EVOLVING A REGIONAL PERSPECTIVE ON 'GREATER CHANDIGARH REGION' (GCR) USING RS & GIS

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Sri Krishna advises Arjuna in the following verses in Gita (Chapter 9, verse 27) :

Whatever you do, or eat, or sacrifice, or give, whatever austerity
you perform, that, O son of Kunti, offer unto Me

I dedicate this labour and its fruit, for the good of society and the nation, to the Lord Almighty.

Sri Ramakrishnam Arpanastu

CERTIFICATE

This is to certify that the dissertation entitled **"Evolving Regional Perspective on 'Greater Chandigarh Region' (GCR) using RS & GIS"** is the original contribution of **Col KK Kakkar** towards partial fulfilment of the of the requirement for the award of Master of Technology in Remote Sensing and GIS at Urban and Regional Studies Department, Indian Institute of Remote Sensing (IIRS), Dehradun.

The project contains original work carried out by him and he has duly acknowledged the sources of data and resources used.

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ABSTRACT

This study has attempted to demonstrate the efficacy of Remote Sensing and GIS as a Decision Support System (DSS) in analysing the cohesiveness of Union Territory of Chandigarh and its adjoining areas in the legally declared 16 km periphery control belt, to form a self regulating geographical entity, and has attempted to offer a sound geospatial perspective to the problems of urban planning in the region. The region under study has been referred to as 'Greater Chandigarh Region' (GCR). A number of diverse database sources were tapped as inputs for the study. Multi sensor, multi resolution, multi temporal satellite images were processed digitally to prepare a number of hybrid products of 5 to 6 metres resolution for three time periods, which would be useful in identification of not only various built up forms, but also, all other types of land-cover relevant to the study. Through careful visual interpretation of the region in terms of a classification scheme devised for such regional study, three temporal Land-use/ land-covers (LULCs), of years 2000, 2006 and 2012, were digitised at 1:10,000 (and higher) resolution. The vector products were used to identify areas of urban physical growth between the three given time periods. These LULC features, which were prepared in Arc GIS, were exported to *IDRISI Taiga* software for further raster analysis. A study was carried out, as first objective, to identify the drivers of urban (physical) growth and their exact mathematical relationship with this growth. Using these drivers, in the second objective, two prediction models (CA_Markov and MLP) were tested on data of 2000 and 2006, and predicted results of 2012 were validated against actual data of LULC 2012. The best suited prediction model, viz, MLP, was applied on Built up (BU) thematic maps of 2000 and 2012 to predict the BU thematic maps of 2024 and 2048 (read 2025 and 2050). These two output templates, viz, BU 2024 and BU 2048, were then used as crucial inputs to understand and address the next objective, viz, delineation of the region. The observations of *Concept Note* of Govt of India were taken forward to complete the delineation of region in a systematic manner. Seven layers of the region were identified, and six of them were geographically delineated. The seventh layer, though being beyond the scope of the current study, was discussed in last chapter.

An innovative ***Regional Development Model : GCR 2050*** has been built upon these six layers, by classifying each layer in five categories and examining each layer against several geospatial inputs (evolved earlier during the study), viz, Builtup scenarios of BU 2024 and BU 2048, the (current) LULC 2012, projected master plans of neighbouring towns/cities and the road infrastructure development proposals (by states in the neighbourhood of Chandigarh). The development model brings out two key policy issues, that of environment preservation and continued urbanisation, and attempts to strike a balance between them. Having achieved all the objectives satisfactorily, the study goes further to demonstrate how it can be extended to analyse any geospatial input that may have a bearing on the GCR planning. Taking plans of *Greater Mohali Region (GMR)* as sub regional inputs for GCR, the study evaluates one aspect, viz, proposal to build an expressway (by GMR) within GCR, and concludes the development as beneficial for GCR. In the final run, the study draws its focus on issues concerning environment, and exhorts the regional planner to use innovative means to preserve and extend the forest cover along the seasonal rivulets in layers five and six, and to develop similar areas as green/recreational parks in layers three and four (where urbanisation is predominant and afforestation is not feasible). An observation, in passing, has also been made on the need to cater for dwellings for the informal sector in the evolution of any regional plan, on lines of what the Chandigarh Administration is currently undertaking in its western part.

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LIST OF ABBREVIATIONS

BRTS	Bus Rapid Transport System
BU	Built up
CA	Cellular Automata
CBD	Central Business District
CIAM	International Congress for Modern Architecture
CISR	Chandigarh Inter State Region
CISMeR	Chandigarh Inter State Metropolitan Region
CCR	Central Chandigarh Region
CRPF	Central Reserve Police Force
CUC	Chandigarh Urban Complex
DBM	Dielectric Breakdown Models
DCC	Dhaka City Corporation
DLA	Diffusion Limited Aggregation
DPI	Dots per Inch
DOS	Department Of Space
ETM+	Enhanced Thematic Mapper Plus
GCR	Greater Chandigarh Region
GIS	Geographic Information System
GMADA	Greater Mohali Area Development Authority
GMR	Greater Mohali Region
GoI	Government of India
IRS	Indian Remote Sensing
ISRO	Indian Space Research Organisation
ITBP	Indo Tibetan Border Police
LISS	Linear Imaging Self Scanner
LPA	Local Planning Area
LUCC	Land use and Cover Change
LULC	Land Use Land Cover
LUP	Land Under Plotting
LCM	Land Change Modeller

MIR	Mid Infra Red
MLP	Multi Layer Perceptron
MMU	Minimum Mappable Unit
MRF	Markov Random Fields
MSS	Multi Spectral Scanner
NBU	Non Built Up
NCR	National Capital Region
NCT	National Capital Territory
NE	North East
NW	North West
NIR	Near Infra Red
NRSA	National Remote Sensing Agency
NUIS	National Urban Information System
OSM	Open Series Maps
PAN	Panchromatic
PLPA	Punjab Land Preservation Act
PCA	Principal Component Analysis
RMS	Root Mean Square
RS	Remote Sensing
SNA	State Nodal Agencies
SPA	School of Planning and Architecture
TBRL	Terminal Ballistic Research Laboratory
TCPO	Town and Country Planning Organisation
UDPFI	Urban Development Plans Formulation and Implementation
UIS	Urban Information System
UNDP	United Nations Development Programme
USGS	United States Geological Survey
UT	Union Territory
UTM	Universal Transverse Mercarator

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1. INTRODUCTION AND BACKGROUND

1.1. Origin and Birth of Chandigarh

After getting independence in 1947, Chandigarh, "The City Beautiful" was planned as 'Capital City' of undivided Punjab. It is located picturesquely near the foothills of the Shivalik range of the Himalayas in Northwest India and is India's first planned and green city. In 1966 Punjab state was reorganised and Chandigarh became capital of Punjab and Haryana with a total of 114 sq. km. which included 26 adjoining villages. Chandigarh derived its name from Chandimandir, a temple of goddess Chandi, which is located near its border in the state of Haryana. The master plan of this city was designed by the well-known French architect LeCorbusier, assisted by three senior architects Pierre Jeanneret, Maxwell Fry and Jane Drew and supported by several young Indian architects and planners. It is acclaimed the world over for an unparalleled architecture. With a focus on architectural aesthetics, urban design and open spaces, its layout conforms to International Congress for Modern Architecture's (CIAM's) Charter of Athens Analogy of Human Organism incorporating elements of living, work, culture and leisure. The Master Plan visualised a population of 1.5 lacks in phase one, later to be expanded to accommodate a total of 5 lacs in second phase. However as per census 2011 this population has already exceeded one million (1,054,686). Chandigarh is one of the seven Union Territories of India and till date serves as a capital for two states, Punjab and Haryana. It has two satellite cities, Panchkula (in Haryana) and Mohali (in Punjab).

1.2. Chandigarh Periphery Act & Subsequent Amendments

The Punjab New Capital (Periphery) Control Act, 1952 was enacted to ensure planned and systematic urban development by checking haphazard and unregulated growth over the land lying in the periphery. The Act extended to the area within a distance of 5 miles (8 km) on all sides from the outer boundary of the land acquired for the capital of the State i.e., Chandigarh. Subsequently, the Act was amended in 1957 & 1962 to enlarge the periphery to cover an area upto 10 miles (16 km). The main objective of the Act was to ensure planned development in the new city and its extension and also to prevent the growth of slums and unauthorized development on the land at the periphery of the new city Chandigarh.

Once the state of Haryana was carved out, the Haryana Amendment Act, 1971 was adopted for controlling the development within the periphery area of Haryana. Subsequently the development plan of this periphery controlled area was revised from time to time to meet the aspirations and needs of people of the periphery areas. Consequently the towns of Panchkula and Mohali came up as satellite towns in the states of Haryana and Punjab respectively. In addition, several special government projects like Chandimandir Cantonment, Indo Tibetan Border Police (ITBP) Complex, Central Reserve Police Force (CRPF) Complex, Terminal Ballistics Research Laboratory (TBRL) and HMT factory were also set up within this periphery control area.

1.3. Need for Regional Perspective and Role of GIS

In the last three decades the population of Panchkula, Mohali and other periphery areas has increased manifolds. Meanwhile the density of Chandigarh has risen to 9252 per sq. km. as per Census 2011, second highest in India after the state of Delhi. Being landlocked on all sides with merely 114 sq. kms. in its ambit, planners have so far done their bit to cater for the high growth rate of population and rising demand for urban dwellings. Densification of southern sectors was done and further expansion by adding sectors 48 to 56 was also resorted to. While the development process in the cities of Chandigarh, Panchkula and Mohali (hereinafter referred to as **Tricity**) is still continuing, some haphazard development of unauthorized colonies, piecemeal commercial development, intermix of conforming and non-conforming uses of land along with inadequate services and facilities have come up within immediate neighbourhood including the fringe areas. Therefore time has come to look at these cities governed by three different entities belonging to three different States/UT in terms of a single region. There is also a strong case to look at the areas beyond the Tricity region, which will include contiguous areas from States of Punjab, Haryana and Himachal Pradesh and bring them under a single planning and development entity . For the purpose of this research project such a region hereinafter will be referred as **'Greater Chandigarh Region'** (**GCR).**

Regional planning has been defined by JB Kshirsagar, Chief Planner, Town and Country Planning Organisation (TCPO) as "a branch of land use planning which deals with the efficient placement of land use, infrastructure and settlements across a significantly larger area than an individual town/city." In planning terms, a region may be administrative or functional and includes a hierarchy of settlements, associated network and agricultural land, forest areas, environmentally sensitive zones and the like. Regional planning also addresses issues related to flood plains, transportation infrastructure, the assigned role of settlements, designating various uses, green belts, setting out regional policies, zoning etc.

The hypothesis is that delineation of the region referred to as GCR accompanied by formulation and implementation of a regional plan for GCR can bring about harmonised, balanced and decentralised development in the region by synergising the efforts of participating States and UT to manage overall growth in their respective areas.

1.4. Research Identification

1.4.1. Research Questions

(a) What are the growth drivers in the GCR and how do they impact the dynamics of urbanisation in the area ?

(b) Given the past trends of growth (2000-12), what would be the projected physical growth of GCR by years 2024 and 2048 ?

(c) How would delineation of GCR take place and based on what criterion ?

1.4.2. Research Objectives

(a) To understand the pattern of growth in GCR, likely urban forms, geospatial drivers of physical growth, and their relationship with growth in the region.

(b) To study the past trends of growth and evaluate models of growth prediction. Using the best prediction model, project the physical growth of GCR by years 2024 and 2048.

(c) To carry out an appraisal of delineation studies done in the past and suggest fresh delineation scheme based on GIS understanding of the processes involved. Evolve a Regional Development Model for year 2050.

1.4.3. Research Aimed at

The overal aim of the project is to use RS & GIS techniques as a Decision Support System (DSS) for regional planning. Based on the research objectives and research questions as discussed above, following innovations are being aimed at in this field:

(a) To demonstrate the utility of using multi sensor, multi temporal images in regional studies. In particular, the image processing techniques of fusion and PCA are put to test in their application for enhanced visual identification in a large study area, well known for its heterogenity.

(b) Using an innovative classification scheme of land use (inclusion of category such as "land under plotting"), to study of the systemic transition cycle between various land uses leading to an understanding of past and current trends of urban growth.

(c) Application of urban growth modelling and prediction techniques to develop an understanding of alternate growth scenarios and to provide a guideline for further delineation studies.

(d) While there have been many delineation studies carried out earlier by eminent planners in the past, this is the first study which aims at an accurate geospatial assessment of the entire region by using precise and cutting edge technology. This study also aims at evolving a "Regional Development Model 2050" which is simple enough to comprehend the complexities of the region holistically and can be used as a powerful DSS tool in the hands of regional planners.

1.5. Outline of Thesis

This thesis is divided into seven chapters. The first chapter deals with background and the origin of Chandigarh. Research questions, their analogous objectives and the purpose behind the research work is also enunciated.The chapter ends with the outline of the thesis. Second chapter deals with the literature review. A substantial review material originates from Government publications and is, therefore, reviewed as a separate sub section.The third chapter deals with the study material used and the scope/restrictions associated with the present work. Next, certain preparatory analysis is done to generate a clear methodology of work which again forms a part of chapter four. Chapter five deals with the three objectives and the results thereof. This is followed by a discussion in chapter six and recommendations in chapter seven.

This research work does not in any way replace a planner's work. It is a product of a GIS specialist having elementary knowledge of issues dealt by an urban and regional planner and therefore only supports and augments the work of urban planner with the help of geospatial technology. Therefore, this work may not be expected to be exhaustive enough to come up with a complete regional plan. However, it brings to the fore centrality of role of Remote Sensing and Geographic Information System (RS & GIS) while carrying out a holistic appraisal of a study area where a regional plan is to be evolved and utility of certain techniques which assist in making of such a plan. Beginning with providing a universal platform with a predefined projection system fitted onto a pre decided geoid system, it proceeds, thereafter, to deal with specificity of the map scale involved. It will be demonstrated through this work how a multiplicity of inputs starting from satellite imagery to maps of varying scales and going up to scanned town plans which are not to scale, and only fall in the category of sketches, are all dovetailed into a single GIS system and assist the regional planner to arrive at sound technical decisions. A unique method to identify and analyse certain well defined geospatial parameters as 'drivers of growth' has been done. Multi temporal analysis is undertaken with a view to understand the past growth pattern and prediction modelling of physical growth is done to assimilate alternate future scenarios. Towards the end, a delineation study is conducted to arrive at a Regional Development Model of GCR upto the year 2050. It includes delineation of the region in six layers with each layer classified in five categories. All miso or micro level planning can thereafter be done within these five classes or major 'blocks' of planning areas. For example, town plans may be developed with a particular orientation or predominant activity within the designated class 'Urbanisable (Proposed)' or certain eco-sensitive area along a seasonal rivulet classified as 'Afforestation (Proposed)' may be placed under restriction for no urban development activity.

2. LITERATURE REVIEW

2.1. Government Publications and Reports

2.1.1. Concept Note On Chandigarh And Its Region (*Concept Note*)

Concept Note was published by Town and Country Planning Organisation (TCPO), Government of India, Ministry of Urban Development in October 2011. It specifies two urgent needs which require to be addressed. In Section 5.0, the need for Chandigarh Inter State Region Plan (CISR) 2031 is discussed and in Section 9, the need for a Master Plan for Chandigarh is discussed. Both sections discuss the modalities and the terms of reference. Barring, the Punjab Regional and Town Planning Development Act, 1995 there is no provision for preparation of regional plan in the legislative framework for planned development in Chandigarh or Haryana. Due to ineffective enforcement, barring Mohali and Panchkula, many settlements have come up in an unplanned manner. In order to ensure sustainable development of the Chandigarh periphery, it would be imperative that the development strategies need to be drawn up at regional level much beyond the areas of periphery.

The Inter-State Region Plan for Chandigarh has to be prepared to achieve balanced and sustainable integrated development which should focus on connectivity / transport linkages between the towns in the region, land use policies, carrying capacity, environmental conservation, disaster management and financial and institutional framework. The inter-state regional plan may be prepared for a 20 year perspective. The broad terms of reference for preparation of Chandigarh Inter-State Regional Plan 2031 would be as under:

(a) To **delineate** the Inter-State Chandigarh Region and assess the development pattern.

(b) To **assess t**he physical base, economic base, demographic pattern, settlement pattern and availability of physical and social infrastructure.

(c) To **carry out** Land Suitability Analysis for urban development and to assess the land availability for perspective year for various uses.

(d) To **examine** the transportation needs and recommend the strategies for the reliable, efficient and seamless transport network for the Region.

(e) To **integrate** infrastructure requirement and environment concerns together with landuse pattern and transportation.

(f) To **identify** appropriate policy zones based on the predominant economic activities and potential in the region and sub-regions.

(g) To **recommend** suitable strategies for the sustainable development of the region based on population forecasting and assessment of the regional infrastructure requirements.

(h) To **develop** policy guidelines for decentralization of economic activities, development of settlements based on hierarchy and redistribution of population thereof in the region.

An activity chart or work plan and an analysis of strengths and weaknesses of National Capital Region (NCR) Planning Board Act 1985 has also been given as annexure.

2.1.2. Chandigarh Inter State Metropolitan Regional Plan 2021 (*CISMeR)*

Chandigarh Inter state Metropolitan Regional Plan 2021 was prepared by Prof. E.F.N. Riberio. The total area covered by CISMeR was 5702 sq.km. and it divided the entire region in six layers. Layer 1 consisted of sectors 1 to 30 of Union Territory (UT) with an area of with an area of 43 sq. km. and a designated population of 3 lacs by 2021. Layer 2 consisted of sectors 31 to 47 covering an area of 5 lacs. Layer 3 consisted of sectors 48 to 56 covering an area of 44 sq. km. with a designated population of 13 lacs. Similarly, next three layers covered 435, 613 and 4158 sq. km.

CISMeR envisaged Chandigarh to emerge as a major metropolitan magnet with national and international linkages. In the long run, it was essential that planned development of the periphery and areas beyond would be undertaken and the entire Chandigarh Inter state Metropolitan Region would emerge as a region which not only ensured generating economic momentum but redistribution of population, employment and development of villages and small and medium towns. A presentation of his study was made to the Government in its 14 th Coordination meeting however there was no follow up of the same.

2.1.3. Report on Formulating a Master Plan for Chandigarh

This report was also prepared by TCPO, Government of India, Ministry of Urban Development and was published in July, 2009. The report discusses salient features of the Le Corbusier Plan and then reviews the same, discusses City Development Plan prepared for JNNURM, Punjab New Capital (Periphery) Control Act, 1952 along with developments in the periphery and carries out a visual analysis of the existing development in and around the Periphery. Bye laws are reviewed and need for master plan discussed. The need for Master Plan for Chandigarh and CISR Plan discussed.

2.1.4. Regional Plan 2021 For National Capital Region (NCR)

The National Capital Region (NCR) Planning Board under Section 10 of the NCR Planning Board Act, 1985 prepared draft Regional Plan 2021 for NCR. After inviting objections/suggestions from public under Section 12 of the NCR Planning Board Act, 1985 on draft Regional Plan-2021, final Plan was approved in 28th meeting of the Board held on 9th July 2005 and was notified on 17th September 2005. The Plan aims to promote growth and balanced development of the whole region through providing economic base in the identified major settlements (Metro Centres/Regional Centres) for absorbing economic development impulse of Delhi, efficient transport network, development of physical infrastructure, rational land use pattern, improved environment and quality of life. The total area of NCR is 33,578 sq. km. The National Capital Region area comprises:

a) National Capital Territory of Delhi.

b) Haryana Sub-region comprising of eight districts namely, Faridabad, Gurgaon, Rohtak, Sonepat, Rewari, Jhajjar, Mewat and Panipat.

c) Rajasthan Sub-region comprises of Alwar district.

d) Uttar Pradesh Sub-region comprising of five districts namely, Meerut, Ghaziabad, Gautam Buddha Nagar, Bulandshahr and Baghpat.

The plan discusses policy zones, demographic profile and settlement pattern, economic activity and fiscal policy, sewerage, solid waste management, drainage and irrigation. Besides, social infrastructure tourism and heritage, environment and disaster management are also incorporated in the plan.

2.1.5. Greater Mohali Region (GMR) - Regional Plan 2008-2058

This report is a part of the consultancy work entitled “Integrated Masterplanning for Greater Mohali Region”. The report documents the Regional plan proposals and strategies for the Greater Mohali Region (GMR). Greater Mohali Region (GMR) covers a geographical expanse of about 1190 sq. km. and is located towards the western part of Chandigarh in the state of Punjab. The entire region is divided into six local planning areas, namely, SAS Nagar, Zirakpur, Kharar, Mullanpur, Banur and Derabassi. The region holds a current population of about 0.7 million, about 60% of which is rural. A large proportion of the 40% urban population is concentrated in SAS Nagar and Zirakpur which have grown along the periphery of Chandigarh owing to development pressures from the capital city. The Regional Plan report is broadly classified into four sections. Section I is an introduction to the overall region and the Chandigarh Periphery Act which governs the entire peripheral area of the city. Section II highlights the broad population and economic projections for the area and hence the overall development strategies which shall guide the detailed Regional Plan. Section III dwells upon the specific sectors like industries, housing, environment, transportation & infrastructure and the strategies for each of such development sector. Finally, Section IV of the report elaborates the proposed land use plan, the zoning regulations and the development controls.

2.1.6. Comprehensive Mobility Plan For Chandigarh Urban Complex

This report was prepared by a consultancy firm RITES Ltd in July 2009. The population of Chandigarh Urban Complex (CUC) comprising Chandigarh, Mohali and Panchkula has been growing fast at a rate of over 5% per year in the last decade. There has been a phenomenal growth in the population of vehicles as well especially the two and four wheelers in this period and their rising use due to rising household incomes. Chandigarh has the highest per capita income in the country. Besides nearby towns such as Zirakpur, Kharar and Dera Bassi in Punjab, Pinjore - Kalka and Alipur Kot Behla in Haryana and Baddi - Nalagarh and Parwanu in Himachal Pradesh are also growing fast and have large traffic interaction with the CUC. In the absence of adequate and quality mass transport system, people are using the personalized modes which is not only leading to congestion on road network but also increasing environmental pollution. Such growing congestion is resulting in loss of productivity, reduced air quality, reduced quality of life, and increased costs for services and goods. The analysis of collected data from primary and secondary sources has brought certain issues regarding the transport system of CUC. These include road network capacity, travel speeds and the is need to optimise the available capacity by adopting transport system management measures. There is also a need to plan high capacity mass transport systems on many corridors.

Outer cordon surveys indicate the need of freight terminals at the periphery of the CUC to cater for high goods traffic. Considering the large employment centres being planned in the CUC and nearby towns, the mass transport system needs to be upgraded/extended substantially. At present, modal split in favour of public transport is only 16% of total motorised person trips. This modal share is very low. Adequate and quality public transport system needs to be provided to the people in order to increase the share of mass transport trips. Share of two wheelers and cars in travel (73% of total motorised person trips) is disturbingly very high. This trend needs to be arrested. Parking is assuming critical dimensions in Chandigarh particularly in Sector 17. Parking facilities need to be augmented substantially. In the long run, city-wide mass transport system needs to provide not only to reduce congestion on roads but also to reduce parking demand. Major developments have been proposed in the suburban towns of CUC. This is likely to further increase interaction between CUC and these suburban towns. There will be need to provide adequate and quality commuter services to these towns from CUC.

2.1.7. National Urban Information System (NUIS) Manual For Thematic Mapping

This manual was published by National Remote Sensing Agency (NRSA), Urban Studies and Geoinformatics Group (RS and GIS Applications Area), Department of Space, Government of India, in Jan 2008. This manual uses data on 1:10,000 scale derived from remote sensing satellite data and GIS techniques to monitor and manage the growth and development of urban landscape by the urban planners and civic authorities under NUIS scheme. This decisive task was achieved using the high resolution satellite data of Cartosat-1 and Resourcesat-1(LISS-IV) coupled with ground and collateral data congregated by

NRSA and ISRO with the active participation of partner institutions in the country. The data adheres to the NUIS Design and Standard elements to bring in uniformity during the generation of database. The non-spatial and attribute data collected by the State Nodal Agencies (SNA) as part of NUDBI require to be integrated in GIS for carrying further analysis to assist in various urban applications and to develop and customize Urban Information System (UIS) in a stand alone or as web based operational system for urban planners and administrators.

2.2. Research Articles

2.2.1. Multi-resolution, Object-Oriented analysis of Remote Sensing data

Two studies are quoted here. Remote sensing imagery needs to be converted into tangible information which can be utilised in conjunction with other data sets, often within Geographic Information Systems (GIS). As long as pixel sizes remained typically coarser than, or at the best, similar in size to the objects of interest, emphasis was placed on per-pixel analysis, or even sub-pixel analysis for this conversion, but with increasing spatial resolutions alternative paths have been followed, aimed at deriving objects that are made up of several pixels.(Blaschke, 2010) Remote sensing from airborne and space borne platforms provides valuable data for mapping, environmental monitoring, disaster management and civil and military intelligence. The object-oriented approach can contribute to powerful automatic and semiautomatic analysis for most remote sensing applications. Synergetic use to pixel-based or statistical signal processing methods explores the rich information contents. Here, principal strategies of object-oriented analysis are explained, discussing how the combination with fuzzy methods allow implementing expert knowledge and describe a representative example for the proposed workflow from remote sensing imagery to GIS. The strategies are demonstrated using the first object oriented image analysis software on the market, eCognition, which provides an appropriate link between remote sensing imagery and (Benz, n.d.) GIS.

2.2.2. Urban Sprawl and Urban Change Analysis using Remote Sensing and GIS techniques

Two separate studies, one in India (Ajmer) and another in China are quoted here. The concentration of people in densely populated urban areas, especially in developing countries, calls for the use of monitoring systems like remote sensing. Such systems along with spatial analysis techniques like digital image processing and GIS can be used for the monitoring and planning purposes as these enable the reporting of overall sprawl at a detailed level. Urban sprawl of the Ajmer city has been studied at a mid scale level, over a period of 25 years (1977–2002), to extract the information related to sprawl, classification of the remotely sensed images obtained from various sensors viz. Landsat MSS, TM, ETM+ and IRS LISS-III was done. Urban sprawl and its spatial and temporal characteristics have been derived,e Shannon's entropy and landscape metrics (patchiness and map density) have been computed in terms of spatial phenomenon, in order to quantify the urban form (impervious area). Further, multivariate statistical techniques have been used to establish the relationship between the urban sprawl and its causative factors. Results reveal that land development in Ajmer is more than three times the population growth(Jat et al., 2008). In China, rapid land use change has taken place in many coastal regions of such as the Zhujiang Delta over the past two decades due to accelerated industrialization and urbanization. In this paper, land use change dynamics were investigated by the combined use of satellite remote sensing, GIS, and stochastic modelling technologies. The results indicated that there has been a notable and uneven urban growth and a tremendous loss in cropland between 1989 and 1997. The land use change process has shown no sign of becoming stable. The study demonstrates that the integration of satellite remote sensing and GIS was an effective approach for analyzing the direction, rate, and spatial pattern of land use change. The further integration of these two technologies with Markov modelling was found to be beneficial in describing and analyzing land use change process (Weng, 2002).

2.2.3. Land Use and Land Cover Modelling Techniques.

Land-Use & Cover Change (LUCC) modeling is a rapidly growing scientific field because land-use change is one of the most important ways that humans influence the environment. The issue is so important that scientists have formed an international organization, called "LUCC," which is connected with the International Human Dimensions of Global Change Program and the International Geosphere Biosphere Program. The LUCC organization holds regular meetings and provides a communication infrastructure for professional scientists interested in land transformation (LUCC 2002). Their publications articulate priorities for land-use change research, which include modeling as particularly important (Turner II et al. 1995; Lambin et al. 1999). The last year of the formal LUCC program is 2005; it is likely that a Global Land Program will pick up where LUCC leaves off. It is difficult to compare the performance of the numerous models because LUCC models can be fundamentally different in a variety of ways. For example, some models, such as IDRISI's GEOMOD, simulate change between two land categories (Silva and Clarke 2002; Pontius et al. 2001) while others, such as IDRISI's CA_MARKOV, can simulate change among several categories (Li and Reynolds 1997; Wagner 1997; Wu and Webster 1998; Pontius and Malanson 2005). Still others simulate change in real variables as opposed to categorical variables (Veldkamp and Fresco 1996). Most models are for raster data, while some are for vector data. Even if all researchers were to use the same model, comparison among model performance would still be difficult because researchers usually focus on one specific study region. Therefore, it is difficult to separate the quality of the model from the complexity of the landscape and of the data. For example, if a model performs poorly, it is difficult to know whether the conceptual foundation of the model is weak, or the phenomenon of land change at the study site is particularly complex, or the data is particularly detailed. Alternatively, if a model performs well, it is difficult to know whether the conceptual foundation of the model is strong, or the phenomenon of land change at the study site is particularly simple, or the data is very simplified. Perhaps most importantly, there is not yet an agreed upon method to measure the performance of LUCC models, so two modelers who use the same model on the same landscape with the same data might evaluate one simulation run differently depending on the criteria used for evaluation. Land-use change modelers seem to agree that the intellectual foundation of validation for land use change models is insufficient. The literature on rigorous validation of LUCC models is scant (Kok et al. 2001; Pontius 2002; Pontius and Schneider 2001; Pontius et al. 2004a). This paper attempts to address these issues. It presents a land-use change model called GEOMOD. In addition, it presents an intellectual foundation and statistical methods to validate land-use change models from the GEOMOD approach. All the concepts are illustrated with an application to simulate the land-use change in Central Massachusetts, USA. One advantage of using IDRISI for land-use change modeling is that in one software package you have:

1) The data,
2) The simulation model, and
3) The statistical techniques of goodness-of-fit. (Pontius Jr and Chen, 2006)

2.2.4. Modelling Techniques in Urban and Regional Studies

Bayes Ahmed and Raquib Ahmed (2012) conducted a study of urban growth in Dhaka to predict and analyze the future urban growth using the Landsat satellite images of 1989, 1999 and 2009. Dhaka City Corporation (DCC) and its surrounding impact areas. At the beginning, a fisher supervised classification method was applied to prepare the base maps with five land cover classes. In the next stage, three different models were implemented to simulate the land cover map of Dhaka city of 2009. These were named as “Stochastic Markov (St_Markov)” Model, “Cellular Automata Markov(CA_Markov)” Model and “Multi Layer Perceptron Markov (MLP_Markov)” Model. Then the best-fitted model was selected by implementing a method to compare land cover categories in three maps: a reference map of time 1, a reference map of time 2 and a simulation map of time 2. The “Multi Layer Perceptron Markov (MLP_Markov)” Model qualified as the most appropriate model in this research. Later, using the MLP_Markov model, the land cover map of 2019 has been predicted.(Ahmed and Ahmed, 2012). General and mathematically transparent models of urban growth suffer from a lack in microscopic realism. Physical models that have been used for this purpose, i.e. Diffusion-limited Aggregation (DLA), Dielectric Breakdown Models (DBM) and Correlated Percolation all have microscopic dynamics for which analogies with urban growth appear stretched. Based on a Markov Random Field (MRF) formulation Andersson et al (2002) developed a model that is capable of reproducing a variety of important characteristic urban morphologies and that has realistic microscopic dynamics. The micro dynamics of thier model, or its "first principles", can be mapped to human decisions and motivations and thus potentially also to policies and regulations. They measured statistical properties of macro states generated by the urban growth mechanism, and compared these to empirical measurements as well as to results from other models. To showcase the open-ended-ness of the model and to thereby relate this work to applied urban planning they also included a simulated city consisting of a large number of land use classes in which also topographical data have been used.(Andersson et al., 2002)

3. STUDY AREA AND MATERIALS USED

3.1. General Description of Chandigarh

After the Partition of India in 1947, the former British province of Punjab was also split between east Punjab in India and west Punjab in Pakistan. The Indian Punjab therefore required a new capital city. After several plans to make additions to existing cities were found to be unfeasible for various reasons, the decision to construct a new and planned city was undertaken. Of all the new town schemes in independent India, the Chandigarh project quickly assumed prime significance, because of the city's strategic location as well as the personal interest of Jawaharlal Nehru, the first Prime Minister of independent India. Commissioned by Nehru to reflect the new nation's modern, progressive outlook, Chandigarh was designed by the French architect and urban planner, Le Corbusier, in the 1950s. The location of the city site was a part of erstwhile Ambala district as per the 1892-93 gazetteer of district Ambala. The site was selected by Dr. M.S. Randhawa, then Deputy Commissioner of Ambala. The foundation stone of the city was laid down in 1952. Subsequently, at the time of reorganization of the state on 1st November, 1967, into Punjab, Haryana, and Himachal Pradesh, the city assumed the unique status of being the capital of two states, Punjab and Haryana, while it itself became a Union Territory under the central Government.

3.2. Topographical Features

The region around Chandigarh has Shivalik hill ranges in the north, which form a fragile Himalayan ecosystem. It is occupied by Kandi (Bhabar) in the north east and Sirowal (Tarai) and alluvial plains in the remaining part. The area is drained by two seasonal rivulets, viz, Sukhna Choe in the east and Patiala ki Rao in the west. The central part forms a surface water divide and has two minor streams. Located at the foothills of the Shivalik range, a large part of the area is designated as an environmentally sensitive zone. The region has a relatively flat topography, with moderately gentle slopes towards south western part of the area, where all the rivers and streams drain through the GCR.The elevation ranges from about 400m above msl in the foot hills to about 200m msl in the plains. Ghaggar River with its tributaries forms the main surface hydrological feature in the area. Due to the flat topography around Chandigarh and southwards, at many places the water channels (locally known as choes) are dry during the inter-monsoon period but swell during the monsoons. The protection of these floodable zones is of paramount importance for ground water aquifers. The soils in the area are very fertile with annual deposition of river silt and as such very productive for raising multiple crops in the year. The area includes a large number of protected and reserved forests and areas north-west of the Chandigarh locked under the Punjab Land Preservation Act (PLPA). The soils in the area are very fertile with annual deposition of river silt and as such, are very productive for raising multiple crops in the year

3.3. Climate

Chandigarh has a humid subtropical climate characterised by a seasonal rhythm: very hot summers, mild winters, unreliable rainfall and great variation in temperature. The average annual rainfall is 111.4 cm. The city also receives occasional winter rains from the Western Disturbance originating over the Mediterranean

Sea. Cold winds usually tend to come from the north near Shimla, capital of Himachal Pradesh and from the state of Jammu and Kashmir, both of which receive their share of snowfall during wintertime.

3.4. Geography

Chandigarh is located near the foothills of the Shivalik range of the Himalayas in northwest India. It covers an area of approximately 114 km². and shares its borders with the states of Haryana and Punjab. The exact cartographic extent Chandigarh is from 30°40'N to 30°47'30"N and from 76°42'15"E to 76°51'E . It has an average elevation of 320 metres.

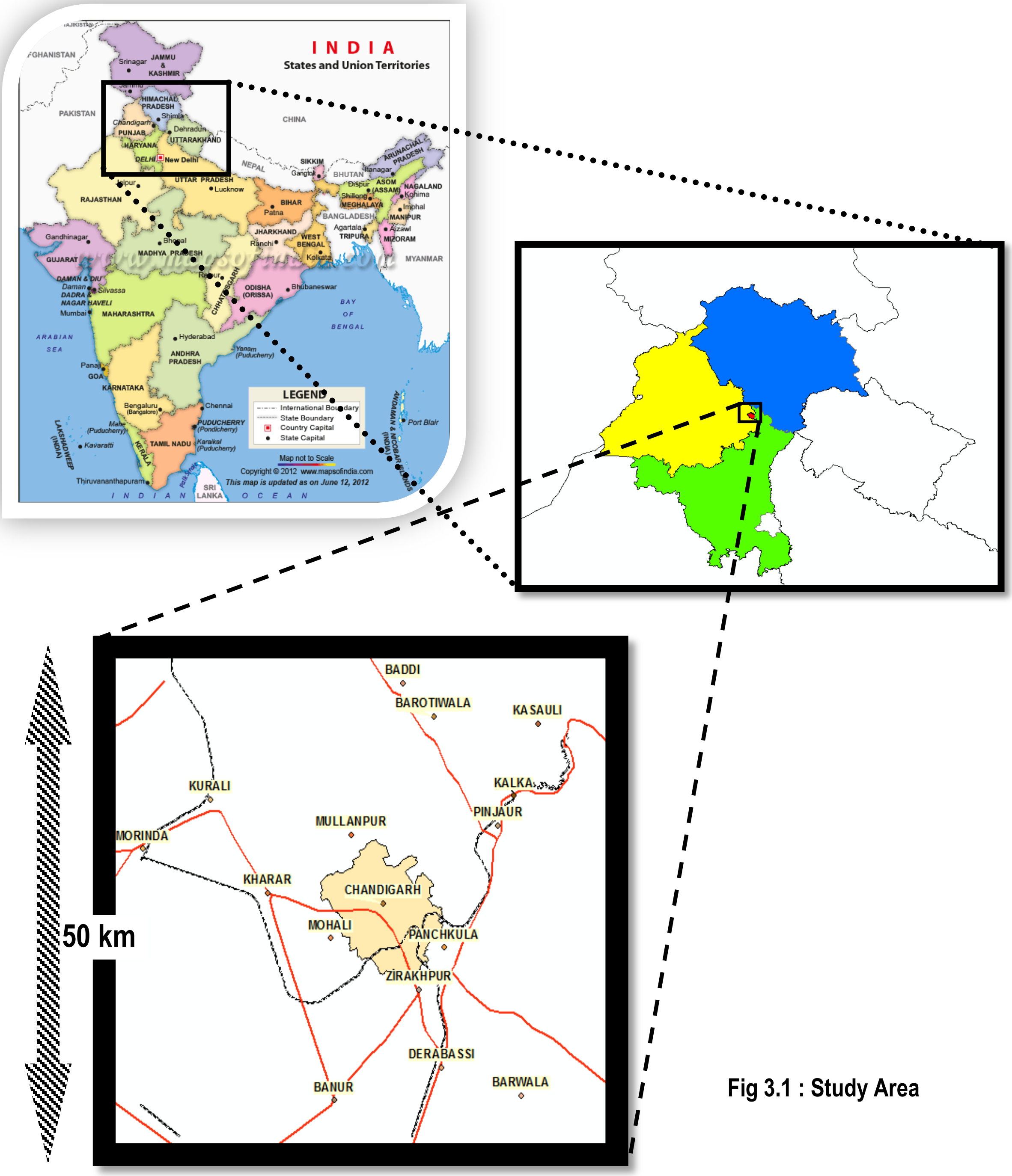


Fig 3.1 : Study Area

3.5. Road, Rail and Air Infrastructure

The Greater Chandigarh Region is strategically located within the northern part of the country. Four national highways intercept the region, namely, NH 21 to Ropar, NH 95 to Ludhiana, NH 22 to Shimla and NH 1 to Ambala and further to New Delhi. Thus, the entire area has a very well developed road network. The railways provide a means of inter-city transport to the masses. Outside the GCR, twin track railway lines run from the east viz from Delhi and Mumbai and meet at Ambala. From there, the railway line runs as a single track in the north-south direction from Ambala to Chandigarh. From Chandigarh the single track line further links to Kalka. From Kalka to Shimla the line is a narrow gauge single track. The single track of Chandigarh to Morinda line is newly built and serves the Greater Mohali part of the region. The air transport, however, is currently under developed owing to the absence of an international airport in the region. The domestic airport at Chandigarh currently hosts flights to major parts of the country including Delhi and Mumbai and is being expanded to cater to international flights.

3.6. Socio-economy

Traditionally, agriculture has been the prime economic activity in the region. However, industrial and services sector has been gaining importance in the past few years. The industrial sector primarily constitutes chemical and pharmaceutical manufacturing units, mainly in Baddi-Barotiwala belt and Parwanu whereas the service sector comprises largely of the fast growing IT and tourism industries. The potential of the tourism industry owes to its rich resource base including religious buildings, historical monuments, Chandigarh and Mohali cricket Stadium and Pinjore gardens, and other key attractions of Chandigarh City. State and Central (UT) Governments themselves are major employers as offices of Punjab, Haryana and UT are concentrated in the region. The presence of Punjab and Haryana High Courts attract significant judicial activity. Real estate, biotech and agro processing have been identified as the key growth areas of future. A number of specialised hospitals have also established base in the region attracting people from far and wide to avail of premium health services.

3.7. Architecture and Urban Planning of Chandigarh

Le Corbusier planned the Capitol Complex at the top of Chandigarh city resembling the head; the intellectual base, reflecting his conviction that governance should begin here as the head rules the body The Capitol complex comprises three architectural masterpieces: the *Secretariat***,** the *High Court* and the *Legislative Assembly***,** separated by mammoth plaza. In the heart of the Capitol Complex stands the giant metallic sculpture of *'The Open Hand'*, the official emblem of Chandigarh, signifying the city's credo of *"open to give, open to receive"***.** One unique feature in the layout of Chandigarh is its roads, classified in accordance to their functions. An integrated system of seven road types (7Vs) was designed to ensure efficient traffic circulation. Later on pathways for cyclists called V8 were added to this circulation system. The city's vertical roads run northeast/southwest (the 'Paths'). The horizontal roads run northwest/southeast (the 'Margs'). They intersect at right angles forming a grid pattern.This arrangement of roads leads to a remarkable hierarchy of movement, which also ensures that the residential areas are segregated from the noise and pollution of traffic. Fig 3.2 shows some of the architechtural and scenic landmarks of Chandigarh along with its architect.

(a)

(b)

(d)

(c)

(e)

(f)

(g)

Fig 3.2 : Architectural Landmarks of Chandigarh

(a) Le Corbusier, the French architect who planned the city map (b) Punjab and Haryana High Court by Le Corbusier (c) Gandhi Bhawan built by Pierre Jeanneret for Punjab University (d) Legislative assembly by Le Corbusier (e) Secretariat Building (f) Rock Garden by Nek Chand (g) Sukhna Lake

(source: http://img.readtiger.com/wkp/en)

3.8. Scope and Restrictions

One of the objectives of this study is to delineate the region which is being referred to as 'GCR'. Therefore, a crisp boundary does not exist *ab initio* to demarcate as a study region. Based on certain parameters which shall be made explicit later, the scope of the study has been restricted to an area of about 50x50 kms encompassing Union territory (UT) of Chandigarh as represented in Fig 3.1, subject to the condition that periphery control belt of 16 kms around UT will be always included in this area.

3.9. Materials Used

3.9.1. Satellite Data

(a) Landsat Enhanced Thematic mapper (ETM+) images (147/39) of 2000, 2006 and 2012 were used. Out of 8 bands, three visible bands, two NIR and one MIR band, all of 30m spatial resolution, along with PAN band, of spatial resolution of 15 metres were used.

(b) IRS 1D image (095/049) of Mar 2000, two IRS 1C images of Mar 2006 and Apr 2006 and one Resourcesat 2 image of Mar 2012 were used.

3.9.2. Topographical Map Sheets

(a) Digital data of OSM series map sheets of Survey of India was used. All layers of eight map sheets pertaining to Chandigarh and surrounding areas were received and relevant layers were used.

(b) Hard copies of the OSM series topographic map sheets were also obtained for planning and cross checking of errors, if any.

3.9.3. Census Data

Census data pertaining to Chandigarh, Punjab and Haryana was obtained. However this data was of limited usage as the urban limits of towns within districts as shown in SoI map sheets were not available. Hence relevant district level urban/rural population polygons could not be implemented in GIS, whose attribute values this census data represented.

3.9.4. Regional Plans and Master Plans

(a) Regional plans of Greater Mohali Region (GMR) were downloaded from internet .

(b) Master plans of SAS Nagar, Panchkula, Pinjore, Kalka, Mullanpur, Banur, Zirakhpur and Kharar were obtained.

4. METHODOLOGY AND PREPARATORY STUDIES

4.1. Preparatory Processing and Analysis

4.1.1. Classification Scheme

A number of classification schemes were considered which would serve the purpose of the current research work. Urban Development Plans Formulation and Implementation (UDPFI) guidelines were also considered. National Urban Information System (NUIS) manual on thematic mapping by Urban Studies and Geo informatics Group of National Remote Sensing Agency (NRSA) , Department of Space (DOS), Govt of India (GoI) was studied wherein four levels of classification have been envisaged. Besides, United States geological survey (USGS) Land use/ land cover (LULC) classification system for use with remotely sensed data was also analysed. However, keeping in view specific needs of the current study at a regional level, wherein one of the tasks was to understand the cycle of transition of land-use towards urbanisation, and also the necessity to avoid higher resolutions required for town level and micro level urban planning, a unique classification scheme was devised. This would have a single level of classification with ten classes. Out of these ten, three major classes relate to urban forms that are most relevant to regional studies and are also discernible on satellite imagery of 5/6 metres resolution. These are : *Built-up urban, Built-up rural* and *Built-up mixed*. Besides two other classes associated with changing urban forms (and discernible in visual analysis) have also been added, which are : *Land under plotting* and *Urban greens or recreational land*. Together these five classes would be manipulated later on for detailed urban analysis whereas balance five classes would form the backdrop against which the purported variations in urban forms would be studied. These are : *Agricultural land, Forest land, Water bodies* (including dry river beds), *Open or barren land*, and lastly, *Restricted areas*. Thus, the set of just ten classes uniquely define the urban eco system required to be studied at regional level. In summation, a new system of classification has been created keeping in view aspects of relevance, compatibility of resolution, ease of interpretation, simplicity and retention of analytical rigour.

4.1.2. Automated Classification Versus Visual Interpretation

Two aspects were considered in deciding on the method of classification. Accuracy required (given the heterogeneity and vastness of the region) and the speed. As an experiment, both supervised and unsupervised classification methods were attempted. Both produced grossly unsatisfactory results, although speed was achieved. How would one distinguish between urban greens and agriculture, river beds (which were mostly infested with weed and grass that resembled scrub) from agriculture spectrally, and sometimes dry river beds that mimicked urban settlements. Again the category *Land under plotting* mimicked vacant or open patches of land thereby giving unsatisfactory results. So the next best solution was to try an automated process which could undertake 'Object based Classification' (instead of pixel based). However, after surveying currently available softwares that would support such an objective, it was averred that the research in this field is still in nascent stage to accomplish the complexities of current study. The above analysis led to the inevitable conclusion that visual interpretation is the only viable method if the desired accuracy of above 85 percent is to be accomplished. This would mean a humongous effort on heads up digitisation, covering the study area of over 2000 square kms, at an expected resolution of 5 to 6 metres, and repeating the effort three times over to obtain temporal changes between years 2000, 2006 and 2012.

4.1.3. Multi Sensor Data Fusion

Having decided to visually interpret the images and digitise the interpreted information, the next question arises as to how to enhance the quality of image so as to make it more pliable for interpretation. *Sometimes the only way to extract urban information required is to utilize multiple type of remote sensor data in the investigation referred to as multi-sensor data fusion* (John R Jenson,2009 and Gamba et al., 2003). Accordingly, ETM/ MSS images from Landsat, LISS IV images from IRS P6 (Resourcesat), PAN images from IRS 1C were fused together using various techniques. A *unique innovation of multiple fusion* was also executed which was found very useful in image interpretation. A Landsat image was first enhanced using *Tasslecap* transformation and then further sharpened spatially by fusing with IRS PAN image using PCA technique. **Table 4.1** shows the numerous fusion products produced with details of radiometric, spatial and spectral enhancement achieved. Three types of transformations for preparation of fusion images, particularly found useful in urban visual interpretation were Brovey, PCA and Tasselcap.

4.1.4. Resolution and Scale for Scanning and Digitisation

While preparing fused products, desired spatial resolution of end product has been kept in mind. For example, a sensor resolution of 15 metres was considered inadequate because digitisation of a polygon would correspond to a minimum width of 3 pixels x 3 pixels which would translate to 45m x 45m on ground. In this case a minimum measurable unit (MMU) of 2025 sq. m. would be achieved and crucial details may at times be lost. Keeping the above in mind a spatial resolution of 5 to 6 m with an MMU of less than 350 sq. m. was considered adequate. Thus, using digital image processing techniques, satellite images have been processed into fused products of 6m resolution which are ready to be ingested in a GIS system. This leads to the next theoretical challenge : What should be the minimum acceptable DPI of a scanned paper map received from Survey of India so as to be compatible with satellite imagery. Survey of India topographical maps have a scale of 1: 50,000. With each line width on paper representing about 0.3 mm, it is desirable that this line be represented by minimum 3 pixels (pxls). This translates to 10 pxls per mm, or, 254 dots per inch (DPI). Therefore, minimum desired DPI is 250. Again, this 0.3 mm of line width on paper map represents 15 m (0.3 x 50,000) on ground, and it has been agreed to break this line width into 3 pxls, therefore each pxl would represent 5m on ground. Keeping these theoretical calculations in mind, scanned map sheets of 300 DPI were received from Survey of India and the cell (pxl) size was measured in Arc GIS software, and it turned out to be 5.16m.

The above discussion brings out the fact that all data ingested is now compatible, with map resolution and satellite data resolution of 5 to 6m. This leads to the next challenge : At what scale should the digitisation be done. At 1:50,000 scale, one hectare (100m x 100m) of ground would be represented by 2mm x 2mm on screen and hence crucial details may be lost. The same area of one hectare would, however, be represented by 1cm x 1cm on screen at 1:10,000 scale, which is considered adequate. Therefore digitisation would be done at a fixed scale of 1:10,000 and, for digitisation of curvilinear features like river bends, even a larger scale of 1:5000 would be preferable.

4.1.5. Preparation of LULC for 2000, 2006 and 2012

Total area under the union territory (UT) of Chandigarh was found to be 114.9 sq. km. using WGS 84 as datum (geoid), UTM as the projection and map boundaries as defined on Survey of India maps. For this purpose four topographic map sheets of 1:50,000 scale were mosaicked together in *Erdas Imagine 9.2* software and complete boundary of Chandigarh running through these sheets was digitised as a polygon. For the purpose of digitising a region around it, a rough yardstick of 20 times this core area (UT) was used which works out to be approximately 2300 sq.km. This yardstick was deduced taking the analogy of National Capital Region (NCR), where total area of the region (33578 sq.km.) was found to be 22.6 times the core area (1483 sq.km.) of National Capital Territory (NCT). Logically the influence of Chandigarh on its neighbourhood would be lesser in comparison to that of the national capital on its neighbourhood. This would later be used for comparison as one of the factors to be kept in mind while delineating a region of influence around UT. It can be safely expected that the 1:20 ratio may serve as the upper limit and that the delineated GCR boundary will actually cover an area lesser than 2300 sq kms. For LULC 2000, a total of 2643 polygons covering an area of 2167 sq. km. were digitised. For LULC 2006 the number of polygons were 2619 and for LULC 2012 these were 2459 over approximately same area. A grid system was devised to assist digitisation and reduce the margin of error. Fused images of relevant years were used as discussed in 4.1.3. Being a visual interpretation work accuracy of all the LULC products was above 90 percent. **Fig 4.1** shows the three LULCs of 2000, 2006 and 2012. **Fig 4.2** shows samples of nine LULC categories (all except restricted areas category) as discerned from a digital fusion product of 2012.

4.1.6. Integration of town plans

Regional plan for GCR must take into account the existing status of development. This includes integration of existing plans and proposed future development envisaged. These plans are available with respective town planners and the same were obtained for the purpose of integration. While the Punjab Govt has put the same in PDF format on their website *www.gmada.gov.in*, plans for Panchkula, Pinjore-Kalka urban complex, Panchkula extension and Panchkula district were obtained from the office of town planner, Panchkula. After conversion into compatible formats, these plans were geo referenced with topographical maps. Thus the GIS system received its third type of geospatial inputs (after maps and images), i.e., town plans. With this the preparatory work for analysis and achievement of research objectives is nearly complete. Other details including census data will be used as per need basis. **Fig 4.3 and Fig 4.4** show the data for integration.

Table 4.1: Image Fusion Products for years 2006 & 2012

S.NO	YEAR	IMG NAME	SPATIAL RESOLUTION	BANDS	RADIOMETRIC RESOLUTION
1	2012	Stack_mar_12.img	30 m	7	8 bits
2	2012	Chd_jun_12.img	24 m	4	16 bits
3	2012	Chd_mar_12.img	5 m	3	16 bits
4	2012	2012_brovy_lut.img	5 m	3	8 bits
5	2012	2012_pca_lis4mar_tassl	5 m	6	32 bits
6	2006	2006_pan_rect.img	6 m	1	6 bits
7	2006	2006_landsat_chd.img	15 m	7	8 bits
8	2006	2006_pca_tsclp_1.img	6 m	6	32 bits
9	2006	2006_pca_tslcp.img	6 m	6	32 bits
10	2006	2006_pca_tslcp_low3	6 m	6	32 bits

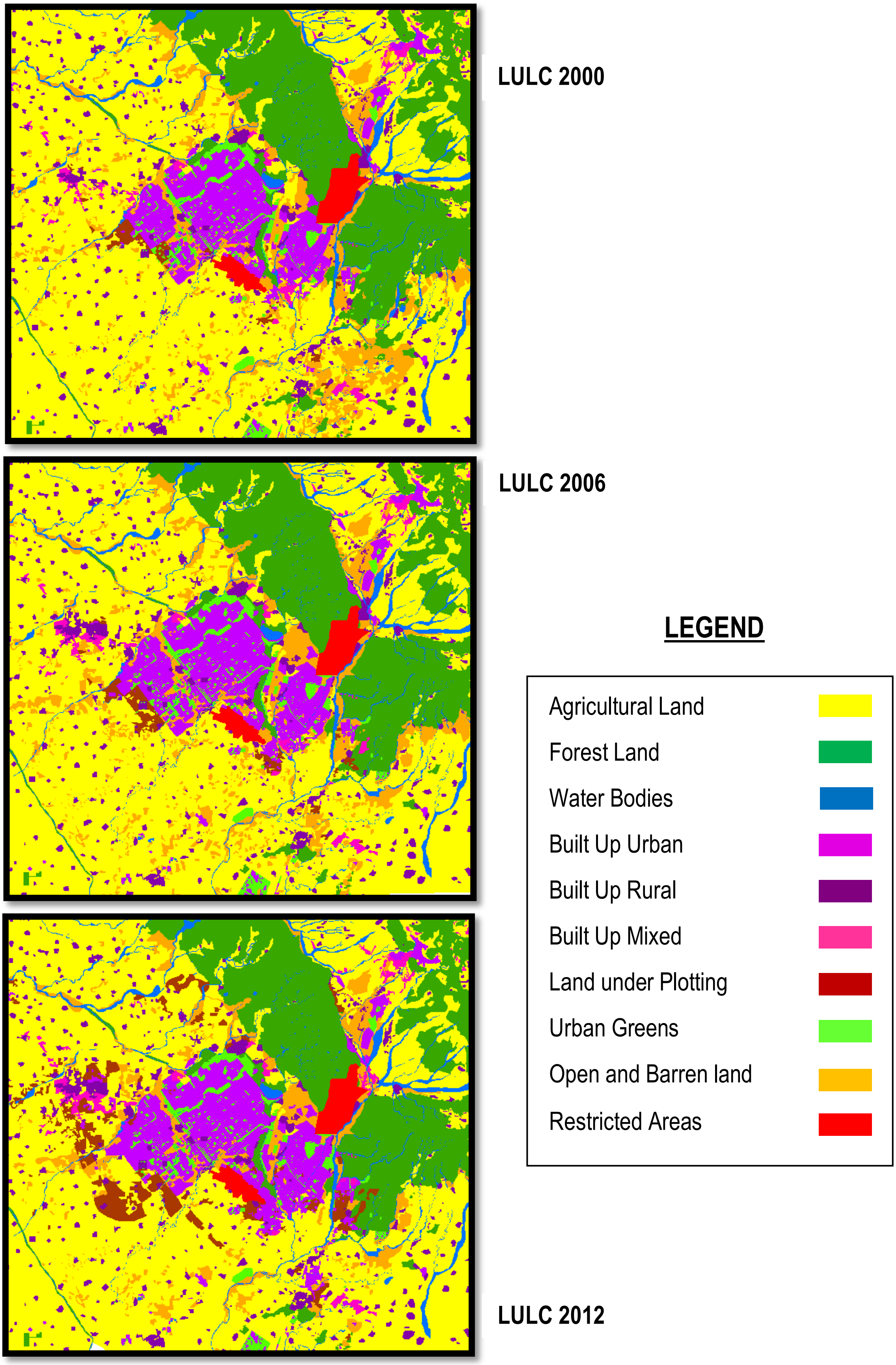
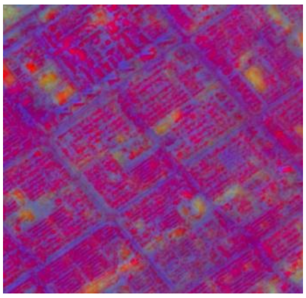
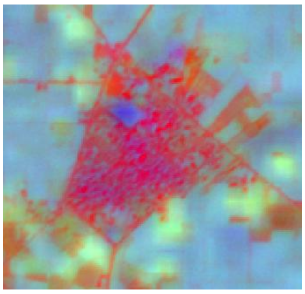


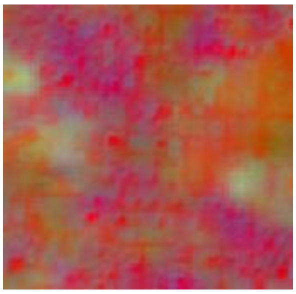
Fig 4.1. Land use / land cover (LULC) maps for the years 2000, 2006 and 2012



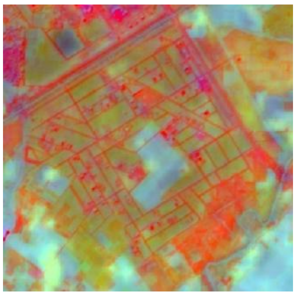
(a) Built up urban
(Sectors of Chandigarh)



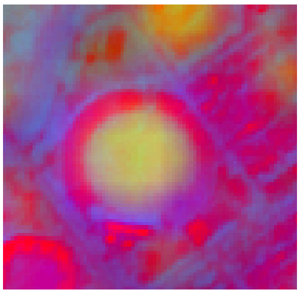
(b) Built up rural
(Village surrounded by agriculture)



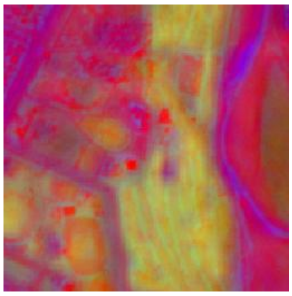
(c) Built up mixed
(Built up with agriculture/barren land)



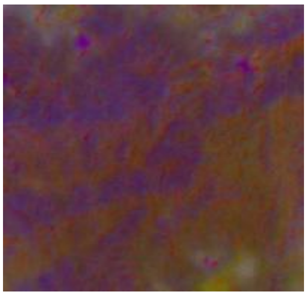
(d) Land under plotting
(Road layout with vacant land)



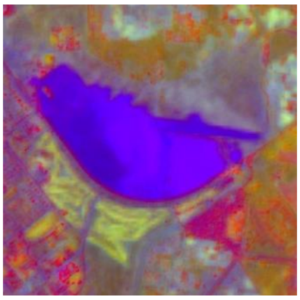
(f) Urban greens or recreational
(Cricket stadium, Mohali)



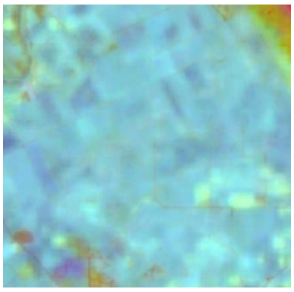
(g) Urban greens or recreational
(Golf Course, Panchkula)



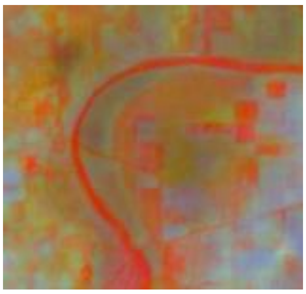
(h) Forest land



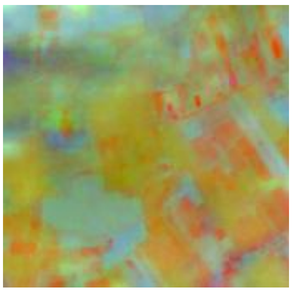
(i) Water body (Lake)



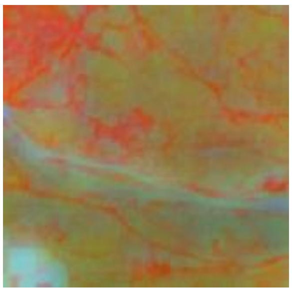
(j) Agricultural land



(k) Dry river bed



(l) Open, barren and wasteland



(m) Barren land and river bed

Fig 4.2 (a) to (m): Samples from an image fusion product showing various LULC categories

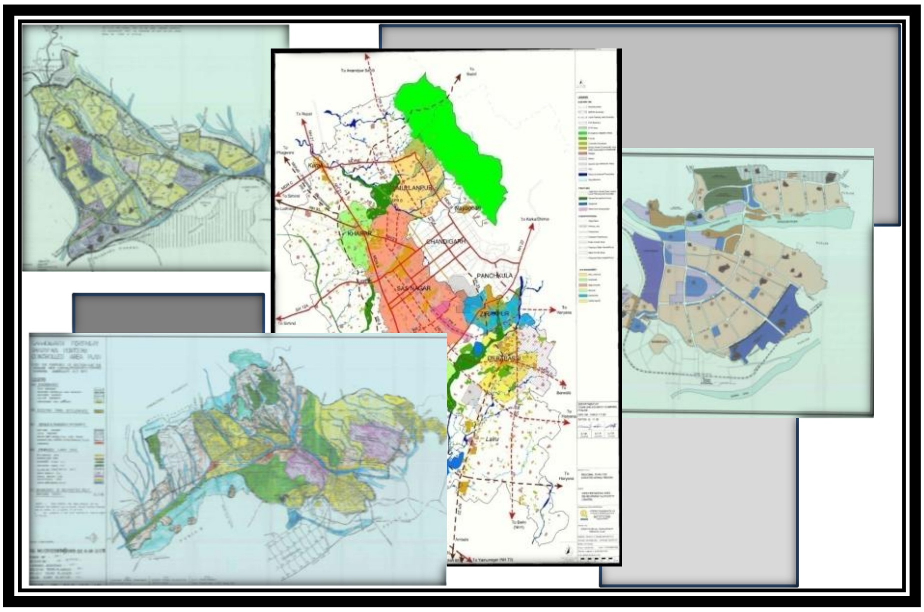


Fig 4.3: Sample scanned maps of Punjab and Haryana sub regions of GCR, which need to be georeferenced and ingested in the GIS system for elaborate geospatial analysis.

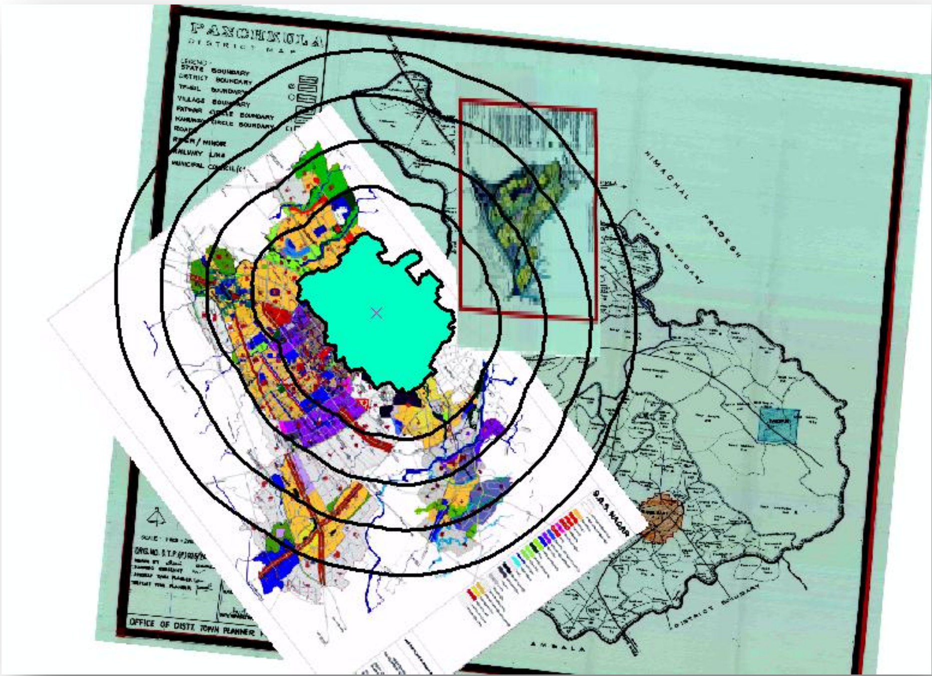


Fig 4.4: Integrated plans of Punjab and Haryana, georeferenced and ingested in GIS

Plans of SAS Nagar, Banur, Dera Bassi, Zirakhpur, Kharar, Mullanpur, of Panchkula district and Pinjore - Kalka have been included. Buffer zones of 4 km each up to 16 km periphery have also been shown. Only one sub regional plan, that of GMR, is ready. However its impact on GCR, with focus on Chandigarh, is yet to be assessed. Consequently, the need for a comprehensive GCR plan is being felt more acutely now .

4.2. GCR : Terrain Imperatives, Functional Aspects and Development Pattern

4.2.1. Chandigarh in Regional Settings.

Chandigarh lies within the surrounding states of Punjab and Haryana. While Punjab lies to its north, west and south, the state of Haryana surrounds its periphery from north-east to east and south east. Further to the north of Punjab and Haryana lies the state of Himachal Pradesh.The districts of SAS Nagar and Panchkula are in its immediate neighbourhood. The district of SAS Nagar came into existence on 14 April 2006 (*Census 2011).*

4.2.2. Terrain Imperatives on Regional Planning

Figures 4.5 and 4.6 show some of the important terrain imperatives and their implication on regional planning. These are as given below :

4.2.2.1 Drainage

Drainage flow is from north-east (NE) to south-west (SW), and is mostly seasonal. This has an implication on layout of roads, storm water drainage and sewage lines. As can be seen from the layout of Chandigarh, major roads run from NE to SW and are criss crossed by perpendicular roads, thus forming a grid iron pattern of roads. Expansion of new roads serving the urban region around Chandigarh could therefore be planned keeping in view this drainage pattern, and its offshoot of grid iron roads, duly modifying the pattern keeping the expected variation in population density in mind among other factors. For gravity collection, sewage disposal sites should be on the SE end of any new proposed settlements. The seasonal rivulets would also dictate ecological preservation programmes and afforestation initiatives in the region. As in the case of Chandigarh city, certain recreational parks, green areas and thematic gardens can be developed along the run.

4.2.2.2 Presence of Shivalik Foothills

Shivalik foothills run north-west (NW) to south-east (SE), aligned almost parellel to Chandigarh city, and lie on its north-east. This has three major implications for the urban planner in the region. First, owing to forests, relative height variation and micro climatic changes NW of foothills, more pleasant micro climate exists in the north and thus attractive tourist destinations can be developed north of Chandigarh. A case in point is the existence of historical Pinjore gardens built by then king Yadvendra Singh of Patiala (and also named after him) and the well known Timber Trail resorts built in recent times by private initiative. Secondly, the necessity of eco conservation of forest area by enforcing a no construction zone, particularly south of Shivaliks, where pressure of urbanisation already exists around Chandigarh. A certain amount of buffer zone (atleast 200 metres) could be earmarked all along the forest and also along the land demarcated under Punjab Land Preservation Act (PLPA), 1900. Thirdly, only low density housing should be permitted immediately south of Shivaliks to prevent unscrupulous builders from bringing high rise multi storied flats, alluring potential residents of 'Shivalic view', and thus disturbing not only the prevailing eco system but bringing about extraneous pressures on existing public utilities, besides adversely impacting the quality of life in Tricity area.

4.2.2.3 Water Bodies

Chandigarh lake is a well known tourist destination. Similarly, some other natural and man made water bodies exist both north and south of Chandigarh. Future urban development in the region should consider exploitation of their recreational potential and enhancement of quality of life. Prominent among them being Siswan lake, about 13 kms NW of Chandigarh and Satluj Yamuna link canal about 17 kms SW of Chandigarh. These locations may be developed as get-away destination from existing settlements rather than population centres themselves.

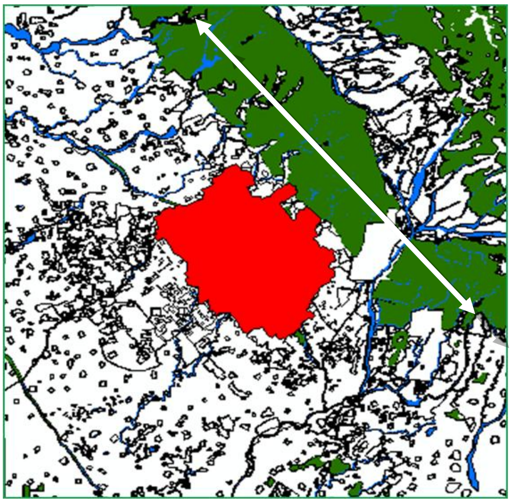


Fig 4.5 Shivalik foothils running NW to SE, NE of UT, influencing microclimatic variations

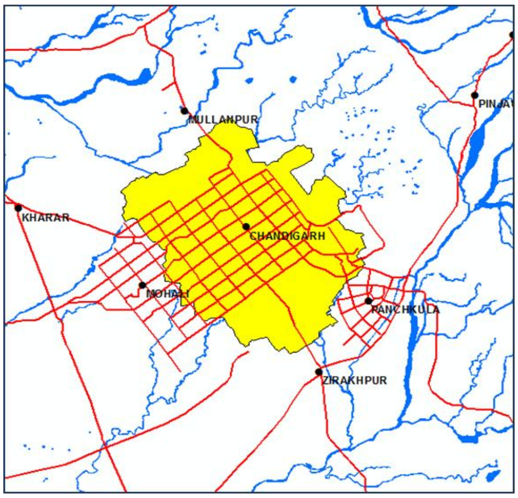


Fig 4.6 Drainage NE to SW and grid iron road pattern following the same alignment

4.2.3. Functional Aspects

In as much as possible, a region must be self sufficient in itself to provide for sources of employment, food, water, housing, transportation, health, education etc, wherein different areas within the region alternately become suppliers and consumers of goods and services. In order to have balanced development in GCR, the urban forms as well as rural areas around Chandigarh must fulfil functions such as these which serve the overall region. In addition, the region must be a net supplier of at least a few well identified economic activities to other regions in order to ensure its growth and prosperity. Moreover, to cater for balanced development, the regional plan for GCR needs to make an assessment of suitable locations for specified gainful activities that make them attractive destination for settling down, investment, production or transient stay. The idea is to make sub regions and smaller entities coexist in participatory mode.

4.2.3.1 Legal Enablement

Towards the fulfilment of above objectives, adequate legislation must exist which would be discussed later in Chapter 6.2. For instance, Section 16 of the National Capital Region (NCR) Planning Board Act, 1985 provides for preparation of `Functional Plan' by the Board with the assistance of the Planning Committee, for the proper guidance of the participating States and the Union Territory after the Regional Plan has come into operation. Also, Section 2(D) of the NCR Planning Board Act, 1985 defines 'Functional Plan' as a plan prepared to elaborate one or more elements of the Regional Plan.

4.2.3.2 Existing Functional Relationships in GCR

For the purpose of the study of GCR, it is important to make a spot assessment of some areas which are traditionally associated with certain predominant functions in the study area. **Figure 4.7** shows functional relationships that already exist in the area. While Chandigarh acts as a magnet in the region and beyond, the neighbourhood has found a niche for itself in specific domains. The key issue, however, remains in asymmetric development and non existence or non implementation of town level plans that would make these deemed locations to emerge as centres of excellence. This brings to fore the need for emergence of a central regional authority with a vision as well as wherewithal of legal status, technical and professional capacity to plan and a robust administration to implement and enforce.

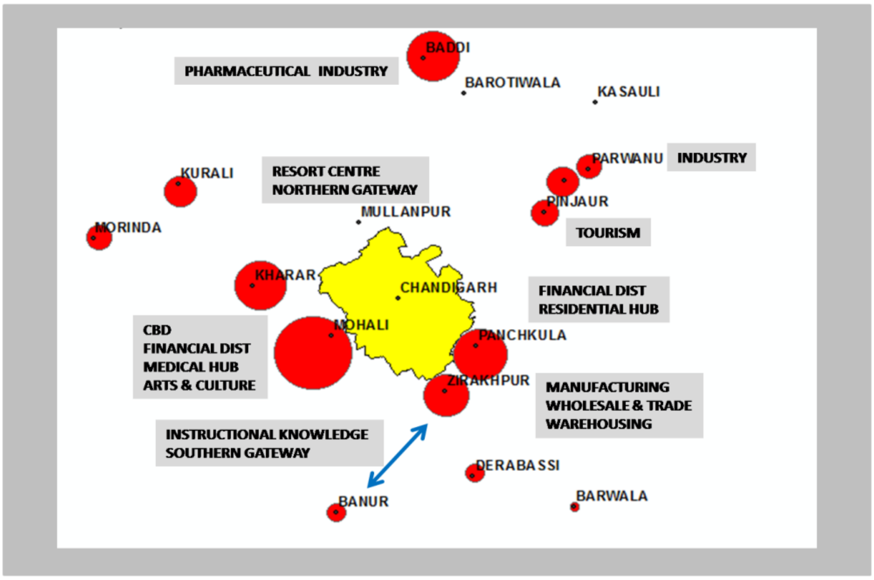


Fig 4.7 Functional Relationships in GCR

With the development of Mohali and Panchkula most of the state Government offices shifted to these cities and some new district level adminstrative setups also came into being. Alongwith anciliary activities of education, health and retailing, these cities fast grew as residential and financial hubs. Mohali with some of its superspeciality hospitals has also developed as a medical hub. A complete sector has been earmarked to come up as Central Business District (CBD) once the population of tricity reaches a critical mass. Zirakhpur has come to be recognised as a manufacturing, wholesale trade and warehousing hub. Pinjore has a major tourist destination and Baddi is recognised as a pharmaceutical manufacturing industrial township. Parwanoo also has a fairly large industry to boast of. Kharar is still largely an agricultural township although there is a fast growth of residential set up owing to its proximity to Chandigarh and Mohali and inclusion in GMADA plan after migrating from Rupnagar district to Mohali in 2006.

4.2.3.3 Importance of Regional Plan to Maintain Functional Relationships

The case of Baddi brings important learning points in regional planning to the fore. Baddi is situated about 20 kms north of Chandigarh along the Baddi-Barotiwala-Nalagarh industrial corridor of Himachal Pradesh and is considered as one of the biggest pharmaceutical hubs of India, thanks to the tax concessions, investment subsidies and attractive schemes by central and state governments. However, lack of matching urban and regional planning has led to a climate of impending doom so to say. Here is what Wikipedia reports on the township :

The Baddi industrial belt is the classic example of a sweet dream gone sour. It was brought into being by a massive tax incentive package in 2003, lately the tax holiday is extended beyond 2010 without bothering to develop the zone. The area has adequate power, a rarity in India, peaceful industrial climate and is close to the rich hinterland of Delhi, Chandigarh and Amritsar. But the most striking aspect, however, is the absence of any reasonably pucca road in the entire belt. And thanks to two decades of inaction - the first units set up shop here in 1991 - the zone, which has become Asia's largest pharmaceutical hub, could wither away as soon as the tax holiday goes. Lack of infrastructure and haphazard industrial development in this town, located in Solan district of Himachal Pradesh, has given nightmares to investors and locals alike. Companies such as Omaxe, Amaravati, Shakun Infrastructure, Suncity projects are striving hard to find buyers for their housing complexes. The lackadaisical approach towards improvement of the inter-state connectivity has been an impediment in trade expansion by the industrial units.Unlike Dubai or Sharjah, this belt has earned the dubious distinction of making industry captains come out on the roads to demand roads, housing for their workers and even hospitals before the employees did so. To prevent further overloading of the ecosystem in Baddi, it is planning to freeze new industrial establishments. And due to ever-expanding migrant labour force in the industrial belt, the area is slowly transforming into an unorganised slum. The number of migrant labourers is on the rise and since there is no provision for accommodation of the workers in majority of the industrial units they live in slums.

4.2.4. Chandigarh Region: A Study of Possible Urban Forms

Ever since its inception, Chandigarh has itself been a growth driver in the region, drawing people from all walks of life and from all corners particularly from neighbouring states towards itself, in search of employment, better housing and enhanced quality of life, thus acting as a magnet. However, due to limited geographical area available, the population density rapidly increased within the Union territory, thus exerting an outward pressure of expansion on its periphery areas. It became obvious to the planners that the ensuing circumstances would have an impact on the development of urban forms in the neighbourhood. Keeping this in view *Professor LR Vagale* of School of Planning and Architecture (SPA), New Delhi, prepared a paper on *A Case Study of Chandigarh and its Environs in the Regional Setting* which was presented in 1966 at a UN sponsored seminar at Nagoya, Japan. It was subsequently published in *UN Economic and Social Paper No E/CN. 11/1 and NR/ PURD/L9.* What follows in this section is a GIS adaptation of the relevant parts of the study.

4.2.4.1 Six Possible Urban Forms : A GIS Adaptation

It was observed that the settlement pattern of Punjab was characterised by large towns situated at the intersections of major highways and the smaller settlements either on the banks of seasonal water courses or along the transportation routes. Each larger area had a tributary area of its own and was surrounded by smaller towns and villages, thus forming a hierarchical system. While discussing the growth patterns, six conceptual urban patterns were considered. These are graphically described in **Figures 4.8 to 4.13.** Indeed the actual expansion has followed a combination of atleast four of these conceptual forms. The six forms being

(a) Expansion of Chandigarh itself,
(b) Building a "linear township" along the highways,
(c) Building a new township around an existing small township,
(d) Building a new town on a virgin site to function as a counter magnet,

(e) Building a series of small satellite towns around Chandigarh and *lastly,*
(f) Planned expansion of Chandigarh in the form of wedges and corridors.

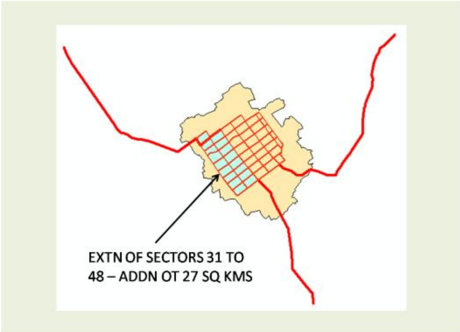


Fig 4.8 Expansion of existing City

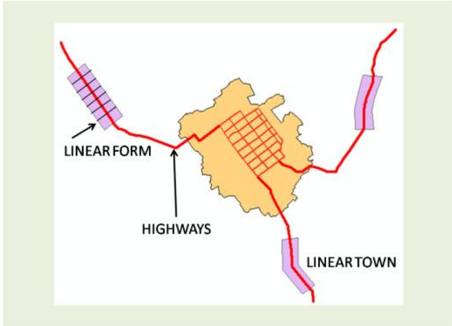


Fig 4.9 Developing linear townships

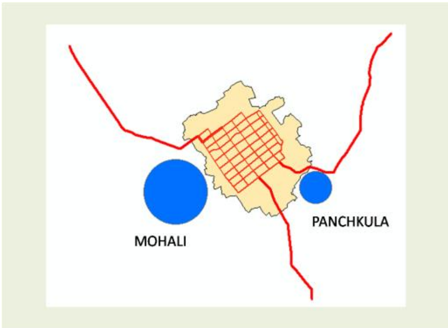


Fig 4.10 New towns on virgin sites as counter magnets

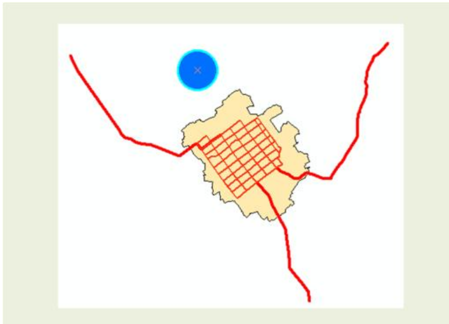


Fig 4.11 New township around existing settlement

Fig 4.12 Series of Satellitel towns

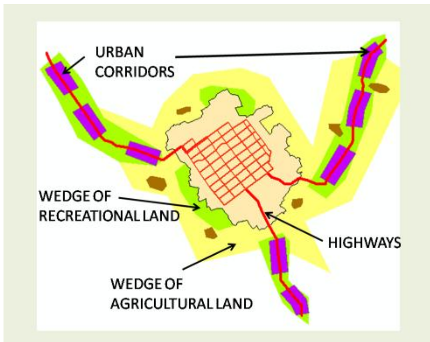


Fig 4.13 Wedge and Corridor expansion

4.2.5. Depiction of Actual Development Pattern in a GIS Model

As mentioned earlier in Section 5.4.1., the actual development of the region around Chandigarh followed a pattern which was a combination of most of the conceptual patterns proposed in 1966. Thus we saw that, as a first response to demand for urban growth, Sectors 31 to 47 were added to Chandigarh in an area of 27 sq kms. Thereafter, Sectors 48 to 56 were also added, reaching upto the southern extremities of Union Territory boundary. Le Corbusier's design had earlier been criticised by some for keeping the density of residential area very low. The permitted density of these southern sectors was increased keeping in view overall demand and the necessity to keep the original character of northern sectors intact. Next, the towns of Mohali and Panchkula were planned by Panjab and Haryana governments in late 60's on virgin lands adjacent to Chandigarh as planned interventions in response to growing pressure for urbanisation. They however took time to grow and reached a stage of maturity and fullness by the 1980s and 1990s respectively. These towns were developed on a pattern similar to Chandigarh. The three cities have since been together referred to as *Tricity* by local population and media, giving them a distinct collective identity, although all three continue to be administered by separate entities. *If Chandigarh is considered as the seed, then growth of these two cities around it by mid 1990s marks the beginning of "regionalisation" of the area*. The process has, however, yet to take a formal shape which will permit the development of the entire area around tricity, as *the first fully integrated and planned inter state regional initiative in modern India*. Coming back to the discussion on actual development pattern, the townships of Kharar, Zirakhpur, Dera Bassi, Kalka Pinjore and Parwanoo can be taken as satellite settlements around Chandigarh. There was, however, no wedge and corridor kind of development pattern discernible as envisaged in the study. Summary of functional development pattern from 1980 to 2010 is shown in Fig. 4.14 below.

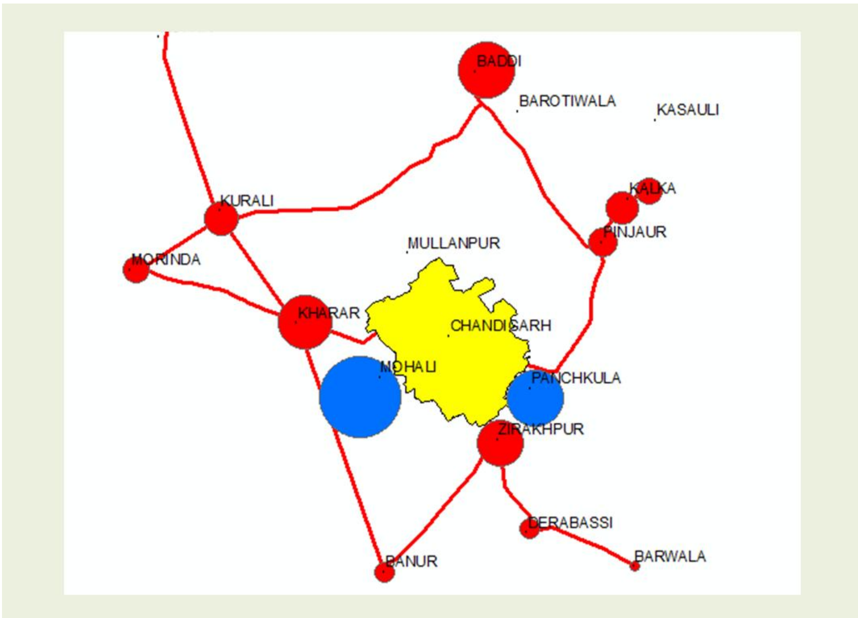


Fig 4.14 : Summary of Functional Development Pattern of GCR between 1980 - 2010.

4.3. Flowchart

Fig 4.15 gives the flowchart of methodology being used for the present study.

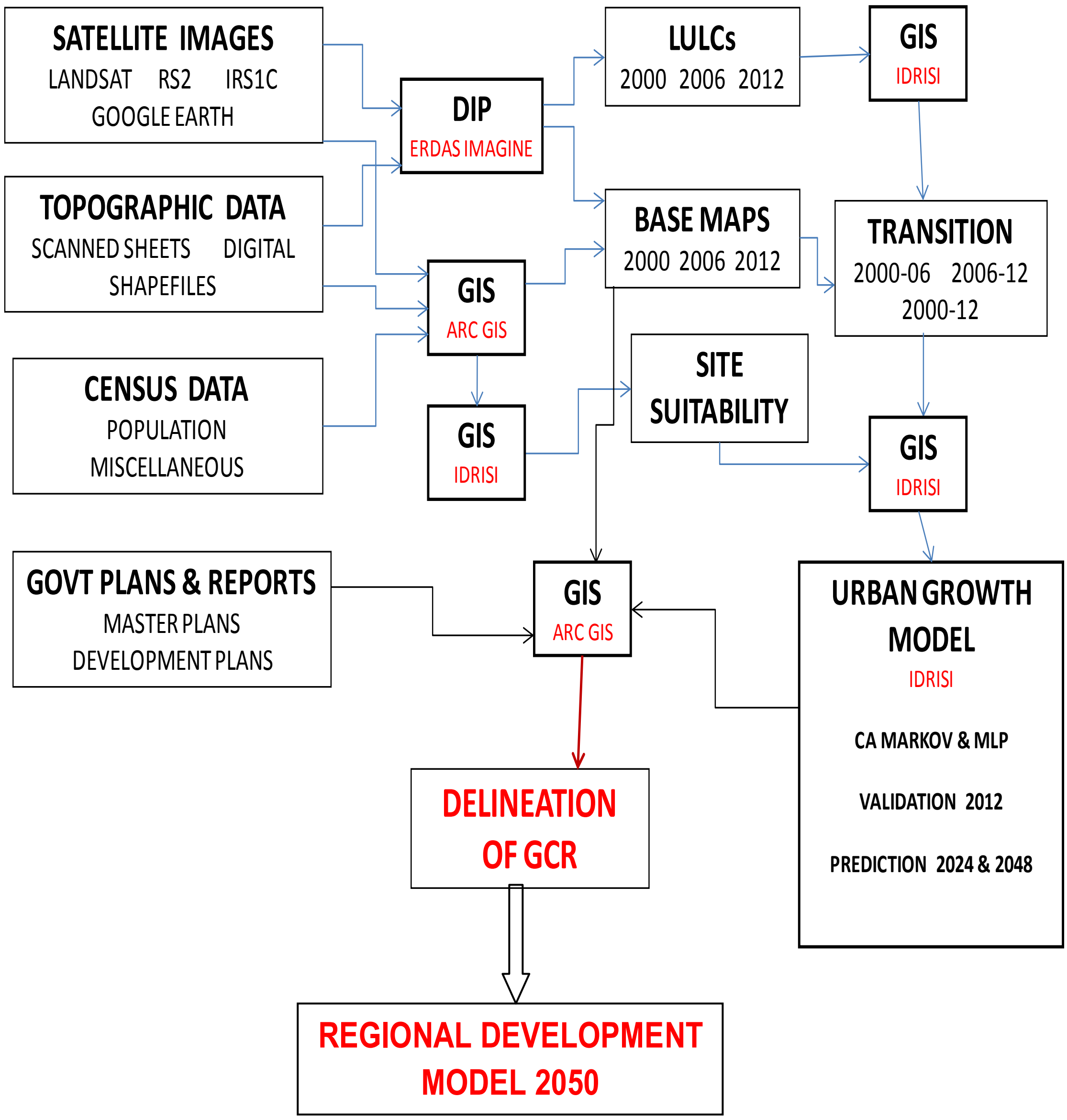


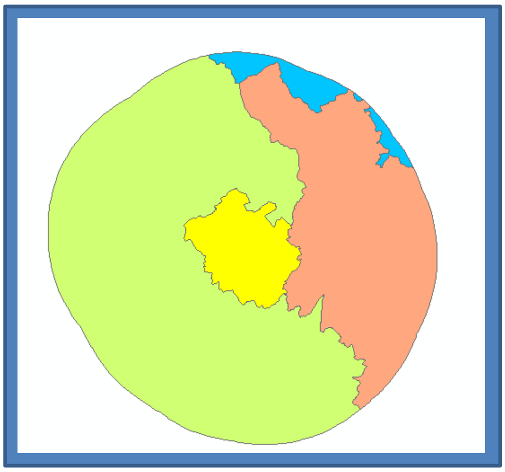
Fig 4.15: Flowchart of Methodology adopted.

5. RESULTS

5.1. General Observations

5.1.1. Four Sub Regions and Area covered

As mentioned earlier, the scope of this study is restricted to 16 km. periphery control belt of UT boundary. It is observed that this region can broadly be divided into four sub regions, based on the state (or UT) under which the area falls. Therefore, GCR would consist of whole of UT and those parts of states of Punjab, Haryana and Himachal Pradesh which verily form 16 km. periphery area. At this point it needs to be pointed out that an assessment of the geographical coverage of this area finds a mention in the Govt of India (GoI) report titled *Report on formulating a master plan for Chandigarh* dated July 2009, issued by *Town and Country Planning Organisation (TCPO), Ministry of Urban Development*. Section 8 of the report refers to the Punjab New Capital (periphery) Act, 1952. Some of the initial results of this research work need to be compared with data given in this section of the report. Firstly, the UT area given in the report closely matches with results of this report. In 1966 when reorganisation of states took place, the area with UT was 114 sq. km. There has been no change in this area ever since. As per this GIS work, the area under UT works out to 114.91 sq. km., which means an accuracy of 99.2%. It can be assumed that this difference (excess) of 0.8% area is attributable to the cumulative errors and variations including human errors (digitisation/ georeferencing), map errors, limitations of scale and resolution, and lastly, variations due to a change in projection and geoid system. In terms of radial distance, this error translates to an average outward increase of 24 metres (taking 114 sq. km. as a circle with radius of 6023.88m), away from the centre of Chandigarh, while digitising the UT boundary. To make subsequent buffer calculations (theoretically) 100% accurate, this correction, by decreasing 24 metres radially, would therefore be applied. Next, the 16 km periphery area was carved out using buffer analysis, a powerful tool of GIS, that works on each point of boundary to work out the periphery area. It is at this point that major deviations with estimates given out in the GoI, TCPO report mentioned above were observed. **Fig 5.1.** shows the geographic and statistical details of area as obtained by this study.



NAME		AREA SQ KM	% AGE AREA
CHANDIGARH		114.91	7.11
HARYANA		462.53	28.63
HIMACHAL		52.33	3.24
PUNJAB		985.71	61.02
		1615.48	100

Fig 5.1 : Distribution of area within 16 km periphery control belt of Chandigarh

5.1.2. Comparison of Area Computations with Govt Estimates

Major differences with estimates given out in TCPO report mentioned above are :

(a) Total area under periphery control act is 1615.48 sq.km. Allowing for radial (negative) correction of 24 m uniformly, this area reduces to 1612.06 sq.km. However, the TCPO estimates this as appx 1400 sq.km, a variation of more than 13% from the GIS based results.

(b) Some parts of Himachal Pradesh (HP), including Baddi, also form part of periphery area. Areawise share of HP in the periphery region is 3.24%, which has not been reflected in TCPO report.

(c) Share of Chandigarh is 7.11% as per this study whereas the same has been estimated at 3% in the Govt report.

(d) Share of Punjab and Haryana as calculated by GIS is 61.02% and 28.63% wheras the same is reflected as 76% and 21% respectively in the Govt report.

5.2. Study of Growth Drivers

5.2.1. Identification of Growth Areas

It has been brought out in section 4.1.5. above that detailed LULC maps have been prepared for the years 2000, 2006 and 2012. These maps were based on ten categories. Here an analysis is being done on binary maps of Settlement and non settlements, which can be prepared by application of a GIS operation called *Reclassification.* Also, only end years, i.e., 2000 and 2012, are being analysed, so that changes can be discerned over a twelve year period. Through standard raster operations, the *Growth Areas* can be mapped over these twelve years in the study area.

5.2.2. Identification of Growth Drivers

Four *growth drivers* were tentatively identified, through visual inspection, which apparently have a bearing on the *growth areas.* These drivers are : a) Proximity to existing settlements b) Proximity to roads c) Proximity to railways d) Proximity to UT boundary; The objective is to find whether a rigorous mathematical relationship exists between these *candidate drivers* of growth and digitally mapped growth areas. In case not, the concerned candidate will be rejected and the remaining ones accepted as growth drivers for further prediction modelling. Here two quick observations are in order. Firstly, our drivers have been so chosen because they can be clearly identified geo-spatially. Secondly, the choice of drivers can similarly be extended to non spatial parameters like population density or cost of land statistics by marrying relevant statistical data to its spatial data. In the instant case the entire area should be divided into *attribute polygons and assign relevant attribute like 'density' or 'land cost'* to the same and proceed thereafter with analysis in a manner similar to what is being attempted in this section. **Figs 5.2 and 5.3** show how candidature of a potential growth driver is visually examined prior to a detailed analysis.

5.2.3. Seven Step Procedure to Evaluate a Growth Driver

In most of the previous growth prediction studies, whether in the field of forest or agriculture or urban studies, one common aspect seen was that the presence of articulated growth drivers were, at first place assumed to be a fact. This study does not accept, ab-initio, the existence of the growth driver, which is only a probable explanatory factor or a candidate for the observed growth in the region. For the study period of

2000 to 2012, each candidate is made to go through seven mandatory processing steps resulting in a clear mathematical relationship with growth, or else, the explanatory factor is dropped. These seven steps, in general, are :

(a) Creation of buffers of fixed distances around the polygons describing the driver. In the present study, three drivers are tested for buffer distance of 200m, 400m, 600m, 800m, 1000m, 1200m and 1400m.Two of these three drivers are described in Figs 5.2.2(a) and 5.2.2(b).

(b) Using *Overlay Analysis*, identifying the growth area within each buffer ring;

(c) Using *Reclassification* procedure, extracting growth areas within each buffer ring;

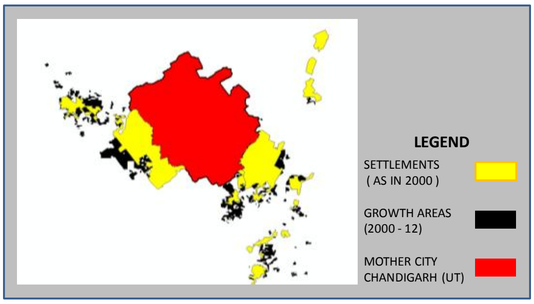
(d) Using *Cross Tabulation,* extraction of data on growth within a buffer as compared to total growth;

(e) Calculating percentage growth in each buffer ring from data obtained in last step;

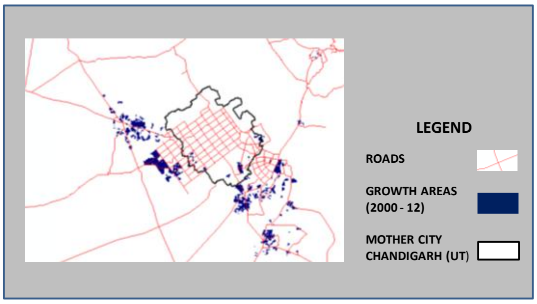
(f) Compile all percentages and

(g) Tabulate the result against the variable of buffer distance.

Thus, the result is ready for display in graphical form. **Fig 5.4** shows seven steps for one of the drivers.



(a) Growth driver 'Proximity to existing settlements' (yellow) under examination against growth (black)



(b) Growth driver 'Proximity to roads' (red) under visual examination against growth areas (blue)

Fig 5.2 : Visual examination of two '*candidate* growth drivers ' against growth areas

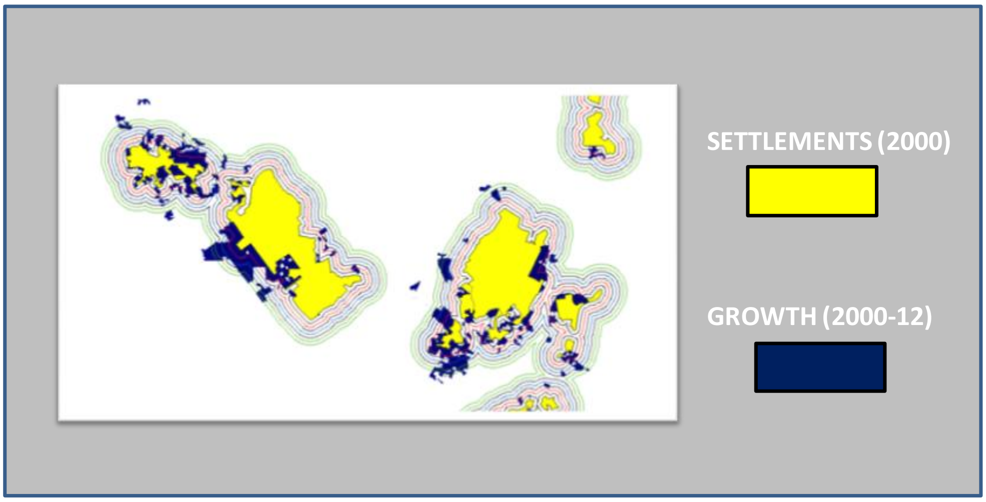
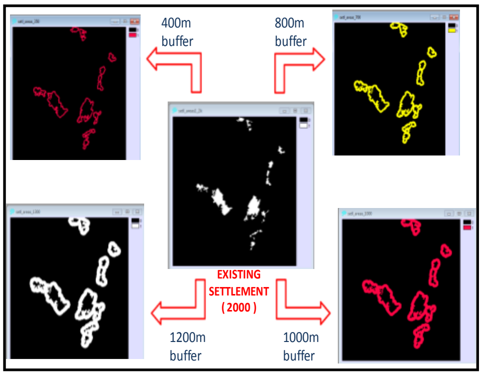


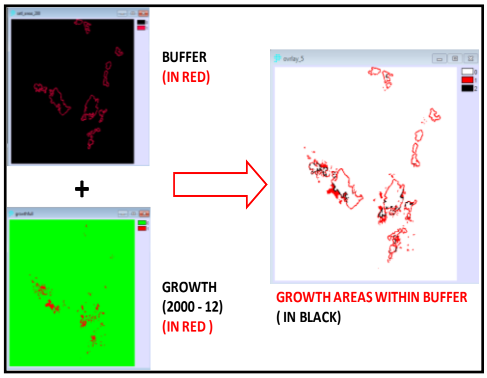
Fig 5.3 : Viewing growth areas (2000-12) through buffers around Settlement 2000

5.2.4. Results and Analysis of Drivers

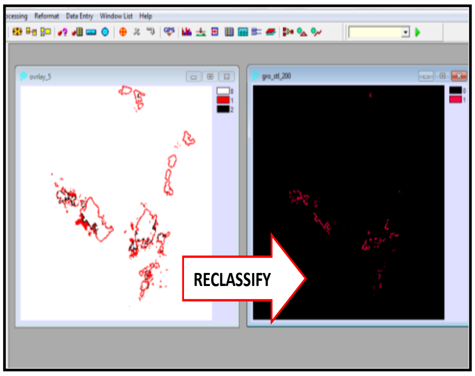
Out of the four drivers tested, three explanatory variables, viz., Proximity to Settlements, Proximity to Roads and Proximity to UT Boundary displayed satisfactory relationship with growth areas over the period of twelve years in the given study area. The fourth - Proximity to Railways - did not show any significant relationship with growth area. The exact mathematical relationships that exist between each growth driver and observed growth over twelve year period of 2000-12 has been graphically shown in **Fig 5.5.** The reason why this semi manual procedure is found better than the automated processes, usually relied upon by researchers, is the *freedom of choosing buffer distance* as relevant to each driver rather than examining the same driver globally over the complete study area. This distance is decided after visual examination of the growth pattern. For example, it was found that growth when related to roads was relevant only up to about 1400m or so (over the last twelve years) and hence seven buffers of 200m were sliced away from roads and studied by this procedure giving a very discernible relationship. Usually researchers rely on parameters like *Cramer's V* which operate globally; however, a given driver, say Proximity to Roads, may not have any influence on the growth beyond 1.5 kms whereas the global parameter would keep evaluating the effect even ten kms. away from the said road, thereby giving a different type of analysis.



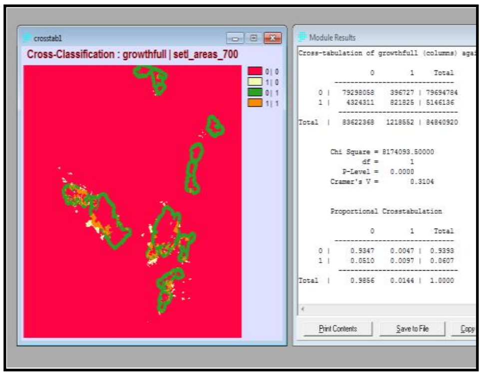
(a)



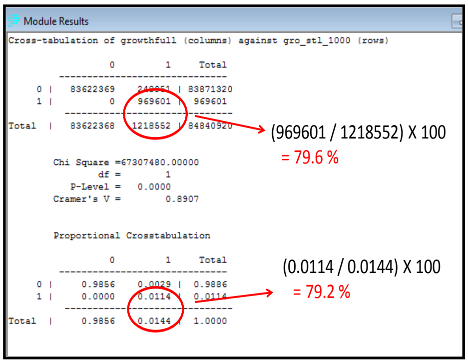
(b)



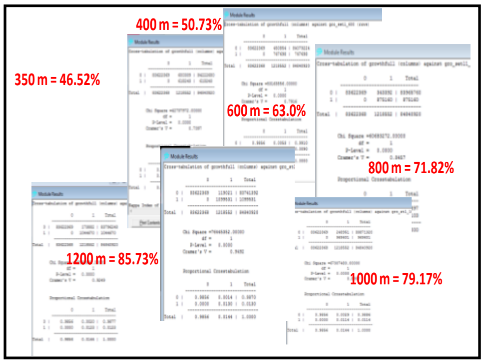
(c)



(d)



(e)



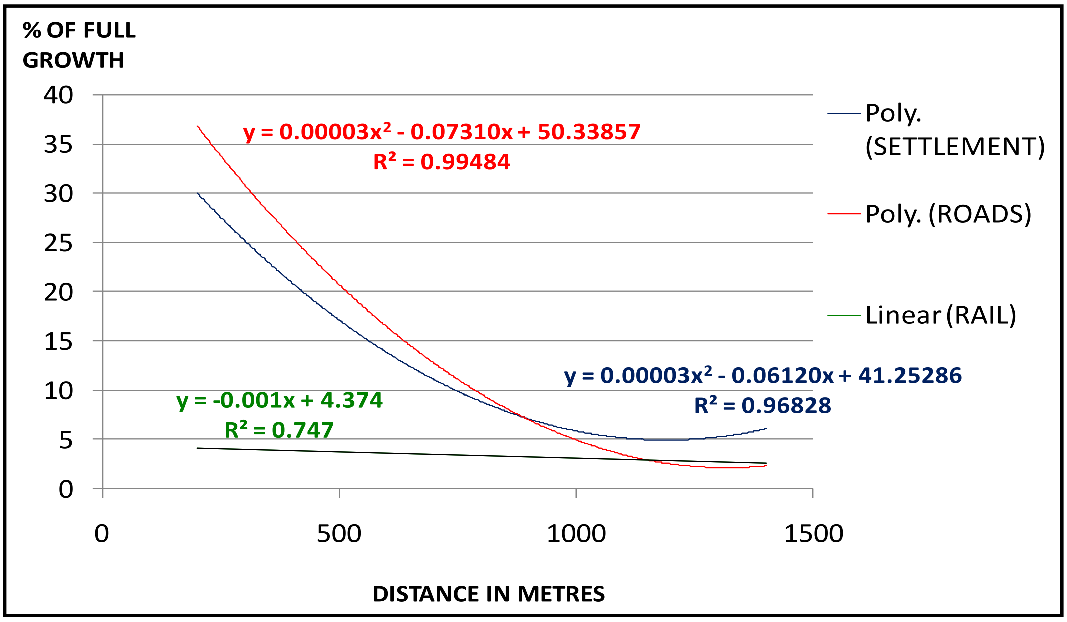
(f)

DISTANCE (metres)	GROWTH WITHIN DISTANCE (sq m)	TOTAL GROWTH (sq m)	GROWTH IN 200m BUFFER	% CUMULATIVE GROWTH
200	388340	1218552	31.87	31.87
400	618243	1218552	18.86	50.73
600	767698	1218552	12.27	63.00
800	875160	1218552	8.82	71.82
1000	969601	1218552	7.75	79.17
1200	1044670	1218552	6.16	85.73
1400	1099531	1218552	4.50	90.23

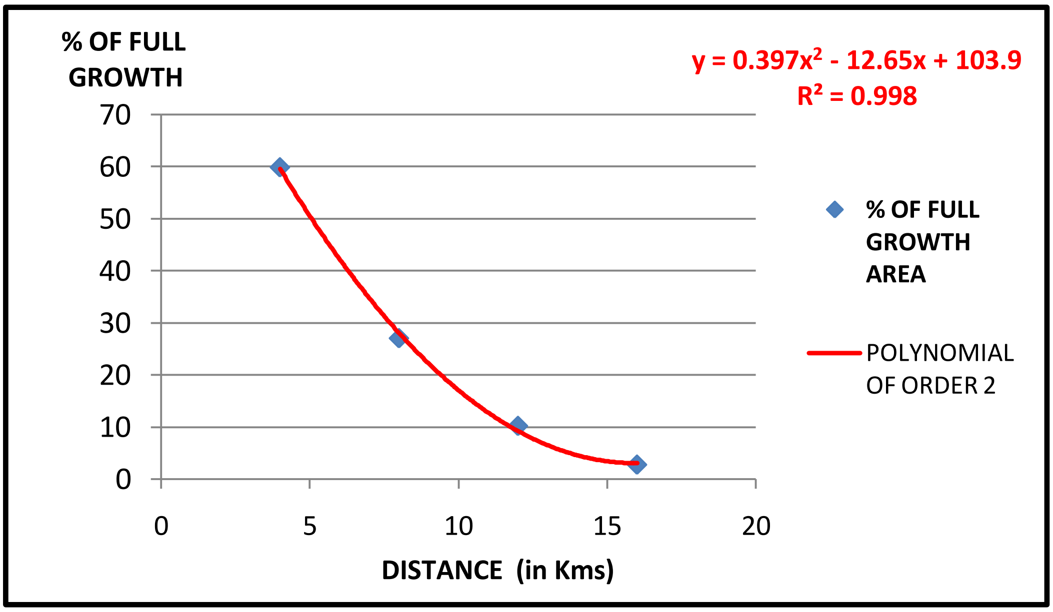
(g)

(a) Creation of buffers (four out seven displayed); (b) Calculate growth area (2000-12) in each of the seven buffers ; (c) Reclassify into a binary class,eg, Growth 200m ; (d) Cross tabulate with full growth; (e) find % growth ; (f) Compile result for each buffer distance (g) Tabulate the results

Fig 5.4 (a) to (g) : Seven Steps to establish a relationship between observed growth area and a growth driver (Distance from settlement).



(a) Drivers - Proximity to Settlements, Roads and Railways
Settlement and roads have significant relationship, however railways have no bearing on growth.



(b) Driver - Proximity to UT boundary (in kms)
Proximity to UT Boundary has a significant relationship, with 60% of total growth within 4 kms

Fig 5.5 (a) and (b) : Relationship between Growth and Growth Drivers

5.3. Growth prediction and alternate scenarios

Till now a method has been developed to identify and confirm the explanatory power of a growth driver by establishing its relationship with previously identified growth areas. Having done that, these drivers can be used to predict the future scenario of urban growth. Before actual prediction process, an intermediate step of *validation of the prediction process* is in order which takes place in two steps.

(a) Firstly, predicting data for 2012 using data of 2000 and 2006.

(b) Secondly, comparing projected data of 2012 with actual data of 2012. This is done in sub section 5.3.2.

In this study, LULC for three years starting with 2000, and with uniform gap of six years, has already been prepared. This LULC data, with ten classes was processed using *reclassification* to prepare a new set of data of binary data : *Built up* (BU) and *Non Built Up* (NBU) data, outside UT boundary upto 16 km periphery area. This is done in sub section 5.3.1. The *Built up* category consisted of five classes of previous LULC classification,viz, *BU Urban, BU Rural, BU Mixed, Urban greens* and *Land under Plotting* (LUP). Last category, LUP, was so added because, during ground visits, it was established that planned intervention around Chandigarh was taking place at a rapid rate, particularly in south and east of Mohali. This meant that the LUP was fast converting into urbanised/ planned structures, and therefore could not be included in *non built up* binary class during reclassification without adversely affecting the prediction results. The *non built up* category consisted two previous classes of *Agricultural land* and *Barren land*. Balance three LULC classes, viz, *Forest land, Water bodies* and *Restricted area* were merged in the background, as these classes are nearly static over the six year period, and changes occuring in them were found to be insignificant to be recorded at regional level. This approach also ensured that all changes being analysed were attributable only to the dynamic variables. As a criticism to this reclassification, it can be argued that inclusion of plotted land in built up class might lead to overprediction. However, this would not be the case, as most software prediction processes are simply linear procedures (dependent upon transition probabilities from past set of two values and then applying the same for the prediction) whereas the actual growth is non linear and becomes steeper as the time progresses, as shown in sub section 5.3.1 below. Thus these two aspects have an overall effect of cancelling out each other. In sub section 5.3.3 prediction results for 2024 and 2048 are given, which maybe used for growth scenarios 2025 and 2050.

5.3.1. Built up Areas Study (outside UT) for 2000, 2006 and 2012

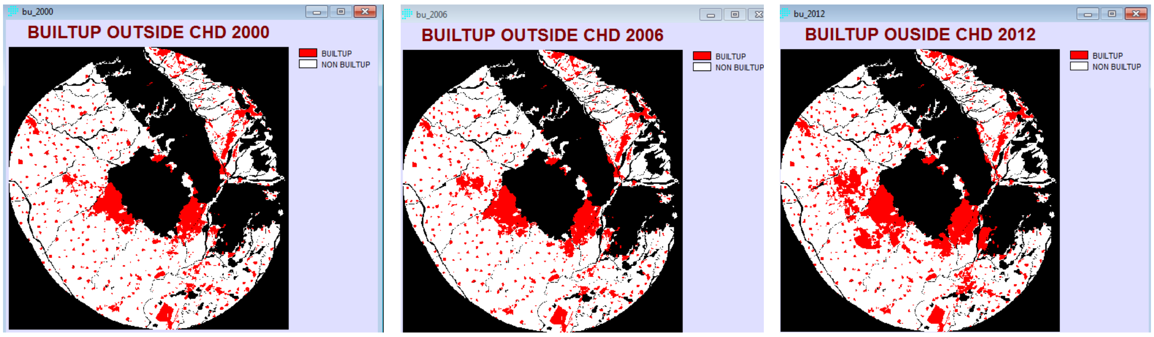
Result of reclassification of LULC into a binary class : *Built up* (BU) and *non-built up* (NBU) areas was done for three temporal periods of 2000, 2006 and 2012 , ignoring UT area and reaching up to 16 km periphery area, as mentioned earlier. The resultant maps, viz, BU 2000, BU 2006 and BU 2012 are shown in **Fig 5.6** and supporting tabular data in **Table 5.1.** As mentioned earlier, the growth in BU area is non linear over 12 year period : 8.54% during 2000-06 and thereafter rising sharply to 31.13% during 2006-12.

5.3.2. Projecting 2012 data and Validating

As mentioned earlier, data of years 2000 and 2006 was used to *project* (also referred to as *prediction*) data for the year 2012 and the same was validated against reference data of 2012 which was prepared earlier. The focus of this regional study being on the region beyond the UT, all predictions were done on similar data, i.e., area starting from UT boundary and extending up to 16 km periphery. However, as a minor variation, data of UT was also included up to validation stage, to get a larger picture including UT. The future growth of union territory of Chandigarh itself is tightly and effectively being managed by Chandigarh

Table 5.1 : Growth of Built up (BU) area (outside UT) up to 16 km periphery

Year	*No of Cells (50m x 50m) of BU area*	*BU area (sq.km)*	*% BU area in 16 km periphery (outside UT)*	*% Growth in BU area (using Column 3 data)*
2000	60609	151.52	10.1	-
2006	65788	164.47	11.0	8.54
2012	86268	215.67	14.4	31.13



(a) BU 2000 : Area 10.1% (b) BU 2006 : Area 11.0% (c) BU 2012 : Area 14.4%

Fig 5.6 : BU area maps of 2000, 2006 and 2012 : Red colour represents built up area (outside Chandigarh boundary) which has progressively increased in a non linear fashion

Administration, empowered with many alternate choices beyond the scope of current study (for example increase of Floor Area Ratio). Therefore, although areas beyond UT would only be subjected to prediction process, for the purpose of validation complete data including Chandigarh was studied. As a first step, three reclassified binary images, viz, BU 2000, BU 2006 and BU 2012 were prepared as shown in **Fig 5.7.** Using the images BU 2000 and BU 2006, two models were used for prediction, namely, *CA Markov* and *Multi layer Perceptron* (MLP). These processes were implemented in *Idrisi Taiga* software. MLP was implemented in a specialised module developed in *Idrisi Taiga*, viz, *Land Change Modeller* (LCM).

CA Markov : *CA_Markov* was implemented in four stages.

(a) Firstly *Markov* model was run on the two temporal images of 2000 and 2006 to generate a matrix of transition suitability areas over these six years. This transition areas file was used by CA_*Markov* model to locate future changes for 2012 in six iterations (each iteration representing one year change).

(b) In the second stage, a set of suitability images were created using four drivers of growth, viz, distance from UT boundary, distance from existing major roads, distance from existing settlements and distance from town centres. The distances in these images were normalised giving values between 0 to 1 using fuzzy membership functions.

(c) In the third stage, these suitability images were grouped together using *Collection Editor* facility of *Idrisi Taiga.*

(d) Thereafter, *CA_Markov* model was run and the outputs produced in previous steps were fed as inputs in this model.

MLP Neural Network model. Similarly, the second prediction model, viz, MLP, was implemented in three stages using the module *Land Change Modeller* (LCM) of *Idrisi Taiga*.

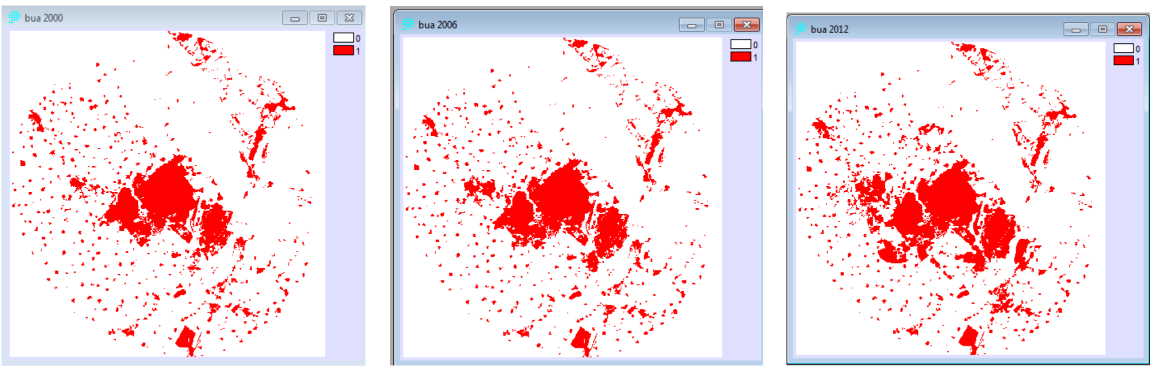
(a) In the first stage, two temporal images of 2000 and 2006 were input as project parameters.

(b) In next stage *change analysis* was carried out. Transition sub model was run for mapping all the changes, followed by evaluating the explanatory power of all growth drivers using Cramer' V.

(c) The chosen drivers were then used to run the MLP Neural Network model with following three stopping criterion: RMS error lesser than 0.01, number of iterations reach 10000 or accuracy achieved is 100%. Number of layer one nodes for MLP were taken as four and the resulting model accuracy achieved was 84.24% as shown in **Fig 5.8.**

Using these results, prediction for 2012 was done followed by validation with actual data of 2012. Validation results of CA Markov and MLP are compared in **Fig 5.9.**

Results and Comparison in two models. Total number of Built up cells for 2012 were found to be 1,17,163 in the map given in Fig 5.7(c). Since each cell is 50m x 50m, this area comes out to 292.90 sq km. Out of the two predicted data of 2012, MLP procedure was found to be more accurate with 1,00,903 built up cells i.e. 86.12% accuracy. CA Markov predicted 95,308 built up cells i.e. 81.34%. These predicted outputs were also validated using *Validate* module of Idrisi, both with and without mask (which was a stratified image of administrative areas). The results once again showed superiority of MLP procedure as shown in **Table 5.2.**



(a) BUA 2000 : 89613 cells (b) BUA 2006 : 95308 cells (c) BUA 2012 : 117163 cells

Fig 5.7 : BU area maps used for prediction (years 2000, 2006) and validation (year 2012). Data of UT has also been included to get a holistic picture of the region**.**

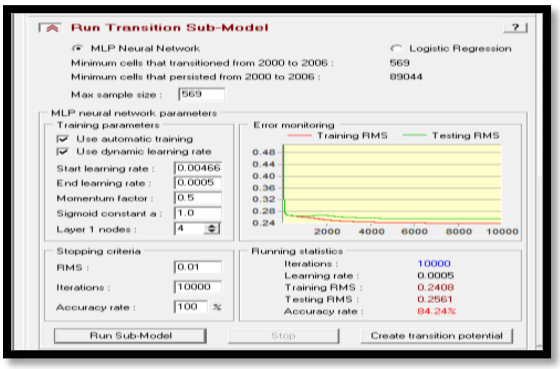
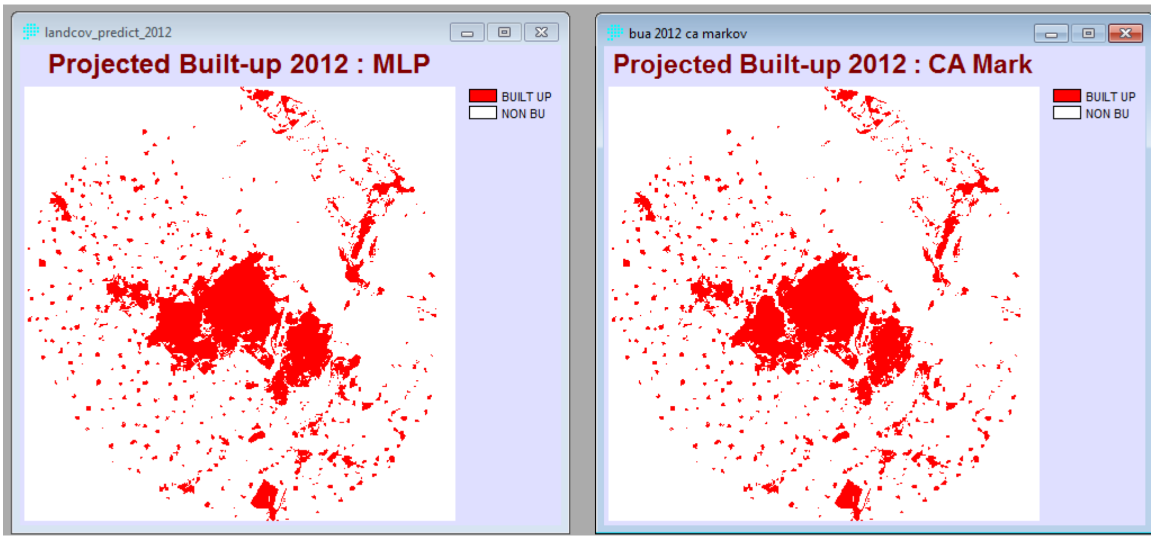


Fig 5.8 : Accuracy in MLP Neural Network MLP Model was run in Land Change Modeller (LCM) module of Idrisi Taiga. Five growth drivers were used in the model which achieved an accuracy of 84.24%

Table 5.2 : Comparison of CA Markov and MLP Model Results in predicting Built up 2012 scenario

	CA MARKOV	*MLP*	*REMARKS*
Without Stratification	0.9438	0.9508	MLP Better
With Stratification	0.9262	0.9354	MLP Better



(a) Prediction by MLP : Accuracy 86.12%
(Built up cells 100903 against actual data 117163)

(b) Prediction by CA Markov : Accuracy 81.34%
(Built up cells 95308 against actual data 117163)

Fig 5.9 : Comparison of two results using MLP and CA Markov models for 2012 data.

5.3.3. Projected Growth trends for Year 2024 and 2048

In the previous sub section it was demonstrated that MLP neural network procedure produced better spatial results than a CA Markov method. Secondly, herein onwards, the study will focus on area outside union territory boundary. Using data of 2000 and 2012, MLP procedure was applied and built up area for 2024, 2036 and 2048 was predicted. As mentioned earlier, the statistical rate of growth in terms of number of grown built up cells every twelve years would remain the same. However, it is the location of these cells which give a definite sense of developmental pattern to the expected growth.

Software and Drivers used. LCM module of *Idrisi Taiga* was again used. Six drivers were tested, five of which were produced on the lines as shown earlier in sub section 5.2. The sixth one was derived from changes (gains and losses) mapped by the software in LCM module. Since this is a qualitative variable, as per the software manual, it needed to be either broken into a set of separate Boolean layers or transformed with Evidence Likelihood transformation (given as a tool in LCM). This driver was therefore transformed using 'Evidence Likelihood' utility in LCM which generated linear values from 0 to 1 associated with the changes occurring between 2000 and 2012. All the six parameters were checked for their explanatory power using Cramer's V values. As per the software manual, values of 0.15 and higher are considered 'useful' and values of 0.4 and higher are considered 'good'.

Inclusion of *Proximity to Railways* as a Driver. In section 5.2 it was brought out that the driver proximity to railways did not bring out a significant relationship with growth during the study period of 2000-12 and therefore a natural question arises as to why this driver has been again picked up as one of the six variables for prediction studies. The answer lies in the fact that there is a need to take into account planned interventions while modelling real world urbanisation. The situation appears changed for a futuristic period if implementation of GMADA plan in Mohali is taken into account. It is observed that the *Agricultural land* of LULC 2000 has transformed into as *Plotted land* in LULC 2012 in southern parts of Mohali and these polygons touch the railways all along south making a U shaped ring. The railways also serve as the farthest limit of *Plotted land*, which is a mature indicator of urbanisation process. It has also been mentioned earlier that *Plotted land* was reclassified into *Built up* class in binary maps used for prediction study. In other words, railways represent a boundary of extension of *Built up land* coming up in Mohali. Hence a decision to test this variable. The results indeed show that a useful relationship exists, although Cramer's V value (0.2427) is not as strong as in the case of other variables.

Model Parameters for MLP. Table 5.3. gives details of all the drivers used, the manner they were derived, processes involved and finally the Cramer's V value. Having tested these variables for their explanatory power, the model on Urbanisation was run with following parameters : Layer one nodes were fixed at 4. Stopping criterion was threefold - attain 100 percent accuracy, or attain RMS error of 0.01, or continue till 10000 iterations. Using these parameters on six variables, the model was able to reach an accuracy of 95.58 percent, which was significantly higher than accuracy achieved at validation stage (84.24%). This model was, therefore, used to create transition potential data further used for prediction. Growth is given in **Fig 5.10** and **Fig 5.11.**

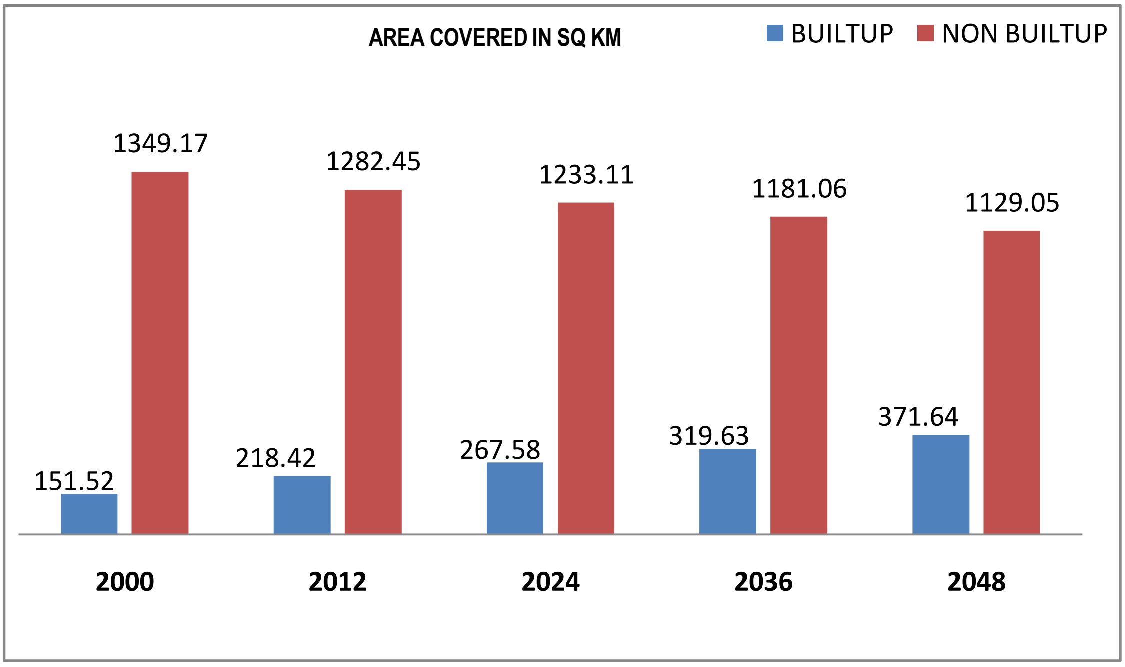
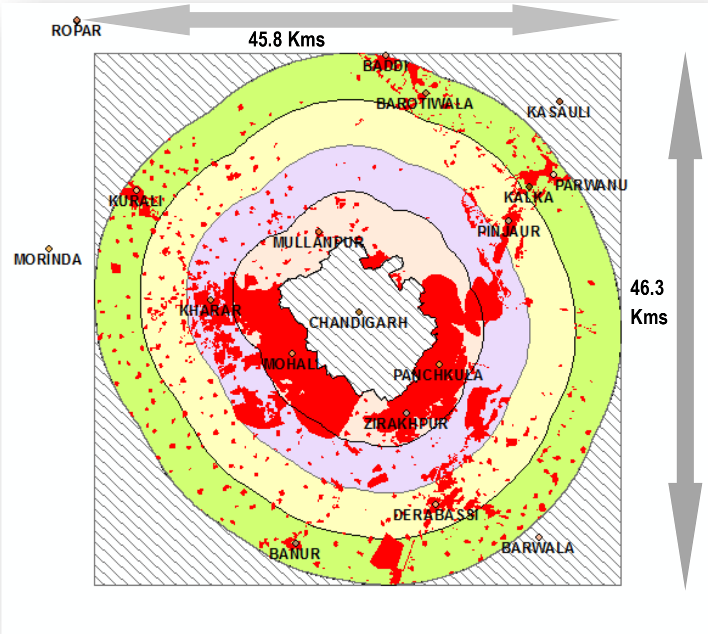


Fig 5.10 : Area of Built up and Non built up from 2000 to 2048 : MLP prediction model.

Table 5.3 : Details of drivers chosen for prediction modelling, related processes and Cramer's V. Values more than 0.15 are 'useful' in MLP model and values more than 0.40 are considered 'good' as per manual on *Idrisi Taiga*. These six drivers produced an accuracy of 95.58%

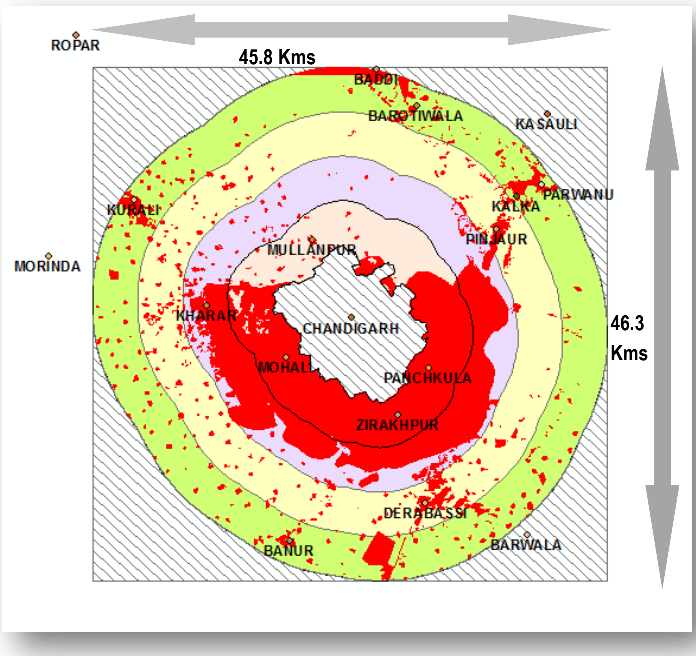
Description of Driver	*Source*	*Processes involved*	*Distance of influence*	*Cramer's V value*
1. Proximity to Chandigarh (UT)	Self generated, digitisation of UT boundary in ArcGIS 10. Imported in Idrisi after rasterisation.	a) Distance operator on Raster b) Fuzzy operator with decreasing sigmoid function	Complete periphery of 16 kms, decreasing from 4 kms to 16 kms monotonically	0.4050
2. Proximity to Roads	Self generated, digitisation of roads network in study area. Exported to Idrisi after rasterisation	a) Distance operator on Raster b) Fuzzy operator with decreasing sigmoid function	2 kms, decreasing from 200m to 2 km monotonically	0.3334
3. Proximity to Settlement 2012	Self generated, Preparation of LULC followed by aggregation of polygons manually	a) Distance operator on raster b) Fuzzy operator with decreasing sigmoid function	2 kms, decreasing from 400 m to 2 km monotonically	0.3668
4. Proximity to Railways	Self generated, digitisation of UT boundary. Exported to Idrisi after rasterisation	a) Distance operator on raster b) Fuzzy operator with decreasing sigmoid function	2 kms, decreasing from 400 m to 2 km monotonically	0.2427
5. Proximity to Town Centres	Self generated, Centres of relevant towns identified on Hybrid image and digitised as points.	a) Distance operator on raster b) Fuzzy operator with decreasing sigmoid function	4 kms, decreasing from 2 km to 4 km monotonically	0.3711
6. Changes between 2000 and 2012 (gains and losses)	Generated by LCM module of *Idrisi Taiga*	Evidence likelihood operator on categorical values	-	0.4569



HIGHLIGHTS : BUILTUP 2024

- BUILTUP COLOUR RED
- BUILTUP (BU) CELLS 107030
- BU AREA 267.58 SQ KM
- BUILTUP % 17.83 %
- NON BU CELLS 493245
- NON BU AREA 1233.11 SQKM
- NON BU % 82.17 %

(a)



HIGHLIGHTS : BUILTUP 2048

- BUILTUP COLOUR RED
- BUILTUP (BU) CELLS 148657
- BU AREA 371.64 SQ KM
- BUILTUP % 24.76 %
- NON BU CELLS 451618
- NON BU AREA 1129.05 SQKM
- NON BU % 75.24 %

(b)

Fig 5.11 (a) and (b): Prediction Results of Builtup Area in 2024 and 2048 in Buffer Rings

The results of *Idrisi Taiga* software were exported to *ArcGIS 10* to enable viewing in multiple buffer rings of 4 km, 8km, 12km and 16km. Upto 2024, maximum urbanisation is in first ring, and it extends into second ring of 8 kms firmly by 2048 . This gives a lead in

5.4. Delineation Study

Till now two major objectives of the study have been covered, viz, identification and study of growth drivers and growth prediction for 2024 and 2048. This sub section covers the third objective, viz, to conduct delineation study for the GCR based on geospatial analysis carried out so far including the results of previous two objectives. A number of aspects were considered for conduct of this study and the same have been given out in sub section 5.4.1. In a regional plan centred around a core of urbanised territory, there is likely to be a relationship between core and surrounding region in terms of extent of geogaphical area. Sub section 5.4.2 discusses the same in respect of National Capital Region (NCR). In sub section 5.4.3, a critical appraisal of Planning Zones of the Chandigarh Inter-State Region (CISR), as enunciated in *Concept Note on Chandigarh and its Region by TCPO, Govt of India* has been done. As a corollary, a new system of delineation - Seven layers of GCR is evolved and compared with the policy zones of CISR in sub section 5.4.4. A detailed geospatial analysis of first six layers (out of seven) is done in sub section 5.4.5. The seventh layer was left out, being beyond the scope of current study.

5.4.1. Aspects Considered in Delineation Studies

A number of aspects were kept in mind for conduct of delineation study. These have been conceptually shown in Fig 5.12**.** Four aspects are clubbed together which are derived from different Govt approved plans or policies, viz, Le Corbusier's vision, policy zones of *Concept Note* of Govt, NCR plan and GMR plan by GMADA. Other three aspects which have been put together pertain to studies, previous and present, on GCR, viz, CISmeR Plan by Prof EFN Rebeiro and the current results discussed in this study up to now.

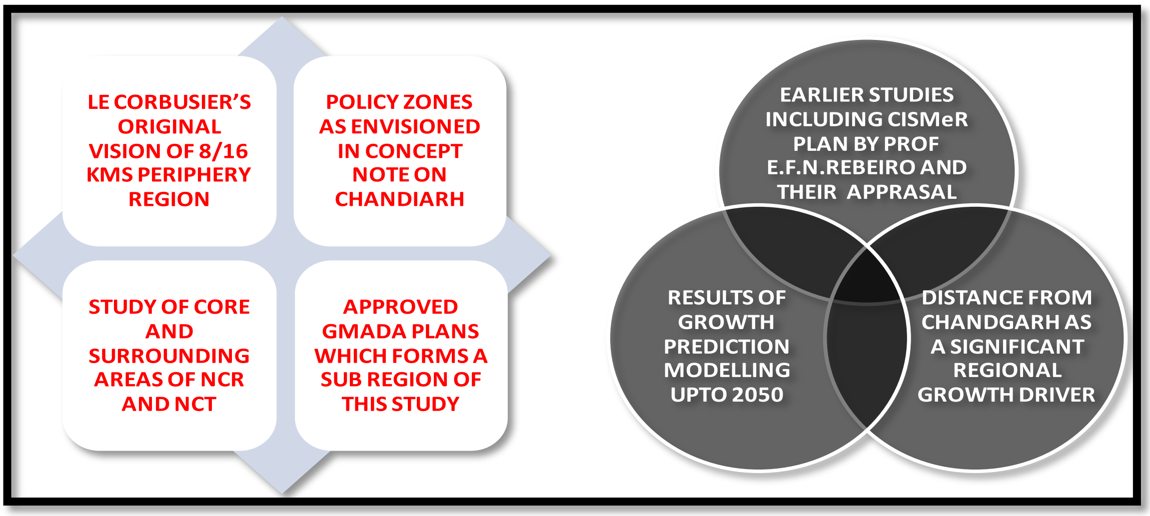


Fig 5.12 : Conceptual appraisal plan of delineation study. Left four are the Govt inputs and the right three depict previous studies as well as the results of the current study discussed so far.

5.4.2. NCR Region : Core area versus Surrounding region

National Capital Region (NCR) comprises of eight districts of Haryana, five districts of Uttar Pradesh and one district of Rajasthan with a total area of 33,578 sq.km. The core area of National Capital Territory (NCT) is 1483 sq.km. The ratio of geographical area occupied by the core territory vs surrounding region is 1:22, with the core - the NCT, acting as a magnet to 14 outer districts. In contrast, the influence of Chandigarh (UT) on its neighbourhood would be far lesser in comparison to NCT on its neighbourhood, Chandigarh being the capital of only two states and NCT being the national capital with vaster array of services and resources exercising influence on the region under its command. It can be safely expected that the optimum area wise influence ratio in case of GCR may be less than 1:22, but, exactly how much would remain a moot question. On the other hand, UT has an area of 114.9 sq km and its surrounding 16 km periphery covers an area of 1615 sq km. Thus, to begin with, if the geographical area of UT is considered as the core and this periphery as its exclusive influencing zone, then the core vs surrounding area ratio would be 1:14, which appears quite optimum when compared to NCT:NCR ratio. However these observations would need to be supported by other factors before it may be firmly concluded to restrict GCR boundary to 16 the km periphery. The option of including other areas in GCR has been discussed in section 7.2.5.

5.4.3. Policy Zones of CISR and its Critical Appraisal

As per the *Concept Note on Chandigarh and its Region* by TCPO, Govt of India, the Chandigarh Inter-State Region (CISR) has been divided into three Planning Zones, which are :

(a) **Zone 1** : This zone has been termed as the 'Mother City' consisting of Chandigarh with 114 sq. km. area under the Master Plan.

(b) **Zone 2** : This zone has been designated as 'Central Chandigarh Region' (CCR), which has been deemed to be coterminous with the Periphery Control Belt.

(c) **Zone 3** : This zone has been designated as ‘Rest of the Chandigarh Region’, for which the boundary is proposed to be defined after delineation study of the CISR Plan.

Critical Appraisal : From the growth prediction studies in section 5.3.3 and fig 5.11, it is observed that the pattern of projected development till 2050 varies significantly, as we proceed radially outwards from UT boundary, typically in buffer rings of 4 kms. Areas upto 4 kms are projected to undergo rapid urbanisation even before 2025. These areas would further densify and expand firmly into the next ring of 8kms by 2050.

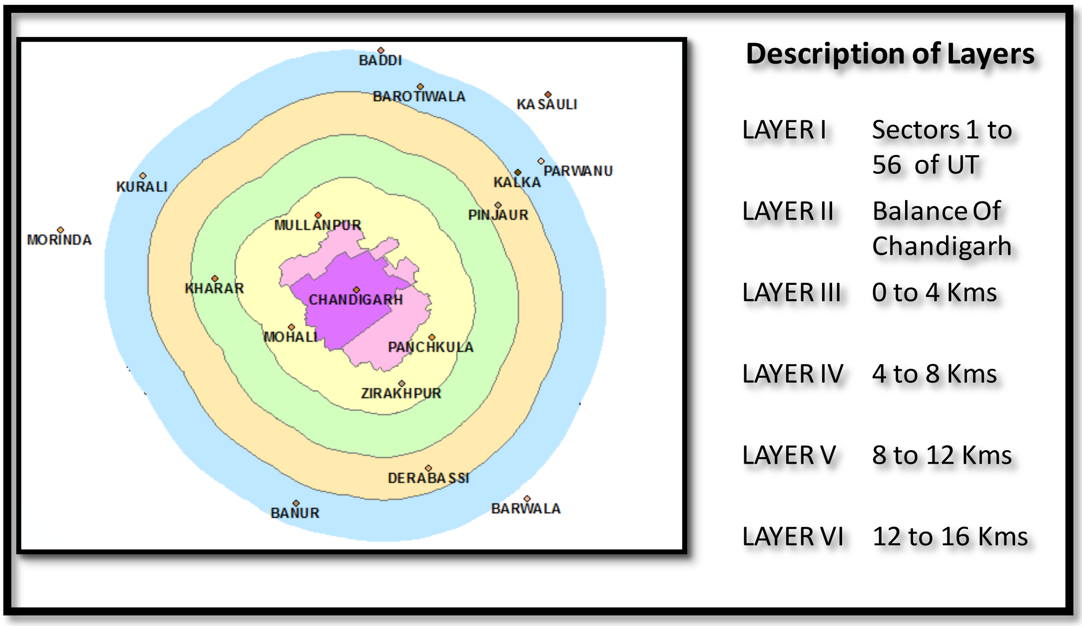


Fig 5.13: Delineation of Six Layers of GCR. The seventh layer represents areas beyond the 16 km periphery control belt, and has not been delineated, as it falls beyond the scope of the current study

However areas in next two rings, beyond 8 kms upto 16 kms, are likely to grow only in small, designated pockets. This leads to an inference that the region designated as CCR in the *Concept Note* may require different planning policy prescriptions in different sub zones, on lines of the projected growth pattern. This has led this study to proceed on delineation process in a slightly different, and perhaps in a greater detail, as shown in next sub section.

5.4.4. Need for Delineation of new Layers of GCR and Comparison with the Designated Planning Zones of CISR

The conceptual requirement of delineation of GCR in seven layers has arisen as a corollary to the critical appraisal done in sub section 5.4.3 above, wherein it was felt that zone 2 needs to be further partitioned and examined in greater detail, so as to arrive at those areas which can be considered homogenous in their growth pattern. This study may be considered as an extension of the three designated planning zones of CISR. To undertake a closer scrutiny, zone 1 has been divided into two layers (sector 1 to 56 as layer 1 and balance as layer 2) and zone 2 into four layers, starting from UT boundary outwards, upto 4 kms, 8kms, 12kms and 16 kms of the periphery control belt. Thus there is a direct corresponding relationship between six layers of GCR, as proposed in this current study, and the first two zones of CISR, as enunciated in the *Concept Note*. The third zone of CISR, which is coterminous with the seventh conceptual layer of GCR has not been delineated in the *Concept Note* except for the mention that it will include areas beyond peripheral control belt. Layer 7, representing the same, has also not been delineated in the current study on GCR , the areas beyond periphery control belt being outside the scope of current study. However the matter will be taken up in last chapter, as a discussion point in section 7.2.5. Comparison between CISR and GCR is therefore in order, and is given in Table 5.4**.**

Table 5.4 : Comparison in Conceptual Approach - Planning Zones of CISR (In Concept Note of Govt of India) and Layers of GCR (current study)

Description of Area	*Layers of GCR*	*Planning Zones of CISR*	*Remarks*
Sector 1 to 56 - UT	Layer 1	Zone 1	Capitol Complex, Lake, University, PGI (Medical Institute), predominantly residential
Rest of UT	Layer 2		Airport, Railways, Industrial area, Forest area
4 km periphery of UT	Layer 3	Zone 2	Mohali, Panchkula, Zirakhpur, Mullanpur
4 to 8 km periphery	Layer 4		Kharar
8 to 12 km periphery	Layer 5		Dera Bassi, Pinjore
12 to 16 km periphery	Layer 6		Banur, Kurali, Kalka, Parwanoo, Baddi (partially), Barotiwala
Areas beyond periphery control belt	Layer 7	Zone 3	Kasauli, Barwala, Baddi (partially). Areas to be included in this layer not yet defined

5.4.5. Detailed Geospatial Analysis of Six Layers

In this sub section a detailed analysis of the first six layers is done. Each layer is separately viewed against the following overlays (background information) in GIS :

(a) **LULC 2012 overlay** : This gives the information on the predominant landcover class and associated activities as on date. Forest information leads to buffer areas that need to be earmarked as eco sensitive zones. Water bodies provide information on areas which may be developed as nature parks, recreational areas and potential tourist hotspots.

(b) **Topographical Sheet overlay** : Important towns existing in this layer can be identified.

(c) **Road and Rail Infrastucture overlay** : This includes both, existing and proposed roads and rail network. Proposed expressways have also been included.

(d) **GMADA and Panchkula development plans overlay :** GMADA and Panchkula being two major sub regions of GCR, this overlay provides information on the same.

(f) **Projected Builtup 2024 and 2048 overlays :** These two overlays give an idea of spatial growth pattern likely to be followed in next four decades, assuming the growth is allowed in its natural course. Therefore these two layers are indeed most crucial inputs for the regional planner as an instrument of planned intervention.

5.4.6. Regional Development Model : GCR 2050

GCR has so far been been divided into seven layers, out of which planning for first six layers has been done. As shown in Fig 5.15 and Fig 5.16, each layer has further been divided into five major classes, which have a direct bearing on regional level planning. Two of the classes, viz, *Proposed Urbanisation* and *Proposed Afforestation* have been evolved so as to have a sustainable development in the region by a balancing the need for urbanisation with concerns of eco conservation. These five classes are :

(a) **Agricultural Land.** The share of agricultural land will reduce considerably in next four decades, particularly in Layer 3 and Layer 4, as seen in the ground visits and as predicted in growth modelling. Therefore these areas need to be earmarked separately in the regional plan where restrictions on urbanisation should be enforced.

(b) **Forest Land.** This has been demarcated and a buffer of 200 metres needs to be enforced for no construction activity. Existing Forest land is 419.55 sq.km.

(c) **Existing Settlements**. These areas have also been aggregated and demarcated. However smaller villages have not been shown, and the same have been aggregated in the class enveloping them. Existing settlements cover a little over 200 sq.km. (207.73 sq.km.)

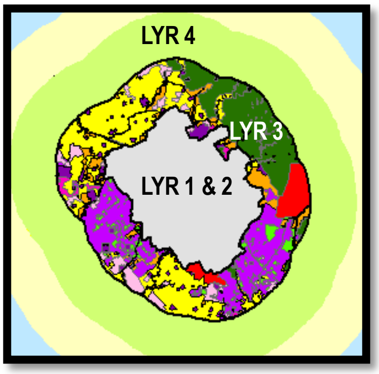
(d) **Proposed Afforestation.** This class has been created in order to address the concerns on environment and eco conservation. These have been earmarked only in layer 5 and layer 6, where pressure of urbanisation will remain low and execution of Government orders is implementable with lesser resistance. Total afforestation area is about 100 sq. km. and these areas have been identified along seasonal rivulets with a width of about 1 to 1.5 km. on either side. However, most of this land is privately owned and implementation is only possible if innovative measures are adopted factoring in economic benefits to land owners.

(f) **Proposed Urbanisation.** An area of about 400 sq. km. has been earmarked for urbanisation within the periphery control belt. This has been done keeping in view approved GMR plans and growth projection studies conducted. As per Fig 5.11(b) total built up area outside Chandigarh for year 2048 is projected to be 371 sq. km., however, here the earmarked 400 sq. km. area represents outer limits within which town planners may undertake meso and micro level planning. Different plans would have to emerge from this macro level template including the proposed townships of Mullanpur, an Aerocity, education-knowledge-health corridors, transportation zones, industrial belt or a new township around Kalka-Pinjore area. Strict policy prescriptions would be required. *Not more than 40% of designated urbanisable area is recommended to be converted to built up area.*

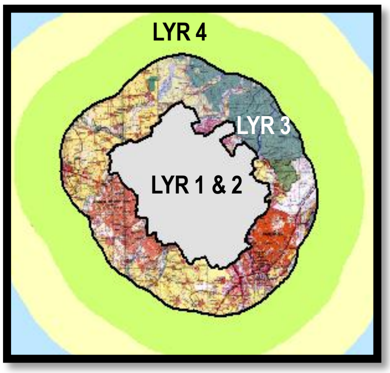
Fig 5.14 displays the use of six overlays to arrive at block area classification of the layer 3. Similarly, all other layers (1 to 6) have been classified into five classes as above. The final development model for the region is based on compilation of all these six layers into five classes as given above, using the same process of analysis of six overlays (section 5.4.5). Table 5.5 gives area wise distribution of classes in each layer. The final product, Regional Development Model : GCR 2050 is displayed in Fig 5.15.

Table 5.5 : Table showing area wise details of proposed Regional Development Model GCR 2050

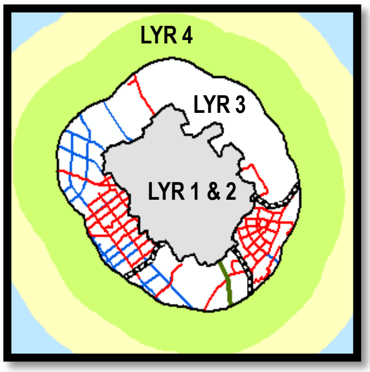
	Total Area (sq km)	**Agricultural land**	**Existing Settlement**	**Forest land**	**Afforestation (Proposed)**	**Urbanisation (Proposed)**
LAYER 1	55.80	-	55.80	-	-	-
LAYER 2	59.11	9.9	29.57	9.81	-	9.83
LAYER 3	235.17	-	86.69	70.31	-	78.17
LAYER 4	322.11	53.14	11.55	107.17	-	150.25
LAYER 5	421.57	172.61	8.83	102.71	43.38	94.04
LAYER 6	521.73	252.28	15.29	129.55	56.13	68.48
	1615.49	**487.93**	**207.73**	**419.55**	**99.51**	**400.77**



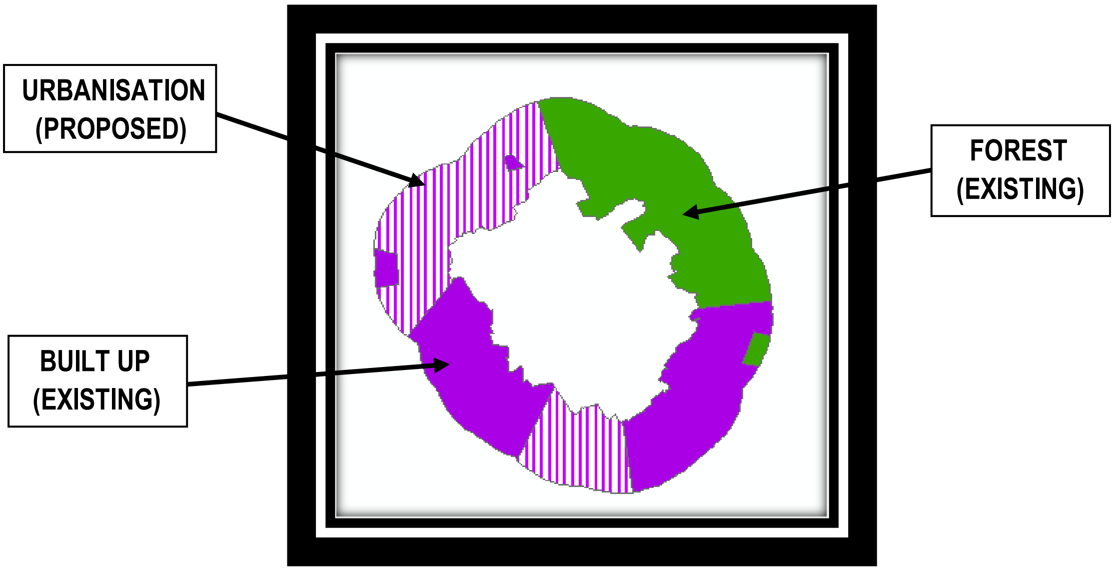
LULC Overlay



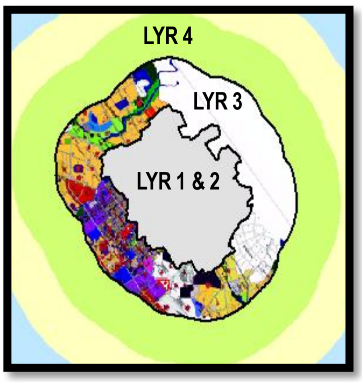
Topographical map sheet overlay



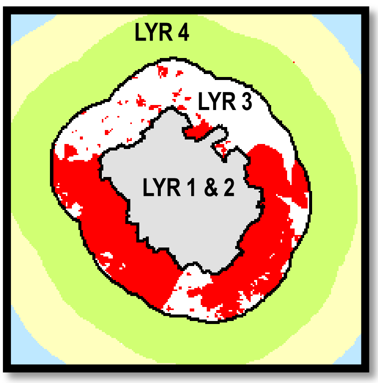
Road and rail overlay



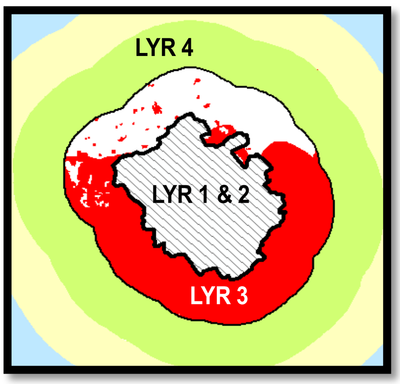
Layer 3 of proposed development model classified into Forest, Builtup,and Urbanisation (Proposed) classes. Other two classes - Agriculture and Afforestation (Proposed) do not exist in this layer.



GMR plans overlay

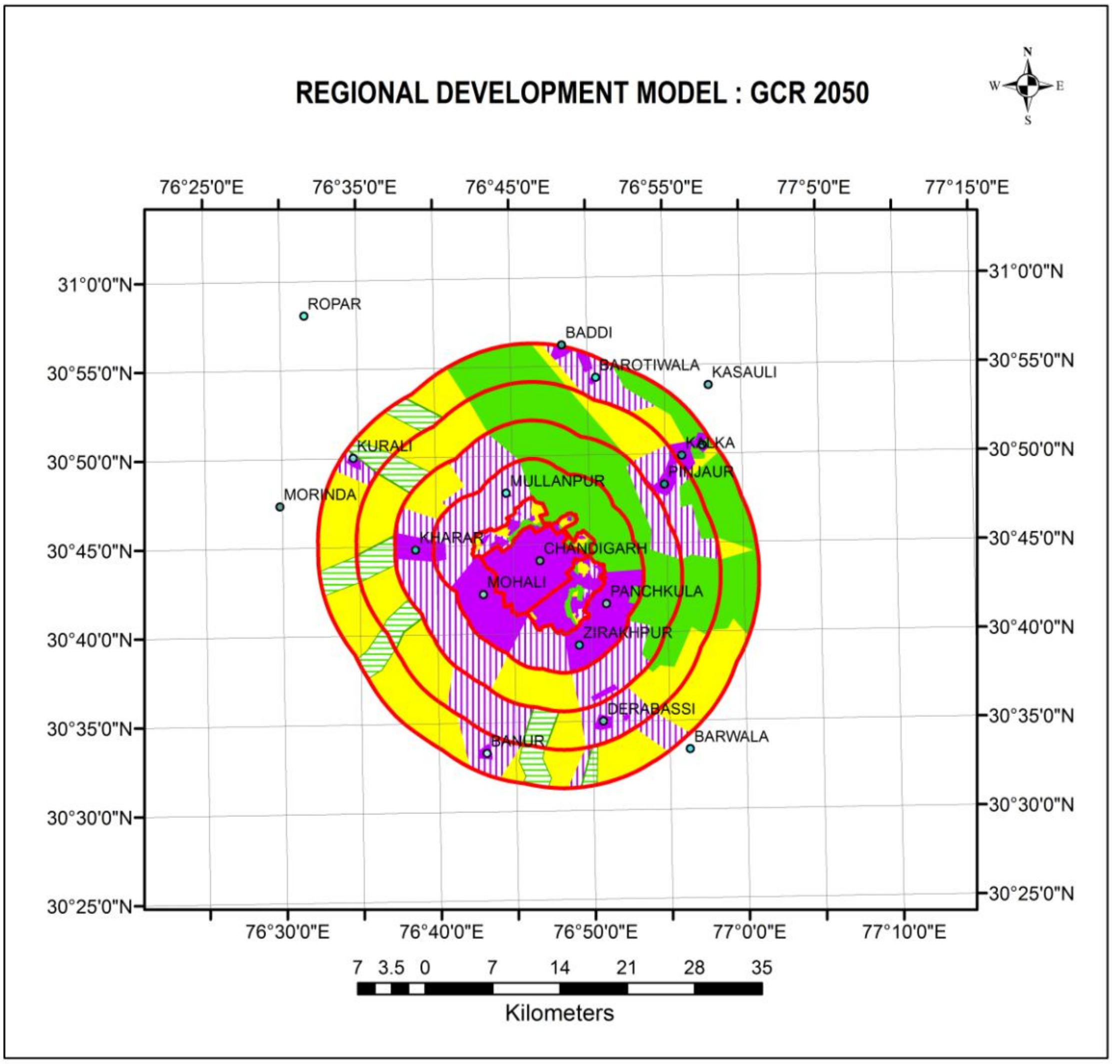


Projected Builtup 2024 overlay



Projected Builtup 2048 overlay

Fig 5.14 : Evaluation process to classify Layer 3 of Regional Development Model : GCR 2050
Inputs from six overlays (area bounded by layer 3) are evaluated to finally divide Layer 3 into five classes



Layers (Bounded in Red)

LAYER 1 : CHANDIGARH (UT) , SECTOR 1 TO 56
LAYER 2 : REST OF CHANDIGARH
LAYER 3 : BUFFER OF 4 KM FROM UT
LAYER 4 : BUFFER OF 4 TO 8 KM FROM UT
LAYER 5 : BUFFER OF 8 TO12 KM FROM UT
LAYER 6 : BUFFER OF 12 TO 16 KM FROM UT
LAYER 7 : AREAS BEYOND 16 KM (NOT DEFINED)

Classes (Colours as given below)

AGRICULTURAL LAND
EXISTING SETTLEMENT
FOREST LAND
AFFORESTATION (PROPOSED)
URBANISATION (PROPOSED)

Fig 5.15 : Regional Development Model : GCR 2050

The Regional Development Model has **seven layers**. Here, six layers have been delineated, seventh one being beyond the scope of current study. Each layer has been classified in **five classes**. The last two proposed classes balance out the need for urbanisation and environment in the region.

6. DISCUSSION

6.1. GCR and Status of Urban Development in India

6.1.1. Guidelines for Urban Development Plans Formulation and Implementation (UDPFI)

With the Seventy-Fourth Constitutional Amendment Act (74th CAA),1992, the Urban Local Bodies in India have a constitutional status and are empowered to function as local self-governments to provide good urban governance. UDPFI guidelines were evolved during a National Workshop held at Delhi in 1995 for administrators and municipal town planners that took note of the existing deficiencies of Master plan approach. However, these deliberations fall short of the requirements of evolving a regional plan such as GCR which has to be an inter state venture.

6.1.2. Hierarchy of Plans and Inter State Regional Planning

As per UDPFI guidelines, urban centres have been classified as Small Towns, Medium Towns and Large Cities as per population range, and depending on whether the area concerned is in plains or hills. Again, the hierarchy of planning starts with a Perspective Plan, which is a long term policy plan looking at 20 to 25 years of spatio-economic development of the settlement. The plan formulation and approval process for the same is executed at the State Government level through the State Chief Town Planner. *But, for the formulation of any inter state regional plans, such as GCR or NCR plans, specific mechanisms do not exist in UDPFI*, although paragraph 9 touches upon the need for a regional approach in such cases. Thus , *there is a void in case of inter state regional planning models such as GCR, which needs to be addressed, both, administratively as well as legally.*

6.1.3. Need for Enabling Legislative Provisions for GCR/CISR

At present there is *no legislative provision* under which a regional plan like GCR/CISR may be formulated. In the meanwhile, the Govt of Punjab, sensing a necessity to check haphazard and unplanned growth in Mohali and other areas adjoining Chandigarh, and perhaps also visualising an unexplored opportunity in it, proceeded with enactment of *Punjab Regional Town Planning & Development Act, 1995.* Chapter 9 of this Act provides for preparation of a regional plan, including delineation of the region and notification of the regional plan. In 2006, Mohali district was carved out to execute Greater Mohali Regional (GMR) plan. This has created a piquant situation with one state proceeding with planning of an area which is verily, only a sub region of GCR, while sub regions north and east of Chandigarh could not be subjected to planning process due to lack of enabling provisions with Chandigarh and Haryana. Thus a comprehensive and balanced development of the entire region is yet to be executed. The *Concept Note* therefore rightly mentions the need to frame a comprehensive Chandigarh Region Planning Act for Chandigarh and its neighbourhood, which should have the provision for preparation of Master Plan and Chandigarh Inter State Region Plan, as also the constitution of Chandigarh Planning Board.

6.2. Further Applications of the Current Study

6.2.1. Development of Roads, Highways and Expressways

In this section, a method has been demonstrated to show how the current study can be extended to analyse

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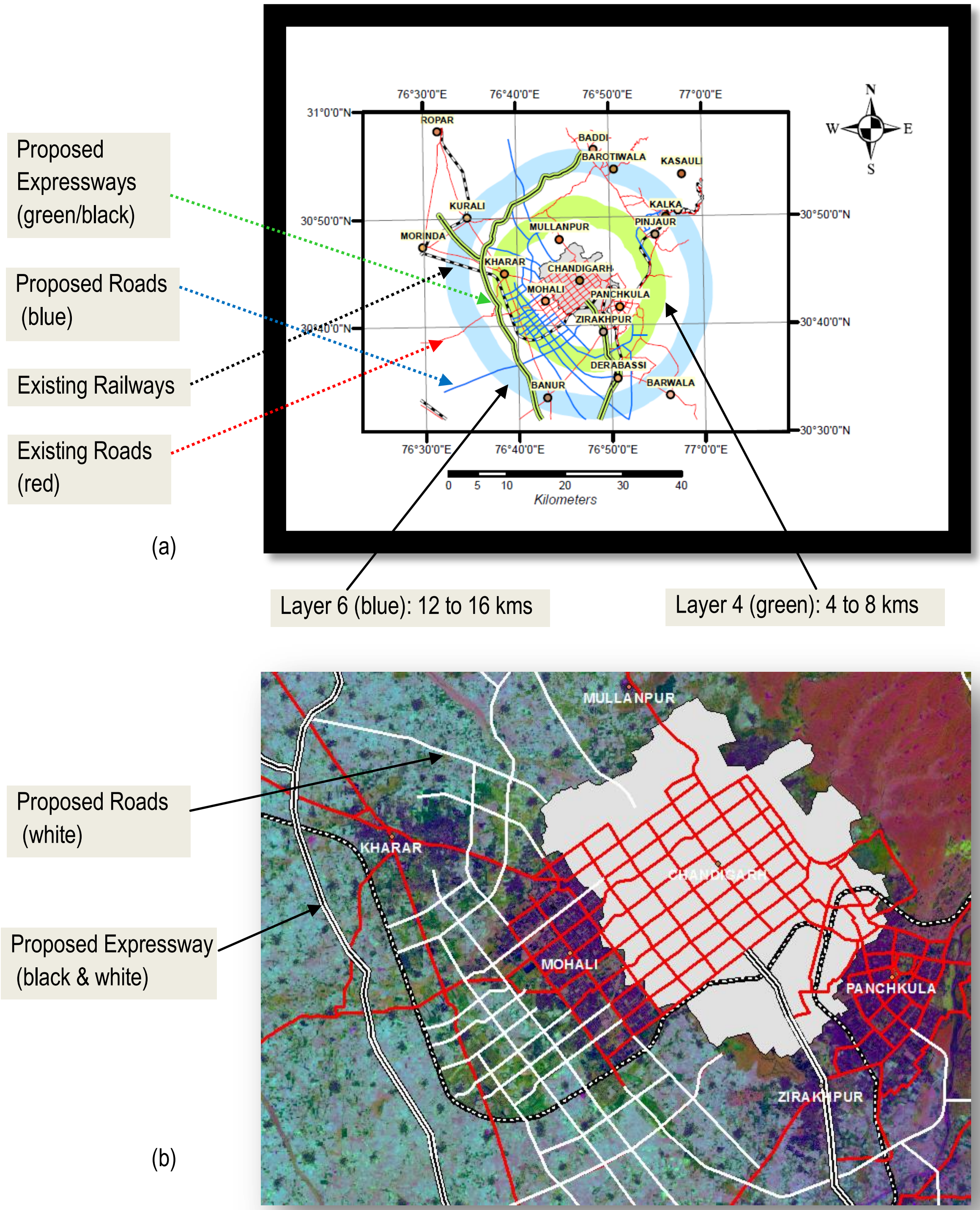


Fig 6.1 (a) and (b) : Analysis of Proposed Roads/ Expressways Infrastructure

any major aspect related to planning of the region. Figure 6.1(a) analyses feasibility of proposed roads and expressway against a hybrid satellite image in which settlements, agricultural land and barren land is visible clearly. In Fig 6.1(b) proposed roads and proposed Expressway are analysed in GIS environment for their impact on regional settings. It has already been demonstrated that Layers 3 and 4 are high growth zones and will be subsumed by urbanisation in next three decades. It would therefore be not suitable to plan an expressway in these layers, as it may lead to further acceleration of Chandigarh centric urbanisation. It is observed that GMADA proposal of Expressway is placed in Layer 5 (8 to 12 kms) west of Chandigarh which is quite appropriate, as it is further away from Chandigarh and additionally, links northern Himachal Pradesh with southern Punjab. Thus, the proposed Expressway is analysed as beneficial for balanced development in GCR. Similarly any other proposal may be analysed critically using geospatial analysis as above to reach a decision on the same.

6.2.2. Mass Rapid Transport System for the Region

A study on comprehensive mobility plan for Chandigarh urban complex, viz, tricity and adjoining areas has been conducted by RITES Ltd, which has suggested medium and long term traffic and transport plan. Suggestions have been given on mass transport system, metro system network, bus rapid transit system (BRTS) and commuter rail system. The accompanying data is very valuable as an input for a comprehensive geospatial analysis, which can be done on lines as demonstrated in sub section 6.2.1 above.

6.3. Environmental and Social Issues

6.3.1. Afforestation

This study has proposed to bring an area of approximately 100 sq. km. of GCR under afforestation alongside 400 sq. km. of urbanisation. A closer visit on ground amply supports this recommendation. Everywhere in the region there is a decline in tree cover. Most of the non urbanised area is taken up for agriculture and there seems to be little incentive in pursuing pro environment issues like afforestation. Land recommended for afforestation lies on both sides of seasonal rivulets or 'choes'. It has also been factored that earmarked areas are in Layer 5 and layer 6 which are unlikely contestants for urbanisation. It is well recognised that most of this land is in private hands. Therefore innovative methods have to be applied to incentivise such a proposal. If need be, provisions be made for the same while bringing legal enactment of CISR/GCR Planning Act. If need be, an 'Afforestation Cess' may be made applicable in all restaurants and hotels of the region. The ratio of Existing Settlements: Existing Forests in GCR is 1:2 in favour of forests (208 sq km of settlements vs 419 sq km of forests). Therefore, adding 400 sq. km. of urbanisation without any afforestation would seriously effect the environment and micro climate in the long run. Be it as it may, but this study stands by a minimum of in principal ratio of 1:4 afforestation / urbanisation ratio in the long term interests of the region.

6.3.2. Disaster Management : Safety Against Natural Hazards

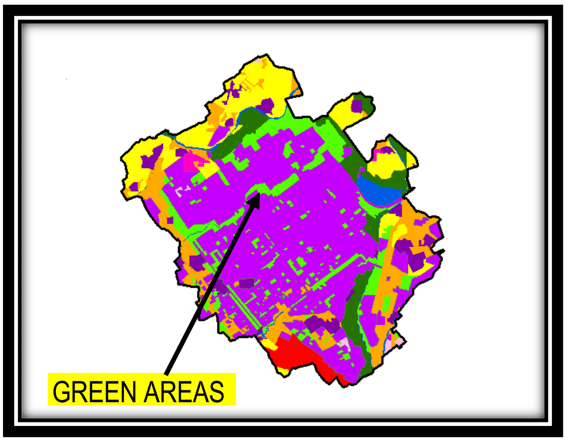
In a regional plan like GCR, different states would be guided by their respective Town and Country Planning Acts. There may be some loopholes in some of these enabling Acts and development control regulations which may be exploited by vested interests and construction lobbies as has been observed during flash floods of Uttarakhand in Jun 2013. To avoid this, a study was conducted in September 2008 under the aegis of Govt of India (GoI), Ministry of Home Affairs, Building Materials & Technology Promotion Council, - UNDP Disaster Management Programme which has come out with '*Suggestive Amendments Pertaining to*

Safety against Natural Hazards in Town & Country Planning Acts, Development Control Regulations and Building Bye Laws of Various States/ UT's (Volume-IV)'. These suggestions are practical and sound, and are therefore recommended to be incorporated while implementing any regional plan like GCR.

6.3.3. Green Spaces and Recreational Parks

LULC of Chandigarh shows a full and continuous run of green spaces all along the flow of seasonal rivlet which has been developed as recreational and leisure belt. Fig 6.2 shows one such park - Shanti Kunj. It is recommended that the same template be extended wherever a seasonal rivulet enters urbanisation belt as proposed in GCR development model.

Thus these choes would have gardens surrounding them in urbanisable areas in layers 3 & 4 and forests along non urbanised areas in layers 5 & 6.



Shanti - Kunj gardens
(Source http://img.readtiger.com/wkp/en)

Green areas as seen in LULC all along the seasonal rivulets running NE to SW in Chandigarh

Fig 6.2 : Green areas of Chandigarh are a model template for an urbanised GCR

6.3.4. Prevention of Slums : Dwellings for Economically Weaker Section

The *Concept note* admits that Chandigarh, even though being one of the well planned cities, did not take into consideration the needs of the informal sector and slums. The way it was planned, it was never thought, that the city may encounter the problem of slums. However, this aspect has been taken care of by Chandigarh Administration now, and similar action should be applicable throughout in GCR (including GMR). A processed product from Satellite imageries showed a unique kind of built up form coming up in the western part of UT, different from existing pattern of development in Chandigarh. During ground verification, it was found to be planned high density residential colony where construction work had reached an advanced stage nearing completion. As per local inputs (not verified from Govt), these dwellings were meant for the residents of Slum colonies No 4 and 5. A further study was conducted to estimate the number of persons likely to be benefited from this allotment using ground photography and imagery. At least 122 builtup blocks are visible in the imagery. Each block has four floors, and each floor has eight dwelling units. Therefore each dwelling unit is likely to cater for 32 families. With average family size taken as 5, each block can accommodate 160 persons. Thus, total estimated population accommodated in these 122 blocks of dwellings is estimated to be 19,200 or approximately 20,000 slum dwellers. Fig 6.3 amplifies the point.

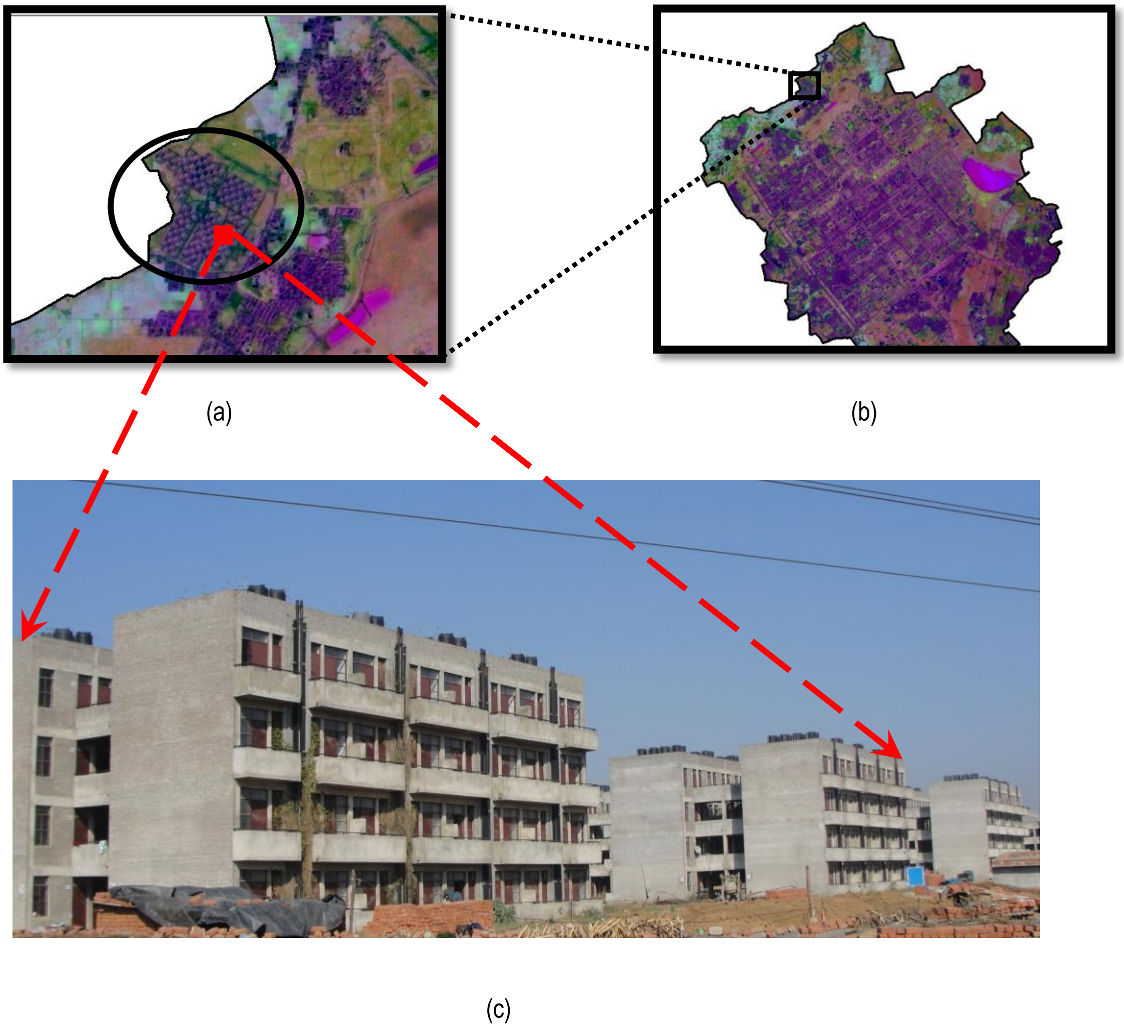


Fig 6.3 : High density residential colony for slum dwellers planned by Chandigarh Administration

A unique high density urban form was identified in imagery (b) and was zoomed in for further investigation, as seen in imagery (a). This was followed by ground verification as seen in photograph (c). A total of 122 blocks are visible in the processed imagery, and each block (c) can accommodate estimated 32 families (of 5 members each). Therefore, an estimated 19,200 (or approximately 20,000) people will be accommodated in this colony. It is strongly recommended that such dwellings for informal sector should be developed in every new urbanisable township of GCR.

7. CONCLUSION AND RECOMMENDATIONS

7.1. Conclusion

7.1.1. Summary of Work Done.

This study has attempted to demonstrate the efficacy of Remote Sensing and GIS as a Decision Support System (DSS) in analysing the cohesiveness of union territory of Chandigarh and adjoining areas in periphery control belt, and has attempted to offer a sound geospatial perspective to the problems of urban planning in the region. The region under study has been referred to as 'Greater Chandigarh Region' (GCR). A number of diverse database sources were tapped as inputs for the study. Multi sensor, multi resolution, multi temporal satellite images were processed digitally to prepare a number of hybrid products of 5 to 6 metres resolution for three time periods, which would be useful in identification of not only various built up forms, but also, all other types of land-cover significant to the study. Through careful visual interpretation of the region in terms of the classification scheme relevant at regional level, three temporal LULCs, of years 2000, 2006 and 2012, were digitised at 1:10,000 (and higher) resolution. The vector products were used to identify areas of urban physical growth between the three given time periods. These LULC features, which were prepared in Arc GIS, were exported to *IDRISI Taiga* software for further raster analysis. A study was carried out, as first objective, to identify the drivers of urban (physical) growth and their exact mathematical relationship with this growth. Using these drivers, in the second objective, two prediction models (CA_Markov and MLP) were tested on data of 2000 and 2006, and predicted results of 2012 were validated against actual data of LULC 2012. The best suited prediction model, viz, MLP, was applied on Built up (BU) thematic maps of 2000 and 2012 to predict the thematic BU maps of 2024 and 2048. These two output templates, viz, BU 2024 and BU 2048, were then used as crucial inputs to understand and address the next objective, viz, delineation of the region. The observations of *Concept Note* of Govt of India were taken forward to complete the delineation of region in a systematic manner. Seven layers of the region were identified, and six of them were geographically delineated, seventh being beyond the scope of the current study.

7.1.2. Implications on Future Work

An innovative ***Regional Development Model : GCR 2050*** has been built upon these six layers, by classifying each layer in five categories and examining each layer against several geospatial inputs (evolved earlier during the study), viz, Builtup scenarios of BU 2024 and BU 2048, the (current) LULC 2012, projected master plans of neighbouring towns/cities and the road infrastructure development proposals (by states in the neighbourhood of Chandigarh). The development model brings out two key policy issues, that of environment preservation and continued urbanisation, and attempts to strike a balance between them. Having achieved all the objectives satisfactorily, the study goes further to demonstrate how it can be extended to analyse any geospatial input that may have a bearing on the GCR planning. Taking plans of *Greater Mohali Region (GMR)* as sub regional inputs for GCR, the study evaluates one aspect, viz, proposal to build an expressway (by GMR) within GCR, and concludes the development as beneficial for GCR also. In the final run, the study draws its focus on issues concerning environment, and exhorts the regional planner to use innovative means to preserve and extend the forest cover along the seasonal rivulets in layers five and six, and to develop similar areas as green/recreational parks in layers three and four (where urbanisation is predominant and afforestation is not feasible). An observation, in passing, has also been made on the need to cater for dwellings for the informal sector in the evolution of any regional plan, on lines of what the Chandigarh Administration is currently undertaking in its western part.

7.2. Recommendations

During the pursuance of this study, a number of salient aspects have come to the fore which would be academically relevant to any other study of like nature. To begin with, this is a first of its kind in India, which deals with geospatial analysis of an inter state regional plan, giving an academic / intellectual perspective into regional planning, rather than presenting a plan *per se* (as is done in turnkey projects of Govt., usually by professional consultants). It uses cutting edge technology of space applications, digital image analysis and GIS analysis including raster based prediction models, and links them to the usual tools of planning like existing maps, existing master plans and development proposals to arrive at a technically sound planning perspective. Its relevance could not be lost to the administrators involved in planning, who could use such studies to articulate technical queries to the regional planner or the GIS expert, who may have been co-opted in the process of regional planning. Keeping the above in view, certain recommendations are being made as under :

7.2.1. Relevance of Preparation of LULC maps

This is perhaps the most crucial building block in any conventional RS & GIS application. *And perhaps the most taken-for-granted work.* The tendency to rely on any ready made data can prove fatal for the outcome of any serious urban studies. A deeper thought needs to be given to the Classification Scheme adopted, as no two studies may have same requirements. Moreover, automated classification procedures like supervised or unsupervised classification are hardly workable in urban studies, and object based classification algorithms are still in nascent stage of development, given the extreme heterogeneity observed in any regional landscape like GCR. It, therefore, took almost three months to prepare the three LULCs by visual interpretation in this study, using a set of hybrid image products, but ultimately the efforts did bring commensurate results.

7.2.2. Use of Projection Systems and Reference Geoids in Master Plans

Remote Sensing and GIS are here to stay, and will be increasingly used by urban planners all over the world in times to come. In order that their work may be GIS-transportable, time has come for architects and planning professionals to switch to more acceptable usage of GIS terminology and reference standards. A Master Plan built on UTM projection with a WGS geoid would later lend itself usable for any other urban application using space based technologies, like a Utilities Map built on top of a Master Plan. This will also help in avoiding large scale errors prevalent in previous low technology methods for area estimation by the Government or real estate management, as has been brought out in para 5.1.1 of the results.

7.2.3. Cadastral Map and Regional Planning

From the viewpoint of technology upgradation, conversion of cadastral 'maps' into maps that maybe correctly geo-referenced (with acceptable RMS error) is perhaps the *biggest inter-departmental challenge* facing all agencies dealing with real estate, urban planning, regional planning and revenue planning in all developing countries. Because of their inherent gross errors, this study could not rely on any cadastral maps. Cadastral /revenue maps are not maps by any standards, and are the most unreliable source of area estimation, although they continue to be the only authentic documents recognised by the law of the land. The solution, however, does not lie in the hands of Revenue Administration. An inter ministerial technical group, including representatives of Department of Space, Survey of India (and its parent ministry- Ministry of Science and Technology), along with concerned state revenue records, duly supported by the academic world, will have to contribute their efforts to find a feasible solution to arrive at *Planimetric Cadastral Maps* that are usable by the Regional Planner. As of date, a regional plan cannot be accurately and seamlessly broken down to the level of a cadastral map. Nor can the bottom to top approach work, working upwards from cadastral map to regional map be executed, even when technology exists to view any rectified high resolution satellite imagery, corresponding to the same regional map, to sub meter accuracy. The hierarchy of all urban plans, from regional to cadastral, therefore exist in their independent and exclusive domains. Their inter-operability needs to be worked out.

7.2.4. Legislation for a Regional Plan for CISR/GCR

It has been brought out by the *Concept Note* of the Govt that there is a need to bring a legislation for preparation of a Master Plan /Zonal Plan for Chandigarh. Punjab and Himachal Pradesh have the required legislation for preparation of a Regional Plan, whereas Chandigarh and Haryana do not. The case of Chandigarh is similar to that of NCR, and therefore, the Chandigarh Region Planning Act must be prepared on similar lines. However, the weaknesses observed in the case of NCR Planning Board Act, 1995 must be avoided in the proposed Act. For example, the proposed Act must have provisions for Chandigarh Administration to intervene, if the sub regional plan of state is not being implemented in a time bound manner. As on date, the situation as it exists, gives all the powers to Punjab and Himachal Pradesh to enact its sub regional plan, and practically no power to Chandigarh even if some of these proposals, by omission or commission, render themselves unacceptable to the larger regional interests of the GCR. A case in point is the unplanned /haphazard execution of development projects in Baddi area in Himachal Pradesh, parts of which are included in Zone 2 of CISR or Layer 6 of GCR, i.e, well within the16 km periphery control belt.

7.2.5. Areas to be Included in Zone 3 of CISR / Layer 7 of GCR

Some of the options to include areas in Zone 3 are as under :

(a) Those areas of Punjab which are outside periphery control belt but included in GMR plans, e.g., areas south west of Banur.

(b) Barwala town and adjoining areas of Haryana.

(d) Parts of Baddi area left outside periphery control belt.

(e) Inclusion of entire Panchkula district in GCR.

However, in order to arrive at an appropriate solution to this question, (which was left out by this study, keeping in mind its scope and restrictions), further study needs to be carried out.

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