AN ASSESSMENT OF URBAN SPRAWL USING GIS AND REMOTE SENSING TECHNIQUES: A CASE STUDY OF PUNE – PIMPRI - CHINCHWAD AREA

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By

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DECLARATION

I hereby declare that the thesis entitled **"An Assessment of Urban Sprawl using GIS and Remote Sensing Techniques: A Case Study of Pune–Pimpri Chinchwad Area"** *completed and written by me has not previously formed the basis for the award of any degree or other similar title of this or any other University or examining body.*

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Place

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CERTIFICATE

This is to certify that the thesis entitled, **"An Assessment of Urban Sprawl using GIS and Remote Sensing Techniques: A Case Study of Pune–Pimpri Chinchwad Area."** *Which is being submitted herewith for the award of the Degree of Vidyavachaspati (Ph. D.) in Geography of Tilak Maharashtra Vidyapeeth, Pune is the result of original research work completed by* **Mr. Santosh A. Bhailume** *under my supervision and guidance. To the best of my knowledge and belief the work incorporated in this thesis has not formed the basis for the award of any Degree or similar title of this or any other University or examining body.*

Dr. Virendra. R. Nagarale
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A Case Study of Pune Pimpri - Chinchwad Area

Abstract

The thesis includes the findings and results of Urban Sprawl and Utility services, carried out in the Pune and Pimpri-Chinchavad, Pune district in Maharashtra.

Pune and Pimpri-Chinchwad area lies between 18° 25' to 18° 42' North latitude and 73° 42' to 73° 57' East longitude. The study area covers 414.90 sq. km. Pune (PMC) area covers 243.31 sq. km. composed of 144 general electoral wards according to 2007 which comes under 14 administrative wards of Pune Municipal Corporation. The city is located in saucer shaped basin at an average altitude of 560 m. above mean sea level. The area surrounded by offshoots of Sahyadri hills and extends from west to east. Pune is slightly hollow on the banks of Mula and Mutha Rivers on Deccan plateau.

Urban sprawl is defined as the scattering of new development on isolated tracts, separated from other areas by vacant land ((cf), Shekhar, 2005). This result in increase in the built-up area and related changes in the urban landuse patterns, causing loss of productive agricultural lands, forest cover, other forms of greenery, loss in surface water bodies, depletion in ground water aquifers and increasing levels of air and water pollution; causing environmental problems. The process of urbanization is affected by population growth and migration. Infrastructure initiatives result in the growth of villages into towns, towns into cities and cities into metros involving large scale migration from rural to urban area. Sprawl is considered to be an unplanned outgrowth of urban centers along the periphery of cities, along highways and along the roads connecting to a city (Sudhira, et.al, 2003).

The PCMC (Pimpri - Chinchawad Municipal Corporation) 94.4 % recorded the highest growth of population according to 2001 Census in Maharashtra, which is the part of Pune Metropolitan region. This is mainly due to the rapid growth in the Information Technology sectoral region. Between 1991 and 2001, the growth has doubled to 62.17 % in Comparison; Pune district has a growth rate of 38.58 %, while the state is experiencing the growth rate of 22.5%. Therefore it is necessary to add the past and present growth trends of these rapidly growing cities, for effective urban management (S. Shekhar, 2005).

For healthy and happy living provision of adequate amenities, facilities and public utility services are essential as they enhance efficiency and economic utilization and time. In order to prepare development plan for utility planning of a city, there is a need of good and reliable information regarding location of existing facilities, their accessibility, adequacy and development trends in relation to socio – economic structure of the city.

Pimpri-Chinchwad (PCMC) area covers 171.59 sq. km composed of 105 general electoral wards according to 1997 which comes under 4 administrative wards of Pimpri-Chinchwad Municipal Corporation. The PCMC is situated in to the Northwest of Pune on the Mumbai-Pune National Highway at an average altitude of 530 to 566 m. above mean sea level. The east-west ridge running midway between Indrayani and Pavana rivers separate this area into two parts. The northern portion gradually slopes towards Indrayani river while the southern portion gradually slopes towards Pavana river.

The precise **aim** of this present study is to find out urban sprawl in Pune city and suggest planning to provide utility services. In order to serve this aim, following **objectives** have been put forth.

➢ to study existing landuse/landcover using satellite imagery in Pune – Pimpri-Chinchwad

➢ to identify various utility services of Pune – Pimpri-Chinchwad area.

➢ to implement the Utility and Planning for future urban sprawl in terms of services

In order to understand Urban Sprawl of Pune and Pimpri-Chinchwad, the **methodology adopted** for the present study was divided into following phases.

1. Library work: Exhaustive literature survey of the topic of investigation was undertaken. Published Literature, Reports were collected from various libraries, institutes; Govt. departments etc. Besides, using relevant literatures had also reference books, Bulletins, Review etc. were studied procure on internet.

2. Prefield phase: Includes collection of different maps, Satellite imageries (LANDSAT ETM+ and IRS P6 LISS III data were used to map the extent of sprawl for 1980 to 2008), topographical maps. Collection of non-spatial data, utility services data details were obtained from PMC and PCMC.

3. Field work: This phase includes visit to the study area and its fringe areas in different seasons, GPS surveys, instrumental surveys, photographs, surveys etc. were

carried out in the sprawl. It facilitated to understand the complexities of a dynamic phenomenon such as urban sprawl, land use changes, urban sprawl pattern.

4. Laboratory work: Includes the digitization of various layers, preparation of maps and other GIS/RS techniques.

> i.e, Georeferencing, Digitization, Attribution, Data attachment, Overlay analysis, Superwised and Unsuperwised classification, Final layouts of different maps were analyzed.

5. Synthesis of the data, Report writing and submission: The data generated during the field, and laboratory studies was synthesized, interpreted and are incorporated in this thesis.

The Approach:

By adopting the above methodology and with defined objectives the entire work has spread over six chapters. The contents of all six chapters are briefly presented below.

First chapter deals with the introduction to the topic, basic concept of Urban Sprawl, its definition and relation with utility services. Occurrence of Sprawl in general and occurrence of sprawl in Pune and Pimpri-Chinchwad have been also discussed briefly. A major component of this chapter is devoted to the introduction of the study area, criterions for the selection of the study area, aims and objectives and the literature Survey. Literature survey and part of this chapter deals with the urbanization, urban planning, urban transport and utility services. Review of modern techniques and methodology adopted for the study is also discussed in detail.

Second chapter comprises the profile of the study area that gives a detailed account of location, extent and aerial coverage of the Pune and Pimpri-Chinchwad in the Pune District, (Maharashtra, India). Physiography and climate of the Pune and Pimpri-Chinchwad. Built-up, landuse, transportation, communication and population characteristics of the Pune and Pimpri-Chinchwad are also discussed in the last part of the chapter to know about socio-economic status of the Pune and Pimpri-Chinchwad.

Third chapter contains database and methodological approach for the monitoring and measurement of sprawl in study area. Methods are given in the beginning of the chapter.

Fourth Chapter under the title 'An assessment of urban sprawl' the LANDSAT ETM+ and IRS P6 LISS III satellite data were used for the monitoring and measuring the sprawl of Pune and Pimpri-Chinchwad over different periods of time from 1980 to 1992, 1992 to 1999, 1999 to 2004 and 2004 to 2008.

Fifth Chapter focuses on the utility services like transportation, hospitals and educational facilities in Pune and Pimpri-Chinchwad area.

Chapter six gives the summary, results and conclusions drawn from the study. It also focuses on the significance of urban studies in unplanned cities. The concluding remarks of the study can be certainly taken into consideration while implementing urban planning, transport planning, utility services planning at Pune and Pimpri-Chinchwad area

.

CONTENTS

List of Figures

List of Tables

List of Diagrams

List of Photos

Chapter I

INTRODUCTION

1.1 Introduction

Food, clothing and shelter are three basic necessities of human beings. Among them clothing is less important. Food and shelter, however, are almost of equal importance. With rapid increase in population during last 100 years, these two have emerged as two most important problems before the society. Security of housing accommodation has problem in both rural as well as urban areas. Due to rapid industrialization and consequent large scale rural-urban migration, housing accommodation has become an acute problem in areas. This is an attempt to understand precisely the nature of this problem. Efforts are being made to solve this problem at individual as well as at mass level.

The houses are constructed and settlements are proposed to protect themselves against the vagaries of weather and to enjoy social life. In fact, settlement is important step towards adopting physical environment. The problem of rural and urban settlements has been increasingly probed by anthropologists, sociologists, ethnographers, economists and geographers. They are however, examined this issues with different objectives and methodologies.

In ancient period urban settlements originated and then developed with considering changes in social, political, religious and historical conditions. Specific settlements get benefits from location, climate, relief, soil, and water supply etc. Some settlements have the central place or nodal place and some settlements are located along the road sides. These settlements naturally get the facilities like health, plenty water, suitable land for settlements and protectable relief from the surrounding area. The types of settlement develop physical personality of the region and functional multiplicity. Hence, the initial state smaller settlements slowly go through the various stages and evolved into town or city. Burgess in 1923 has studied the growth of the city. This study related to the model regarding landuse in city. The concentric zone model was inductive and based on the number of American cities in general. This model consists of six zones away from centre. The Burgess model is applicable only to older and larger cities of western or developed countries. Newer, smaller and rapidly growing cities do not follow such concentric zone pattern. This model excludes wide variety of factors which affect the urban landuse. Sector model

suggested that which is an extension of Burgess Model studied entitled "The structure and growth of residential neighborhoods in American cities (Homer Hoyt 1939). Theory and proposed a new model for the further modification, namely, the multiple nuclei model in 1945 both the concentric zone theory and sector theory were based upon the argument that the city develops around a single centre. ((c.f.), Patil S. 2010)

1.2 Urbanization

Urbanization is a process of villages to be developed into towns and further into cities and so on. There is no universally accepted definition of urban settlement. Different countries adopt different criteria for defining the urban settlement. Urban places are not even similar in character. This can be distinguished on the basis of defined demographic characteristic and available infrastructures. In India, criteria of urban centers are more or less similar to the ones suggested by the United Nations. In Census of India (1961) has defined urban centers as "Places having a minimum population of 5000 with at least 75 percent of male workers being engaged in non-agricultural activities and the density of population should be 400 persons per square Kilometers". According to Trewartha, the level of urbanization is defined as the proportion of urban population to total population residing in urban places by shifting population from village to city and the process of transformation of villages into city is called urbanization. Urbanization is broadly defined as a growth of towns and increasing ratio of urban to rural population of a country. The growth of a country's towns and cities is conditioned by the natural, economic and social progress. The concept of urbanization as a set is related to the socio-economic process which implies a shift in focus from the city as a cultural aspect to process that leads to the expansion of cities and generate and diffusing element of urban life and culture. Urbanization and modern civilization go together for in developing stage due to increasing economic specialization and advancing technology. The simplest and most common definition of urbanization is "Proportion of population living in urban settlement to total population". Geographers have studied urbanization as a process of concentration of population in larger human settlement either through multiplication or concentrated. However, urbanization is not merely a demographic phenomenon. It has its economic and other concomitant at the same time. It is a special concomitant phenomenon involving the complex process of change involving population

concentration, structural transformation and socio-psychological change affecting both people and places by following dimensions:

I)   A progressive concentration of people and activities in towns and cities, thereby increasing the general scale of settlement

II)   A change in the economy of a country or region, whereby non agricultural activities become dominant

III)   A change in the "structural" characteristics of population (Lower birth rates, higher death rates, positive migration balances etc.).

IV)   A change in the social , psychological and behavioral patterns of the people overtime to adopt an 'Urban Way' of life i.e. Urbanism as a way of life and the spread of urbanism beyond the built up areas of towns and cities, thereby inducing rural dilution

V)   The transmission or diffusion of change (Economic, social and technological) down the urban hierarchy and into rural areas, urbanization does not always take the same form, nor does its progress at the same rates everywhere

Urbanization is regarded as a complex process. It leads society towards the industrial and technological enrichment. The understanding of the growth dynamics of urban settlements at different levels becomes the primary requirement for any explanation of emerging pattern. The concept of urbanization as a process of change and transformation is yet in the stage of evolution through the verge and more in developing countries. Urbanization challenges for government and city authorities and struggling for various services for rapidly increasing city population. Urban population brings a critical need to look for new ways? Many strategies to reduce poverty tend to focus on rural poverty, ignoring the differing need of poor urban dwellers. The need of improve the lives of urban dwellers has been recognized in the United Nations. Millennium development goals, which pledge to achieve significant improvement in the lives at least 100 millions slum dwellers by 2020. In India, urbanization has occupied vital role in economic development of different regions. Urban development is a direct and immediate concern to 27 percent population who live in towns and cities 'India lives in huts and cottages of olden days. But it also proved that India has a tradition of urban living and town planning which goes back to 3000 B.C. The cities of Indus valley civilization, Mohanjodaro and Harappa, which flourished in 3000 B. C., were large and well planned. The Indus valley people had

attained high standard of town planning and architectural signs. Hence, India's urban tradition has continued through centuries and during the ancient period of our history when there were well planned and beautiful cities in different parts of country. Patliputra of Chandragupta Mourya, Ujjain of the Gupta's Kannauj, Banaras and Mathura were some of the great cities found in northern India. In south India, the cities were established in medieval period by the Chalukya, the Rashtrakut, the Chola, the Hoysala and others. However, urban tradition of south has continued through Vijaynagar which flourished during the fifteenth and sixteenth centuries to modern Mysore and Bangalore. It is imperative in modern world the settlement may develop continuously by increasing growth of population and facility in urban areas. India is a developing country showing rapid urbanization. India has long history of urbanization in term of absolute number of towns and cities and size of urban population. India's urban population in 2001 was 286 million living in towns and cities. The present urban hierarchy, both administrative and economics and interdependence among cities and towns have led to the formation of present urban system routed in British colonial era. The urban system has been found to be highly distorted being dominated by large metropolitan centers leading to hypertrophy like Mumbai in west, Kolkata in east, Delhi in north and Chennai in south. The urban system has developed around these four distinct metropolises in response to its politico-economic system, transport and communication and level of economic development.

The unprecedented growth of towns and cities in India has been a result of modernization process causing rapid growth of agriculture and industry. About 27 percent of India's urban population was accounted in 2001 with 286 million people nearly as many as the entire population of the U.S.A. There are areas of high urban growth which are push created by out migration from poor rural regions. By contrasts, states like Punjab, Haryana, Rajasthan, Tamilnadu, Uttar Pradesh and Bihar. Urbanization is pool created by dynamic urban expansion. Until 1931 urbanization in India was slow and halting due to low rate of economic development. India's level of urbanization in 1901 was roughly comparable to that of United States in 1830. Since 1931 the rate of urbanization has quickened and in 2001 Census it has increased to 286 million persons.

Today, industry is the most dominant factor of urbanization. It has accelerated the process of rural–urban migration and the creation of new and enlargement of existing urban centers. In a country like India, the level of urbanization is related to

the degree of industrialization. Maharashtra State is one of the urbanized states in India accounting one third of its population lives in towns .This stands in sharp contrast to 16.59 percent of its population living in towns; at the turn of the twenty first century. In fact the population living in towns today is more than that of total population of Maharashtra State in 1911. During the period from 1911-2001, urban population of Maharashtra has increased thirteen-fold and last two decades are critical where urban population of the state became double. More than half of the total urban population of Maharashtra state lives in three large towns, viz. Mumbai, Pune and Nagpur accounts for over 40 percent of Maharashtra's urban population. The earliest towns of Maharashtra State, namely, as Paithan, Junnar, Karad and Devgiri were governed as administrative and defence centers due to their strategic location. Solapur, Barshi lying in Bhima valley, Satara in Krishna valley and Nandurbar, Dhulia in Tapi valley as market centers. Nasik, Pandharpur and Trimbakeshwar are religious centers. The towns of Maratha were Sangli, Kurundwad, Kagal, Ichalkaranji, Miraj, Phaltan, Bhor, Aurangabad, Poona, and Mumbai too.

Urban geography is rapidly growing sub-discipline of human geography; it increases rapidly after Second World War. A systematic study of urbanization is a recent fact in developed countries. In India, urban study has attempted by conducting socio-economic surveys for selected cities. Town planners have conducted specific survey in several cities focusing on the development and trends of urbanization in India. The first review of urban geography was made by Aurousseau in 1924. He commented that urban geography embraces such a large section of human geography that it is hardly a specialization at all. Thus, studying consequence of the problems involved in identifying urban geography as a systematic study. Many Indian geographers have contributed in the field of urban geography.

In the study of municipal geography one mainly studies urban places and the problems associated with urban areas. These problems are of different types and arise due to rapid urbanization. Our cities are increasing at phenomenal rate in other haphazard manner, particularly during recent decades.

The second urban phenomena was associated with the 'Industrial Revolution' in the closing half of the nineteenth century, with new and vigorous dimensions of the development of urban centers. Towards the end of nineteenth century, the world witnessed an unprecedented swelling in proportion of the urban population to the total population. The economically and industrially advanced western countries faced rapid

growth of urban centers. Today 80% of their population lives in urban places and in some western countries and particularly in the U. S., there is also counter urbanization.

On the other hand, the less developed countries have on an average only 34% urban population; but they face rapid growth of urban centers, mainly metropolitan cities, due to economic development and industrialization. It is believed that such countries will have more than 50% of their population living in cities at the end of 20th century.

Rapid Urbanization in the world is quite alarming in the developed countries, as compare to developing countries e.g. Asian countries. Urbanization is the process through which the forests, fertile agricultural lands, surface water bodies are being irretrievably lost, (Pathan, 1991). In India the percentage of people living in cities and urban area almost doubled to 27.78% in year 2001, which was low when compared to developed countries. However, the 28.53 crore urban population living in 27 metros, 396 cities and 4738 towns is more than the total population of developing and developed countries. This kind of uncontrolled, haphazard, low density settlements leads to Urban sprawl.

Urban sprawl defined as the spreading of new development on isolated tracts, separated from other areas by vacant land ((cf), Shekhar, 2005). The result is increase in the built up area and related changes in the urban landuse patterns, causing loss of fruitful agricultural lands, forest cover, other forms of greenery, loss in surface water bodies, reduction in ground water aquifers and increasing levels of air and water pollution; causing ecological problems. The process of urbanization is contributed by population expansion and migration. Infrastructure initiatives result in the growth of villages into towns, towns into cities and cities into metros involving large scale migration from rural to urban area. Sprawl is considered to be an unplanned outgrowth of urban centers along the fringe of cities, along highways, along the road linking a city (Sudhira, et.al, 2003).

The current rapid high level of urbanization at world level is relatively a recent phenomenon. One among six people on this world live in India: After China, India is the second largest populated country and is projected to cross China's population with 1.5 billion people by 2040. India has more population than all of Africa and also more than South America and North America put together.

In year 1901, per person out of 10 used to live in urban areas in India, but by 2001, one out of 4 is living in towns and cities. The urban population in India increased from 62.4 million in the year 1951 to 285.4 million in 2001.

The Maharashtra state is a highly urbanized with 42.40 % of the population in urban areas as against 27.78 % at all India level (Census, 2001).

As per census 2001 an urban area should have

1. A minimum population of 5000.
2. At least 75% of male working population engaged in non agricultural practices.
3. A density of population should be at least is 400 persons /sq km

The PCMC (Pimpri - Chinchawad Municipal Corporation) 94.4 % was recorded highest development of population according to 2001, census in Maharashtra, which is the part of Pune Metropolitan area. This is mainly due to the rapid increase in the Information Technology divisional section. Between 1991 and 2001, the growth has doubled to 62.17 % in contrast; Pune district has a growth rate of 38.58 %, while the state is experiencing the growth rate of 22.5 %. Therefore it is necessary to add the precedent and nearby growth trends of these rapidly growing cities, for effective urban management (S. Shekhar, 2005).

Providing the basic services of civic life, services such as water supply and sanitation, roads and drains, street-lights, collection and disposal of solid waste, maintenance of public places, burial grounds and crematoria, cattle pounds, registration of births and deaths, maintenance of markets have long been seen as the function of municipal bodies. In addition, they performed certain regulatory functions relating construction of buildings, public Health areas such as eating places, slaughter houses and tanneries, etc.

For healthy and happy living provision of sufficient community facilities and public utility services are essential as they enhance efficiency and economic utilization of time. As a matter of fact, there is wide gap between the resource availability and resource need which is reportedly due to the permanent arrival of rural population to urban centres. As a result, the accessible infrastructure gets burdened. One of the major reasons leading to immigration to these big cities is the lack of services in small and medium towns. In order to control such migration, Government has undertaken the Integrated Development of Small and Medium

Towns (IDSMT) project. Under the project community facilities and public utility services have been considered as the most necessary component of urban life. In order to prepare development plan of a city, there is a need of good and reliable information regarding location of existing facilities, their accessibility, adequacy and development trends in relation to socio-economic structure of the city. The process of planning for urban areas involves use of both spatial and non-spatial data. Planners need updated accurate maps and other critical information to prepare useful development plan. In this context, Geographic Information System (GIS) has emerged as the central component in the world's environmental information structure and it will continue to play a fundamental (primary) role in the ensuing decades.

1.3 Conceptual Framework: Urban Sprawl

The urban sprawl means the urban settlements spread towards the rural fringe, i.e., growth of built-up area outside the city limits. In India major metropolitan cities are already saturated due to large scale migration of population. Many big urban centers are facing problems of congestion of city core and in some cases decay also due to saturation within the proper city or the urban limits. This results in pressure on the cities. Fringe areas and nearby villages were start merging and become part of the city due to the process of suburbanization. The rapid growth of population and congestion of the core areas strength of middle class people to settle along the fringe areas and urban sprawl starts, i.e., the outward spread of cities. Slowly the surrounding villages are absorbed and the sprawl further extends outward into a new fringe area, which is a continuous process of expansion of cities. The suburbanization in many Indian cities started with newly added industrial and commercial functions. The cities have developed haphazardly without proper planning, because planning was introduced only after the conditions started failing.

Urban sprawl is defined as the physical pattern of low density development of large urban areas under market conditions into the surrounding agricultural areas. Sprawl life in advance of the principal lines of urban growth and implies little planning control of land subdivision. Development is patchy, scattered and strung out, with a tendency to discontinuity because it leap-frogs over some areas, leaving agricultural enclaves. Its three major forms are low density, continuous development, ribbon development and leap frog sprawl.

Causes of Urban Sprawl - the process of urbanisation is moderately contributed by population growth, migration and transportation initiatives resulting in the growth of villages into towns, towns into cities and cities into metros. However, in such a fact for economically feasible development, planning requires a kind of the growth dynamics. Nevertheless, in most cases there are lot of inadequacies to ascertain the nature of uncontrolled progression of urban sprawls. Sprawl is considered to be an unplanned outgrowth of urban centres along the periphery of the cities, along highways, along the road connecting a city, etc. Due to lack of prior planning these outgrowths are devoid of basic amenities like water, electricity, sanitation, etc. condition of certain transportation facilities like new roads and highways; fuel such sprawls that ultimately result in inefficient and extreme change in land use affecting the ecosystem. With respect to the role of technology in urbanisation, has illustrated a new linkage between transport infrastructure development cycles and spurts in urbanisation. Urban infrastructure development is doubtful to keep pace with urban population development.

Human Causes of Land-Use Change - Land use is obviously constrained by environmental factors such as soil characteristics, climate, topography, and vegetation. But it also reflects the importance of land as a key and finite resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, and water catchments and storage. Land is a fundamental factor of production, and through much of the course of human history, it has been tightly coupled to economic growth (Richards 1990). As a result, control over land and its use is often an object of intense human interactions.

Human activities that make use of, and hence change or maintain, attributes of land cover are considered to be the proximate sources of change. They range from the initial conversion of natural forest into cropland to on-going grassland management (e.g., determining the intensity of grazing and fire frequency) (Schimel et al. 1991; Hobbs et al. 1991; Turner 1989).

Such actions arise as a consequence of a very wide range of social objectives, including the need for food, fiber, living space, and recreation; they therefore cannot be understood independent of the underlying driving forces that motivate and constrain production and consumption. Some of these, such as property rights and the structures of power from the local to the international level, influence access to or control over land resources. Others, such as population density and the level of

economic and social development, affect the demands that will be placed on the land, while technology influences the intensity of exploitation that is possible. Still others, such as agricultural pricing policies, shape land-use decisions by creating the incentives that motivate individual decision makers.

Interpretations of how these factors interact to produce different uses of the land in different environmental, historical, and social contexts are controversial in both policymaking and scholarly settings. Furthermore, there are many theories regarding which factors are the most important determinants. Particular controversy arises in assessing the relative importance of the different forces underlying land-use decisions in specific cases. For example, apparent dry land degradation could be the result of overgrazing by increasingly numerous groups of nomadic cattle herders; an unintended consequence of a "development" intervention such as the drilling of bore holes which increases stress on land close to the wells; or the political clout of groups that, through governmental connections, are able to over-exploit land belonging to the state or local communities (Pearce 1992; NERC 1992). Identifying a particular cause may have implications for the rights of competing user groups or the formulation of policy responses.

Land use is the way in which, and the purposes for which, human beings employ the land and its resources: for example, farming, mining, or lumbering. Land cover describes the physical state of the land surface: as in cropland, mountains, or forests. The term land cover originally referred to the kind and state of vegetation (such as forest or grass cover), but it has broadened in subsequent usage to include human structures such as buildings or pavement and other aspects of the natural environment, such as soil type, biodiversity, and surface and groundwater.

Land cover is affected by natural events, including climate variation, flooding, vegetation succession, and fire, all of which can sometimes be affected in character and magnitude by human activities. Both globally and in India, though, land cover today is altered principally by human use: by agriculture and livestock raising, forest harvesting and management, and construction. There are also incidental impacts from other human activities such as forests damaged by acid rain, from fossil fuel combustion and crops near cities damaged by tropospheric ozone resulting from automobile exhaust.

Information on the spatial spread and monitoring the dynamics of the land use/land cover is the basic prerequisite for planning and implementing various

developmental activities. Apart from this, nation wide land use information becomes important room the point of view of addressing changing pattern in land use/land cover and also an overall reporting on the nation's land use/land cover scenario.

Urban Land Use Suitability - Identification of suitable land for urban development is one of the critical issues of planning. The suitability of land for urban development is based on a set of physical parameters and economic factors. The cumulative effect of this factor determines the degree of suitability and also helps in further categorizing of the land into different orders of development. The assessment of the physical parameters of the land is possible by analyzing the land use, soil, slope, geology, flood hazard, physiography, distance from the road network and railway stations etc. and which very much amenable to GIS analysis. However the assessment of physical parameters gives an identification of the limitations of land for urban development. The concepts of limitation are derived from quality of land for e.g., if the slope is high the limitation it offers is more than for a land, which has gentle slopes or a flat terrain. Practically this would mean that the development of high slope land would require considerable inputs (finance, man power, materials, time etc.) and thus may be less suitable as against the flat land where the inputs required are considerably less. This concept is true for all the land parameters that are assessed. In this particular study 10 such physical parameters have been considered for analysis, which are mostly accepted by urban planners. The parameters are soil depth, soil texture, slope, land use, flood hazard, erosion hazard

1.4 Need of the Study

In industrialised countries the future growth of urban populations will be moderately humble since their population growth rates are low and over 75% of their population already live in urban areas. Conversely, developing countries are in the middle of the transition process, when growth rates are highest. The exceptional growth of many urban agglomerations in many developing countries is the result of a threefold structural change process: the transition away from agricultural employment, high overall population growth, and increasing urbanisation rates. Sprawl is seen as one of the potential threats for such development.

Normally, when rural pockets are linked to a city by a road, in the initial stages, development in the form of service centres such as shops, restaurant, etc. is seen on the roadside, which eventually become the core of trade and industry

activities leading to sprawl. In time a major amount of increase could be observed along these roads. This type of upsurge caused by a road system between urban / semi-urban / rural centres is very much established and constant at most places in India. These regions are devoid of any infrastructure, since planners are unable to visualise this type of growth patterns. This growth is normally left out in all government surveys (even in national population census), as this cannot be grouped under either urban or rural centre. The investigation pattern of this kind of growth is very crucial from regional planning point of view to provide basic amenities in these regions.

The study of this kind reveals the type, extent and nature of sprawl taking place in a region and the drivers responsible for the growth. This would help developers and town planners to project growth patterns and facilitate various infrastructure facilities. In this direction, an attempt is made to identify the sprawl pattern, quantify sprawl across roads in terms of Shannon's entropy, and estimate the rate of change in built-up area over a period with the help of spatial and statistical data of nearly three decades using GIS and remote sensing.

1.5 Significance of the Study

Advancement of information technology has provided wide arrays of new digital tools that can support the generic activity of geographical analysis and urban modal. In spatial decision-making and designing, in particular, these tools support different stages of the process which involve rapid and effective storage and retrieval of information, various kinds of visualization to inform survey and analysis, and different strategies for communicating information and plans to the affected community (cf. S. Shekhar, Delaney, 2000).

Ever since our culture came to form urban agglomerations, there has been a stable expression of interest in the study of urbanization. Yet in geographic studies, urban geography has been regarded as less topical in comparison to the other more recognized fields (cf. S. Shekhar, Carter, 1995).

This can be explained partly by the nature of urbanization that comprises a number of fundamentals from landscape modal to transportation networks to various socio- economic exchanges. In addition, as each element plays its own role in the formation of urban structure, every city possesses a unique structure with its own momentum, presenting entities that are occasionally regarded as too diverse for a

single topical study. Nevertheless, "geography is not about the precise analysis of particular service areas... it is more concerned with the ways in which these relationships are reflected in the functional and physical structure of the town" (Dickinson, 1959).

This facility will aid management of public utilities like Hospital utility information, water supply, drainage, sewage system, roads, drains, streetlights etc. These facilities can be applied to town planning schemes, urban and estate management and property tax- related matters. The more important components of the new maps will be the precise pinpointing of the water supply pipes; sewage drains that cover the city. It will also help in better transport management of the city. The urban resource information system is a step towards it useful during emergency services like since all information is brought around the hot spots with the click of a button. The most beneficial amongst all departments are the roads and building and town planning.

1.6 Scope of the Study

GIS is an effective and efficient tool to display, store, analyze and retrieve (at will) spatial and non-spatial data. GIS supports up gradation, modification and extension of information as and when necessary. Pune Information System is such an outcome that can be utilized effectively by any person to gather information about different types of facilities and/or services in any neighborhood/ward within PMC limit. It would support one's decision-making ability through accessing geographical location and its attribute data.

Common man can make a decision fixing a wide range of queries such as

- Where are suitable locations for buying a new house considering municipal water supply?
- What are timings and ticket rates for a movie show in different theaters?
- What are the sites he can visit in a day in a certain neighborhood?
- What is the shortest path from a fire station to reach to a place of fire incidence?

This study is an example of the information system and can be applied to other metropolitan cities in India. This can be an efficient database in a GIS platform for administrators and town planners to assess the adequacy of and identify potential

areas for allocation of the given facility like school or hospital. However project deals with only selected facilities in the study area. Due to time constraint data acquired is not complete in all respects, only certain important attributes were taken into consideration. Further the coverage of database is limited to PMC and PCMC area only. This project can be expanded depending on area and administrative jurisdiction. Information in the existing modules i.e. Post office/Police Station/Fire Brigades & Hospitals can be upgraded and additional facilities can be included accordingly. Resident of any large urban area always needs information and timely availability of emergency services like police, hospital, fire brigade & support services like post and communication. The present study develops an information system within PMC and PCMC area for utility services. The information of availability is essential in case of civic emergencies. A user can identify and select these services depending upon his needs for personal security and medical support.

The generated datasets has been integrated into an Urban Resource Information System, which will provide an effective management tool for utilization of the urban resources. Such type of study has following types of utilities.

a) Monitoring horizontal sprawl over different periods of time.

b) Generation of utility database for emergency planning

c) Urban planning, including town planning

d) Study of landuse/landcover

e) Application of advanced GIS and Remote Sensing technique to monitor the sprawl using temporal remote sensing data

1.7 Satellite Data Based Urban Land Use Inventory

Multi-temporal and repetitive satellite data offer unique opportunities for mapping and monitoring as well as assessing some of the elements of urban core, its dynamics and the resultant urban structure. The complexities and elements of urban dynamics as well as the required satellite data characteristics are controlling factors in urban inventory and analysis. With careful analysis and assessment of satellite data capability, and also with the experience gained through earlier studies with IRS satellite data, this study is limited only to the delineation of major classes in urban core as well as urban sprawling trends.

Satellite data based mapping and monitoring has its own limitations in terms of monitoring the elements of urban dynamics. At very coarse or preliminary level of

mapping using the satellite data would be delimitation of built-up space, vacant/open spaces, recreational zones, industrial sites and other emerging suburban zones. The nature and interpretability of satellite land data decides the accuracy levels as well as the possible constraints in identification of urban features. Very fine resolution in the order of 5 meters will enable us to map urban land uses in level III or more (Welch, 1985). This attempt of delimiting the sprawling suburbs is to identify the zones of growth as well as the emerging suburban land uses such as developing in industrial/residential cluster and dynamism in rural urban fringe agricultural areas. These thus help in identification of typical and use zones and its territorial association to its urban core of the region shall enable to derive the emerging spatial urban structure. This process of evolution with reference to time and space forms essential component of the current dynamic phenomena of urban structure.

1.8 Selection of the Study Area

Pune city and Pimpri Chinchwad in India are growing at a very fast rate, acquired a complex urban structure over the years. The central part or the core has gone through unusual changes in terms of social and physical transformations. For a comprehensive study it is imperative to select all kinds of civic facilities and emergency services, required for urban areas considering Road network. However, due to time constraint, it was not feasible; hence in the present study emergency services such as hospitals, Solid Waste Management, Seawage, fire brigade services, police stations and postal service have been selected.

1.9 Aims and Objectives of the study

Aim: The precise aim to this present study is to find out urban sprawl in Pune city and Pimpri-Chinchwad in India, suggest planning to provide utility services.

Objectives

1) To study existing land use/land cover using various satellite imageries
2) To identify various utility services
3) To implement the utility and planning for future urban sprawl in terms of services

1.10 Role of Remote Sensing and Geographic Information System

The 19th century witnessed a trickle of urbanization and the emergence of metropolises. Control the world's urban development as crucial for future of humankind. This rapid and haphazard growth of urban sprawl and increasing population pressure is resulting in loss of productive agricultural land and loss of surface water bodies, green open spaces, besides causing air pollution, health hazards and contamination of water.

Geographic Information System (GIS) is a powerful set of tool for collecting, storing, retrieving, transforming and displaying spatial data from the real world. It has an ability to assimilate divergent sources of data both spatial and non spatial. GIS allows the user to integrate database generated from various sources on signal platform and analyze them in a spatiotemporal domain. GIS provides support in resource management and decision making (Burrough, 1986).

The term GIS comprises Three integrated parts.

- **Geographic** - Geographic of the world, the spatial reality, the geography
- **Information** - Data and information, their meaning and use
- **System**   - The computer technology and support infrastructure

Although GIS has three parts, information is its heart. Without "I" information "G" and "S" are unrelated. Different people defined GIS, according to its capability and purpose for which it is applied A very brief description of GIS is that it is a computerized system (tool) that deals with spatial and non-spatial data in terms of collection, storage, management, and retrieval at will, conversion, analysis, and modeling and display. GIS accepts data from multiple sources which can be in a variety of formats. In other words GIS is very flexible in the types and structure of data. GIS is used by various disciplines as a tool for spatial data handling. Depending on the interest of a particular application, a GIS can be considered to be a data store, a tool, a technology, and information source or science. In India major development has occurred in the last decade with significant contribution from Department of Space, which emphasized the GIS application for National Resources Management. Recently commercial organizations have realized importance of GIS for diverse applications and many GIS based projects are in operation according to the requirements of user organizations.

The modern technology of remote sensing which includes both aerial as well as satellite based systems, allow us to collect lot of physical data rather easily, with speed and on repetitive basis, and together with GIS helps us to analyze the data spatially, offering possibilities of generating various options (modeling), thereby optimizing the whole planning process. These information systems also offer interpretation of physical (spatial) data with other socio-economic data, and thereby providing an important linkage in the total planning process and making it more effective and meaningful.

The satellite remote sensing and its ability to provide the accurate and reliable information to making map measure and monitor the various facts of urban development. When Geographical Information System, Remote Sensing and Global Positioning system coupled then it becomes a very powerful tool for planning and making the maps.

1.11 Literature Review

C. D. Deshpande (1975) has observed this process in India in the following forms, i) The rural fringe or the periphery along which the city starts sprawling, ii) The ribbon development along the main roads, railway lines and beaches, iii) The centers of the planned rail-linked suburbs and their expansion, iv) The working class migrations to industrial centers, v) The shanty towns and strip slums. A city region develops in stages 1) Rural-Urban fringe 2) Urban Sprawl 3) Suburbanization. Suburbanization is a result of over congestion in the core of city and high land values in the central localities (cf. Latkar S. R. 1993).

Sokhi & Rashid (1999) studied the landuse and landcover mapping in urban areas using areal photographs and satellite imageries of Jaipur (1983 & 1989), Coimbatore (1984), Ujjain (1985), Delhi (1987), Dehradun (1989), Banglore (1994) and Jammu (1995), on the basis of urban sprawl analysis of these cities they concluded that human settlements are tend to expand in all directions of favorable conditions. In another case Raju (1999) used landsat MSS, SPOT and LISS II satellite data for mapping urban landuse and urban sprawl of Hydrabad and Vishakhapattanam cities in Andhra Pradesh. Prasad et.al (2001) worked on urban sprawl for Hydrabad city and its environs. They applied Shannon's entropy approach to measure the degree of spatial concentration of geographical variables they demonstrated the utility of

entropy approach to identify, measure and monitor spatio temporal patterns of urban sprawl.

Ramchandra and Jagdish (2003) studied urban sprawl pattern and modeling using GIS on Udupi and Manglore highway according to them pattern of urban sprawl and analysis of spatial and temporal changes could be done cost effectively and efficiently using GIS and Remote Sensing data, they quantified the urban sprawl in terms of change in Built-up area.

Rosero and Bixby (2004) used traditional measurements of access based on the distance to the closest facility and proposed a more comprehensive index of accessibility that results from the aggregation of all facilities weighted by their size, proximity and characteristics of both the population and the facility.

Sulochana Shekhar 2005, studied Changing space of Pune – A GIS perspective with urban sprawl pattern and modeling using GIS on Pune city according to her pattern of urban sprawl and analysis of spatial and temporal changes could be done cost effectively and efficiently using GIS and Remote Sensing data, they quantified the urban sprawl in terms of change in Built-up area. Abundant references, research papers can be ahead on urban sprawl. In this study tried to analysis civic amentias in the different wards of the pune city.

Saikh Moiz Ahmed (2006). Studied solid waste management planning of Aurangabad city he analysis the how collect and management of solid waste material.

Paul Langlois (2006). A GIS approach for evaluating municipal planning capability: residential built form in Markham and Vaughan Ontario. This research describes a methodology for measuring built form patterns using spatial data and GIS that is amenable to the study of large geographical areas. This methodology was used to investigate the capability of municipal planning to influence residential development. In the early 1990s, the Town of Markham, Ontario, Canada adopted a residential development philosophy inspired by New Urbanism. An adjacent municipality, the City of Vaughan, has employed a conventional development approach. By calculating several built form measures derived from the design prescriptions associated with New Urbanism, this study seeks to discern if Markham's adoption of an unconventional development philosophy has resulted in a residential built form distinct from that in aughan.

Rudraiah developed (2006) `Systematic Land Information System' (SLIM) for Kanpur town as a management tool for strategic urban planning as well as real estate management highlighting the need of physical planners for various types of topographical maps. Objectives of the SLIM as reported were to conduct the modern ground surveys using latest tools and technology and prepare topographical maps with cadastral information on 1:1000 scales.

Suman Rao (2007), emphasized the significance of remote sensing as a source of information and GPS and GIS as powerful technologies for analyzing spatial and non-spatial data in urban facility analysis. She prepared location maps for selected urban facilities and services available in Dehra Dun to identify service areas of different facilities. This would form inputs for preparation of comprehensive development plan of the city. This would guide the service providers to identify areas for future expansion and location of those facilities and services. The study also included calculation of indices for ward wise levels of facilities available to the population of Dehra Dun city.

The cities are growing in all directions resulting in large-scale urban sprawl and changes in urban land use. The spatial pattern of such changes is clearly noticed on the urban fringes or city marginal rural areas, than in the city centre. Unconsciously this is resulting in increase in the built up area and related changes in the spatial urban land use patterns causing loss of fruitful agricultural lands, forest cover, other forms of greenery, loss in surface water bodies, diminution in ground water aquifers and rising levels of air and water pollution. Further, it is widely agreed that disintegration of land use is also harmful to biological conservation. There is a demand to regularly observe such changes and distinguish the processes for taking helpful and corrective actions towards a planned and healthy development of urban areas. In the recent times, Remote sensing data is being widely used for mapping and monitoring of urban sprawl of cities. The spatial patterns of urban sprawl over different time periods, can be scientifically mapped, monitored and accurately assess from satellite data in company with conventional ground data. In the present study 'Entropy Approach' for studying the urban sprawl patterns of Pune Municipal Corporation (PMC) and Pimpri-Chinchwad Municipal Corporation (PCMC) over different time scales has been attempted in the present study. Further, the use the GIS for quantifying the urban sprawl trends at various land use sites, viz., commercial, industrial, residential sensitive and mixed zones is also attempted.

Abundant references, research papers can be ahead on urban sprawl. But it was the author's observation that very few scholars has worked out on services and facilities, the city is providing. Few scholars analyzed neighborhoods analysis of some regular services such as shopping plazas, vegetable market places or the shortest path leading to have some important goods and commodities.

In this present work author has emphasized on urban sprawl and utility planning for the cities grown up/ peripheral area which is lacking in various utility services.

1.12 Conclusion

This chapter deals with the introduction to the topic, basic concepts of urban area, urbanization, urban Sprawl, and its definitions, and relation with utility services. This chapter deals with recent trends at global, national, and state level. Occurrence of Sprawl in general and occurrence of sprawl in Pune and Pimpri-Chinchwad have been also discussed briefly. A major component of this chapter is devoted to the introduction of the study area, criterions for the selection of the study area, aims and objectives and the literature Survey. Literature survey and part of this chapter deals with the Urbanization, urban planning, Urban Transport and Utility Services. Review of modern techniques and methodology adopted for the study is also discussed in detail.

Chapter II
STUDY AREA

2.1 Introduction

Pune's origins can be traced small agricultural settlement called 'Punyak' in 8th century A.D. In mid 18th century, Pune became a seat of 'Peshava' then it become a predominantly market place and mixed landuse prevailed. Pune's political importance diminished with defeat of Peshva's in the battle of Panipath in the year 1761 and finally after defeat of Maratha's. Political fortunes of Pune came in hands of British in year 1818. Under British rule Pune Municipality came into existence. Today it has three cantonment areas which are within the geographical limits of Pune Municipal Corporation (PMC). The head quarter of Southern Command and Indian Army is situated in Pune.

After independence, until 1960, Pune's socio-cultural life was dominated by intellectuals, writers, scholars. By 2000 A.D. Pune has taken lead in engineers, software, automations, automobiles, machines & machine tools and electronic industries.

Alongside, Pune has been functioning as one of the engines powering the Indian economy. The Mumbai-Pune corridor has emerged as the most vibrant economic belt of the nation. Pune has capitalised on its strategic positioning, its close proximity to India's commercial capital Mumbai. The industrial development in Pune began in 1953 with the establishment of Hindustan Antibiotics at Pimpri and Kirloskar Engines at Khadki. In later years, several other establishments followed.

Pimpri-Chinchwad is situated towards the northeast of Pune and 160 km. from Mumbai. The city of Pimpri-Chinchwad is predominantly an industrial area, which has developed largely during the last four decades. Pimpri Chinchwad is a relatively newly developed urban area of Pune city. Pimpri was basically established as a centre for refugees from Pakistan. Industrialisation in Pimpri area commenced with the establishment of Hindustan Antibiotics Limited in 1956. The establishment of the Maharashtra Industrial Development Corporation (MIDC) in 1961-62 considerably facilitated industrial development in the area. The establishment of large-scale core industries has led to the growth of ancillary and small-scale industries in and around this industrial belt. With each passing year, the landscape saw significant changes, long stretches of farmland giving way to clusters of enclosed factory campuses. Just as the manufacturing prowess of Pune is well documented and acknowledged, it is

difficult to ignore that the first Software Technology Park (STP) of India had its home in Pune. Pune has emerged at the forefront of the Indian software technological revolution that has changed the business dynamics of the service industry of developed economies.

As industry developed and the employment base widened, migrant population from all over flocked to Pune. Pune witnessed two types of immigration – that of impoverished rural laborers and highly qualified professionals from other states. Pune is now no longer regarded as a pensioners' haven or just an administrative and educational centre as before; it has transformed into a young city with more and more professionals flocking into the city. These changes led to urban development in a ribbon form around the city along its eripheries. The demographic profile of Pune too acquired a cosmopolitan touch as the city's ambience changed from sedate to upbeat.

It is not surprising that in the early 18th century, when Pune was under British control, the city was barely 5 sq. km. in size. Today, it has catapulted to emerge as the eighth largest city in the nation. In 2005, the city measured 243.9 sq. km. with a population of close to 30 lakhs. Pune has had a glorious past and has been successful in developing a good balance between industry, services, education and cultural activities. Few cities can boast of such an eminent positioning in diverse aspects of modern day life.

2.2 Pune Municipal Corporation (PMC)

Established in 1950, PMC is governed by the Bombay Provincial Municipal Corporation (BPMC) Act, 1949. As per this Act, PMC is obligated to provide basic infrastructure like water supply, drainage, sewerage, and roads and services such as conservancy, fire fighting, streetlights, education and primary health.

The administrative wing of PMC is divided into 14 wards, each headed by a ward officer. The total strength of officers and employees at PMC is about 16,731, as against the approved employment level of about 17,986.

Administrative Wards
Pune Municipal Corporation (PMC)

Mula River

Mula-Mutha River

Mutha River

18°36'0"N

18°26'0"N

73°46'0"E

73°58'0"E

N

0   1.5   3 Km.

Fig. 2.1

23
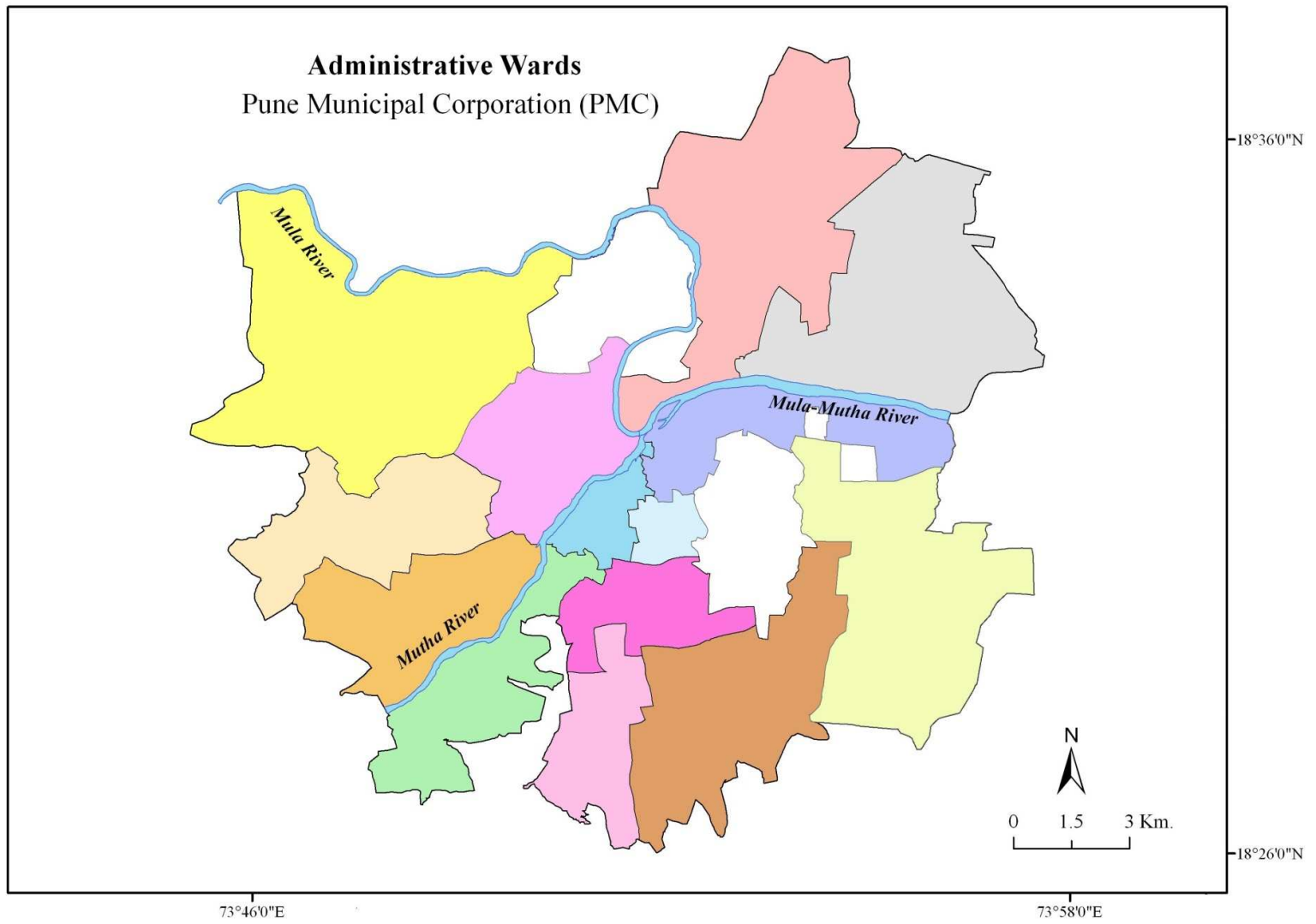
2.3 Pimpri Chinchwad Municipal Corporation (PCMC)

The origin of Pimpri and Chinchwad can be traced back to two rural settlements situated on the outskirts of Pune. Pimpri Chinchwad is a newly developed urban area of Pune city and was basically established as a centre for refugees from Pakistan. Industrialisation in Pimpri area commenced with the establishment of Hindustan Antibiotics Limited in 1956. The establishment of the Maharashtra Industrial Development Corporation (MIDC) in 1961-62 considerably facilitated industrial development in the area. In the last five decades, Pimpri-Chinchwad has developed as a major industrial centre and is home to large industrial conglomerates like the Tatas and Bajajs as well as other large Indian and multinational companies. The presence of large-scale industries has spawned the development of a large ancillary sector, particularly Small and Medium Enterprises (SME) and Small Scale Industries (SSI). The city provides employment to industrial workers and of late has emerged as an affordable urban destination for low-level residential purposes. In order to plan, manage and regulate development the Pimpri-Chinchwad Municipal council was formed in 1970 by merging four villages, namely Pimpri, Chinchwad, Bhosari and Akurdi, which led to the upgradation of civic life in the in the area.

In order to meet the problems of rapid industrialization and the resulting need for better infrastructure and basic facilities, the Pune Metropolitan Regional Planning Board suggested the establishment of Pimpri-Chinchwad new township at distance of approximately 15 kilometers from Pune city. The main objective was to create a planned environment for the working population in the vicinity of their work place.

The chronology of events, which led to development of Pimpri and Chinchwad are as follows:

a) 1975 – Status of Municipal Council was changed from 'C' class to 'A' class

b) 1982 – formation of Municipal corporation by merging seven surrounding villages in the Municipal Council, Sangavi, Rahatni, Thergaon, Wakad (part), Pimple Nilankh, Pimple Gurav, Pimple Saudagar and PCNTDA area covering a total area of 86 sq. km.

c) 1997- Further increase in the area of PCMC adding 18 new villages (extended area of 84.51 sq. km.), thus leading to a total of 170.51 sq. km. area under the command of PCMC.

The Pimpri-Chinchwad area is the most developed industrial belt in the state of Maharashtra. It accommodates some of the most reputed industrial companies of the country such as Hindustan Antibiotics, Telco, SKF, Bajaj Auto, Philips, Alfa Laval, Bajaj Tempo etc.

The establishment of Hindustan Antibiotics and MIDC marked the beginning of industrialization in the area. State government of Maharashtra strict the expansion of industries in Mumbai and Thane coupled with the availability of necessary infrastructure facilities for industrialization, the Pimpri-Chinchwad area attached national and multi- national companies to setup establishments along rail corridor. Due to rapid growth of industries in this area there was a pressing need to cope with the demands for housing, social and physical infrastructure and other amenities. In the transport world this part of Pune metropolis is now recognized as the Auto Nagar or the Detroit of India due to the presence of several automobile ancillary units. Rapid increase in the population of PCMC and presence on existing basic services is a major consequence of its development and industrialization.

Administrative Ward Commitee

Pimpri-Chinchwad Municipal Corporation (PCMC)

Fig. 2.2

26
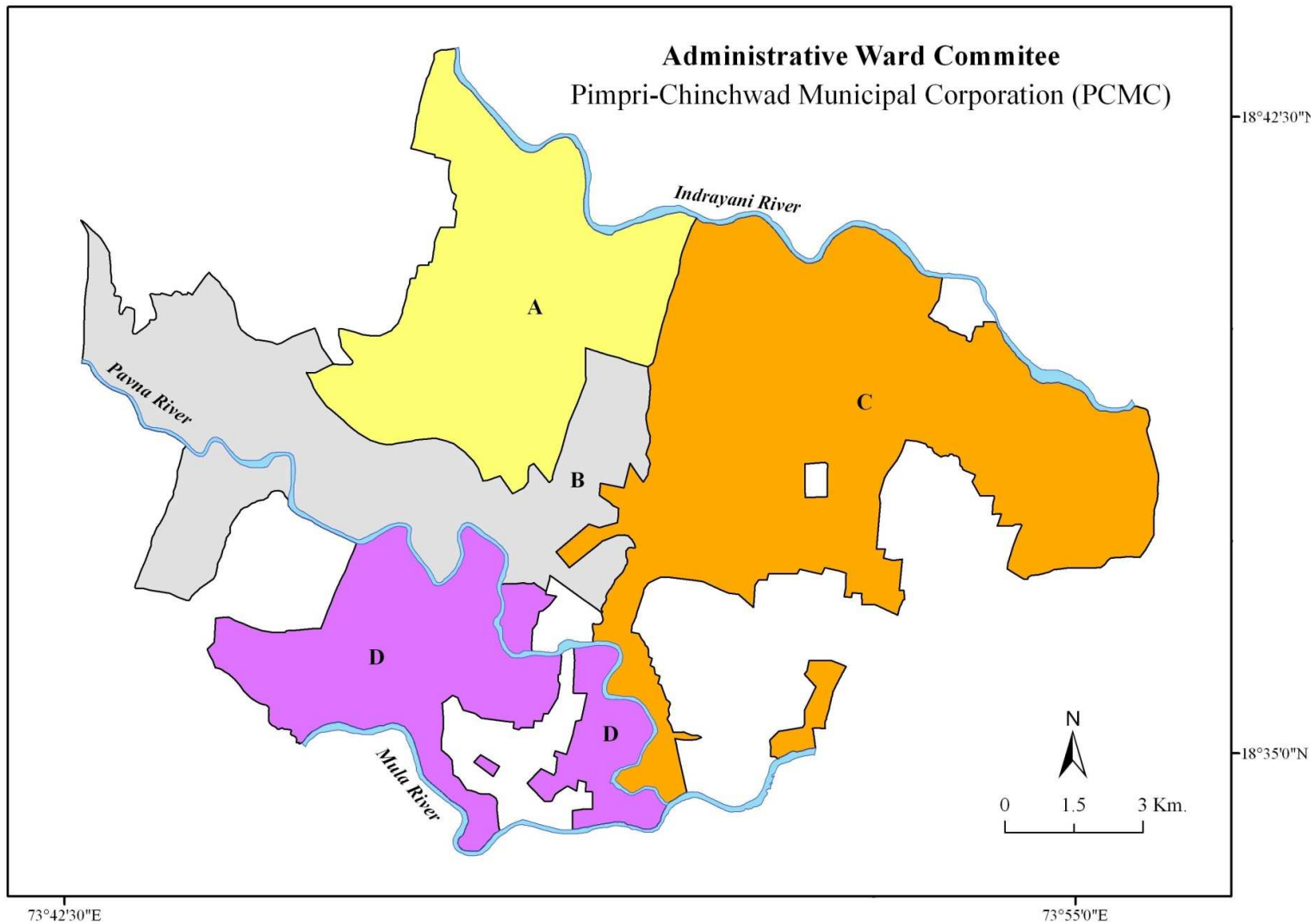
2.4 Location and Extent (PMC & PCMC)

Pune and Pimpri-Chinchwad lies between $18^o 25'$ to $18^o 42'$ North latitude and $73^o 42'$ to $73^o 57'$ East longitude. The study area covers 414.90 sq. km. Pune (PMC) area covers 243.31 sq. km. composed of 144 general electoral wards according to 2007 which comes under 14 administrative wards of Pune Municipal Corporation. The city is located in saucer shaped basin at an average altitude of 560 m. from mean sea level. The area surrounded by offshots of Sahyadri hills extends mostly from west to east. Pune is slight hollow on bank of Mula and Mutha Rivers on Deccan plateau.

Pimpri-Chinchwad (PCMC) area covers 171.59 sq. km composed of 105 general electoral wards according to 1997 which comes under 4 administrative wards of Pimpri-Chinchwad Municipal Corporation. The PCMC is situated in to the Northwest of Pune on the Mumbai-Pune National Highway at an average altitude of 530 to 566 m. from mean sea level. The east-west ridge running midway between Indrayani and Pavana rivers separate this area into two parts. The northern portion slopes towards Indrayani river while the southern portion slopes towards Pavana river.
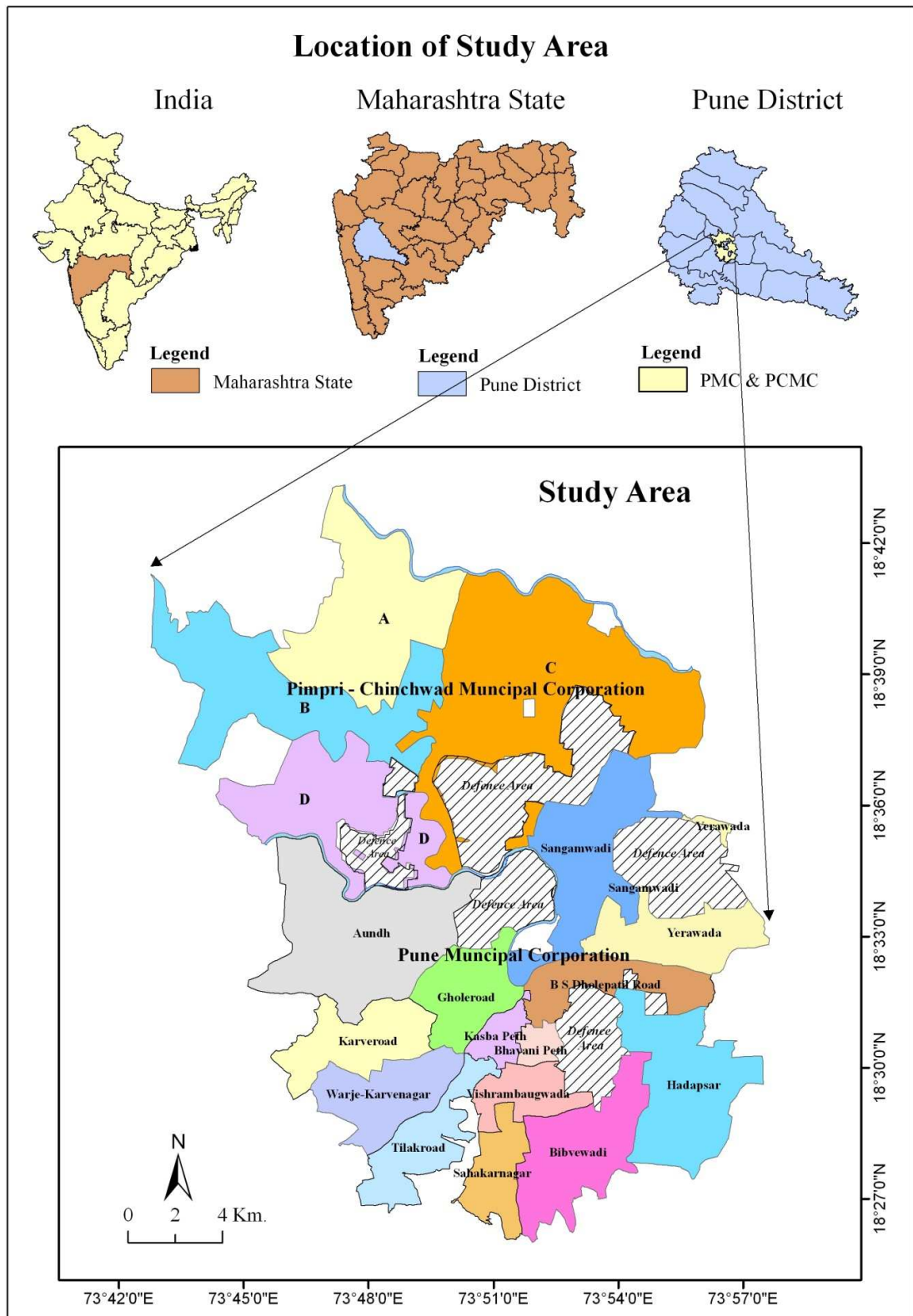
Fig. 2.3

2.5 Physiography

PMC and PCMC are situated on the banks of Mula, Mutha, Pavana and Indrayani Rivers, at an average altitude of 530 to 566m. above mean sea level. Nested in the picturesque Sahyadris (Western Ghats) just, 150 km. southeast of Mumbai, the study area is situated near western margin of the Deccan Plateau, and on leeward side of the Western Ghat crest. Mumbai the state capital of Maharashtra is just at distance of 160 km. from Pune by road. PCMC area is having two Rivers, R. Pavna and R. Indrayani traverse the northwest outskirts of Pune. The Mula and Mutha Rivers latter empties into Bhima River. Thus the city is located in upper Bhima basin. The city is surrounded by hills on west and south side. The highest point within the city is located in Wetal hill whereas highest point maintains the height of surrounding is of Sinhagad fort situated 20 km. west of the city.

Contour map (Fig. 2.4) of the study area shows the gentle slope in central, East and North side, contour interval between 2 lines are very high it shows low gradient of the area and the southern and western side becoming steep due to high elevation of the surface. The distance between two contour lines is less in northern side as compared to southern side. The trend of elevation increased from north to south and from east towards the western side.

The Triangulated Irregular Network (TIN) is generated from contours, shows elevation information. TIN is used to study the surface topography of the study area.

Fig. 2.5 shows the TIN of the PMC and PCMC. From the map one can easily make out that the general trend of slope is from West to East. PMC and PCMC area is having hills and hill ranges in the western side within average altitude of 600 - 800 meters. The city is well bounded by East-West stretching. Katraj hill range in the Southern side whereas the eastern part of the city is having gently sloping topography. In general, city has overall slope towards East with hill and rugged topography at its extreme West, Southwest and South.

Pune is situated on the Sahyadri Hills. Earlier, due to the presence of trees on the hills and mountains, the city's weather was pleasant and comfortable. But in recent years the climate has considerably changed due to exponential rise in the number of concrete structures and the loss of green cover on the hills. The city has approximately 12% land under hilltop and hill slope.

There are 11 natural hills in the city, these are as follows:

(1) Parvati Hill

(2) Arai and Malwadi Hill

(3) Fergusson College Hill

(4) Vetal Hill

(5) Ram Hill

(6) Baner Hill.

(7) Taljai Hill

(8) Chaturshringi Hill

(9) Law College Hill

(10) Katraj Hill

(11) Kirkitwadi Hill

Contour Map of PMC and PCMC area

Legend

— Contours
CI = 10 meter

0   2   4 Km.
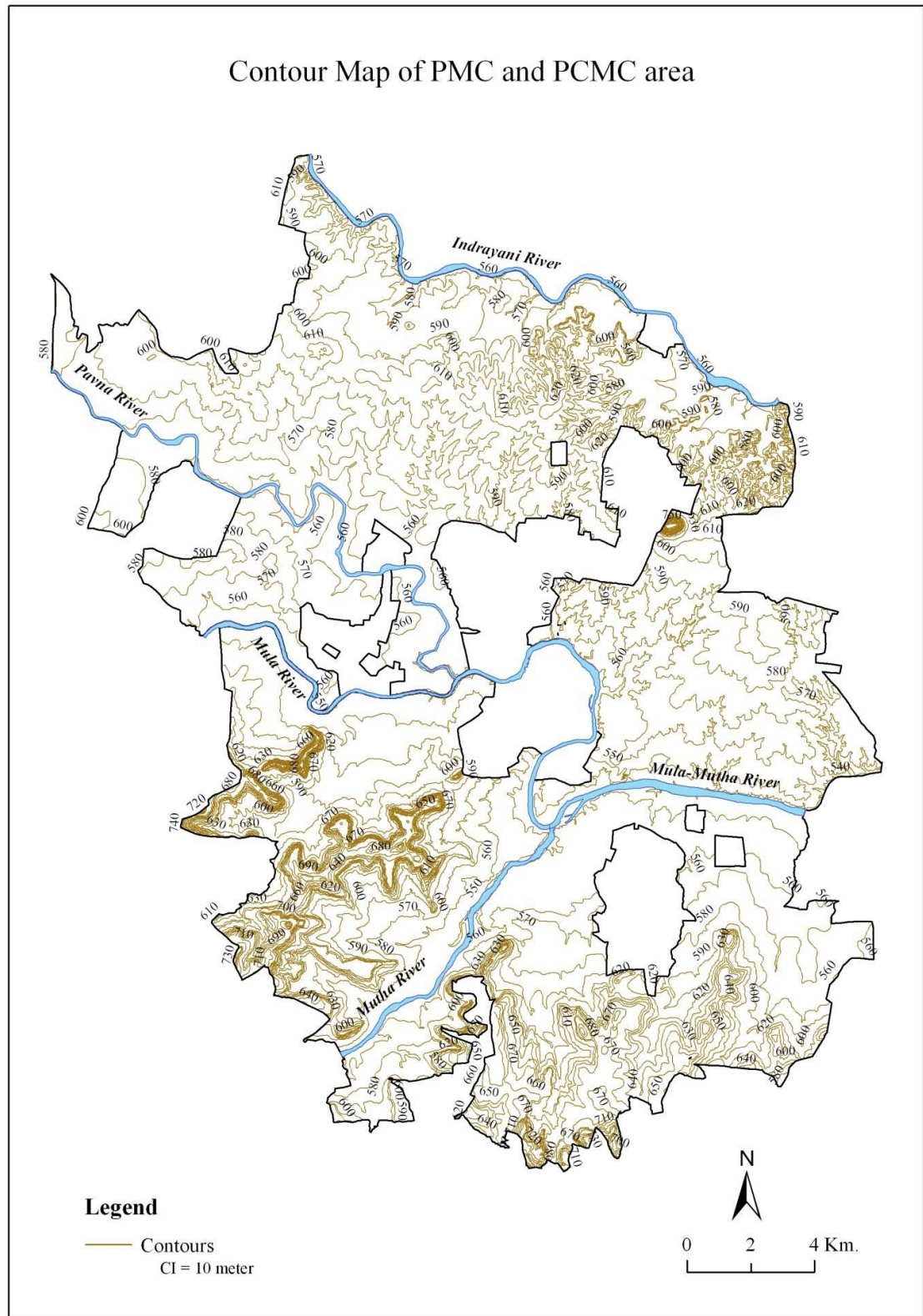
Fig. 2.4

Triangulated Irregular Network (TIN) of PMC and PCMC area

Indrayani River

Pavna River

Mula River

Mula-Mutha River

Mutha River

Legend

Height in meters (ASL)

540 - 580
580 - 620
620 - 660
660 - 700
700 - 770

N

0   2   4 Km.
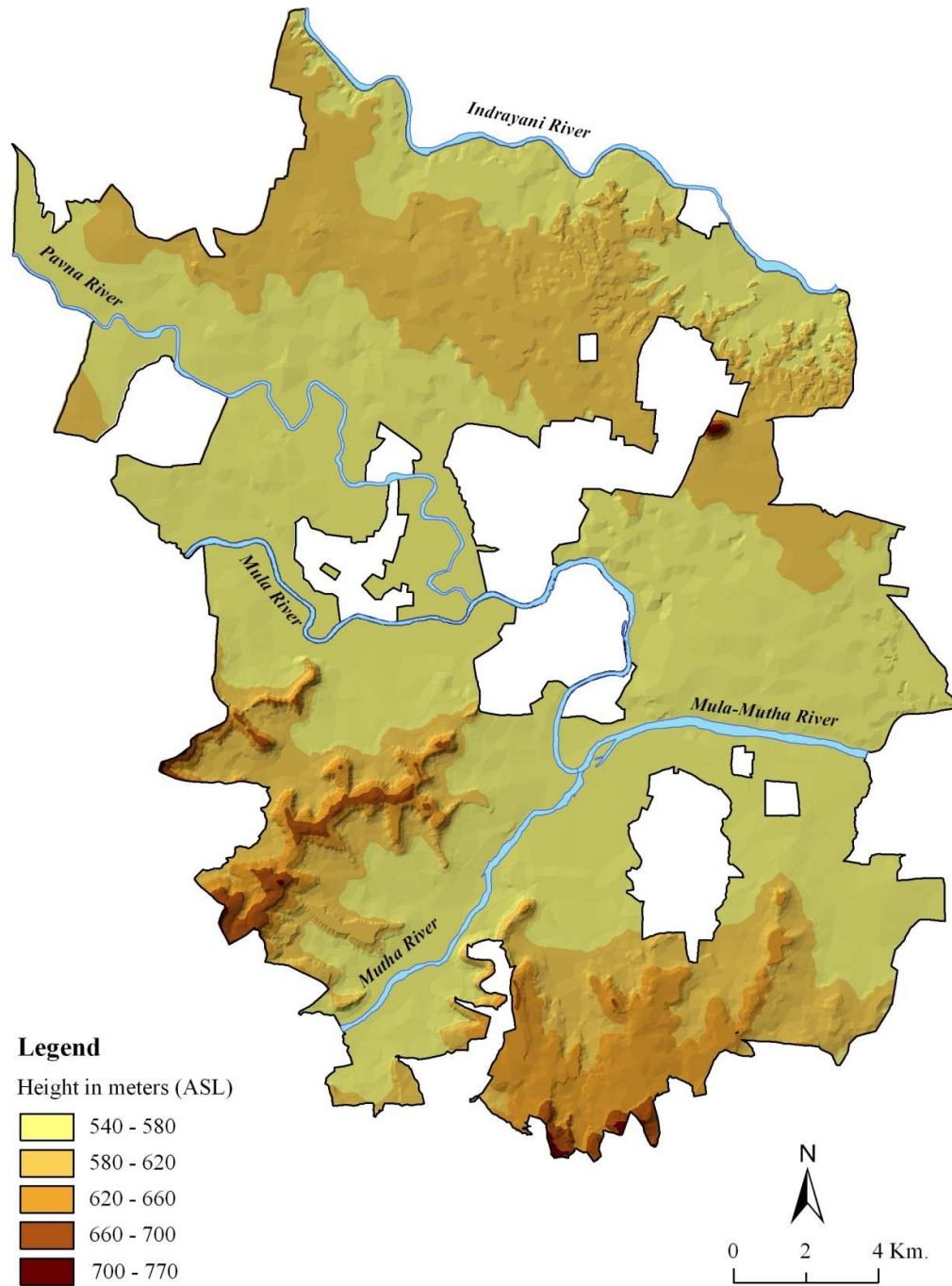
Fig. 2.5

2.6 Climate

The city has a typical tropical climate, with three distinct seasons- summer, monsoon and winter. The Leeward location with reference to the Western Ghat has made the city's climate moderate and pleasant. The mean daily maximum and the minimum temperature for the hottest month - May is around 40°C and 23°C respectively. The evening sea breeze from west-northwest keeps the city cool during summer nights. For the coldest month of December the temperature ranges from 30°C to 12°C. The relative humidity ranges from 36% in March to 81% in August. Three fourth of the annual rainfall of 70 cm is received during June to September. Average annual rainfall at Pune, Pimpri-Chinchwad is about 850 mm.

2.7 Drainage

Lying between Indrayani River in the north and Katraj Lake in the south, Pune is located in the valley between four Rivers and several other minor streams. The River Ambi and River Mose, tributaries of the River Mutha have dams upstream, 40.23 km west of the Pune City. River Ambi's Tanaji Sagar dam has a catchment area of 12,030 hectares and yields about 304 million cubic meters of water annually. River Mose's Veer Baji Pasalkar dam has an yield of 397 million cubic meters of water annually. 17.70 Km west of Pune is Khadakwasla dam on River Mutha with a catchment area of 50.180 hectares, which catches almost 1088 million cubic meters of water annually. Khadakwasla reservoir has been designed to store only 86 million cubic meters. The overflows from the Tanaji Sagar and Veer Baji Pasalkar dam flow into the Khadakwasla dam from where the overflow is released into the Mutha River. The water from Khadakwasla travels through the Mutha right bank canal, running within 6.4 km. parallel to the River, supplying water to Pune city and Cantonment Boards as well as to the rural hinterland's irrigation needs. The total length of the Mutha River within the city limits is approximately 8 km. The floodwater passes through the River during the monsoon at the rate of 700 cubic /sec up to a maximum of 2450 cubic meters/sec, occurred once in the last 55 years. The post monsoon flow averages 60 to 80 cubic /sec. Since the River, without a definite channel and low water level, is creating an unhealthy environment because of the stagnant water-breeding mosquitoes, the PMC decided to create a channel in the middle of the Riverbed of 110 m width and 2 to 2.5 m high walls on both sides to pass 283 cumecs of floodwater. The banks were filled up with soil for gardens and playgrounds.

However, slums have developed on a certain stretch of these banks, which has had a negative impact on the River water quality. The major stretch of the River carries slushy slit clay, pebbles and shingles as well as rubble to the extent of approximately 60,000 cu. m.

2.8 Demography

2.8.1 Population Growth Trends (PMC)

The population of Pune city as per Census 2001 is close to 25 lakhs. In the last 50 years, the city's population has grown by more than five times. The growth in population testifies to the Vibrancy of its economic activity.

Table 2.1 Population Growth Trends (PMC)

Census year	Total Population	Decadal Change	Growth Rate (%)
1951	400902	-	-
1961	794052	393150	98.07
1971	1029466	235414	29.64
1981	1202848	173382	16.84
1991	1566651	363803	30.24
2001	2540069	973418	62.13

Source: Census of India

India has a very young population with a median population age of 24 years; about 65% of the total population is less than 35 years old. Pune is also reflective of this demographic characteristic with the median age being closer to the national level. But, 62 percent of the total population is under the age of 30 years. In Pune, the 25-34 age group forms a larger proportion of the total population compared to that prevailing at the national level. It would not be incorrect to say that the tendency to migrate will probably be the highest within this age bracket. It is estimated that about 50 percent of the population increase is on account of in-migration. This probably explains Pune's relatively larger share of population in the 25-34 age groups.

For the last decade, the decadal growth rate of population has been in the range of 60% while the previous three decades witnessed population growth in the range of 15-30%. Between 1951 and 1961 the decadal growth rate of population has

been 98%. The population of Pune city as per 2001 Census is 2540069 persons. The current population is estimated to be in the range of 30 lakhs.

2.8.2 Population Growth Trends (PCMC)

Pimpri Chinchwad provides employment to industrial workers and of late has emerged as an affordable urban destination for residential purposes. The increasing demand for industrial and residential areas led to continuous addition of areas and up-gradation of the erstwhile Municipal Council to Corporation.

Table 2.2 Population Growth Trends (PCMC)

Census year	Total Population	Decadal Change	Growth Rate (%)
1951	26367	-	
1961	39654	13287	50.39
1971	98572	58918	148.58
1981	251769	153197	155.42
1991	520639	268870	106.79
2001	1006417	485778	93.30

Source: Census of India

For the last two decades, the decadal growth rate of population has been in the range of 100% while the previous two decades witnessed population growth in the range of 150%. The population of Pimpri-Chinchwad as per 2001 Census is 1,006,417 persons. The current population is estimated to be in the range of 12 lakhs.

It is pertinent to note that the population dynamics in Pimpri-Chinchwad is a cumulative causation of demographic and economic changes in Pune and vice-versa. Hence, it is essential to gain an understanding of both the cities to grasp their population dynamics and make growth projections.

2.8.3 Population Growth Trends in PMC and PCMC

Table 2.3 Population Growth Trends in PMC and PCMC

Census year	Total Population	Decadal Change	Growth Rate (%)
1951	427269	-	-
1961	833706	406437	95.12
1971	1128038	294332	35.30
1981	1454617	326579	28.95
1991	2087290	632673	43.49
2001	3546486	1459196	69.91

Source: Census of India
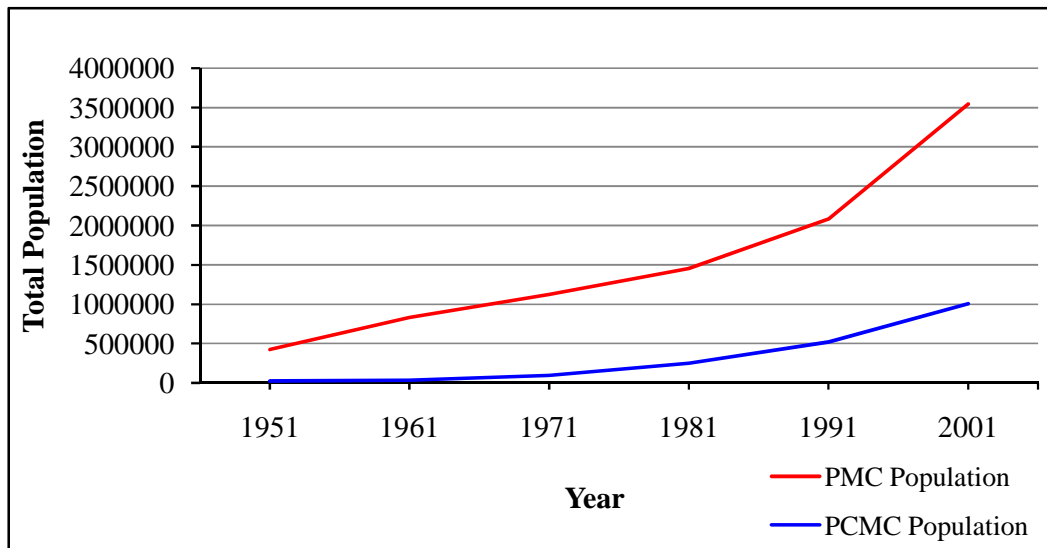
Fig. 2.1 Total Population of PMC and PCMC area
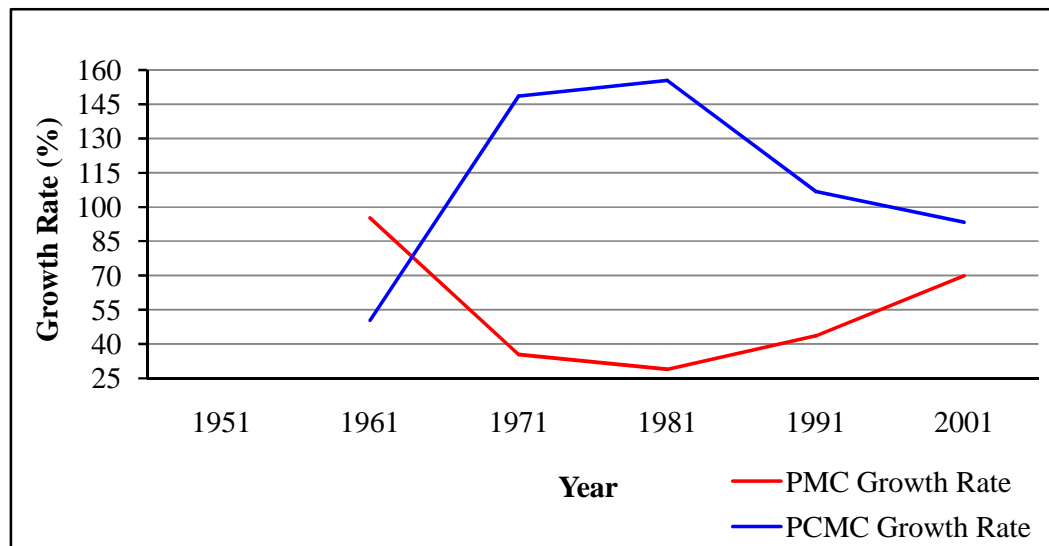
Fig. 2.2 Population Growth Rate of PMC and PCMC

Fig. 2.1 and 2.2 shows Population and population growth rate of PMC and PCMC from 1951 to 2001. The blue line shows the population and growth rate of PCMC and red line shows population and growth rate of PMC. For the last decade, the decadal growth rate of population has been in the range of 70% while the previous three decades witnessed population growth in the range of 30-45%. Between 1951 and 1961 the decadal growth rate of population has been 95%. The population of Pune and Pimpri-Chinchawad as per 2001 Census is 3546486 persons. The current population is estimated to be in the range of 42 lakhs.

2.9 Landuse of PMC and PCMC
2.9.1 Landuse of PMC

During the 1970's, the urban activities spilled beyond the erstwhile city limits and it was felt that for comprehensive and integrated planning, a metropolitan region converging on Pune be defined. Accordingly, the Pune metropolitan region was defined in July, 1967. Earlier, the Pune Municipal Corporation city area was 18.3% of the Pune Urban Agglomeration, while about 45% was village areas, 9% cantonment area and 17% was the town area. In 1997, PMC's area increased by 14,611 hectares, to include 10 census towns and 26 villages bringing the land extent to over 46,713 hectares. This increased the PMC's share in the PUA to 58.75%. However the city forms a mere 31.28% of this area, the rest being villages (45.7%), and towns (23.02%). It is clear that the expansion of the urban area into neighboring towns and villages needs to be checked. At present after delusion of few newly added villages, the PMC area is 243.96 sq. km.

Table 2.4 PMC Landuse distribution as per Development Plan

Land use	Area in Sq. Km.		Total	Area in %
	1987 DP	**Newly Merged areas**		
Residential	50.58	53.16	103.74	42.53
Commercial	2.35	1.57	3.92	1.61
Industrial	7.26	2.62	9.88	4.05
Public and Semi Public	15.22	1.45	16.67	6.83
Public Utilities	1.38	0.00	1.38	0.57
Transport	22.00	9.81	31.81	13.04
Reserved, Forest & Agri.	2.35	26.70	29.05	11.91
Water Bodies	12.04	2.48	14.52	5.95
Hills and Hill Slopes	12.45	0.00	12.45	5.10
Recreational	12.73	7.79	20.52	8.41
Total	**138.36**	**105.58**	**243.94**	**100**

Source: Town Planning Department, Pune

The combined land use distribution as per both the Development Plan indicates that about 42 percent is allocated for residential use. The land use plan indicates that about 13.04 per cent of the area is allocated for transport, and 11.91 per cent is for reserved and forest areas.

PMC Landuse Distribution

Residential 42%
Commercial 2%
Industrial 4%
Public and Semi Public 7%
Public Utilities 1%
Transport 13%
Reserved, Forest & Agri. 12%
Water Bodies 6%
Hills and Hill Slopes 5%
Recreational 8%
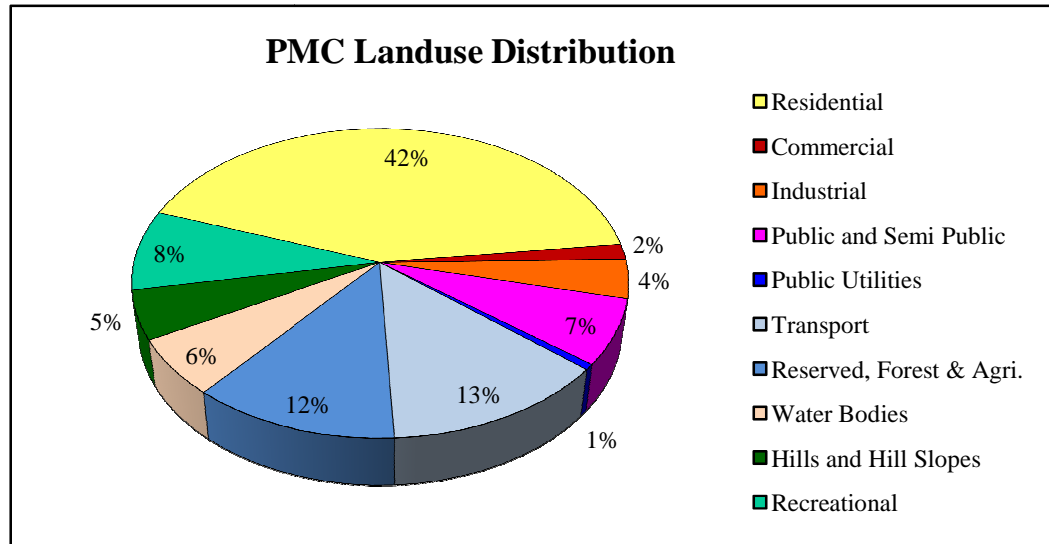
Fig. 2.3 PMC Landuse distribution

Within PMC, the newly added villages show a predominance of agricultural activity and some forestland. This should continue to remain so, in order to sustain the ecological demands of the city. The urbanization of the agricultural land has displaced many farmers, who, having lost their sources of livelihood, have settled down in the city's informal settlements. The Riverbed is not spared from slums either. The landuse pattern of the city reveals a dense core with commercial and residential areas bisected by the River. The southern bank, having the older parts of the city, has a haphazard high-density development, while the cantonment areas to the north have comparatively low densities. The city shows a concentric growth pattern with the River as the center.

2.9.2 Land use (PCMC)

In DPs for the old PCMC measuring 86 sq. km. different reservations for public purposes have been worked out on the basis of planning norms and a projected population for ten years. Zoning proposals to accommodate the population for 20 years have been distributed into different planning units.

Table 2.5 PCMC Landuse Distribution as per Development Plan

| Land use | Area in Sq. Km. | | Total | Area in % |
	1986 DP	**Newly Merged areas**		
Residential	10.16	22.26	32.42	19.01
Commercial	0.40	0.19	0.59	0.35
Industrial	10.85	1.48	12.33	7.23
Public and Semi Public	0.84	0.82	1.66	0.97
Public Utilities	0.42	0.39	0.81	0.48
Transport	4.26	2.38	6.64	3.89
Reserved, Forest & Agri.	26.27	33.27	59.54	34.92
Water Bodies	1.89	0.95	2.84	1.67
Quarry	0.22	2.46	2.68	1.57
Recreational/Open Spaces	0.69	0.01	0.70	0.41
Barren/Vacant Lands	30.01	20.29	50.30	29.50
Total	**86.01**	**84.50**	**170.51**	**100**

Source: Town Planning Department, Pune

In case of the old DP, sanctioned for an area of 86.01 sq. km. in 1986, against a planned development of about 74% of the 86.01 sq. km., 32% of the area was developed. However, today a reconnaissance survey indicates that the entire area of 86.01 sq. km. has been developed though not in line with what was envisaged in the DP. The DP is due for revision in 2007 and a survey of the existing land use is in progress for this area.
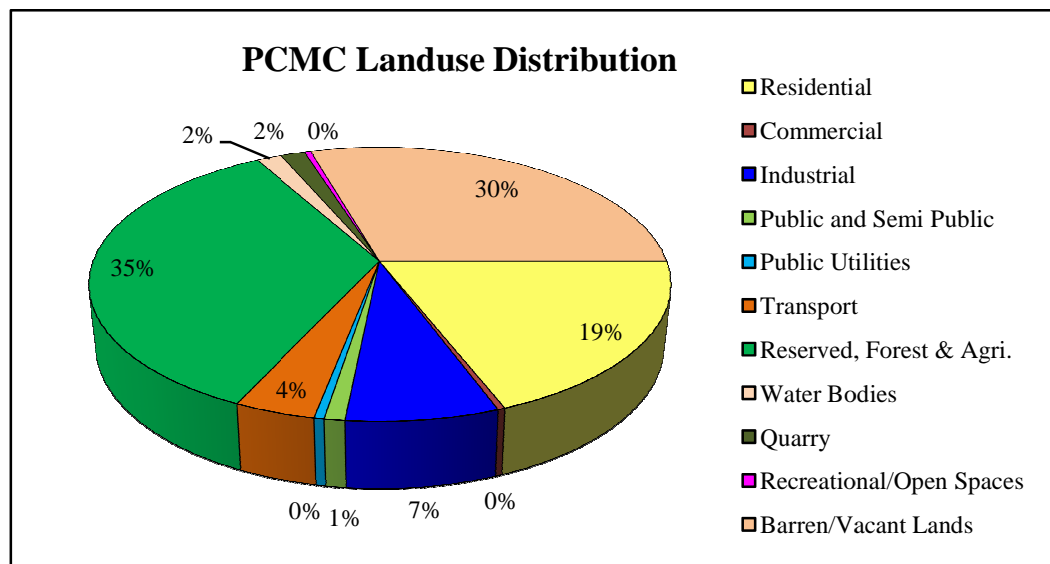
Fig. 2.4 PCMC Landuse distribution

In the old DP, the projected population for a period of 10 years (1996) and 20 years (2006) is 8.01 lakhs and 12.32 lakhs respectively. In the sanctioned DP for old area of 86.01 sq. km. 488 sites were earmarked for different public purposes. PCMC can take up acquisition for 464 sites identified in the DP.

Even for the DP of the newly merged area in PCMC limits admeasuring 84.51 sq. km. different reservations for public purposes have been worked out on the basis of planning norms, taking into account the projected population of 10 years; zoning proposals, to accommodate the population for 20 years, have been distributed in different planning units. In the draft DP for this extended area, 643 sites are earmarked for different public purposes. The draft DP for these newly merged areas has been submitted to the state government and approval for the same is awaited.

Revision of the Development Plan for the old PCMC area of 86.01 sq. km. is due in 2007. It is considered necessary that a comprehensive Development Plan for the entire area of 170.51 sq. km. be drawn up. Hence, the draft DP for the newly added areas has to be merged into the revised DP to ensure a comprehensive plan for the PCMC area.

Landuse of PMC (1987) and PCMC (2006) area

Legend

+++	Railway
—	Roads
■	Agriculture
■	Commercial
▧	Defence
■	Hill Slopes
■	Industrial
■	Public Utility
■	Public-Semipublic
■	Recreational
■	Residential
■	Transport
■	Water Bodies

0   2   4 Km.
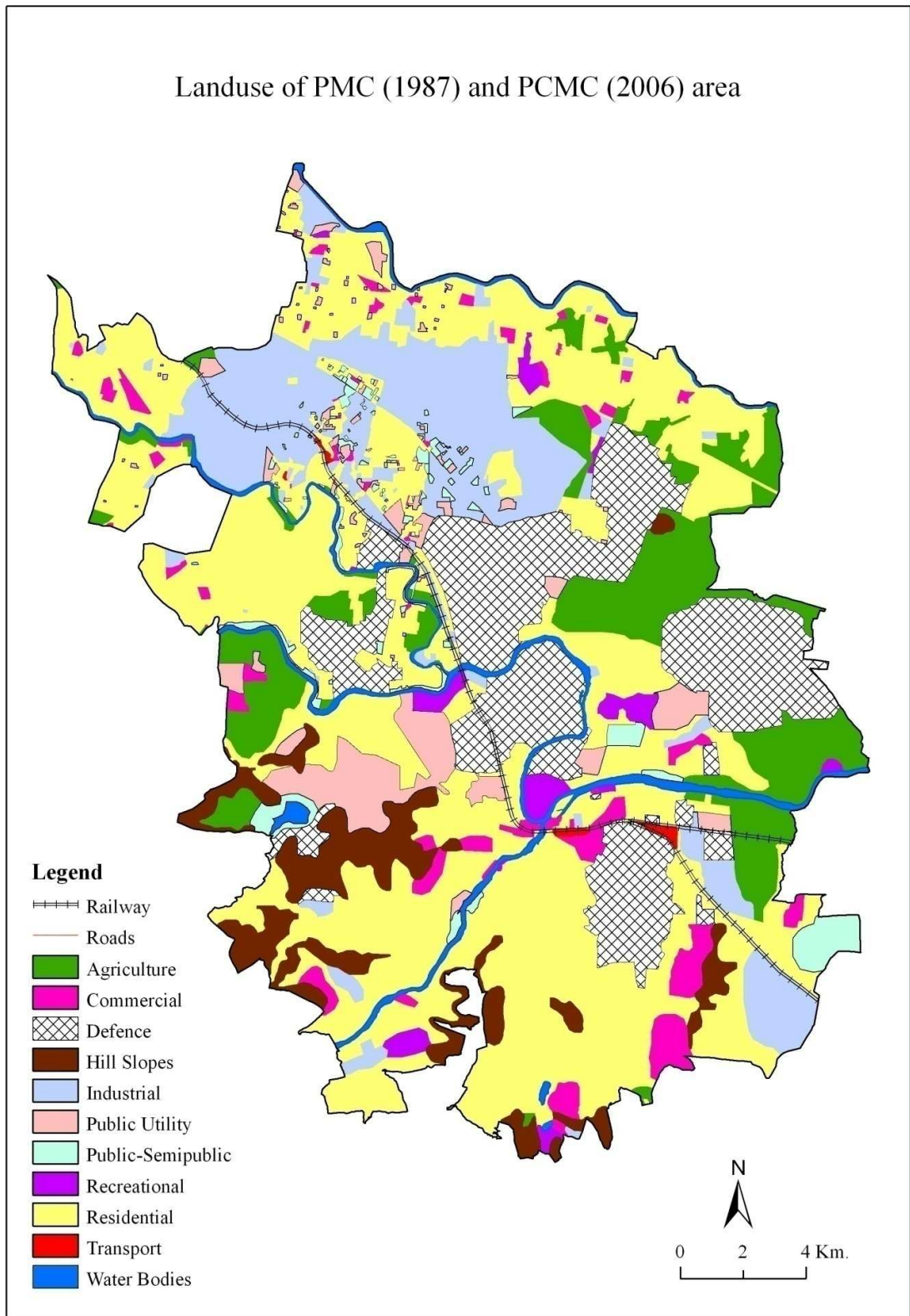
Source: Town Planning Department Pune & Pimpri-Chinchwad

Fig. 2.6

41

2.10 Landuse/Landcover of PMC and PCMC area based on SOI Toposheet, LANDSAT ETM+ and IRS P6 LISS-III Classified Images

Table 2.6 Landuse/Landcover of PMC and PCMC area based on SOI Toposheet, LANDSAT ETM+ and IRS P6 LISS-III Classified Data

Classes	Toposheet (1980)	LANDSAT ETM+ (1992)	LANDSAT ETM+ (1999)	IRS P6 LISS-III (2004)	IRS P6 LISS-III (2008)
Built-up	16.85	59.25	107.24	170.16	233.20
Barren land	167.20	141.21	127.45	104.09	88.28
Vegetation	160.46	105.18	105.57	94.80	62.31
Water body	10.44	9.57	8.65	7.53	7.20
Fallow land	59.95	99.69	65.98	38.31	23.91
Total	**414.90**	**414.90**	**414.90**	**414.90**	**414.90**

Source: SOI Toposheets and Satellite Image

PMC and PCMC based on SOI Topographeet (1980)

0   2   4 Km.
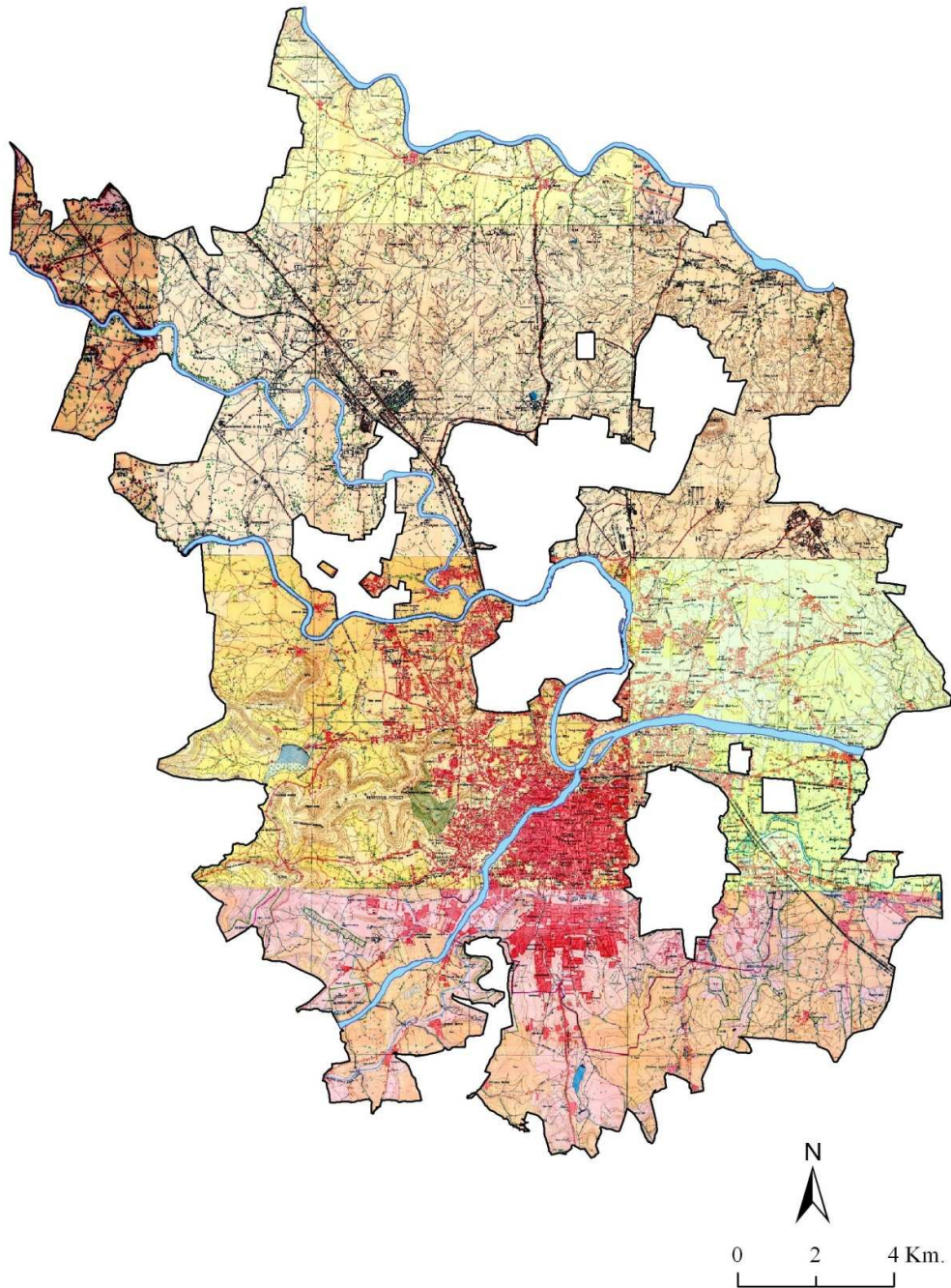
Source: & Modified from SOI   **Fig. 2.7**

Landuse of PMC and PCMC based on Topographical map (1980)

Legend

Admin Ward/Committee Boundary

Built-up

Open Land with or without shrubs

Vegetation

Water Bodies

N

0   2.5   5 Km.
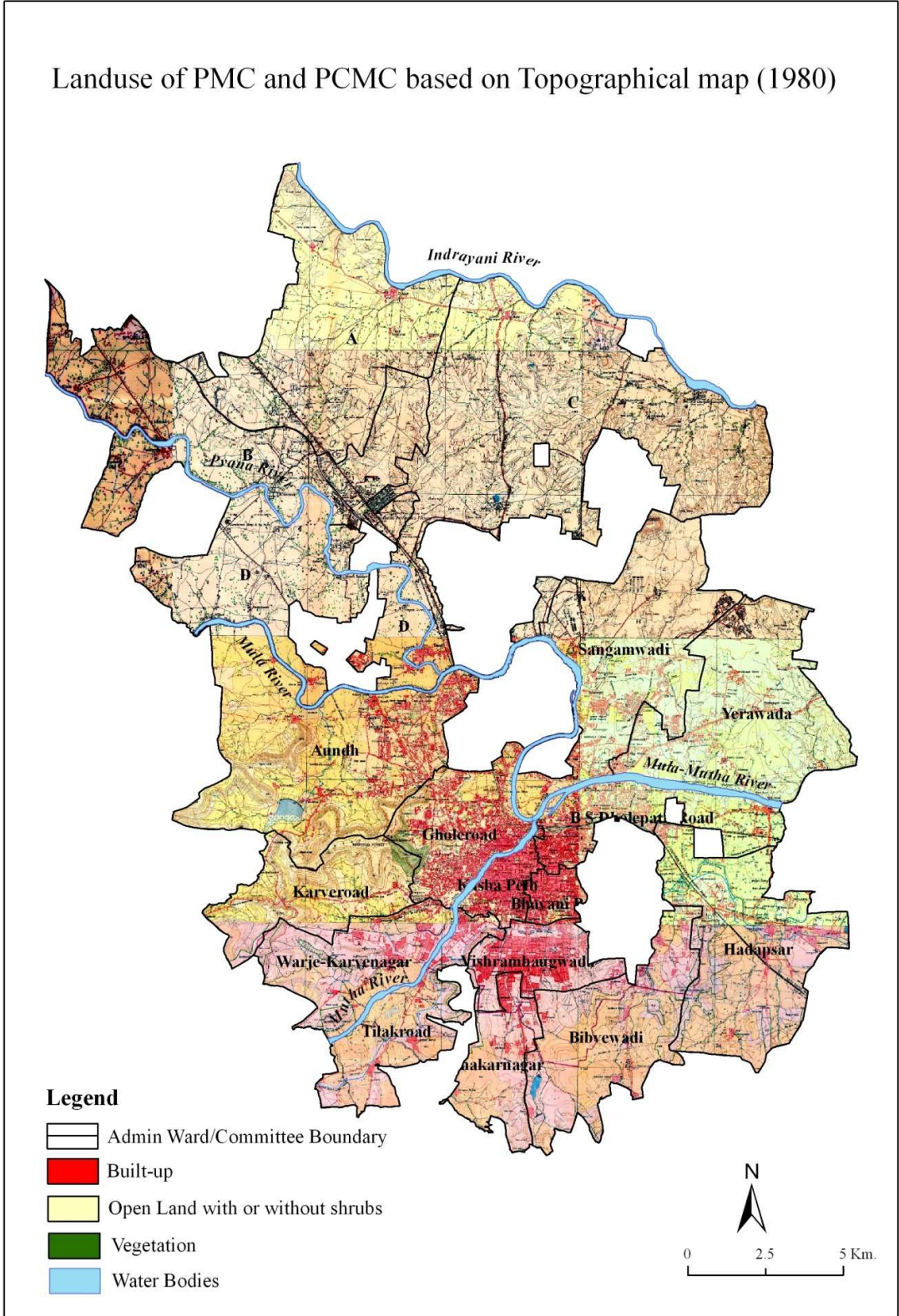
Source: & Modified from SOI   **Fig. 2.8**

44

LANDSAT ETM+ (1992) False Color Composite (FCC)
image of PMC and PCMC
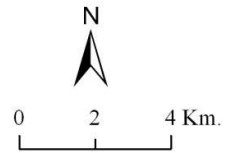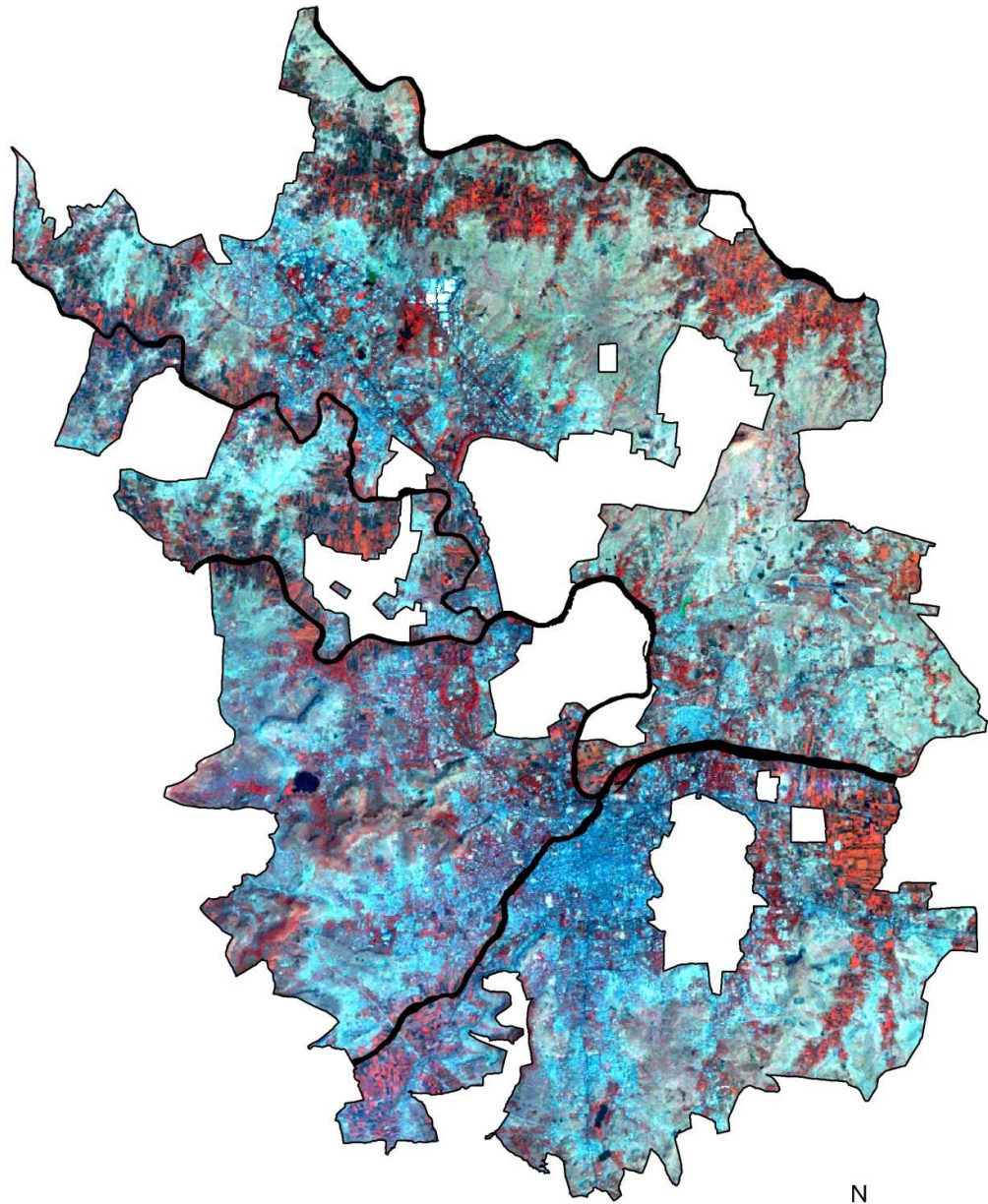
Source: Modified from NRSC   **Fig. 2.9**

PMC and PCMC Classified Image based on LANDSAT ETM+ (1992)

Legend

■ Built-up
■ Barren Land
■ Vegetation
■ Fallow Land
■ Water Bodies

N

0   2   4 Km.
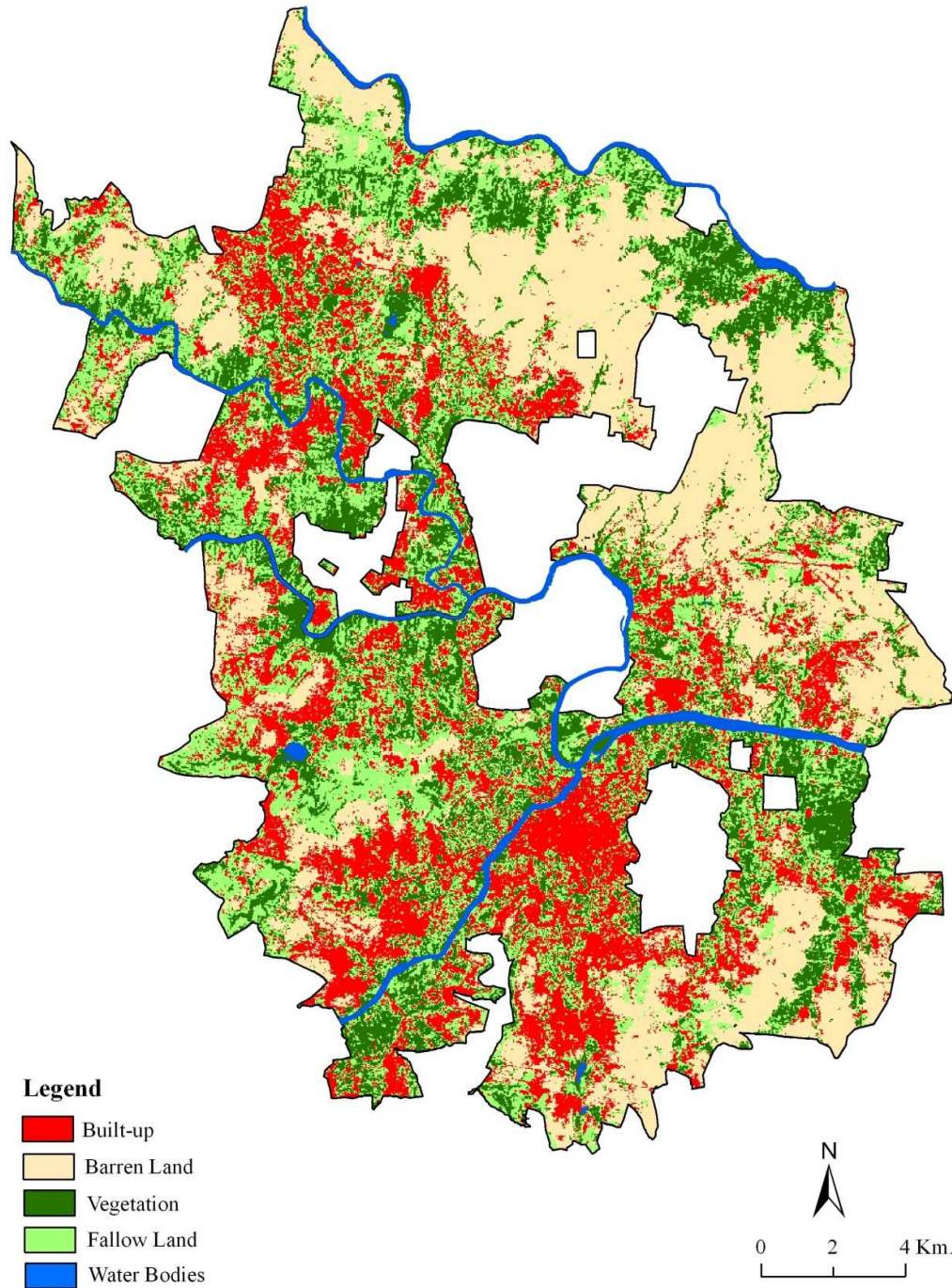
Source: Modified from NRSC　　　　　**Fig. 2.10**

LANDSAT ETM+ (1999) Satellite Image of PMC and PCMC
False Color Composite (FCC)
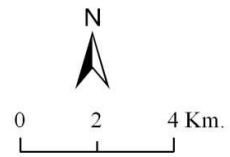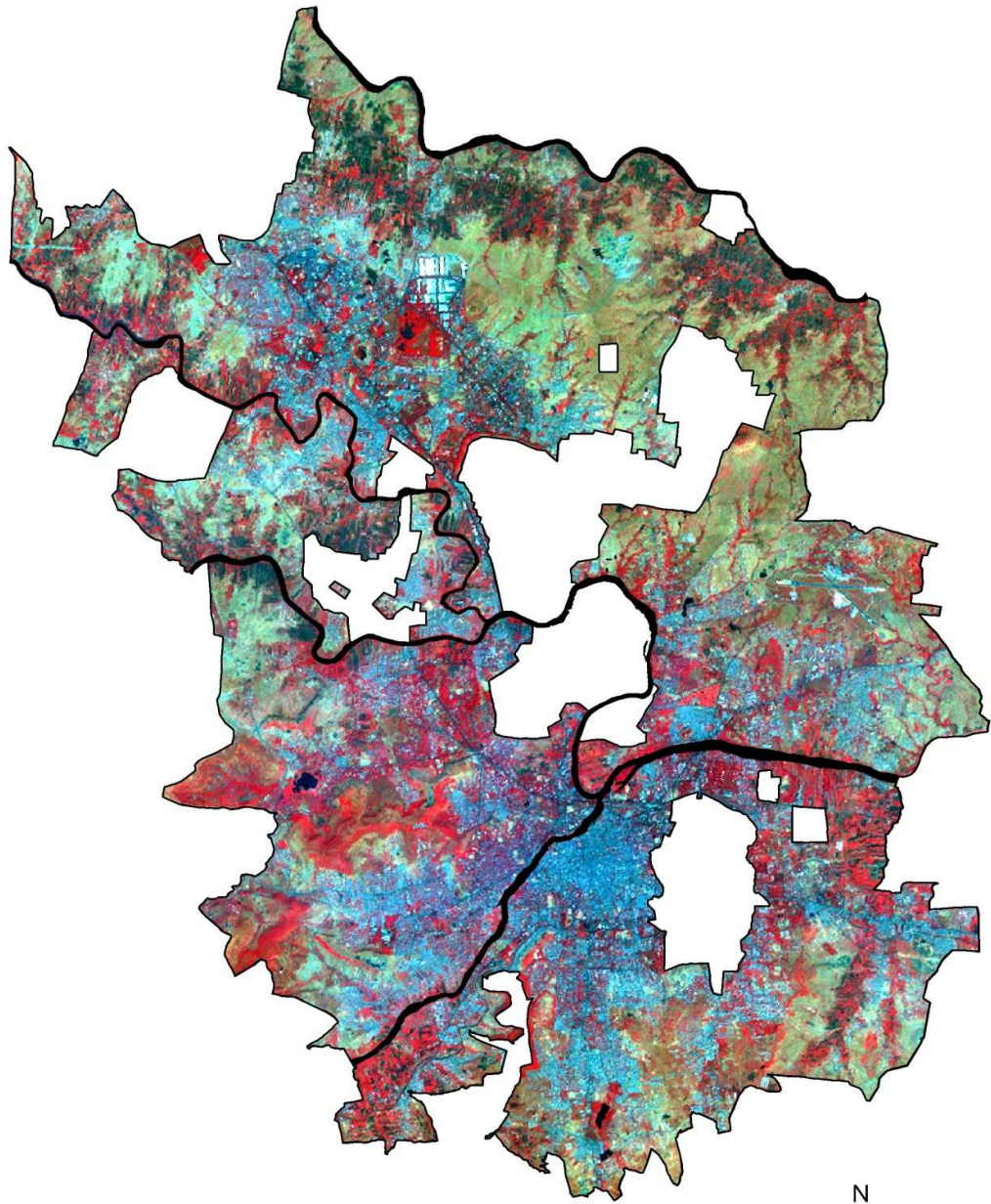
Source: Modified from NRSC   **Fig. 2.11**

PMC and PCMC Classified Image based on LANDSAT ETM+ (1999)

Legend

- ■ Built-up
- ■ Barren Land
- ■ Vegetation
- ■ Fallow Land
- ■ Water Bodies

N

0   2   4 Km.
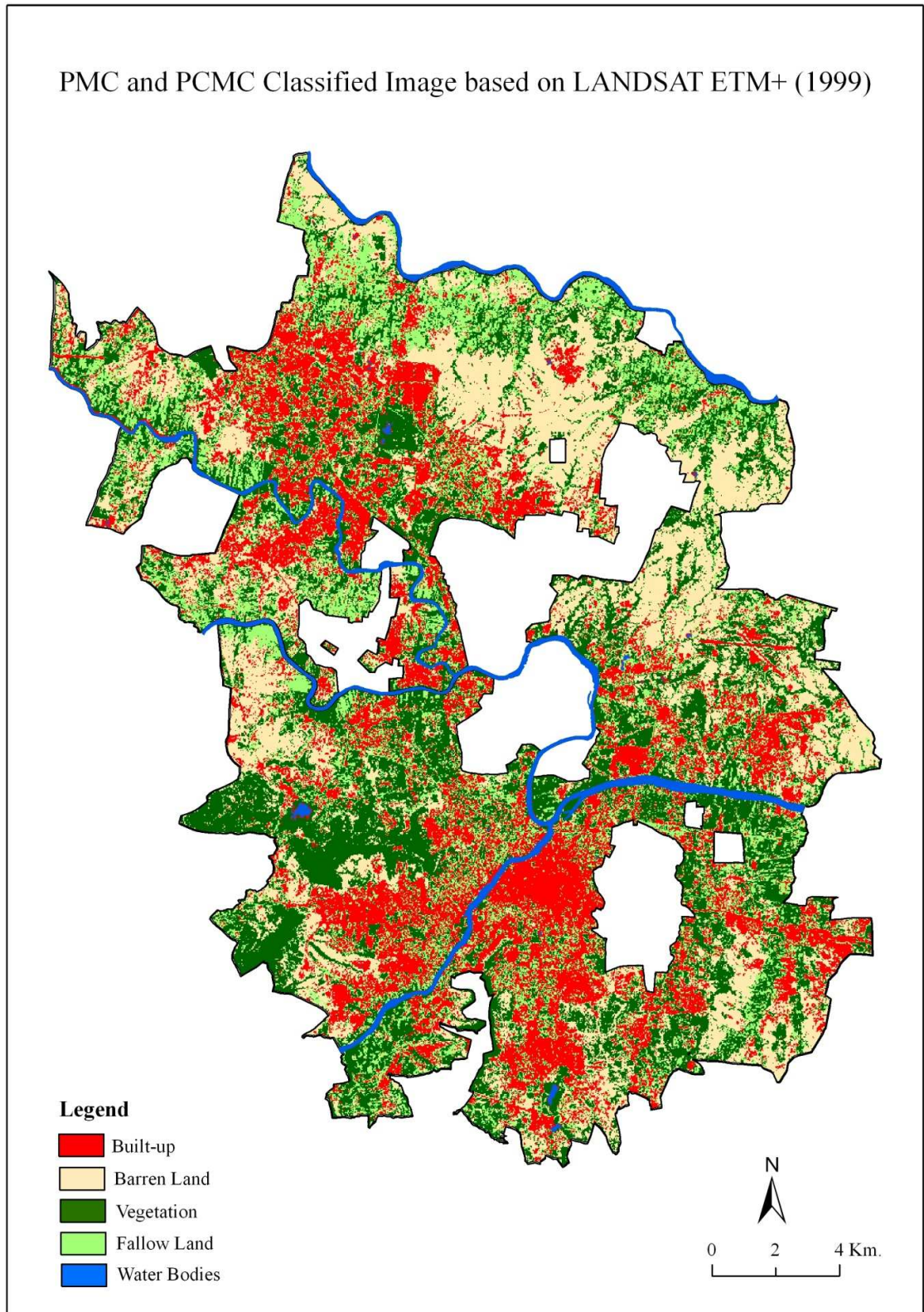
Source: Modified from NRSC   **Fig. 2.12**

IRS P6 LISS-III (2004) False Color Composite (FCC) Image of PMC and PCMC
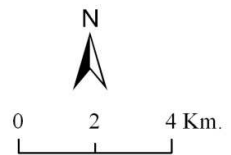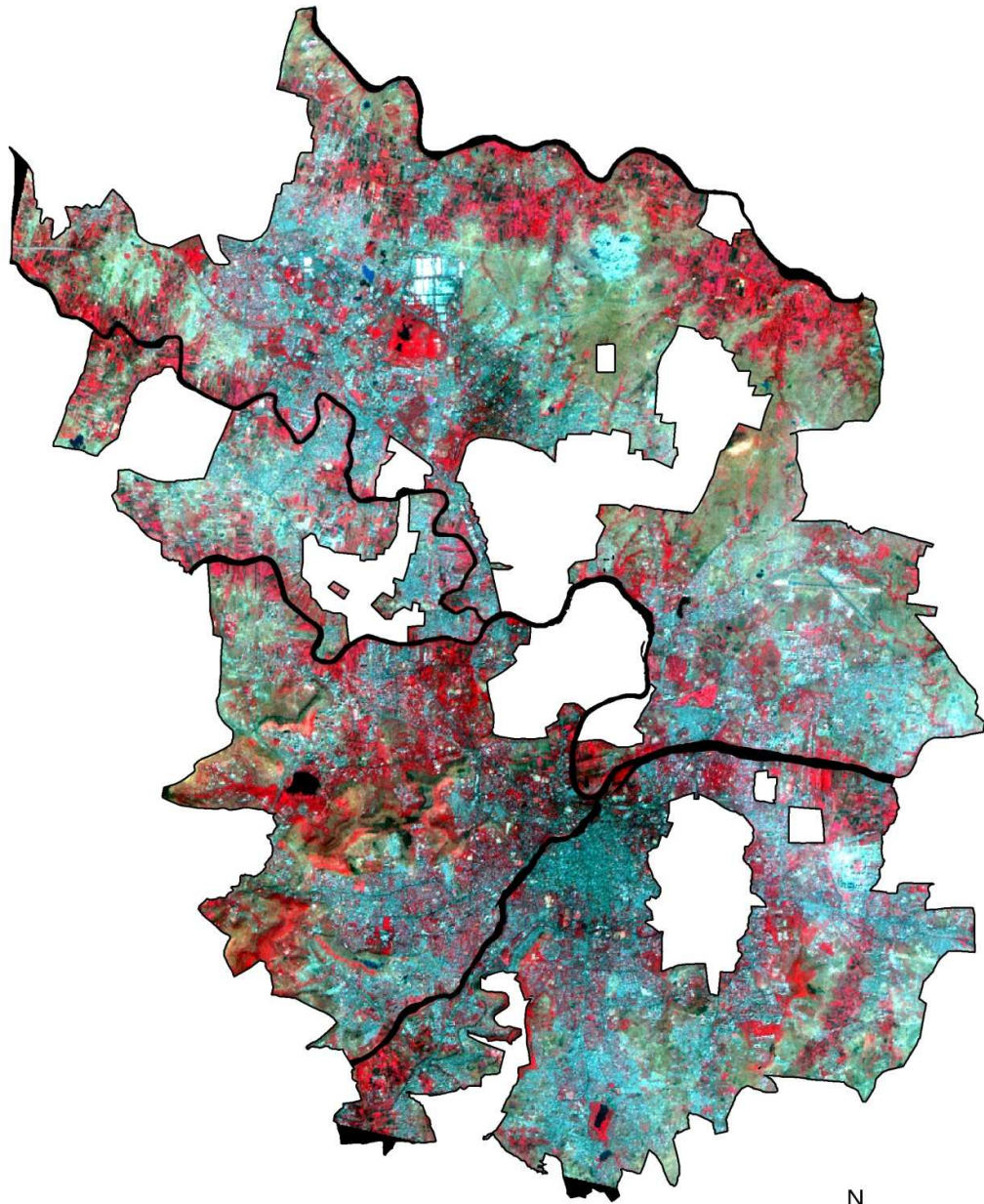
Source: Modified from NRSC **Fig. 2.13**

PMC and PCMC Classified Image based on IRS P6 LISS III (2004)

Legend

Built-up
Barren Land
Vegetation
Fallow Land
Water Bodies

N

0   2   4 Km.
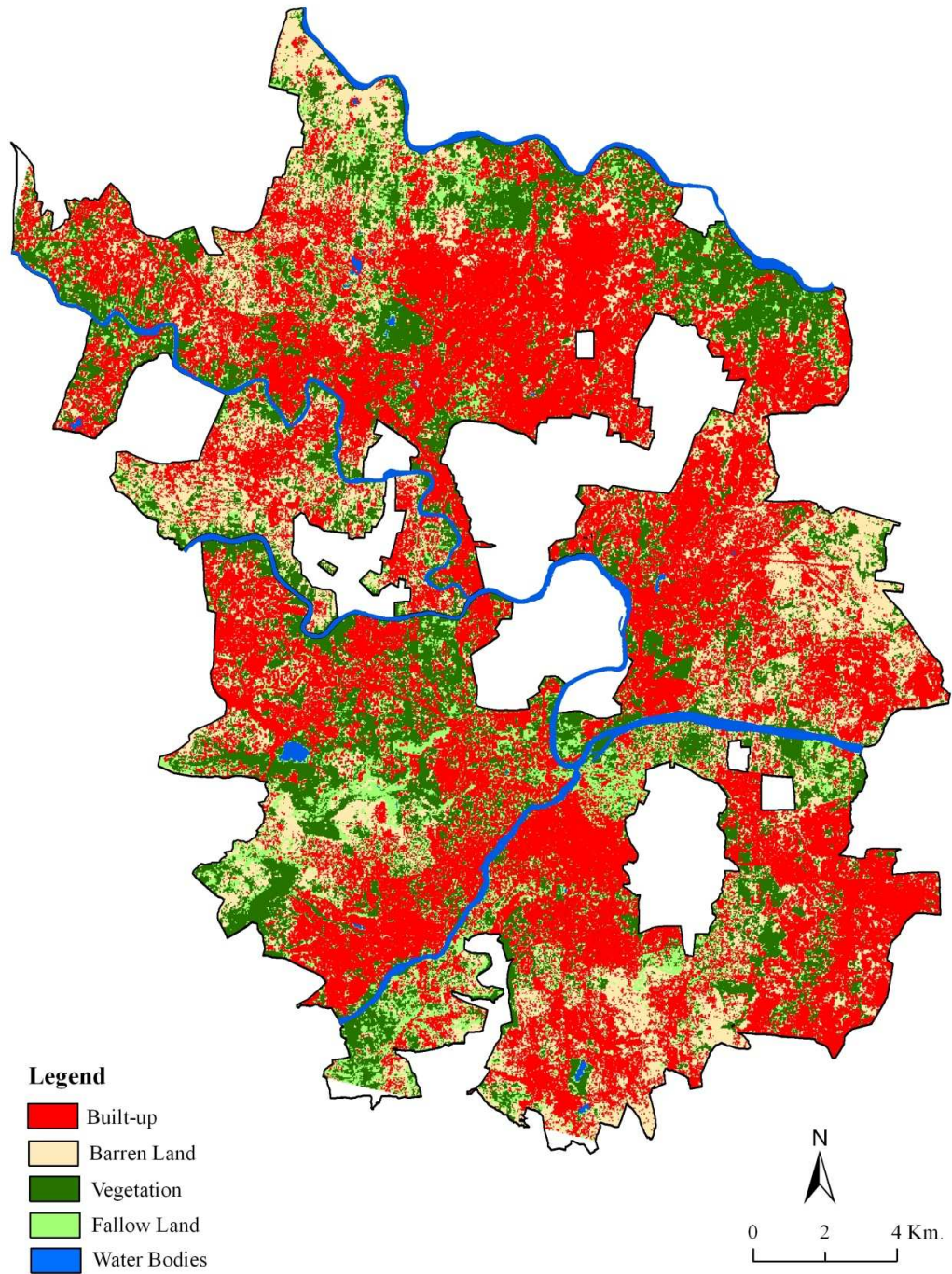
Source: Modified from NRSC   **Fig. 2.14**

IRS P6 LISS-III (2008) False Color Composite (FCC) Image of PMC and PCMC
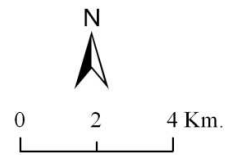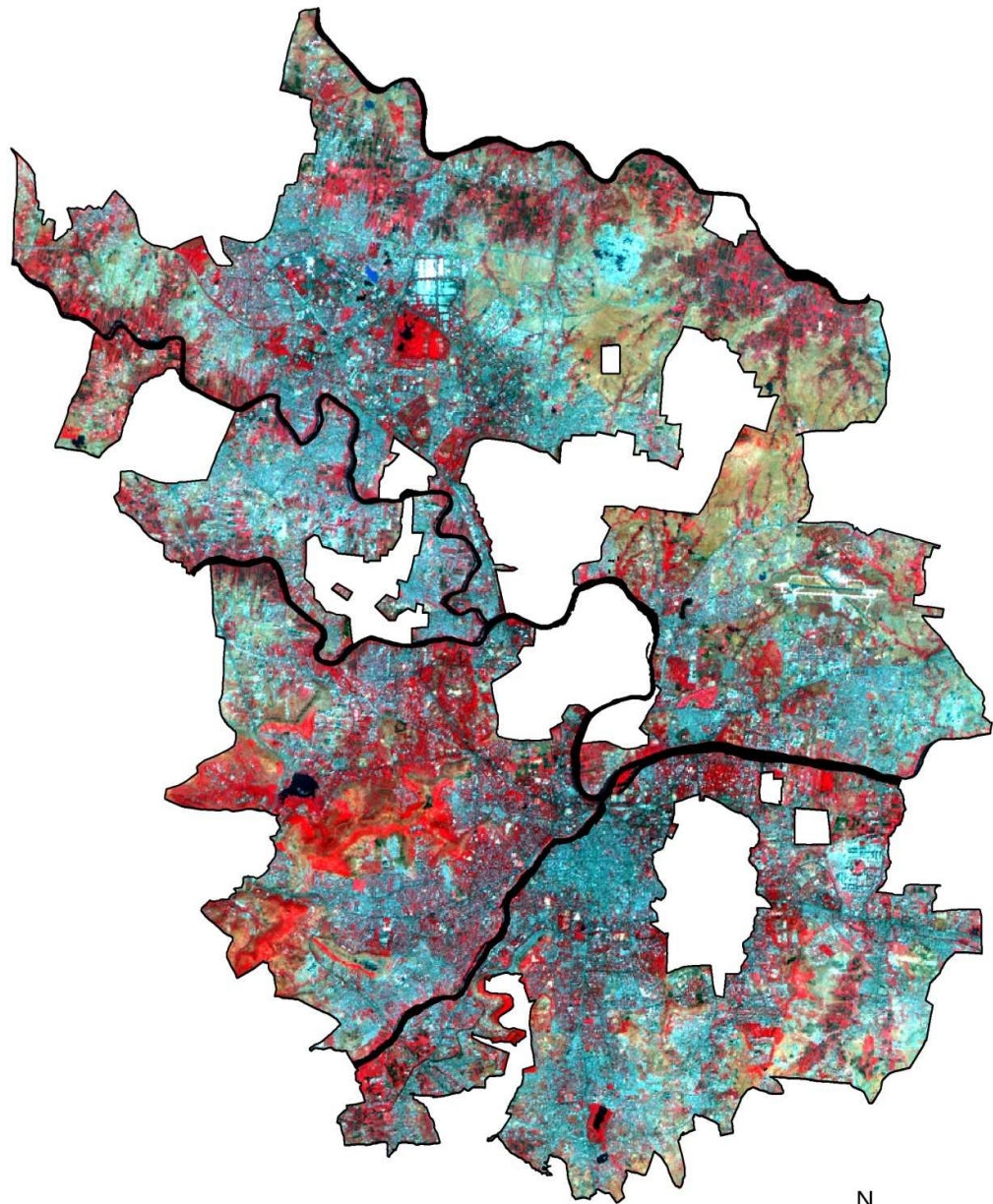
0   2   4 Km.

Source: Modified from NRSC   **Fig. 2.15**

51

PMC and PCMC Classified Image based on IRS P6 LISS III (2008)

Legend

- Built-up
- Barren Land
- Vegetation
- Fallow Land
- Water Bodies

N

0   2   4 Km.
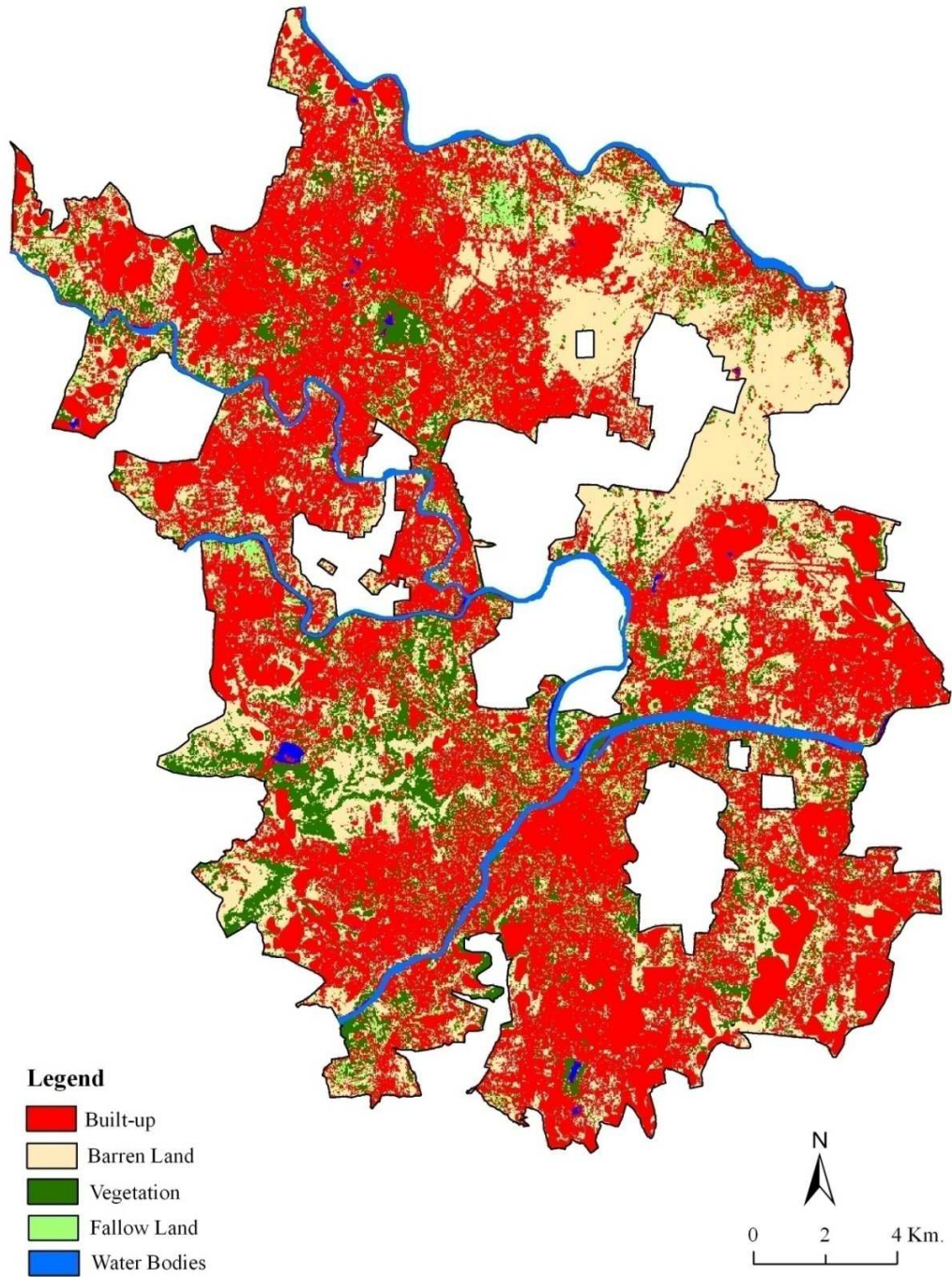
Source: Modified from NRSC   **Fig. 2.16**

2.11 Landuse change PMC

Table 2.7 Expansion of City limit (PMC)

Year	Total Area Sq. km.	Area added Sq. km	Newly Merged Areas/Villages
1857	7.74	-	South- Shankarsheth road to Ambila road North East – Right bank of Mutha river East- Welesly road to new Modikana near Nagzari
1889	9.86	2.12	Area between Shankarsheth road, Satara Road and Golibar Maidan
1890	18.04	8.17	Erandwana and Bhamburda villages
1931	18.79	0.75	Parvathi Gaothan and area till Hingne
1935	19.05	0.26	Chaturshringi Area
1958	138.98	27.02	Inclusion of 18 villages
1975	**138.05**	**(-)0.84**	**Exclusion of some part of Bhosari**
1981	146.95	7.33	Inclusion of Sutarwadi
1983	146.11	10.01	Inclusion of survey_no. 79 of Ghorpadi
2001	243.87	97.84	Inclusion of 23 villages

Source: JNNURM, City Development Plan, PMC

Pune has grown from an area of 7.74 sq. km. in 1857 to 243.87 sq. km in 2001 i.e. it has increased by 236.82 sq. km in the last 144 years. In 1981, the area of old PMC was 146.95 sq. km. which increased to 243.87 sq. km. in 2001, with the inclusion of the 23 villages. The expansion of the PMC limits over the years is shown in the Table. 2.5.

Pune agglomeration includes the area under Pune and Pimpri - Chinchwad Municipal Corporations, Pune, Khadki and Dehuroad Cantonments, Talegaon and few semi-urbanized villages on the periphery.

In 1967, Pune Municipal Corporation, Pimpri Chinchwad Municipal body, Pune Khadki and Dehuroad Cantonment, Talegaon Municipal body and surrounding villages were included in the limits of Pune Metropolitan Region. The landuse of the Pune Metropolitan Region in past 30 years is given below. In the past 30 years, the area under residential use has increased by 2.4 % and the area under agriculture and plantation has decreased by 34 %. The area under water bodies, hills and forest has remained the same. However most of the hills areas have been encroached upon.

As per landuse map, comparative Toposheet and Image major landuse changes observed in built up area, then secondary agricultural and fallowland respectively. In

the present study concentration is focused on built up i.e. urban sprawl which is explained in detailed forth coming chapters.

2.12 Landuse change PCMC

Table 2.8 Expansion of City limit (PCMC)

Year	Area (Sq. Km.)	Increased Area in Sq. Km.
1982	86.01	-
1991	86.01	-
1997	170.52	84.51 (After inclusion 18 fringe villages)
2011	170.52	-

Source: Census & PCMC records

Pimpri - Chinchwad has grown from an area of 86.01 sq. km. in 1982 to 170.52 sq. km in 1997 i.e. it has increased by 84.51 sq. km in the last 30 years. In 1982, the area of old PCMC was 86.01 sq. km. which increased to 170.52 sq. km. in 2011, with the inclusion of the 18 villages. The expansion of the PCMC limits over the years is shown in the given Table. 2.6.

2.13 Pune City (PMC) Growth

From a small area around Kasba Peth, Pune has grown dramatically; in 1958, small pockets of land in parts of the villages of Katraj, Dhankavadi, Lohagaon, Dapodi, etc. were added increasing the area within PMC's jurisdiction. The last such annexation took place in 1997 wherein 36 villages with an area of 97.84 sq. km. were added to Pune city. As a result, the PMC area increased from 146 sq. km. to 243.9 sq. km. According to JNNURM Pune Development Draft Plan, new PMC area is now more than double the Chennai Municipal Corporation's area.

To see the change occurred in economical activities of Pune city in last 150 years and how Pune city transformed from small hamlet with only 15 huts in 613 A.D. to 1.3 million in 1981 and in 2001 the population has reached to 3.5 million. In the present work emphasis is also given on how spatial changes occurred in different phases of Pune city.
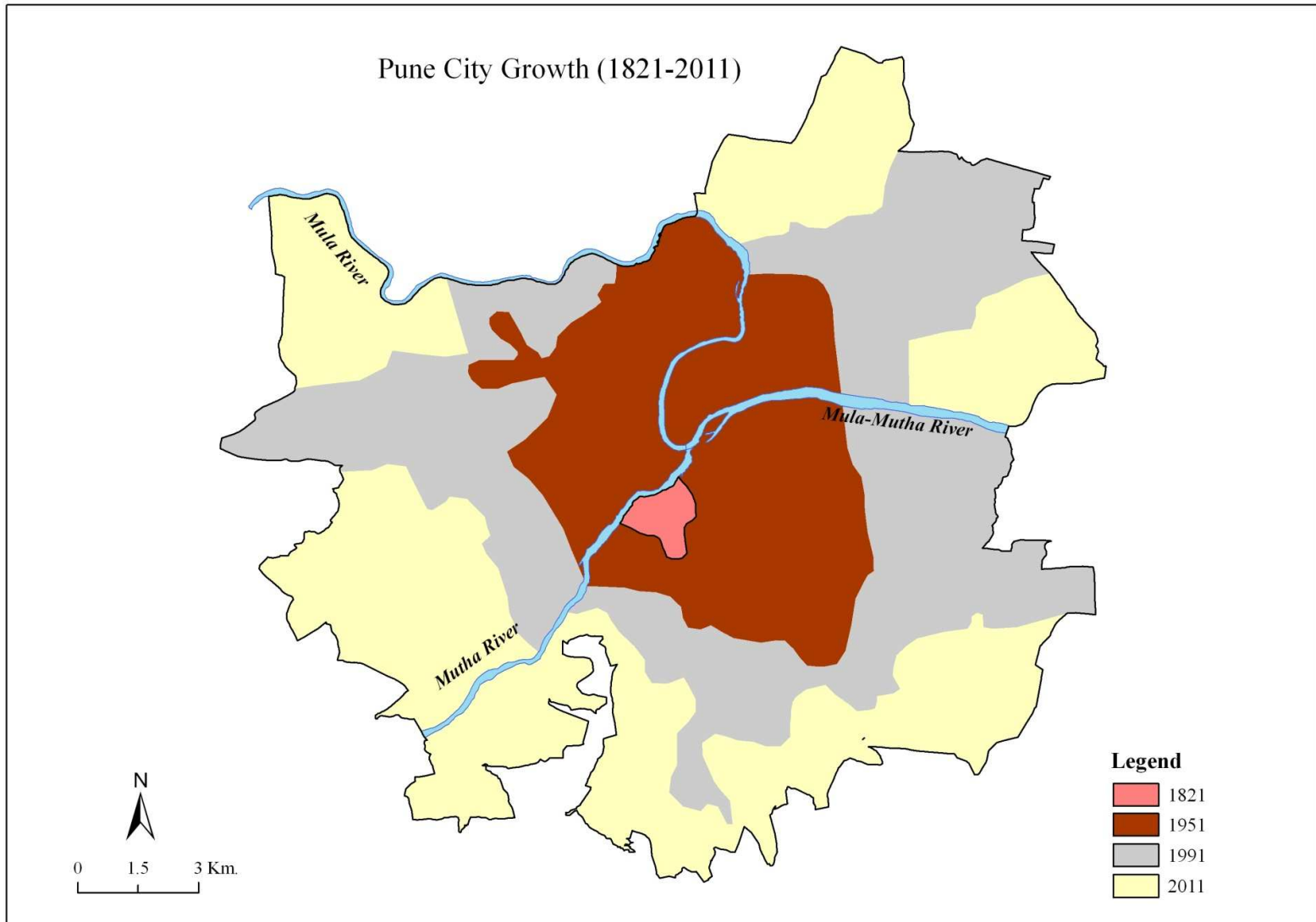
Fig. 2.17 Pune city Growth map (1821 to 2011)

55

2.14 Pimpri - Chinchwad (PCMC) Growth

The process of formation of the Pimpri-Chinchwad New Municipal Council in 1970 and its subsequent conversion to a Municipal Corporation in 1982 along with the extension of the PMC and PCMC limits in 1997 has made the Pune agglomeration one of the largest in the country. From its embryonic origin covering a small area around the Kasba Peth, it has grown in size by successive affiliations of the peripheral areas and is now rated as the seventh largest urban agglomeration in the country. The latest merger in 1997 proved to be extraordinary. The 38 peripheral villages were merged in the Corporation's limits, resulting in an area of 368.69 Sq. km. However, the Government of Maharashtra in 2001, decided to de-link 15 villages completely and 5 villages partly from PMC's limits, reducing the total area to 243.96 Sq. Km.

The growth of the city in sixties was mainly due to industrial development in the Pimpri – Chinchwad area by private industrialists and MIDC. The bursting of the Panshet dam in 1961 changed the growth pattern and the city started growing along the Mutha River. A number of town planning schemes under the Bombay Town Plan Act, 1945 were planned and completed giving an orderly development pattern to the city. Unfortunately Pune Municipal Corporation took up no town-planning scheme since 1970 and now the city is growing based on a broad development plan and by using development strategies like zoning, reservation TDR, and accommodation reservation. These half-hearted efforts have created haphazard urban pattern.

2.15 Conclusion

Second chapter comprises profile of the study area that gives a detailed account of location, extent and aerial coverage of the Pune and Pimpri-Chinchwad in the Pune District, (Maharashtra, India). Physiography and climate of the Pune and Pimpri-Chinchwad. Built-up, landuse, transportation, communication and population and demographic structure with characteristics of the Pune and Pimpri-Chinchwad are also discussed in the last part of the chapter to know about socio-economic status of the Pune and Pimpri-Chinchwad.
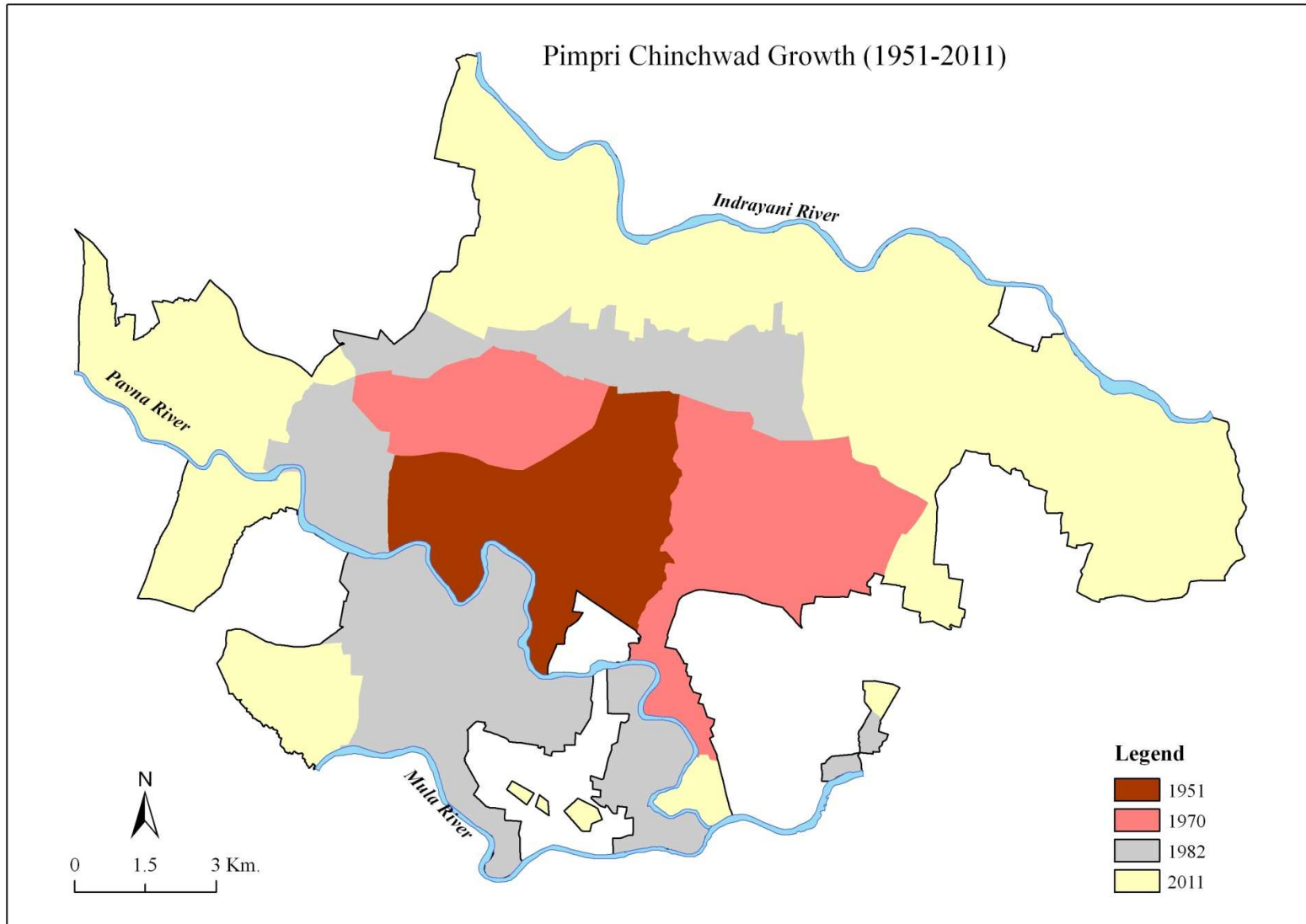
Fig. 2.18

Chapter III

DATABASE AND METHODOLOGY

3.1 Introduction

The data is the backbone of any research. In order to study the change of spatial extent of growth and infrastructural facilities, SOI toposheets and IRS P6 LISS III and LANDSAT-TM data was used to generate different layers of years 1980, 1992, 1999, 2004 and 2008 respectively. Multi-temporal data has been used to monitor the urban sprawl. The census data of the city was integrated with the above mentioned data to identify the elements at risk associated with different forms of urban hazards.

Methodology of the work involves utilization of various methods, tools and techniques used to assessment of urban sprawl for fulfillment of the objectives. GIS techniques were used for utility planning in terms of sprawl. Remote Sensing data of the study area has also given spatio-temporal information on the urban landuse.

3.2 Database

The data required for the present study comprises topographical maps, Satellite Images, Census data and Utility services data details. For mapping, the extent of the urban area as it stood at the 1979-1980 level, Survey of India topographical maps were used. Apart from that extent of the urban area, this has details of built-up, drainage, water bodies, rail and road networks and administrative boundaries. LANDSAT ETM+ and IRS P6 LISS III data were used to map the extent of sprawl for 1980 to 2008. In this study the secondary data has been collected from various sources.

Table 3.1: Secondary Data details for the study area

Segment	Type of Data	Centre
Spatial data	Toposheets no. 47 F/14/2, 47/F/14/3, 47F/14/6, 47/F/15/NE, 47/F/15/NW	Survey of India, Scale 1:25000
	Satellite Imagery–LANDSAT ETM+ Dated: 4 December 1992	National Remote Sensing Centre, Hyderabad (NRSC)
	Satellite Imagery–LANDSAT ETM+ Dated: 14 November 1999	
	Satellite Imagery–LISS-III (Sensor-IRS P6) Dated: 13 March 2004	
	Satellite Imagery–LISS-III (Sensor-IRS P6) Dated: 11 November 2008	
Non-Spatial data	Transportation Educational Facilities Hospitals	Pune Municipal Corporation (PMC), Pimpri Chinchwad Municipal Corporation (PCMC), PCMC website, Indian Medical Association, Indiacom Yellow Pages, www.Indiacom.com, www.pcmcindia.in, www.pcmcgisda.org.in, www.punediary.com.
	Ward wise Population data	PMC, PCMC and Census year book 2001

3.3 Methodology

This work covers Pune –Pimpri Chinchwad Municipal Corporation Area. To understand urban sprawl of the Pune and Pimpri-Chinchwad, the methodology adopted for the present study is divided in following phases.

3.3.1 Library work

Exhaustive literature survey of the topic of investigation has been undertaken. published literature, reports will be collected from various libraries, institutes; Govt. departments etc. Besides, relevant literatures like reference books, bulletins, review etc. were obtained through internet.

3.3.2 Pre field phase

This phase deals with the literature review for the understanding the complexity of a dynamic phenomena of urban sprawl and an urban environment. Literature referred to urban sprawl, extraction of sprawl, problems related upon agglomeration were collected to have some general understanding of the topic. Application of remote sensing technology have been identified and used as an important tool to monitor land use and surface changes. Satellite remote sensing collects multi-spectral, multi-resolution, multi-temporal data providing valuable information for understanding and monitoring the process of urban sprawl. As it is in the digital format, it can be brought into GIS, to provide a suitable platform for data analysis, update and retrieval. Land use can be captured both in terms of geographic location and absolute area. The growth profile obtained helps in formulation of development policies. (Patkar.V.N & Sampathkumar. D, cf. Shekhar S. 2005)

The collection of different types of maps includes satellite imageries and topographical maps. Collection of non-spatial data, utility services data details has been obtained from PMC and PCMC.

3.3.3 Field work

This phase includes visit to the study area and its fringe areas in different seasons, GPS surveys, instrumental surveys, photographs, questionnaire survey etc. it facilitated to understand the complexity of a dynamic phenomenon such as urban sprawl, land use changes, urban sprawl pattern.

3.3.4 Laboratory work

Includes sorting of data, digitization of various layers, preparation of maps and other GIS/RS techniques, like Georeferencing, Data attachment, area calculation, Overlay analysis, Unsupervised classification, Final layouts of different maps.

3.3.5 Synthesis of the data, Report writing and submission

The data generated during the field, and in laboratory was studied synthesized, interpreted have been produced in this thesis.

3.4 Data Processing Work

3.4.1 Scanning the Toposheets

Topographical maps of the study area have been obtained from Survey of India (SOI) Pune. These toposheets were scanned in **.tiff** (300 Dpi) format to have them into digital format, so that further processing should become easy.

3.4.2 Georeferencing the Toposheets

Scanned toposheets were then transformed to in ArcGIS 9.1 for georefrencing using 12 well distributed Ground Control Points and kept 3rd polynomial order. RMS error kept 0.4 which is below half pixel and resampled the image with WGS 84, 43 North Zone. After resampling and reproject in the same toposheets were converted from WGS 84 to UTM. The reprojection of toposheet is useful for area calculation.

3.4.3 Georeferencing the Images

After georefrencing of toposheets, next task was georefrencing of the IRS P6 LISS IV imagery of the same area. For the georfrencing of satellite imagery reprojected toposheets were used. 15 well distributed ground control points were used and RMS error was kept below half pixel.

3.4.4 Normalization of attribute data

Attribute data was mainly collected from secondary data sources. Using MSOffice 2003 this data was then converted into digital format. Degree of accessibility and application of database depends on the nature and systematic logical arrangement of data. Making efficient geodatabase data was normalized and unique id were generated for data attachment. The same unique Id field was generated in spatial data so as to facilitate easy attachment of all attribute data to the spatial data.

3.4.5 Generation of Geodatabase

The attribute data which was in hard copy format that was also converted into digital spreadsheet (**.dbf**) format. Due to unique Id, normalized attribute data became ready for attachment. In spatial data generation, a personal geodatabase in ArcGIS software for analysis purpose, the same unique Id field was also generated in spatial data. Due to this attachment of spatial and non spatial data has become easier.

3.4.6 Data Attachment

Attribute data saved in **db IV** format was then imported into attribute data table format in ArcGIS. Unique Id for spatial data was assigned and attached to all attribute data and the spatial data. It is the important characteristics of GIS in which one can see both spatial and non spatial data at a glance.

3.5 Processing on Toposheet

3.5.1 Area Calculation

The study of changing landuse pattern in urban area over period of time is important task for determining the trend of urban sprawl. In present scenario the study area was classified into various classes. Each class was then compared with the area obtained from satellite images of the different years. It gives a significant trend of urban sprawl.

3.6 Ward boundary map

Wardwise boundary map has been obtained from Municipal Council of Pune and Pimpri Chinchwad Using registration techniques in GIS environment, the map has been properly digitized and registered with SOI topographic graticule. This map has been used in the integration analysis to get Administrative ward wise information. Demographic data obtained from census records were linked to the wards coverage using unique item related to the ward code. All the thematic maps were digitized in GIS environment and integrated with spatial framework of Pune and Pimpri Chinchwad planning area. Area statistics were obtained for all the above-mentioned parameters considered for the study directly from GIS database.

3.7 GIS, Remote Sensing and Image Processing Techniques

GIS and remote sensing are very useful in the formulation and implementation of the spatial and temporal changes, which are essential components of regional planning to ensure the sustainable development. The different stages in the formulation and implementation of a regional development strategy can be generalised as determination of objectives, resource inventory, analysis of the existing situation, modelling and projection, development of planning options, selection of planning options, plan implementation, and plan evaluation, monitoring and feedback (Yeh and Xia, 1996). GIS and remote sensing techniques are quite developed and

operational to implement such a proposed strategy. The spatial patterns of urban sprawl on temporal scale is studied and analysed using the satellite imageries and cadastral data from Survey of India, mapped, monitored and accurately assessed from satellite data along with conventional ground data. The image processing techniques are also quite effective in identifying the urban growth pattern from the spatial and temporal data captured by the remote sensing techniques. These help in delineating the growth patterns of urban sprawl such as, the linear growth and radial growth patterns.

3.8 Satellite Image Processing

3.8.1 Landuse / Landcover Map

Landuse means, use of land for different purposes like built-up recreation, commercial, forest etc. Landcover means the area covered by various physical features like vegetation, hills, water bodies etc. remote sensing technology plays key role in landuse/landcover mapping of urban area.

3.8.2 Classification of Land Use/Land Cover

Land Use land cover is mainly classified in to following categories

Level I

1. Urban or Built-up Land

2. Agricultural Land

3. Forest Land

4. Water bodies

5. Wetland

6. Barren Land

3.8.2.1 Urban Built-Up Land

"All places with a municipality, corporation or cantonment or which are notified town areas, & all other places which satisfy the criteria of minimum population of 5000, at least 75% of whose male working population is non-agricultural & having a density of population of at least 400 per sq.km. are placed under this category" It includes;

Residential It includes all the constructions used primarily for residential purpose. The residential areas include apartments, detached houses, row houses & farmhouses of different density groups.

Industrial - It includes all the constructions that are used for industrial activity. It include light manufacturing industries focused on design, assembly, finishing & packaging of products, to heavy manufacturing industries such as chemical plant, electric power generating stations, oil refineries, brick making plants, steel plants etc.

Transportation - This type of land is used basically for transportation activity. Major transportation routes such as roadways, railways, airways & waterways are included in this category. The roadways include major & minor roads, bridges & terminal facilities such as bus & truck terminals. The rail facilities include stations, parking lots, repair, & switching yards, tracks & related areas. The airways include all facilities directly connected with air transport. The areas include runways, intervening land, terminals, service buildings, plane hangars, navigation aids, fuel storage areas, parking lots & limited buffer zone. The water transportation includes those areas related to water transportations excluding the water. The major areas of this category are the port areas, docks, shipyards, dry-dock & lock.

Recreational areas - "It includes all the recreation facilities & areas which are devoted for recreation & basically on open land." It includes incidental buildings such as shelters, toilets, beach change areas, etc.

Public and semi-public - "It includes all educational facilities such as schools, colleges & universities, religious places, health centers, cantonment areas & areas associated with the transport of gas, oil, water & electricity."

Open spaces/Vacant areas - "It includes all the open spaces which are not used for any purpose & vacant land, both within & outside built-up areas"

3.8.2.2 Agriculture Land

"This is broadly defined as the land used primarily for production of food & fiber." This includes cropped areas, fallow lands & plantation areas.

Crop Land - It includes both cropped lands & un-irrigated crops grown under natural climatic conditions.

Plantations - It includes plantations such as coconut, areca nut, citrus, banana, cashew, casuarinas, eucalyptus, & other orchards/nurseries.

3.8.2.3 Fallow Land

It is basically an agricultural land but devoid of any crop at the time of collection of remotely sensed data.

3.8.2.4 Wasteland

"Lands which are capable or have the potential for the development of vegetative cover & are not being used due to different constraints of varying degrees are classified under this category."

Undulating upland with or without scrubs - "This is the land which is prone to degradation & may or may not have scrub cover. Such land occupying topographically high locations & excludes plain, hill & mountainous terrain."

Sandy areas - "Sandy areas other than beaches are composed primarily of dunes & accumulation of sand transported by the winds. Sand accumulations occurring in coastal plains, river flood plains or inland areas are included in this category."

3.8.2.5 Water Bodies

"It include the areas that are persistently water covered."

Rivers/Streams - "This category includes rivers, streams & creeks."

Reservoirs/Tanks/ Canals - "This is artificial impoundment of water used for irrigation, flood control, municipal water supplies, recreation, hydro-electric power generation & so forth."

Lakes/Ponds - "These are non-flowing, naturally enclosed bodies of water, including regulated natural lakes but excluding reservoirs."

3.9 Urban sprawl assessment

The base maps prepared from toposheets (1979-80) and different years satellite imageries (1992, 1999, 2004 and 2008), the built-up area was calculated from same and Shannon's entropy was applied to measure the urban sprawl.

3.10 Analytical Framework

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                              │   Data   │
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          │ Spatial Data │                    │ Non-Spatial Data │
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  ┌──────────────────┐ ┌──────────┐ ┌──────────┐ ┌──────────────┐
  │Satellite Imageries│ │Toposheet │ │PMC/PCMC  │ │Transportation│
  └────────┬─────────┘ │ 1979-80  │ │  Data    │ └──────────────┘
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┌──────────────┐┌──────────────┐ ┌──────────┐   │Hospital Data │
│LANDSAT ETM+  ││IRS P6 LISS-III│ │ Scanning │   └──────────────┘
│1992 & 1999   ││2004 & 2008   │ └────┬─────┘   ┌──────────────┐
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  ┌──────────────────┐        │Georeferencing│  └──────────────┘
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  │(Toposheet to Image)│      ┌──────────────┐ ┌──────────┐
  └────────┬─────────┘        │ Vectorization│ │ Attribute│
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│Supervised Classification│          │         ┌──────────────┐
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│Landuse/Landcover │◄──┐     ┌──────────────────┐  
│    Mapping       │   │     │Data base Generation│─►┌──────────────┐
└──────────────────┘   │     └──────────────────┘   │Data Attachment│
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│ Built-up area    │◄──┘            ┌─────────────┬─────────┴──────────┐
│    Mapping       │          ┌──────────┐ ┌──────────────────┐ ┌──────────────┐
└──────────────────┘          │ Built-up │ │Landuse/Landcover │ │Civic Amenities│
                              └──────────┘ └──────────────────┘ └──────────────┘
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3.11 Conclusion

This chapter contains Database and Methodological approach for the monitoring and measurement of sprawl in study area. SOI toposheets (1979-80) and different years satellite data (1992, 1999, 2004 and 2008), were used for calculation of built-up area. For assessment of urban sprawl the Shannon's entropy technique was used. Utility services like, multispecialty hospitals, public transportation and medium wise schools data were used.

Chapter IV

ASSESMENT OF URBAN SPRAWL

4.1 Introduction

The study of urbanisation has interest from a wide range of experts. The multidisciplinary scope of the theme invokes the interest from ecologists, to urban planners and civil engineers, to sociologists, to administrators and policy makers, and finally the common man. This is because of the large amount of activities and processes that take place in the urban ecosystems everyday. Thus when the early humans evolved they settled on the banks of the rivers that downed the advent of civilisations. An unplanned increase in the population complimented with creativeness, humans were able to invent wheel and light fire, created settlements and started lived in forests too.

An unprecedented population growth and migration, an increased urban population and urbanisation is unplanned. More towns and cities bloomed with a change in the land use along the many of landscapes and ecosystems found on earth. Today, humans can boast of living under a wide range of climatic and environmental conditions. This has further led to humans contributing the urban centres at almost every corner of the earth. These urban ecosystems are a consequence of urbanisation through rapid industrial centres and flourishing up of suburban colonies, also became heart of economic, social, cultural, and political activities.

4.2 Urbanisation and Urban Sprawl

In India, with an extraordinary population growth and migration, an increased urban population and urbanisation is unexpected. More and other towns and cities are up-and-coming with a change in the land use along the highways and in the immediate surrounding area of the city. This scattered development outer of compact urban and village centres along highways and in rural countryside is defined as sprawl. Urbanisation is a form of metropolitan growth that is a response to often bewildering sets of economic, social, and political forces and to the physical geography of an area. Some of the causes of the sprawl include - population growth, economy, patterns of transportation initiatives like the structure of roads and the condition of infrastructure using public capital encouraging development. The direct implication of such urban sprawl is the change in land use and land cover of the region.

4.3 Urban sprawl - spatial and temporal changes: pattern assessment

Mapping urban sprawl provides a "picture" of where this type of growth is occurring, and helps to identify the environmental and natural resources threatened by such sprawls, and suggests the likely future directions and patterns of sprawling growth. Analysing the sprawl over a period of time will help in understanding the nature and growth of this phenomenon. Ultimately the power to manage a sprawl resides with local municipal governments that vary considerably in terms of will and ability to address sprawl issues.

4.4 Consequences of Urban Sprawl

There is no doubt that urban sprawl exists in most of the cities nowadays. For many, a suburban home or apartment is a very comfortable place to live in. To those who have recently escaped from the inner city, the suburbs are wonderful places. For most people the rise in affluence has meant a better, not a worst, existence, and they look upon their much despised 'suburban middle-class lives' as fulfillment rather than deprivation." The consequences and significance of such sprawling, average or good are evaluated, based on its socio-economic and environmental impact.

Urban sprawl, according to Cornell University's Department of Development Sociology, "is generally defined as the increased development of land in suburban and rural areas outside of their respective urban centers." Sprawl is most often characterized by low-density development marked by detached single-family homes, strip malls and reliance on the automobile for transportation. Urbanists, particularly those associated with "new urbanism" and "smart growth" movements, have roundly criticized urban sprawl for a variety of reasons.

4.5 Measuring Urban Sprawl

To understand the complexity of a dynamic phenomenon such as urban sprawl; land use change, urban sprawl pattern and computation of sprawl indicator indices were determined. Mapping urban sprawl provides a picture where this type of expansion is occurring, and also helps to identify the ecological situation threatened by such sprawl (H. Sudhira et. al., 2003).

The characteristics of land use / land cover, drainage network, roads and railway network and the administrative boundaries from the toposheets were digitised. Individual layers for each character were digitized.

Urban sprawl over the period of three decades (1980-2008) was determined by computing the area of all the settlements from the digitized toposheets of 1979-80 and comparing it with the area obtained from the classified satellite imagery for the built-up theme. The vector layers were digitized from the toposheets of 1979-80, included themes as; built-up area, drainage (rivers, streams and water bodies), administrative boundaries, and road network.

The toposheets as mentioned in **Table 3.1** were first geo-registered. Since urban sprawl is a process, which can affect even the smallest of wards, each and every ward was analyzed. Details of villages like population density were extracted from census books of 2001 and were added to the attribute database. The area under built-up was later added to this attribute database after digitization of the toposheets for the built-up feature for each village.

Satellite image data for mapping the extent of the urban area from 1980 & 2008 level, Survey of India topographic maps and satellite imageries were used. Apart from that extent of the urban area, this has details of built-up, drainage, water bodies, rail and road networks and administrative boundaries. LANDSAT ETM+ and IRS P6 LISS III data were used to map the extent of Sprawl for 1980 to 2008.

The standard processes for the analyses of satellite imagery such as extraction, restoration, classification, and enhancement were applied for the present study. The Maximum Likelihood Classifier (MLC) was employed for the image classification. The original classification of land-use of five categories was aggregated to vegetation, built-up (residential & commercial), agricultural lands and open land and water bodies. Area under built-up theme was recognized and the whole built-up theme from that imagery was digitized; this vector layer gave the urban area of 1980 to 2008. Further, by applying vector analyses, the built-up area under each ward was calculated.

4.6 Built-up area as an indicator of urban sprawl

The percentage of an area covered by impervious surfaces such as asphalt and concrete is a straightforward measure of development (Barnes et al, 2001). It can be safely considered that developed areas have greater proportions of impervious surfaces, i.e. the built-up areas as compared to the lesser-developed areas. The proportion of the total population in a region to the total built-up of the region is a measure of quantifying sprawl.

Considering the built-up area as a potential and fairly accurate parameter of urban sprawl has resulted in making considerable hypothesis on this phenomenon. Since the sprawl is characterized by an increase in the built-up area along the urban and rural fringe, this attribute gives considerable information for understanding the behavior of such sprawls. This is also influenced by parameters such as population density, population growth rate, etc.

4.7 Shannon's Entropy

The term Entropy is most frequently used while describing the quantity efficiency of elements. Entropy is related to the expansion of the spatial variable in a given area or limit, which was given by Shannon's Entropy. This method is useful to measure and distinguish types of sprawl. The Entropy method is beneficial with GIS because of simplicity and uncomplicated integration. As an important exercise, the Shannon's entropy approach (Yeh and Li, 2001 and S. Shekhar 2005) was quantified to detect the urban sprawl phenomenon. Entropy value varies from 0 to 1. If the distribution of built-up is most concentrated in one area, the lowest Entropy value is 0. Distribution of built-up across space will give the maximum Entropy value 1.

This Entropy (E_t) method could be calculated using following formula.

$$E_t = \frac{\sum_{j=1}^{m} PDj\left(\log\left(\frac{1}{PDj}\right)\right)}{\log(m)} \tag{1}$$

Where $PDj = \frac{Dj}{\sum_{j=1}^{m} Dj}$

Dj is the density of land growth. That equals to quantity of Built-up land divided by the total quantity of land in the $\mathbf{j}^{th}$ zone in the total of **m** zones.

While using Entropy to measure the distribution of a physical occurrence, the difference on entropy among two different time periods of time can be used to indicate the change in the amount of circulation of urban sprawl.

$$\Delta E_t = E_t(y+1) - E_t(y) \tag{2}$$

Where Δ Et is the difference of the relative entropy values between two time periods, Et(y+1) is the relative entropy value at time period y+1, Et(y) is the relative entropy value at time period y.

4.8 Measuring the sprawl of PMC and PCMC

Urban sprawl is a complex phenomenon, which not only has environmental impacts, but also social impacts (Barnes et al. 2001; www.sprawlwatch.org/).The entropy comes up to be effectively applied to find out urban sprawl. Due to its complexity, there is no specific, measurable, and generally accepted definition of urban sprawl (P. Sutton, et al., 2003). The urban area of China (Yeh and Li, 2001) it gained fame among the world researchers. Modeling Urban Land Use Change and Urban Sprawl of Calgary, Alberta, Canada (Heng Sun, et al., 2007), Monitoring the sprawl of Pune city (S. Shekhar, 2005) , Hyderabad City (M. Latha, et al., 2001) and Mysore – Banglore National Highway between Manglore and Udupi by H. Sudhira, et al., (2003) are some of the examples. For PMC and PCMC areas growing rapidly urban agglomeration, Shannon's entropy approach applied to measure the sprawl of municipality.

Table 4.1 Administrative Ward/Committee wise Total Built-up Area of PMC and PCMC in sq. km.

Ward /Committee Number	Name		TGA	1980	1992	1999	2004	2008
1	Aundh		38.73	0.96	6.24	8.66	10.18	18.64
2	Karve Road		15.46	0.08	2.82	4.24	5.44	7.00
3	Ghole Road		13.91	1.78	2.19	2.46	4.55	4.73
4	Warje-Karvenagar	**P**	15.26	0.80	2.12	4.49	7.37	9.00
5	BS Dholepatil		12.64	1.18	1.75	2.11	4.19	4.80
6	Hadapsar		26.86	0.63	3.12	6.28	11.55	19.03
7	Yeravada	**M**	29.24	0.37	2.50	6.68	14.00	20.64
8	Sangamvadi		30.39	0.78	2.40	5.90	12.51	14.09
9	Bhavanipeth		2.79	1.04	0.03	2.05	2.39	2.36
10	Kasbapeth	**C**	4.26	1.61	0.18	2.18	2.73	3.11
11	Vishrambaugwada		8.56	2.75	1.42	2.61	4.26	4.80
12	Tilak Road		13.60	0.67	3.15	2.83	5.68	6.24
13	Bibvewadi		22.13	0.62	2.79	6.51	13.15	17.08
14	Sahkarnagar		9.47	0.69	1.19	3.13	6.47	6.79
A	A Committee	**P**	36.01	0.31	7.39	9.94	14.83	22.74
B	B Committee	**C**	39.54	0.83	8.08	12.28	12.44	24.59
C	C Committee	**M**	66.85	0.69	6.35	15.00	26.80	27.46
D	D Committee	**C**	29.19	0.4	5.53	9.88	11.62	20.10
	Total		**414.90**	**16.19**	**59.25**	**107.23**	**170.16**	**233.20**

Source: Computed by author

Table 4.2 Total Built-up area of PMC and PCMC in Percentage

Ward Number	Committee/Ward		TGA	TGA in %	1980	Built-up Area in %	1992	Built-up Area in %	1999	Built-up Area in %	2004	Built-up Area in %	2008	Built-up Area in %
1	Aundh		38.73	9.34	0.96	2.48	6.24	16.11	8.66	22.36	10.18	26.28	18.64	48.13
2	Karve Road		15.46	3.73	0.08	0.52	2.82	18.24	4.24	27.43	5.44	35.19	7.00	45.28
3	Ghole Road		13.91	3.35	1.78	12.80	2.19	15.74	2.46	17.69	4.55	32.71	4.73	34.00
4	Warje-Karvenagar		15.26	3.68	0.80	5.24	2.12	13.89	4.49	29.42	7.37	48.30	9.00	58.98
5	BS Dholepatil	P	12.64	3.05	1.18	9.34	1.75	13.84	2.11	16.69	4.19	33.15	4.80	37.97
6	Hadapsar		26.86	6.47	0.63	2.35	3.12	11.62	6.28	23.38	11.55	43.00	19.03	70.85
7	Yeravada	M	29.24	7.05	0.37	1.27	2.50	8.55	6.68	22.85	14.00	47.88	20.64	70.59
8	Sangamvadi		30.39	7.32	0.78	2.57	2.40	7.90	5.90	19.41	12.51	41.16	14.09	46.36
9	Bhavanipeth		2.79	0.67	1.04	37.28	0.03	1.08	2.05	73.48	2.39	85.66	2.36	84.59
10	Kasbapeth	C	4.26	1.03	1.61	37.79	0.18	4.23	2.18	51.17	2.73	64.08	3.11	73.00
11	Vishrambaugwada		8.56	2.06	2.75	32.13	1.42	16.59	2.61	30.49	4.26	49.77	4.80	56.07
12	Tilak Road		13.60	3.28	0.67	4.93	3.15	23.16	2.83	20.81	5.68	41.76	6.24	45.88
13	Bibvewadi		22.13	5.33	0.62	2.80	2.79	12.61	6.51	29.42	13.15	59.42	17.08	77.18
14	Sahkarnagar		9.47	2.28	0.69	7.29	1.19	12.57	3.13	33.05	6.47	68.32	6.79	71.70
A	A Committee	P	36.01	8.68	0.31	0.86	7.39	20.52	9.94	27.60	14.83	41.18	22.74	63.15
B	B Committee	C	39.54	9.53	0.83	2.10	8.08	20.44	12.28	31.06	12.44	31.46	24.59	62.19
C	C Committee	M	66.85	16.11	0.69	1.03	6.35	9.50	15.00	22.44	26.80	40.09	27.46	41.08
D	D Committee	C	29.19	7.04	0.4	1.37	5.53	18.94	9.88	33.85	11.62	39.81	20.10	68.86
	Total		**414.90**	**100**	**16.19**		**59.25**		**107.23**		**170.16**		**233.20**	

Source: Computed by author

73

The precise aim of this present study is to find out urban sprawl in PMC and PCMC area. Therefore such kind of study requires temporal data to get trend of change in urban built-up area. In this work 1979-80, SOI toposheets, 1992 & 1999 LANDSAT ETM+ and 2004 & 2008, IRS P6 LISS-III satellite imageries has been used to detect the change in urban built-up. These five temporal data's shows the trend of changing pattern in built-up over periods of time.

Tables 4.1 and 4.2 represents the total built-up area, total geographical area (TGA) and percentage (%) of both areas under PMC and PCMC administrative wards/committees. The Study area comprises 14 wards in PMC and 4 committees of PCMC. C committee (66.85 sq. km.) is biggest in study area under PCMC and smallest ward is Bhavanipeth. Aundh (38.73 sq. km.) ward is biggest in PMC area followed by Sangamwadi, Yerawda and Hadapsar. In 1980 Vishrambaugwada was having 2.75 sq. km. built-up area followed by Ghole Road (1.78 sq. km) and Kasbapeth (1.61 sq. km.). Karve Road ward was having very less built-up area in 1980 compare to other wards/committees which was 0.08 sq. km. followed by A, committee (0.31 sq. km.) and Yerawada ward (0.37 sq. km.).

In 1992 B, committee had 8.08 sq. km. built-up area followed by A, committee (7.39 sq. km) and Aundh (6.24 sq. km.). Bhvanipeth ward was having very less built-up area in 1992 compared to other wards/committees which was 0.03 sq. km. next is Kasbapeth (0.18 sq. km.) and Vishrambaugwada ward (1.42 sq. km.).s

Year 1999 shows C, committee had 15.00 sq. km. built-up area followed by B, committee (12.28 sq. km) and Aundh (8.66 sq. km.). Bhavanipeth ward had very less built-up area in 1999 compared to other wards/committees which was 2.05 sq. km. next is Dhole Patil Road (2.11 sq. km.) and Kasbapeth ward (2.18 sq. km.).

Year 2004 shows C, committee had 26.80 sq. km. built-up area followed by A, committee (14.83 sq. km) and Yerawada (14.00 sq. km.). Bhavanipeth ward was having very less built-up area in 2004 compare to other wards/committees which was 2.39 sq. km. next is Kasbapeth (2.73 sq. km.) and Dhole Patil Road ward (4.19 sq. km.).

Year 2008 shows C, committee had 27.46 sq. km. built-up area followed by B, committee (24.59 sq. km) and A, committee (22.74 sq. km.). Bhvanipeth ward had very less built-up area in 2008 compared to other wards/committees which was 2.36 sq. km. next is Kasbapeth (3.11 sq. km.) and Ghole Road ward (4.73 sq. km.).

Table 4.3 Entropy Calculation for the Time Period of 1980

Sr. No.	Ward Number	Committee/Ward		TGA (sq. km.)	1980	Density (Dj)	PDj	1/PDj	log(1/PDj)	PDj*log(1/PDj)
1	1	Aundh		38.73	0.96	0.0248	0.0151	66.2174	1.8210	0.0275
2	2	Karve Road		15.46	0.08	0.0052	0.0032	317.1624	2.5013	0.0079
3	3	Ghole Road		13.91	1.78	0.1280	0.0780	12.8254	1.1081	0.0864
4	4	Warje-Karvenagar	P	15.26	0.80	0.0524	0.0319	31.3059	1.4956	0.0478
5	5	BS Dholepatil		12.64	1.18	0.0934	0.0569	17.5803	1.2450	0.0708
6	6	Hadapsar	M	26.86	0.63	0.0235	0.0143	69.9725	1.8449	0.0264
7	7	Yeravada		29.24	0.37	0.0127	0.0077	129.6994	2.1129	0.0163
8	8	Sangamvadi	C	30.39	0.78	0.0257	0.0156	63.9438	1.8058	0.0282
9	9	Bhavanipeth		2.79	1.04	0.3728	0.2271	4.4028	0.6437	0.1462
10	10	Kasbapeth		4.26	1.61	0.3779	0.2303	4.3426	0.6377	0.1469
11	11	Vishrambaugwada		8.56	2.75	0.3213	0.1957	5.1086	0.7083	0.1386
12	12	Tilak Road		13.60	0.67	0.0493	0.0300	33.3140	1.5226	0.0457
13	13	Bibvewadi		22.13	0.62	0.0280	0.0171	58.5803	1.7678	0.0302
14	14	Sahkarnagar		9.47	0.69	0.0729	0.0444	22.5249	1.3527	0.0601
15	A	A	P	36.01	0.31	0.0086	0.0052	190.6442	2.2802	0.0120
16	B	B	C	39.54	0.83	0.0210	0.0128	78.1825	1.8931	0.0242
17	C	C	M	66.85	0.69	0.0103	0.0063	159.0111	2.2014	0.0138
18	D	D	C	29.19	0.4	0.0137	0.0083	119.7709	2.0784	0.0174
		Total		**414.90**	**16.19**	**1.6412**				**0.9463**

Source: Computed by author   **TGA**= Total Geographical Area in Square km.

Log (m)=log 18   Et = 0.9463/1.2552

Log 18 = 1.2552   **Et = 0.7539**

Table 4.4 Entropy Calculation for the Time Period of 1992

Sr. No.	Ward Number	Committee/Ward		TGA	1992	Density (Dj)	PDj	1/PDj	log(1/PDj)	PDj*log(1/PDj)
1	1	Aundh		38.73	6.24	0.1611	0.0656	15.2400	1.1830	0.0776
2	2	Karve Road		15.46	2.82	0.1824	0.0743	13.4601	1.1290	0.0839
3	3	Ghole Road		13.91	2.19	0.1574	0.0641	15.5945	1.1930	0.0765
4	4	Warje-Karvenagar		15.26	2.12	0.1389	0.0566	17.6728	1.2473	0.0706
5	5	BS Dholepatil	P	12.64	1.75	0.1384	0.0564	17.7336	1.2488	0.0704
6	6	Hadapsar		26.86	3.12	0.1162	0.0473	21.1368	1.3250	0.0627
7	7	Yeravada	M	29.24	2.50	0.0855	0.0348	28.7161	1.4581	0.0508
8	8	Sangamvadi		30.39	2.40	0.0790	0.0322	31.0890	1.4926	0.0480
9	9	Bhavanipeth		2.79	0.03	0.0108	0.0044	228.3339	2.3586	0.0103
10	10	Kasbapeth	C	4.26	0.18	0.0423	0.0172	58.1065	1.7642	0.0304
11	11	Vishrambaugwada		8.56	1.42	0.1659	0.0676	14.8004	1.1703	0.0791
12	12	Tilak Road		13.60	3.15	0.2316	0.0943	10.6002	1.0253	0.0967
13	13	Bibvewadi		22.13	2.79	0.1261	0.0513	19.4744	1.2895	0.0662
14	14	Sahkarnagar		9.47	1.19	0.1257	0.0512	19.5385	1.2909	0.0661
15	A	A	P	36.01	7.39	0.2052	0.0836	11.9637	1.0779	0.0901
16	B	B	C	39.54	8.08	0.2044	0.0832	12.0144	1.0797	0.0899
17	C	C	M	66.85	6.35	0.0950	0.0387	25.8481	1.4124	0.0546
18	D	D	C	29.19	5.53	0.1894	0.0772	12.9602	1.1126	0.0858
		Total		**414.90**	**59.25**	**2.4552**				**1.2097**

Source: Computed by author

log (m)=log 18   Et = 1.2097/1.2552

log 18 = 1.2552   **Et = 0.9638**

Table 4.5 Entropy Calculation for the Time Period of 1999

Sr. No.	Ward Number	Committee/Ward		TGA	1999	Density (Dj)	PDj	1/PDj	log(1/PDj)	PDj*log(1/PDj)
1	1	Aundh		38.73	8.66	0.2236	0.0420	23.8208	1.3770	0.0578
2	2	Karve Road		15.46	4.24	0.2743	0.0515	19.4194	1.2882	0.0663
3	3	Ghole Road		13.91	2.46	0.1769	0.0332	30.1151	1.4788	0.0491
4	4	Warje-Karvenagar		15.26	4.49	0.2942	0.0552	18.1009	1.2577	0.0695
5	5	BS Dholepatil	P	12.64	2.11	0.1669	0.0313	31.9049	1.5039	0.0471
6	6	Hadapsar		26.86	6.28	0.2338	0.0439	22.7792	1.3575	0.0596
7	7	Yeravada	M	29.24	6.68	0.2285	0.0429	23.3127	1.3676	0.0587
8	8	Sangamvadi		30.39	5.90	0.1941	0.0365	27.4329	1.4383	0.0524
9	9	Bhavanipeth		2.79	2.05	0.7348	0.1380	7.2484	0.8602	0.1187
10	10	Kasbapeth	C	4.26	2.18	0.5117	0.0961	10.4075	1.0173	0.0978
11	11	Vishrambaugwada		8.56	2.61	0.3049	0.0572	17.4673	1.2422	0.0711
12	12	Tilak Road		13.60	2.83	0.2081	0.0391	25.5944	1.4081	0.0550
13	13	Bibvewadi		22.13	6.51	0.2942	0.0552	18.1048	1.2578	0.0695
14	14	Sahkarnagar		9.47	3.13	0.3305	0.0621	16.1138	1.2072	0.0749
15	A	A	P	36.01	9.94	0.2760	0.0518	19.2943	1.2854	0.0666
16	B	B	C	39.54	12.28	0.3106	0.0583	17.1482	1.2342	0.0720
17	C	C	M	66.85	15.00	0.2244	0.0421	23.7364	1.3754	0.0579
18	D	D	C	29.19	9.88	0.3385	0.0636	15.7356	1.1969	0.0761
		Total		**414.90**	**107.23**	**5.3259**				**1.2201**

Source: Computed by author

$$\text{Log (m)} = \text{log } 18 \qquad\qquad Et = 1.2201/1.2552$$

$$\text{Log } 18 = 1.2552 \qquad\qquad \mathbf{Et = 0.9720}$$

77

Table. 4.6 Entropy Calculation for the Time Period of 2004

Sr. No.	Ward Number	Committee/Ward		TGA	2004	Density (Dj)	PDj	1/PDj	log(1/PDj)	PDj*log(1/PDj)
1	1	Aundh		38.73	10.18	0.2628	0.0317	31.5508	1.4990	0.0475
2	2	Karve Road		15.46	5.44	0.3519	0.0424	23.5661	1.3723	0.0582
3	3	Ghole Road		13.91	4.55	0.3271	0.0394	25.3508	1.4040	0.0554
4	4	Warje-Karvenagar		15.26	7.37	0.4830	0.0582	17.1697	1.2348	0.0719
5	5	BS Dholepatil	**P**	12.64	4.19	0.3315	0.0400	25.0155	1.3982	0.0559
6	6	Hadapsar		26.86	11.55	0.4300	0.0519	19.2841	1.2852	0.0666
7	7	Yeravada	**M**	29.24	14.00	0.4788	0.0577	17.3191	1.2385	0.0715
8	8	Sangamvadi		30.39	12.51	0.4116	0.0496	20.1442	1.3041	0.0647
9	9	Bhavanipeth		2.79	2.39	0.8566	0.1033	9.6802	0.9859	0.1018
10	10	Kasbapeth	**C**	4.26	2.73	0.6408	0.0773	12.9397	1.1119	0.0859
11	11	Vishrambaugwada		8.56	4.26	0.4977	0.0600	16.6625	1.2217	0.0733
12	12	Tilak Road		13.60	5.68	0.4176	0.0504	19.8549	1.2979	0.0654
13	13	Bibvewadi		22.13	13.15	0.5942	0.0717	13.9551	1.1447	0.0820
14	14	Sahkarnagar		9.47	6.47	0.6832	0.0824	12.1373	1.0841	0.0893
15	A	A	**P**	36.01	14.83	0.4118	0.0497	20.1353	1.3040	0.0648
16	B	B	**C**	39.54	12.44	0.3146	0.0379	26.3561	1.4209	0.0539
17	C	C	**M**	66.85	26.80	0.4009	0.0483	20.6850	1.3157	0.0636
18	D	D	**C**	29.19	11.62	0.3981	0.0480	20.8314	1.3187	0.0633
		Total		**414.90**	**170.16**	**8.2923**				**1.2352**

Source: Computed by author

Log (m) = log 18   Et = 1.2352/1.2552

Log 18 = 1.2552   **Et = 0.9841**

78

Table 4.7 Entropy Calculation for the Time Period of 2008

Sr. No.	Ward Number	Committee/Ward		TGA	2008	Density (Dj)	PDj	1/PDj	log(1/PDj)	PDj*log(1/PDj)
1	1	Aundh		38.73	18.64	0.4812	0.0456	21.9403	1.3412	0.0611
2	2	Karve Road		15.46	7.00	0.4528	0.0429	23.3195	1.3677	0.0587
3	3	Ghole Road		13.91	4.73	0.3400	0.0322	31.0509	1.4921	0.0481
4	4	Warje-Karvenagar		15.26	9.00	0.5898	0.0559	17.9028	1.2529	0.0700
5	5	BS Dholepatil	**P**	12.64	4.80	0.3797	0.0360	27.8044	1.4441	0.0519
6	6	Hadapsar		26.86	19.03	0.7085	0.0671	14.9030	1.1733	0.0787
7	7	Yeravada	**M**	29.24	20.64	0.7059	0.0669	14.9581	1.1749	0.0785
8	8	Sangamvadi		30.39	14.09	0.4636	0.0439	22.7734	1.3574	0.0596
9	9	Bhavanipeth		2.79	2.36	0.8459	0.0801	12.4825	1.0963	0.0878
10	10	Kasbapeth	**C**	4.26	3.11	0.7300	0.0691	14.4630	1.1603	0.0802
11	11	Vishrambaugwada		8.56	4.80	0.5607	0.0531	18.8296	1.2748	0.0677
12	12	Tilak Road		13.60	6.24	0.4588	0.0435	23.0124	1.3620	0.0592
13	13	Bibvewadi		22.13	17.08	0.7718	0.0731	13.6805	1.1361	0.0830
14	14	Sahkarnagar		9.47	6.79	0.7170	0.0679	14.7261	1.1681	0.0793
15	A	A	**P**	36.01	22.74	0.6315	0.0598	16.7202	1.2232	0.0732
16	B	B	**C**	39.54	24.59	0.6219	0.0589	16.9776	1.2299	0.0724
17	C	C	**M**	66.85	27.46	0.4108	0.0389	25.7052	1.4100	0.0549
18	D	D	**C**	29.19	20.10	0.6886	0.0652	15.3342	1.1857	0.0773
		Total		**414.90**	**233.20**	**10.5586**				**1.2417**

Source: Computed by author

Log (m) = log 18   Et = 1.2417/1.2552

Log 18 = 1.2552   **Et = 0.9893**

4.9 Rise of on-going urban sprawl

The calculation of Shannon's entropy measure indicated that PMC and PCMC continue to sprawl from 1980 to 2008. The entropy value for 1980 is lower than that of 2008. In comparison to 1993 average relative entropy value of 0.767, calculated by Yeh and Li (2001) for the 24 buffer zones around the 29 towns of Dongguan City in Guangdong Province in China, all 6 entropy values for Calgary are higher. This implies that urban sprawl in PMC and PCMC was a far more serious matter than that detected by Yeh and Li in their study.

Given an existing set of land development policies or lack therefore, the driving force behind urban sprawl in PMC and PCMC is population growth. Figure 4.3 shows PMC and PCMC population growth from 1951 to 2001, for demonstrating a strong correlation with the growth of sprawl.

Table 4.8 Shannon's Entropy values of PMC and PCMC in the 5 years

Sr. No.	Year	Entropy (Et)	ΔEt
1	1992 - 1980	0.7539	**0.2099**
2	1999 - 1992	0.9638	**0.0082**
3	2004 - 1999	0.972	**0.0121**
4	2008 - 2004	0.9841	**0.0052**
5	2008	0.9893	

Source: Computed by author
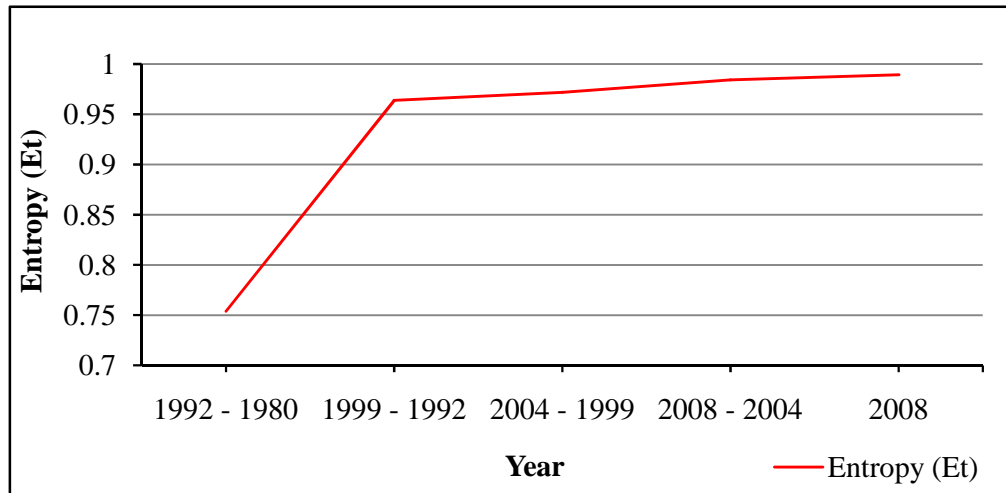
Fig. 4.1 Five Years Relative Entropy Values
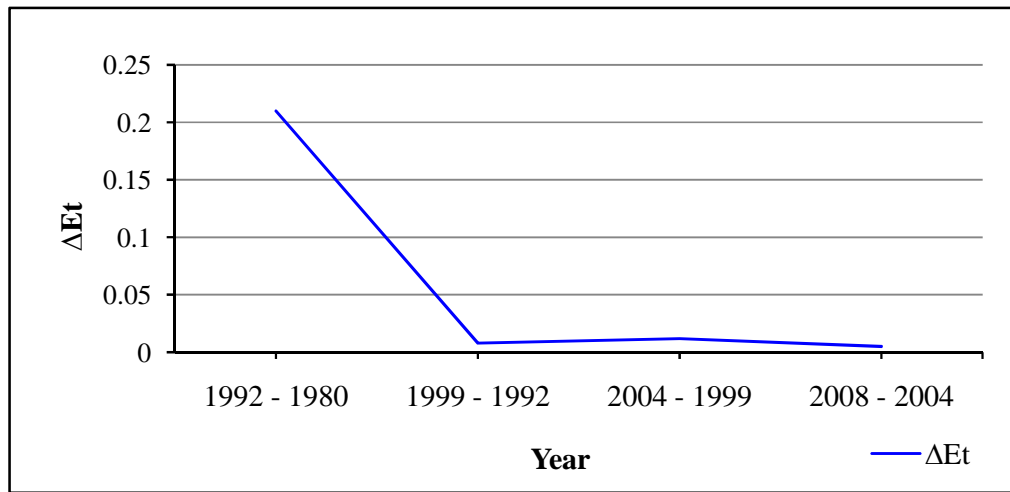
Fig. 4.2 Differences of Relative Entropy Values in Each Pair Years
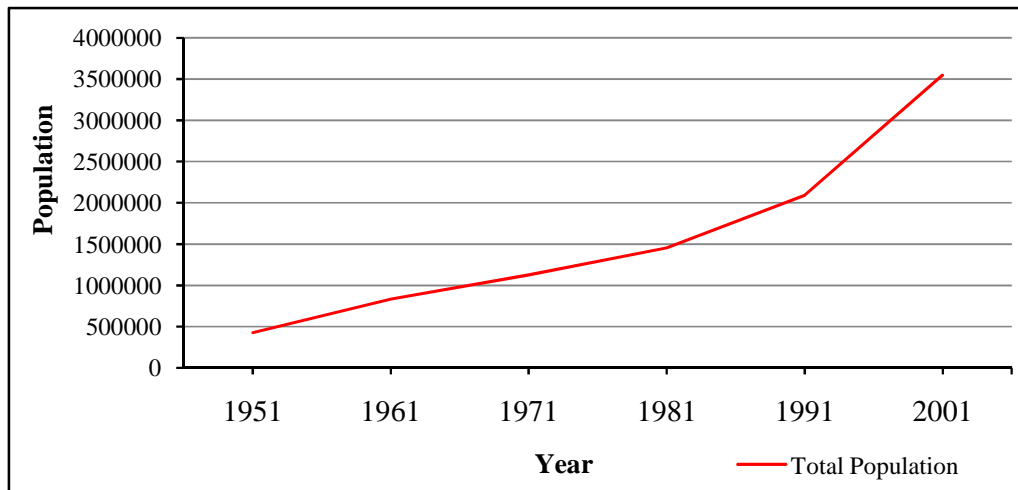
Fig. 4.3 Population Growth of PMC and PCMC area

The analysis shows the Entropy (Et) for the different years 1979-80 (Toposheets) was 0.7539 for a population of 14.54 lakhs. In comparison to 2008 (IRS P6 LISS – III), Entropy value was 0.9893 for a population of 39.24 lakhs estimated. Even then the Entropy values in these both cases were above 0.5, indicating a higher rate of sprawl.

Built-up area of PMC and PCMC from Toposheet (1980)

Legend

Built-up

Administrative Ward/Commitee Boundary

N

0   2   4 Km.
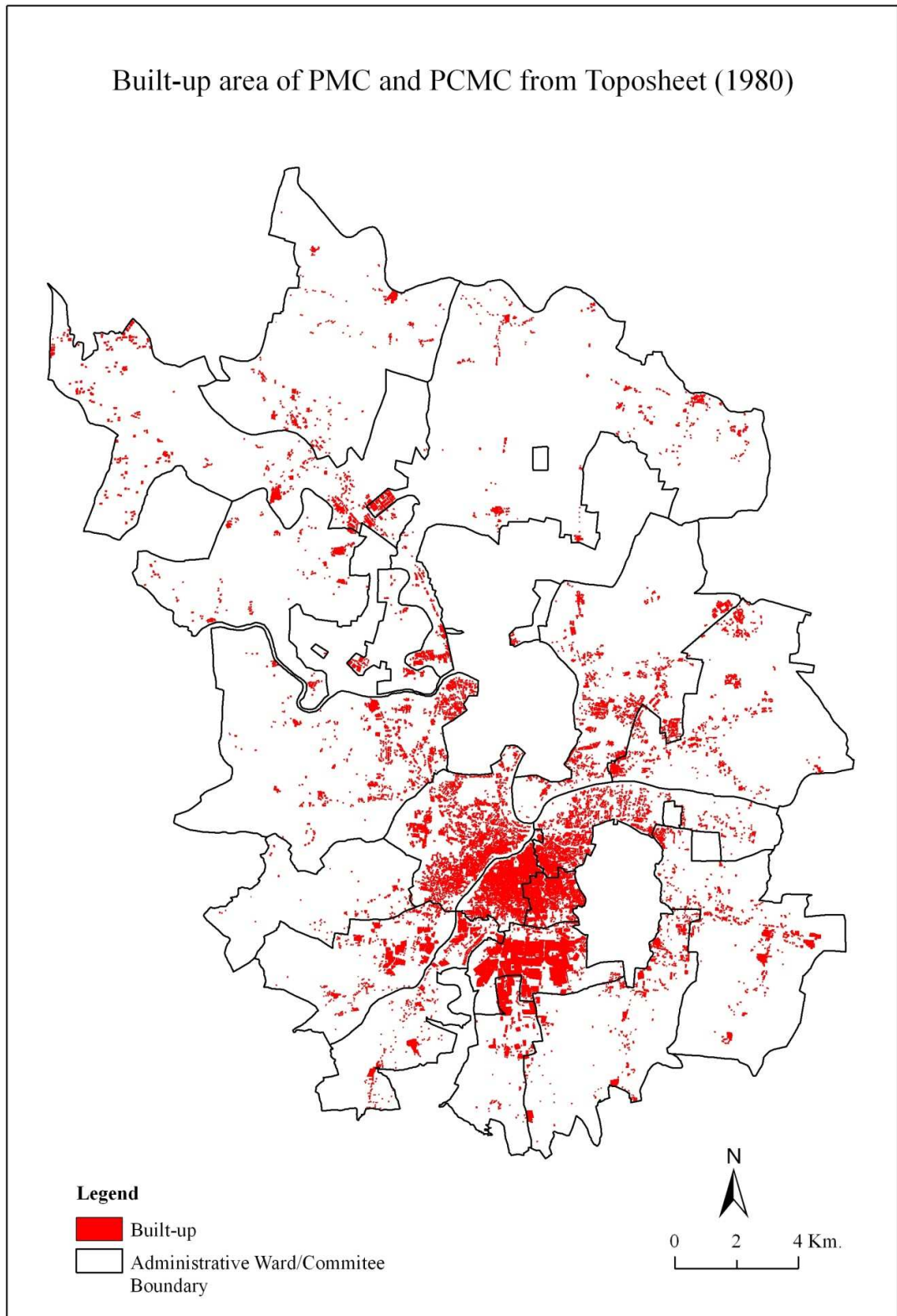
Fig. 4.1

Built-up area of PMC and PCMC from LANDSAT ETM+ (1992)

Legend

Built-up

Administrative Ward/Commitee Boundary

N

0   2   4 Km.
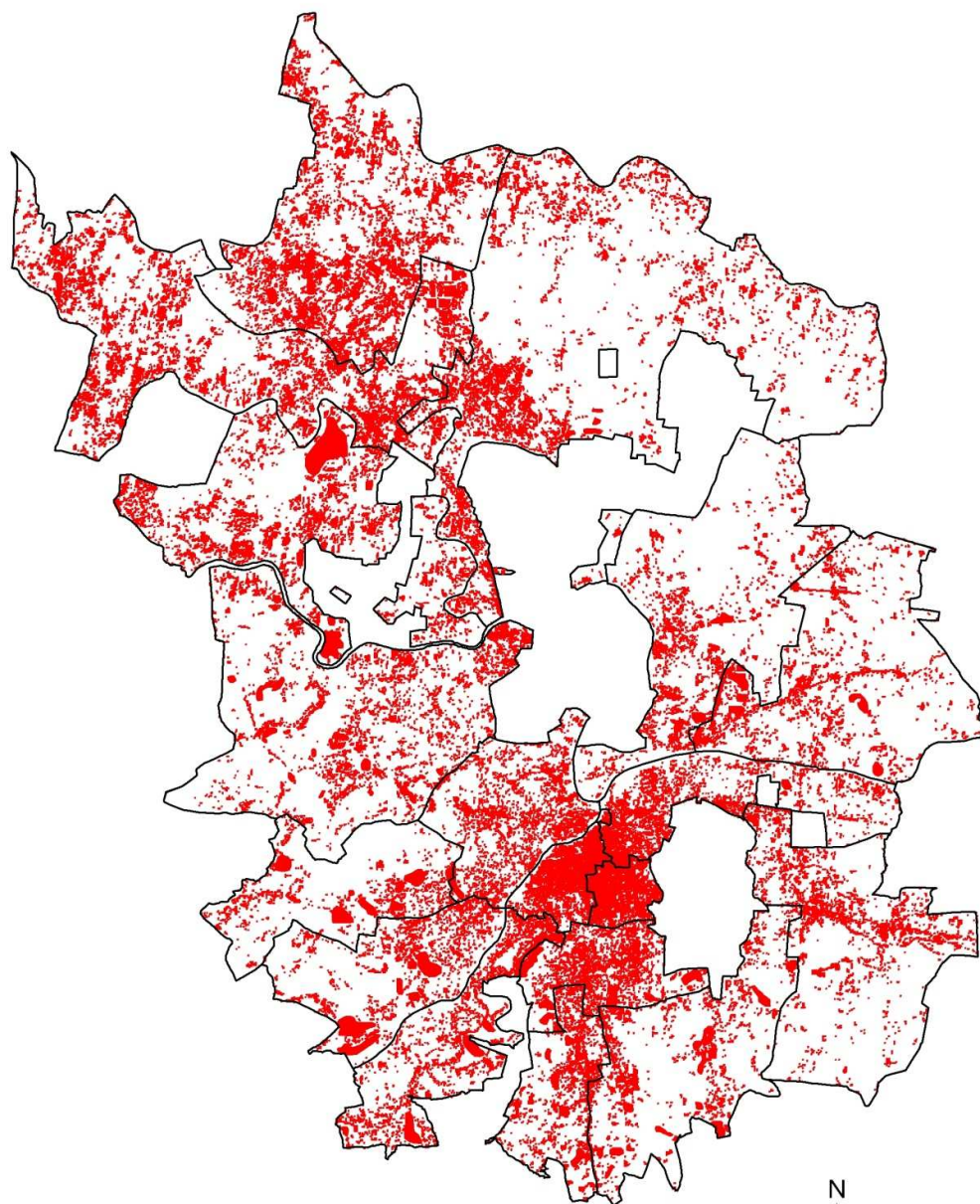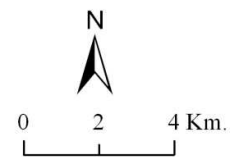
Fig. 4.2

Built-up area of PMC and PCMC from LANDSAT ETM+ (1999)

Legend

■ Built-up

□ Administrative Ward/Commitee Boundary

N

0   2   4 Km.
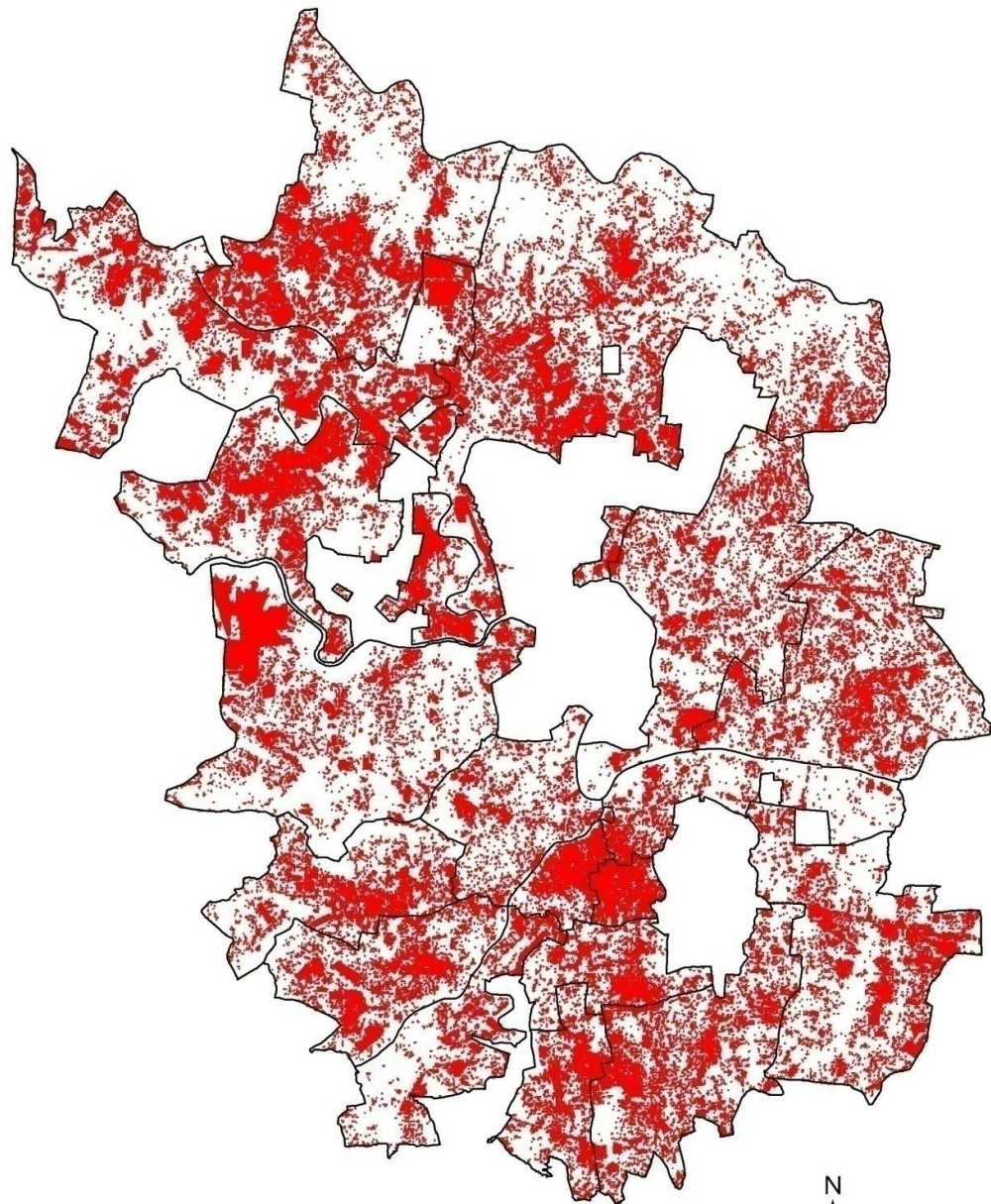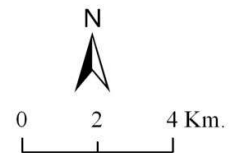
Fig. 4.3

Built-up area of PMC and PCMC from IRS P6 - LISS III (2004)

Legend

Built-up

Administrative Ward/Commitee
Boundary

N

0   2   4 Km.
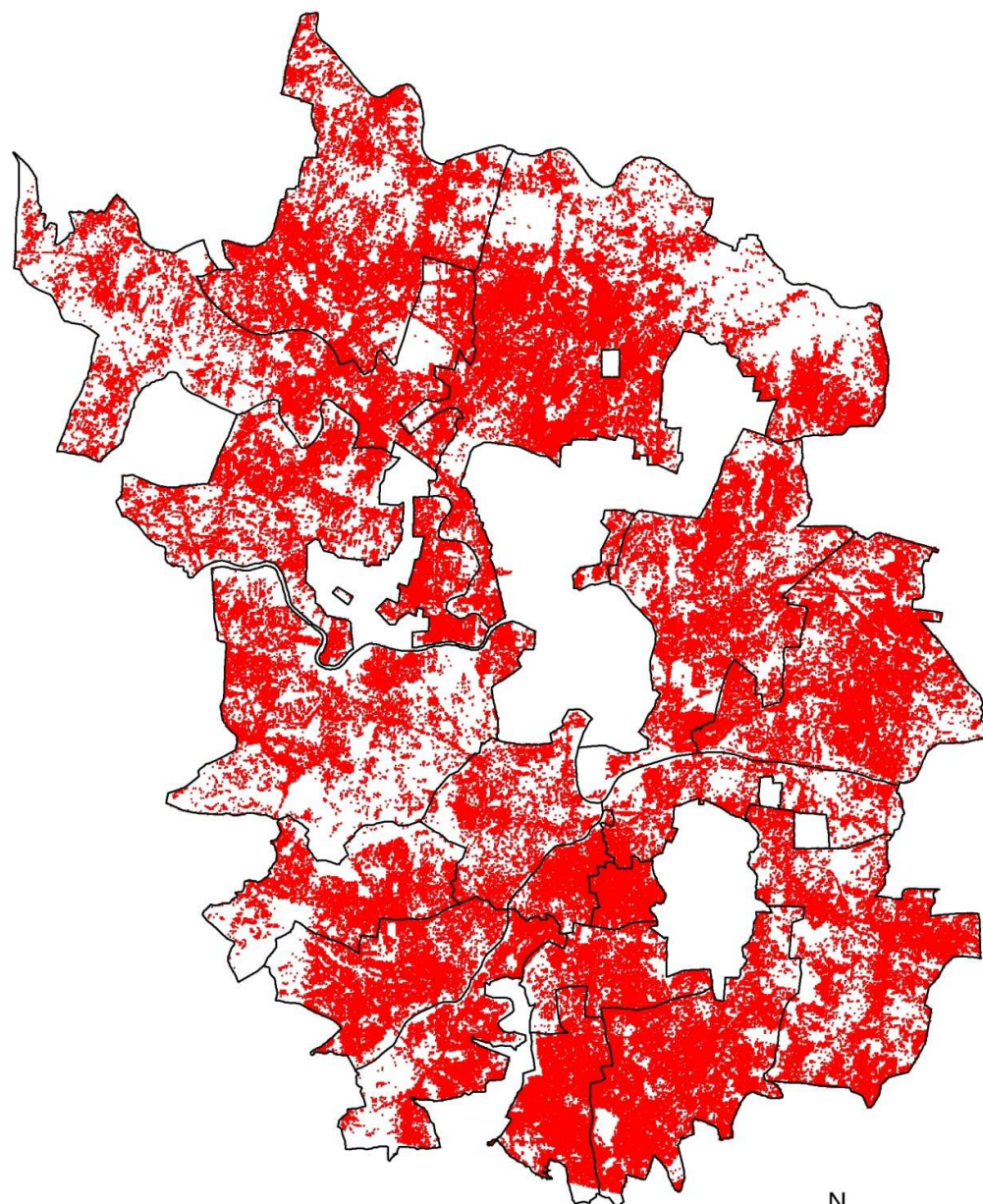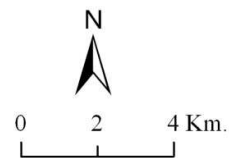
Fig. 4.4

Built-up area of PMC and PCMC from IRS P6 - LISS III (2008)

Legend

■ Built-up

☐ Administrative Ward/Commitee Boundary

N

0   2   4 Km.
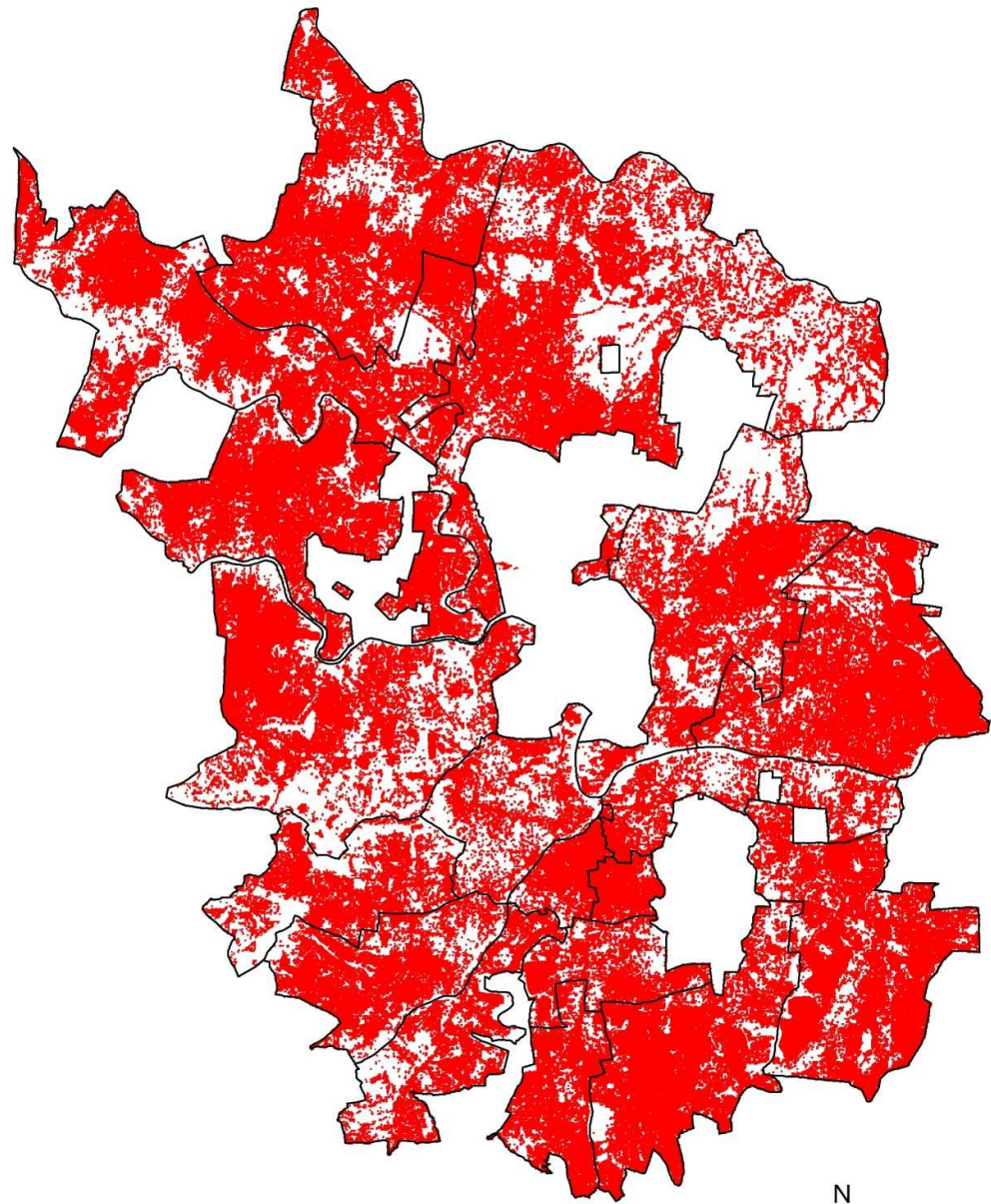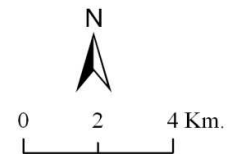
Fig. 4.5

Table 4.9 Change in Built-up area from 1980-2008

Sr. No.	Committee/Ward		Built-up area 1980	Built-up area in %	Built-up area 2008	Built-up area in %	Difference area in %
1	Aundh		0.96	2.48	18.64	48.13	45.65
2	Karve Road		0.08	0.52	7.00	45.28	44.76
3	Ghole Road		1.78	12.80	4.73	34.00	21.20
4	Warje Karvenagar	P	0.80	5.24	9.00	58.98	53.74
5	BS Dholepatil		1.18	9.34	4.80	37.97	28.63
6	Hadapsar		0.63	2.35	19.03	70.85	68.50
7	Yeravada	M	0.37	1.27	20.64	70.59	69.32
8	Sangamvadi		0.78	2.57	14.09	46.36	43.79
9	Bhavanipeth		1.04	37.28	2.36	84.59	47.31
10	Kasbapeth		1.61	37.79	3.11	73.00	35.21
11	Vishrambaugwada	C	2.75	32.13	4.80	56.07	23.94
12	Tilak Road		0.67	4.93	6.24	45.88	40.95
13	Bibvewadi		0.62	2.80	17.08	77.18	74.38
14	Sahkarnagar		0.69	7.29	6.79	71.70	64.41
15	A	P	0.31	0.86	22.74	63.15	62.29
16	B	C	0.83	2.10	24.59	62.19	60.09
17	C	M	0.69	1.03	27.46	41.08	40.05
18	D	C	0.4	1.37	20.10	68.86	67.49
	Total		**16.19**		**233.20**		

Source: Computed by author
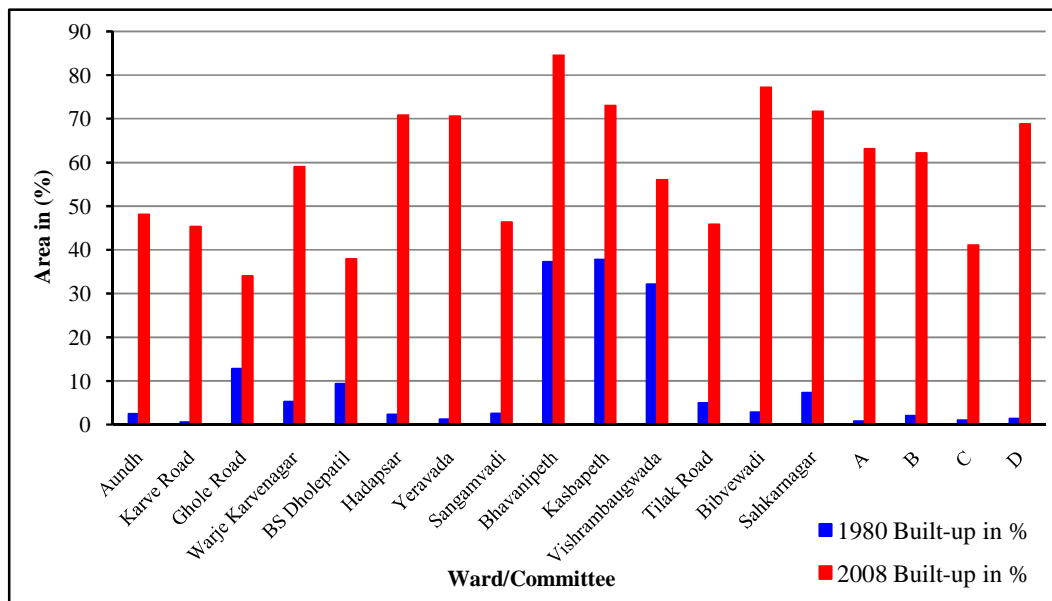
Fig. 4.4 Administrative Ward/Committee wise Built-up area from 1980-2008

Above Table 4.9 and Fig. 4.4 represents administrative ward/committee wise built-up area changed from 1980 to 2008. The year 1980, shows 16.19 sq. km. (3.9%), area was under the built-up and according to IRS P6 LISS III 2008 satellite imagery 233.20 Sq. km. (56.20%), area is under built-up. The rate of increase is high in 12 administrative wards which was located on periphery of city centre. In year 1980, Aundh shows only 0.96 sq. km (2.48%), area under built-up, but in 2008 it has grown to 18.64 sq. km (48.13%). C committee in year 1980 shows only 0.69 sq. km (1.03%), area under built-up and in 2008 it grew to 27.46 sq. km (41.08%). Karve Road was 0.08 sq. km. (0.52%) in 1980 and in 2008 it was 7.00 sq. km. (45.28%), area under built-up. The core area shows the vertical sprawl and peripheral wards were showing the horizontal sprawl. In PCMC area A ward was grown 0.31 sq. km. (0.86%) to 22.74 (63.15%), it means that this ward has grown to 22.43 sq. km. (62.29%). This table and bar graph shows the total percentage of area under built-up from 1980 to 2008 it was grown with an average 49.54% and total difference between these two years is that 217.01 sq. km. in 28 years.
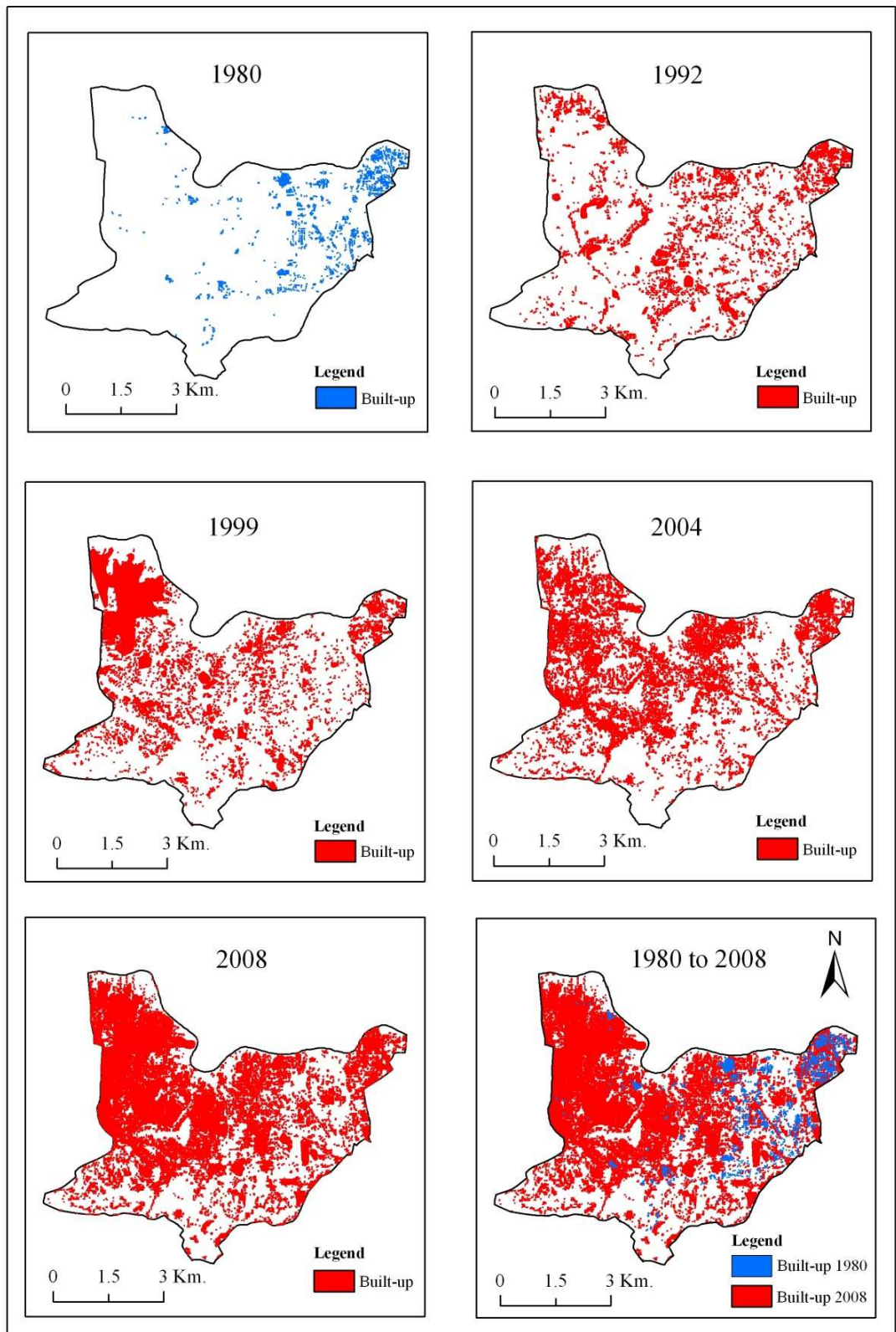
Fig. 4.6 Aundh Built-up
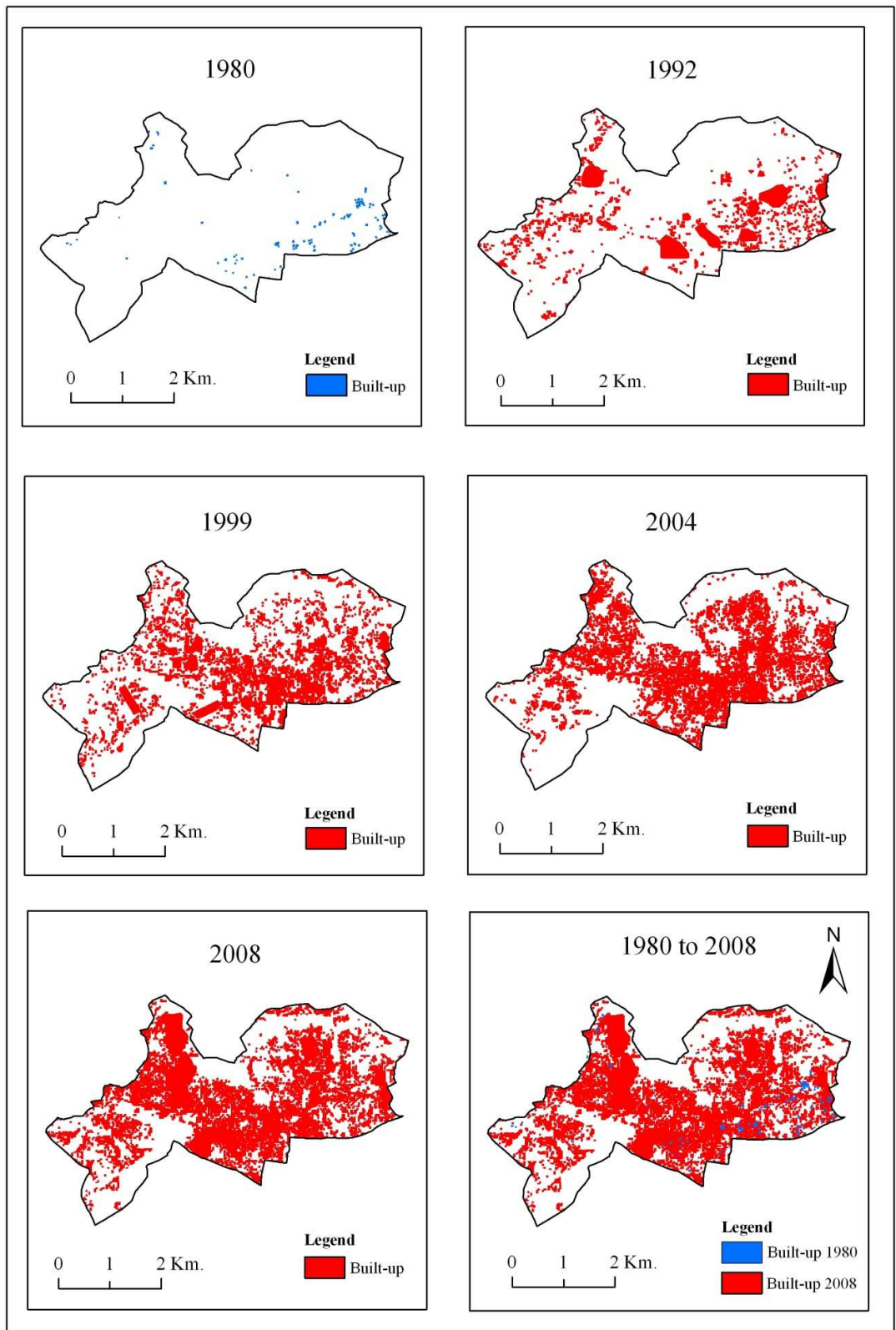
Fig. 4.7 Karve Road Built-up
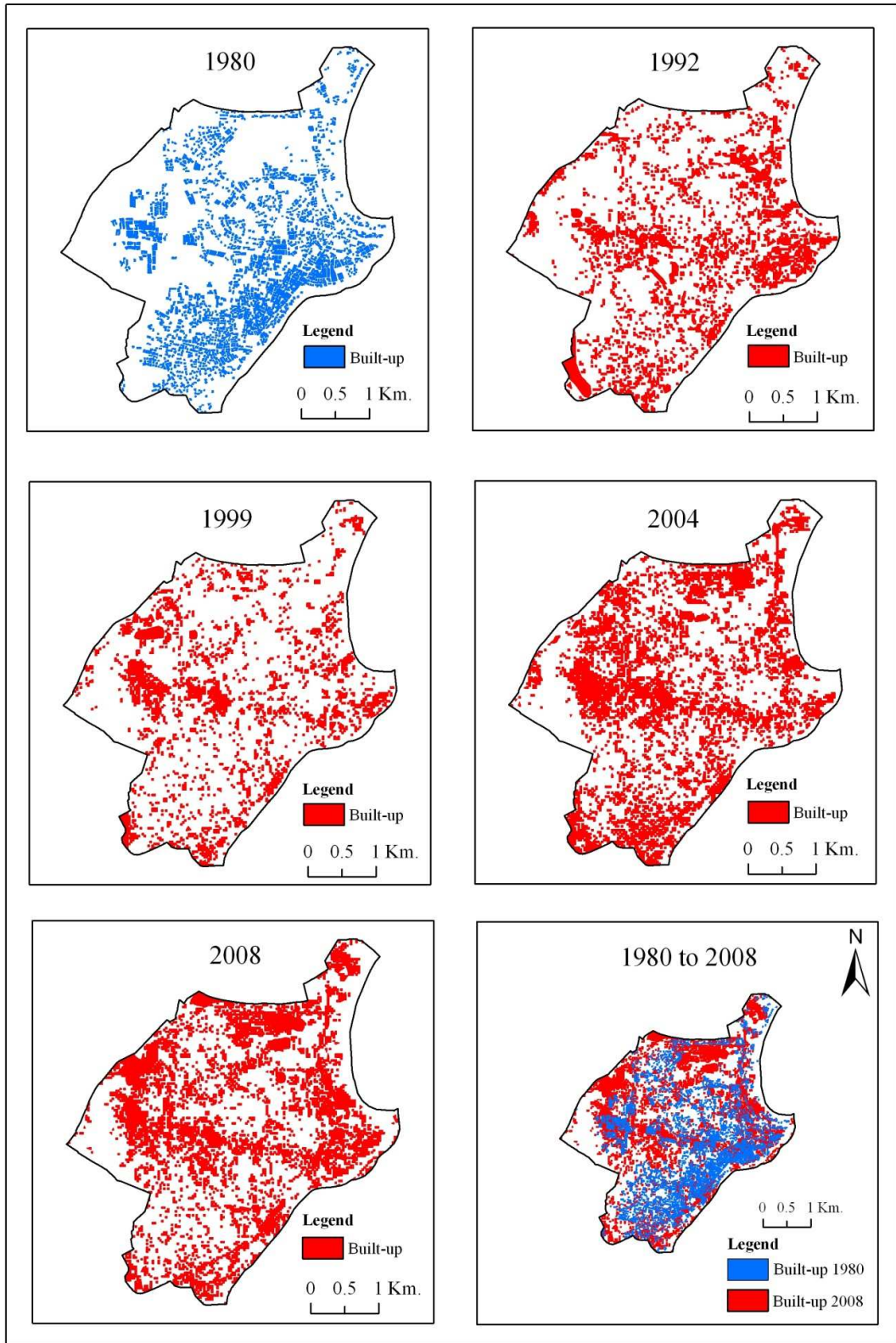
Fig. 4.8 Ghole Road Built-up
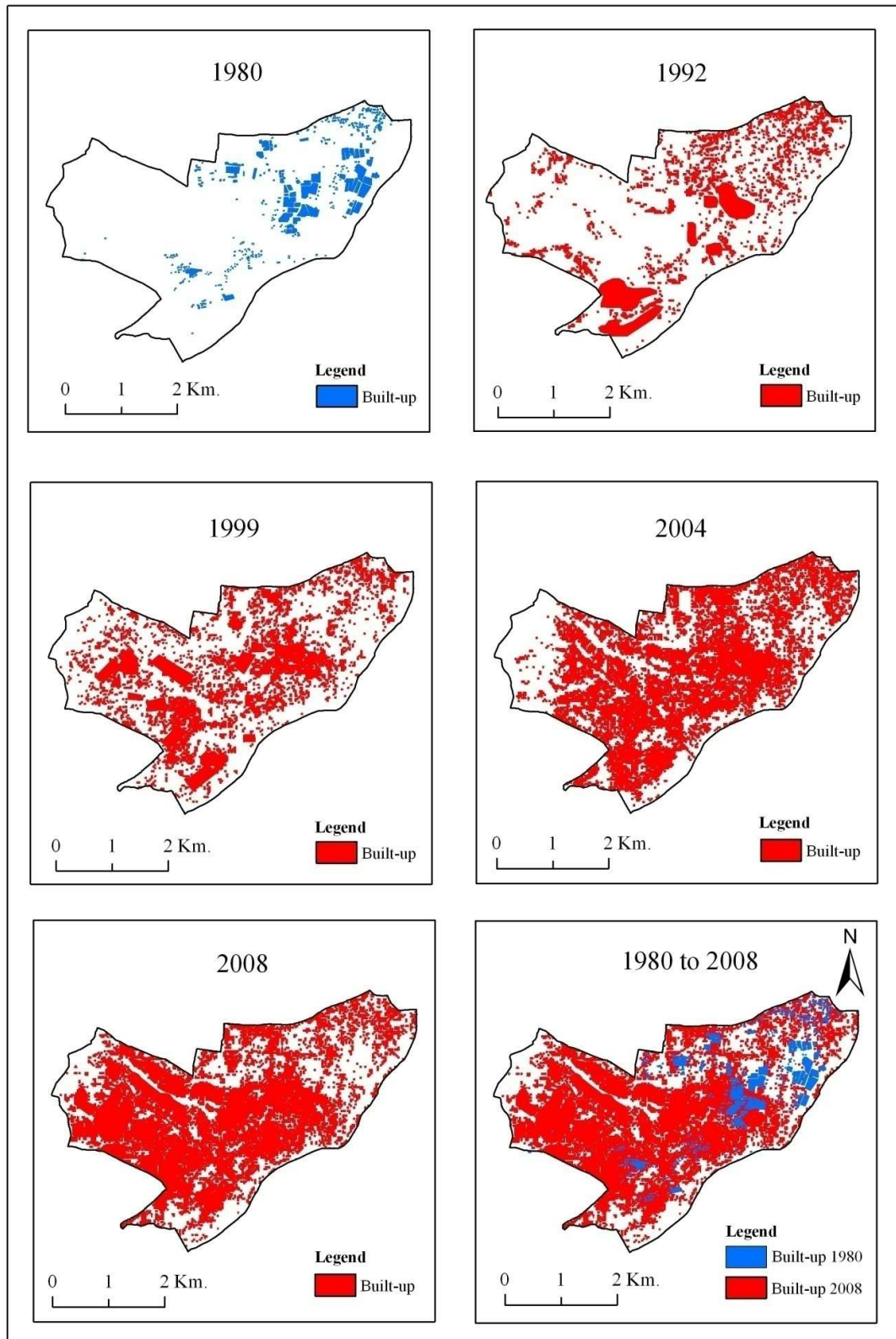
Fig. 4.9 Warje Karvenagar Built-up
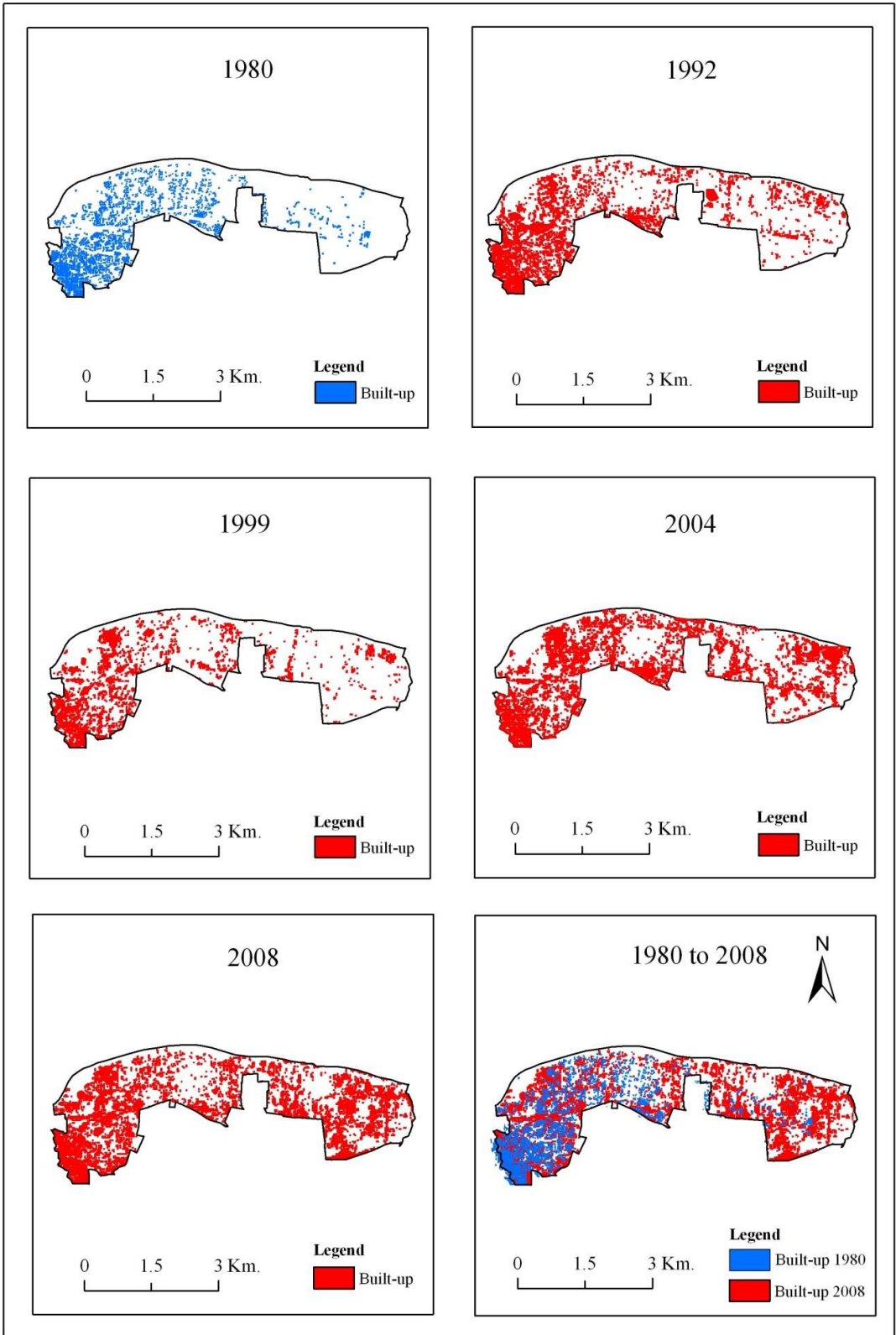
Fig. 4.10 Dholepatil Road Built-up
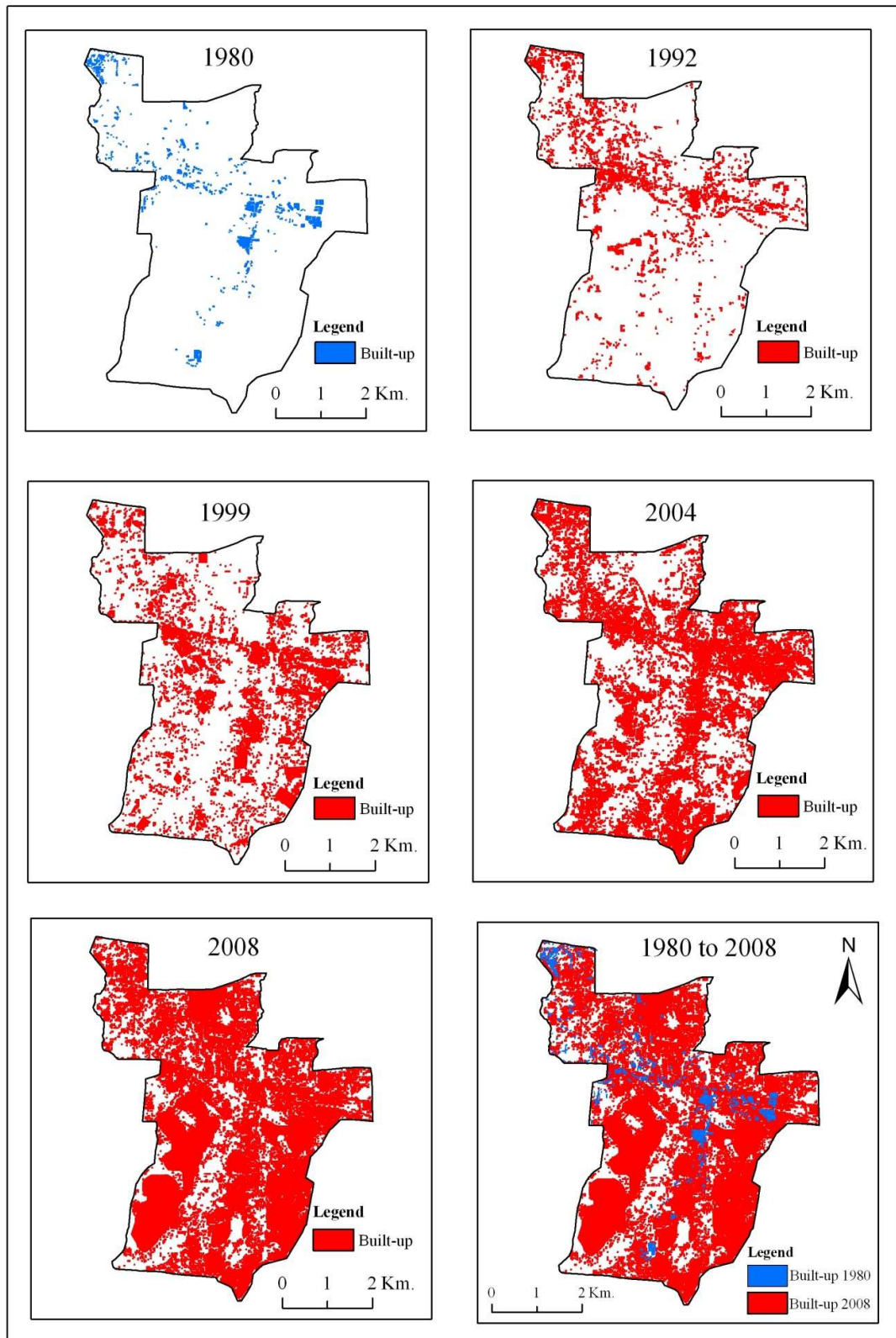
Fig. 4.11 Hadapsar Built-up
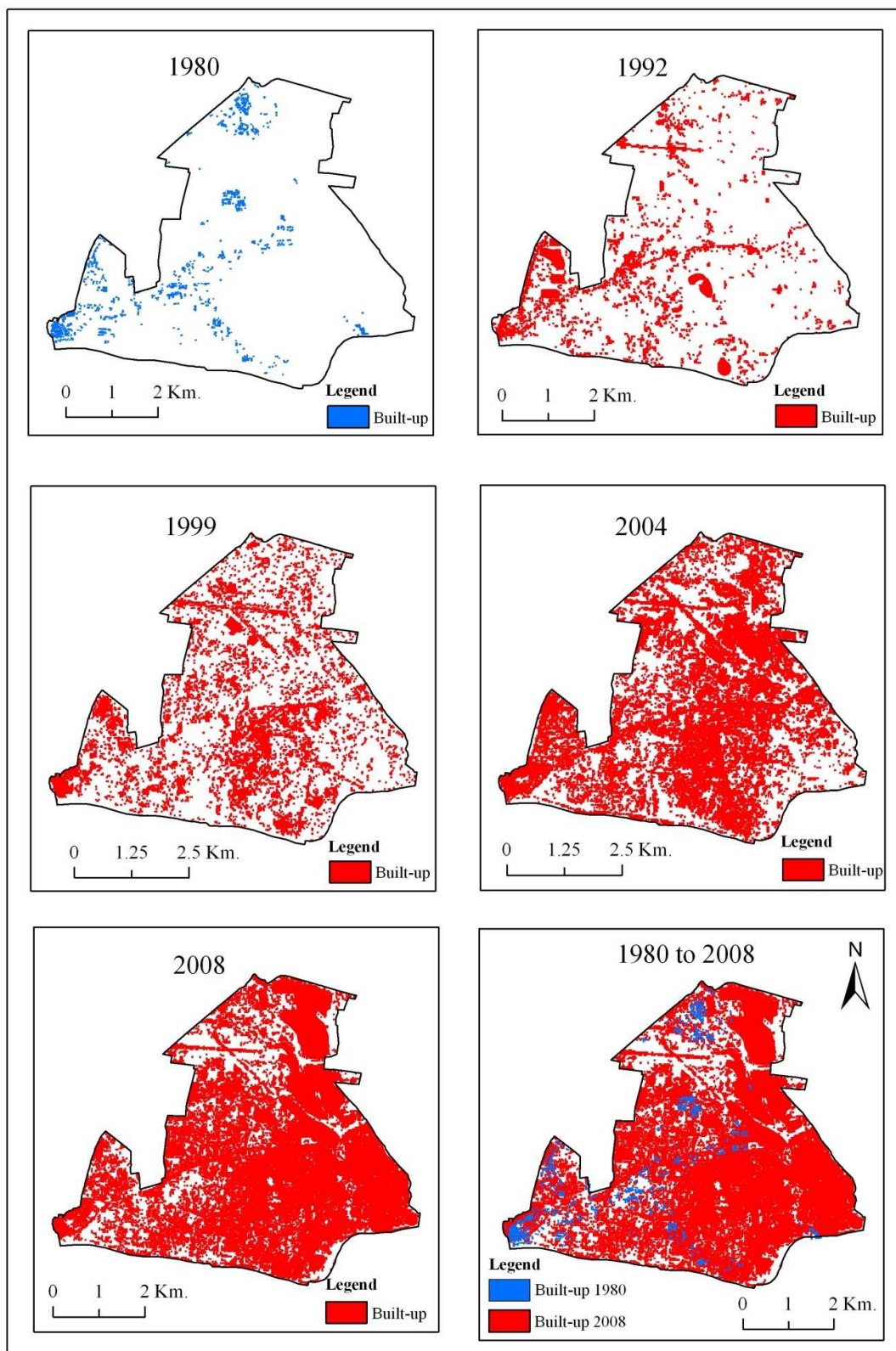
Fig. 4.12 Yerawada Built-up
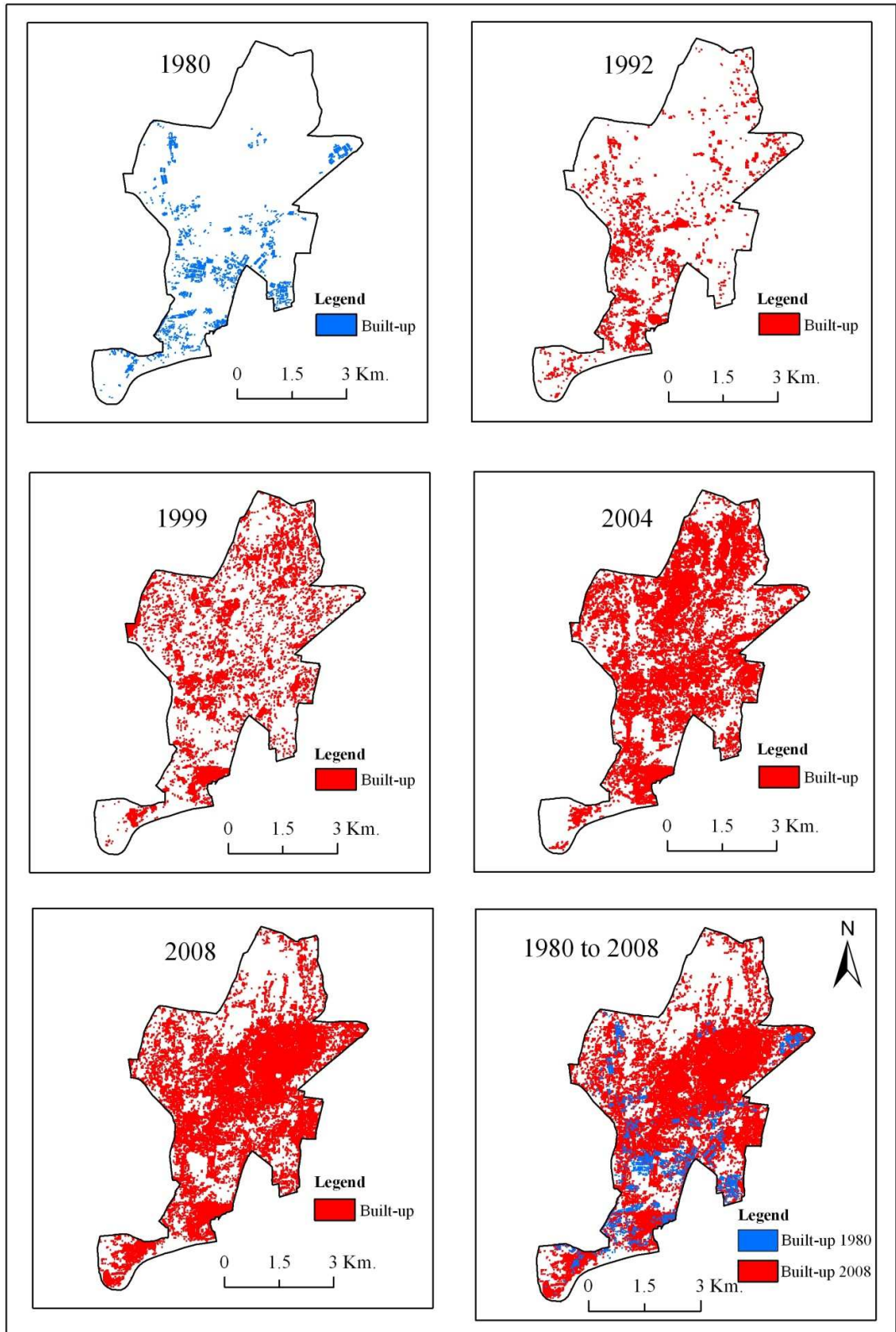
Fig. 4.13 Sangamwadi Built-up
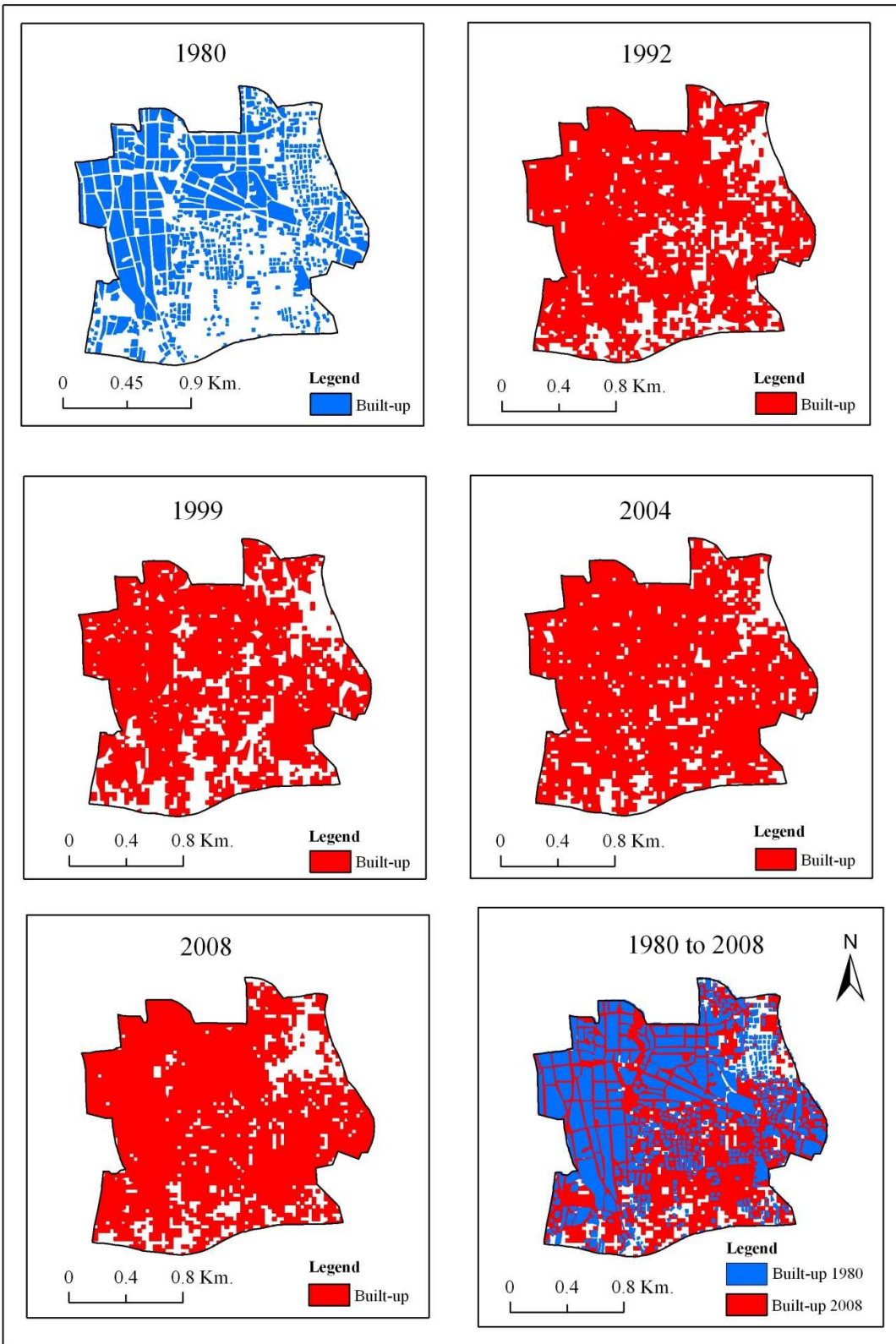
Fig. 4.14 Bhavanipeth Built-up
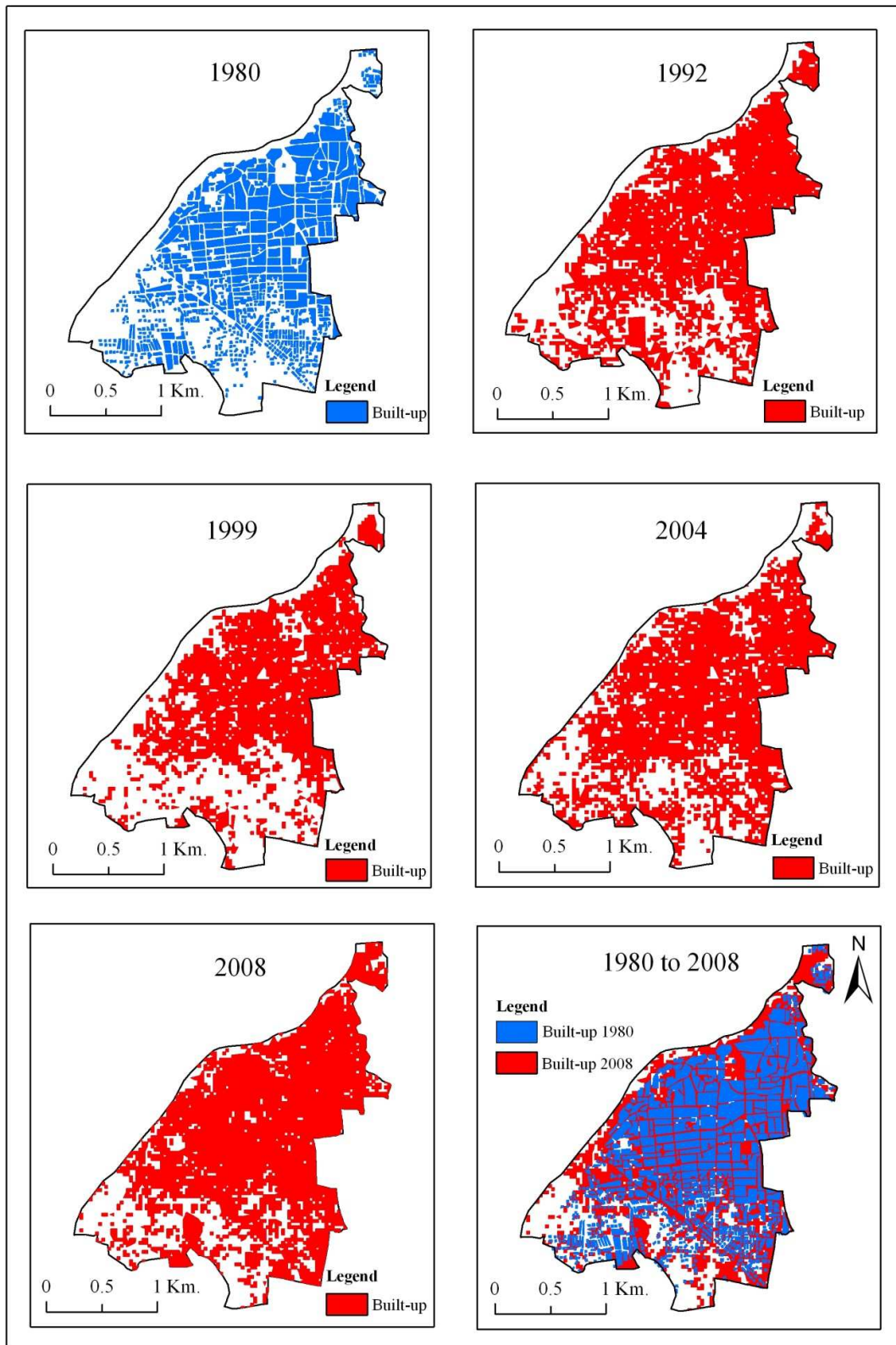
Fig. 4.15 Kasbapeth Built-up
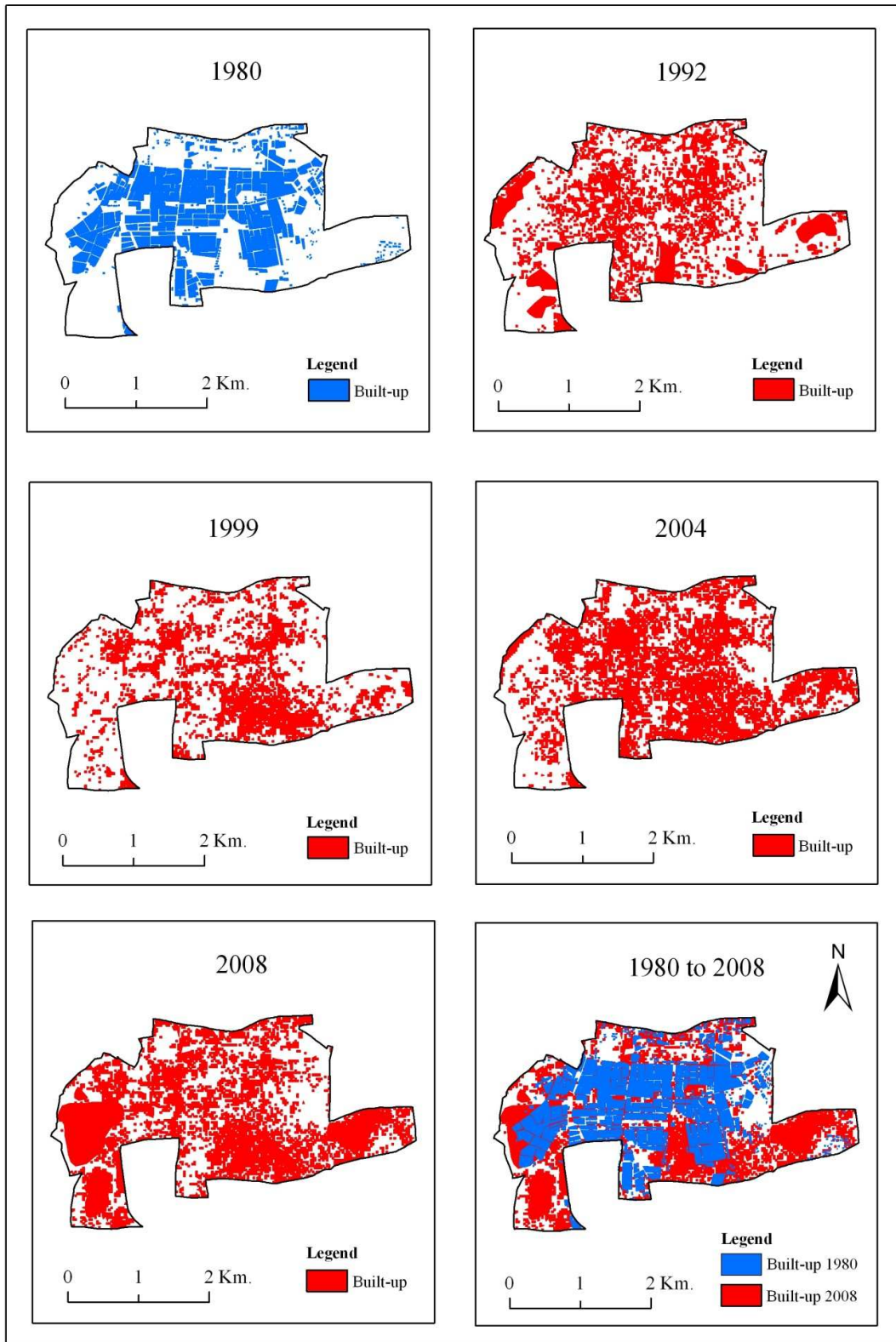
Fig. 4.16 Vishrambaugwada Built-up
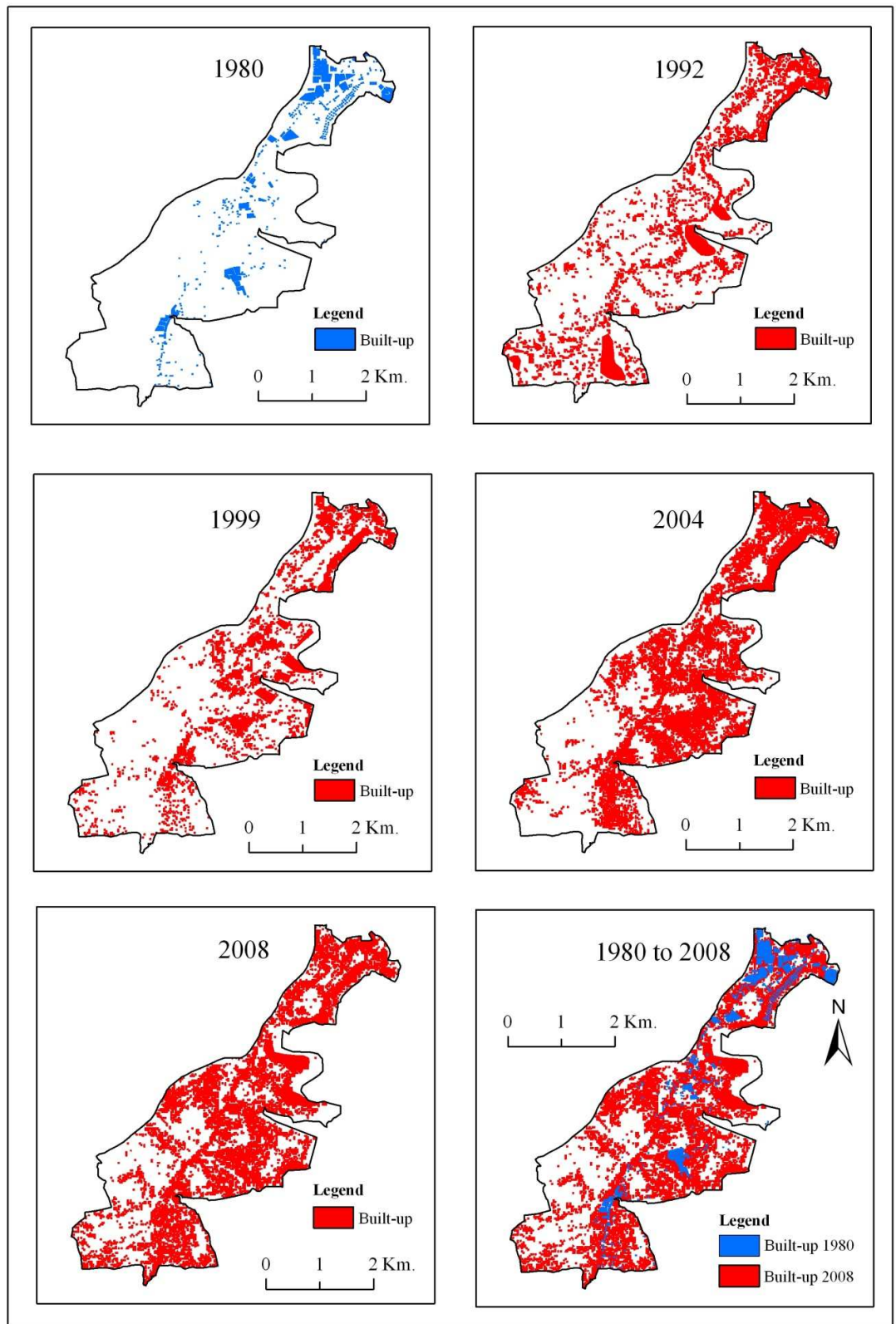
Fig. 4.17 Tilak Road Built-up
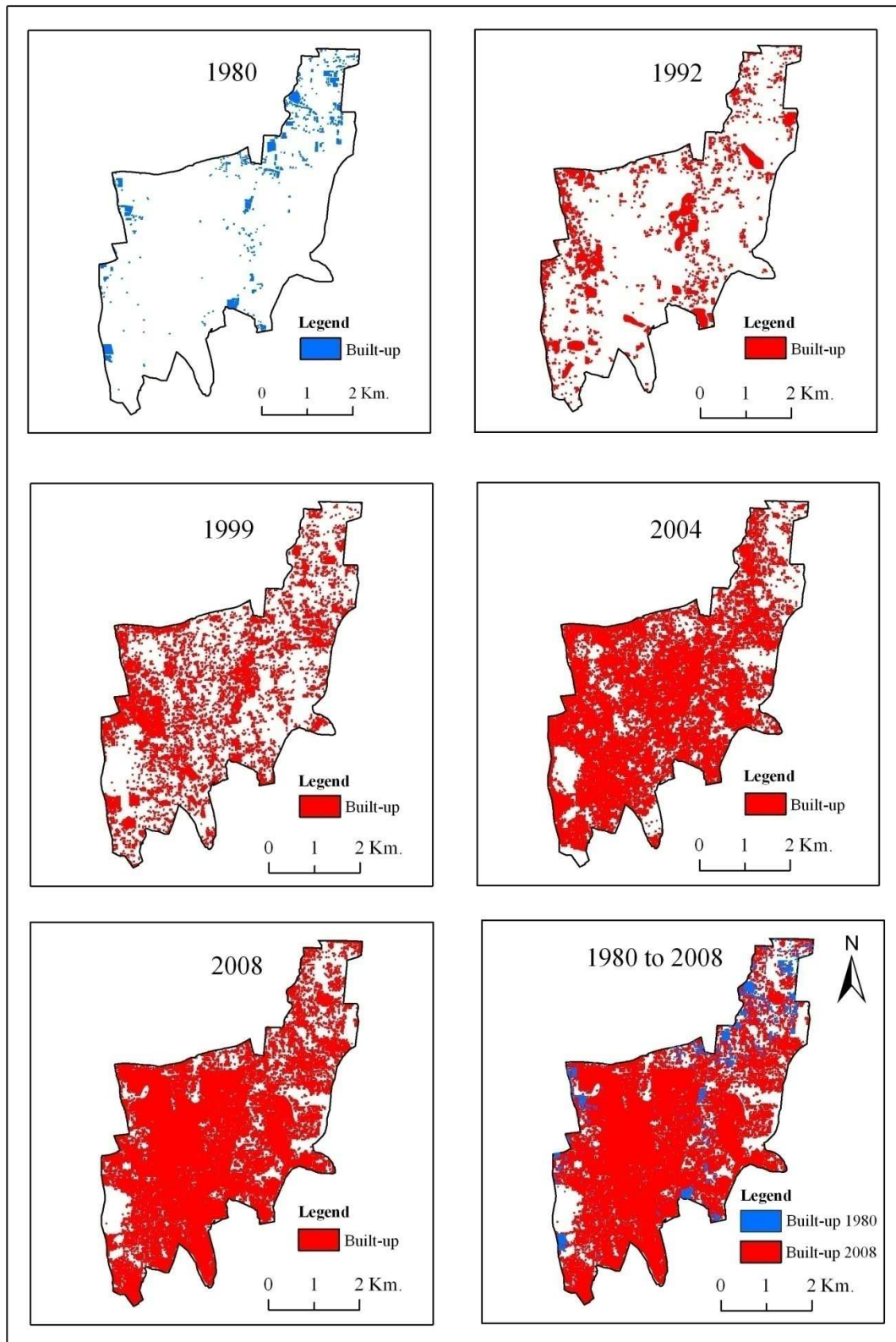
Fig. 4.18 Bibvewadi Built-up
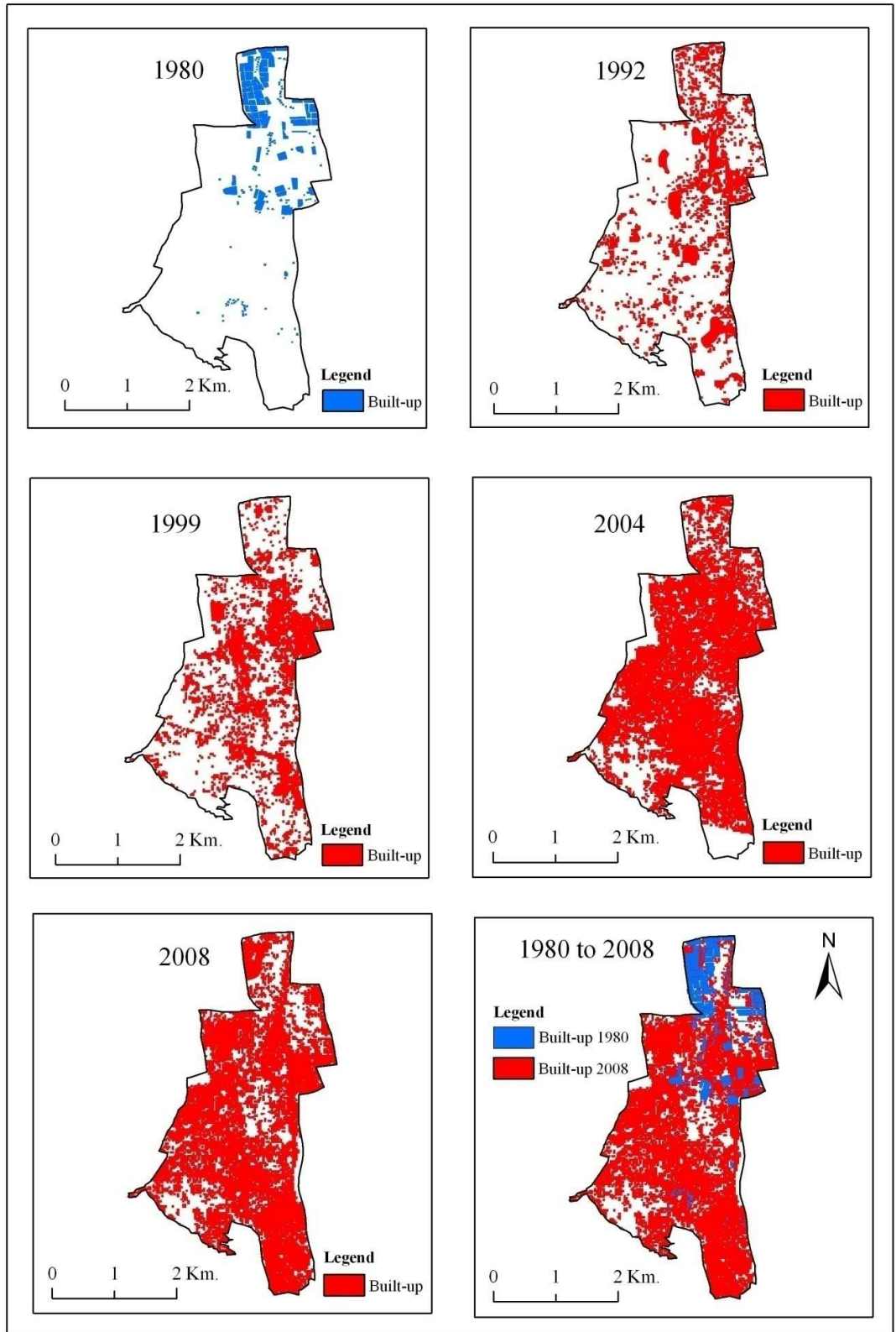
Fig. 4.19 Sahakarnagar Built-up
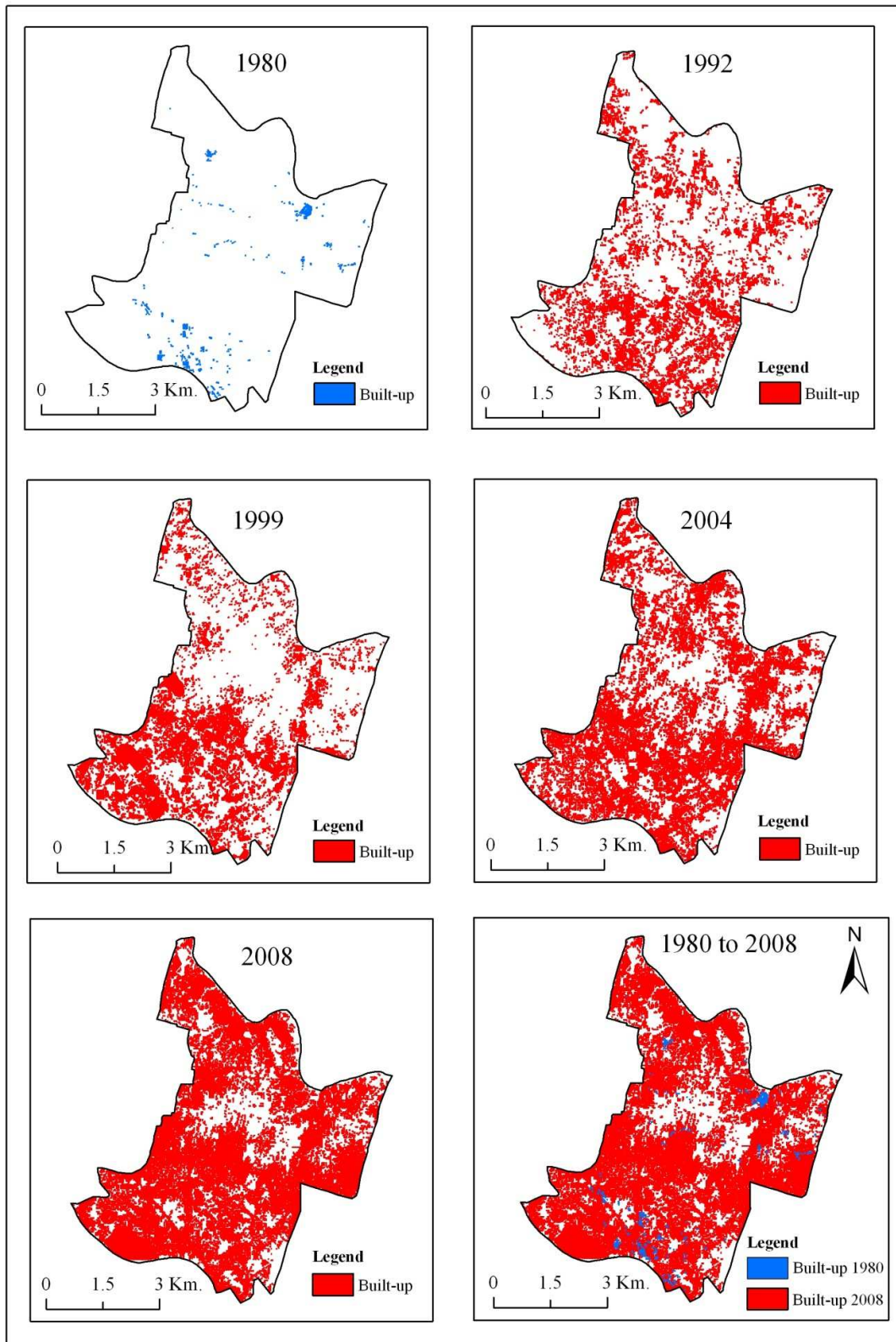
Fig. 4.20 A Committee Built-up
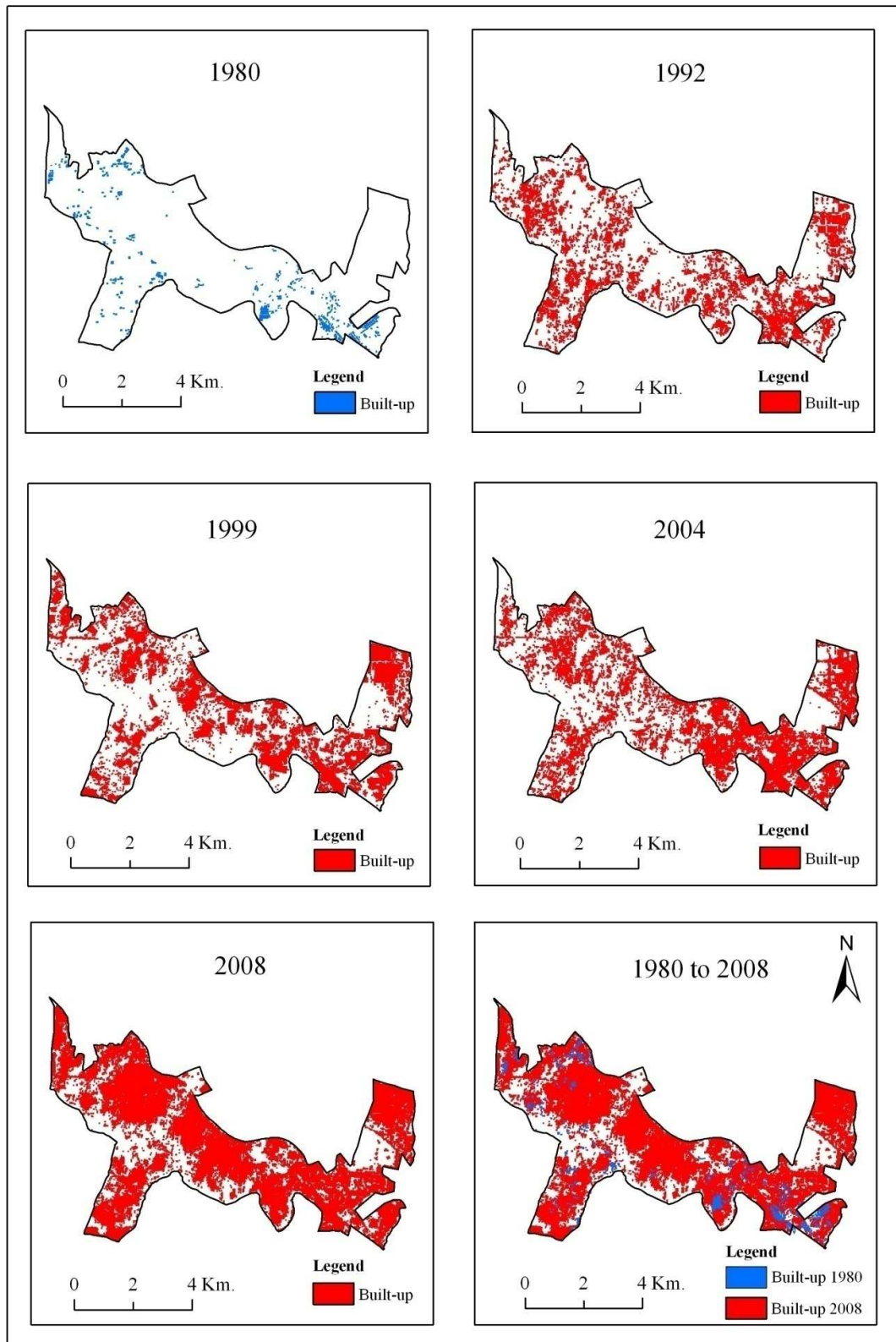
Fig. 4.21 B Committee Built-up
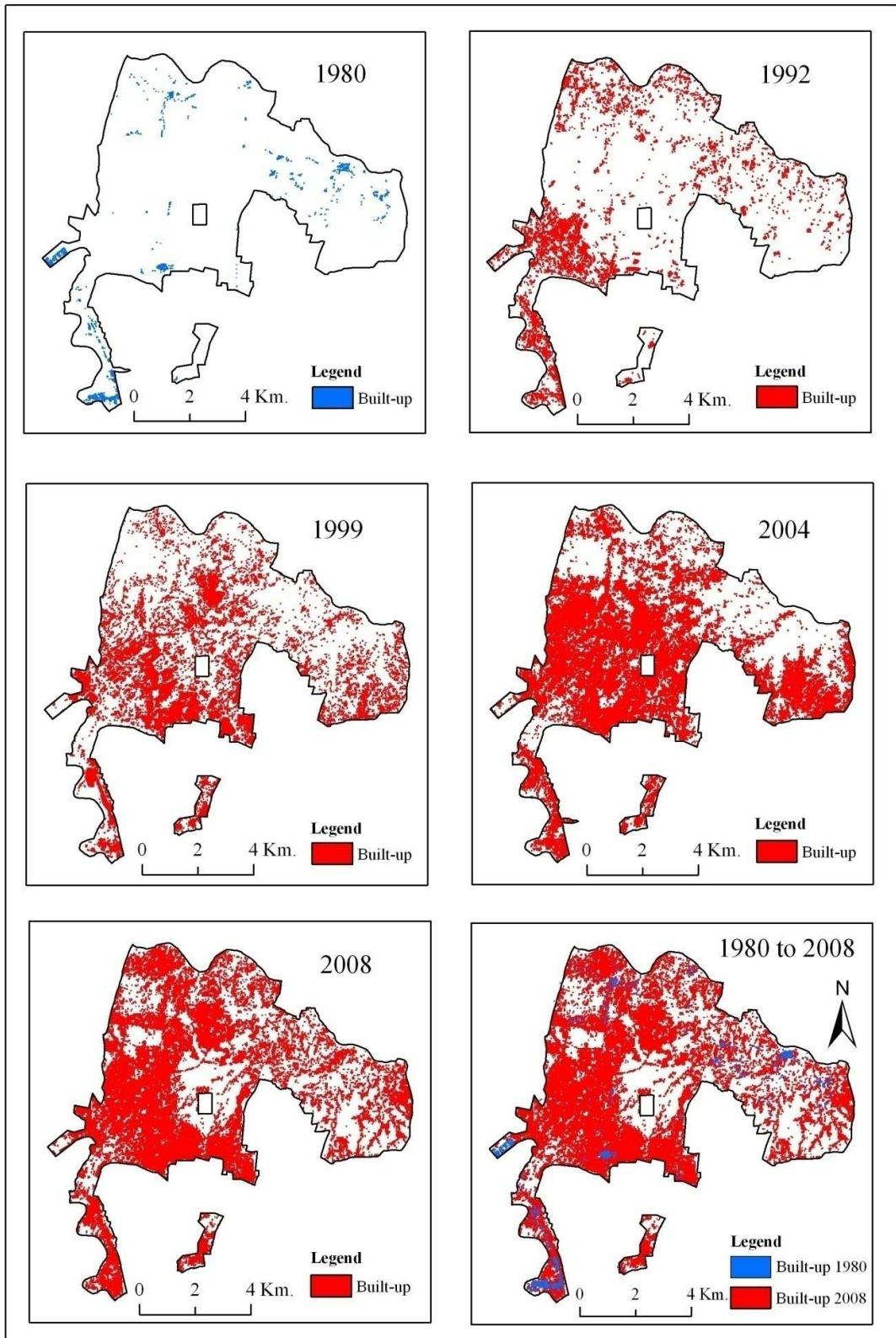
Fig. 4.22 C Committee Built-up
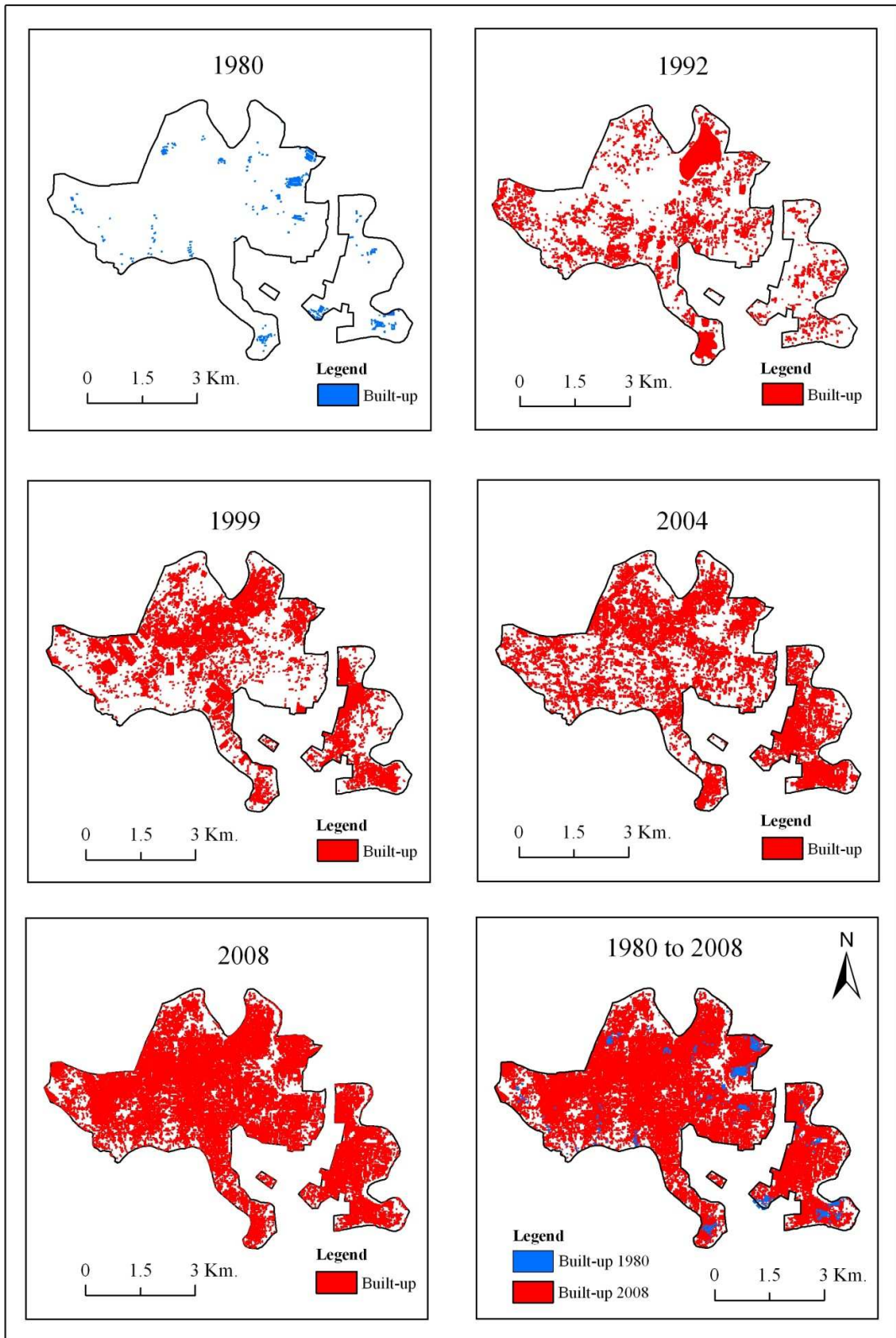
Fig. 4.23 D Committee Built-up

Change in Built-up area of PMC and PCMC from
Toposheet and IRS P6 - LISS III (1980 and 2008)
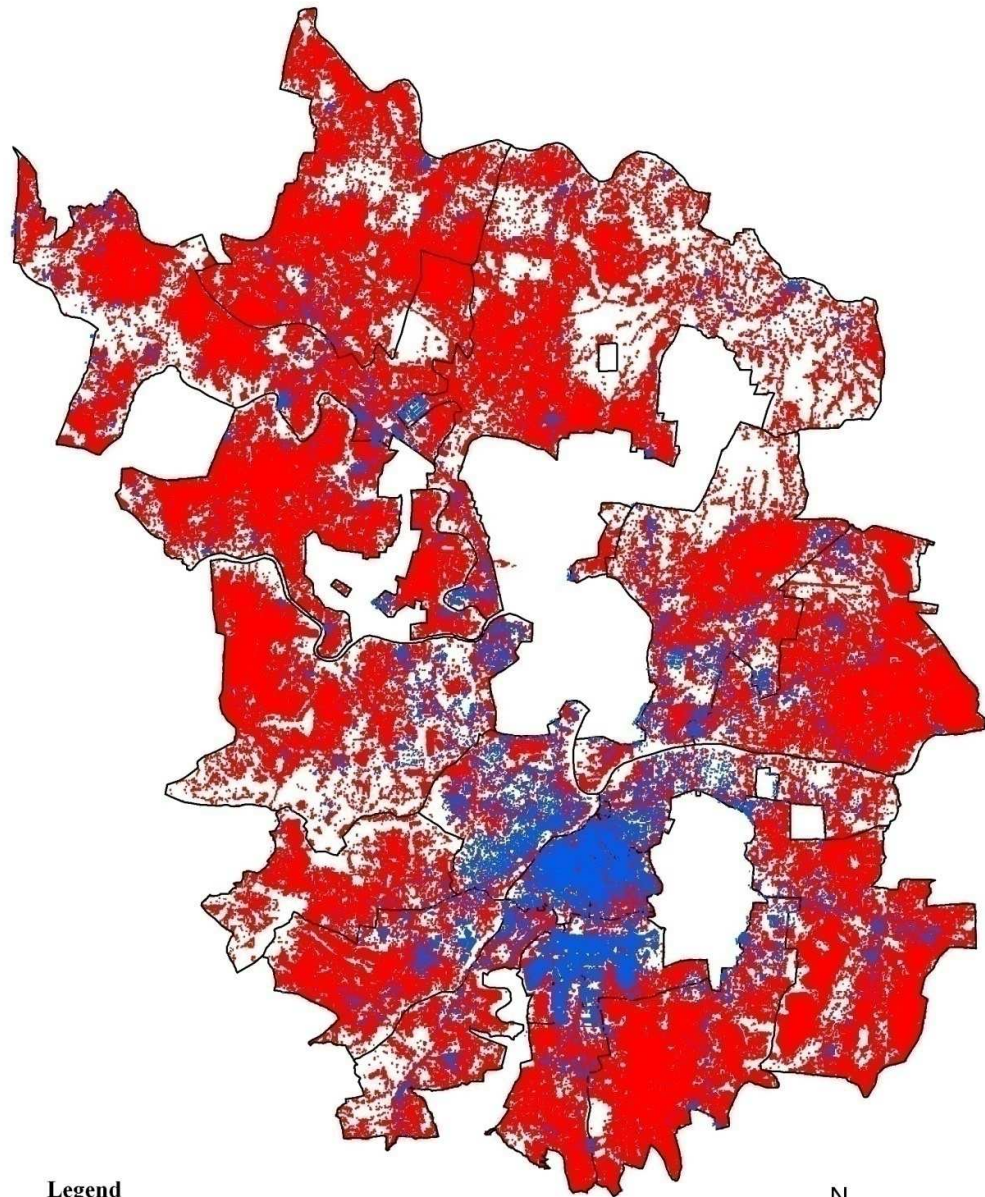
Legend

Built-up (Toposheet 1980)

Built-up (Image 2008)

Administrative Ward/Commitee
Boundary

N

0   2   4 Km.
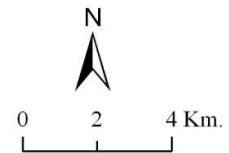
Fig. 4.24

PMC and PCMC built-up change from 1980-2008

Aundh

Aundh (Figure 2.6) administrative ward is having an area out of total geographical area is 9.33% of study region. In 1980, 2.48% area of total administrative ward is under built-up and it increased in 2008, at 48% means the total sprawl is 45.65%. In another words this ward grew 23 times in the sprawl within 28 years. The annual growth of urban sprawl is 1.77%. The probable causes of this sprawl are due to many geographical, administrative, defence factors. Among the urban factors Kirkee Cantonment, Pune University, Spicer College and Pune – Mumbai highway goes through this ward. After 2000 the built-up was spread the East side because of Indian Meteorological Department (IMD), National Chemical Laboratory (NCL), and Balewadi sports stadium already established in East side. Therefore West, NW and East sides are highly suitable for the urban sprawl and its growth.

Karve Road

Karve Road (Figure 2.7) administrative ward shows 3.73% of area Out of total geographical area in study region. In 1980, 0.52% area of total administrative ward is under built-up and it increased in 2008, at 45.28% means the total sprawl is 44.76%. The growth of urban sprawl is 1.59% per year. In the actual study, growth is towards the SW and West in 1980. One of the fastest growing suburbs in the nineties, it developed into a self-contained township at the inter section of Karve Road and Paud Road was virtually given over to fruit gardens, a decade back. This area is primarily a residential area with larger shopping complexes and restaurants. It has Institutions like MIT, Cummins, which are among the best engineering institutions in Pune. Banglore High-way has gone from East side of this ward. South, SW and NE areas are highly grown after 1999. These are the favorable reasons for built-up growth.

Ghole Road

In study area Ghole Road (Figure 2.8) administrative ward is having 3.35% area out of total geographical area. In 1980, 12.80% area of total administrative ward is under built-up and it increased in 2008, at 34% means the total sprawl is 21.20%. The annual growth of urban sprawl is 0.75% per year. This ward is located near core

area of Pune city. East side was covered with hills. A South and West side built-up was strong in between 1980 to 1999. But from 2004 to 2008 the East side shows built-up. This area is grown because of Agricultural University, Deccan Gymkhana, ILS Law Collage, Ferguson College, Symbiosis, Balbharati, Chatushrungi Temple, Malls, Shopping Complexes, Movie Theaters, good infrastructure facilities, Transport is well and healthcare facilities are stronger in this ward. That's why this ward was fully grown with built-up.

Warje - Karvenagar

Out of total geographical area, Warje-Karvenagar (Figure 2.9) administrative ward shows 3.68% of study region. In 1980, 5.24% area of total administrative ward is under built-up and it increased in 2008, at 58.98% means the total sprawl is 53.74%. The annual growth of urban sprawl is 53.74/28=1.91% per year. This ward is located peripheral area of the city. East side was covered with hills. A South, North and West sides built-up were suitable for settlements. This area was grown because of Hingne Sri Shikshan Sanstha, Dinanath Mangeshkar Hospital and healthcare facilities are very strong in this ward.

B. S. Dholepatil Road

B. S. Dholepatil Road (Figure 2.10) administrative ward covers 3.05% Out of total geographical area in the study area. In 1980, 9.34% area of total administrative ward is under built-up and it increased in 2008, at 37.97% means the total sprawl is 28.63%. The annual growth of urban sprawl is 1.02% per year. This ward is located near cantonment areas of the city. The ward shows less built-up in year 1980 towards west of the ward. But in the year 2008 this ward shows built-up were both sides of the ward. The middle areas were having less built-up compare to others. This area was grown because of Pune Railway Staion, Sasoon Hospital, Dr. Babasaheb Amedkar Udyan, Naidu Hospital, Wadia Collage, Ruby Hall Clinic, Jahangir Hospital, Osho Garden and Koregaon Park.

Hadapsar

Hadapsar (Figure 2.11), administrative ward is located the periphery of the study area and this ward covers 6.47% area Out of total geographical area. In 1980, 2.35% area of total administrative ward is under built-up and it increased in 2008, at

70.85% means the total sprawl is 68.50%. The annual growth of urban sprawl is 2.44% per year. This ward is located on periphery of the city. The ward shows built-up in year 1980 towards NE to west, diagonal built-up was found in this ward. But in year 1999 to 2004 this ward shows built-up East, West and South sides of the ward and in 2008 this ward was grown fully. This area was grown because of Magar Patta City, Nobel Hospital and Hadapsar PMPML Depot.

Yerawda

Yerawada (Figure 2.12), administrative ward shows 7.05% of area in the study region. In 1980, 1.27% area of total administrative ward is under built-up and it increased in 2008, at 70.59% means the total sprawl is 69.32%. The annual growth of urban sprawl is 2.47%. This ward is located on periphery of the city. The ward shows built-up in year 1980 towards East and middle part of the ward. In 1992 to 2008 this ward was grown in Pune-Nagar Highway side, Lohgaon Airportside and Mula-Mutha river side. This area grew because of Yerawada Jail, Lohagaon Airport, Agakhan Palace, and Kharadi Infotech.

Sangamwadi

Sangamwadi (Figure 2.13), administrative ward is having 7.32% of study region. In 1980, 2.57% area of total administrative ward is under built-up and it increased in 2008, at 46.36% means the total sprawl is 43.79%. The annual growth of urban sprawl is 1.56% per year. This ward is located on periphery of the city. The ward shows built-up in the year 1980 towards North, South and some part of West direction in ward. In 1999 to 2008 this ward was grown in Three Directions of ward only North direction had less built-up compared to other directions. This area has grown because of the confluence of Mula and Mutha rivers, Deccan Collage, Nanasaheb Parulekar Vidyalaya and Subhashchandra Bos Vidyalaya.

Bhavanipeth

In the total geographical area, Bhavanipeth (Figure 2.14), administrative ward occupies 0.67% of study region. In 1980, 37.28% area of total administrative ward is under built-up and it increased in 2008, at 84.59% means the total sprawl is 47.31%. The annual growth of urban sprawl is 1.68% per year. This ward is located in the core of the city. The ward shows built-up in the year 1980 towards North, East and West

direction and southern part shows less built-up in ward. In 1999 to 2008 this ward has grown in all Directions of ward. This area has grown because Mahatma Fule Wada, J. A. V. Stadium, Nanapeth commercial area, and social factors of the ward. This ward has strong health care facilities because of various multispecialty hospitals were located in this ward.

Kasbapeth

In the view of total geographical area of PMC and PCMC, the Kasbapeth (Figure 2.15) administrative ward covering 1.03% area. In 1980, 37.79% area of total administrative ward is under built-up and it increased in 2008, at 73% means the total sprawl is 35.21%. The annual growth of urban sprawl is 1.26% per year. This ward is located in the core of the city. This ward shows less built-up on southern and NE side in year 1980. But in 1999 southern side shows very less built-up. In 1999 to 2008 this ward was grown in all directions of ward. This area was grown because Shaniwar Wada, Vishrambaugwada, Kasba Ganpati Temple, Dagdusheth Halwai, Ganpati, Mahatma Fule Mandai, Tulshibag, Laxmi Road, Cloth garments, commercial complexes, shopping plazas area, and social factors of the ward. This ward has a strong multiple facilities because this ward is in the core of the city.

Vishrambaugwada

Vishrambaugwada (Figure 2.16), administrative ward is comes under core area of the PMC and out of total geographical area, this ward occupied 2.06% area of study area. In 1980, 32.13% area of total administrative ward is under built-up and it has increased in 2008, at 56.07% means the total sprawl is 23.94%. The growth of urban sprawl is 0.85% per year. This ward is located near the core of the city. This ward shows built-up on middle and south side in year 1980. But after 1992 shows growth from all sides of the ward, only NE side has less built-up in 2008. This area has grown because of Swargate is in the main centre for transportation and PMPML Depot as well as Head Office was established in this ward. But Market yard, Parvati Temple, Salisbury Park, Taljai Temple, Tilak Maharashtra Vidyapeeth and Cloth garments, commercial complexes, shopping plazas and social factors were also responsible for the growth of the ward.

111

Tilak Road

Pune and Pimpri-Chinchwad area is double than Chennai municipal area according to PMC and PCMC JNNURM draft and out of this total geographical area, Tilak Road (Figure 2.17), administrative ward shows 3.28% of study region. In 1980, 4.93% area of total administrative ward is under built-up and it increased in 2008, at 45.88% means the total sprawl is 40.95%. The annual growth of urban sprawl is 1.46% per year. This ward is located periphery of the city. This ward shows diagonal built-up on south to NE side in year 1980. But after 1992 to 2004 it shows growth towards west and south of the ward, only SE side was shows less built-up in 2008. This area was grown because this area was used as residential, Commercial and cultural purposes. This ward was highly suitable for built-up and Mutha River was blowing from north border of the ward.

Bibvewadi

The total geographical area of PMC and PCMC is 414.90 and out of that Bibvewadi (Figure 2.18), administrative ward covered 5.33% of area. In 1980, 2.80% area of total administrative ward is under built-up and it increased in 2008, at 77.18% means the total sprawl is 74.38%. The annual growth of urban sprawl is 2.66% per year. This ward is located periphery of the city. This ward shows more built-up on North and NE side in year 1980. But 1992 to 2004 years shows the growth towards all sides of the ward, only some parts were having less built-up and in 2008 built-up was spread with all directions. This area was grown because St. Patrick's Church (e.g. Fatima nagar was built around the church), Shinde Chattri, NIBM, Katraj Lake, Military area, Army School of Physical Training (ASPT) and industries like Kirloskar Pneumatic Indian Hume Pipe, Tata Honeywell and Bharat Forge.

Sahakarnagar

Sahakarnagar (Figure 2.19), administrative ward is located on periphery area of the study area and it has 2.28% area, out of total geographical area. In 1980, 7.29% area of total administrative ward is under built-up and it increased in 2008, at 71.70% means the total sprawl is 64.41%. The annual growth of urban sprawl is 2.30% per year. This ward is located periphery of the city. This ward shows more built-up on North and NE side in year 1980. But 1992 to 2004 years shows the growth towards all sides of the ward, only some parts were having less built-up and in 2008 built-up

spread in all directions. This area has grown because of Bharati Vidyapeeth, Rajiv Gandhi Prani Sangrahalaya, Agam Temple, Ambegaon Pathar and Pune-Satara Highway goes through this ward.

A Committee

In the analysis of study area A (Figure 2.20), administrative committee, showing 8.68% out of total geographical area. In 1980, 0.86% area of total administrative ward was under built-up and it increased in 2008, at 63.15% means the total sprawl is 62.29%. The annual growth of urban sprawl is 2.22% per year. This committee shows more built-up on south and NE side in year 1980. But 1992 to 2008 years shows the growth of all sides of the committee, only middle part had less built-up otherwise this built-up was spread in all directions. This area has grown because Nigdi Pradhikaran, industrial areas, Commercial areas and residential areas were located in this Committee. Pune-Mumbai National Highway has gone through this committee

B Committee

The study area is having 18 administrative wards/committees, out of these B (Figure 2.21), administrative committee shows 9.53% of study region. In 1980, 2.10% area of total administrative ward was under built-up and it increased in 2008, at 62.19% means the total sprawl is 60.09%. The annual growth of urban sprawl is 2.14% per year. This committee shows more built-up on west and east side in year 1980. But 1992 to 2008 years shows the growth towards all sides of the committee, only some part of NE had less built-up, otherwise this built-up was spread in all directions. This area has grown because Hindusthan Antibiotics Factory, YCM Hospital, Chinchwad gaon, industrial areas, Commercial areas and residential areas were located in this Committee. Pune-Mumbai National Highway has gone through this committee.

C Committee

C (Figure 2.22), administrative committee occupies 16.11% area out of study area. In 1980, 1.03% area of total administrative ward was under built-up and it increased in 2008, at 41.08% means the total sprawl is 40.05%. The annual growth of urban sprawl is 1.43% per year. This committee shows more built-up on southeast and

west side and other areas had less built-up in year 1980. 1992 image shows the growth towards east to west including north area and SE of the committee shows more built-up. 1999 to 2008 shows the growth from all sides of the committee. This area has grown because Pune-Nashik National Highway has gone through this committee. Bhosari gaon, industrial, Commercial and residential areas were located in this Committee.

D Committee

Out of total geographical area, D (Figure 2.23), Committee, administrative ward shows 7.04% of study region. In 1980, 1.37% area of total administrative ward was under built-up and it increased in 2008, at 68.86% means the total sprawl is 67.49%. The annual growth of urban sprawl is 67.49/28=2.41% per year. This committee shows small patches were spread with built-up in 1980. 1992 to 2008 shows the growth in all directions. This area has grown because Pune-Mumbai National Highway has gone through this committee. Kasarwadi, industrial, Commercial and residential areas were located in this Committee.

4.10 Conclusion

This Chapter was under the title 'An assessment of urban sprawl'. The LANDSAT ETM+ and IRS P6 LISS III satellite data were used for the monitoring the sprawl and for measuring the sprawl the Shannon's entropy was used. Administrative ward / committee wise sprawl of Pune and Pimpri-Chinchwad over different periods of time from 1980 to 1992, 1992 to 1999, 1999 to 2004 and 2004 to 2008 analyzed with the help of Shannon's entropy technique.

Chapter V
CIVIC AMENITIES

5.1 Introduction

The pressures of utility market around the globe are open out. Utilities are often required to compete with domestic and foreign privatization forces for cost-effective operations and manage facilities adopting time-proven, quality-driven, and realistic business practices to better serve the public. In today's competitive market, managing utility services has become a challenging to entrepreneurs for effective utilization of economic concepts to develop a practical cost management approach. An integrated Utility Management System with Geographical Information System (GIS) is essential to capture, store and analyze the demographic changes, spatial changes and aging infrastructure of the utility services. Utility GIS have become an excellent way to record what you have and where it's located. Thus, it helps to quickly identify maintenance problems and also the engineering of utilities.

The various utility services like urban transportation, multispecialty hospitals and medium wise primary schools were given below.

5.2 Urban Transport

Keeping traffic moving is the big challenge that all levels of management are facing globally. Private travelers, commercial road users, and the public sector are continually searching for a new and faster travel routes. The old adage, 'information is power' is the understandable solution to the traffic problem. Travelers wish for real-time information to help them to select the best route to take at any given time. They need to know traffic speeds, incidents and road conditions.

An India's transportation structure represents improvement phase of India. But at the same time highly urbanized countries are facing higher difficulties of transportation management and spending lots capital and endeavor for solving individual's problems. Increasing traffic congestion, the need to protect the situation and the problems of road security is the main reason for many cities worldwide to think of new plans in public transportation scheme.

Urban Bus: In view of the technological superiority and other advantages, urban bus may be introduced in metropolitan cities replacing the standard bus currently in use. The Central Government should finance 50 per cent of the cost of 2,000 urban buses, as an initial investment towards more efficient public transport.

115

Dedicated Bus-ways: As a major part of the transport demand will continue to be met by the bus system in cities, it is important to facilitate their movement through provision of dedicated bus-ways.

5.3 Pune Mahanagar Parivahan Mahamandal Limited (PMPML)

Pune Mahanagar Parivahan Mahamandal Ltd or PMPML is the public transport service provider for the city of Pune and Pune Metropolitan region, which includes areas surrounding Pune and Pimpri-Chinchwad.

At present, the PMPML has around 1600 buses on the roads on a given day. The number of routes has almost reached 300 due to the addition of a couple of new routes over the past few months, operating 63.4 million km of route and transports approximately 0.23 billion passengers per annum. Bus fares are charged on the basis of km travelled, and range from the minimum fare of Rs.1.4 for 2 km to Rs.14.85 for a journey of 60 km.

In February 2008, the Union urban development ministry cleared a proposal to provide funds for purchasing 650 public transport buses for Pune and Pimpri-Chinchwad. The funds have been issued under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM). Of the total, 200 were supposed to be semi-low floor buses. The number of buses sanctioned for Pune is 500, while that for Pimpri-Chinchwad is 150.

5.3.1 PMPML Depots

Pune Mahanagar Parivahan Mahamandal Ltd or PMPML is having 10 depots in PMC and PCMC area. Currently these depots have 1609 working buses out of these 327 buses are Casual contract buses and 1282 are PMPML buses. PMC and PCMC areas are having 3380 bus stops throughout the city as well as 344 routes and 18522 trips per day. Depot wise distribution of PMPML buses are given in following table.

Table 5.1 PMPML Depot wise Distribution of Buses in PMC and PCMC area

Sr. No	Name	Regular PMPML Buses	No. of Casual Contract Buses	Total No. of Buses	% of Buses
1	Hadapsar	144	36	180	11.19
2	Katraj	155	51	206	12.80
3	Swargate	212	36	248	15.41
4	Marketyard	56	21	77	4.79
5	Kothrud	160	17	177	11.00
6	N T Wadi	197	41	238	14.79
7	Pune Station	88	37	125	7.77
8	Bhakti-Shakti (Nigdi)	81	49	130	8.08
9	Sadguru Nagar (Bhosari)	45	22	67	4.16
10	Nehrunagar	144	17	161	10.01
	Total	**1282**	**327**	**1609**	**100**

Source: PMPML Head Office, Swargate, Pune
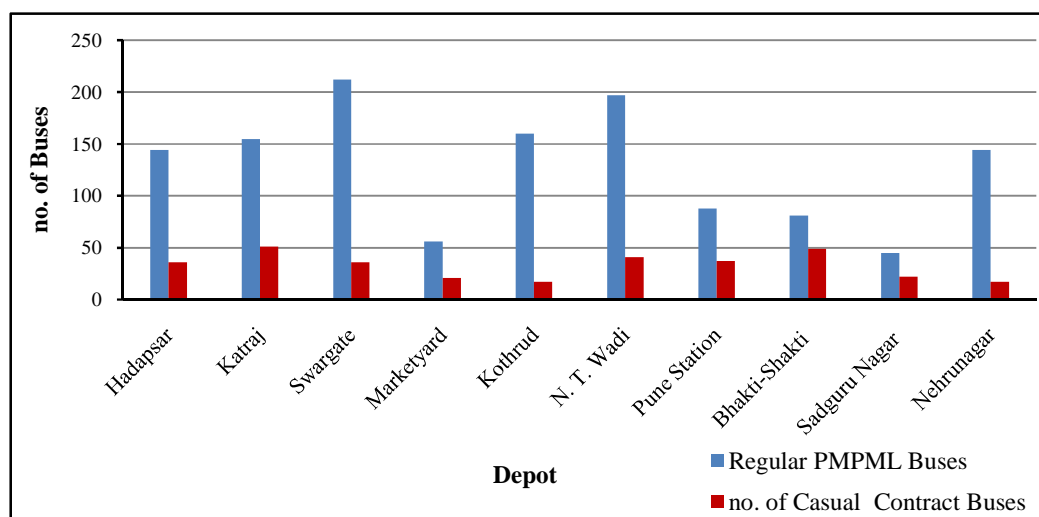
Fig 5.1 Depot wise Distribution of Buses in PMC and PCMC

From the study of utility services Swargate depot shows the highest buses in depot 15.41% (248) followed by N. T. Wadi 14.79% (238) and Katraj 12.80% (206) in Depots. Sadguru Nagar (Bhosari) depot was shows only 4.16% (67), Marketyard 4.79% (77) and Pune Station 7.77% (125) in depot. Kothrud 11% (177), Hadapsar 11.19% (180 buses), Nehrunagar 10.01% (161) and Bhakti-Shakti 8.08% (130) PMPML buses.

PMPML Bus Depots in PMC and PCMC area
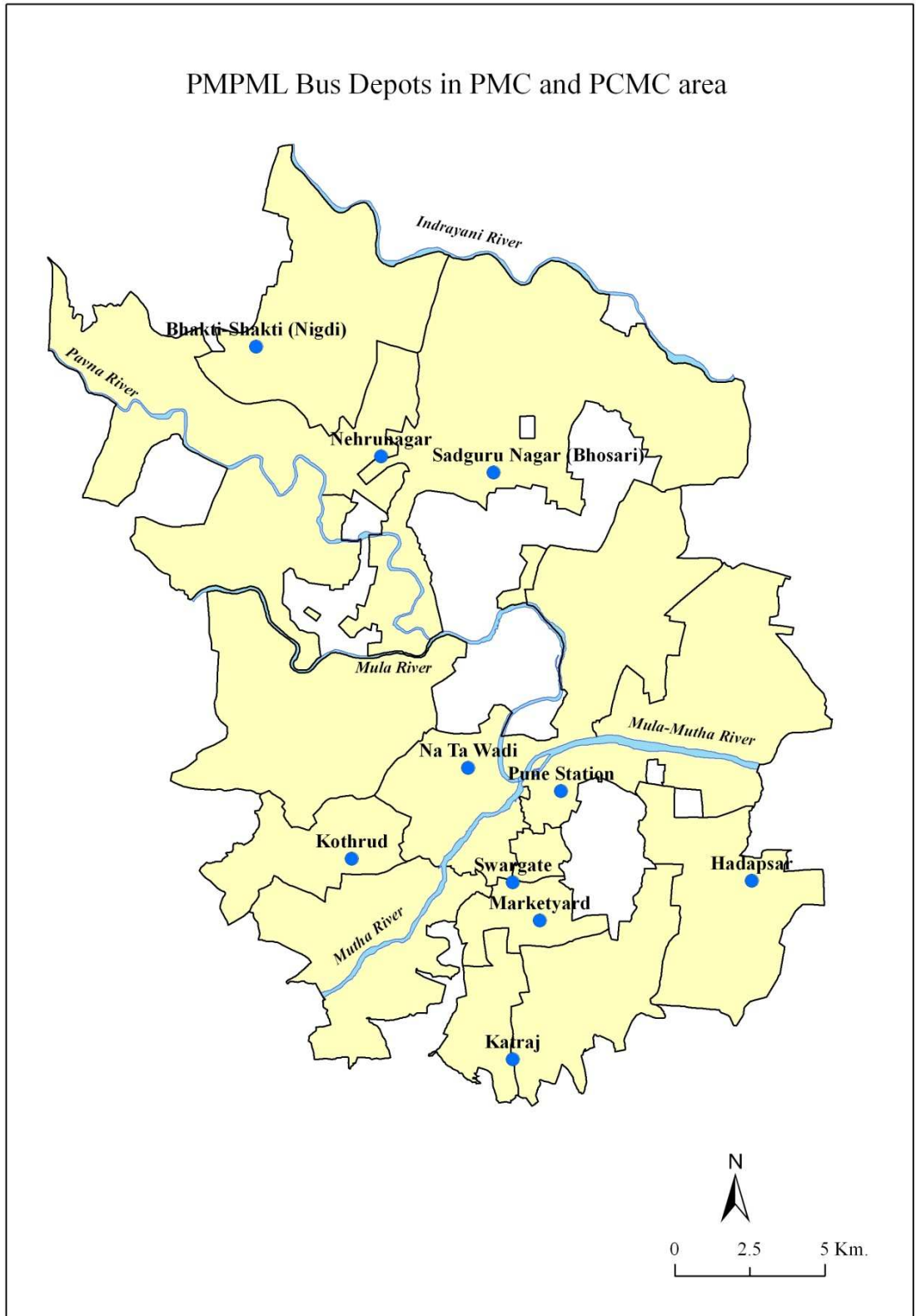
Fig. 5.1

PMPML Bus Depots with Road Network in PMC and PCMC area

to Mumbai

Indrayani River

to Mumbai

to Mumbai

Pavna River

Bhakti-Shakti (Nigdi)

Nehrunagar

Sadguru Nagar (Bhosari)

Mula River

to Ahmednagar

Mula-Mutha River

Na Ta Wadi

Pune Station

Kothrud

to Paud

Swargate

Marketyard

Hadapsar

to Solapur

Mutha River

to Miraj-Sangli

to Sinhagad

Katraj

to Satara

Legend

● PMPML Depots
— Main Roads
╫╫╫╫ Railway Line
▬ Major Rivers

N

0   2.5   5 Km.
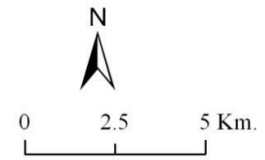
Fig. 5.2

Depotwise Distribution of regular PMPML Buses in
PMC and PCMC area

Bhakti-Shakti (Nigdi)

Nehrunagar

Sadguru Nagar (Bhosari)

Na Ta Wadi

Pune Station

Kothrud

Swargate

Hadapsar

Marketyard

Katraj

Legend

● Bus Depots

No. of buses

High : 212

Low : 45

N

0   2   4 Km.
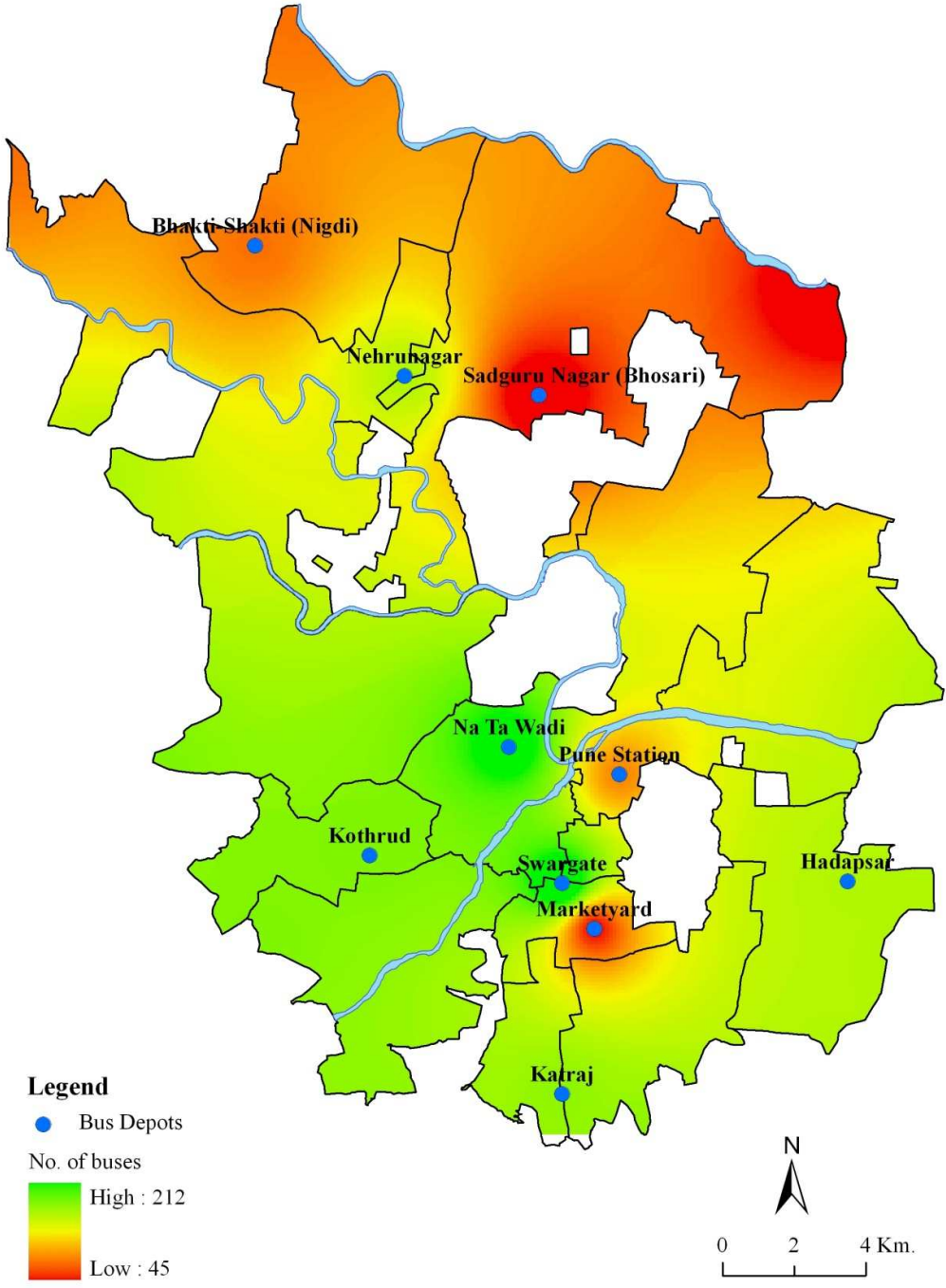
Fig. 5.3

Depotwise Distribution of PMPML Casual Contract Buses
in PMC and PCMC area

Legend

● Bus Depots

No. of buses

High : 51

Low : 17
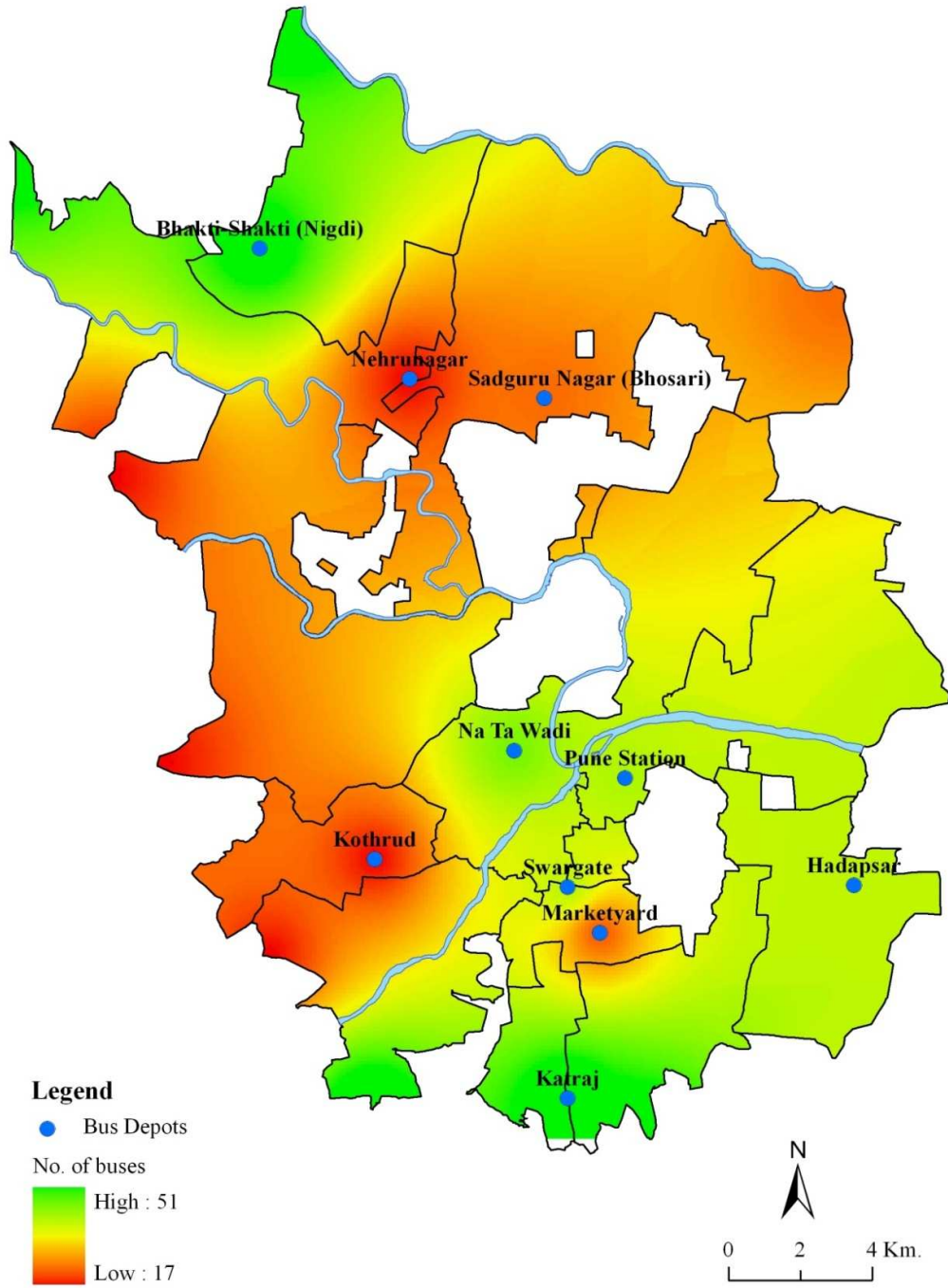
Fig. 5.4

PMPML Bus Depots with total number of Buses
in PMC and PCMC area

Bhakti-Shakti (Nigdi)

Nehrunagar

Sadguru Nagar (Bhosari)

Na Ta Wadi

Pune Station

Kothrud

Swargate

Hadapsar

Marketyard

Katraj

Legend

● Bus Depots

No. of buses

High : 248

Low : 67

N

0   2   4 Km.
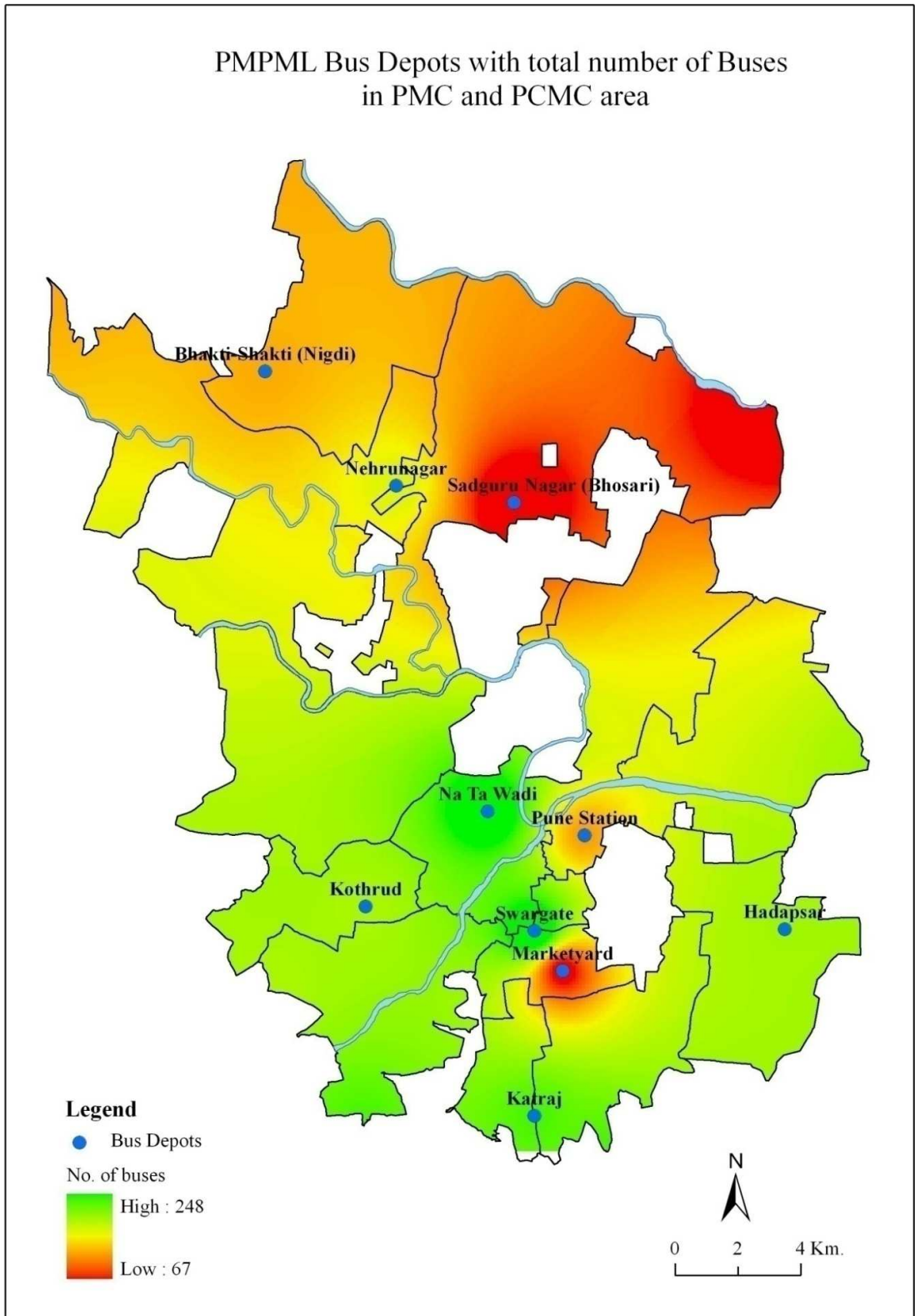
Fig. 5.5

One Kilometer Buffer along PMPML Depots in PMC and PCMC area
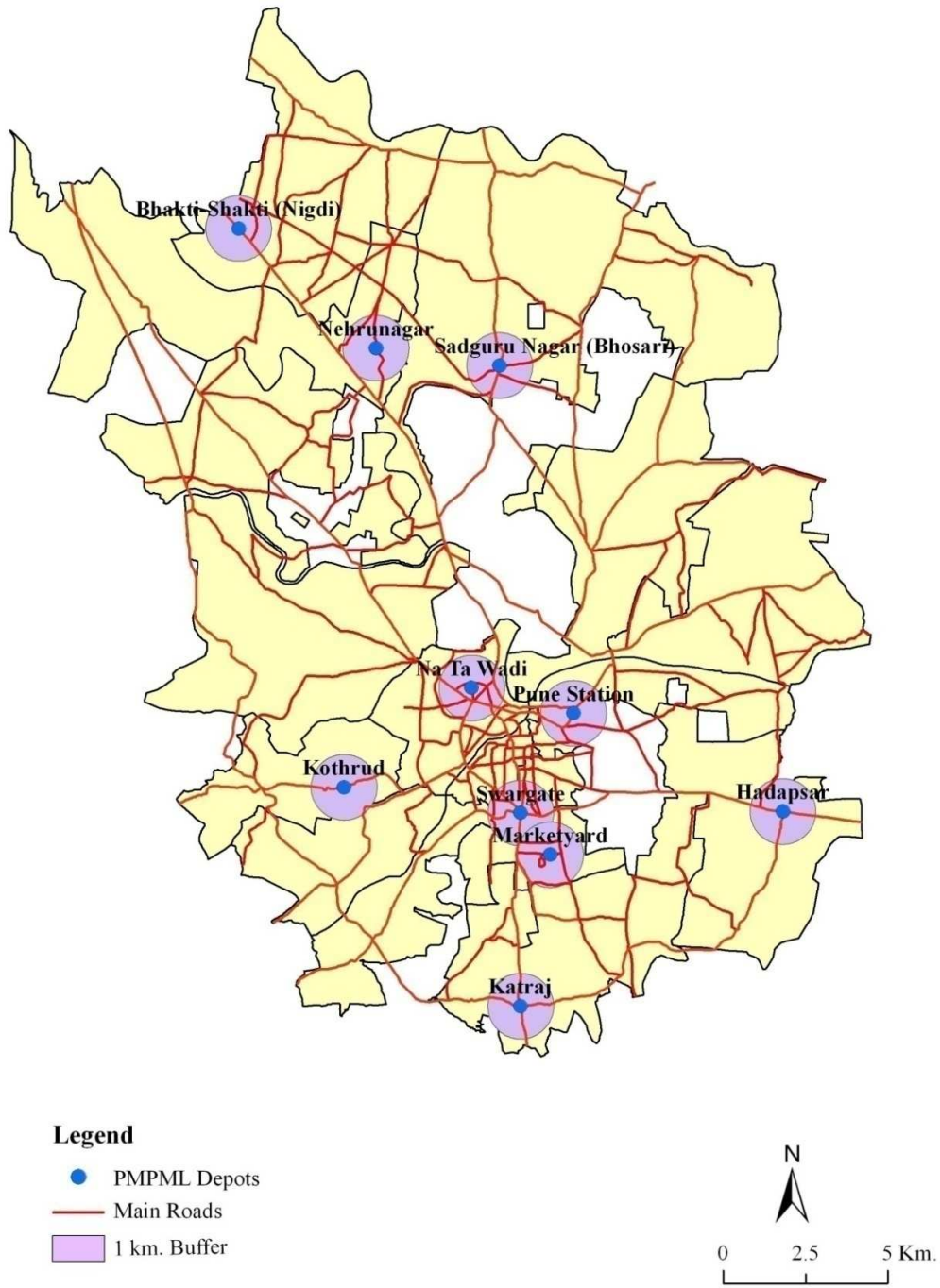
Fig. 5.6

Two Kilometer Buffer along PMPML Depots in PMC and PCMC area

Bhakti-Shakti (Nigdi)

Nehrunagar

Sadguru Nagar (Bhosari)

Na Ta Wadi

Pune Station

Kothrud

Swargate

Marketyard

Hadapsar

Katraj

Legend

● PMPML Depots

— Main Roads

▢ 2 km. Buffer

N

0   2.5   5 Km.
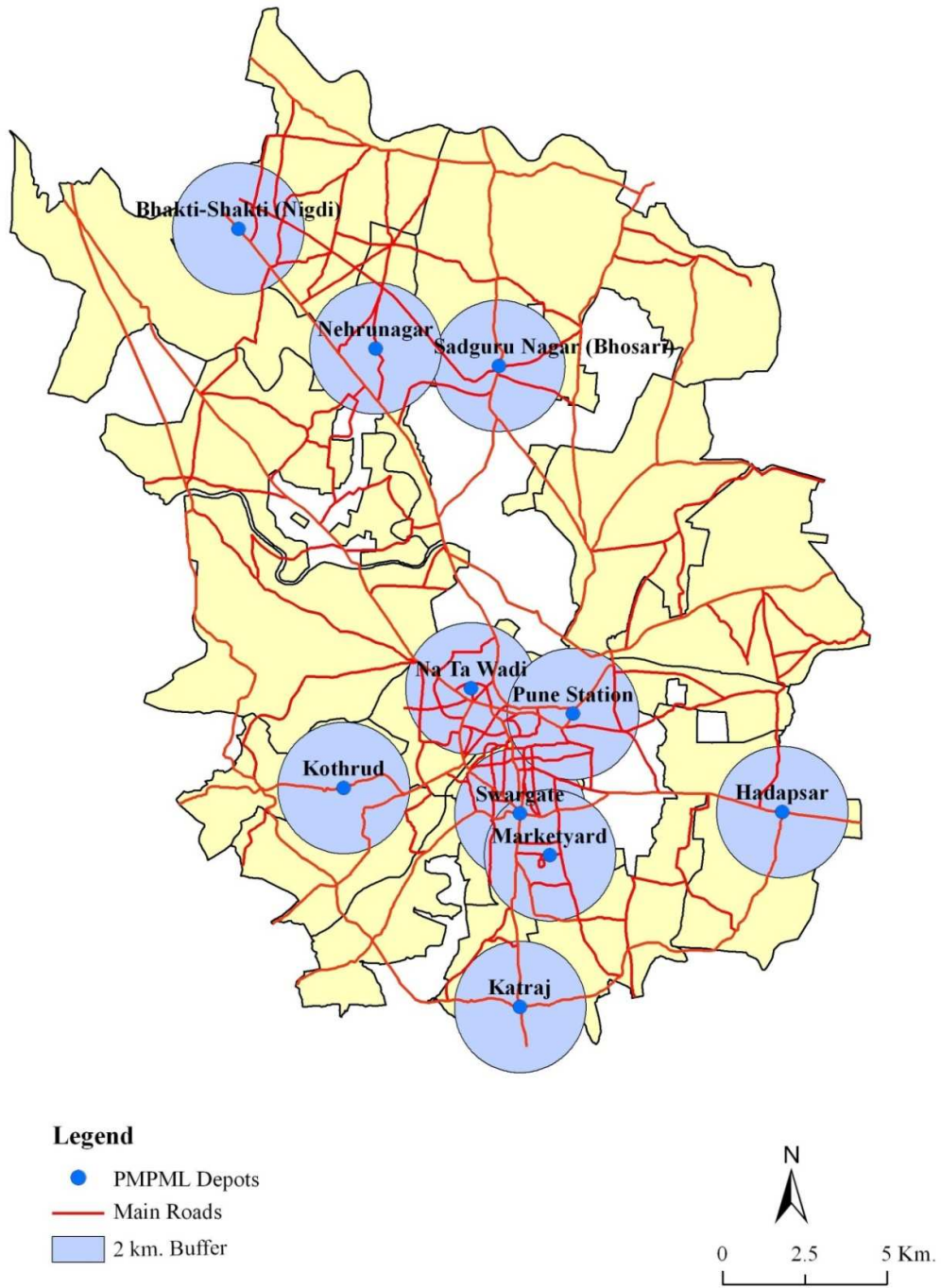
Fig. 5.7

Three Kilometer Buffer along PMPML Depots
in PMC and PCMC area
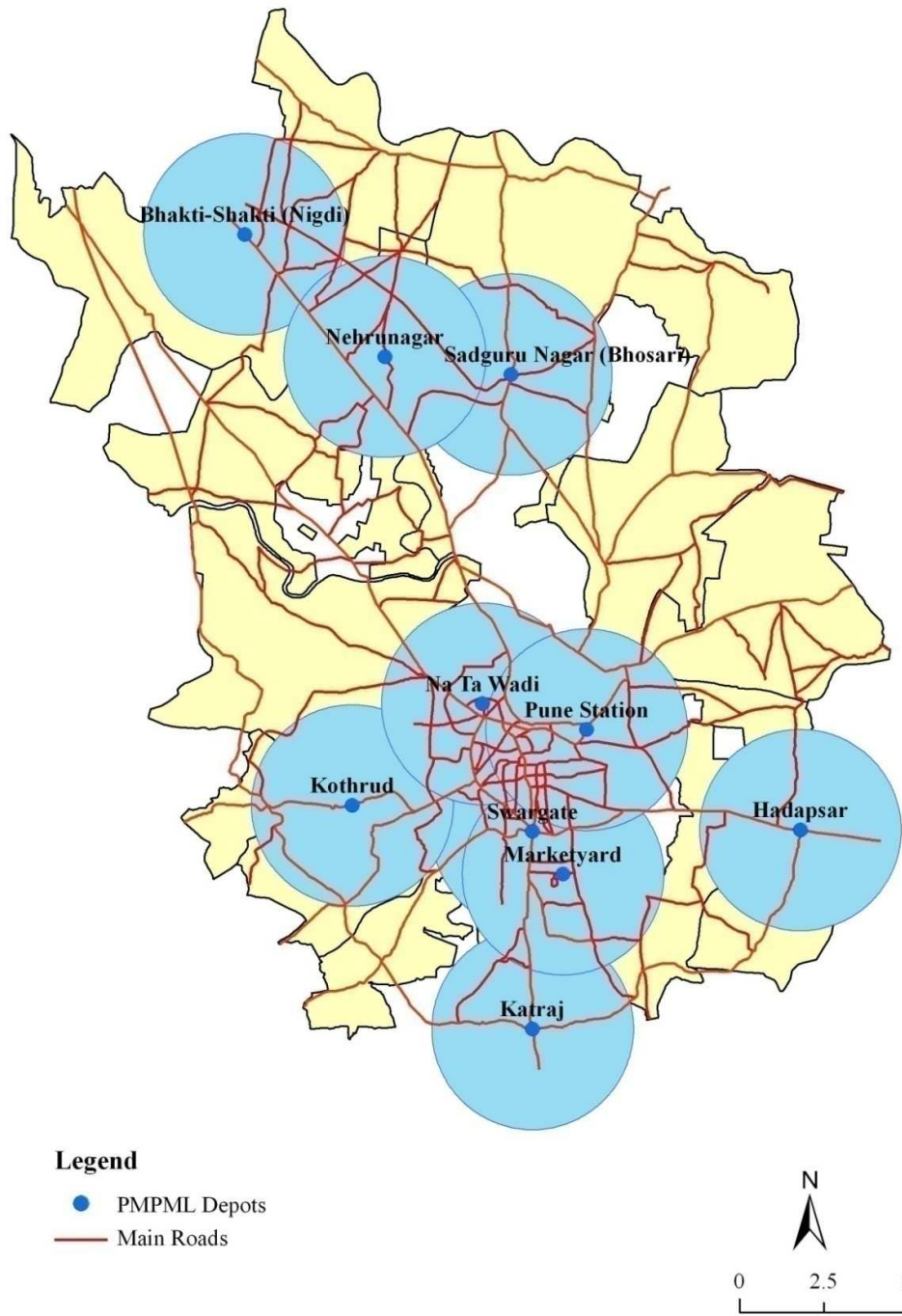
Fig. 5.8

Multiple Ring Buffer along PMPML Depots
in PMC and PCMC area
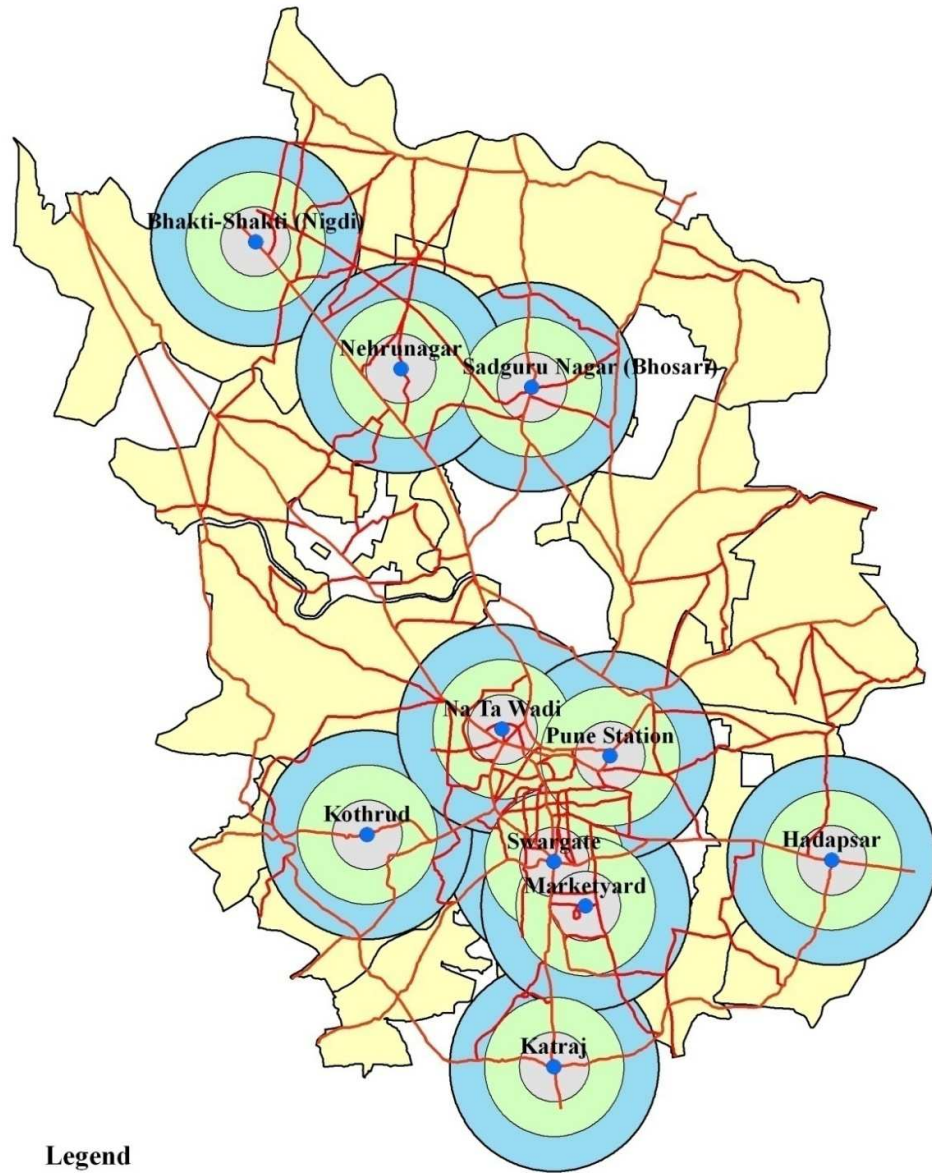
Legend

● PMPML Depots

— Main Roads

⬜ 1 Km. Buffer

🟩 2 Km. Buffer

🟦 3 Km. Buffer

N

0   2.5   5 Km.
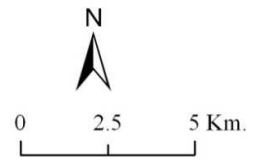
Fig. 5.9

5.4 Inverse Distance Weighted interpolation (IDW)

An interpolation technique that estimates cell values in a raster from a set of sample points that have been weighted so that the farther a sampled point is from the cell being evaluated, the less weight it has in the calculation of the cell's value.

Figure No. 5.3, 5.4 and 5.5 shows the distribution of Regular PMPML Buses, Casual Contract Buses and Total No. of Buses in each depot respectively. Green, color shows higher concentration of buses and red, color shows less concentration of buses in each depot.

Fig 5.3 shows Swargate, N. T. Wadi, Kothrud, Katraj, Hadapsar, and Nehrunagar depots have the high concentration of regular buses in depot. Bhakti-Shakti, Sadgurunagar, Pune Station and Marketyard bus depots show less concentration of regular buses in depot.

Fig 5.4 shows Swargate, N. T. Wadi, Katraj, Hadapsar, Pune Station and Bhakti-Shakti depots are the high concentration of casual contract buses in depot. Nehrunagar, Sadgurunagar, Kothrud and Marketyard bus depots show less concentration of casual contract buses in depot.

Fig 5.5 shows the total No. of regular and casual contract buses in the study area. Swargate, N. T. Wadi, Katraj, Hadapsar and Kothrud depots are the high concentration of buses in depot compare to other depots. Nehrunagar, Sadgurunagar, Pune Station, Kothrud and Marketyard bus depots are showing less concentration of buses in depot. Bhakti-Shakti depot shows medium concentration of buses in depot.

5.5 Buffer Analysis

A zone around a map feature measured in units of distance or time. A buffer is useful for proximity analysis. A polygon is enclosing a point, line, or polygon at a specified distance.

5.5.1 Point Buffer

Figure No. 5.6, 5.7 and 5.8 shows 1 km. 2 km and 3 km. buffer along the PMPML depots. These buffers cover an area of 1 to 3 kilometer from the depot location. These areas are under public zone though they were taking the benefits of the bus transport.

5.5.2 Multiple Ring Buffer

This buffer analysis creates a new feature class of buffer features using a set of buffer distances. The new features may be dissolved using the distance values, or as a set of individual features.

Fig No. 5.9 shows the multiple ring buffers along the PMPML depots in PMC and PCMC area. Gray color shows the 1 km. buffer, Green color shows the 2 km. buffer and Blue color shows 3 km. buffer along the depots. These buffers cover the area from 1 to 3 km. These buffers are going to cover almost all the area of the city as well as some parts of the outside area.

5.6 Generation of Hospital Utility Database

In present work the author has considered only the medical services (Hospitals). In the last 5 to 6 years No. of accidents have increased dramatically. Population increase leads to the increase in no. of patients in various diseases such as heart, mental, and kidney etc.

In the present study only hospitals having multidignosis and treatment facilities and 24 hrs open hospitals have been considered, while nursing home or clinics are also considered.

In the present study an attempt has been made to list out no. of hospitals (Administrative Ward/Committee wise) with their specialty, facility available and other emergency services. At present PMC is categorized into 14 administrative wards and PCMC is categorized into 4 committees which have no. of 2262 Hospitals in PMC and PCMC which includes Govt. added hospitals and medical colleges with multispecialty hospitals. But they are concentrated in core areas. As urban built-up expands all around peripheral areas of the city, there newly added PMC and PCMC areas lacks special and super specialty hospitals. E.g. Karvenagar, and other ward lack big hospitals.

In the present study, with the help of GIS one can easily approach any kind of medical information such as nearest multispecialty hospitals providing at glance information such as hospital location and nearest multispecialty hospital in the study area.

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Table 5.2 Multispecialty Hospitals in PMC and PCMC

Sr. No	Committee/Ward		Population	General / Practice	Gynecologist	General Surgeon	Family Physician	Pediatrics	Anaesthilogy	ENT	Others	Total	% of Hospitals
1	Aundh		179886	140	7	6	0	4	1	1	16	175	8.49
2	Karve Road		201527	93	3	1	0	1	2	0	17	117	5.67
3	Ghole Road		204316	237	11	2	4	4	2	1	23	284	13.77
4	Warje Karvenagar	P	116386	190	12	8	7	14	9	4	34	278	13.48
5	BS Dholepatil		218306	114	7	3	5	2	1	0	9	141	6.84
6	Hadapsar	M	239370	45	3	2	0	1	3	3	5	62	3.01
7	Yeravada		251100	33	0	0	1	1	1	0	8	44	2.13
8	Sangamvadi		213718	13	2	0	0	0	0	0	3	18	0.87
9	Bhavanipeth	C	205009	64	1	1	1	1	2	2	6	78	3.78
10	Kasbapeth		100059	170	14	3	7	5	12	6	24	241	11.69
11	Vishrambaugwada		154425	73	3	0	3	2	0	1	9	91	4.41
12	Tilak Road		211103	114	9	2	8	2	3	1	13	152	7.37
13	Bibvevadi		239530	82	6	4	4	4	1	1	16	118	5.72
14	Sahkarnagar		161665	115	7	4	5	3	3	1	19	157	7.61
15	A Committee	P	199995	17	1	1	0	0	0	0	2	21	1.02
16	B Committee	C	168967	35	0	0	2	0	0	0	1	38	1.84
17	C Committee	M	209139	13	1	0	0	0	0	1	1	16	0.78
18	D Committee	C	167345	23	4	1	0	1	0	0	2	31	1.50
	Total		**3441846**	**1571**	**91**	**38**	**47**	**45**	**40**	**22**	**208**	**2062**	**100**

5.7 Multispecialty Hospitals in PMC and PCMC

Table 5.1 shows multispecialty hospitals in PMC and PCMC in various administrative wards/committee. Fig No. 5.18 shows the total no. of multispecialty hospitals in each ward/committee. Total No. of hospitals are 2062 in the study area. Ghole Road 13.77% (284), Warje-Karvenagar 13.48% (278) and Kasbapeth 11.69% (241), administrative wards have highest multispecialty hospitals. General/Practice hospitals are highest compared to other hospitals, followed by other multispecialty (208) and Gynaecologists (91) in the study area. ENT, Family Physician and Pediatrics are very less in the study area.

5.7.1 General / Practice Hospitals

Figure 5.10 shows the distribution of general / practice hospitals in the study area. Bhavanipeth, Bibvewadi and Yerawada wards have more hospitals in the study area. Karve Road, Kasbapeth, Hadapsar, A, B, C and D wards/committees has less concentration of hospitals in the study area.

5.7.2 Gynaecology Hospitals

Figure 5.11 shows the distribution of gynaecology hospitals in the study area. Bhavanipeth, Bibvewadi and Yerawada wards have more hospitals in study area. Karve Road, Kasbapeth, Hadapsar, Warje-Karvenagar, Sahakarnagar, A, B, C and D wards/committees has less concentration of hospitals in the study area. Aundh, Ghole Road, Tilak Road and Sangamwadi wards have medium hospitals.

5.7.3 General Surgeon Hospitals

Figure 5.12 shows the distribution of general surgeon hospitals in the study area. Bibvewadi ward is having more hospitals in study area. Aundh, Ghole Road, Sangamwadi, Tilak Road and Yerawada wards are having medium and other wards are comes under less concentration of hospitals in the study area.

5.7.4 Family Physician Hospitals

Figure 5.13 shows the distribution of family physician hospitals in the study area. Bibvewadi, Vishrambaugwada and Yerawada wards have more hospitals in the study area. Warje-Karvenagar, Ghole Road, Sangamwadi, Tilak Road and

Bhavanipeth wards have medium and other wards come under less concentration of hospitals in the study area.

5.7.5 Pediatrics Hospitals

Figure 5.14 shows the distribution of pediatrics hospitals in the study area. Bibvewadi ward has more hospitals in the study area. Tilak Road, Yerawada, Aundh and Bhavanipeth wards have medium and other wards come under less concentration of hospitals in the study area.

5.7.6 Anaesthilogy Hospitals

Figure 5.15 shows the distribution of anaesthilogy hospitals in the study area. Yerawada ward has more hospitals in the study area. Bibvewadi ward is having medium and other wards come under less concentration of hospitals in the study area.

5.7.7 ENT Hospitals

Figure 5.16 shows the distribution of ENT hospitals in the study area. Yerawada ward has more hospitals in the study area. Bibvewadi and Hadapsar wards have medium and other wards come under less concentration of hospitals in the study area.

5.7.8 Other Multispecialty Hospitals

Figure 5.17 shows the distribution of other multispecialty hospitals in the study area. Bibvewadi ward is having more hospitals in the study area. Yerawada and Bhvanipeth wards are having medium and other wards are comes under less concentration of hospitals in the study area.

Distribution of General Hospitals in PMC and PCMC

Legend

No. of. Hospitals

	< 50
	51 - 100
	101 - 150
	151 - 199
	> 200
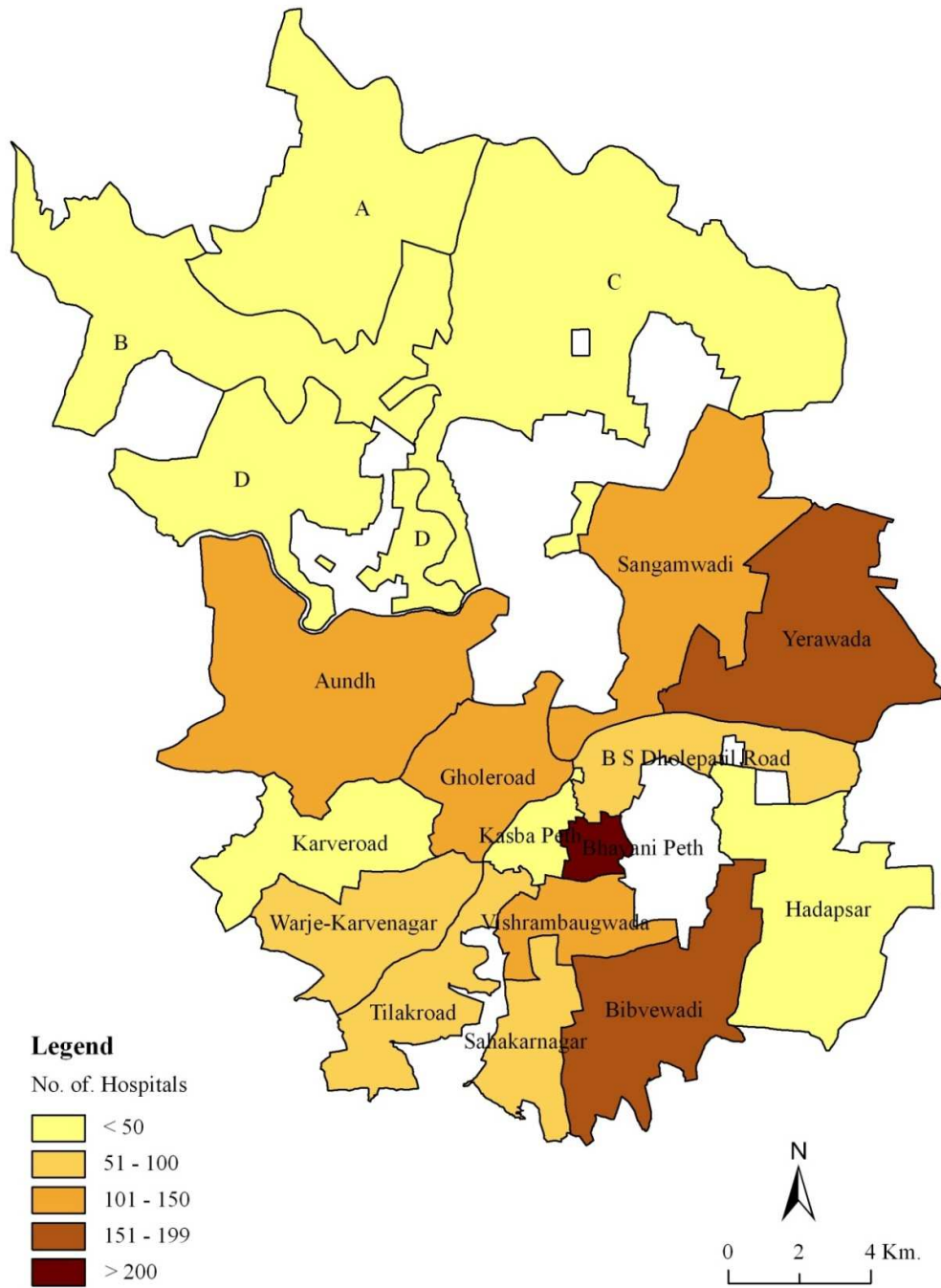
Fig. 5.10

Distribution of Gynaecology Hospitals in PMC and PCMC

A

C

B

D

D

Sangamwadi

Yerawada

Aundh

Gholeroad

B S Dholepatil Road

Kasba Peth

Bhavani Peth

Karveroad

Warje-Karvenagar

Vishrambaugwada

Hadapsar

Tilakroad

Sahakarnagar

Bibvewadi

Legend

No. of. Hospitals

< 5

6 - 10

> 10

N

0   2   4 Km.
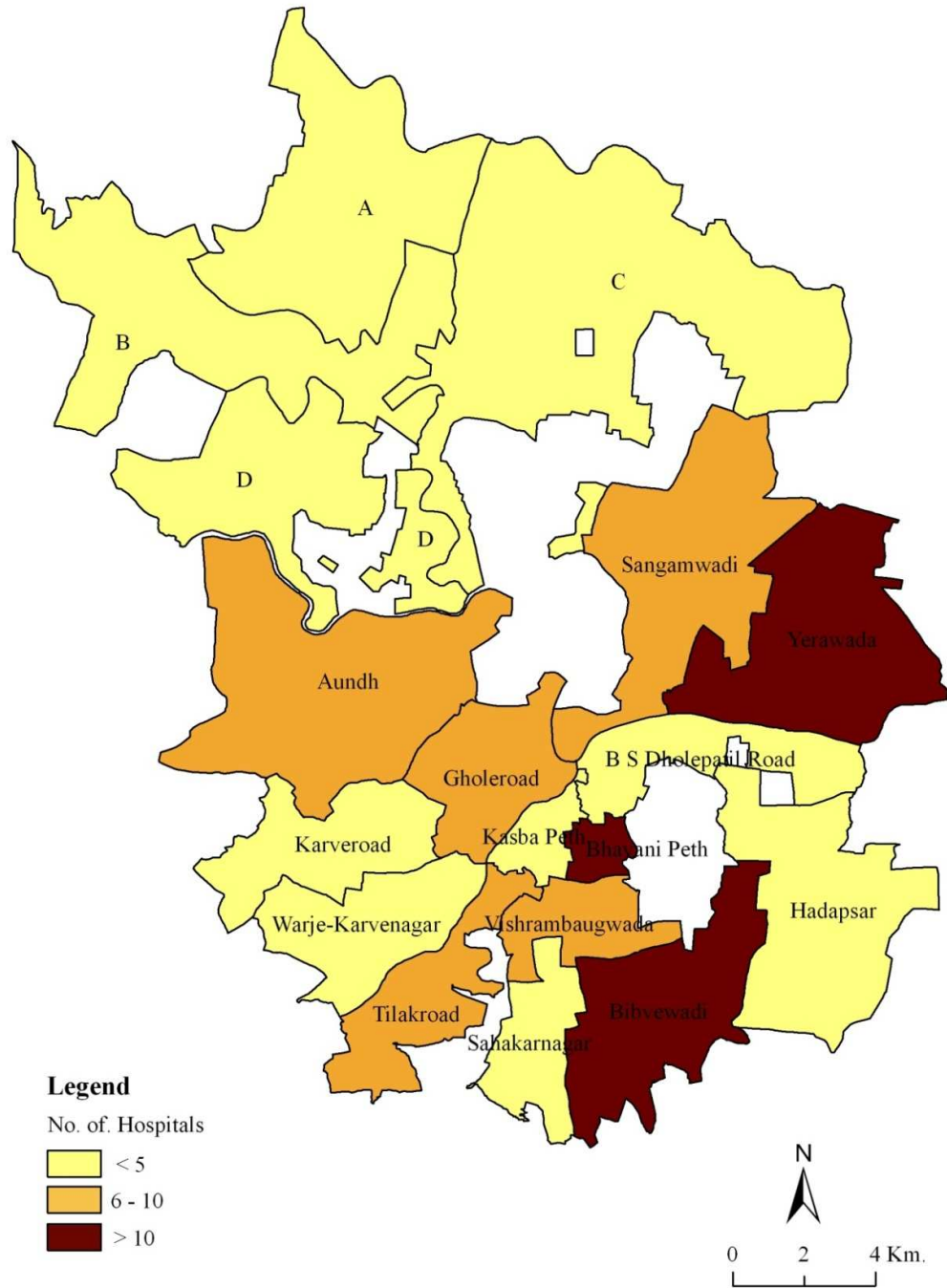
Fig. 5.11

Distribution of General Surgeon Hospitals in PMC and PCMC

A

C

B

D

D

Sangamwadi

Yerawada

Aundh

Gholeroad

B S Dholepatil Road

Karveroad

Kasba Peth

Bhavani Peth

Hadapsar

Warje-Karvenagar

Vishrambaugwada

Tilakroad

Bibvewadi

Sahakarnagar

Legend

No. of. Hospitals

< 3

4 - 6

> 6

N

0   2   4 Km.
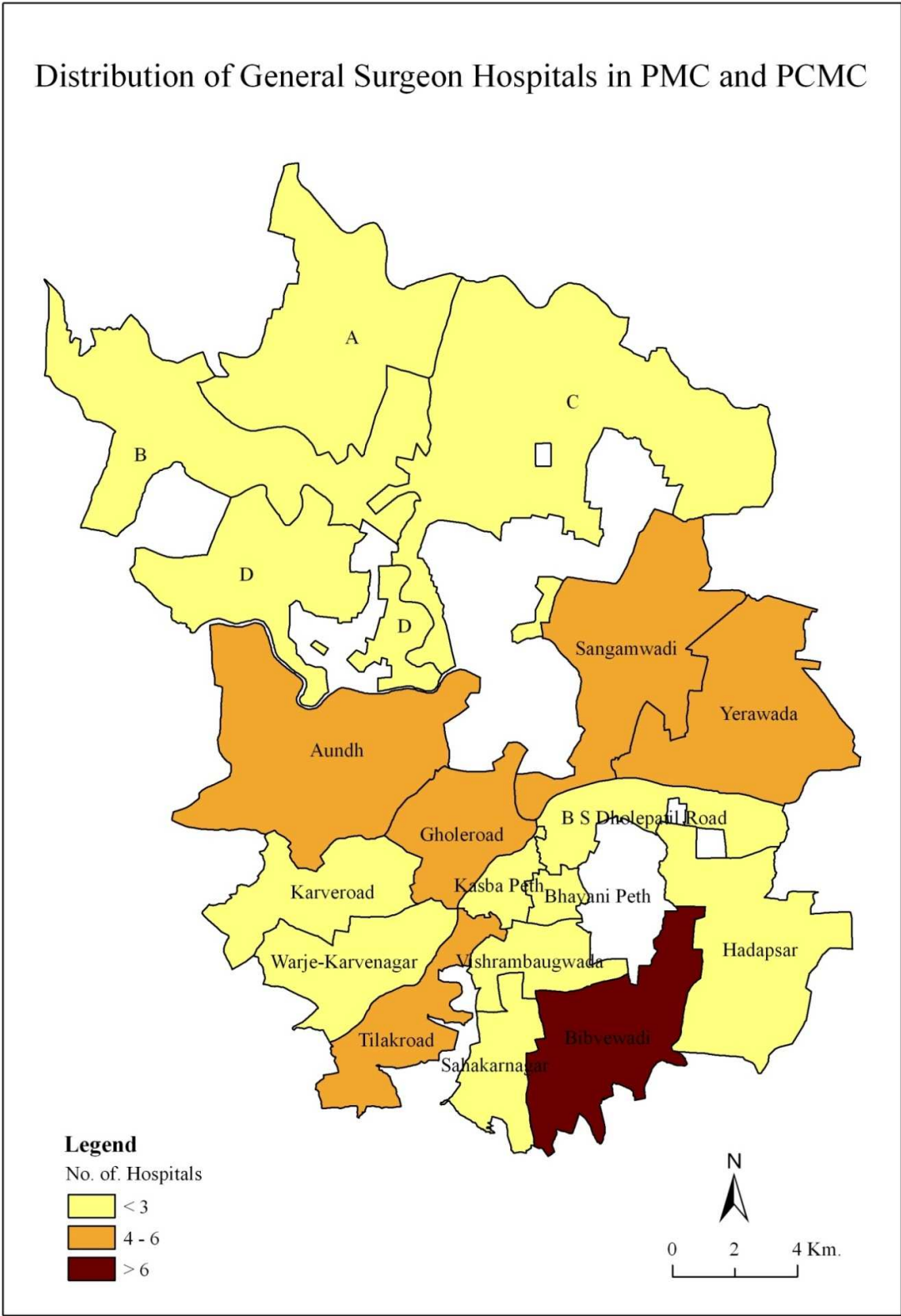
Fig. 5.12

Distribution of Family Physician Hospitals in PMC and PCMC

Legend

No. of. Hospitals

- < 3
- 4 - 6
- > 6
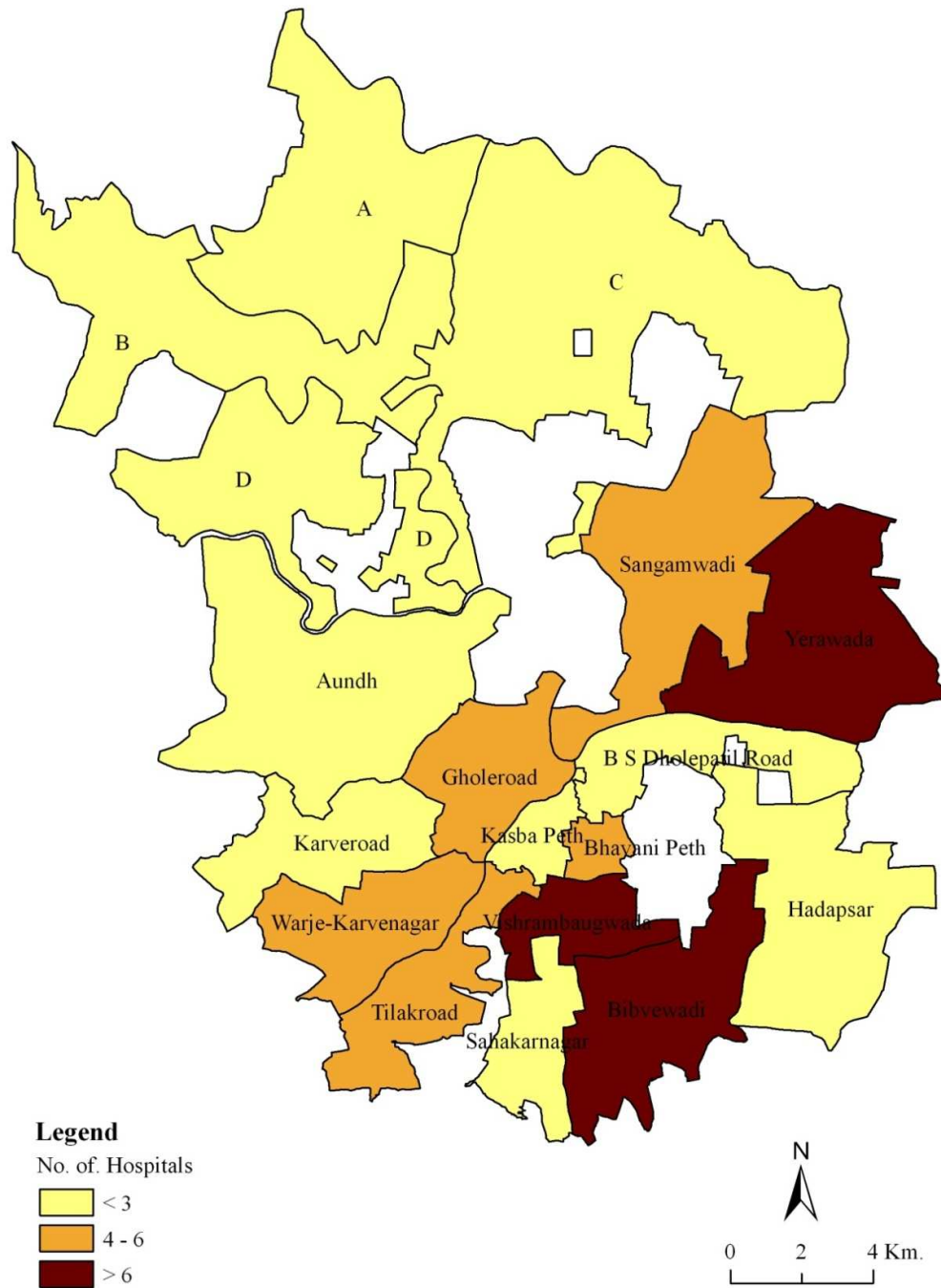
Fig. 5.13

Distribution of Paediatrics Hospitals in PMC and PCMC

A

C

B

D

D

Sangamwadi

Yerawada

Aundh

Gholeroad

B S Dholepatil Road

Kasba Peth

Bhavani Peth

Karveroad

Hadapsar

Warje-Karvenagar

Vishrambaugwada

Tilakroad

Sahakarnagar

Bibvewadi

Legend

No. of. Hospitals

< 4

5 - 7

8 - 11

> 12

N

0   2   4 Km.
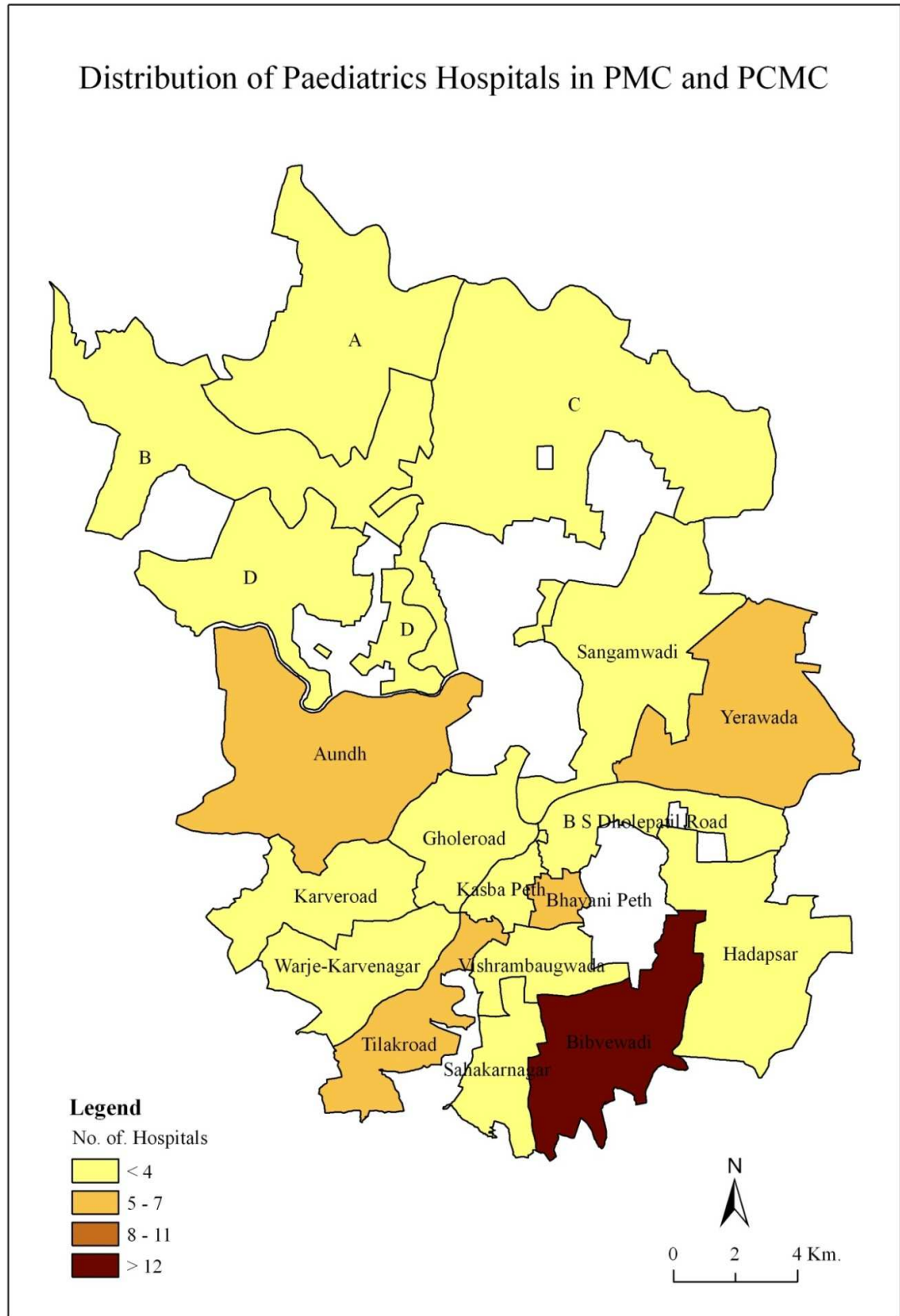
Fig. 5.14

Distribution of Anaesthiology Hospitals in PMC and PCMC

Legend

No. of. Hospitals

- < 5
- 6 - 10
- > 10
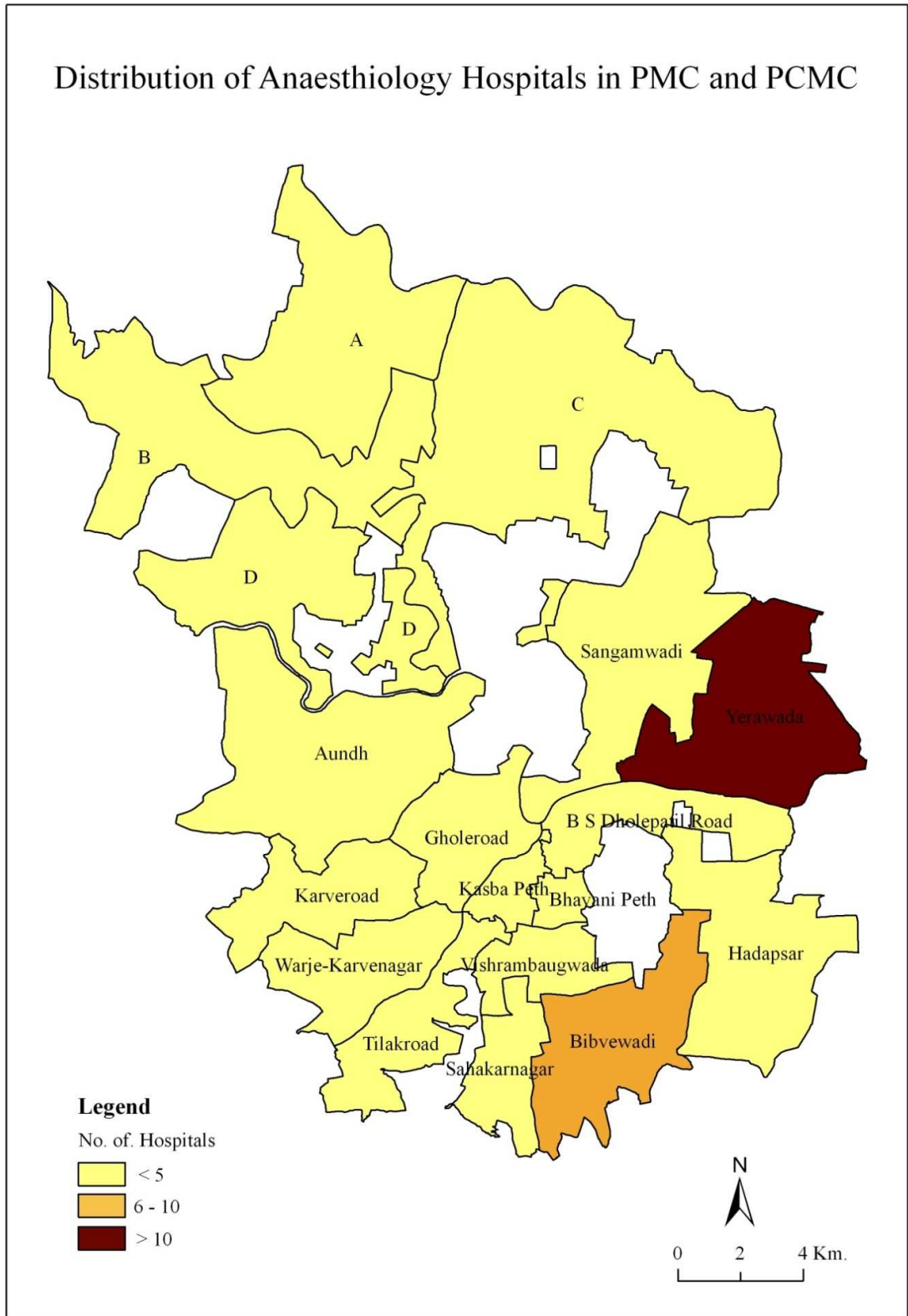
Fig. 5.15

Distribution of ENT Hospitals in PMC and PCMC

A

C

B

D

D

Sangamwadi

Yerawada

Aundh

B S Dholepatil Road

Gholeroad

Kasba Peth

Bhavani Peth

Karveroad

Hadapsar

Warje-Karvenagar

Vishrambaugwada

Tilakroad

Bibvewadi

Sahakarnagar

Legend

No. of. Hospitals

< 2

3 - 5

> 5

N

0   2   4 Km.
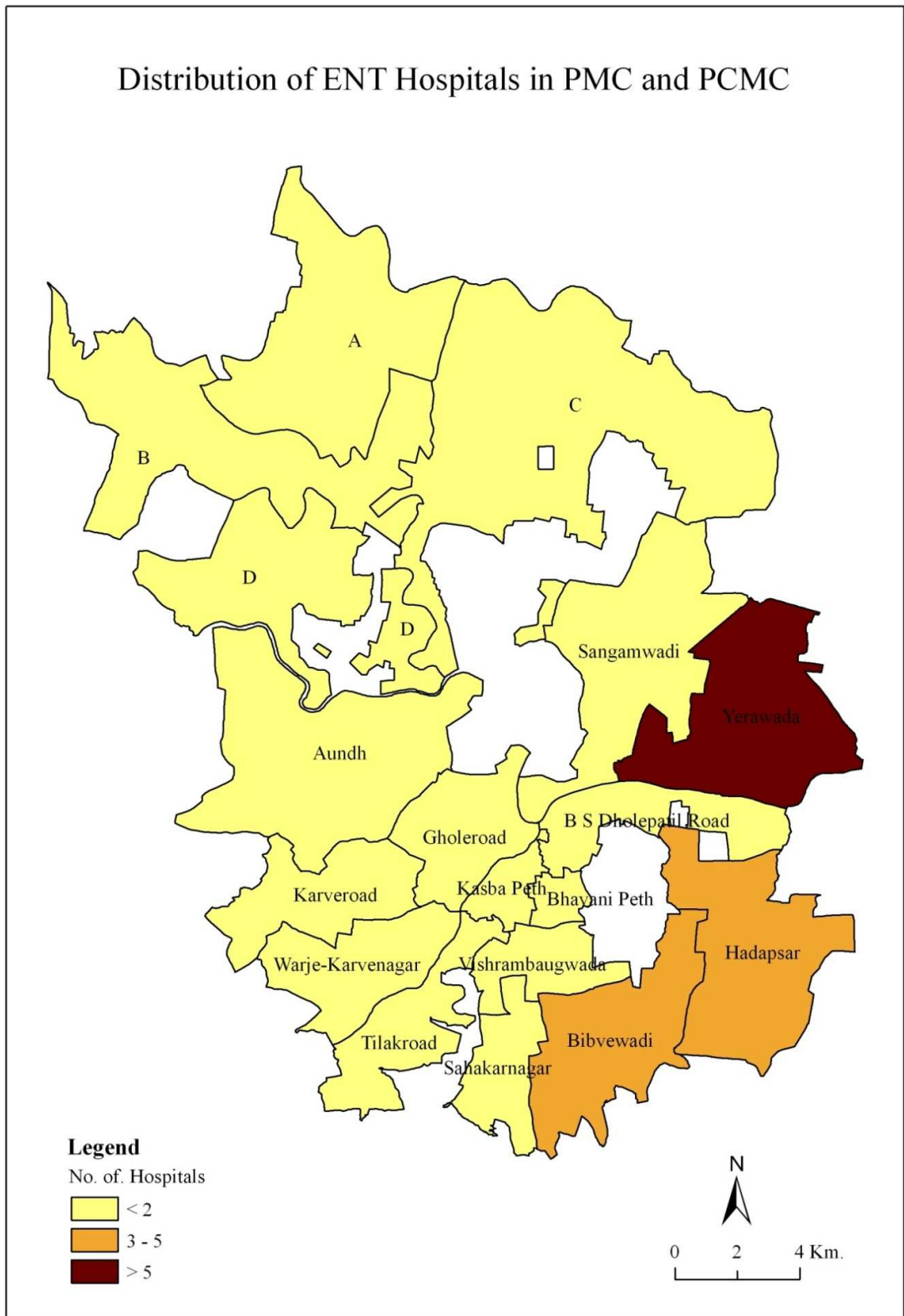
Fig. 5.16

Distribution of Other Specialty Hospitals in PMC and PCMC
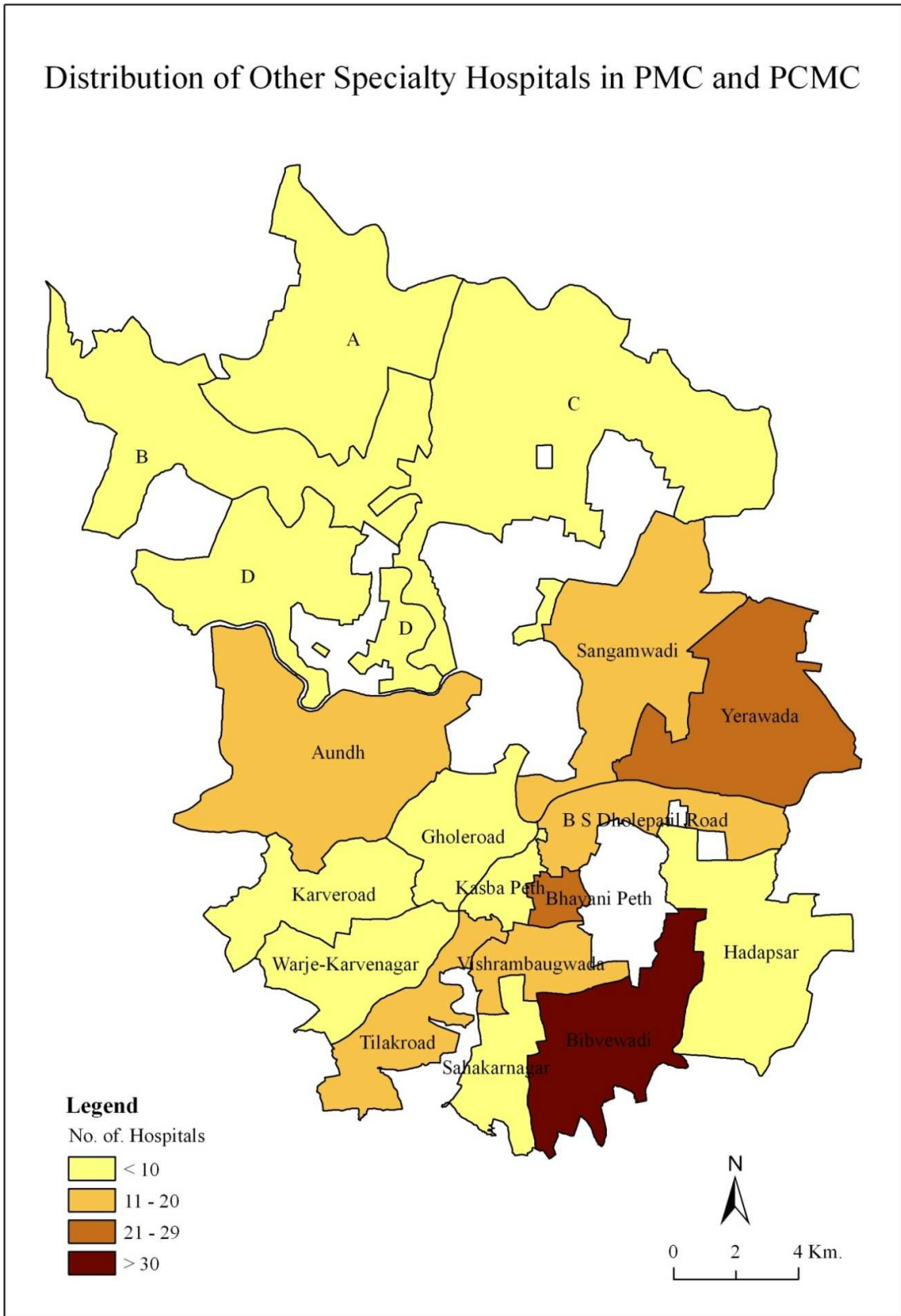
Fig. 5.17

Total Number of Multispecialty Hospitals in PMC and PCMC area

Legend

No. of Hospitals

- 16 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 284

Fig. 5.18

140
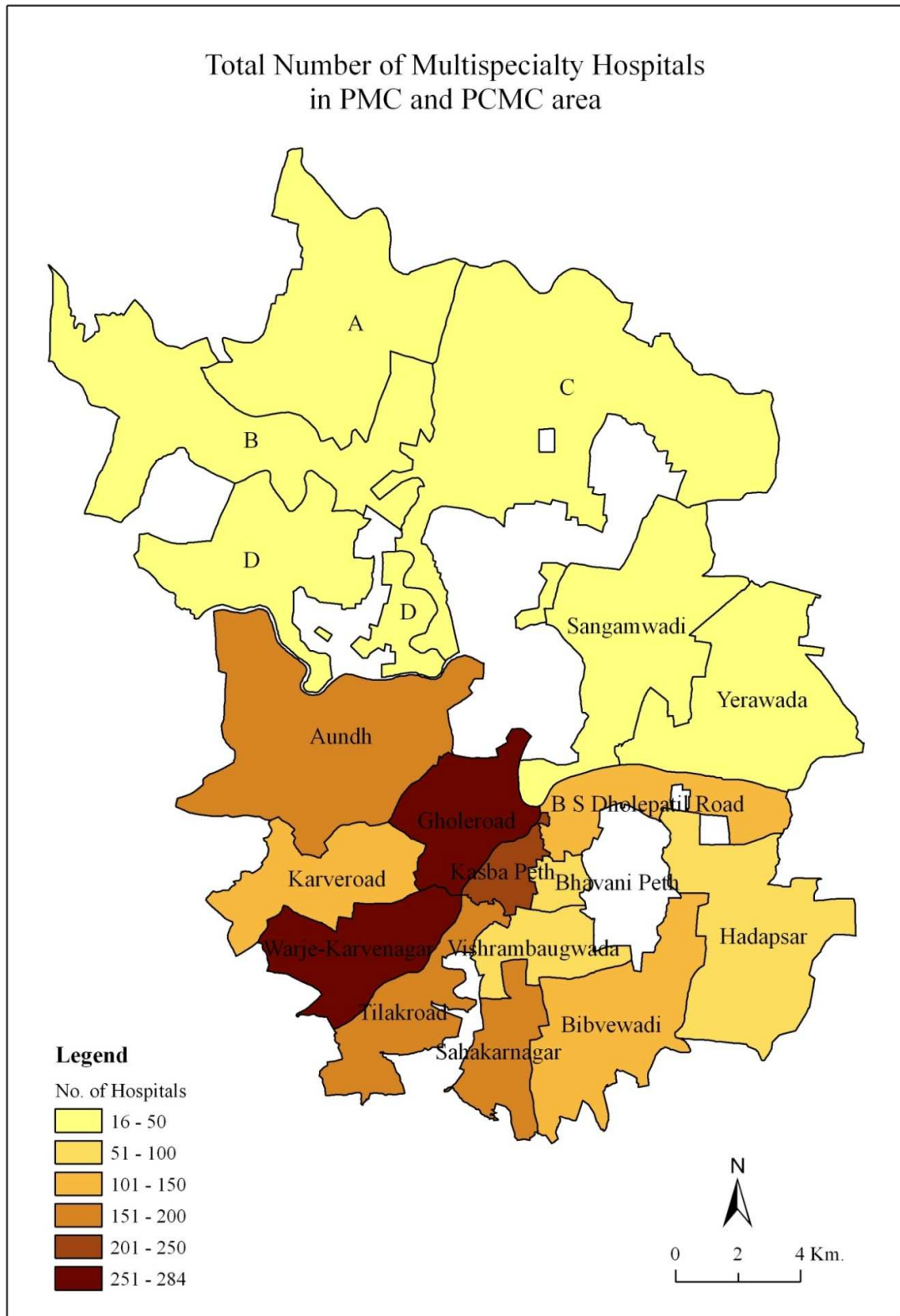
5.8 Primary Schools

Table 5.3 and Figure no. 5.24 represent the total number of primary schools in PMC and PCMC area. 484 primary schools are present in the study area. A Committee 12.19% (59), D Committee 10.74% (52), C Committee 9.71% (47) and Yearawada 9.50% (46) has more primary schools in the study area. Karve Road 1.02% (5), Sahakarnagar 1.45% (7) and Sangamwadi 1.65% (8) wards have less concentration of schools. Other remaining wards come under medium concentration of schools.

Table 5.3 Total number of Primary schools in PMC and PCMC

Sr. No.	Committee/Ward		TGA	TGA in %	No of Schools	% of Schools
1	Aundh		38.73	9.34	24	4.96
2	Karve Road		15.46	3.73	5	1.03
3	Ghole Road	P	13.91	3.35	25	5.17
4	Warje Karvenagar		15.26	3.68	22	4.55
5	BS Dholepatil		12.64	3.05	29	5.99
6	Hadapsar		26.86	6.47	30	6.20
7	Yeravada	M	29.24	7.05	46	9.50
8	Sangamvadi		30.39	7.32	8	1.65
9	Bhavanipeth		2.79	0.67	21	4.34
10	Kasbapeth		4.26	1.03	18	3.72
11	Vishrambaugwada	C	8.56	2.06	10	2.07
12	Tilak Road		13.60	3.28	22	4.55
13	Bibvevadi		22.13	5.33	28	5.79
14	Sahkarnagar		9.47	2.28	7	1.45
15	A Committee	P	36.01	8.68	59	12.19
16	B Committee	C	39.54	9.53	31	6.40
17	C Committee	M	66.85	16.11	47	9.71
18	D Committee	C	29.19	7.04	52	10.74
	Total		**414.90**	**100**	**484**	**100**

Source: PMC and PCMC Shikshan Mandal

Table 5.4 Medium wise Primary Schools in PMC and PCMC

Sr. No	Committee/Ward		Marathi	English	Hindi	Urdu	Kannad
1	Aundh		20	3	0	1	0
2	Karve Road		3	0	1	0	1
3	Ghole Road		15	3	3	4	1
4	Warje Karvenagar	**P**	20	2	0	0	0
5	BS Dholepatil		16	7	0	6	1
6	Hadapsar		28	1	0	1	0
7	Yeravada	**M**	34	7	0	5	0
8	Sangamvadi		8	0	0	0	0
9	Bhavanipeth		11	4	0	6	0
10	Kasbapeth	**C**	8	3	2	5	0
11	Vishrambaugwada		7	2	0	1	0
12	Tilak Road		18	3	0	1	0
13	Bibvevadi		21	4	0	3	0
14	Sahkarnagar		6	1	0	0	0
15	A Committee	**P**	54	4	0	1	0
16	B Committee	**C**	28	2	0	1	0
17	C Committee	**M**	37	7	0	3	0
18	D Committee	**C**	45	7	0	0	0
	Total		**379**	**60**	**6**	**38**	**3**

Source: PMC and PCMC Shikshan Mandal

5.8.1 Marathi Medium Schools

Figure 5.19 shows the distribution of Marathi medium schools in the study area. A committee 54, D committee 45, C committee 37 and Yerawada 34 ward has more Marathi medium schools in the study area. Hadapsar, B committee, Warje-Karvenagar and Aundh wards have medium and other wards come under less concentration of Marathi medium schools in the study area.

5.8.2 English Medium Schools

Figure 5.20 shows the distribution of English medium schools in the study area. C committee, D committee, Sangamwadi and Yerawada wards have more English medium schools in the study area. A committee, Bibvewadi and Bhavanipeth wards has medium and other wards come under less concentration of English medium schools in the study area.

5.8.3 Hindi Medium Schools
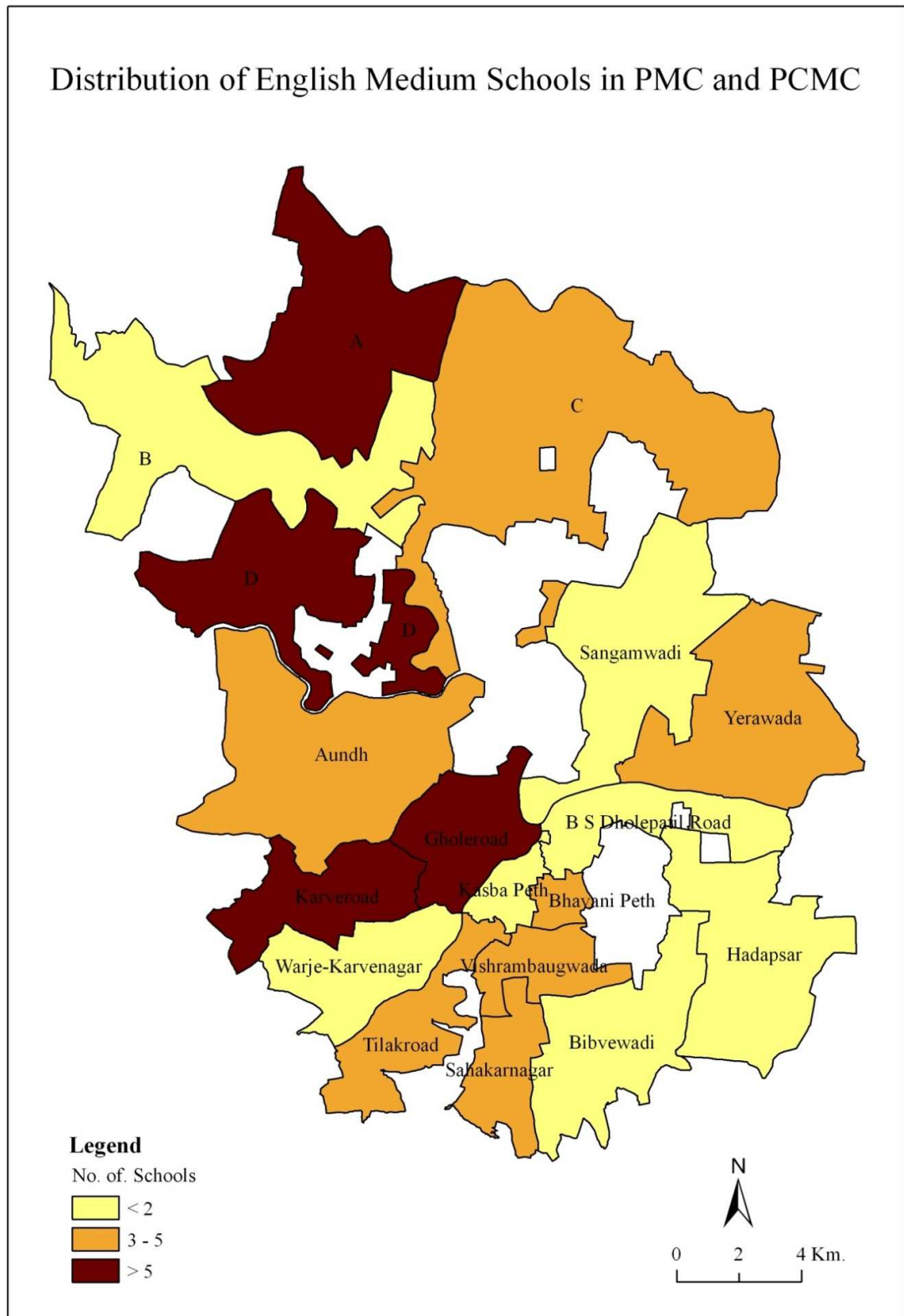
Figure 5.21 shows the distribution of Hindi medium schools in the study area. Ghole Road ward has more Hindi medium schools in the study area. Kasbapeth ward has Hindi medium and other wards come under less concentration of Hindi medium schools in the study area.

5.8.4 Urdu Medium Schools
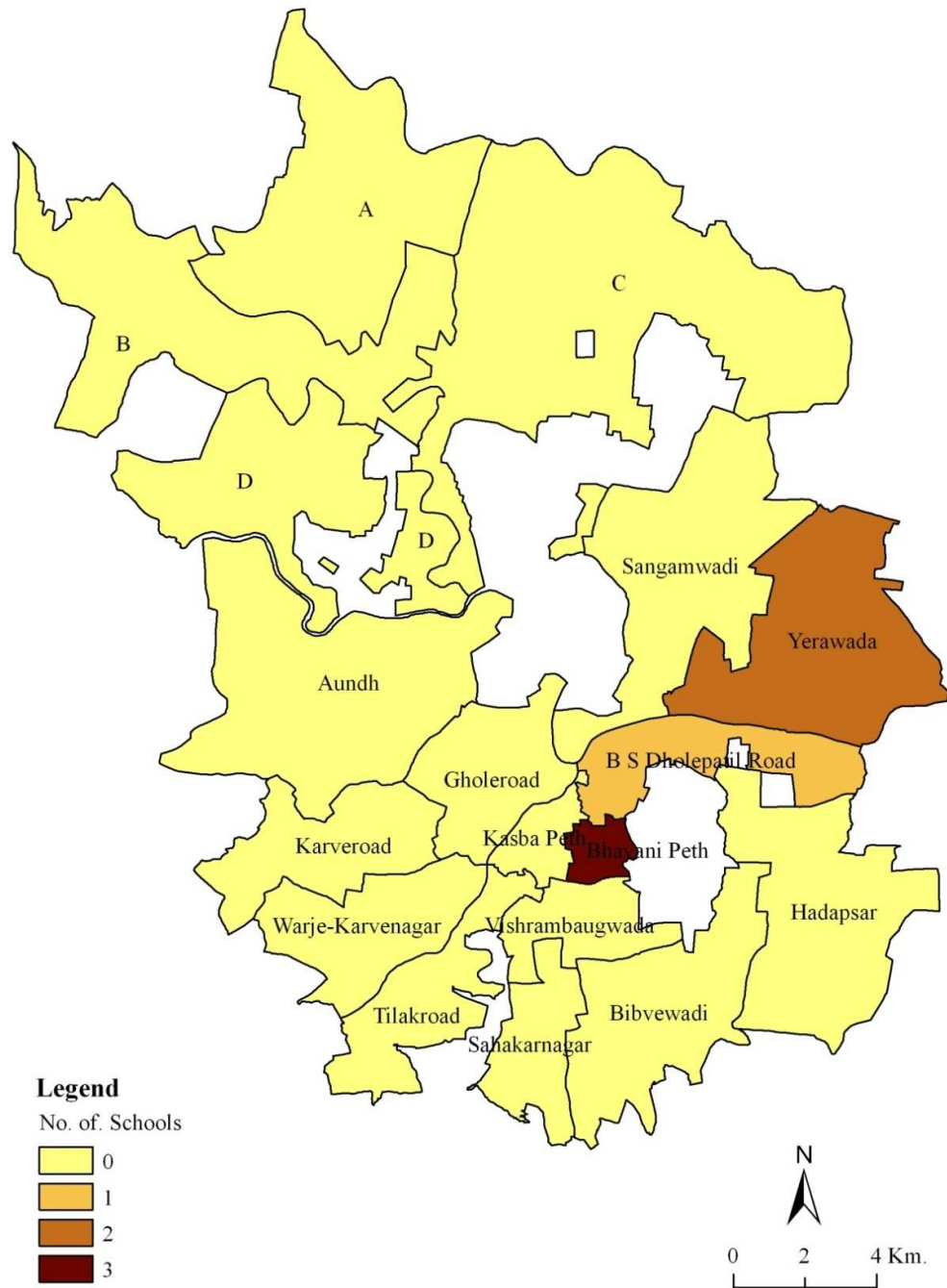
Figure 5.22 shows the distribution of Urdu medium schools in the study area. B. S. Dholepatil Road and Bhavanipeth wards has more Urdu medium schools in the study area. Yerawada, Kasbapeth and Ghole Road wards has Urdu medium and other wards come under less concentration of Urdu medium schools in the study area.

5.8.5 Kannad Medium Schools

Figure 5.23 shows the distribution of Kannad medium schools in the study area. B. S. Dholepatil Road, Ghole Road and Karve Road wards has Kannad medium schools in the study area. Other wards do not have any Kannad medium schools in the study area.

Distribution of Marathi Medium Schools in PMC and PCMC

Legend

No. of. Schools

- < 15
- 16 - 30
- 31 - 45
- > 45

Fig. 5.19

Fig. 5.20

Fig. 5.21

Fig. 5.22

Distribution of Kannad Medium Schools in PMC and PCMC

Legend

No. of. Schools

0

1
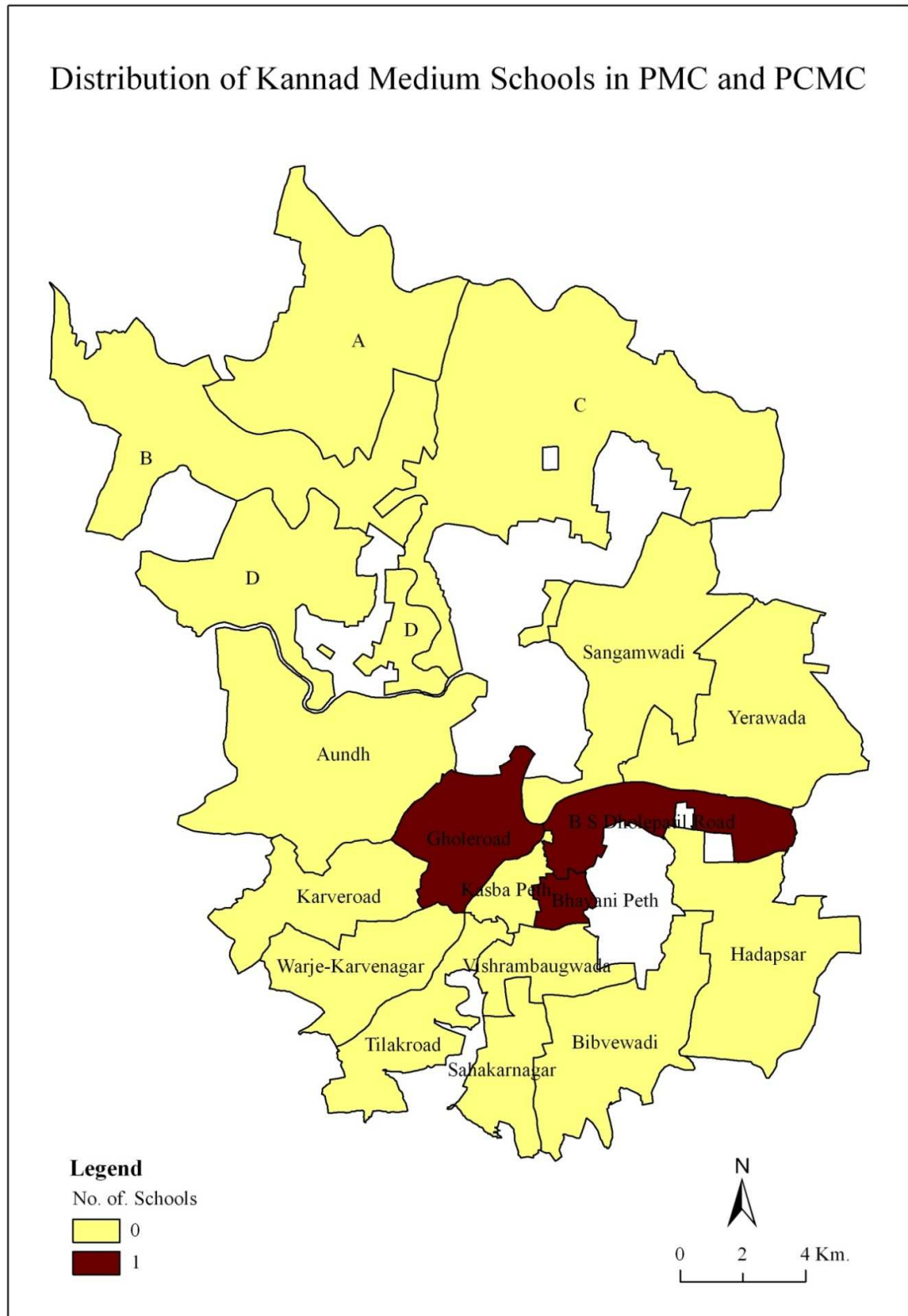
Fig. 5.23

Total No. of Primary Schools in PMC and PCMC area

Legend

No. of Schools

- 5 - 15
- 16 - 30
- 31 - 45
- 46 - 59

Fig. 5.24

149
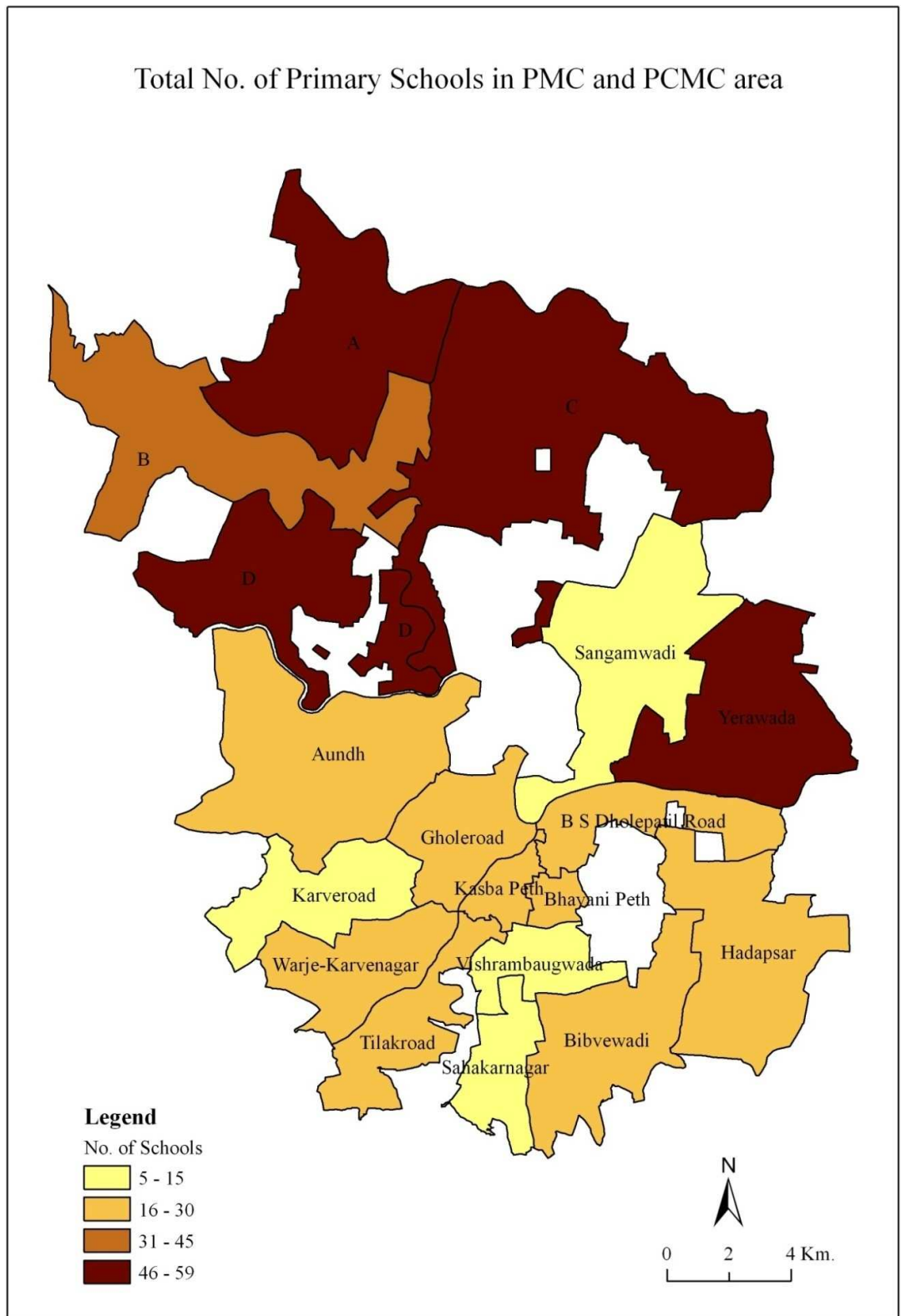
5.9 Conclusion

Fifth Chapter focuses on the utility services like transportation, hospitals and primary educational facilities in Pune and Pimpri - Chinchwad area. Buffer analysis and shortest path techniques were used for bus transport i.e., PMPMl with the location of PMPML depots in study area. The distribution of multispecialty hospitals in study area was shown with the help of maps. The third utility is Medium wise distribution of primary schools like Marathi, English, Hindi, Urdu and Kannad schools shown using maps.

Chapter VI
CONCLUSIONS AND SUGGESTIONS

6.1 Introduction

Urbanization as a process of change and transformation is yet in the stage of evolution through the verge and more in developing countries. Urbanization is also procedure of villages to be developed into towns and further into cities and so on. In India, criteria of urban centers are more or less similar to the ones suggested by the United Nation. In Census of India (1961) has defined urban centers as "Places having a minimum population of 5000 with at least 75 percent of male workers being engaged in non-agricultural activities and the density of population should be 400 persons per square Kilometers".

The urban sprawl means the urban settlements spread towards the rural fringe, i.e., growth of built-up area outside the city limits. In India major metropolitan cities are already saturated due to large scale migration of population.

This thesis has demonstrated a methodology for producing built-up and land use classification from SOI toposheets, LANDSAT ETM+ and IRS P6 LISS III images using the Shannon's entropy formula. The classified images were then used to predict future land use change in the Pune and Pimpri-Chinchwad. Shannon's entropy statistics was used to measure the degree of sprawl in the city. This was shown to be high and increasing. Smart Growth policies were advocated as a remedy to problems generated by high rates of urban sprawl.

An integrated utility management system with geographical information system (GIS) is used to capture, store and analyze the demographic changes, spatial changes and aging infrastructure of the utility services. Utility GIS has been become an excellent way to record what you have and where it's located. The various utility services like urban transportation, multispecialty hospitals and medium wise primary schools were studied and analyzed in this thesis. Buffer analysis and Multi ring Buffer analysis techniques were used.

151

6.2 Summary

The major aim of the proposed work was to find out urban sprawl in Pune and Pimpri-Chinchwad area and suggest planning to provide utility services. In order to serve this aim, following objectives have been put forth. In order to understand Urban Sprawl of Pune and Pimpri-Chinchwad, the methodology adopted for the present study was divided into following phases. i.e. **Library work phase**, exhaustive literature survey of the topic of investigation was undertaken. Published Literature, Reports were collected from various libraries, institutes; Govt. departments etc. Prefield phase, **i**ncludes collection of different maps, Satellite imageries (LANDSAT ETM+ and IRS P6 LISS III data were used to map the extent of sprawl for 1980 to 2008), topographical maps. Collection of non-spatial data, utility services data details were obtained from PMC and PCMC. **Field work phase**, this phase includes visit to the study area and its fringe areas in different seasons, GPS surveys, instrumental surveys, photographs, surveys etc. were carried out in the sprawl. **Laboratory work phase** includes the digitization of various layers, preparation of maps and other GIS/RS techniques. **Synthesis of the data, Report writing and submission phase,** the data generated during the field, and laboratory studies was synthesized, interpreted and are incorporated in this thesis. Entire work is presented into six integrated chapters, which can be summarized as follows.

First chapter deals with the introduction to the topic, basic concepts of urban area, urbanization, urban sprawl, and its definitions, in relation with utility services. This chapter deals with recent trends at global, national, and state level. Occurrence of sprawl in general and occurrence of sprawl in Pune and Pimpri-Chinchwad have been also discussed briefly. A major component of this chapter is devoted to the introduction of the study area, criterions for the selection of the study area, aims and objectives and the literature survey. Literature survey and part of this chapter deals with the urbanization, urban planning, urban transport and utility services. Review of modern techniques and methodology adopted for the study is also discussed in detail.

Second chapter comprises the profile of the study area that gives a detailed account of location, extent and aerial coverage of the Pune and Pimpri-Chinchwad in the Pune District, (Maharashtra, India). Physiography and climate of the Pune and Pimpri-Chinchwad. Built-up, landuse, transportation, communication and population and demographic structure with characteristics of the Pune and Pimpri-Chinchwad are

also discussed in the last part of the chapter to know about socio-economic status of the Pune and Pimpri-Chinchwad.

Third chapter contains database and methodological approach for monitoring and measurement of sprawl in study area. SOI toposheets (1979-80) and different years satellite data (1992, 1999, 2004 and 2008), were used for calculation of built-up area. For assessment of urban sprawl the Shannon's entropy technique was used. Utility services like, multispecialty hospitals, public transportation and medium wise schools data were used.

Fourth Chapter was under the title 'An assessment of urban sprawl'. The LANDSAT ETM+ and IRS P6 LISS III satellite data were used for the monitoring the sprawl and to measuring the sprawl, Shannon's entropy was used. Administrative ward / committee wise sprawl of Pune and Pimpri-Chinchwad over different periods of time i.e., from 1980 to 1992, 1992 to 1999, 1999 to 2004 and 2004 to 2008 has been analyzed with the help of Shannon's entropy technique.

Fifth Chapter focuses on the utility services like transportation, hospitals and primary educational facilities in Pune and Pimpri-Chinchwad area. Buffer analysis and shortest path techniques were used for bus transport i.e., PMPML with the location of PMPML depots in study area. The distribution of multispecialty hospitals in study area was shown with the help of maps. The third utility is medium wise distribution of primary schools like Marathi, English, Hindi, Urdu and Kannad schools shown using maps.

Sixth Chapter focuses on the conclusions and recommendations for urban sprawl and utility services in the Pune and Pimpri-Chinchwad area.

An assessment of urban sprawl is mainly to find out the type and location of land conversion for future development planning. The period 1980 to 2008 was used to monitor the sprawl. Shannon's Entropy (Et) method was used to assessment or measurement the urban sprawl over a period of almost 4 decades. GIS software's was easily integrated with this technique, GIS enables to capture the amount of sprawl in this period.

Satellite imageries of different years and toposheets (1980) were used to take built-up area from these. The toposheets were digitized in ArcGIS 9.3 and images were classified in ERDAS 9.2 software.

6.3 Conclusions

The present study demonstrated the efficiency of Geoinformatics as a tool in the study of land use /land cover changes. The study investigated the urban sprawl phenomenon occurring in the PMC and PCMC area and found that there has been an overall growth in built-up area by1340.39% from 1980 to 2008. The PMC and PCMC area is having the highest percentage (265.97%) from 1980 to 1992 and lowest percentage (37.05%, 2004 to 2008), change in built-up area. With the Shannon's entropy analysis, the study could identify where the sprawl was taking place and its degree as well.

Based on Shannon's entropy analysis, carried out in the PMC and PCMC area the following conclusions are made.

1. In the study area overall average increase in built-up area by 49.54%, from 9.12% in 1980 to 58.66% in 2008.

2. Aundh administrative ward shows 45.65% (2.48% to 48.63%) growth from 1980 to 2008. It can be concluded that there is 23 times growth within 28 years. The annual growth of urban sprawl is 1.77%.

3. Karve Road administrative ward shows 3.73% of area covered out of total geographical area. In 1980, 0.52% area of total administrative ward is under built-up and it increased in 2008, at 45.28% means the total sprawl is 44.76%. The growth of urban sprawl is 1.59% per year.

4. Among all the administrative wards in the study area, Ghole Road administrative ward is having lowest growth i.e. 21.20%. The annual growth of urban sprawl is 0.75%.

5. Out of total geographical area, Warje-Karvenagar administrative ward occupies 3.68% of study region. In 1980, 5.24% area of total administrative ward is under built-up and it increased in 2008, at 58.98% means the total sprawl is 53.74%.

6. B. S. DholePatil Road administrative ward occupies 3.05% of total geographical area in the study region. In 1980, 9.34% area of total administrative ward is under built-up and it increased in 2008, at 37.97% means the total sprawl is 28.63%. The growth of urban sprawl is 1.02% per year.

7. Hadapsar, administrative ward shows annual growth of urban sprawl 2.44% between 1980 to 2008.

8. The annual growth of urban sprawl in Yerawada administrative ward shows 2.47% and total difference in built up from 1980 to 2008 is 69.32%.

9. In 1980 Sangamwadi, administrative ward is having 2.57% built-up and it increased in 2008, at 46.36% means the increase in total sprawl is 43.79%.

10. Among the all administrative wards in the study area Bhavanipeth is located in core part and shows 47.31% growth in sprawl from 1980 to 2008.

11. In the view of total geographical area of PMC and PCMC, the Kasbapeth administrative ward shows total sprawl 35.21% and annual growth of urban sprawl is 1.26%.

12. Vishrambaugwada, administrative ward is also comes under core area of the PMC .In 1980, 32.13% area of total administrative ward is under built-up and it increased 56.07% in 2008,indicates that total sprawl is 23.94%.

13. Tilak Road, administrative ward shows total sprawl change 40.95% and annual growth of urban sprawl is 1.46% per year.

14. Among the 18 administrative wards/committees Bibvewadi shows highest sprawl from 1980 to 2008 i.e.74.38% . The annual growth of urban sprawl is 2.66% per year.

15. Sahakarnagar, administrative ward is located on periphery study area and built-up increase inbetween 1980 to 2008 reaches 71.70% means the total   28 yrs change in sprawl is 64.41%.

16. In the analysis of study area A administrative committee, showing 8.68% out of total geographical area. In 1980, 0.86% area of total administrative ward is under built-up and it increased in 2008, at 63.15% means the total sprawl is 62.29%. The annual growth of urban sprawl is 2.22% per year.

17. B administrative committee shows 62.19% builtup changes between 1980 to 2008 with 2.14% annual growth of urban sprawl.

18. C administrative committee occupies 16.11% area out of study area. In 1980, 1.03% area of total administrative ward is under built-up and it increased in 2008, at 41.08% means the total sprawl is 40.05%.

19. Out of total geographical area, in the D Committee, administrative ward growth of urban sprawl is 2.41% per year with 67.49%, increase in total sprawl.

20. In the view of civic amenities services, transportation of PMPML bus, Swargate depot shows the highest buses in depot 15.41% (248) and lowest buses at Bhakti-Shakti depot 8.08% (130).

21. In the study area total no. of hospitals are 2062 comprises with Ghole Road (13.77%), Warje-Karvenagar (13.48%) and Kasbapeth (11.69%) administrative wards are having highest multispecialty hospitals. General/Practice hospitals are highest as compare to other hospitals.

22. Primary education is considered as one of important indicator for human resource planning and development. PMC and PCMC are having medium wise primary schools in an area. Most of the primary schools are concentrated in PCMC region of study area.Out of total 484 primary schools A Committee 12.19% (59), D Committee 10.74% (52), C Committee 9.71% (47)   of PCMC region shows 32.66% schools.

6.4 Recommendations

Pune Metropoliton (PMC&PCMC Study region) is facing high growth rate of population, traffic congestion, increase in pollution level, and decrease in green cover, encroachment on the hill slopes, sewage and waste disposal, power crisis, water problem and so on. In addition to this, the city is sprawling very rapidly. The continew growth in the sprawl is accelerating the magnitude of these problems.

The study demonstrates that GIS and Remote Sensing coupled with statistical analysis, such as Shannon's entropy can help immensely in spatial and temporal analyses of the sprawl. The existing utility services in PMC and PCMC area like urban transport, hospitals and primary schools can help in urban sprawl analysis

The conclusions drawn from the present research work and keeping in view the major problems of the PMC and PCMC, following recommendations have been suggested.

1. In the present study, most of the utility services are concentrated in the core areas of the city hence decentralization of these services are necessary for the future planning.

2. The new techniques like satellite imageries (spatio-temporal data) can be used for the forthcoming sprawl and to resolve the problems arises through the sprawl.

3. In the view of transportation as a civic amenity, in the study area numbers of depots are not well distributed. Therefore even distribution of bus depots with quantity, among the study area is recommended for better transportation.

4. In the study area, hospitals are not evenly distributed though PMC region is better as compared to PCMC region. It is strongly recommended that general hospitals run by the government, municipal corporation or other NGO's should try to establish new hospitals in the fringe areas of urban sprawl.

5. Taking the consideration/willingness of parents there is increasing demand of English medium schools it is recommended that PMC and PCMC corporations should start aided English medium primary schools.

6. The problems arise through urban sprawl and future probable problems it is recommended that the policy makers should consult with scientists, academicians, administrators, planners, social organizations, NGO's and political leaders.

7. To know the intensity of forthcoming sprawl related problems it is recommended that awareness should be created among the students and citizens of study area.

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Appendix-A List of Administrative and General Wards of PMC

Sr. No.	PMC Adminastrative Wards	
1	**Aundh**	**Ward Number**
1	Sanjay Gandhi Rugnalaya	24
2	Bopodi	25
3	Pune Vidyapeeth	26
4	Aundh Gaon	27
5	Baner, Balewadi	28
6	Sutarwadi	29
7	Pashan	30
8	Aundh ITI	31
9	Rajbhavan	32

2	**Karve Road**	
1	Shankarrao More Vidyalaya	57
2	Rambaug Colony	58
3	Kishkindha Nagar	59
4	Ramkrishna Paramhance	60
5	Vedbhavan	61
6	Mahatma Sosayati	62
7	Vanaj Company	63
8	Yashvantrao Chavan Natyagriha	64
9	Ideal Colony	65

3	**Ghole Road**	
1	Kamalnayan Bajaj Udyan	22
2	Shetki Mahavidyalaya	23
3	Chatushrungi Mandir	33
4	Model Colony	34
5	Modern Collage	35
6	Pune Muncipl Corporation	36
7	Fergussion Collage	53
8	Dr. Homibhaba Hospital	54
9	Gokhalenagar	55
10	Vidhi Mahavidyalaya	56
11	Deccan Jymkhana	67

4	Warje Karvenagar	
1	Dinanath Mangeshkar Hospital	66
2	Major Tathawade Udyan	105
3	Kothrud Gaon	106
4	Happy Colony	107
5	Dahanukar Colony	108
6	Warje Jalshuddhakaran	109
7	Popularnagar - Warje	110
8	Warje Malwadi	111
9	Maharshi Karve Nagar	112
10	Hingane Shri Shikshan Sanstha	113

5	B. S. Dholepatil Road	
1	Dr. Naidu Hospital	37
2	Bundgarden	38
3	Wadia Collage	39
4	Koregaon Park	40
5	Mundhava Gaon	41
6	Dr. Babasaheb Ambedkar Udyan	46
7	Sasoon Hospital	47
8	Kamala Nehru	48
9	Tilak Ayurved Mahavidyalaya	73

6	Hadapsar	
1	Magar Patta - Hadapsar	42
2	Hadapsar Audyogik	43
3	Sent Patrik Town	44
4	Vikasnagar - Ghorpadi	45
5	Ramtekdi	90
6	Hadapsar Gaon	91
7	Gliding Centre	92
8	Sadhana Vidyalaya	93
9	Satavwadi	94
10	Kaleborate Nagar	95
11	Mohammad Wadi	96

7	Yerawada	
1	Lohgaon Vimantal	7
2	Kharadi Gaon	8
3	Kharai Infotech	9
4	Sundarbai Marathe Vidyalaya	10
5	Vadgaon Sheri	11
6	Ramwadi	12
7	Agakhan Palace	13
8	Don Bosko Higschool	14
9	Nagpur Chal	15
10	Yeravada Gaon	18

8	Sangamwadi	
1	Dhanori	1
2	Vidyanagar Lohgaon	2
3	Tingare Nagar Pumping	3
4	Kalas Vishrantwadi	4
5	Nanasaheb Parulekar Vidyalaya	5
6	Yerawada Prizan Press	6
7	Phulenagar Yerawada	16
8	Netaji Subhashchandra Bos Vidyalaya	17
9	Parnkuti	19
10	Yerwada Hotmix	20
11	Deccan Collage	21

9	Bhavanipeth	
1	Rajewadi	74
2	Harkanagar	75
3	Janral Arunkumar Vaidya Stadium	76
4	Doke Talim	77
5	Swami Samartha Nagar	78
6	Dr. Kotnis	79
7	Ghorpade Udyan	83
8	Panch Haud Mission	84
9	Mahatma Phule Smarak	85
10	Lohia Nagar	86
11	Akbote Colony	87
12	Gurunanak Nagar	88

10	Kasbapeth	
1	Juna Bazar	49
2	Kasaba Ganpati	50
3	Shaniwar Wada	51
4	New English School (Ramanbaug)	52
5	Rajendranagar	68
6	Vishrambagwada	69
7	Mahatma Phule Mandai	70
8	City Post	71
9	Ganeshpeth Gurudwara	72
10	Renuka Swarup Prashala	80
11	S. P. Collage	81
12	Subhash Nagar	82

11	Vishrambaugwada	
1	Salisburg Park	98
2	Tilak Maharashtra Vidyapeeth	99
3	Parwati Darshan	100
4	Shahu Collage	115
5	Parwati Industrial Estate	116
6	Maharshi Nagar	117
7	Chatrapati Shivaji Marketyard	118
8	Deadi Colony	119
9	Taljai Mandir	126

12	Tilak Road	
1	Parwati Gaon	101
2	Parwati Jalkendra	102
3	Dandekar Pool	103
4	P. L. Deshpande Udyan	104
5	Janta Vasahat	114
6	Anandnagar - Hingane	127
7	Vitthalwadi	128
8	Wadgaon Dhayri	129
9	Wadgaon Budruk	130
10	Manikbaug	131

13	Bibwewadi	
1	Wanawadi Gaon	89
2	Mahadji Shinde Chatri	97
3	Kondhava Khurd	120
4	NIBM	121
5	Mithanagar	122
6	Bibvewadi Gaon	123
7	Sukhsagar Nagar	137
8	Vishwakarma Instittute	138
9	Appar Indira Nagar	139
10	Kondhava Budruk	140
11	Katraj Gaon	141

14	Sahakarnagar	
1	Shankar Maharaj Math	124
2	Padmavati - Araneshwar	125
3	Chavan Nagar	132
4	Dhankawadi Ambegaon	133
5	Dhankawadi Gaon	134
6	Chaitanya Nagar	135
7	Balaji Nagar	136
8	Rajiv Gandhi Prani Sangrahalaya	142
9	Bharti Vidyapeeth	143
10	Agam Mandir Katraj	144

Appendix-B List of Administrative Committee and General Wards of PCMC

Sr. No.	PCMC Adminastrative Ward Committees	Ward Number
1	**A Ward Committee**	
1	Talwade Gaonthan	1
2	Rupinagar	2
3	Triveninagar	3
4	Krushnanagar	4
5	Morevasti	5
6	Ganeshnagar	6
7	Chikhali Gaonthan	7
8	Kudalwadi-Jadhavwadi	8
9	Chinchwad Station	37
10	Sanghavi Kesari College	38
11	HDFC Colony	39
12	Mohannagar	40
13	Kalbhornagar	41
14	Sambhajinagar	42
15	Ajanthanagar	43
16	Yamunanagar	44
17	Dattmandir-Otaskim	45
18	Kai.Madhukar Pavale	46
19	Nigadijakatnaka	47
20	Nigadigaonthan	48
21	Bhakti-Shakti	49
22	Saint Tukaram Maharaj	50
23	Dattawadi	51
24	Tuljaivasti	52
25	Akrudigaonthan	53
26	Ganganagar	54
27	Pimpri-Chinchwad Polytechnic Co	55

2	**B Ward Committee**	
1	Masulkar Colony	29
2	Y .C. M Hospital	31
3	Sant Tukaramnagar	32
4	Kharalwadi	33
5	Gandhinagar	34
6	Morwadi	35
7	Anantnagar	36
8	Vikasnagar	56

9	Kiwale Mamurdi	57
10	Rawet Punavale	58
11	Valhekarwadi	59
12	Chinchwadenagar	60
13	Pawananagar	61
14	Dalvinagar	62
15	Udyognagar	63
16	Chinchwad Gaonthan	64
17	Kesavnagar	65
18	Darshan Hall	66
19	Proff. Ramkrushan More Prekshag	67
20	Bhatnagar	68
21	Bhajimandai	69
22	Jijamata Hospital	70
23	Vaishandevi Mandir	71

3	**C Ward Committee**	
1	Borhadewadi	9
2	Moshigaonthan	10
3	Wadmukhwadi	11
4	Charholigaon	12
5	Dighigaonthan	13
6	Sadgurunagar	14
7	Chakrapani Vasahat	15
8	Ramnagari	16
9	Sandvik Colony	17
10	Gavalinagar	18
11	Gavhanevasti	19
12	Vitthalrukhmai Mandir	20
13	Dhavadevasti	21
14	Landewadi	22
15	Gulavevasti	23
16	Indrayaninagar	24
17	Balajinagar	25
18	Mahatma Fulenagar	26
19	Annasaheb Magar	27
20	Swapnnagari	28
21	Neharunagar	30
22	Shankarwadi	99
23	Kasarwadi	100
24	Fugewadi	101

25	Dapodi Gaonthan	102
26	Hutatma Bhagatshing Vidyalay	103
27	Shiddharthnagar	104
28	Bopkhel	105

4	D Ward Committee	
1	Ashok Theatere	72
2	Nav Maharashtra Vidyalay	73
3	Bhairavnath Mandir	74
4	Pimple Soudagar	75
5	Rahatani Gaonthan	76
6	Rahatani Shreenagar	77
7	Tapkirnagar	78
8	Kalewadi	79
9	Nadenagar	80
10	Vijaynagar	81
11	Thergaon Gaonthan	82
12	Saimandir Bapujibuva Nagar	83
13	Bethikanagar	84
14	Padmjipaper Mill	85
15	Ganeshnagar	86
16	Wakad Gaonthan	87
17	Wakad Venunagar	88
18	Vishalnagar	89
19	Pimple Nilakh	90
20	S.T. Colony	91
21	Sangavi Gaonthan	92
22	Madhuban	93
23	Kirtinagar	94
24	Kavadenagar	95
25	Gajanan Maharajnagar	96
26	Pimple Gurav Gaonthan	97
27	Sudarshan Nagar	98

Appendix-C Abbreviations

CDP	City Development Plan
CI	Class Interval/ Contour Interval
DB	Data Base
DBF	Data Base Format
DP	Development Plan
E	East
ENT	Ear Nose and Throat
ERDAS	Earth Resources Data Analysis Systems
Et	Entropy
ETM+	Enhanced Thematic Mapper Plus
GIS	Geography Information System
IGA	Total Geographical Area
IMA	Indian Medical Association
IRS	Indian Remote Sensing
JNNRUM	Jawaharlal Nehru National Urban Renewal Mission
Km.	Kilometer
LANDSAT	Land Remote-Sensing Satellite
LISS	Linear Imaging Self Scanner
MIDC	Maharashtra Industrial Development Corporation
MLC	Maximum Likelihood Classifier
MSS	Multi Spectral Scanner
N	North
N. T. Wadi	Narveer Tanaji Wadi
NE	North-East
NRSC	National Remote Sensing Centre
NW	North-West
PCMC	Pimpri Chinchawd Municipal Corporation
PCNTDA	Pimpri-Chinchwad New Town Development Authority
PMC	Pune Municipal Corporation
PMPML	Pune Mahanagar Parivahan Mahamandal Limited
S	South
SE	South-East
SLIM	Systematic Land Information System
SOI	Survey of India
SPOT	Système Probatoire d'Observation de la Terre
sq. km.	Square Kilometer
SSI	Small Scale Industries
SW	South-West
TGA	Total Geographical Area
TIN	Triangulated Irregular Network
W	West