover, and cannot easily provide information about the actual uses of land that has been converted. As a result, a substantial gap exists between our ability to sense land cover and the needed knowledge of the density and pattern of various land use within study area. Spatially explicit snapshots of cropland and pasture, created by fusing the patterns of land cover to census-based broad scale quantifications of land use, can begin to bridge this gap. Models of land-use change and abandonment can provide the crucial link to better understanding not only the state of converted land (as expressed in the static maps of land use through time) or the additions to the pools of land in use (as expressed in land-cover studies), but the long-term fate of that land as it passes through cycles of active use and abandonment. The flexibility of these models suggests the opportunity for collaboration between social scientists and remote sensing specialists to synthesize our understanding of land-cover change and land-use change across the basin, with the goal of better understanding the current variation in these dynamics through time. The images presented here show the overall increase in built up, the changes in major land uses that occurred between 1990 and 2005. Land-use changes were not spatially uniform; rather, different apparent land use dynamics operated. Cropland or natural pasture in either time period, and the increase in planted pasture is probably largely attributable not to conversion from other land uses but to deforestation. Detailed information contained in censuses presents a largely untapped resource that, when combined with satellite imagery, can greatly expand our knowledge of the uses of land converted in this region. The mapped land-use time series and the models explaining how they are linked to deforestation rates can broaden our understanding of the many impacts of the changes in study area over the fifteen years.

The study has shown the utility of satellite data for the studies of land use/land cover change detection. Based on the results obtained from the present study and the spatial distribution of features on the surface of earth, in the study area following conclusions are drawn.

- Landsat and IRS 1C LISS satellite data in association with other elements (like rainfall data, temperature, humidity and census data), and SOI toposheets can be effectively used in preparing various resource maps and land use/land cover maps with limited field checks. This is also very useful for geomorphologic studies.
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- The area of rural built up is decreased in respect to increase in urban built up; this is due to migration of rural people to urban area.
- Micro-tectonic activities in the form of fault in Ropar area.

- Heavy downpour during monsoon months, which owing to steep gradient in hilly area, generates high surface runoff in terms of fast moving streams, hence eroding the hills and plain areas.

Based on all these facts listed above, the area deserve to draw a serious attentions of the geologist, environmentalists, and common people with the need to adopt sustainable management techniques in order to conserve the ecosystem as well as deaccelerate the erosion by the anthropogenic activities as well as by the natural forces. The study area is not the only one to be given attention but the entire area of India is needed to be studied and at the land use/land cover information's should be properly evaluated and appropriate management practices should be adopted.

Filed photographs

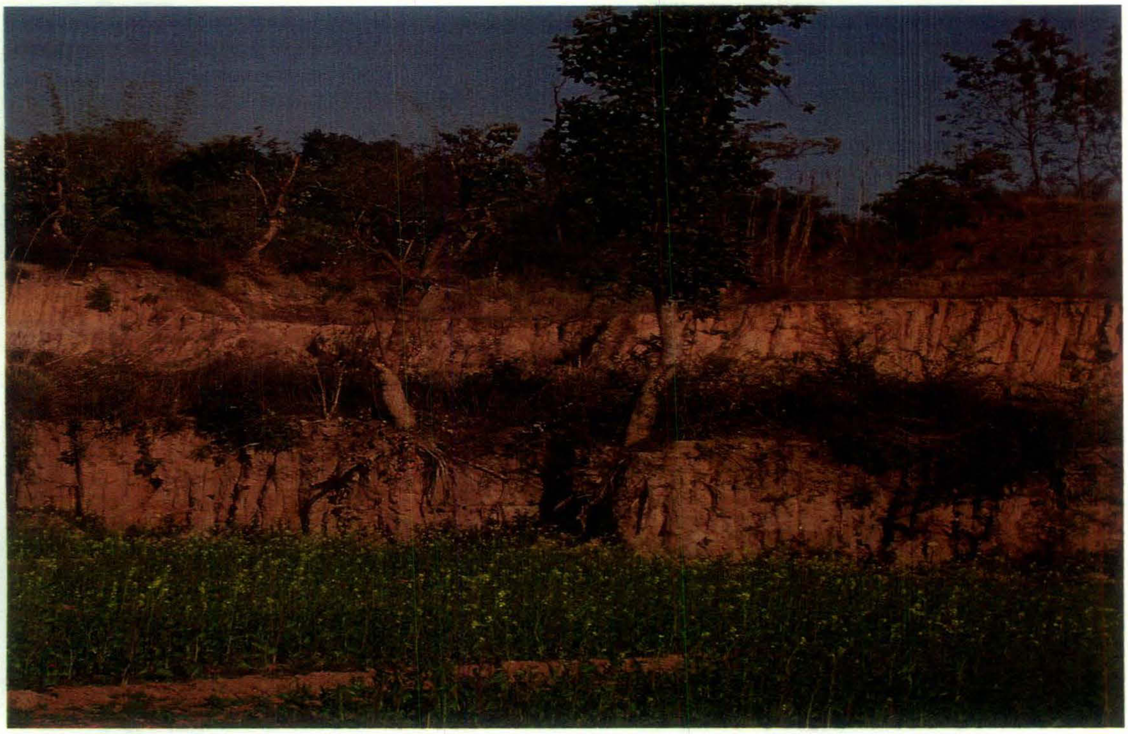

Plate-1 Photograph showing the soil erosion by the illegal mining.

Plate-2 Photograph showing the wasteland with scanty vegetation.

Plate-3 Photograph showing the highly urbanized area.

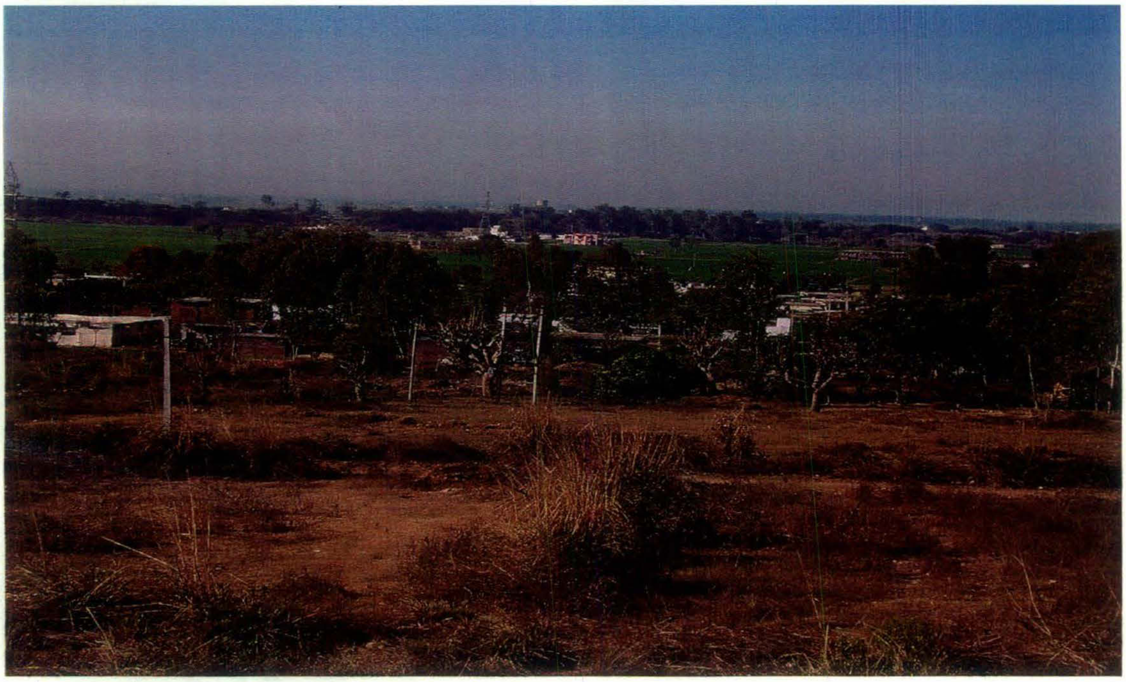

Plate-4 Photograph showing scattered urban settlement.

Plate-5 Photograph showing the crop land far way from the hilly area (Siwaliks Hills).

Plate-6 Photograph showing the crop land near the hill regions (Siwaliks Hills).

Plate-7 Photograph showing the plantation, mainly *Eucalyptus* within the natural plant.

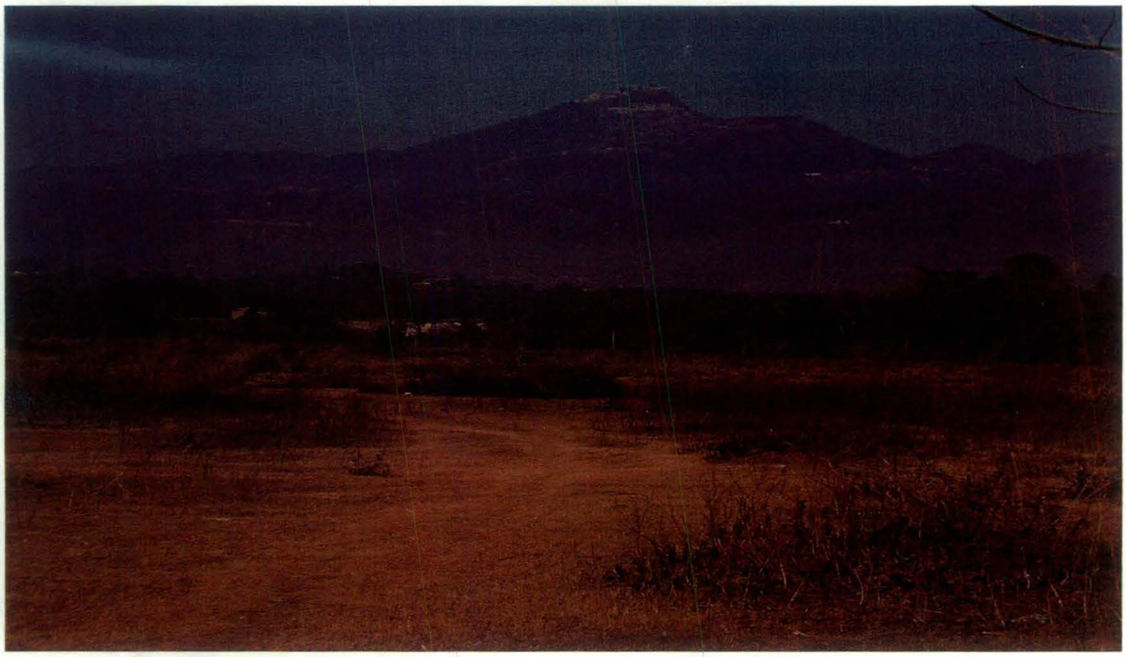

Plate-8 Photograph showing the dense forest in the Siwaliks.

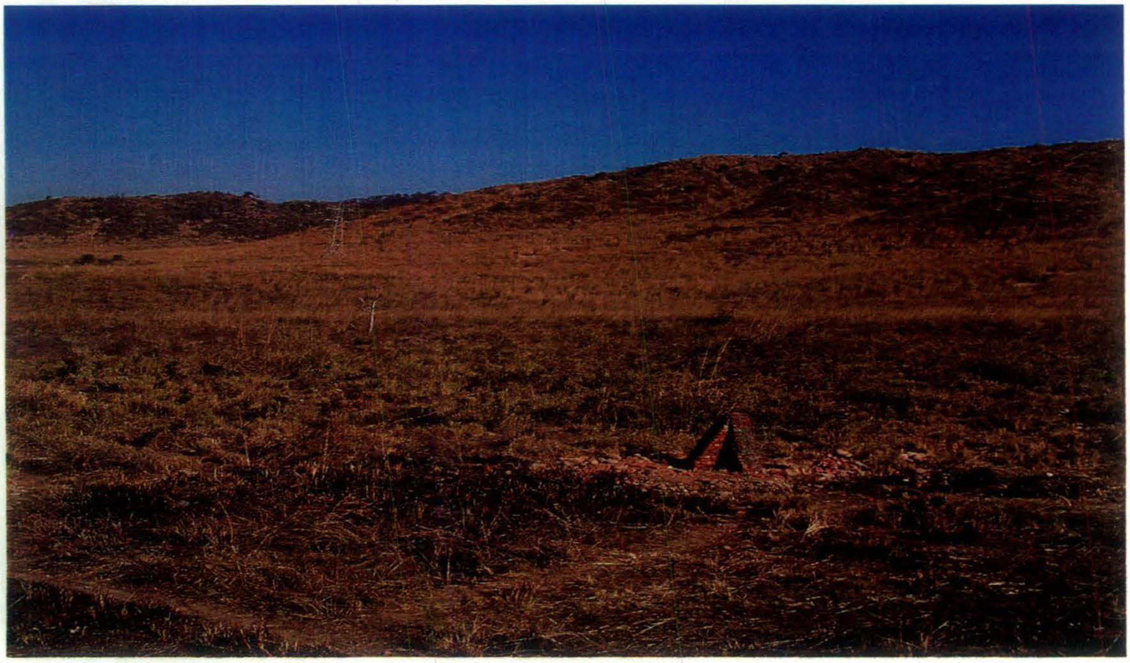

Plate-9 Photograph showing the land with scrub.

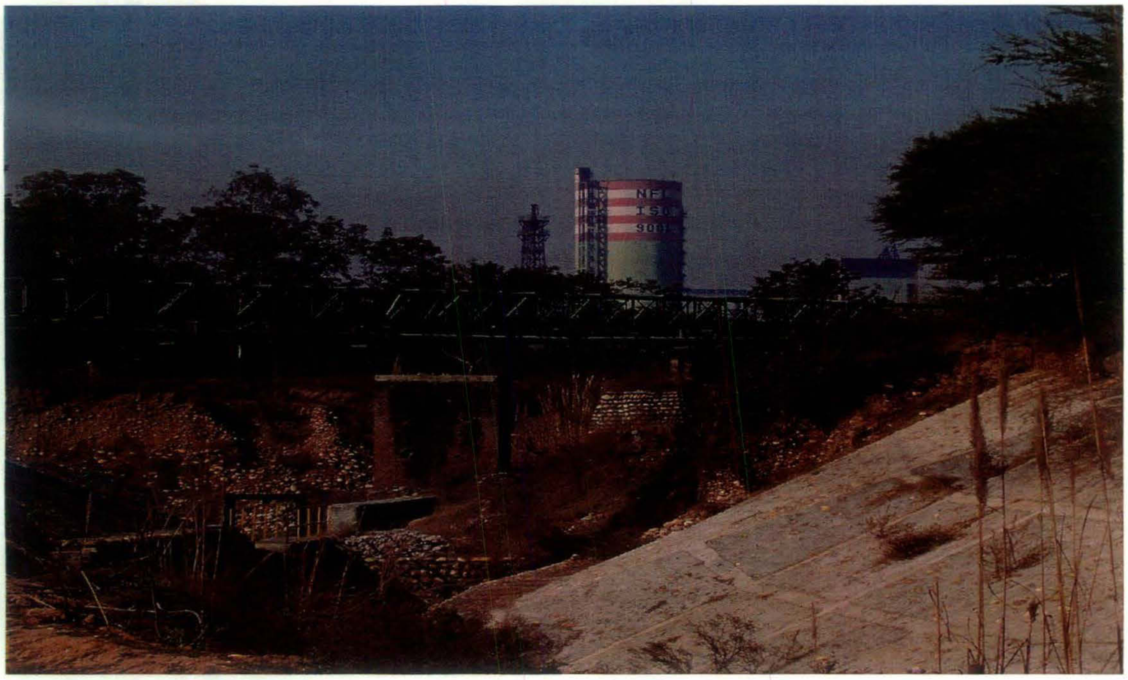

Plate-10 Photograph showing the industrial set up (NFL, National Fertilizer Limited).

Plate-11 Photograph showing the effluent, which is discharging from NFL.

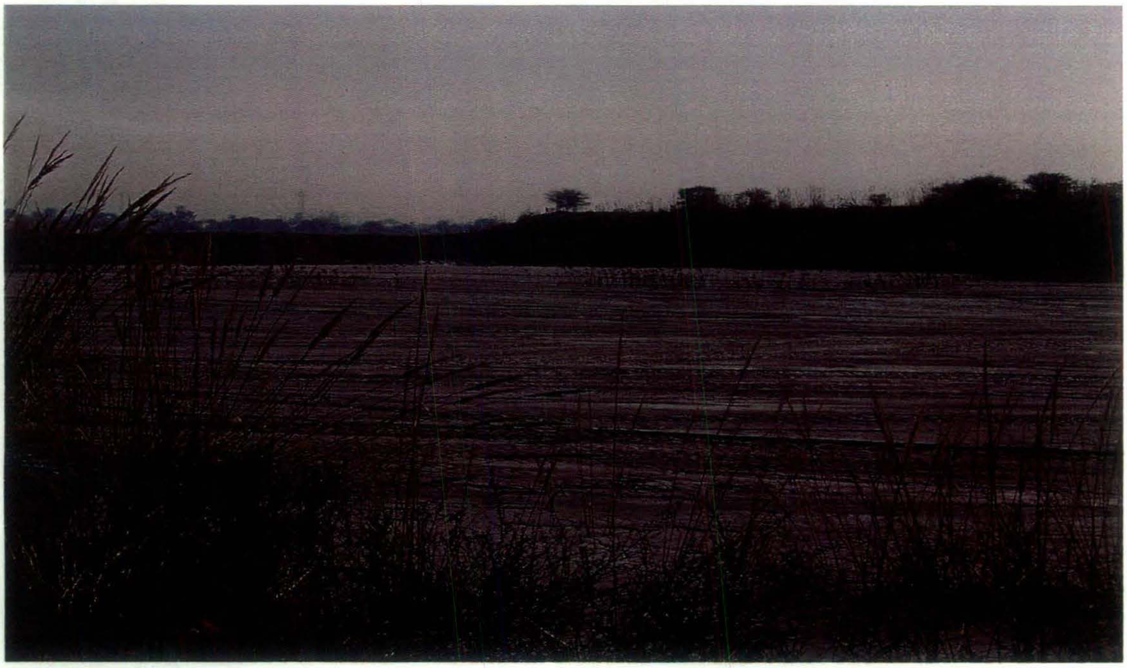

Plate-12 Photograph showing the solid waste, which is openly dried in the field.

Plate-13 Photograph showing the canal, with running water.

Plate-14 Photograph showing the River Sutlaj

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