Project

Report

IMPACT OF URBANIZATION ON CHANGING LAND USE FOR SUSTAINABLE ENVIRONMENT:

CASE STUDY OF MYSORE – BANGALORE URBAN CORRIDOR

UGC MAJOR RESEARCH PROJECT

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CHAPTER I

INRODUCTION

Introduction

Cities are dynamic in nature as they change over time. They change due to various factors such as population growth (natural growth, in-migration), industrialization and economic escalation, infrastructural development; and a host of factors. Cities not only grow and expand within themselves, but they also grow all over the place as and when the population grows. As a result their social and economic demands for space also increase leading to the growth and expansion of urban areas.

Urbanization is considered as the most influential drivers of land use and land cover change associated with growth of populations and economy. The integration of remote sensing (RS) and Geographical Information System (GIS) techniques acts as an effective tool for detecting urban growth and modeling in the recent years.

Urbanization and construction activities results in the conversion of natural lands into impervious built-up lands and such changes can put significant impacts on the ecosystem, thus affecting the hydrologic system, biodiversity and micro-climate changes and consequently may have negative impact such as the urban heat island phenomenon (Deka et al., 2011; Xu et al., 2000). Since urbanization is an unavoidable process, efforts can be made to direct it in the most proper way by urban land use planning so as to protect the natural resources and the needs and rights of the people (Soffianian et al., 2010). Hence, accurate mapping of urban environments and monitoring urban growth is becoming increasingly important at the global level (Guindon & Zhang, 2009). The conventional surveying and mapping techniques are expensive and time consuming for urban growth estimation, hence statistical techniques along with remote sensing and GIS have been used as an alternative for urban growth studies (Punia & Singh, 2012; Sudhira et al., 2004; A. G.-O. Yeh & Xia,2001).

Over the last 20 years many urban areas have experienced dramatic growth, as a result of rapid population growth and as the world's economy have been transforming by a combination of rapid technological and political changes. (Su et al.,2012) analyzed landscape pattern and ecosystem service value changes, the results exhibited a similar urbanization process of rapid population growth, economic development and urban expansion. The spatial patterns of urbanization in Mysore: Emerging Tier II City in Karnataka, (Aithal et al., 2012) was studied focusing on the spatial and temporal dynamics of urban growth during five decades. The study indicates the coalescence of urban areas surrounding the Central Business District. It has indicated rapid urban growth from 2000 to 2009 and a moderate growth during 1980's and 1990's. Rapid urbanization has resulted in the irreversible land use and land cover (LULC) changes, which is the prime driver of global warming and consequent climate changes.

The Mysore-Bangalore urban corridor is one of the crucial areas where urbanization is catching up in recent times. The distance separating between Mysore and Bangalore is only 140 Km. The urban effects of Bangalore are most likely to influence the urban character and land use structure of the study area. The danger of urban impact and its consequent land use change is one of the critical situations assumed to be faced in the study area. This region is also one of the fertile agriculture areas of south Karnataka, growing food crops and commercial crops, it also supplies raw material catering to the agro based industries of south Karnataka.

Owing to the location of this region the land uses and land values are most sensitive leading to Land grabbing, land hording, and land speculation which are the most common playoffs of realtors in this region. All these politico economic manifestations have generated spurts of ubiquitous urban growth in the study area. The present study tries to focus the nature of urbanization and growth of urban areas during the past four decades. The growth of urban infrastructure corridor connecting Mysore and Bangalore has added more vigor in the rapidity of land use change.

Tree Carbon sequestration

Urban process and declining vegetation is a serious concern to all because of the issues related to health, aesthetic, and hygiene. Therefore it is important to study the trends in the rate of carbon sequestration. Carbon sequestration is a process involved in carbon capture and a long-term storage of atmospheric carbon dioxide to mitigate global warming and avoid dangerous climate change (Sedjo & Sohngen,2012). (Moulton & Richards, 1990), observed that, increasing the number of trees might potentially slow the accumulation of atmospheric carbon, trees act as a sink for CO_2 by fixing carbon during photosynthesis and storing excess carbon as biomass. The net long-term CO_2 source/sink dynamics of forests change through time as trees grow, die, and decay. (Graedel & Crutzen, 1989; Hamburg et al., 1997) stated that increasing levels of atmospheric carbon dioxide (CO_2) and other ''greenhouse'' gases, chlorofluorocarbons, nitrous oxide (N_2O), and tropospheric ozone (O_3) are thought by many to be contributing to an increase in atmospheric temperatures by the trapping of certain wavelengths of radiation in the atmosphere. (Vincent & Saatchi, 1999) compared and studied different methods of remote sensing to measure carbon sequestration in their paper "Comparison of Remote Sensing Techniques for Measuring Carbon Sequestration". The purpose of the study was to find the optimum combination of measurements, and define the technology investments necessary to enable them.

(David P Turner et al., 2004) stated that the integration of remote sensing and modeling thus produces spatially explicit information on carbon storage and flux. For the study of contemporary carbon flux, a carbon- cycle model is initialized with high-spatial-resolution (30 m) satellite remote sensing of surface vegetation characteristics and driven with spatially derived climate from distributed meteorological stations (David P. Turner et al., 2004) used an integrated approach to compare carbon flux for the different time periods in western Oregon. Carbon-cycle process models coupled to regional climate databases can provide information on potential rates of production and related rates of decomposition. Forest management is an important activity that affects the global carbon stock. Attaining sustainable harvesting potentials without sacrificing forest's ability to store carbon is very complicated. Carbon stock is defined as the quantity of carbon in a "pool", meaning a reservoir or system which has the capacity to accumulate or release carbon (FAO, 2005).

(David J Nowak et al., 2013) quantified the Carbon storage and sequestration by urban trees in the United States to assess the magnitude and role of urban forests in relation to climate change. These data were applied to state wide urban tree cover measurements to determine total urban forest carbon storage and annual sequestration by state and nationally. (Gelman et al., 2013) examined the forest management practices and forest carbon in relation to possible climate change mitigation and they discuss implications of the results of different forest management practices in the world. They conclude “Impacts of forest management practices on forest carbon” that carbon sequestration can be increased by management techniques such as prolonged rotations, increased thinning, continuous forest cover, supporting litter production and natural ecological conditions, keeping the right water level and cleaning the high emission ditches in peat lands. (Chaudhari et al., 2007) made an attempt to monitor CO_2levels in ambient air of Nagpur city at industrial, commercial and residential sites. In addition to this a remote sensing studies and biotic survey for floral biodiversity were carried out to study the green cover at respective sampling locations. The observations showed that the largest amount of CO_2occurred at night due to absence of photosynthesis and lowest concentration of $CO_2$was observed in the afternoon due to photosynthesis at its maximum level. Growing trees in urban areas can be potential contributor in reducing concentration of CO_2 in atmosphere by its accumulation in the form of biomass (Chavan & Rasal,2010).

Avenue trees in urban areas play a vital role to maintain the ecological balance of crowded and polluted environment. Road side trees, because of their proximity to generation of vehicle emissions, are important in reducing pollution (Kiran &Kinnary, 2011). Carbon is the major component of all cellular life forms; trees utilize carbon as a building material with which to form trunks, roots, stems, branches, and leaves. Trees remove (sequester) carbon from the atmosphere through photosynthesis (Ferrini & Fini, 2011). (Kiran & Kinnary, 2011) have studied carbon sequestration by urban trees on road sides of Vadodara city. In this study, the aspect of the measurement of the amount of carbon has been carried out and this was based on the amount of standing woody biomass of trees on the road sides of Vadodara City. A case study by (Desai & Nandikar, 2012) on the impacts of urbanization on avenue trees and its role in carbon sequestration in Kolhapur city, they are on the opinion that Avenue trees will be most effective in providing “true” shade and a commanding visual contrast between dense landscaping and open space when planted in groups. Moreover, avenues are part of urban forestry and in terms of atmospheric carbon reduction; avenues proffer the advantage of shortest carbon storage to sustain ecological stability of teeming and polluted environment. The existing literature focuses on the causes and effects of urban growth and expansion. Further research is needed on the benefits of vacant land development for urban planning and tree carbon sequestration to guide urban planners in more effective manner.

Significance of the Study

First, the present study provides a new urban planning approaches. Because the traditional and typical planning issues and methods are no longer appropriate and acceptable in present day context. An effective urban planning approach has to be therefore considered which involves; a vision, a value creation and a proper coordination.

It provides a better understanding of the relationship between urban growth and its impact on the decline of tree carbon sequestration. There is a lack of research in these issues. The present study focuses attention in the trends of carbon sequestration and its relation with urban growth.

CHANGING URBAN ELEVATION AND SHRINKAGE OF STREAMS AND WATER BODIES: Another important and significant role of this study is that it will attempt to Analysis of urban terrain with respect to its general environmental setting. With the construction of roads, railways, bridges the built up land and the settlements in general and particularly urban areas are under going huge transformation and changes in natural environment. All these phenomena have direct and indirect influences on relief, slope, and elevation, resulting in shrinkage and diversion of streams and other Water bodies in and around the urban fringe. The relationship between urban expansion and its influence upon the streams and Water bodies is therefore important for the conservation of the urban environment. Several techniques have been used historically to study terrain but in this study an attempt to retrieve the terrain characteristics with the help DEM is envisaged. The generation of DEM, using CARTOSAT for this region at a resolution of 2.5 meters is a great source of information for further work, which has not been done so far.

IMPERVIOUSNESS AND TEMPERATURE CHANGE: Urban areas are the large continuous space where the land in going through the process of imperviousness. As a consequence of imperviousness, the natural vegetation and groundwater levels have significantly depleted. This study is therefore important since it is an attempt at understanding the spatio-temporal characteristics of imperviousness on the growth and expansion of the urban areas. The imperviousness is also a factor affecting the urban temperature. This study also tries to investigate the impact on urban environment on temperature.

Objectives of The Study

1. To analyze the population growth, urbanization and urban growth pattern over four decades using (1981, 1991, 2001 and 2011).

2. To study the Mysore – Bangalore road condition and the characteristics.

3. To study the land-use changes related to Built-up area, Water bodies, Vegetation and Waste/barren/uncultivated land and agriculture land.

4. To study the nature and distribution of different types of vegetation in the study area,

5. To study the Tree Carbon Sequestration and to approximate the capacity of carbon filtration in the existing vegetation in urban vicinity and estimation of carbon sequestration capacity compared between 2006 and 2021.

6. To study the impact of urbanization on Elevation and Water bodies.

7. To study the impact of urbanization on Land Surface Temperature (LST)

Methodology

The methodology followed is shown in detail in figure 1. The present study mainly based on both spatial and non-spatial data consisting of primary and secondary data and review of related literature. The methodology followed for the chapter four, five six and seven is discussed in detail in the respective chapter.

Spatial data: Includes census map. Satellite imageries and ground control points of land use.

Non Spatial data: Consists of demographic data

Data source and Analysis: Census Maps, Satellite Imageries, Census data and Literatures.

Census Maps, Satellite Imageries: Census maps for the decade of 1981 to 2011 have been used to prepare the base map of the respective decades of the study area. Later the boundary of the study area has been superimposed on the imageries to get the clipped study area.

Population data - secondary data: Population data from the census of India for the four decade of 1981 to 2011 has been collected to find out the growth and density of population of the settlements in the study area which identifies the urbanization and change in the rank of the settlements.

Satellite Imageries- secondary data: Land sat-5 (TM) 1991, Land sat -7 (ETM) 2001 and Land sat -8 (OLI) 2014 have been used to obtain land use and land cover changes for the different decades of the study through supervised classification using Erdas 2014. The radiometric, atmospheric and geometric corrections are done in ATCOR module inErdas.

METHODOLOGY

The methodology followed is shown in chart 1.1 in detail. The present study mainly based on both spatial and non-spatial data consisting of primary and secondary data and review of related literature. The methodology followed for chapter IV, V, VI, VII VIII, IX is discussed in detail in the respective chapter.

1.5.d. Census Maps, Satellite Imageries

Census maps for the decade of 1981 to 2011 have been used to prepare the base map of the respective decades of the study area. Further the boundary of the study area has been superimposed on the imageries to get the clipped study area.

1.5.e. Population data- secondary data

Population data from the census of India for the four decade of 1981 to 2011 has been collected to find out the growth of urban expansion and the distribution of population according to census classification which also identifies change in population class during four decades. Census and Industrial data were also used to find weightage to all villages in order to find the trends in urbanization

1.5.f.Satellite Imageries- secondary data

Landsat -5 (TM), 1999, 2009 and Landsat -8 (OLI) 2019 have been used to obtain land use land cover changes for different decades of the study through supervised classification using Erdas 2014. The radiometric, atmospheric and geometric corrections are done in ATCOR module in Erdas.

Landsat-5 (TM) 1999, 2009 and Landsat -8 (OLI) 2019 have been used to obtain land use and land cover changes for the different decades of the study through supervised classification using Erdas 2014. The radiometric, atmospheric and geometric corrections are done in ATCOR module in Erdas. The LULC results have been further used as an input for the land change modeler for the prediction of land use change dynamics for the year 2029.

For Land Surface Temperature Estimation Landsat 5 (TM) for 1999 and 2009 and for 2019 Landsat 8 OLI has been used. NDVI, NDWI, NDBaI, NDBI indices has been analyzed with the same satellite imageries for the respective years.

Organization of the report

The present study has been divided into ten chapters and they are as follows.

Chapter 1-Introduction: - This chapter will introduce brief introduction, significance to the study, statement of problem, methodology and organisation of the thesis.

Chapter 2- Study Area describes the location, setting and characteristics of the towns contained within the study area.

Chapter 3 – Urban growth and development of Mysore – Bangalore. Explains the urban system, and demographic characteristics of the study area.

Chapter 4 – Road Network pattern, types and traffic flow on Mysore – Bangalore Corridor.

Chapter 5 – Land use and Land cover patterns and trends in the Study area.

Chapter 6 – Impact of urban growth on stream disappearance.

Chapter 7 – impact of urban growth on land surface temperature.

Chapter 8 – Occupational pattern in the study area.

Chapter 9 – Socio Economic characteristics of the study area.

Chapter 10 – Estimation of Carbon storage and Sequestration

CHAPTER II

STUDY AREA :MYSORE – BANGALORE URBAN CORRIDOR

Mysore – Bangalore urban corridor is an exceptionally fast growing regions in south India. The urban fabric, the economic spurt, and the geographical setting of this region is producing great attraction for various activities. It is considered as one of the most favourable hot spot for all operation due to the progressive people, smart economy, and salubrious climate. This region has Bangalore on the north east end and Mysore on the south western end, separated by beautiful fertile agricultural land drained by the river Cauvery in the south and the hilly terrain of Ramanagara in the north. Along the Mysore – Bangalore axis road national highway No.17 are located important towns such as Srirangapatana, Mandya, Maddur, Channapatana, Ramanagara, and Bidadi.

Mysore city: Mysore city is geographically located between 12° 18′ 26″ north latitude and 76° 38′ 59″ east longitude. It is located at an altitude of 770 m (2,530 ft) above mean sea level.

Mysore is situated at the foothills of Chamundi Hills about 145.2 km (90 mi) towards the southwest of Bangalore and spread across an area of 155 km^2 (60 sq mi). Mysore City Corporation is responsible for the civic administration of the city, which is also the headquarters of Mysore district and Mysore division

It is spread across an area of 286.42 km^2 (111 sq mi) at the base of the Chamundi Hills in the southern region of Karnataka. Mysore is the southernmost city of Karnataka and is a neighbouring city to the states of Kerala and Tamil Nadu in the south, flanked by the state cities Mercara, Chamarajanagara, and Mandya.

In 2011, total land area usage in Mysore city was 39.9% residential, 16.1% roads, 13.74% parks and open spaces, 13.48% industrial, 8.96% public property, 3.02% commercial, 2.27% agriculture and 2.02 water. The city is located between two rivers: the Kaveri River that flows through the north of the city and the Kabini River, a tributary of the Kaveri, that lies to the south. As per provisional reports of Census India, population of Mysore in 2011 is **893,062**; The current metro area population of Mysore in 2022 is 1,261,000, a 2.11% increase from 2021.

SRIRANGAPATNA

Srirangapatna situated a mere 15 km from Mysore city, it lies in the neighbouring district of Mandya at 12.41°N 76.7°E. It has an average elevation of 679 metres (2227 feet).The entire town is enclosed by the river Kaveri to form a river island, northern half of which is shown in the adjacent image. While the main river flows on the eastern side of the island, the *Paschima Vaahini* segment of the same river flows to its west. The town is easily accessible by train from Bengaluru and Mysore and is also well-connected by road, lying as it does just off the Bangalore-Mysore National Highway 275. The highway passes through this town and special care was taken to minimize any impact on the monuments.

PANDAVAPURA

Pandavapura is a town located at 12.5°N 76.67°E. It has an average elevation of 709 metres (2326 feet) it is a Municipality Town in Mandya district in the Indian state of Karnataka and approximately 130 km from Bangalore and 25 km from Mysore. Total area of pandavapura taluka is 528 km² including 524.32 km² rural area and 3.68 km² urban area. Total number of villages in this Taluka is 168

MANDYA

Mandya it is the headquarter of Mandya district and is located 45 kilometres (28 mi) from Mysore and 100 kilometres (62 mi) from Bangalore.

Sugar factories contribute to the major economic output. It is also called Sugar city (which in Kannada means Sakkare nagara) because sugarcane is a major crop. Mandya district is located between north latitude 12°13' to 13°04' N and east longitude 76°19' to 77°20' E. It has an average elevation of 678 metres (2,224 ft).

It is bounded by Mysore district to the west and southwest, Tumkur district to the northeast, Chamrajnagar district to the south, Hassan district to the northwest, and Ramanagar district to the east. It has an area of 4,961 square kilometres (1,915 sq mi). The administrative center of Mandya District is Mandya City. Mandya

District has five rivers: Kaveri River and four tributaries main Hemavathi, Shimsha, Lokapavani, Veeravaishnavi. ***It has the highest desnity of cannal irrigation in Karnataka. The surrounding the city is used for the cultivation sugar cane and paddy. Population of Mandya City Municipal*** Council ***City*** in ***2011*** was 137358. As per census ***2011***, literacy rate and sex ratio for ***Mandya*** was 85.32 % and 973 per 1000.

MADDUR

Maddur (also pronounced as **Maddūru**) is a town in Mandya district in the Indian state of Karnataka. It lies on the banks of the river Shimsha. It is 82 kilometers from the state capital Bangalore and 60 kilometers from Mysore. ***Maddur Town Municipal*** Council has ***population*** of 28,754 . agriculture is the main occupation and the literacy level is 65%.

CHANNAPATANA

Channapatana is a city and taluk headquarter in Ramanagara District, Karnataka, India. Channapatana also known as "the land of toys". Famous for its wooden handicrafts world wide. This town has a rich cultural history and is home to a seasoned artisans practicing their craft from hundreds of years. Various dignitaries, most notably the Obama's have received these crafts as state gifts to take back home. Channapatna is approximately 60kms from Bangalore and 80kms from Mysore. Channapatna has an average elevation of 739 metres (2424 ft).Channapatna is located on the Bangalore - Mysore highway. It is about 55 km from Bangalore and 80 km from Mysore.

Tirumakudalu Narasipura

Tirumakūḍalu Narasīpura commonly known as **T. Narasipura** or **T.N. Pura**, refers to the land at the confluence, at the confluence of the Kaveri, Kabini and Spatika Sarovara (a mythical lake or spring, also named Gupta Gamini). Tirumakudalu Narasipura town is the headquarters of the Tirumakudalu Narasipura taluk of the same name (with a 2001 Census population of 279,005) within Mysore District. It is 29 km south-east of Mysore, the district headquarters and 130 km from Bangalore, the state capital. The town is well connected with roads, NH 212 bypasses the town, SH79, SH84 will pass inside the town.

RAMNAGARA

Ramanagara district, is one of the 31 districts of Karnataka state in southern India. Ramanagara City is the administrative headquarters of this district. The district is part of Bengaluru Division. Ramanagara is approximately 50 km southwest of Bengaluru. The district shares borders with the districts of Bangalore Urban in the east, Bangalore Rural in the North-east, Tumkur in the North-west, Mandya in the west and Chamarajanagar in the south-west and Krishnagiri district of Tamilnadu state in the south. It has an average elevation of 747 metres (2450 feet). Ramanagara is famous for the huge rocky outcroppings.

Ramanagar district was part of the Bengaluru rural district was reconstituted as a separate district in 2007, District Head Quarters is located at Ramanagar Taluk along with three taluks viz., Channapatna, Kanakapura and Magadi. It has 130 Grama Panchayats and population of 10,82,739 according to the census of 2011. Ramanagar Town is situated along Bengaluru - Mysuru State Highway No.17 at a distance of 50 km from Bengaluru. The town is located about 622.80 meters above the sea level and receptive of an average rainfall of 931.58 mm annually. The Area is around 3,556 km (1,373). The district has a population density of 303 inhabitants per square kilometre (780). Its population growth rate over the decade 2001-2011 was 5.06 per cent.

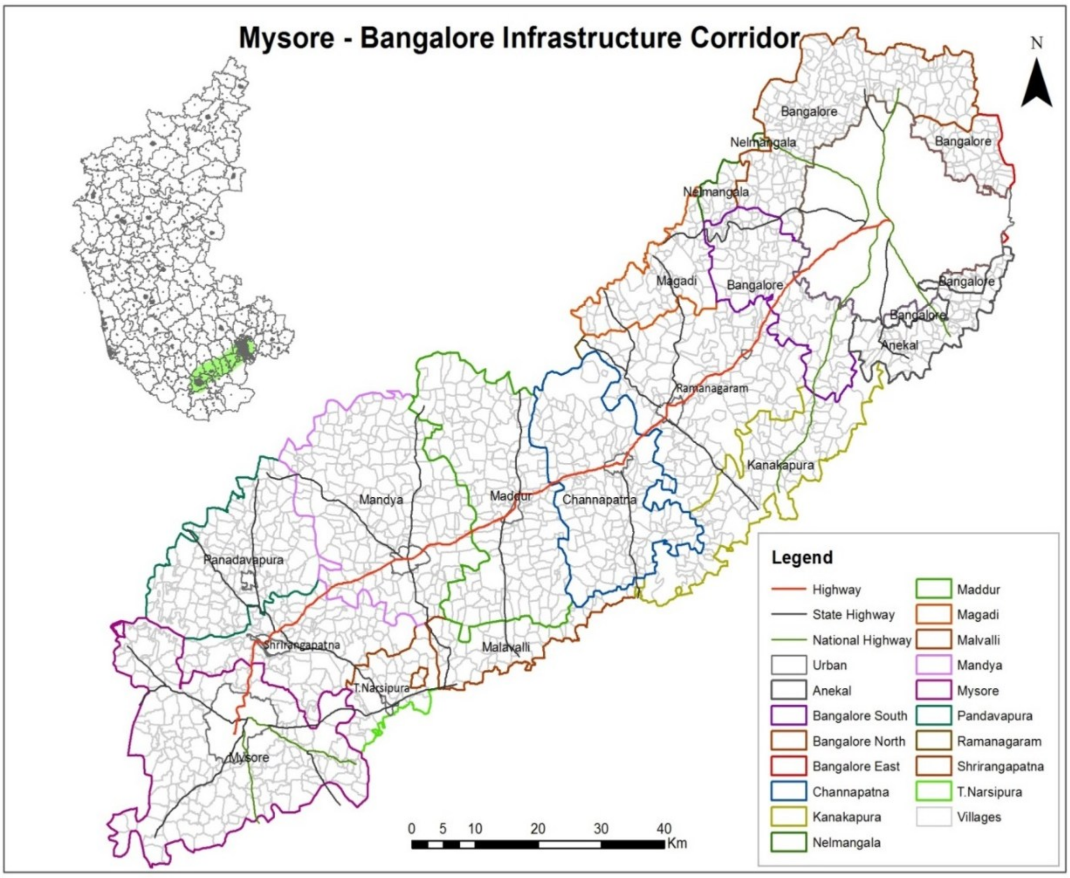
Ramanagara district has a population of 10,82,739 in 2011, about 50 km from Bangalore and Bangalore-Mysore State Highway No.17. The average rainfall is 622.80 meters above sea level and 931.58 mm annually.

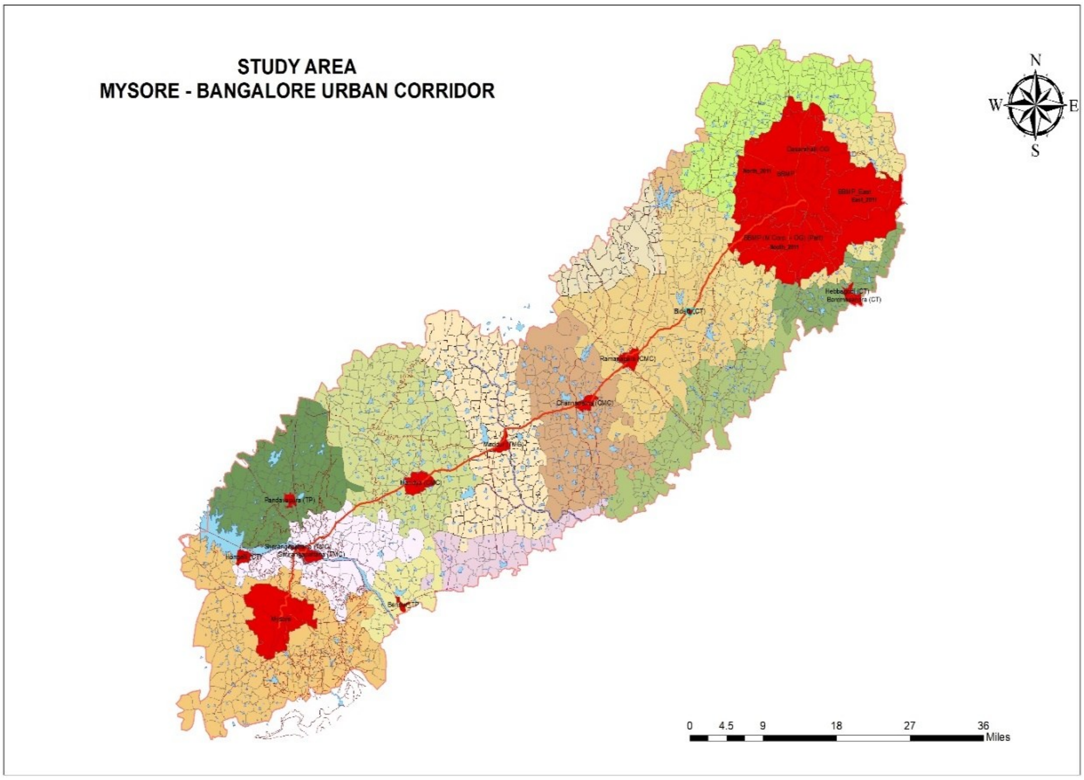
BIDADI

Bidadi is a town situated on the Bengaluru – Mysuru expressway and is part of the Ramnagar in the state of Karnataka. The town is located 32 km from Bangalore towards Mysuru and is connected by both rail and bus to Bengaluru City.

ANEKAL

Anekal is a major town and taluk of Bengaluru Urban district. It is a major town in the suburbs of Bengaluru city. Approximately 36 km from Bengaluru Centre and around 15 km from Hosur and Electronic City. Express lines run from Silk Board to Anekal passing through the National Highway and SH broadway thus providing excellent connectivity. Anekal is located at 12.7°N 77.7°E. It has an average elevation of 915 metres (3001 feet). Anekal is one of the growing towns around Bangalore urban district, situated close to major economic sites like Electronic City, Jigani and Hosur. Muthyala Maduvu also known as Pearl Valley is a major tourist spot just a few km from the town and attracts tourists from all over the state. Anekal is also known for its Silk industry and is home to a number of skilled weavers





KANAKAPURA

Kanakapura is a town in the Ramanagara district of Karnataka on the banks of the Arkavathi river and the administrative center of the taluk of the same name. Kanakapura is located at 12.55°N 77.42°E.[2] It has an average elevation of 638 m (2,093 ft).

Kanakapura is 55 km (34 mi) south of Bangalore (capital) on National Highway NH 209, on the banks of the river Arkavathi (Incarnation of River Kaveri) and 27 km (17 mi) from Ramanagara and 96 km (60 mi) from Mysore.

NH 209 (Bangalore – Coimbatore) passes via KanakapuraPreviously belonged to Bangalore Rural District. It was formerly the largest constituency in the country. The taluk is very widespread (1,553 km^2 [600 sq mi]). It is located among the lush green forests of the state of Karnataka. The town is a tourism hotspot and an often visited tourist favorite in the entire state of Karnataka, as it has something for everyone ranging from avid trekkers to history buffs and wildlife enthusiasts.The forest area in this taluk is very wide and about half of the Bannerghatta National Park is located in our Kanakapura area.Kodihalli wildlife range and harohalli wildlife range its division.The Kaveri Wildlife Sanctuary consists of two main zones namely the Sangam Wildlife range, the Mugur Wildlife range

MALAVALLI

Malavalli is a town and a taluka place in Mandya district in the Indian state of Karnataka. Malavalli town is located at 12.38°N 77.08°E. It has an average elevation of 610 metres (2001 feet).

Bengaluru Metropolitan region: Bangalore is the capital of Karnataka and largest city of the Indian state of Karnataka. Bangalore Urban district, is the most densely populated district in the Indian state of Karnataka. It is surrounded by the Bangalore Rural district on the east and north, the Ramanagara district on the west. Bangalore Urban district came into being in 1986, with the partition of the erstwhile Bangalore district into Bangalore Urban and Bangalore Rural districts. Bangalore Urban has five taluks: Hebbala (Bangalore North), Kengeri (Bangalore South), Krishnarajapura (Bangalore East), Yelahanka (Bangalore North Additional) and Anekal. The city of Bangalore is situated in the Bangalore Urban district and is the headquarters of the district. The district has 2 divisions, 5 talukas, 17 hoblies, 872 villages, 11 rural habitations, 5 towns, 1 tier-three city and 1 tier-one city, administered by 96 Village Panchayats (*Grama Panchayitis*) 97 Taluk Panchayats (*Taluk Panchayitis*), 5 Town Municipal Councils (*Purasabes)*, 1 City Municipal Council (*Nagarasabe*) and 1 City Corporation (*Mahanagara Palike*).[3][4]

The district had a population of 6,537,124 of which 88.11% is urban as of 2001. As of Census 2011, its population has increased to 9,621,551, with a sex-ratio of 908 females/males, the lowest in the state and its density is 4,378 people per square km.

Bangalore's rapid growth has created several administrative problems relating to traffic congestion and degrading infrastructure. The unplanned nature of growth in the city resulted in massive traffic gridlocks; a flyover system and one-way traffic systems were introduced, which were only moderately successful. A 2003 study (BEES) made an evaluation of Bangalore's physical, biological and socioeconomic parameters indicated that Bangalore's water quality and terrestrial and aquatic ecosystems were close to ideal, while the city's socioeconomic parameters (traffic, quality of life) air quality and noise pollution were poor.

Located in southern India on the Deccan Plateau, at a height of over 900 m (3,000 ft) above sea level, Bangalore is known for its pleasant climate throughout the year. Its elevation is the highest among the major cities of India. Bangalore is widely regarded as the "Silicon Valley of India" because of its role as the nation's leading information technology (IT) exporter.

Bangalore lies in the southeast of the South Indian state of Karnataka. It is in the heart of the Mysore Plateau (a region of the larger Cretaceous Deccan Plateau) at an average elevation of 900 m (2,953 ft). It is located at 12°58′44″N 77°35′30″E and covers 741 km^2 (286 sq mi). The majority of the city of Bangalore lies in the Bangalore Urban district of Karnataka and the surrounding rural areas are a part of the Bangalore Rural district.

Bangalore Urban district, is the most densely populated district in the Indian state of Karnataka. It is surrounded by the Bangalore Rural district on the east and north, the Ramanagara district on the west and the Krishnagiri district of Tamil Nadu on the south. Bangalore Urban district came into being in 1986, with the partition of the erstwhile Bangalore district into Bangalore Urban and Bangalore Rural districts. Bangalore Urban has five taluks: Hebbala (Bangalore North), Kengeri (Bangalore South), Krishnarajapura (Bangalore East), Yelahanka (Bangalore North Additional) and Anekal

. In recent decades, the city has witnessed rapid growth in population and urbanized area. While Central Bangalore is the commercial heart of the city, Eastern and South-Eastern Bangalore areas are major hubs for IT and financial companies. Southern and Western parts of the city are mainly residential areas. The neighbour hoods in the Northern and North-Eastern regions are both industrial and residential.

CHAPTER III

MYSORE – BANGALORE ROAD NETWORK AND ITS IMPACT ON LNDUSE AND LANCOVER

THE HISTORY OF THE DEVELOPMENT OF MYSORE BANGALORE ROAD

The Mysore Bangalore road which is popularly called Mysore Road or SH17 is one of the most important life line of the southern maidan region of Karnataka. It is this road which connects the important towns and cities to the capital city of Karnataka. The development of Mysore road has been progressing over centuries during the times of different kings and emperors. Some of the significant improvements have happened in pre-independence period also, especially during the time of Wadiyars, Tipu Sultan, and the Britishers. However a more significantdevelopment has happened during the post-independence period because of the rapid growth in population, and economic development..

In 1882 -1902 the British restored the rule of the kings which brought about enormous prosperity to the Mysore kingdom. The queen mother who was the regent, installed confidence in the administration and geared the economic development of Mysore and focused attention on cleaning of Mysore City and providing modern amenities. The political capital of Mysore state had been shifted to Bangalore during the British rule, but the ruler continued to reside in Mysore with his courtiers, which kept the economy and importance of Mysore from sagging and became the cultural capital of the State. As a result of these changes, the two cities Mysore and Bangalore rose to importance. The development of Mysore Bangalore road became inevitable.

Modernization and Rapid Growth in all spheres of social, political and economic life was realized during 1903-1947 in Mysore state. The period covering the first half of this century witnessed considerable physical expansion and rise in the population of the City and hence can be considered as the golden age in the history of Mysore City. During this time the city was experiencing a great industrial development which took place primarily due to the availability of hydroelectric power from Shivanasamudram. The industries, which were started during this period, were the Government Sandal Oil Factory, the Silk Factory in the City and K.R. Mills, Coffee Curing Works, Fertilizer Factory and the Paper Mills on the periphery. These not only aided the physical expansion of the City but also boosted up the construction activity (Mahadev2 ,1975).

During the Post-Independence Period starting from 1947 to Till Date, India's emergence as an independent and democratic country had tremendous impact on the development of road infrastructure. The establishment of popular Government in the State was accompanied by the complete shift in the power center. The decision-making authority was shifted to Bangalore. Though this was slow in the beginning, buy\t it 01became drastic in the later years. Mysore State during pre-independence was considered as one of the most industrially advanced states in the whole of India, besides having good educational facilities, Mysore also became the tourist capital with its beautiful historical and architectural features. There was special emphasis on the development of Mysore – Bangalore Road in order to connect Mysore with not only within the region and the state but with the whole nation. However, with the reorganization of states and shifting of the capital to Bangalore in 1956, the City lost its importance, considerably. As a consequence of these changes, there was stagnation in economy of the City and only a very few industries were started during this period. The population growth rate slumped to about 3 percent during 1951 - 61 and the physical expansion was almost halted. However, during the succeeding decade the growth rate picked up and several new extensions were formed by the Trust Board. It was transformed from a palace-oriented economy to tourism and education. There was expansion of the educational facilities at Mysore and several educational and research institutions of national and regional importance were established at Mysore. These improvements are reflected in the development and strengthening and modernization of roads 1985. Today Mysore is the second largest City in the State of Karnataka and is also the divisional headquarters. It is an important administrative, educational, tourist, industrial and trade center of the State.

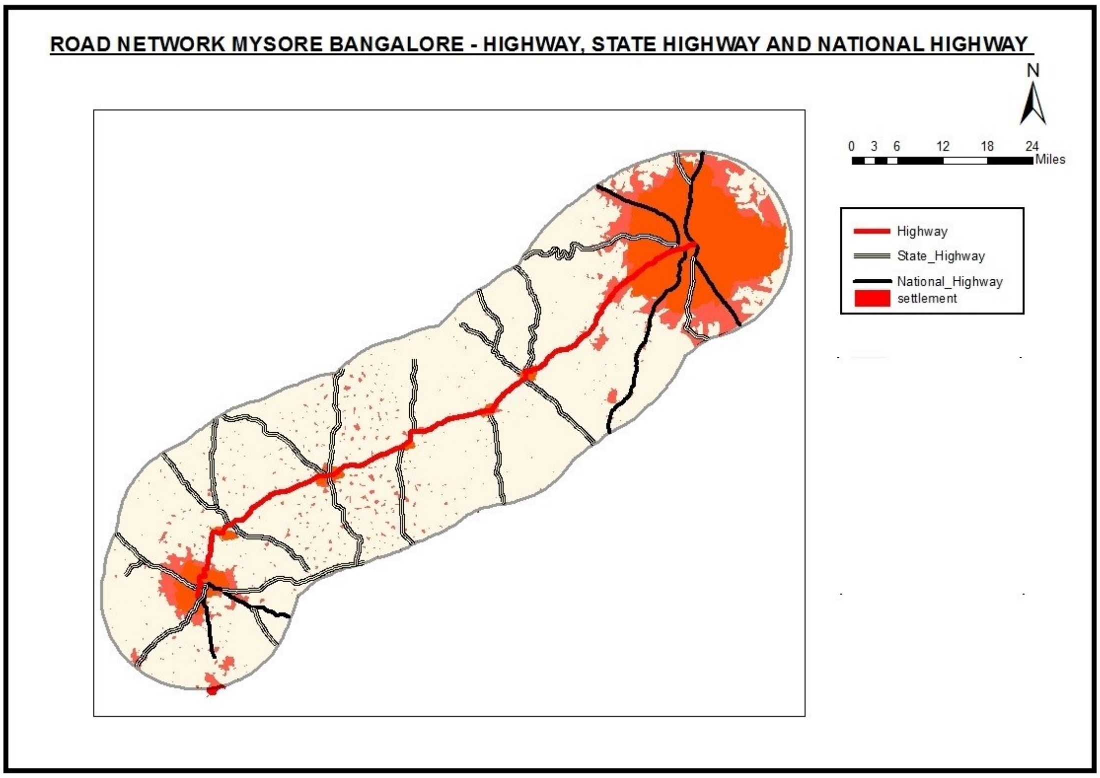
Number of Vehicles / day			
Road	1982	1990	Percentage
Bangalore	2776	7892	184.1

CHARACTERISTICS OF MYSORE BANGALORE ROAD OR STATE HIGHWAY SH17

This road is presently designated as NH-275 with 45 m width. It is having (2+2 lanes) at present with divided CW of 7.4m on either side or 1.5 m median. It is operated by two way traffic, which connects Bangalore to one side and Mysore to another side. The SH-17 has got upgraded to NH-275 by National Highway Authority of India (NHAI). The road will be of 45 m including (3+3 lanes) CW, median, Area separators and Service roads on either side for local traffic.

The characteristics of the road can be studied under the following heads.

1. Speed of the vehicles.
2. Number of vehicles at peak traffic time plying on the road to different destinations.
3. Variety of vehicles plying at different time of the day.
4. Passenger vehicles
5. Goods vehicles
6. Socio economic characteristics of the passengers.

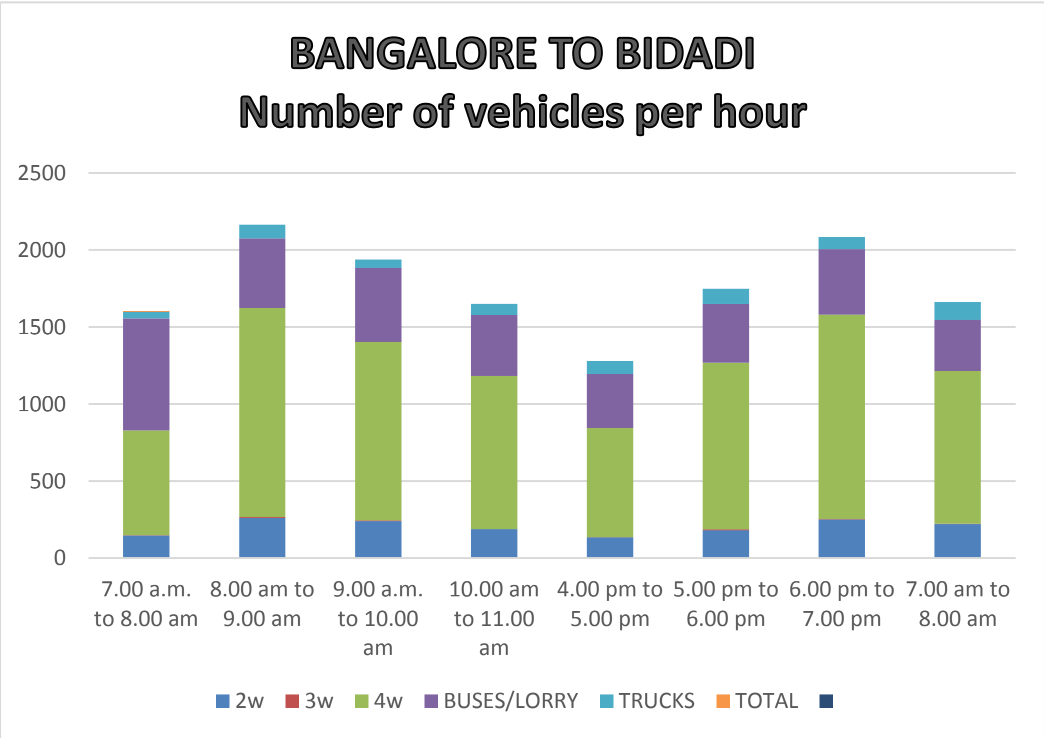


1. SPEED OF THE VEHICLES.

Speed spectrum for the study roads (kmph)											
Road	**Towards**	**2 Wh**		**3 Wh**		**4 Wh (C,J,V)**		**Buses/ Lorries**		**Truck**	
		Max	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
Mysore Road (SH-17 / NH-275) (2+2 lanes divided)	**To Bidadi**	**52**	**30**	**28**	**16**	**75**	**48**	**40**	**22**	**43**	**25**
	To Kengeri	**55**	**32**	**25**	**18**	**79**	**45**	**45**	**20**	**48**	**28**

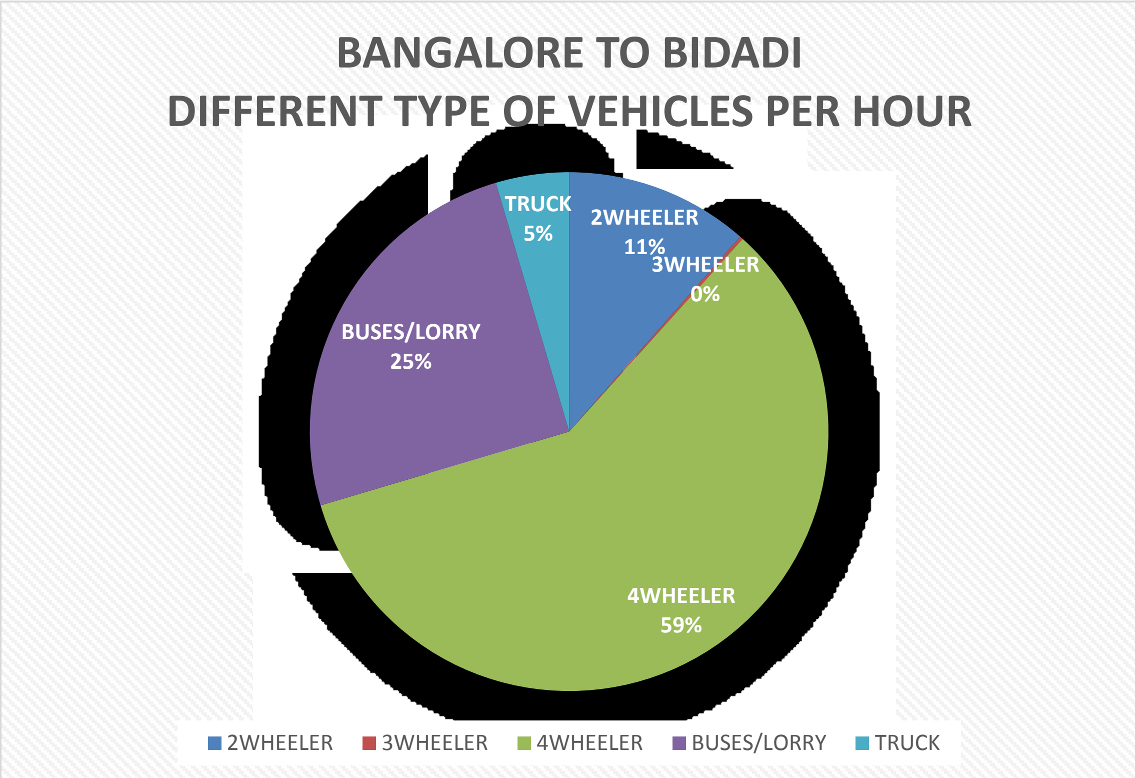
2. NUMBER OF VEHICLES AT PEAK TRAFFIC TIME PLYING ON THE ROAD TO DIFFERENT DESTINATIONS.

	Bangalore to Bidadi										
Time	2w		3w		4w		buses/lorry		truck		total
	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2	
7.00 a.m. to 8.00 am	97	49	1	1	340	340	561	168	9	36	1602
8.00 am to 9.00 am	173	87	4	3	678	678	113	339	18	72	2165
9.00 a.m. to 10.00 am	160	80	2	2	580	580	120	360	11	44	1939
10.00 am to 11.00 am	125	63	0	0	498	498	98	294	15	60	1651
4.00 pm to 5.00 pm	89	45	1	1	355	355	87	261	17	68	1279
5.00 pm to 6.00 pm	120	60	4	3	541	541	95	285	20	80	1749
6.00 pm to 7.00 pm	167	84	2	2	663	663	106	318	16	64	2085
7.00 am to 8.00 am	148	74	1	1	496	496	83	249	23	92	1663



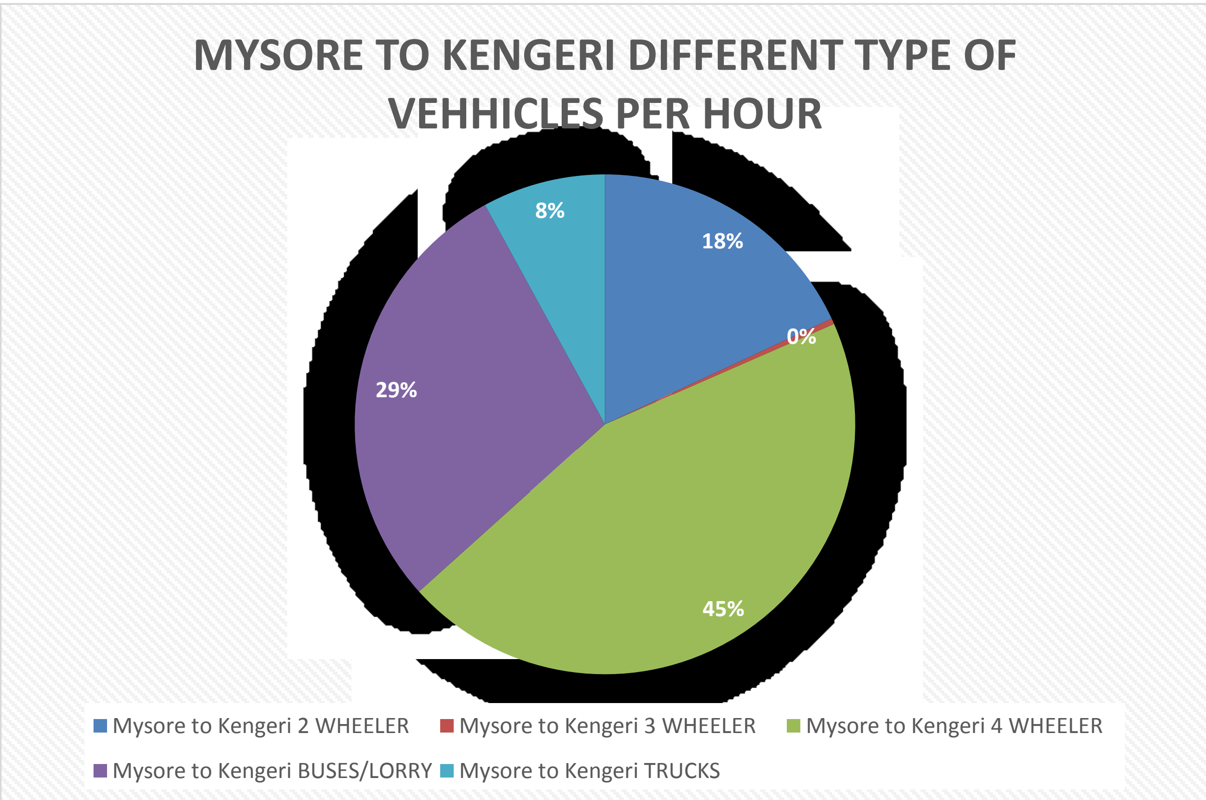
There is a very high flow of 4 wheelers in the moring time between 8 am to 10 am especially from Bangalore to Bidadi. Again the same intensity is followed in the second peak hour from 5 pm to 7 pm from Bidadi to Bangalore. This segment of the traffic is purely catering to the place of work to home.

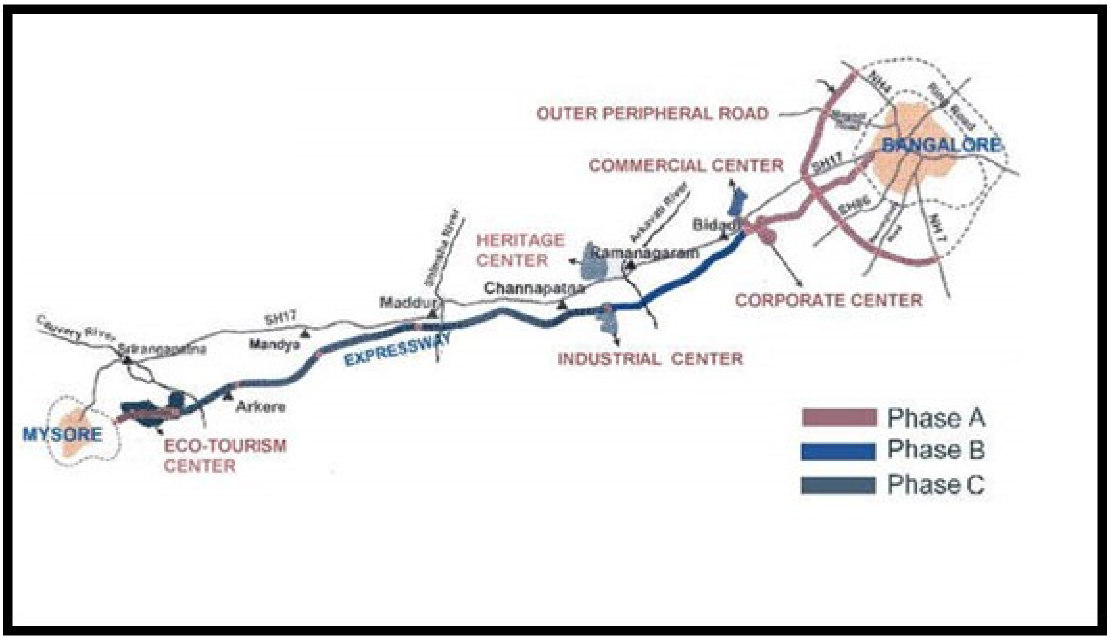
Similarly during the same peak hour there is also high traffic between Mysore to Kengeri by 4 wheelers which covers at least 59% of the traffic. Whereas 25% of the traffic is occupied by the buses, trucks and lorryies.



	Mysore to Kengeri										
	2w		3w		4w		buses/lorry		truck		total
	L1	L2	L1	L 2	L1	L2	L1	L2	L1	L2	
7.00 a.m. to 8.00 am	112	56	1	1	352	352	59	177	8	32	1150
8.00 am to 9.00 am	178	89	3	2	642	642	91	273	15	60	1995
9.00 a.m. to 10.00 am	185	93	2	2	715	715	106	318	25	100	2261
10.00 am to 11.00 am	174	87	4	3	758	758	110	330	21	84	2329
4.00 pm to 5.00 pm	151	76	2	2	426	426	87	261	24	94	1549
5.00 pm to 6.00 pm	165	83	3	2	589	589	101	303	33	132	2000
6.00 pm to 7.00 pm	194	97	5	4	786	786	121	343	22	88	2446
7.00 am to 8.00 am	149	80	3	2	632	632	113	339	26	104	2080

3. TYPE OF VEHICLES PLYING ON THE MYSORE – BANGALORE ROAD.





LOCATION	DIRECTION	TOTAL VEHICLES	TOTAL PCU	BOTH DIRECTION VEHICLES	BOTH DIRECTION PCU
Old outer ring road	Towards Mysore road	1459	1317	2734	2425
	Towards satellite town	1275	1108		
Bangalore university	Towards university	904	647	3054	2084
	Towards Mysore road	2150	1437		
Bidadi	Towards Bangalore	2018	1690	4227	
	Towards Mysore road	2209			
Ramanagaram	Towards Bangalore	1820	1466	3576	
	Towards Mysore road	1756			
Channapatana	Towards Bangalore	1624	1376	3192	
	Towards Mysore road	1568			
Maddur	Towards Bangalore	1520	1232	2887	
	Towards Mysore road	1367			
Mandya	Towards Bangalore	1433	1109	2547	
	Towards Mysore road	1114			
Srirangapatana	Towards Bangalore	1509	1267	2714	
	Towards Mysore road	1245			
Mysore	Towards Bangalore	1410	1346	2877	
	Towards Mysore road	1467			

Mysore road	volume of vehicles	PCU	24 hours volume	24 hours PCU
9 am – 10 a.m	15926	1842		
1 p.m. – 2 p.m.	1917	2347	33937	45525

Mysore road	LCV	TRUCKS	MAV	TOTAL
Coming to Bangalore	545	1827	221	2593
Going from Bangalore	883	2136	361	3380

Passenger vehicles	Goods vehicles	Passenger vehicle in %	Goods vehicles in %	Peak hour volume			
				Passenger vehicles	Goods vehicles	Passenger vehicles %	Goods vehicles %
27489	6447	81	19	1687	231	88	12

Analysis on purpose of journey revealed that majority of the trips are work related trips as 81% of passengers use Rail, 4.2% private cars, and 25% use buses.

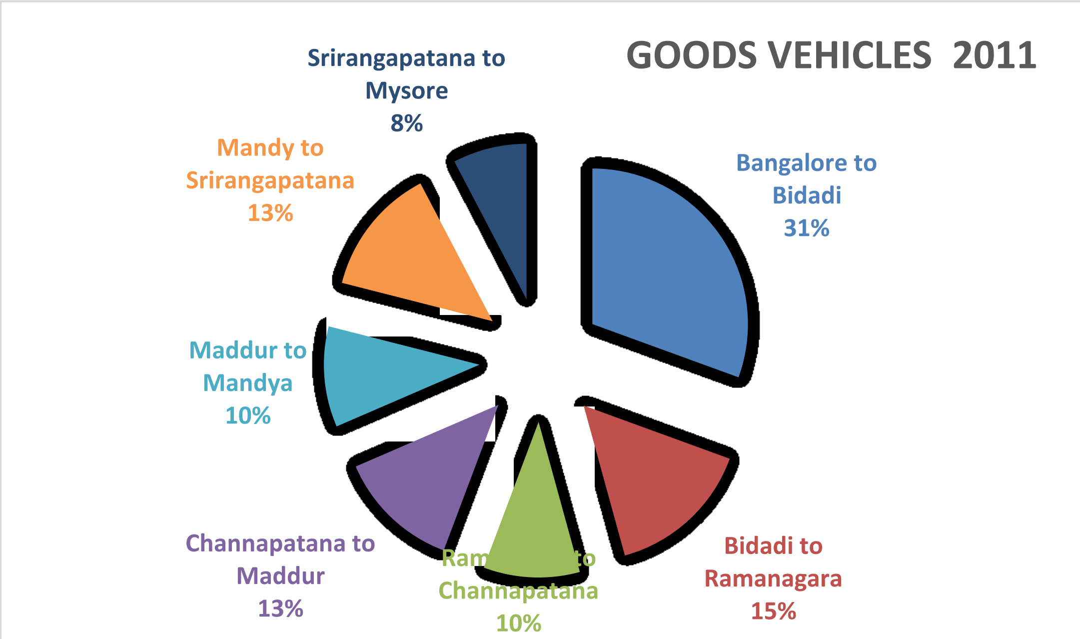
SOCIO ECONOMIC CHARACTERISTICS :

Various existing socio-economic characteristics viz. distribution of the households according to household size, household income, vehicle ownership, distribution of the individuals by their occupation, education and expenditure on transport etc. are derived from analysis of the household interview survey.

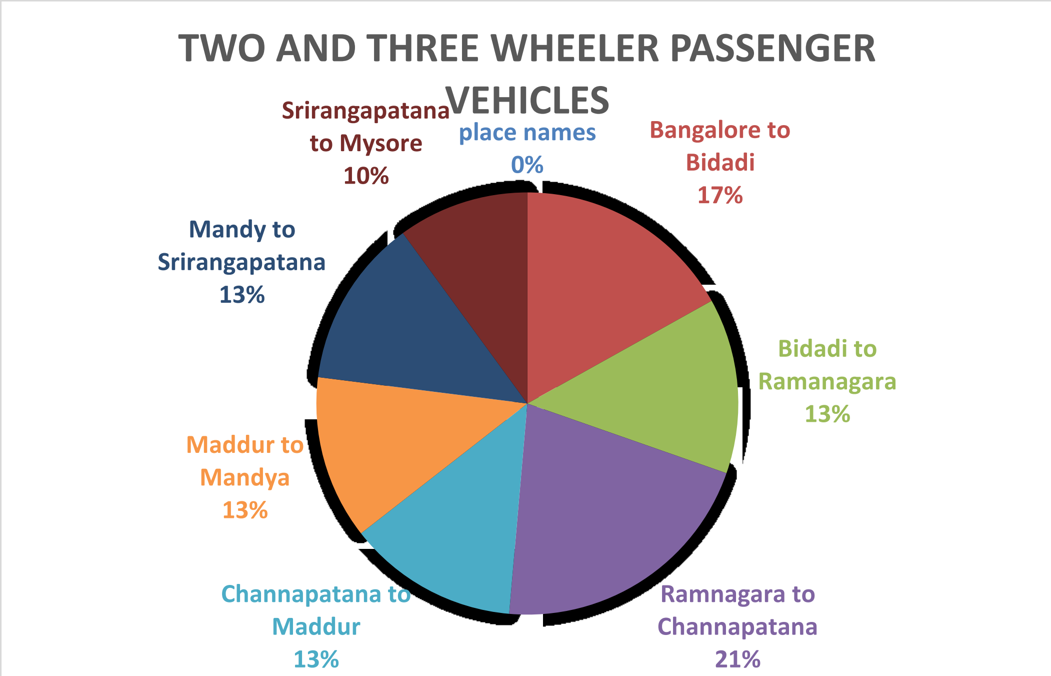
(i) Nearly 16% of households have no vehicle. About 20% of the household have one car. About 60% of households have at least 1 scooter/motor cycle.

(ii) Average household income per month in the study area was observed to be Rs. 32374/-.

(iii) Average expenditure on transport per household is estimated as Rs 2473 per month, which is about 7.6% of average household income.

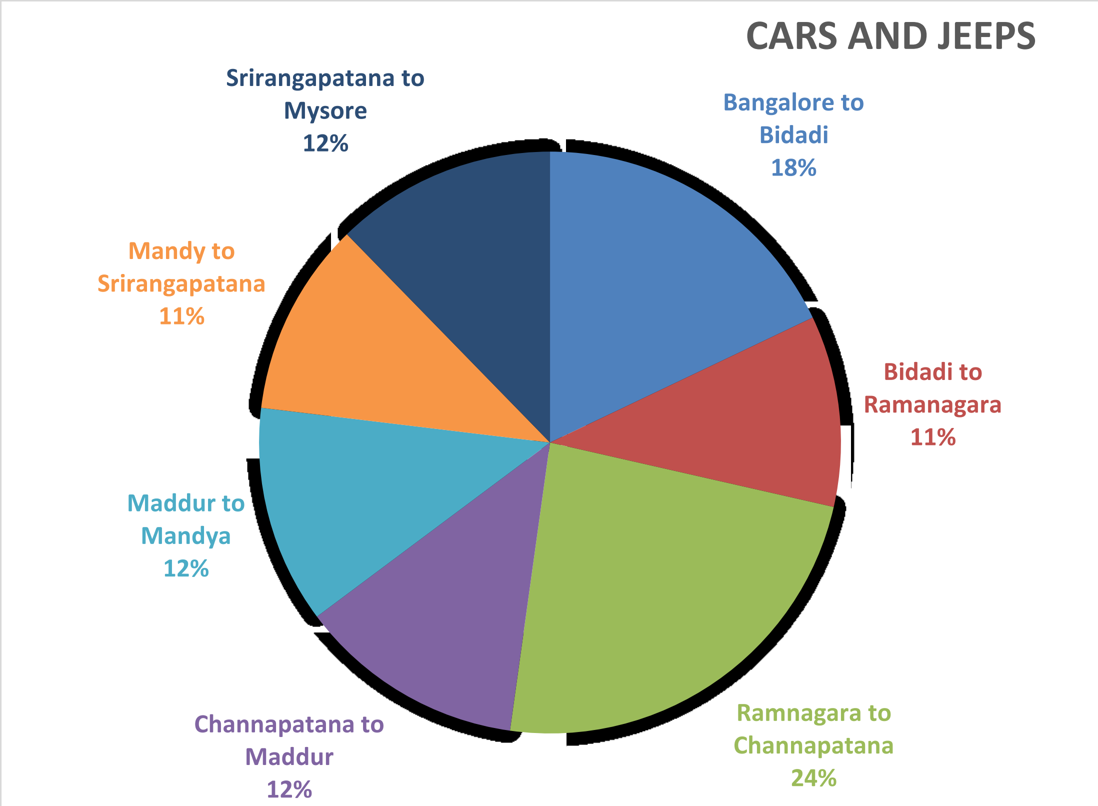


place names	2 axel rigid 6 tyres	3axel rigid 10 tyres	Multi axle more than 10 tyres	Tractor with trailers	Total
Bangalore to Bidadi	9716	3873	1860	425	15874
Bidadi to Ramanagara	5017	1734	720	408	7879
Ramnagara to C.patana	3692	824	301	382	5199
Channapatana to Maddur	4809	1028	443	357	6637
Maddur to Mandya	3296	1115	514	508	5433
Mandy to Srirangapatana	5622	437	285	592	6936
Srirangapatana to Mysore	3115	611	154	110	3990

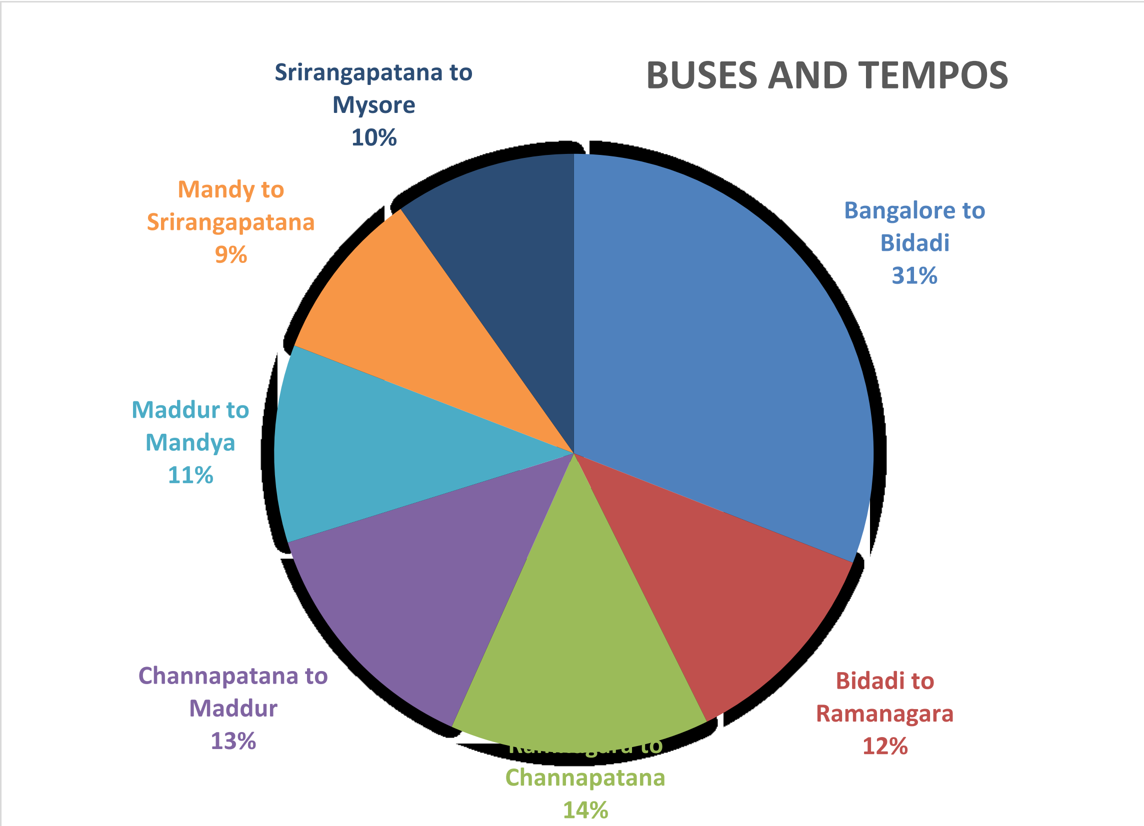


The highest intra-regional movement of traffic is between Bangalore to Channapatana.

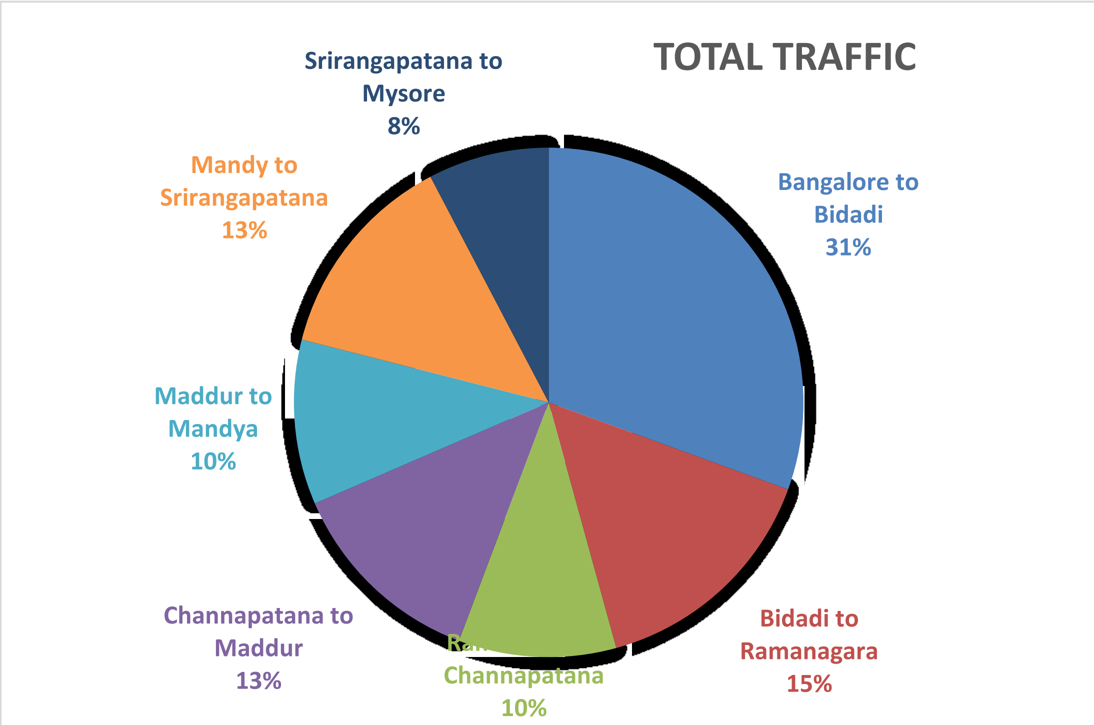
place names	**Two wheeler**	**Auto Rickshaw**	Total
Bangalore to Bidadi	10385	2700	13085
Bidadi to Ramanagara	8062	2342	10404
Ramnagara to C.patana	13636	2628	16264
Channapatana to Maddur	8275	1846	10121
Maddur to Mandya	8268	1438	9706
Mandy to Srirangapatana	9195	830	10025
Srirangapatana to Mysore	7330	442	7772



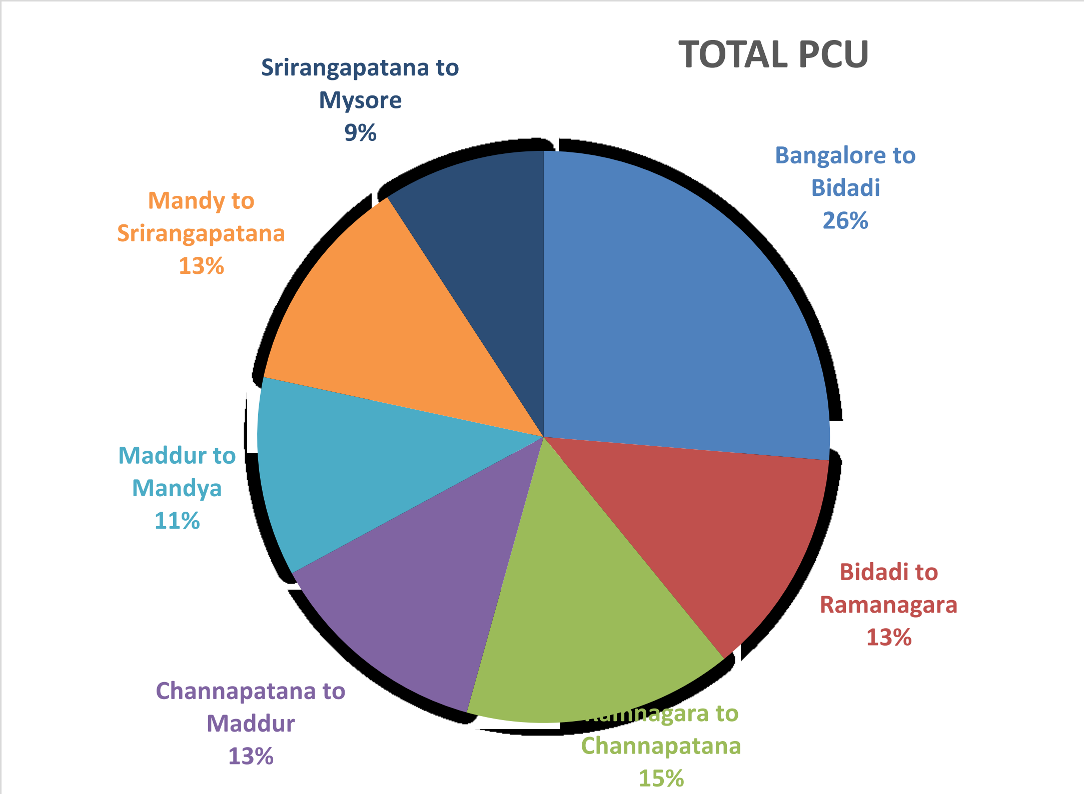
Place names	Cars and Jeeps
Bangalore to Bidadi	13451
Bidadi to Ramanagara	7972
Ramnagara to C,apatana	17733
Channapatana to Maddur	9443
Maddur to Mandya	9092
Mandy to Srirangapatana	8097
Srirangapatana to Mysore	9226



place names	Vans and tempos	Mini buses	buses	LCV	Total vehicles
Bangalore to Bidadi	3936	4852	8823	4403	22014
Bidadi to Ramanagara	3126	1093	4004	115	8338
Ramnagara to Channapatana	1368	1021	5994	1582	9965
Channapatana to Maddur	1573	708	3414	3904	9599
Maddur to Mandya	2023	814	3944	816	7597
Mandy to Srirangapatana	1286	508	4072	767	6633
Srirangapatana to Mysore	1648	823	3116	1390	6977



Traffic between places	Total traffic on Mysore – Bangalore Road
Bangalore to Bidadi	15874
Bidadi to Ramanagara	7879
Ramnagara to Channapatana	5199
Channapatana to Maddur	6637
Maddur to Mandya	5433
Mandy to Srirangapatana	6936
Srirangapatana to Mysore	3990



	Road segment	No. of vehicles
1	Bangalore to Bidadi	116709
2	Bidadi to Ramanagara	56876
3	Ramnagara to Channapatana	67408
4	Channapatana to Maddur	56595
5	Maddur to Mandya	50002
6	Mandy to Srirangapatana	55245
7	Srirangapatana to Mysore	40748

CHAPTER IV

POPULATION AS A FACTOR OF URBAN GROWTH

Population and Urbanization

Urban systems behave like engines producing dynamic force attracting people towards it and simultaneously enforce dynamic effects, thereby boosting complex set of processes by which the proportion of population concentrated in urban areas increases over time. The rural – urban migration also plays a vital role in the process of stimulating urbanization.

There are manifold factors which play significant roles in the analysis and understanding of urban growth and development process. Among these prerequisites, markets, transportation and commercial centres play very important roles in urban expansion process. Cities did not come into existence nor grow by themselves single-handedly. Towns do not exist in vacuum, nor they are split from the continuous area along clear-cut boundary lines; on the contrary, they are always related to the bigger towns or cities than themselves. The towns do not grow separately; there is no distinct boundary in between them. On the contrary, their growth is set on a mutual relationship as the existence heavily depends on each other. The small towns are interlinked with the bigger ones, which are in turn intricately annexed to the cities, and cities become a web of inter-connectivity, which directly contributes to the concept of urbanisation. Urbanisation has been mostly defined as a process through which people flux to the industrialised sector of the society from the agrarian one primarily for employment and economic progress. This socio-economic mobility within the country opens up the way towards an urban life. The metropolitanisation bears a dual acting force - centripetal and centrifugal. On one hand, urbanisation, as a centripetal instrument, has the power to attract people inwards, whereby its towns and cities become the point of convergence. On the other hand, it radiates its influence outwards based on its centrifugal potentials. In this way, it reinforces the centripetal role. Urbanization in its most general sense refers to the complex set of processes by which the proportion of population concentrated in urban areas increases over time. In our global and contemporary times, cities have witnessed a commendable rise in population and size. Consequently, rapid urbanisation is a direct result of many active agencies. However, growth, distribution and density of population are deemed to be of uttermost significance.

Urbanization, in this sense, is an irreversible process involving changes in vast expanse of land cover and local ecology with the progressive concentration of human population. Rapidly urbanizing landscapes with high population density often face severe crisis due to inadequate infrastructure and lack of basic amenities. Studies conducted about the urban growth in developing countries highlight the nature of urban transition and the regional differences in these nations. It also examines the quality of past urban population projections, assess and estimate whether there has been commendable diversity in their quality through geographic region, level of development and size of the country.

Distance is a major factor responsible for spread of urban characteristics. It has been argued that towns cannot grow as isolated pockets without maintaining any functional linkage with the rural hinterland. Rapid urbanization causes disorganized and unplanned expansion of the towns and cities respectively. The pressure of an ever-growing population becomes the burden on the limited civic amenities, which are virtually collapsing. This preoccupation brings about the need to balance the available present requirements of land against future needs.

4.2 METHODOLOGY

The *population data over four decades is used starting from 1981, 1991, 2001 and 2011.*

Analysis

- Urban growth rate and pattern - A comparative study of the population between towns along the axis of Mysore – Bangalore corridor was conducted between Mysore-Mandya-Maddur-Ramanagara-Bangalore Corridor region.

- The rate of population growth and change has been detected and analysed using the rate of change formula and percentage of change projected for the next two decades by using the GIS technique.

URBANIZATION TREND BASED ON CENSUS DATA

Characteristics of Household information in the Mysore – Bangalore corridor

Some of the indicators of urbanization and development have been considered to understand the process of change.

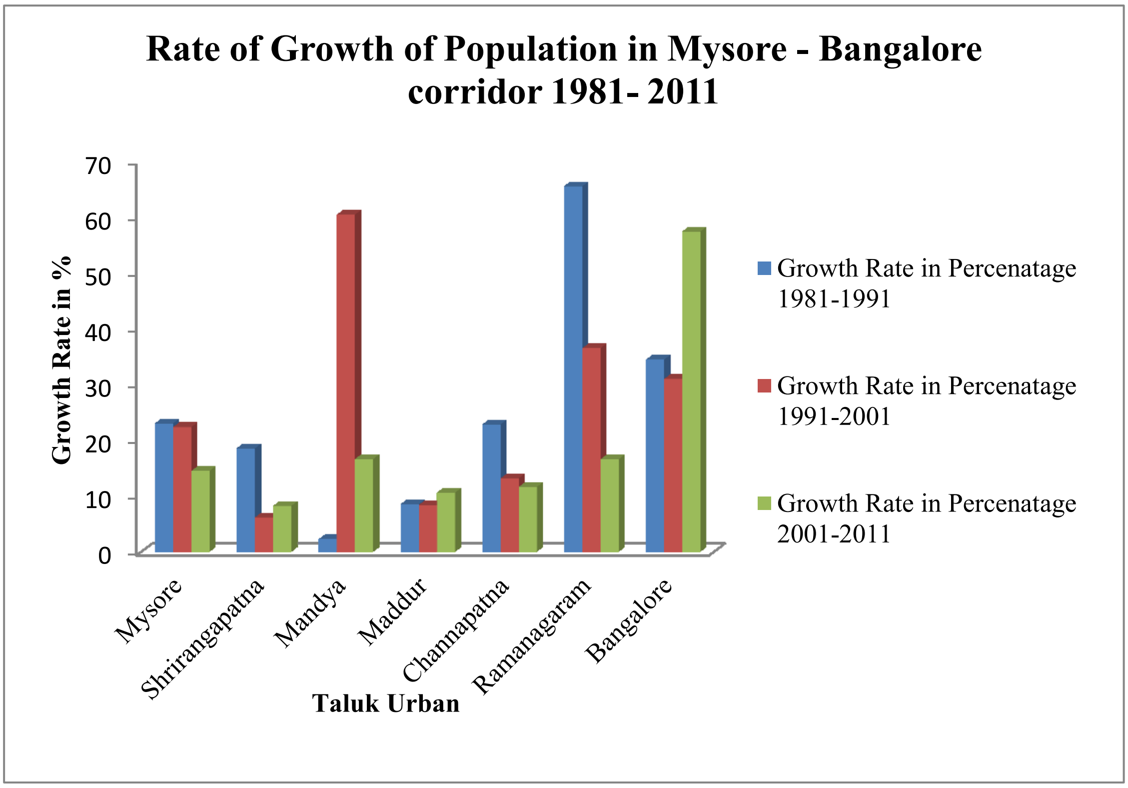
1. Population growth
2. House hold characteristics
3. Literacy
4. Main workers
5. Marginal workers
6. Proportion of Agriculture occupation
7. Non workers

The spatial patterns of the above variables have been presented through graphs and tables.

Growth of Population

Population growth in Mysore – Bangalore corridor (1981 -2011)				
Taluk	TOT_P_81	TOT_P_91	TOT_P_01	TOT_P_11
Mysore	470567	611223	787179	920550
Shrirangapatna	18137	22265	23729	25861
Mandya	50725	51905	131179	157358
Maddur	44005	48115	52521	58754
Channapatna	42601	55209	63577	71942
Ramanagaram	17402	50437	79394	95167
Bangalore	2400285	3660088	5301326	12443675

Rate of Growth of population in Mysore – Bangalore corridor (1981)			
Taluk Urban	Growth Rate in Percentage		
	1981-1991	1991-2001	2001-2011
Mysore	23	22	14
Shrirangapatna	19	6	8
Mandya	2	60	17
Maddur	9	8	11
Channapatna	23	13	12
Ramanagaram	65	36	17
Bangalore	34	31	57

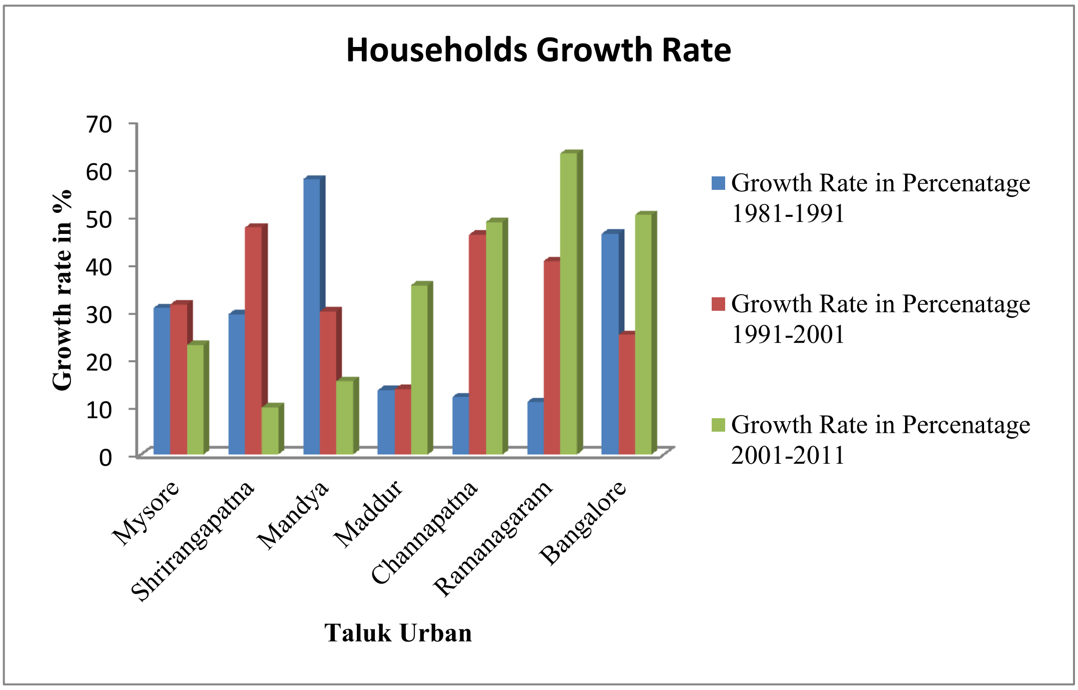


HOUSE HOLD POPULATION

Table No. 1

Number of households in the Mysore – Bangalore corridor

Taluk	No_HH_81	NO_HH_91	NO_HH_01	NO_HH_11
Mysore	78846	113738	165815	215061
Shrirangapatna	3334	23205	25164	27903
Mandya	8256	19475	27799	32839
Maddur	7250	8376	9698	15014
Channapatna	8765	9961	18460	35919
Ramanagaram	8252	9265	15562	42096
Bangalore	422256	515138	947169	2101831



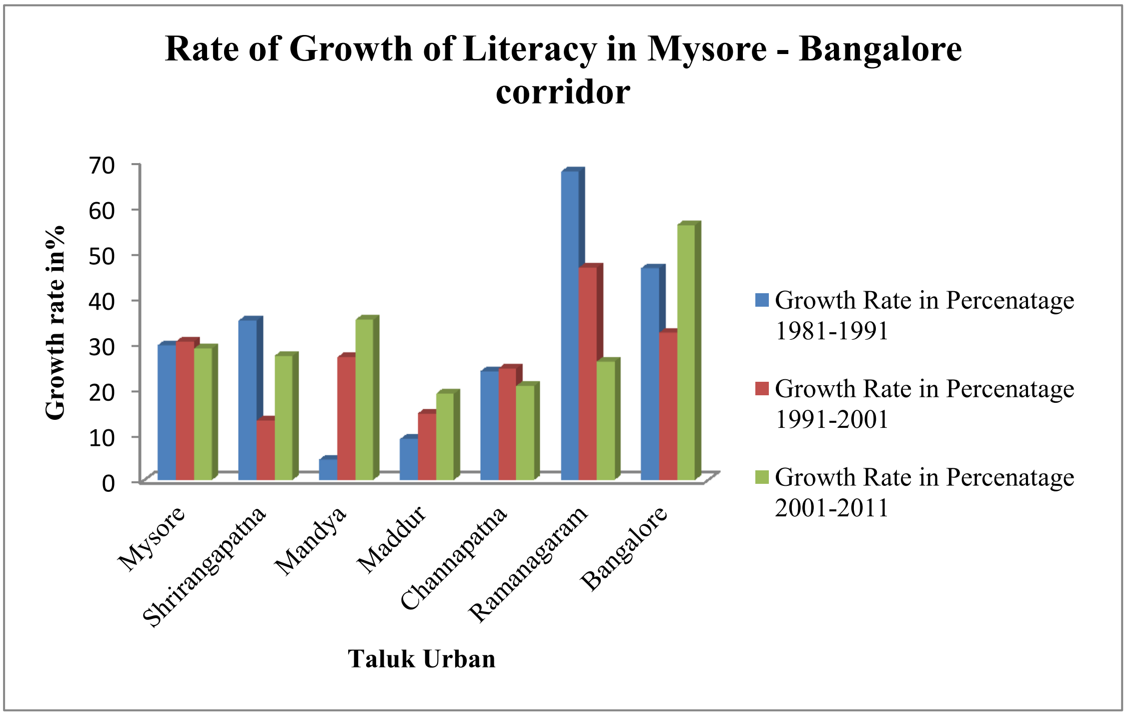
Growth rate of house hold population

Taluk Urban	Growth Rate in Percentage		
	1981-1991	1991-2001	2001-2011
Mysore	31	31	23
Shrirangapatna	29	48	10
Mandya	58	30	15
Maddur	13	14	35
Channapatna	12	46	49
Ramanagaram	11	40	63
Bangalore	46	25	50

LITERACY CHARACTERISTICS:

Number of Literates in Mysore – Bangalore corridor				
Taluk	TOT_LIT_81	TOT_LIT_91	TOT_LIT_01	TOT_LIT_11
Mysore	290017	411769	591478	830906
Shrirangapatna	9110	14009	16110	22133
Mandya	23812	24923	34083	52536
Maddur	17863	19616	22956	28293
Channapatna	24724	32458	42954	54127
Ramanagaram	8541	26390	49407	66743
Bangalore	1545078	2886654	4265702	9677194

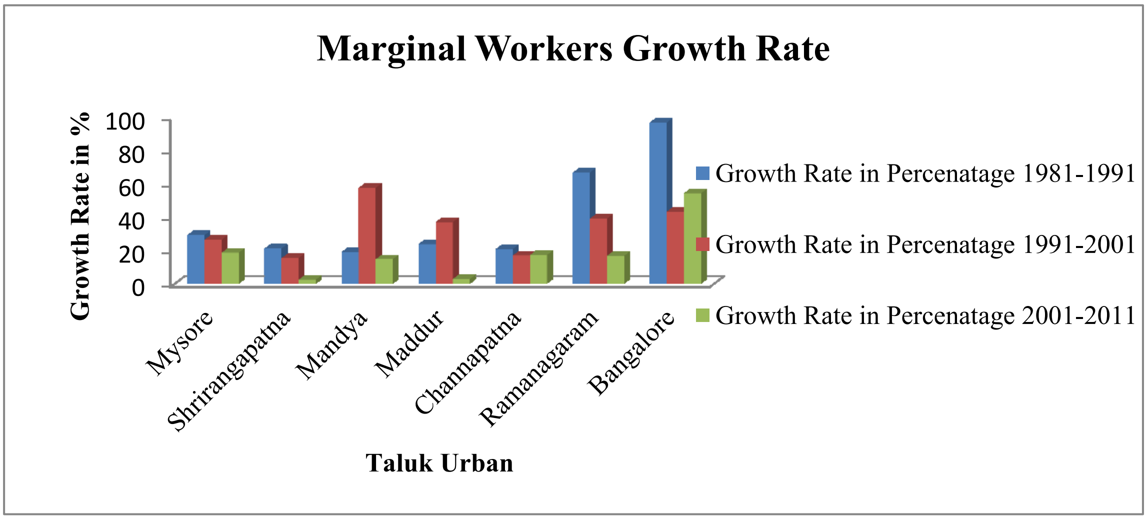
Taluk Urban	Rate of Growth (Percentage) of Literacy in Mysore – Bangalore corridor		
	1981-1991	1991-2001	2001-2011
Mysore	30	30	29
Shrirangapatna	35	13	27
Mandya	4	27	35
Maddur	9	15	19
Channapatna	24	24	21
Ramanagaram	68	47	26
Bangalore	46	32	56



MARGINAL WORKERS

Marginal Workers				
Taluk	TOT_ MWORK_81	TOT_ MWORK_91	TOT_ MWORK_01	TOT_ MWORK_11
Mysore	129639	183279	249360	306784
Shrirangapatna	5303	6731	7965	8174
Mandya	14808	18313	43198	50715
Maddur	13788	18112	28769	29635
Channapatna	13772	17401	20978	25358
Ramanagaram	5636	16932	27813	33428
Bangalore	27884	868525	1534642	3364213

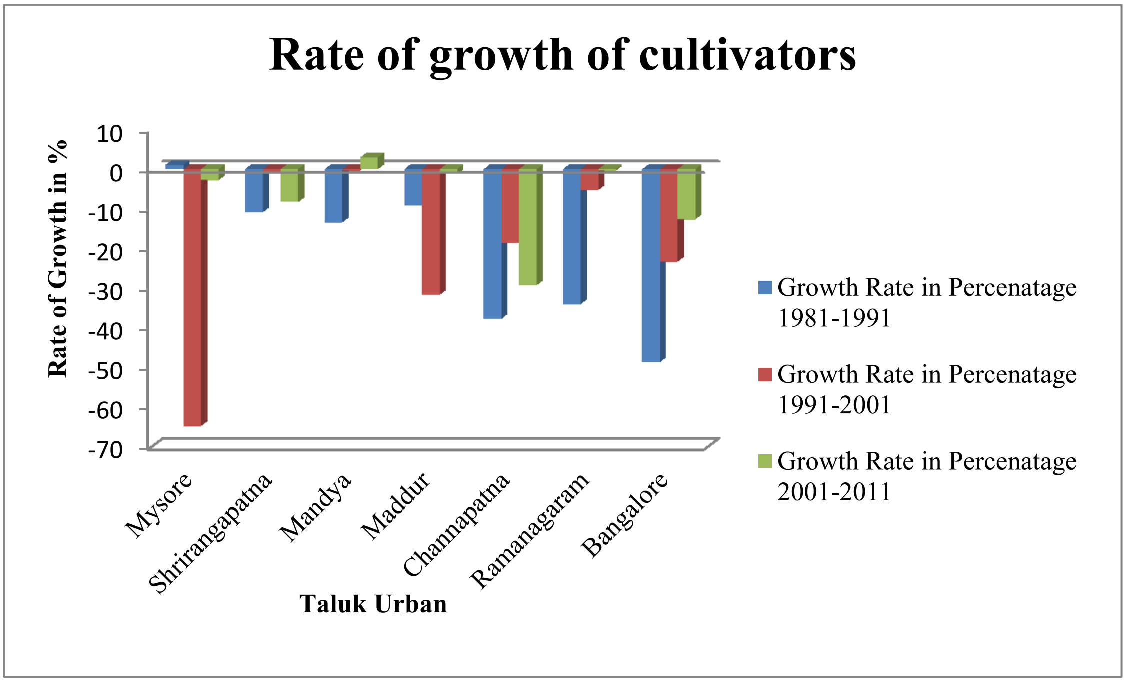
Taluk Urban	Growth Rate in Percentage		
	1981-1991	1991-2001	2001-2011
Mysore	29	27	19
Shrirangapatna	21	15	3
Mandya	19	58	15
Maddur	24	37	3
Channapatna	21	17	17
Ramanagaram	67	39	17
Bangalore	97	43	54



PROPORTION OF POPULATION IN AGRICULTURE OCCUPATION

Number of cultivators				
Taluk	TOT_MA_CL_81	TOT_MA_CL_91	TOT_MA_CL_01	TOT_MA_CL_11
Mysore	3761	3802	2306	2245
Shrirangapatna	2938	2650	2619	2419
Mandya	2844	2508	2500	2576
Maddur	942	864	656	648
Channapatna	3943	2862	2414	1867
Ramanagaram	917	684	650	648
Bangalore	2152	1447	1173	1041

Rate of Growth of Cultivators in Percentage			
	1981-1991	1991-2001	2001-2011
Mysore	1	-65	-3
Shrirangapatna	-11	-1	-8
Mandya	-13	0	3
Maddur	-9	-32	-1
Channapatna	-38	-19	-29
Ramanagaram	-34	-5	0
Bangalore	-49	-23	-13

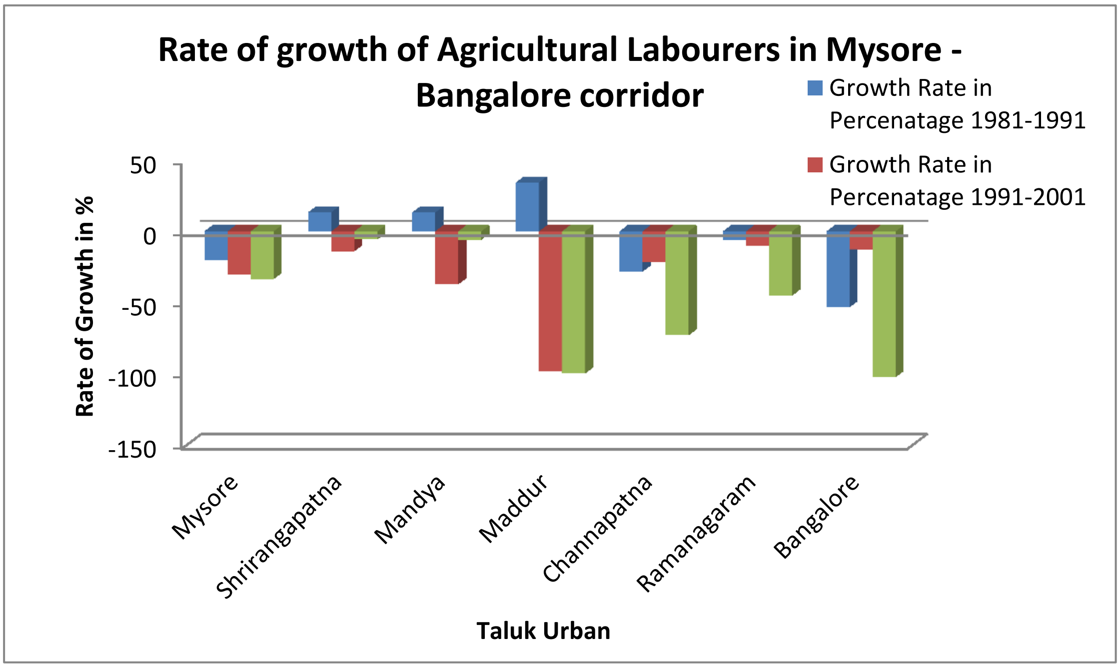


Agricultural Labourers

NUMBER OF AGRICULTURE LABOURS				
Taluk	TOT_AL_81	TOT_AL_91	TOT_AL_01	TOT_AL_11
Mysore	1402	1167	896	671
Shrirangapatna	1936	2235	1962	1857
Mandya	1806	2078	1514	1429
Maddur	1127	1714	864	432
Channapatna	1556	1212	995	575
Ramanagaram	1151	1082	984	678
Bangalore	2701	1761	1563	772

	Rate of Growth Rate of agriculture labour in Percentage		
	1981-1991	1991-2001	2001-2011
Mysore	-20	-30	-34
Shrirangapatna	13	-14	-6
Mandya	13	-37	-6
Maddur	34	-98	-100
Channapatna	-28	-22	-73
Ramanagaram	-6	-10	-45

Bangalore	-53	-13	-102

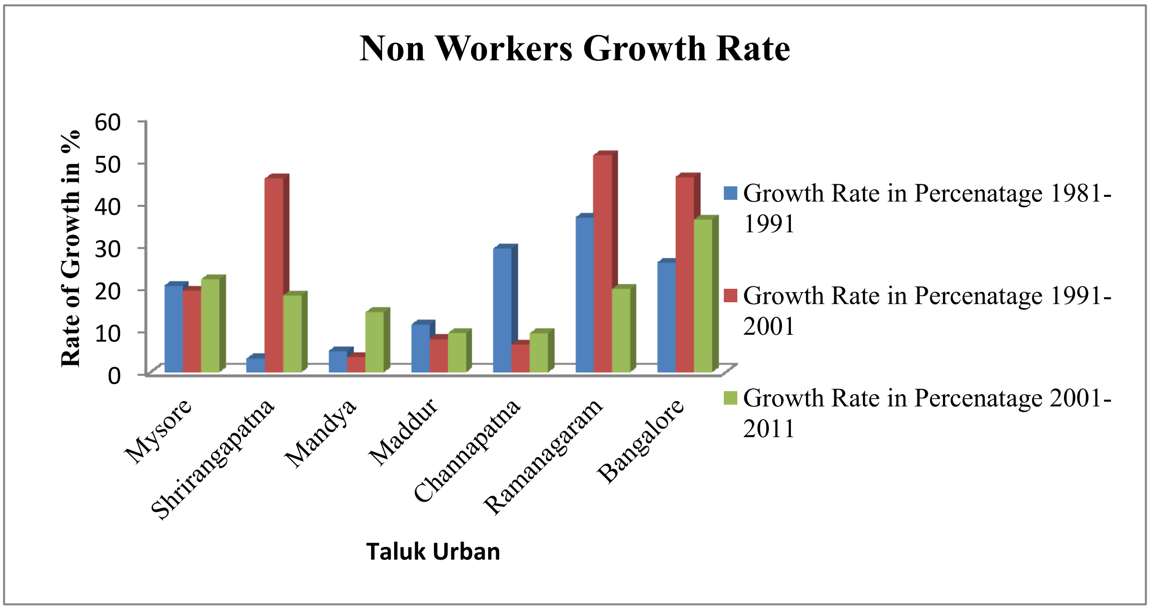


Non Workers

NUMBER OF NON WORKERS IN MYSORE – BANGALORE CORRIDOR				
Taluk	TOT_ N_WRK_81	TOT_ N_WRK_91	TOT_ N_WRK_01	TOT_ N_WRK_11
Mysore	338334	425014	525656	672837
Shrirangapatna	12808	13232	24360	29748
Mandya	35426	37288	38632	44979
Maddur	30169	33964	36815	40517
Channapatna	26408	37267	39873	43881
Ramanagaram	11728	18450	37805	47010
Bangalore	1472130	1986092	3681170	5751281

GROWTH RATE OF NON WORKERS IN PERCENTAGE			
	1981-1991	1991-2001	2001-2011
Mysore	20	19	22
Shrirangapatna	3	46	18
Mandya	5	3	14
Maddur	11	8	9
Channapatna	29	7	9

Ramanagaram	36	51	20
Bangalore	26	46	36



The spatial characteristics indicate that the region is fertile for a rapid growth in view of the very strong potency-profile of the growth characteristics. There is a very high growth in Bangalore, followed by Mysore and all other urban centres with respect to increasing literacy, decrease of employment in agriculture, increasing household population etc. in the entire region based on the ranking of the centres.

TRENDS PATTERNS AND PROCESS OF URBANIZATION IN MYSORE – BANGALORE URBAN CORRIDOR

The urban centres located in the Mysore – Bangalore Urban Corridor can be classed into 4 groups.

1. Bangalore
2. Mysore.
3. Mandy, and Ramanagara
4. Srirangapatana, Pandavapura, Malvalli, Maddur, and Channapatana.

The fourth group of urban areas are Srirangapatana, Pandavapura, Malvalli, Maddur and Channapatana. Srirangapatana town had a total population of 25,061 in 2011, Pandavapura

20,400,

Table No.(1)

BANGALORE URBAN AGGLOMERATION (1981 – 2011)

Malvalli 37,600, Maddur – 28,700, and Channapatana – 71,971 according to 2011 census. They come under the category of forth in order of urban importance. They are taluk headquarters and perform local services to the surrounding villages.

BANGALORE METROPOLITAN AREA

Bangalore is the metropolitan city as per provisional reports of census of India, the population of Bangalore in 2011 was 85 lakhs, and 131 lakhs in 2021 census with a growth rate of 3.55%. It is the premier city of not only the study area but it is the fifth largest city of India. The gigantic size of the metropolis is indicative of the abundant local and regional impact on all frontiers of activities.

The buffer zone has been executed to study the various regional dimensions within 20 Kms around Bangalore metropolitan area. The buffer area around Bangalore contained 702 to 612 villages during different times. Their numbers have been varying as a result of the increasing population and merging within the metropolitan area. However it is noticed that the merging is more predominant feature of this region.

VILLAGE POPULATION	_1981	1991	2001	2011
0 - 500	280	268	236	187
500 - 1000	184	214	194	150
1000 - 5000	6	209	245	234
5000 - 10,000	2	11	21	22
10000 -20,000	3	0	1	14
20,000 - 50,000	204	0	0	2
50,000 - 100,000	20	0	0	3
100,000 - 500,000	0	0	0	0
500,000 - 1000,000	0	0	1	2
TOTAL VILLAGES	699	702	699	612

The number containing population less than 5000 were 464, 691, 675, 571 respectively during 1981, 1991, 2001, and 2011 respectively. Whereas the number of towns in the size of 5000 – 10000 have been consistently increasing from 2, 11, 21 and 21 during the same period. The number of urban centres with 10,000 to 20,000 have suddenly increased from 3 in 1981 to 14 in 2011.

The extent of Bangalore expansion has impacted on the life and occupation of people in all the neighbouring regions spread over the entire state of Karnataka, however its impact on the vicinity areas has a very strong neighbourhood connotation. The taluks of Anekal, Kanakapura, Magadi, Nelamangala, and of course the city itself is largely rooted inside the taluks of Bangalore north, south and east.

(Table No. 3) BANGALORE URBAN AGGLOMERATION AND POPULATION DISTRIBUTION IN 1991								
	Anekal	Banga lore East	Kanaka pura	Magadi	Bangalore _North	Bangalo re_ south	Nelam angala	Bangalore _1991
0 - 500	23	33	23	25	100	54	10	268
500 - 1000	14	34	17	17	76	49	7	214
1000 - 5000	18	39	30	13	65	43	1	209
5000 - 10,000	1	3	1	0	2	4	0	11
10000 -20,000	0	0	0	0	0	0	0	0
20,000 - 50,000	0	0	0	0	0	0	0	0
50,000 - 100,000	0	0	0	0	0	0	0	0
100,000 - 500,000			0	0	0	0	0	0
500,000 - 1000,000	1	0	0	0	0	0	0	0
TOTAL VILLAGES	56	72	71	55	243	150	18	702

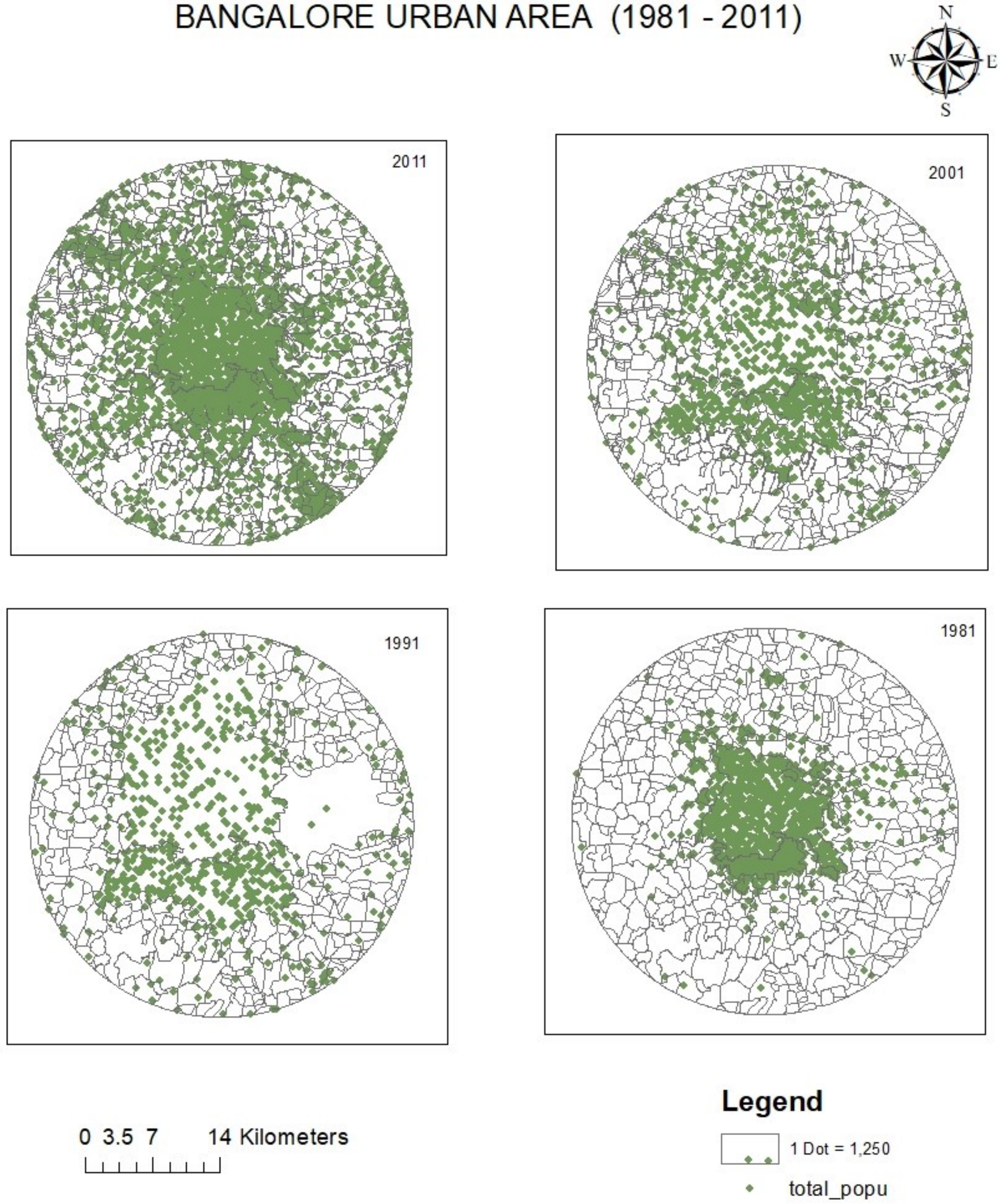
(Table No. 5) BANGALORE URBAN AGGLOMERATION AND POPULATION DISTRIBUTION IN 2011								
VILLAGE POPULATION	Anek al	Bangal ore East	Kanakap ura	Maga di	Nelman gala	Bangal ore _North	Bangalo re_ south	TOTAL VILLAGES
0 - 500	14	17	23	27	11	62	33	187
500 - 1000	17	9	34	17	4	53	16	150
1000 - 5000	28	35	32	10	2	80	47	234
5000 - 10,000	6	2	0	0	0	9	5	22
10000 -20,000	4	0	1	0	1	5	3	14
20,000 - 50,000	1	0	0	0	0	0	1	2
50,000 - 100,000	1	0	0	0	0	1	1	3
100,000 - 500,000	0	0	0	0	0	0	0	0
500,000 - 1000,000	0	0	0	0	0	1	1	2
>100,00000	0	0	0	0	0	0	1	0
TOTAL VILLAGES	71	63	90	54	18	213	107	612

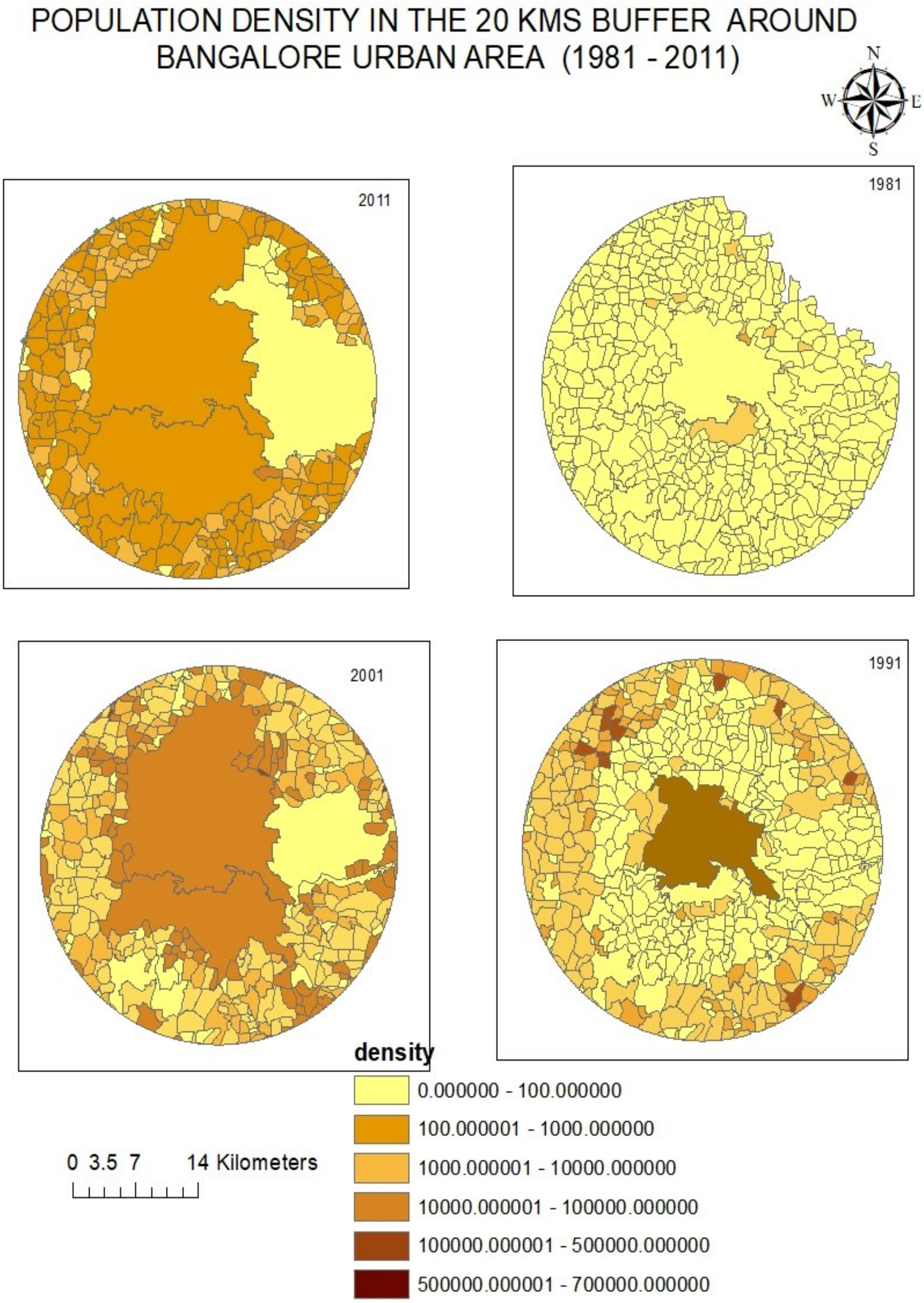
Table 2, 3, 4 and 5 shows the number of villages existing inside each taluk in the classified buffer during 1981, 1991, 2001, and 2011 respectively.

Table No.(2) BANGALORE URBAN AGGLOMERATION AND POPULATION DISTRIBUTION IN 1981								
	Anekal	Bangal ore East	Kanak apura	Mag adi	Bangal ore_ North	Bangal ore South	Nela mang ala	
0 - 500	30	19	26	20	65	46	44	250
500 - 1000	11	25	22	10	46	54	10	178
1000 - 5000	0	3	0	0	2	1	0	6
5000 - 10,000	0	0	0	0	1	1	0	2
10000 -20,000	0	2	0	0	1	0	0	3
20,000 - 50,000	15	17	22	24	55	38	19	190
50,000 - 100,000	0	6	1	0	11	2	0	20
100,000 - 500,000	0	0	0	0	0	0	0	0
500,000 - 1000,000	56	72	71	54	181	142	73	649

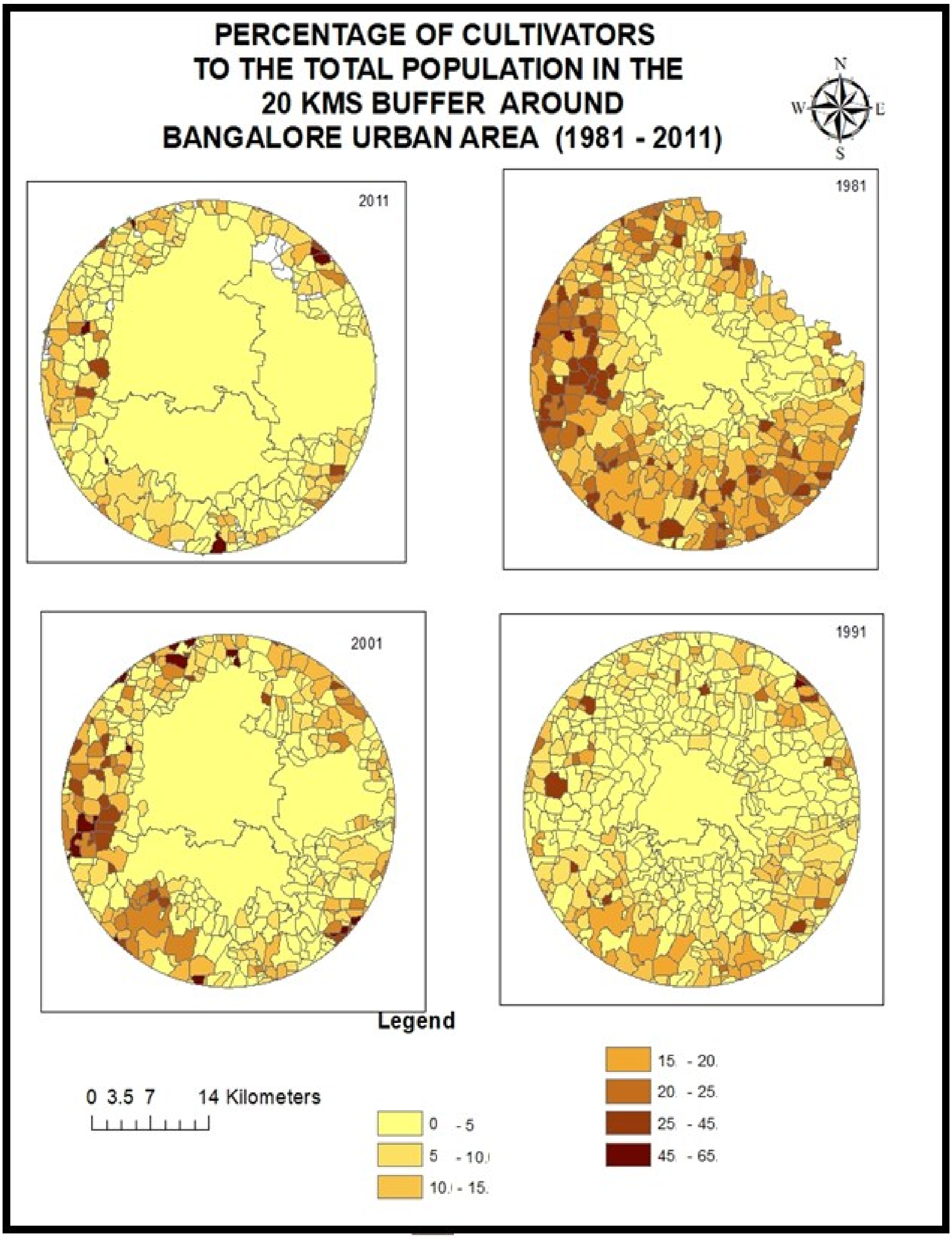
The perceived pattern is indicating a trend towards merging villages into the Bangalore Urban Agglomeration. The growth and expansion of urban areas is largely supported by its Economic Base which would sustain urbanization.

POPULATION DISTRIBUTION IN THE 20 KMS BUFFER AROUND BANGALORE URBAN AREA (1981 - 2011)

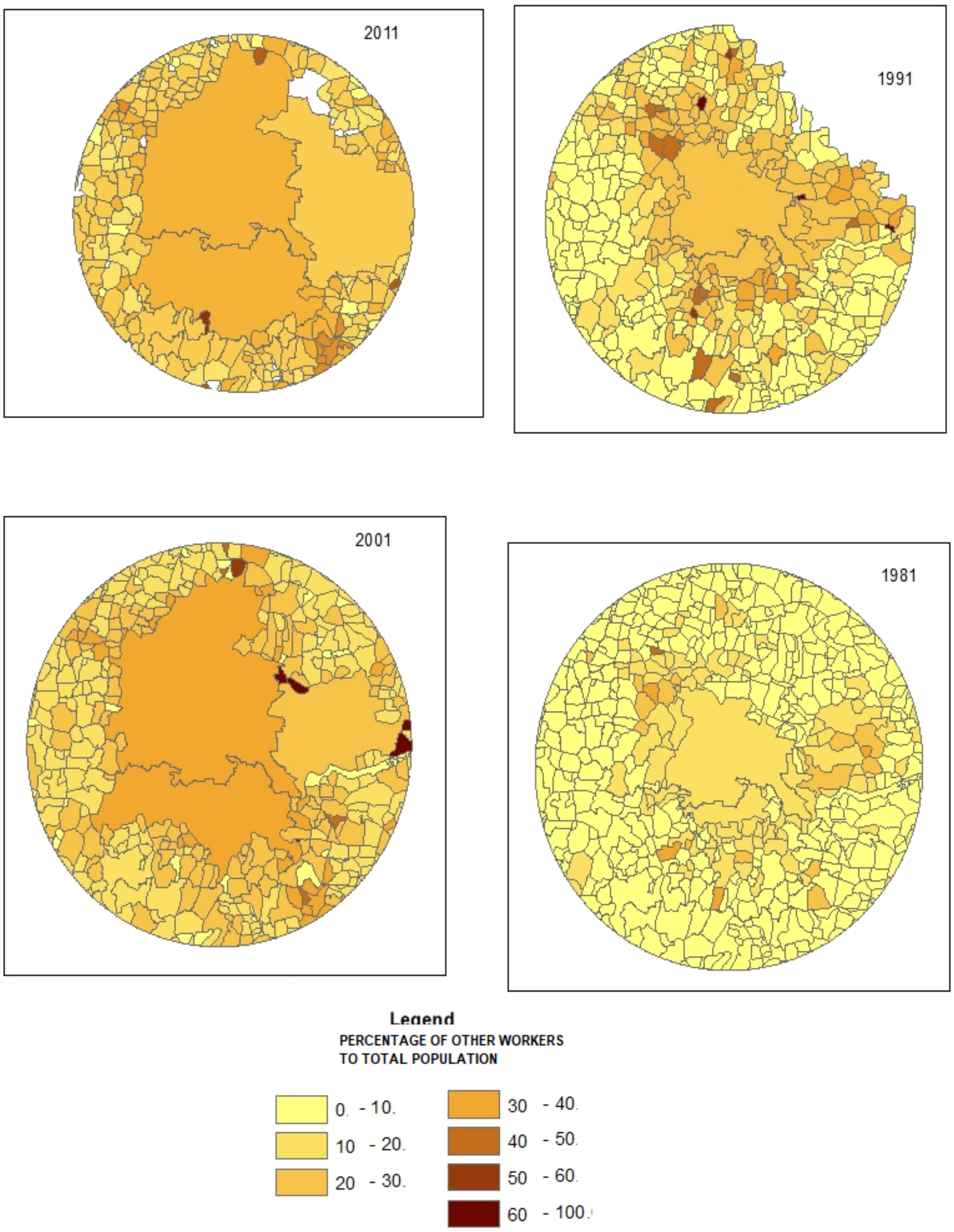




The figure No. 1 and 2 illustrates the growth of population from 1981 to 2011 and the resultant density of population. With the increasing urban population, there is a drastic shift of occupation from "Agriculture" to "Other Than Agriculture"


PERCENTAGE OF CULTIVATORS
TO THE TOTAL POPULATION IN THE
20 KMS BUFFER AROUND
BANGALORE URBAN AREA (1981 - 2011)
N
W
E
S
2011
1981
2001
1991
Legend
0 3.5 7 14 Kilometers
0 - 5
5 - 10.
10. - 15.
15. - 20.
20. - 25.
25. - 45.
45. - 65.

PERCENTAGE OF OTHER WORKERS TO THE TOTAL POPULATION IN THE 20 KMS BUFFER AROUND BANGALORE URBAN AREA (1981 - 2011)



MYSORE URBAN AGGLOMERATION

Urbanization in Mysore taluk has been a very prominent feature from the historical times. But with the shifting of the status of capital city from Mysore to Bangalore there was a sudden halting effect in the process of urbanization. However the overcrowding and over congestion in Bangalore Metropolitan area, has led to spurts in the growth of urbanization in Mysore Urban area. Mysore is the second important city in the study area. According to 2011 census it has a total population of 8.9 lakhs. Mysore has already attained the status of metropolitan city with a total population of 12.6 lakhs in 2021 with a growth rate of 2.07%.

(Table No. 6)

DISTRIBUTION OF DIFFERENT CLASSES OF POPULATION IN 20 KMS BUFFER AROUND MYSORE URBAN AGGLOMERATION

urban	Mysore_1981	Mysore_1991	Mysore_2001	Mysore_2011
0 - 500	46	15	12	15
500 - 1000	47	20	16	10
1000 - 5000	51	12	18	15
5000 - 10000	20	18	11	9
10000 - 20000	0	77	80	83
20000 - 50000	0	0	0	0
50000 - 100000	0	0	0	1
100000 - 500000	0	3	8	10
	0	0	1	0
Total	167	145	145	143

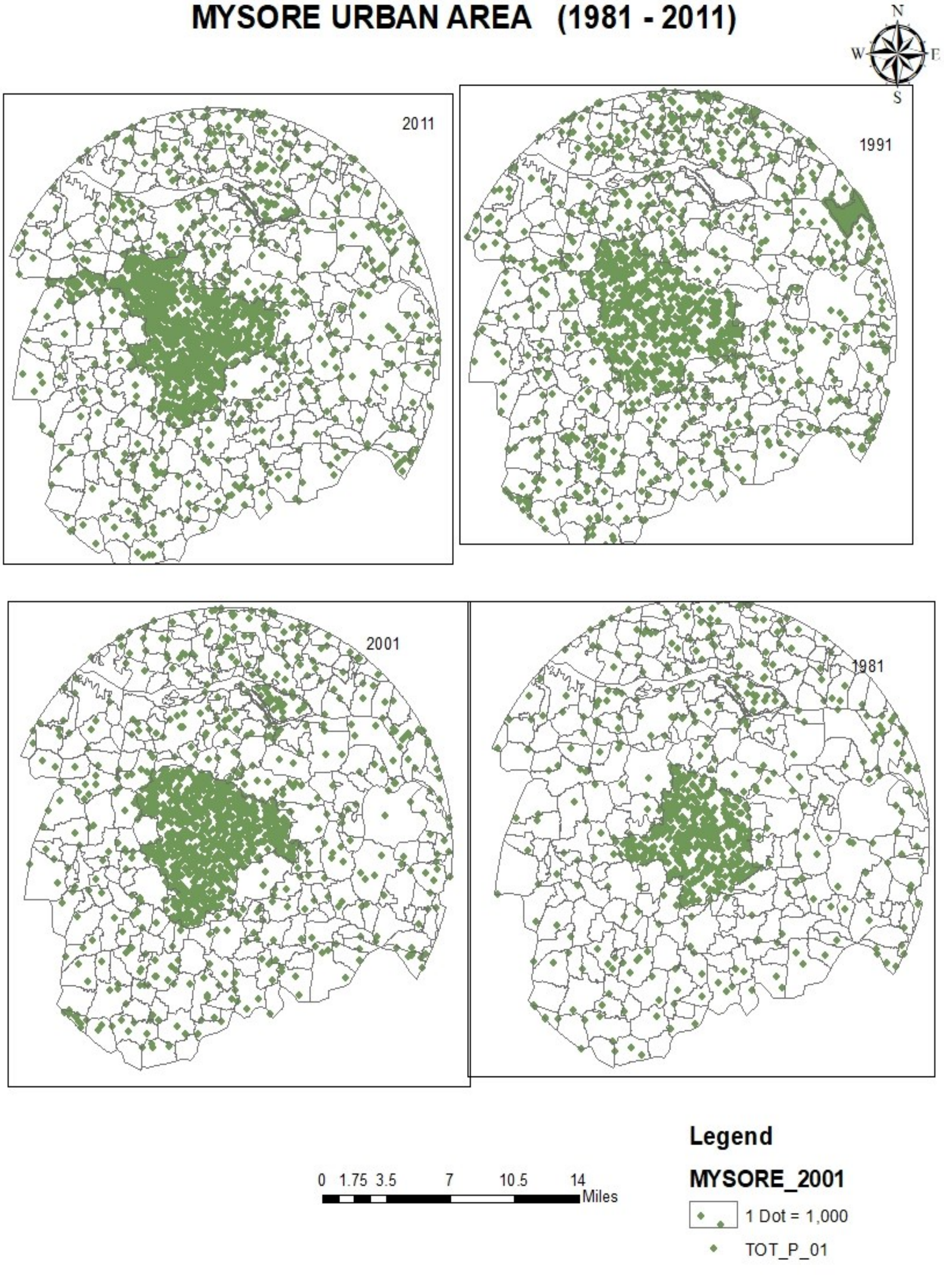
Urbanization in Mysore urban Agglomeration has leapt up in a great speed in recent times with a rapid increase in the population living in surrounding villages thereby leaving no reason to reconsider the inclusion of these villages into the agglomeration. The 20 Kms buffer is largely consisting of towns of the size of class 6 and 7 with a population between 5000 – 10,000 and 10,000 – 20,000. This pattern of settlements will help in the balanced pattern for a planned growth in future.

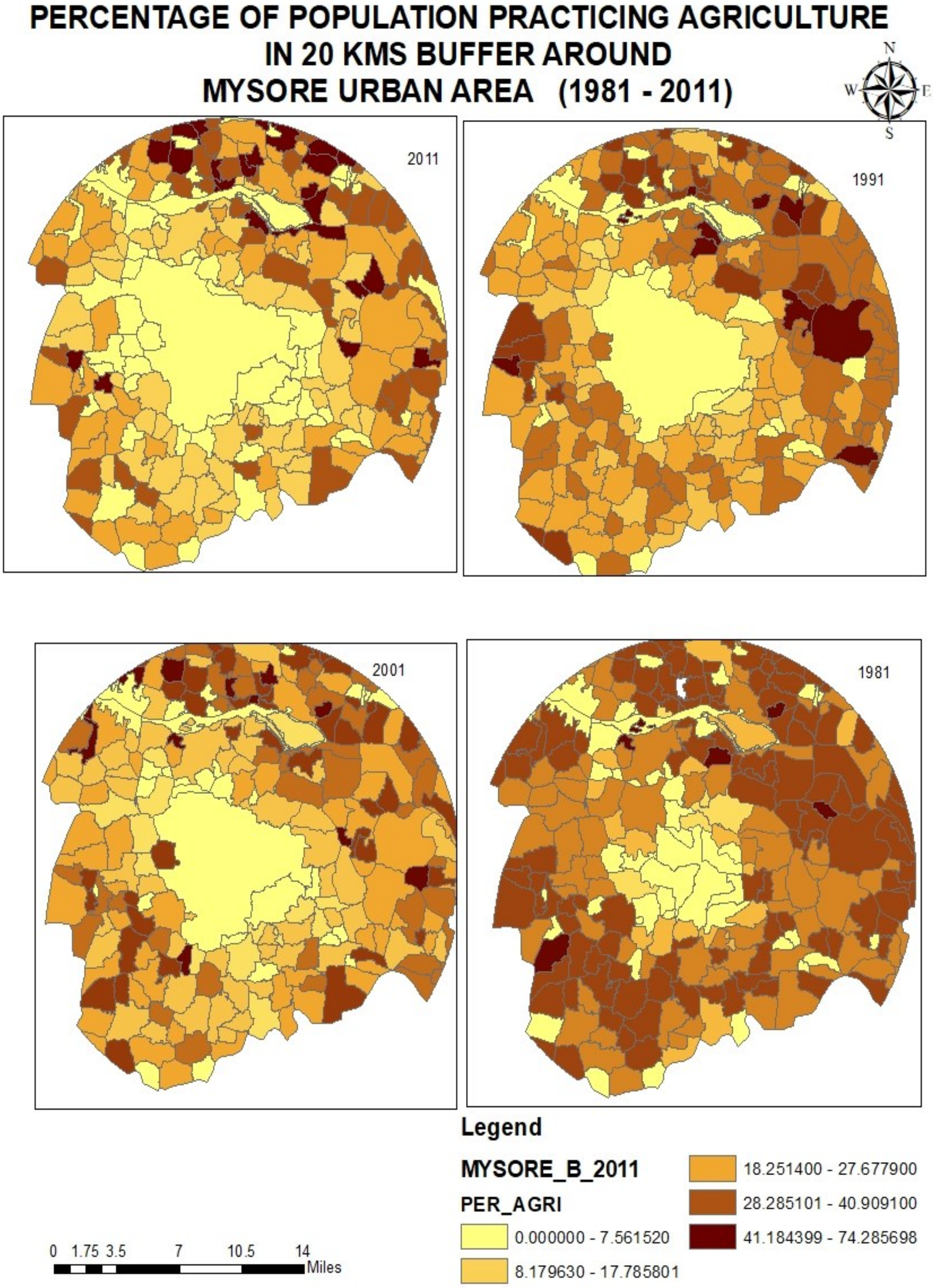
PERCENTAGE OF POPULATION PRACTICING AGRICULTURE OCCUPATION IN 20 KMS BUFFER AROUND MYSORE AGGLOMERATION				
	Mysore_1981	Mysore_1991	Mysore_2001	Mysore_2011
0	0	18	13	18
0 - 5	22	2	8	13
5 - 10	4	1	10	19
10 - 15	12	6	15	20
15 - 20	12	17	17	23
20 - 30	54	49	47	34
30 - 40	49	39	17	11
40 - 50	13	10	16	4
50 - 75	1	3	2	1
75 - 100	0	0	0	0
	167	145	145	143

PERCENTAGE OF POPULATION PRACTICING OCCUPATION OTHER THAN AGRICULTURE IN 20 KMS BUFFER AROUND MYSORE URBAN AGGLOMERATION				
	Mysore_1981	Mysore_1991	Mysore_2001	Mysore_2011
0	22	17	14	98
0 - 5	12	123	17	18
5 - 10	1	0	31	0
10 - 15	12	5	27	4
15 - 20	54	0	29	2
20 - 30	49	0	21	3
30 - 40	13	0	6	2
40 - 50	4	0	0	5
50 - 75	0	0	0	4
75 - 100	0	0	0	7
	167	145	145	143

The urban population of Mysore agglomeration is growing at a very fast rate. Most of the villages in the agglomeration have urban infiltration with a sweeping change in the characteristics of villages.

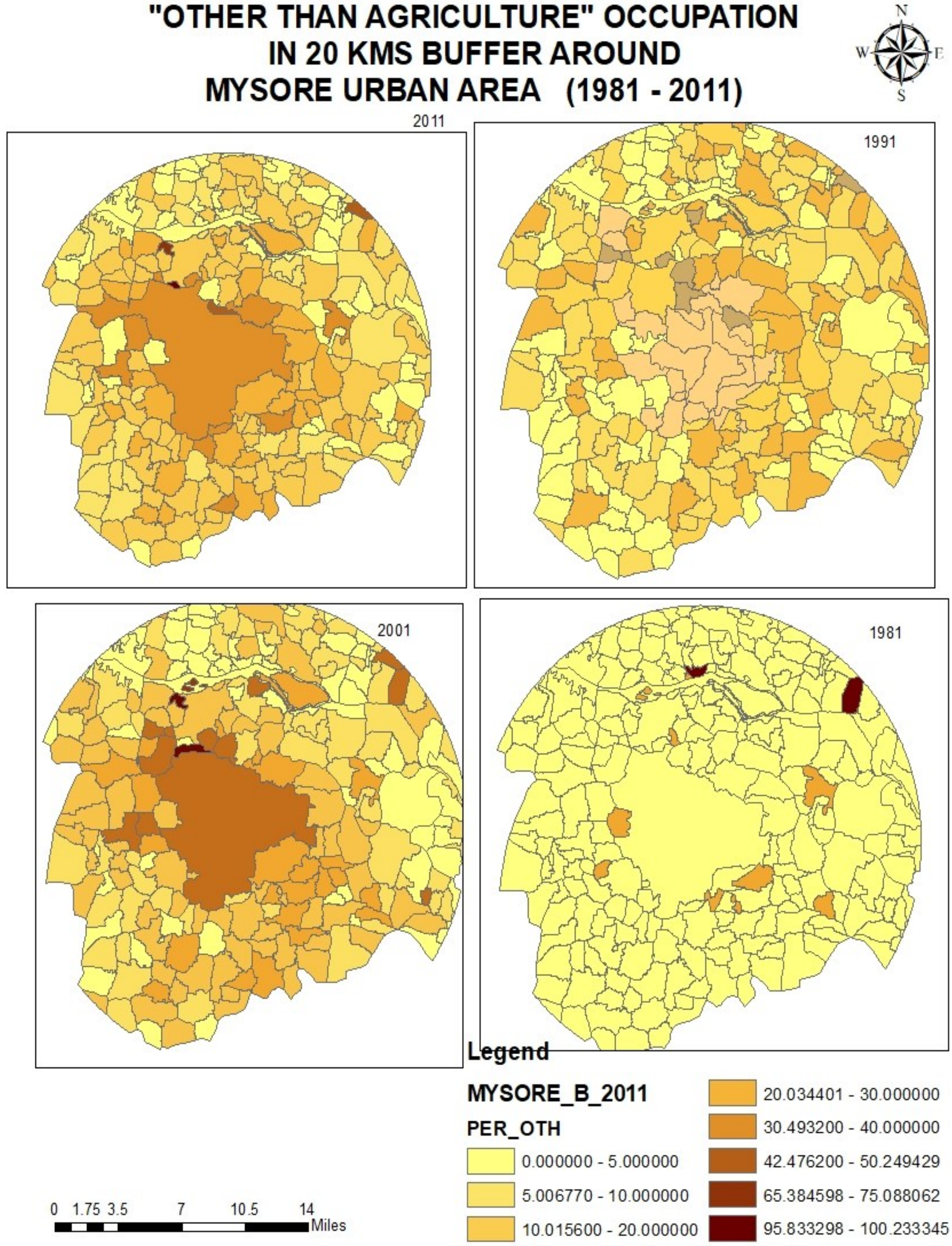
DISTRIBUTION OF POPULATION IN 20 KMS BUFFER AROUND MYSORE URBAN AREA (1981 - 2011)





Mandya urban area:

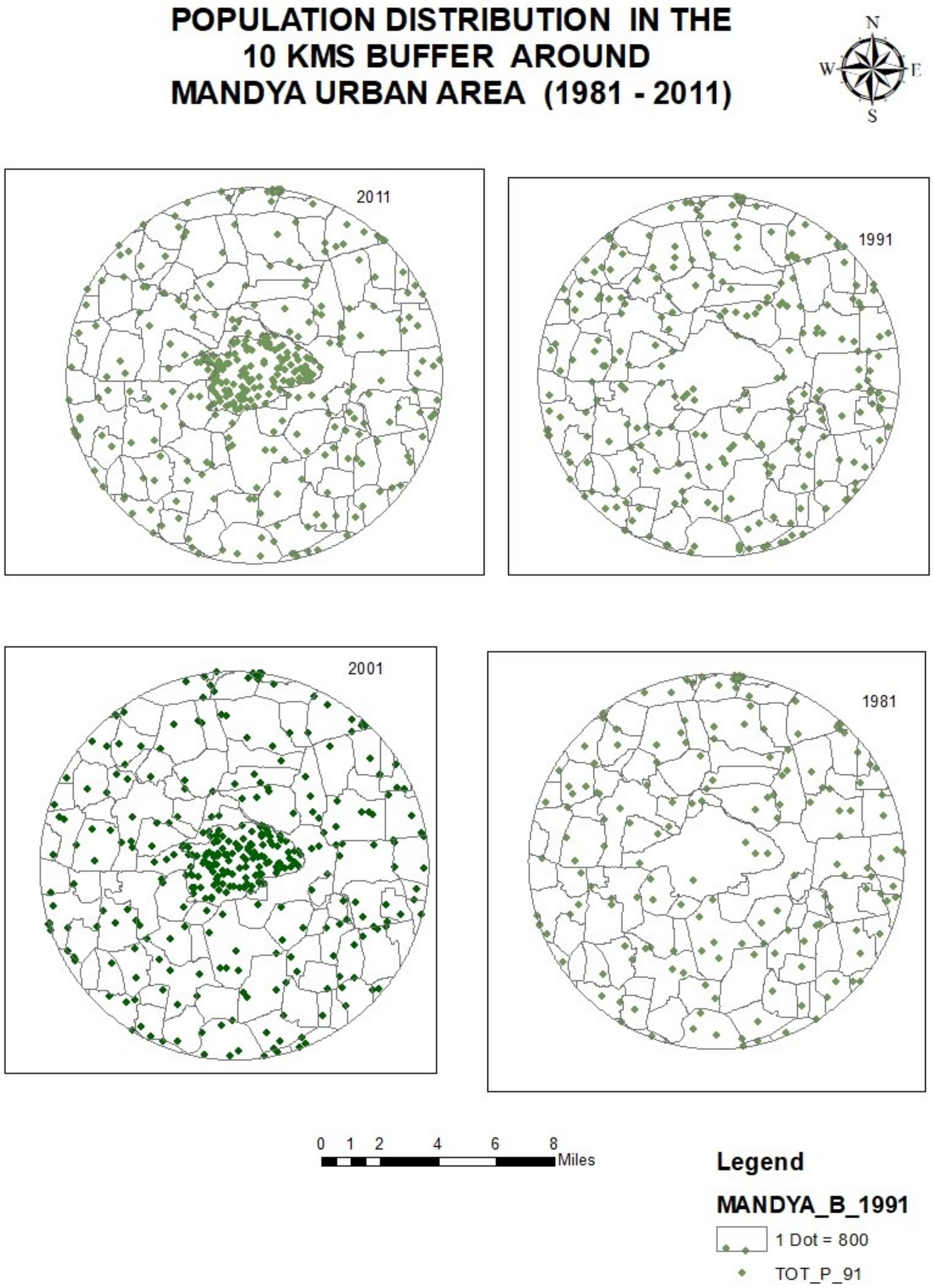
PERCENTAGE OF POPULATION PRACTICING "OTHER THAN AGRICULTURE" OCCUPATION IN 20 KMS BUFFER AROUND MYSORE URBAN AREA (1981 - 2011)



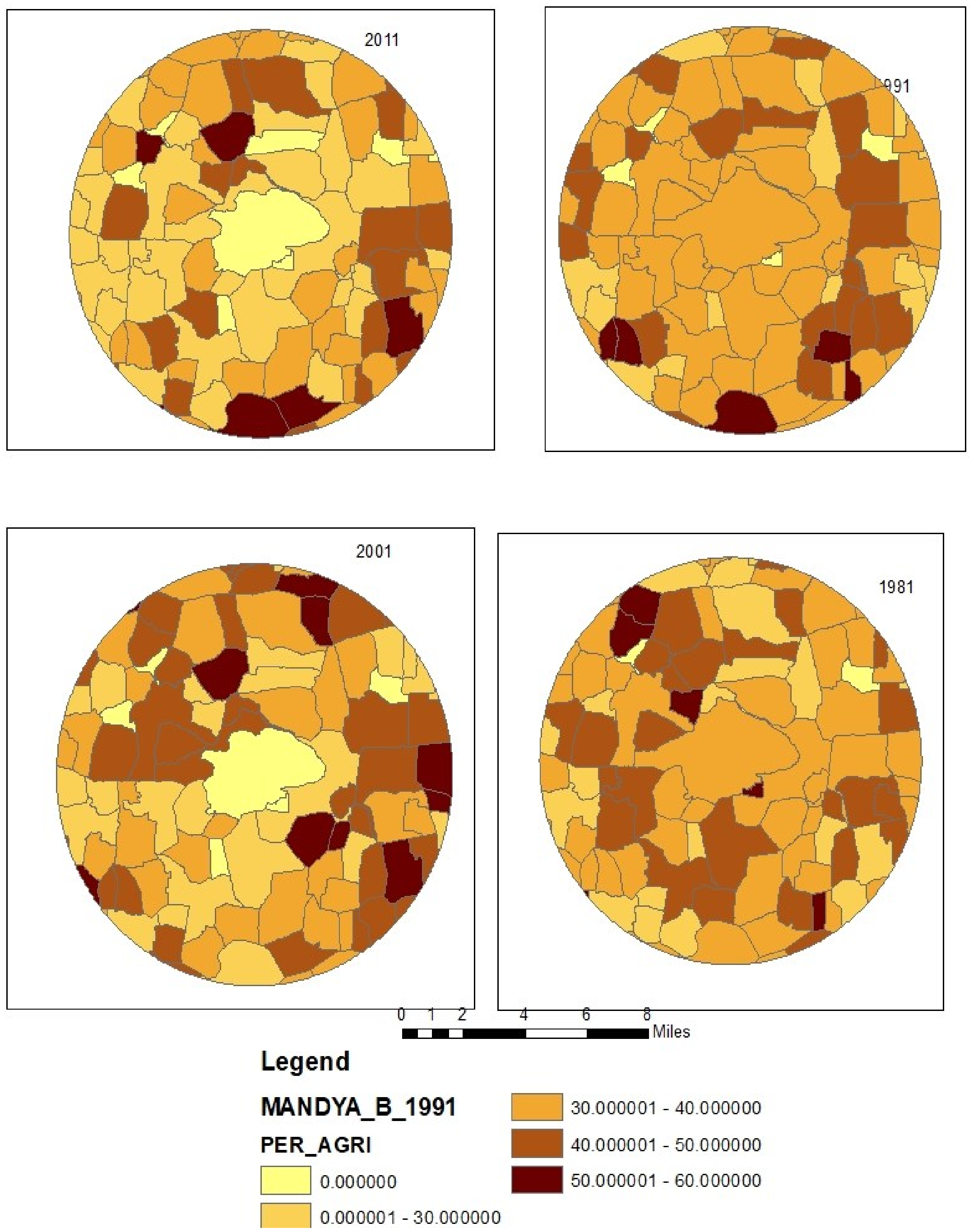
3. MANDYA AND RAMANAGARA

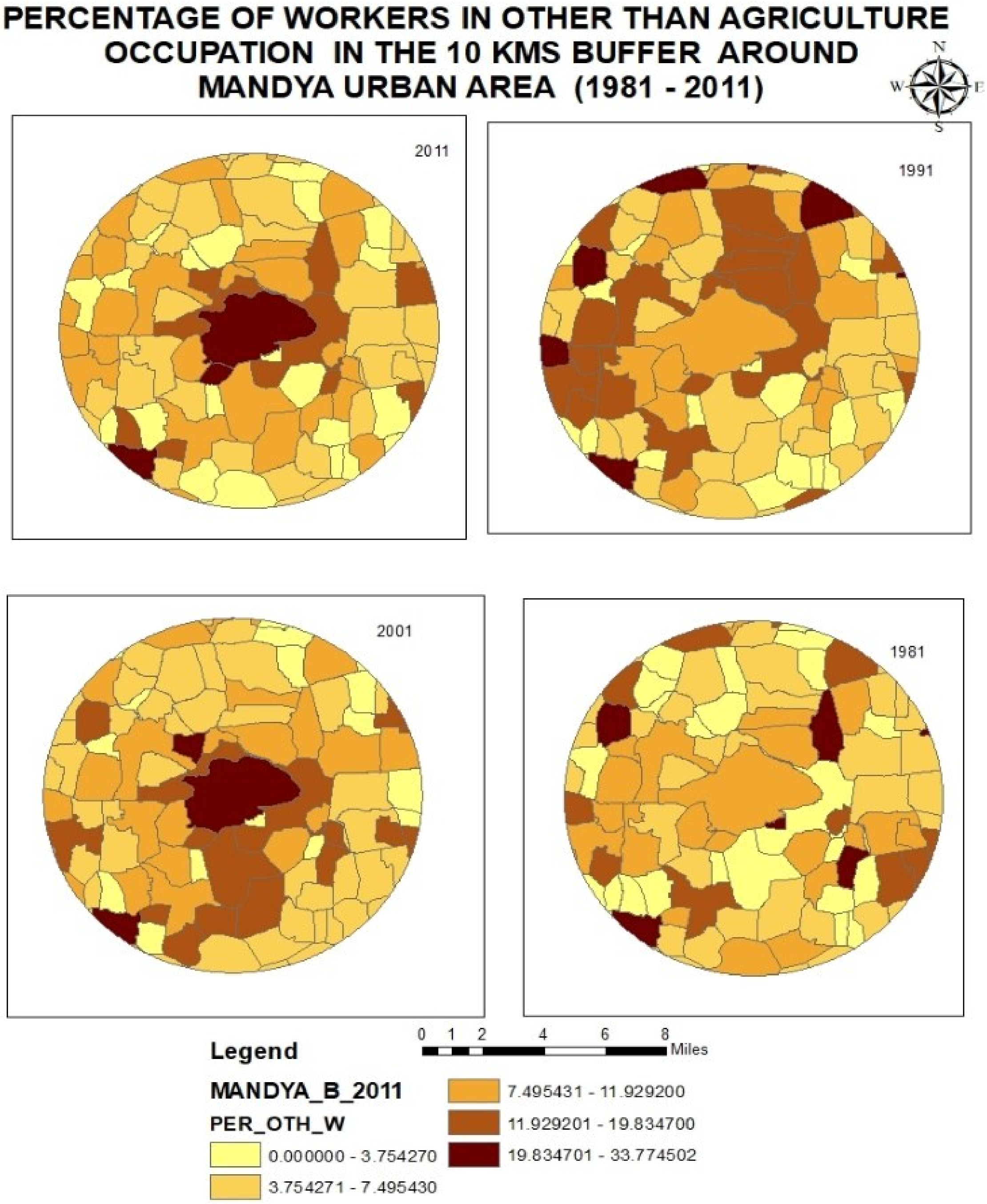
The third group of urban centres include Mandya and Ramanagara. The third class of urban centres are Mandy and Ramanagara. Mandya urban area had a total population of 1.37 lakhs in 2011.

POPULATION DISTRIBUTION IN BUFFER AREA OF 10 KMS AROUND MANDYA URBAN AREA. 1981- 2011)				
urban	1981	1991	2001	2011
0 - 500	56	46	41	43
500 - 1000	45	0	0	0
1000 - 5000	77	47	45	42
5000 - 10000	5	0	0	0
10000 - 20000	0	85	91	91
20000 - 50000	0	183	0	0
50000 - 100000	0	0	1	1
Total	183		0	184


POPULATION DISTRIBUTION IN THE
10 KMS BUFFER AROUND
MANDYA URBAN AREA (1981 - 2011)
N
W
E
S
2011
1991
2001
1981
0 1 2 4 6 8
Miles
Legend
MANDYA_B_1991
1 Dot = 800
TOT_P_91

PERCENTAGE OF WORKERS IN AGRICULTURE OCCUPATION IN THE 10 KMS BUFFER AROUND MANDYA URBAN AREA (1981 - 2011)

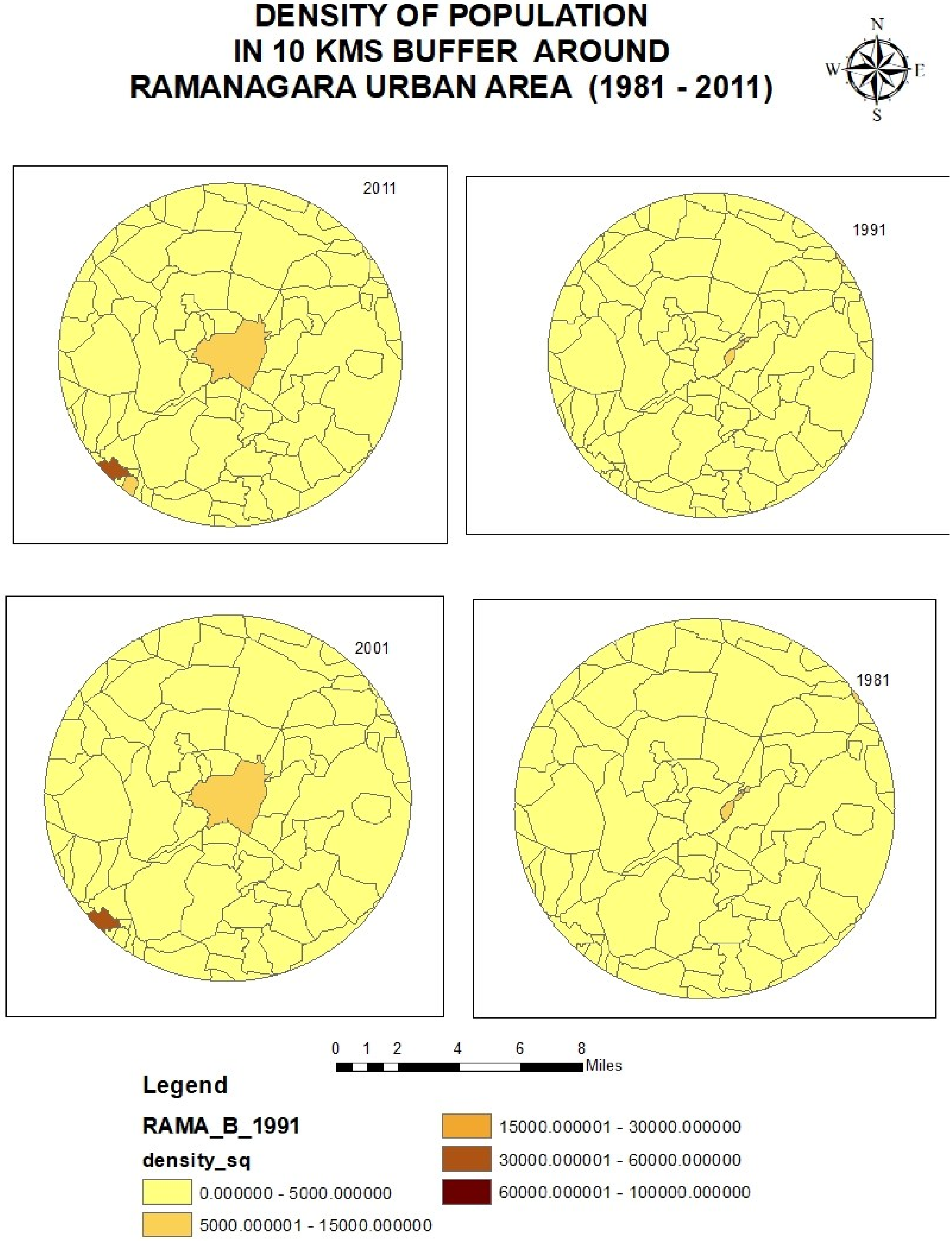


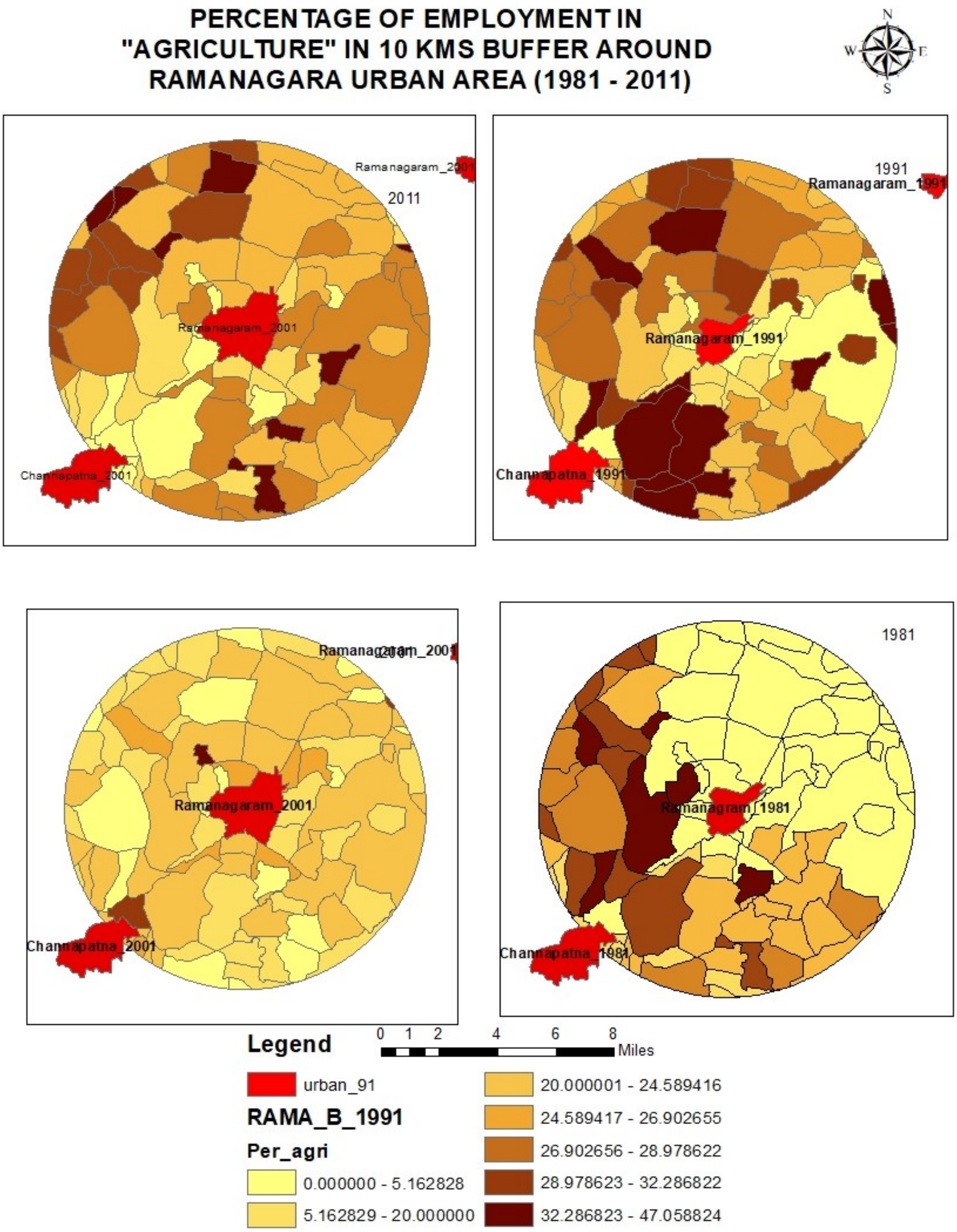

PERCENTAGE OF WORKERS IN OTHER THAN AGRICULTURE OCCUPATION IN THE 10 KMS BUFFER AROUND MANDYA URBAN AREA (1981 - 2011)
N
W
E
S
2011
1991
2001
1981
Legend
0 1 2 4 6 8 Miles
MANDYA_B_2011
PER_OTH_W
0.000000 - 3.754270
3.754271 - 7.495430
7.495431 - 11.929200
11.929201 - 19.834700
19.834701 - 33.774502

Ramanagara municipal area had a population of 95.167 in 2011, and they are the third in the order of urban importance. They are not only important urban centres but also they are the district headquarters and perform important service activities to their surrounding taluks.

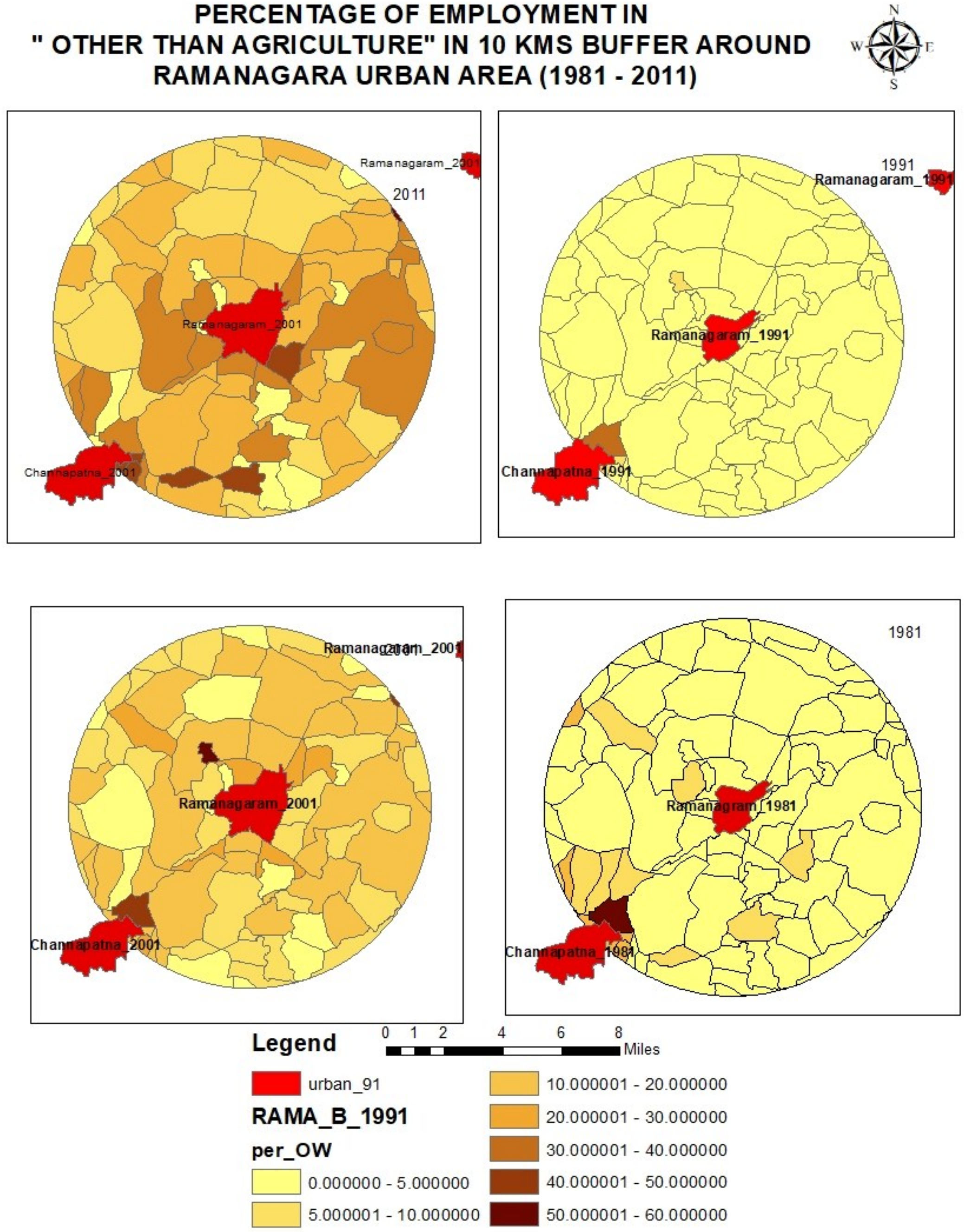
TOTAL POPULATION IN THE 10 KMS BUFFER AROUND RAMANAGARA URBAN AREA (1981 - 2011)

**DENSITY OF POPULATION
IN 10 KMS BUFFER AROUND
RAMANAGARA URBAN AREA (1981 - 2011)**




PERCENTAGE OF EMPLOYMENT IN
"AGRICULTURE" IN 10 KMS BUFFER AROUND
RAMANAGARA URBAN AREA (1981 - 2011)
N
S
E
W
2011
Ramanagaram_2001
Channapatna_2001
1991
Ramanagaram_1991
Channapatna_1991
Ramanagaram_2001
Channapatna_2001
1981
Ramanagram_1981
Channapatna_1981
Legend
0 1 2 4 6 8
Miles
urban_91
RAMA_B_1991
Per_agri
0.000000 - 5.162828
5.162829 - 20.000000
20.000001 - 24.589416
24.589417 - 26.902655
26.902656 - 28.978622
28.978623 - 32.286822
32.286823 - 47.058824

PERCENTAGE OF EMPLOYMENT IN " OTHER THAN AGRICULTURE" IN 10 KMS BUFFER AROUND RAMANAGARA URBAN AREA (1981 - 2011)



PERCENTAGE OF POPULATION PRACTICING “OTHER THAN AGRICULTURE OCCUPATION IN 10 KMS BUFFER AROUND RAMANAGARA URBAN AREA (1981 – 2011)				
	1981	1991	2001	2011
0	9	9	11	79
0 - 5	2	123	27	15
5 - 10	5	2	16	5
10 - 15	38	0	17	6
15 - 20	47	0	14	4
20 - 30	21	0	3	4
30 - 40	1	0	2	7
40 - 50	12	0	41	1
50 - 75	0	0	1	9
75 - 100	0	0	1	10
	135	134	133	140

PERCENTAGE OF POPULATION PRACTICING AGRICULTURE OCCUPATION IN 10 KMS BUFFER AROUND RAMANAGARA URBAN AREA (1981 – 2011)				
	1981	1991	2001	2011
0	9	10	13	6
0 - 5	2	2	7	8
5 - 10	5	3	8	9
10 - 15	38	8	4	9
15 - 20	47	32	38	29
20 - 30	21	45	25	34
30 - 40	1	21	19	22
40 - 50	12	1	4	4
50 - 75	0	12	15	19
75 - 100	0	0	0	0
	135	134	133	140

DISTRIBUTION OF DIFFERENT CLASS SIZES OF POPULATION IN 10 KMS BUFFER AROUND RAMANAGARA URBAN AREA				
	1981	1991	2001	2011
0 - 500	45	37	34	38
500 - 1000	29	0	0	0
1000 - 5000	60	28	27	34
5000 - 10000	0		1	1
10000 - 20000	0	68	70	66
20000 - 50000	1	1	0	0
50000 - 100000	0	1	1	1
	135	134	133	140

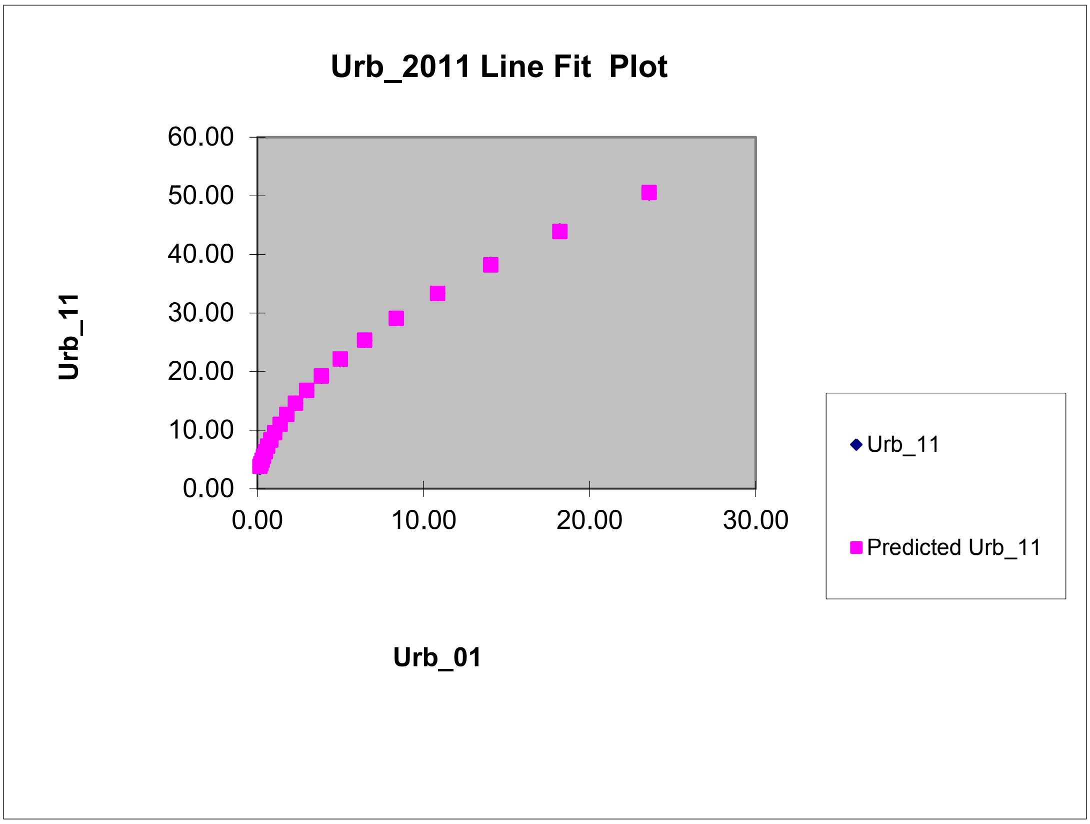
5. The fourth group of urban areas are Srirangapatana, Pandavapura, Malvalli, Maddur and Channapatana. Srirangapatana town had a total population of 25,061 in 2011, Pandavapura 20,400, Malvalli 37,600, Maddur – 28,700, and Channapatana – 71,971 according to 2011 census. They come under the category of forth in order of urban importance. They are taluk headquarters and perform local services to the surrounding villages.

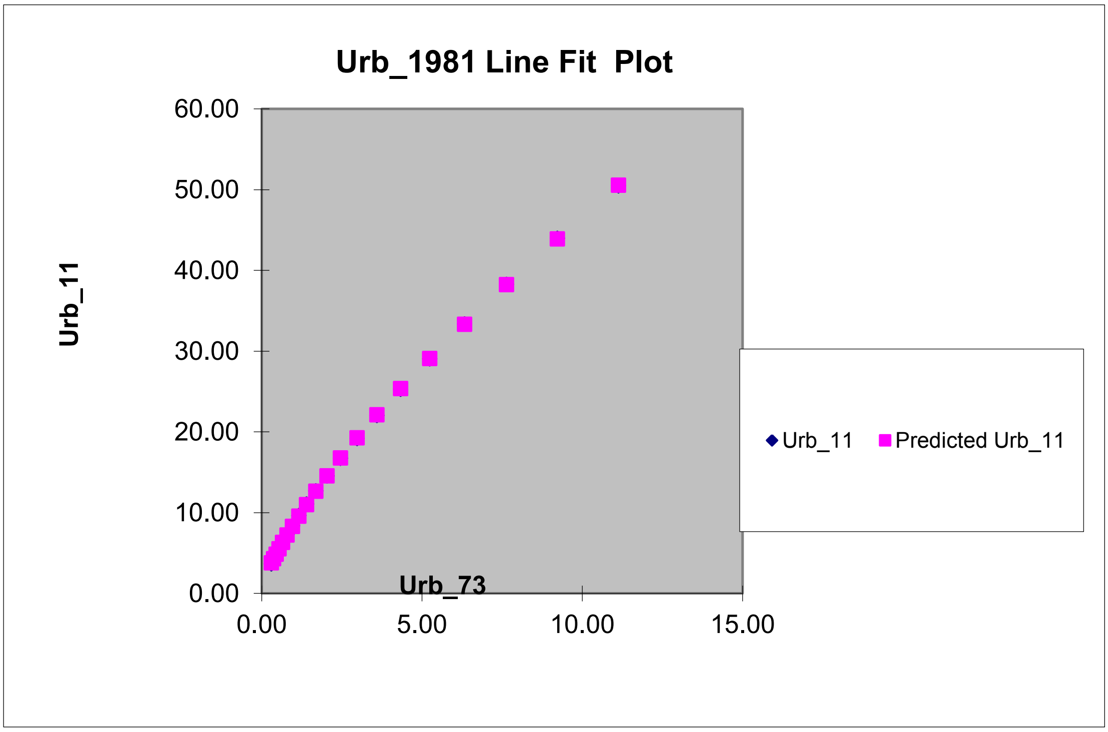
	PERCENTAGE OF POPULATION PRACTICISNG OTHER THAN AGRICULTURE (2011)					
	Channapatna	Maddur_	Malavalli	srirangapatana	Panadavapura	T.Narsipura
	62	72	19		36	17
0 - 5	16	15	6		46	1
10 - 15	3	4	3		7	2
15 - 20	2	5	1		8	1
20 - 30	10	11	3		9	0
30 - 40	14	12	5		5	1
40 - 50	4	5	1		7	4
5 - 10	2	2	2		12	0
50 - 75	20	19	9		9	4
75 - 100	12	16	3		8	1
	145	161	52		147	31

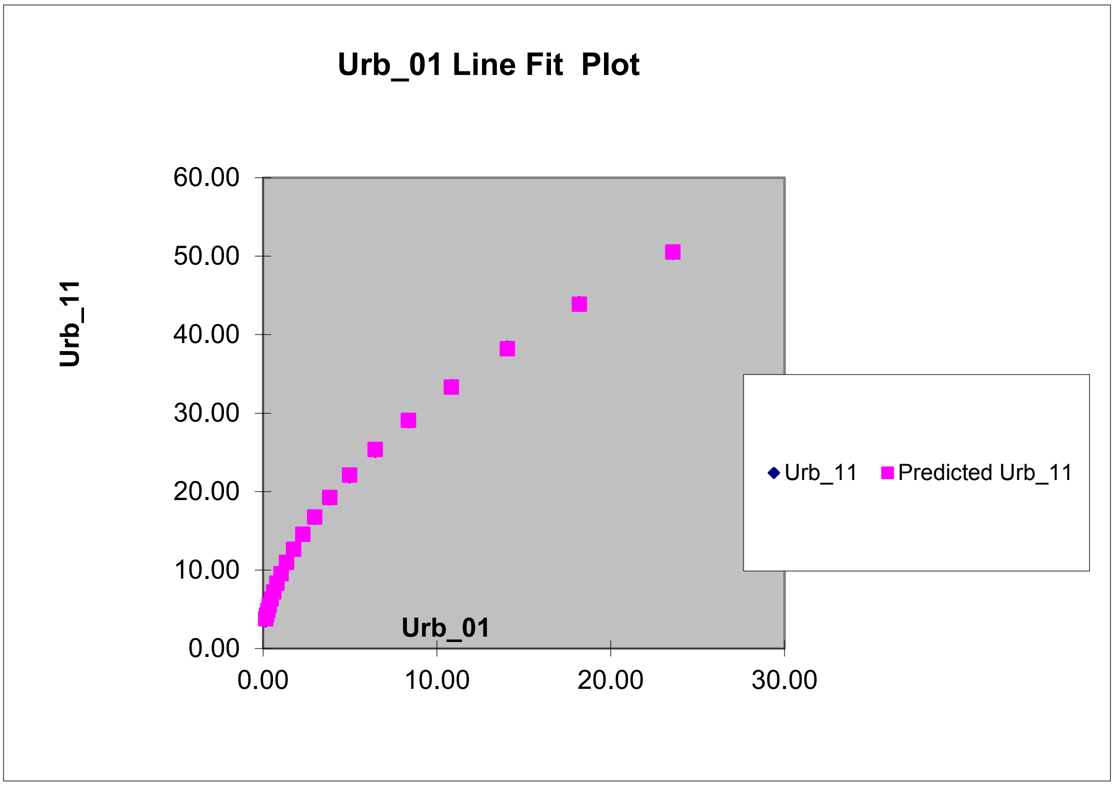
PERCENTAGE OF POPULATION PRACTICISNG AGRICULTURE (2011)						
	Channapatna	Maddur	Malvally	Shrirangapatna	Panadavapura_	T.Narsipura
1	32			26	52	1
2	39			24	40	4
3	71			38	51	25
4	2			5	3	0
5	0			2	0	0
6	0			1	1	1
7	1			0	0	0
8	0			0	0	0
	145			96	147	31

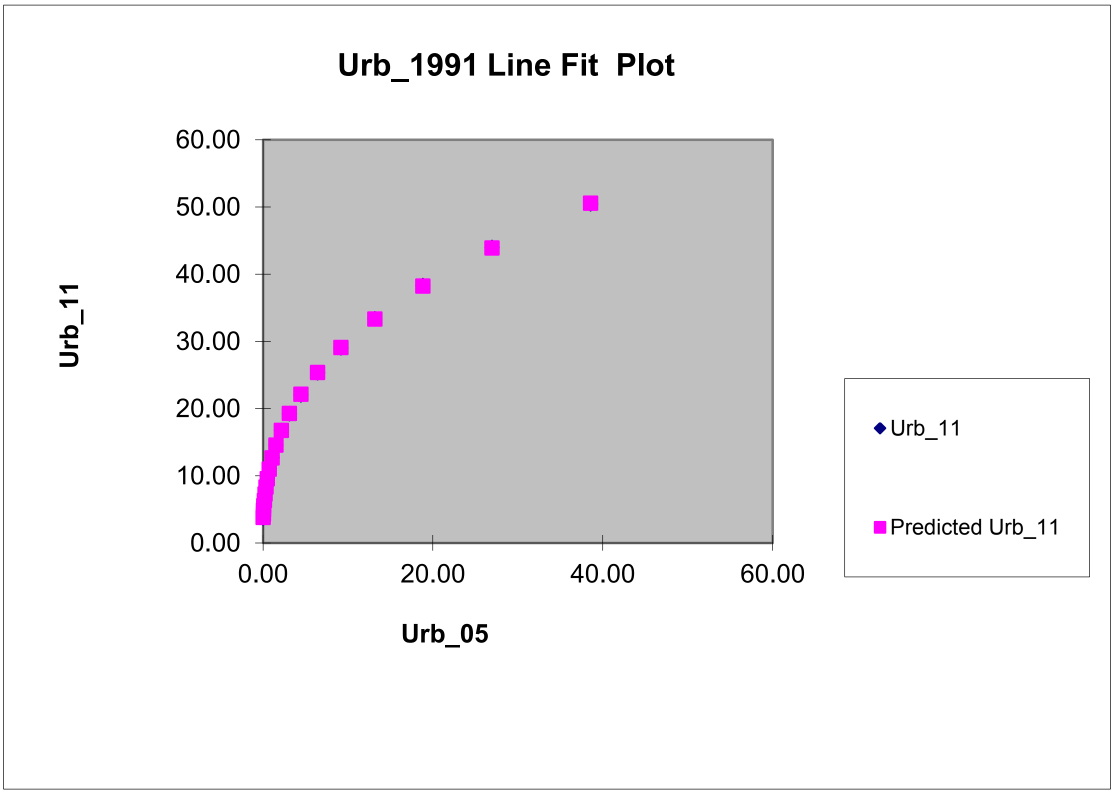
PERCENTAGE OF POPULATION PRACTISING AGRICULTURE OCCUPATION IN DIFFERENT TALUKS IN **MYSORE = BANGALORE REGION (2011)**							
	Channapatna_ 2011	Maddur_ 2011	Malavalli_ 2011	Panadavapura_ 2011	Shrirangapatna_ 2011	T.Narsipura_ 2011	total villages
	12	8	5	31	6	1	63
0 - 5	4	1	0	2	6	0	13
5 - 10	5	3	0	1	4	1	14
10 - 15	6	4	2	1	9	3	25
15 - 20	14	9	2	4	9	1	39
20 - 30	31	36	12	23	18	12	132
30 - 40	39	59	22	35	20	9	184
40 - 50	24	26	6	24	15	4	99
50 - 75	10	15	3	26	9	0	63
total	145	161	52	147	96	31	632

Urban expansion






Urb_01 Line Fit Plot
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Urb_11
0.00
10.00
20.00
30.00
Urb_01
Urb_11
Predicted Urb_11


Urb_1991 Line Fit Plot
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Urb_11
0.00
20.00
40.00
60.00
Urb_05
Urb_11
Predicted Urb_11

Buffer_Km	**Urb Expansion_73 TO_81**	**Urb Expansion_01 TO_91**	**Urb Expansion_05 TO_01**	**Urb Expansion_73 TO_11**
1	1.12	0.64	0.31	3.53
2	0.97	0.48	0.63	3.76
3	0.84	0.34	1.03	4.01
4	0.71	0.21	1.53	4.26
5	0.60	0.10	2.15	4.54
6	0.49	0.00	2.93	4.82
7	0.39	0.00	3.90	5.12
8	0.29	0.00	5.10	5.44
9	0.21	0.00	6.61	5.77
10	0.12	0.00	8.48	6.12
11	0.05	0.00	10.81	6.48
12	0.00	0.00	13.72	6.87
13	0.00	0.00	17.35	7.27
14	0.00	0.00	21.86	7.70
15	0.00	0.00	27.49	8.15
16	0.00	0.00	34.51	8.62
17	0.00	0.00	43.25	9.11
18	0.00	0.00	54.14	9.63
19	0.00	0.00	67.72	10.18
20	0.00	0.00	84.64	10.75

	Urb_1981	*Urb_91*	*Urb_01*	*Urb_2011*
Mean	3.17	5.14	6.40	18.31
Median	1.87	2.04	1.30	13.61
Standard Error	0.72	1.49	2.35	3.16
Standard Deviation	3.20	6.68	10.49	14.13
Sample Variance	10.23	44.65	110.05	199.65
Kurtosis	0.79	2.14	4.17	-0.05
Skewness	1.29	1.67	2.12	0.98
Minimum	0.31	0.17	0.04	3.65
Maximum	11.14	23.59	38.59	50.46
Range	10.83	23.42	38.55	46.81
Sum	63.39	102.89	128.04	366.29
Count	20	20	20	20

Very High correlation between Urban area 1981, 91 , 2001 , 2011 means very Rapid urban expansion.

The R square of (0.99) reveals the accuracy of the regression model is 99 %

Since (Significance F < F) in ANOVA test , this reveals the regression model is valid.

The Multi-Regression Model reveals that the urban expansion in 2011 based on the urban expansion from 1981 till 2011

Correlation	*Urb_1981*	*Urb_91*	*Urb_2001*	*Urb2011*
Urb_73	1			
Urb_01	0.992203	1		
Urb_05	0.964949	0.989885	1	
Urb_11	0.994666	0.974265	0.933956	1

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.99999
R Square	**0.999979**
Adjusted R Square	0.999976
Standard Error	0.069938
Observations	20

ANOVA

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	3793.286	1264.429	258503.1	1.1E-37
Residual	16	0.078262	0.004891		
Total	19	3793.364			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.14461	0.061028	18.75558	2.57E-12	1.015237	1.273983	1.015237	1.273983
Urb_73	10.68659	0.176888	60.41446	2.59E-20	10.3116	11.06157	10.3116	11.06157
Urb_01	-4.178246	0.156599	-26.68125	1.08E-14	-4.51022	-3.84627	-4.51022	-3.84627
Urb_05	0.748857	0.047372	15.80802	3.47E-11	0.648433	0.849281	0.648433	0.849281

RESIDUAL OUTPUT

Observation	*Predicted Urb_11*	*Residuals*
1	50.53118	-0.071559
2	43.86152	0.085002
3	38.19768	0.076426
4	33.3164	0.017457
5	29.06908	-0.037813
6	25.35322	-0.06918
7	22.09457	-0.074083
8	19.23623	-0.058041
9	16.73203	-0.029276
10	14.54274	0.004098
11	12.63382	0.035373
12	10.97424	0.059671
13	9.535797	0.073907
14	8.292784	0.076543
15	7.221805	0.067247
16	6.301643	0.046571
17	5.513164	0.01565
18	4.839214	-0.024033
19	4.264501	-0.070842
20	3.775479	-0.123119

Correlation		
	Urb Expansion_81 TO_01	Water Shrinking_81to 2011
Urb Expansion_1981 TO_01	1	
Water Shrinking_1981 to 01	-0.8543	1

Regression Analysis

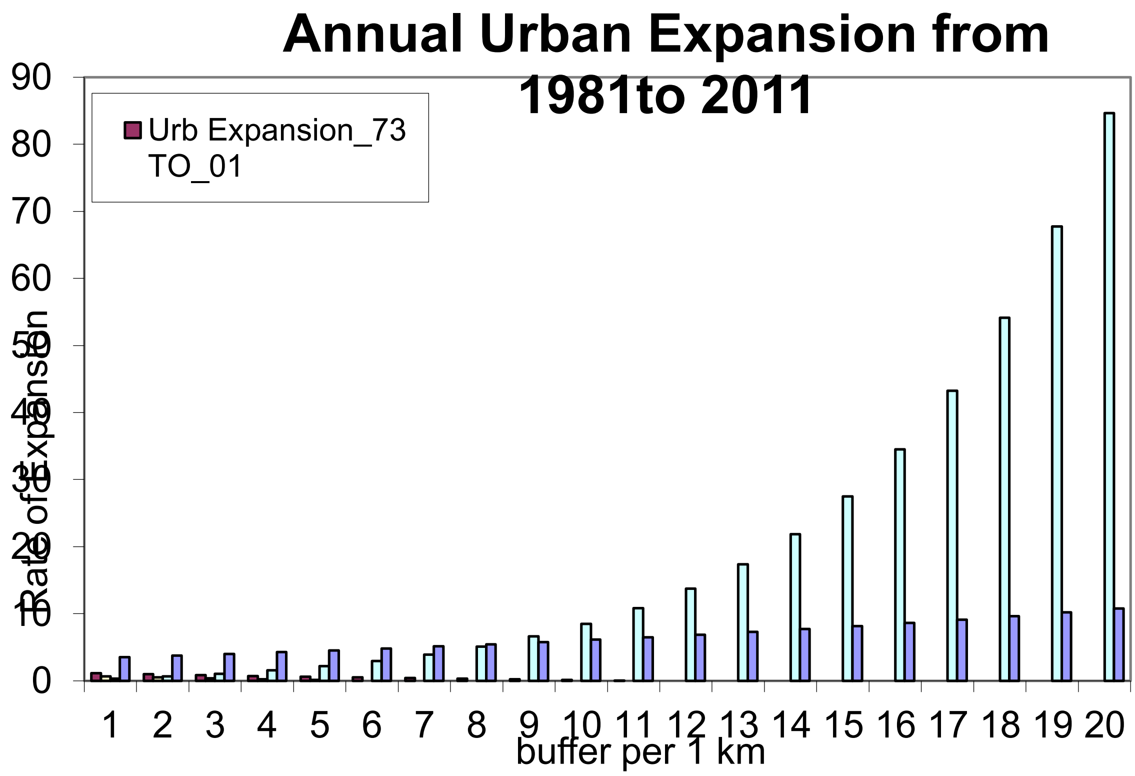
SUMMARY OUTPUT

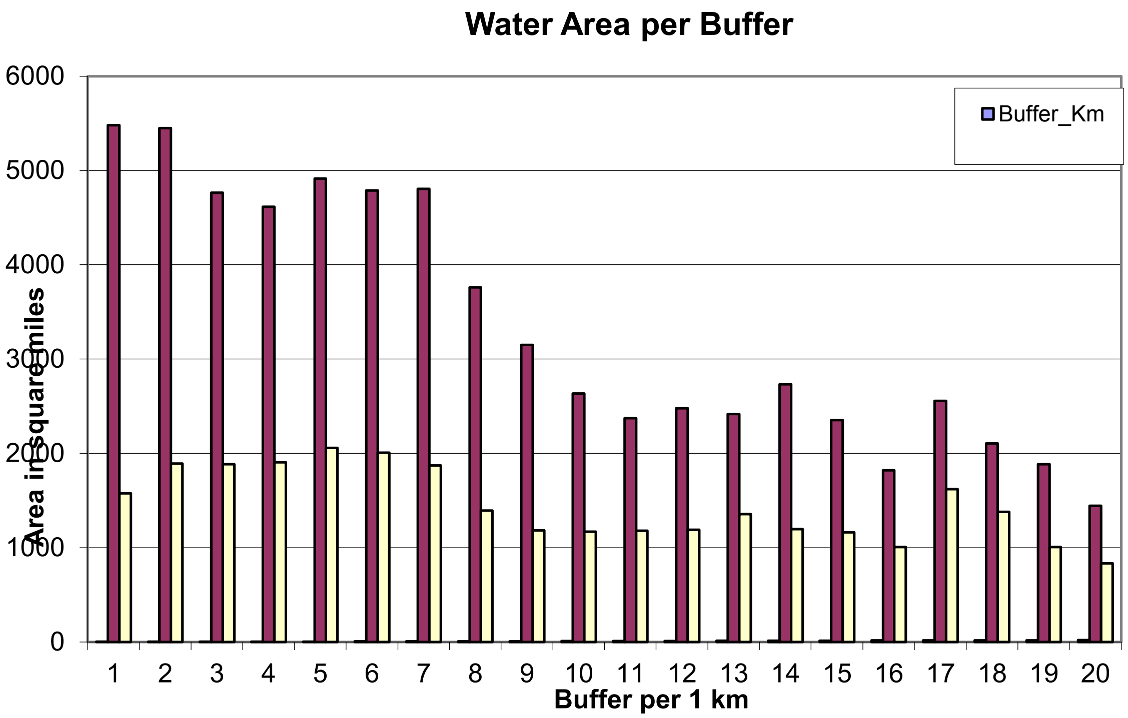
Regression Statistics	
Multiple R	0.854
R Square	**0.730**
Adjusted R Square	0.715
Standard Error	0.002
Observations	20

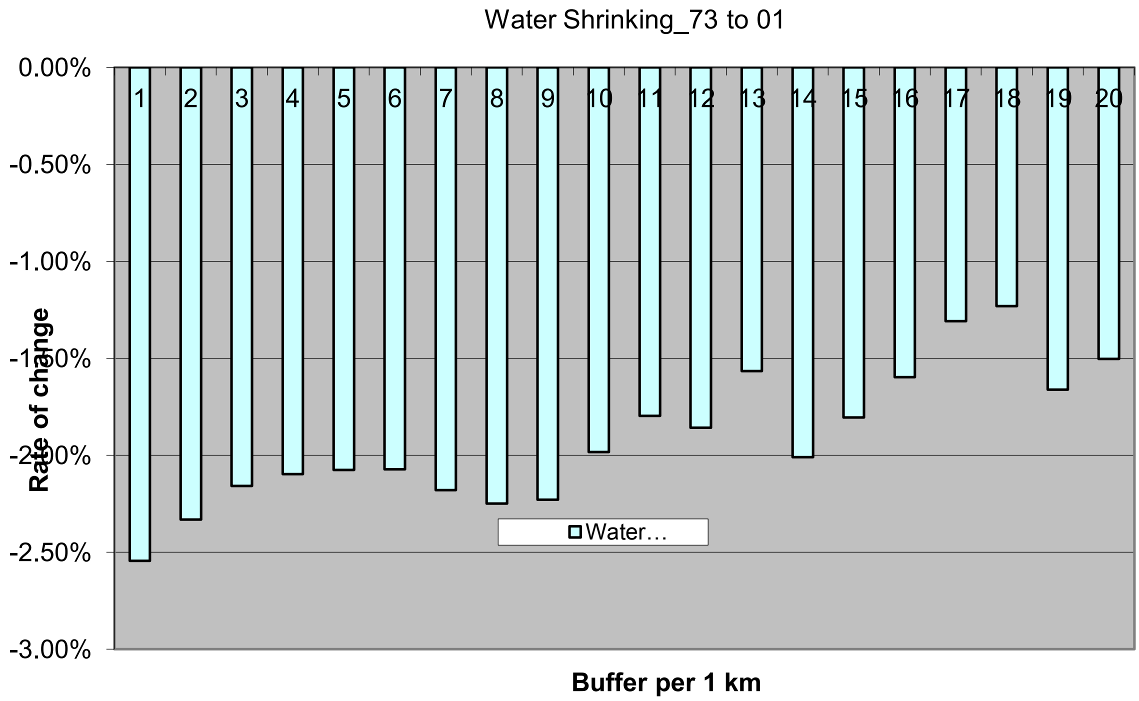
ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.000169848	0.000169848	48.63209643	1.63391E-06
Residual	18	6.2865E-05	3.4925E-06		
Total	19	0.000232713			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.018031877	0.000446387	-40.3951752	4.08375E-19	-0.018969701	-0.017094053	-0.01897	-0.01709
Urb Expansion_ 73 TO_01	-0.173654536	0.02490145	-6.973671661	1.63391E-06	-0.225970541	-0.121338531	-0.22597	-0.12134

	Urb Expansion_81 TO_01	*Urb Expansion_91 TO_05*	*Urb Expansion_2001 TO_11*	*Urb Expansion_2011 TO_11*
Mean	0.290	0.088	20.408	6.606
Median	0.086	0.000	9.646	6.298
Standard Deviation	0.372	0.185	24.523	2.240
Standard Error	0.083	0.041	5.483	0.501
Sample Variance	0.138	0.034	601.363	5.017
Kurtosis	-0.176	3.780	1.379	-1.035
Skewness	1.058	2.143	1.465	0.371
Minimum	0.000	0.000	0.308	3.529
Maximum	1.118	0.636	84.637	10.755
Range	1.118	0.636	84.330	7.226
Sum	5.791	1.769	408.160	132.113
Count	20.000	20.000	20.000	20.000




Water Area per Buffer
6000
5000
4000
3000
2000
1000
0
Area in square miles
Buffer_Km
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Buffer per 1 km


Water Shrinking_73 to 01
0.00%
-0.50%
-1.00%
-1.50%
-2.00%
-2.50%
-3.00%
Rate of change
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Water…
Buffer per 1 km

CONCLUSION:

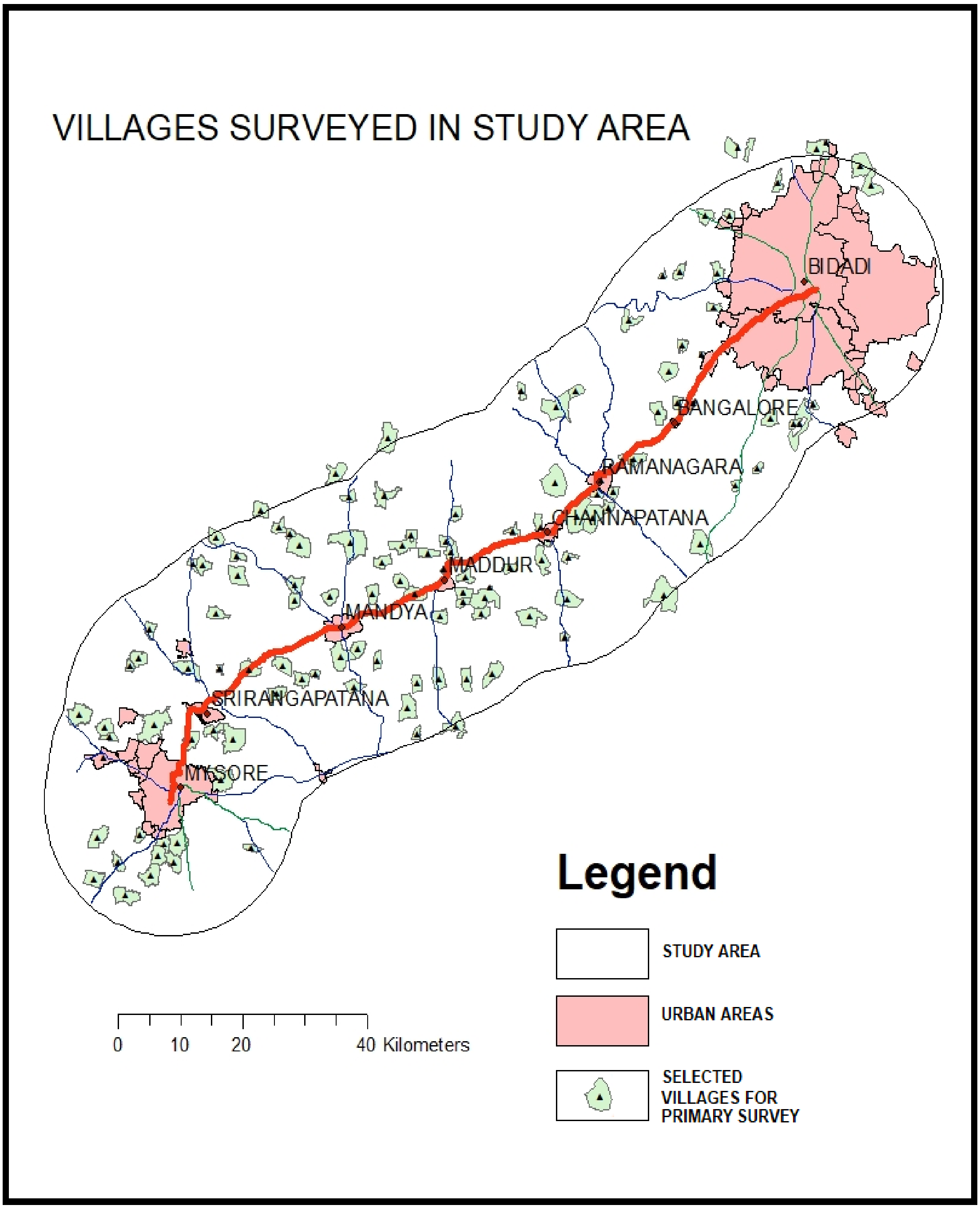
Urbanization in developing countries have problems which are excessively as a result of citizen friendly attitude in policy making and planning mechanisms. The free and flexible approach of urban plans has lot of interference from stakeholders working at individual, institutional, and political levels. Our urban system's planning is utterly non futuristic and non-rigid. Our urban forms are loosely scattered irrespective of the nature of sensitivity towards environment, infrastructure or accessibility for services, or towards the protection of fertile agriculture land.. Our urban system's planning needs to be strengthened at large. Bangalore which is a Mega metropolitan area has a huge impact over the surrounding smaller towns. If this trend of free spreading continues, then very soon we will find that the land under agriculture is missing from our surroundings. Vegetation would be wiped out, leaving room barrenness and imperviousness. While most countries have already been pursuing policies from long time ago which implicitly or explicitly aim at promoting the concept of 'Compact Urban Form', this urban policy is devoted to focus concern upon the free real estate markets which fails to deliver efficient and equitable allocations of land for various uses and infrastructure.

From a policy evaluation perspective, 'compact city' over the decades to come, can provide a better option for accessibility (to jobs and amenities), productivity, innovation, rent, various environmental outcomes (open space preservation, biodiversity, pollution reduction, energy efficiency), efficiency of public service delivery, health, safety, social equity, transport (ease of traffic flow, sustainable mode choice), and self-reported well-being. the free market of land, the desire to spread, acquire, and dominate over land are not the approaches for sustainable development.

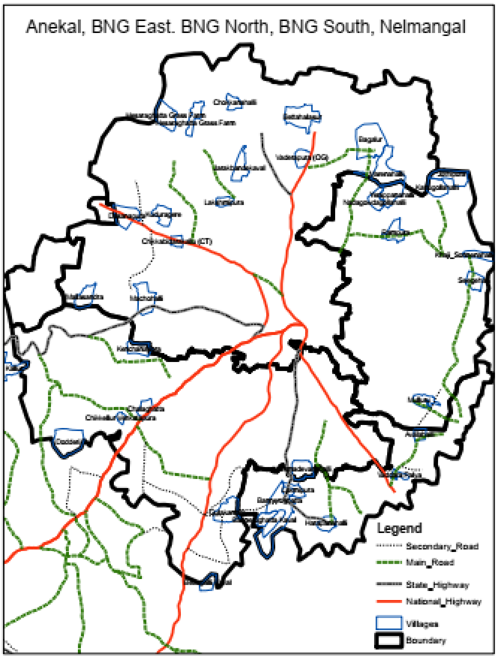
CHAPTER V

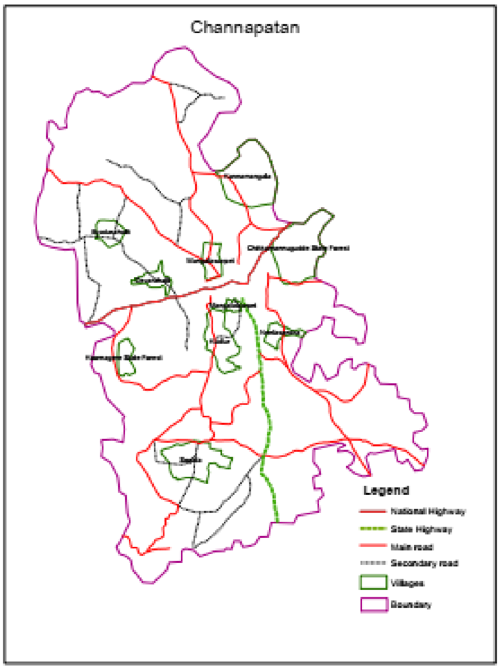
SOCIO ECONOMIC ANALYSIS OF THE STUDY AREA

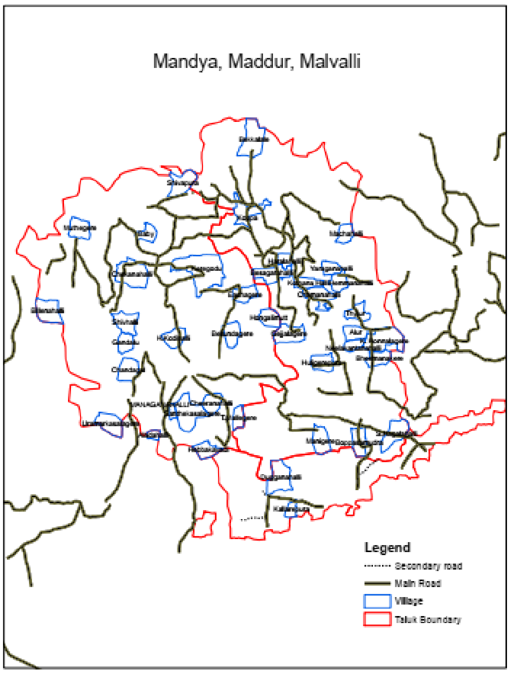
The study area consists of1300 villages and the sample villages for survey were 129 which were surveyed by the field assistants during 2017-2018. The following are the sampled villages.

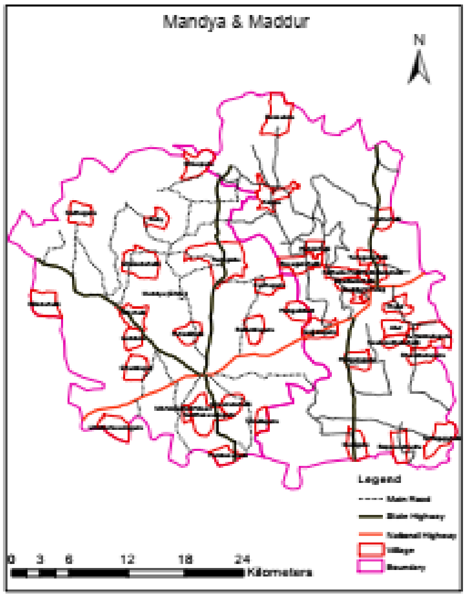


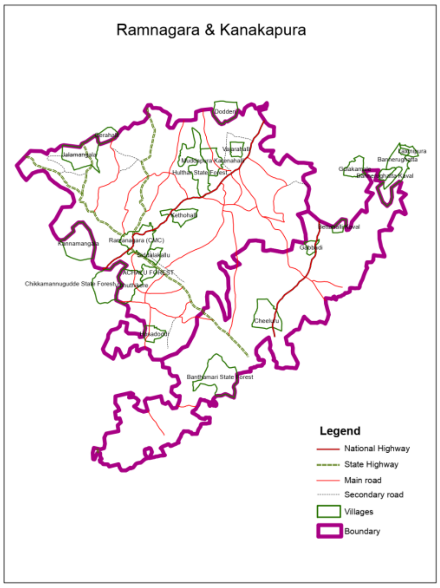
SOCIO ECONOMIC SURVEY MAPS FOR THE PROJECT AREA

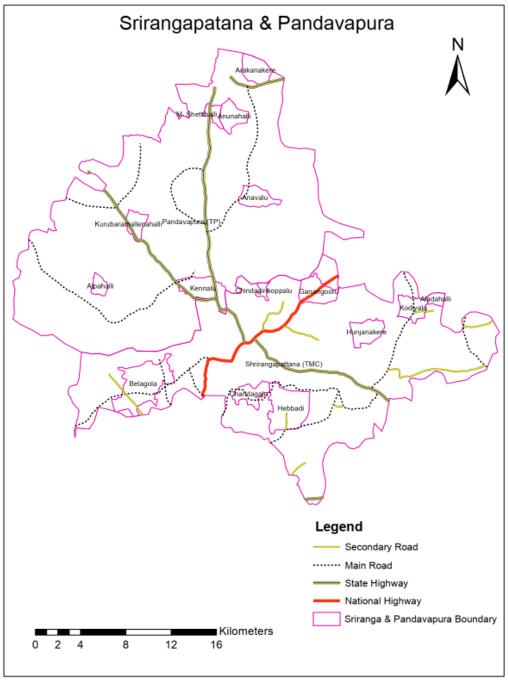


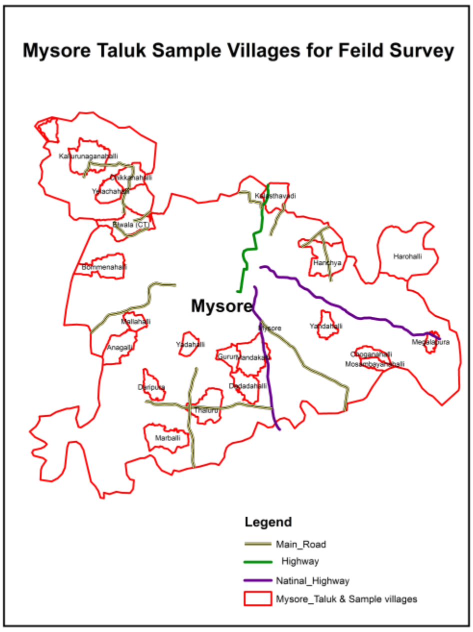





Mandya & Maddur
N
Legend
Main Road
State Highway
National Highway
Village
Boundary
0 3 6 12 18 24
Kilometers


Ramnagara & Kanakapura
Legend
National Highway
State Highway
Main road
Secondary road
Villages
Boundary


Srirangapatana & Pandavapura
N
Legend
Secondary Road
Main Road
State Highway
National Highway
Sriranga & Pandavapura Boundary
Kilometers
0 2 4 8 12 16


Mysore Taluk Sample Villages for Feild Survey
Mysore
Legend
Main_Road
Highway
Natinal_Highway
Mysore_Taluk & Sample villages

The following shows the distribution of the number of villages in each taluk.

Name of the Taluks		Total villages surveyed	Total Respondents
	Anekal	6	19
	Bangalore_E	7	26
	Bangalore_N	11	39
	Bangalore_S	5	19
	Channapatana	9	35
	Kanakapura	4	11
	Maddur	19	53
	Magadi	3	12
	Malvalli	2	10
	Mandya	19	63
	Mysore	20	76
	Pandavapura	7	29
	Ramanagara	9	26
	Srirangapatana	8	38
	Total	129	466

The results for the 129 villages surveyed presented above suggest that in terms of the sample, we found that the majority of households were mostly local with 100 percent local population inMagadi and Malvalli, while the other taluks like Channapatana, Maddur, Mandy, Mysore, Pandavapura, Ramanagara, and Srirangapatana have local population ranging between 97 to 93 percent. The localpopulation in and around Bangalore South, Bangalore North and Bangalore East ranges between 73 - 80 percent.

	Name of the Taluks	Percentage of surveyed householders	
		local population	Migrant population
1	Anekal	94.44	5.56
2	Bangalore East	100.00	0.00
3	Bangalore North	80.00	20.00
4	Bangalore South	73.68	26.32
5	Channapatana	97.22	2.78
6	Kanakapura	100.00	0.00
7	Maddur	98.15	1.85
8	Magadi	100.00	0.00
9	Malvalli	100.00	0.00
10	Mandya	95.31	4.69
11	Mysore	93.42	6.58
12	Pandavapura	96.67	3.33
13	Ramanagara	96.30	3.70
14	Srirangapatana	97.44	2.56

In terms of their previous places of residence it was approximately athird of all migrant population that came from other states like Kerala, Tamil Nadu, and Andhra Pradesh another third from adjoining township, and another third from surrounding rural areas. Most residents said that they initially moved to be closerto employment.

FAMILY TYPE:

	Family Type		
	Percentage of Joint family	Percentage of single family	total householders
Anekal	86(15)	14(3)	18
Bangalore_East	73(19)	27 (7)	26
Bangalore_North	79(31)	21(9)	40
Bangalore_south	88(17)	11(2)	19
channapatana	91(32)	9(5)	36
kanakapura	83(10)	17(2)	12
Maddur	88(42)	22(12)	54
Magadi	87(11)	13(2)	13
Malvalli	100(10)	0	10
Mandya	92(58)	8(12)	64
Mysore	78(58)	2217)	75
Pandavapura	87(26)	13(4)	30
Ramanagara	86(23)	14(4)	27
Srirangapatana	89(34)	11(5)	39
Total respondents	251	211	463

The survey showed that majority of families are living in a joint family system. The parents are forming a very significant part of the family both in the rural and urban areas, however the urban areas especially Bangalore East, Bangalore North and Bangalore South and Mysore show a marginal increase in single families.

The survey also found that almost 325respondents were living with families, while 135 were either widowers, loners, or living as dependants. Single headed households were not necessarily small as the average household was four people per household and about a quarter of the households had five members or more.

EDUCATION QUALIFICATION:

The education levels of the sample population were almost a third havingcompleted matric and another third had some high school education. 4% said that they had postmatric qualifications.

Education levels						
	Name of the village	Middle	High school	Puc	Degree	Total
1	Anekal	66.7	16.7	16.7	0.0	100.0

2	Bangalore East	84.6	3.8	11.5	0.0	100.0
3	Bangalore North	72.5	10.0	15.0	2.5	100.0
4	Bangalore South	57.9	42.1	0.0	0.0	100.0
5	Channapatana	94.4	5.6	0.0	0.0	100.0
6	Kanakapura	58.3	25.0	16.7	0.0	100.0
7	Maddur	87.0	9.3	3.7	0.0	100.0
8	Magadi	84.6	7.7	7.7	0.0	100.0
9	Malvalli	80.0	10.0	10.0	0.0	100.0
10	Mandya	87.5	7.8	4.7	0.0	100.0
11	Mysore	84.2	6.6	7.9	1.3	100.0
12	Pandavapura	80.0	13.3	6.7	0.0	100.0
13	Ramanagara	66.7	18.5	14.8	0.0	100.0
14	Srirangapatana	79.5	7.7	10.3	2.6	100.0

ECONOMIC ACTIVITY AND OCCUPATION STRUCTURE:

PERCENTAGE OF HOUSEHOLDERS ENGAGED IN DIFFERENT OCCUPATIONS						
	Name of the village	Agriculture	Manufacturing	Coolie	Service	Total
1	Anekal	27.8	5.6	27.8	38.9	100
2	Bangalore East	3.8	3.8	50.0	42.3	100
3	Bangalore North	2.5	5.0	60.0	32.5	100

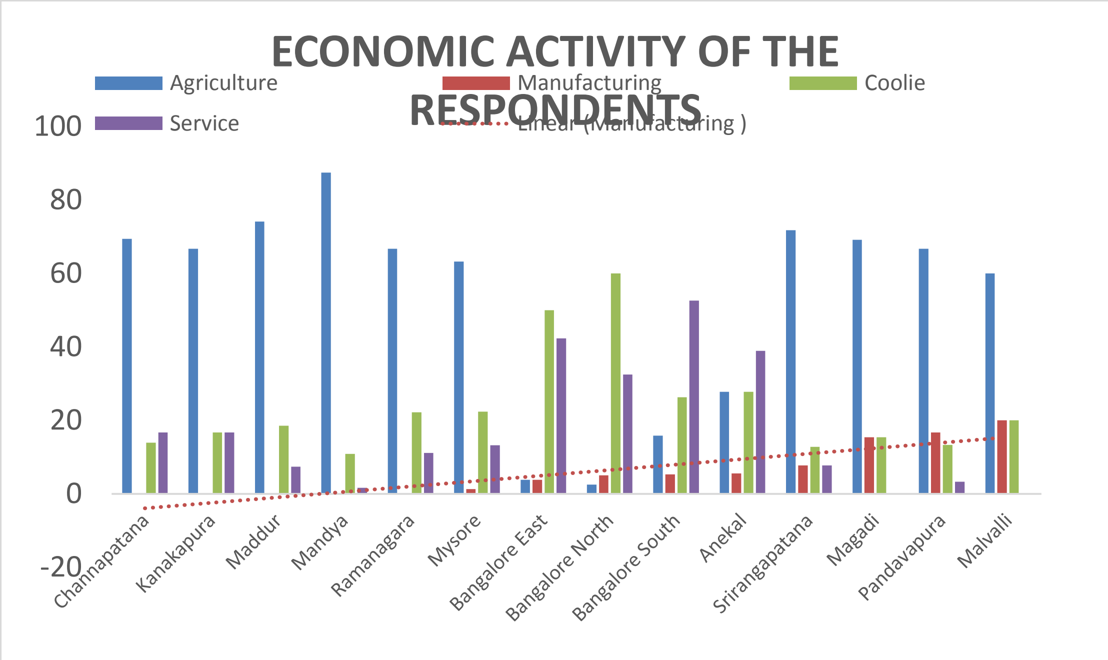
4	Bangalore South	15.8	5.3	26.3	52.6	100
5	Channapatana	69.4	0.0	13.9	16.7	100
6	Kanakapura	66.7	0.0	16.7	16.7	100
7	Maddur	74.1	0.0	18.5	7.4	100
8	Magadi	69.2	15.4	15.4	0.0	100
9	Malvalli	60.0	20.0	20.0	0.0	100
10	Mandya	87.5	0.0	10.9	1.6	100
11	Mysore	63.2	1.3	22.4	13.2	100
12	Pandavapura	66.7	16.7	13.3	3.3	100
13	Ramanagara	66.7	0.0	22.2	11.1	100
14	Srirangapatana	71.8	7.7	12.8	7.7	100

The pattern of occupation is very interesting and it can be grouped into distinct classes of occupations.

1. Agriculture, service and coolie:Channapatana, Kanakapura, Mandya, Maddur, Ramanagara, Mysore.

2. Agriculture and agro industries (manufacture of agro based products): Malvalli, Pandavapura, Anekal, Srirangapatana, Mandya.

3. Service and coolie: Bangalore North, Bangalore South, Bangalore East, Mysore



In terms of employment, slightly more than half of all households had oneor more member in full time jobs. The majority of the remaining household seemed to have atleast one person in irregular casual employment. Overall, we also found that almost 90 percent ofhouseholds had BPL (Below Poverty Line) ration cards. They were also served by the Anganwadichild welfare services. The old age pension scheme was also enjoyed by some of the respondents. The income of respondents in Bangalore and Mysore are mostly in the range between 20 to 50 thousand rupees per month. Where as in the smaller towns and their rural areas, the income range between 10 to 20 thousand per month.

PERCENTAGE OF HOUSEHOLDERS IN DIFFERENT INCOME GROUPS						
	Name of the village	10000-20000	20000-500000	50000-100000	100000-500000	total
1	Anekal	16.7	61.1	22.2	0.0	100
2	Bangalore East	7.7	73.1	19.2	0.0	100
3	Bangalore North	2.5	80.0	17.5	0.0	100
4	Bangalore South	15.8	84.2	0.0	0.0	100
5	Channapatana	19.4	80.6	0.0	0.0	100
6	Kanakapura	8.3	66.7	25.0	0.0	100
7	Maddur	27.8	72.2	0.0	0.0	100
8	Magadi	7.7	53.8	38.5	0.0	100
9	Malvalli	10.0	40.0	50.0	0.0	100
10	Mandya	26.6	73.4	0.0	0.0	100
11	Mysore	18.4	69.7	6.6	5.3	100
12	Pandavapura	10.0	60.0	26.7	3.3	100
13	Ramanagara	14.8	70.4	14.8	0.0	100
14	Srirangapatana	10.3	61.5	28.2	0.0	100

BASIC AMENITIES:

With respect to basic amenities such as electricity and clean water supply and toilet facilities, 100% have access to community water taps, and access to electricity. However the availability of these amenities have a differing pattern among respondents in different taluks. At least 90% in Bangalore claimed that they had very good availability of electricity and water supply.

	Accessibility and availability to clean water and electricity				
	Name of the village	Available plenty percentage	Moderately available percentage	Limited supply	total
1	Anekal	27.78	62.22	10	100
2	Bangalore East	92.31	7.69	-	100
3	Bangalore North	95.00	5.00	-	100
4	Bangalore South	94.74	5.26	-	100
5	Channapatana	42.11	38.89	19	100
6	Kanakapura	16.67	53.33	29.99	100
7	Maddur	28.15	51.85	19.97	100
8	Magadi	52.31	27.69	18.11	100
9	Malvalli	10.00	50	40	100
10	Mandya	36.56	40	23.44	100
11	Mysore	50.51	40	6.49	100
12	Pandavapura	3.33	60.50	36.67	100
13	Ramanagara	29.63	40.0	20.37	100
14	Srirangapatana	100.00	0.00		100

A very negligible percentage of respondents in Mysore and Bangalore had only moderate access to water supply. In rural areas the availability was divided equally between plenty and moderate categories.

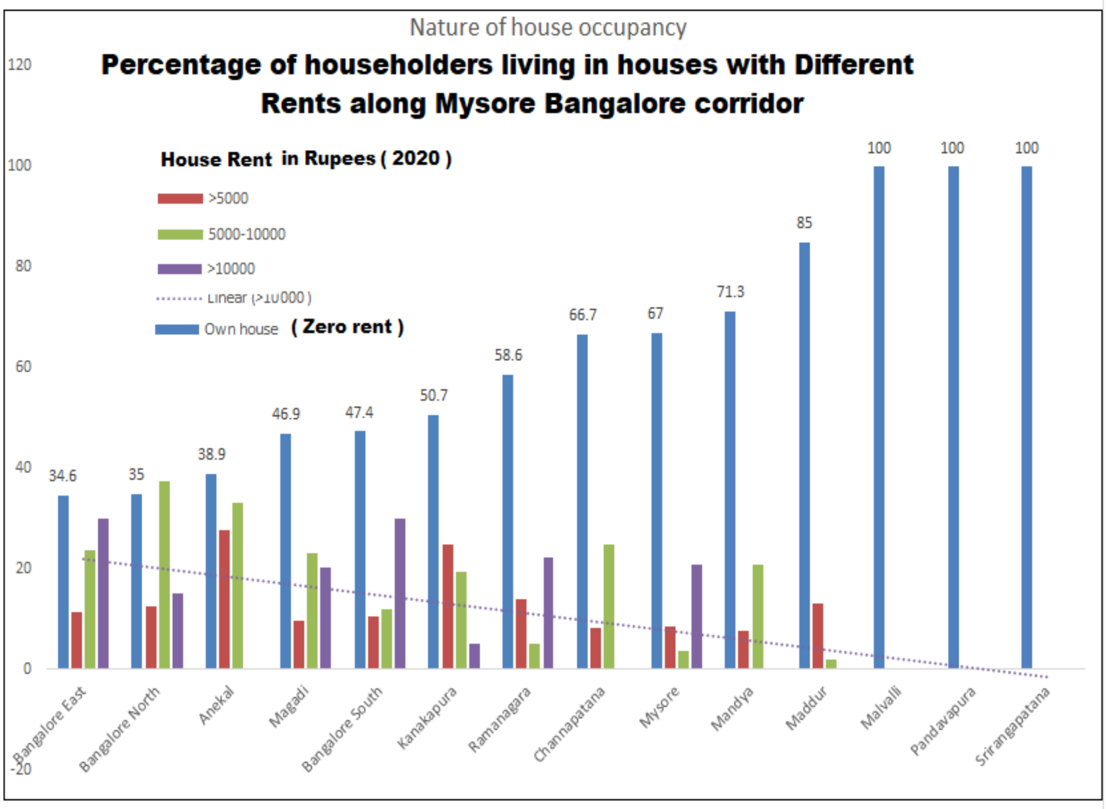
NATURE OF OCCUPANCY OF RESIDENTIAL BUILDINGS:

In relation to ownership of the houses, almost 100% of households stated a preference to own rather than rent accommodation. They also stated categorically that they wanted to upgrade their present houses, where they are now, and they would prefernot to living in rented accommodation. The majority said that theyalready have plans for some time to construct new homes of their own.

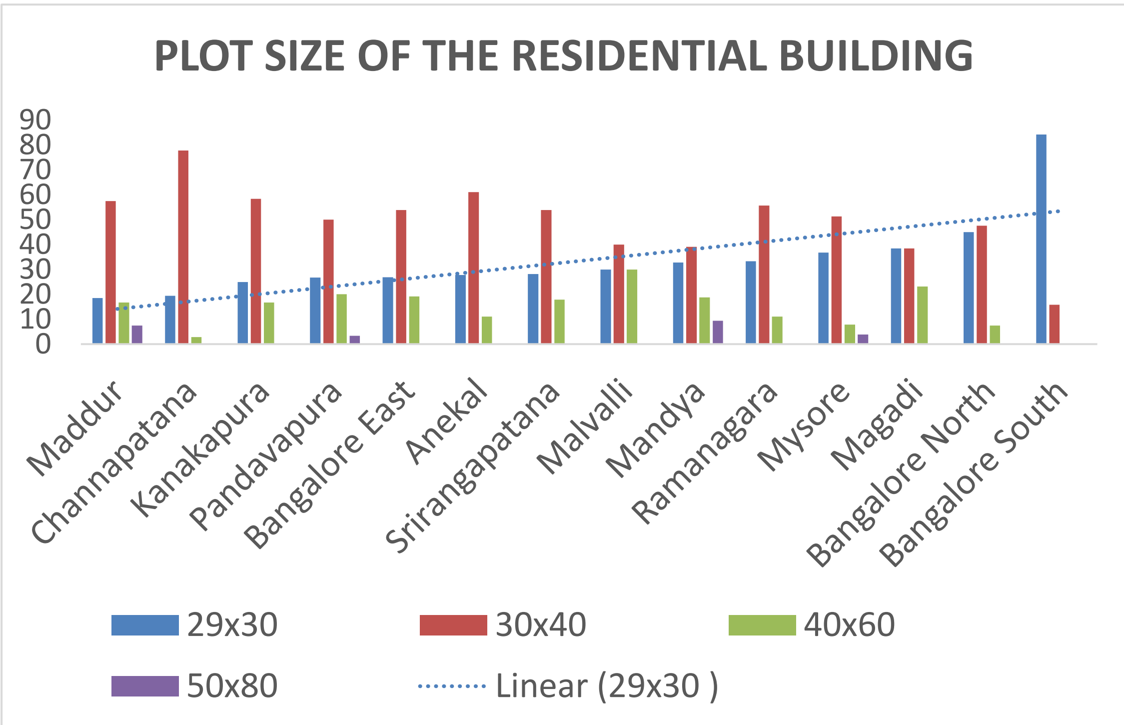
	PERCENTAGE OF HOUSEHOLDERS DWELLING IN DIFFERENT CATEGORIES OF RENTED HOUSE					
	Name of the village	Own house	>5000	5000-10000	>10000	total
1	Anekal	38.9	27.8	33.3	0	100
2	Bangalore East	34.6	11.5	23.8	43	100
3	Bangalore North	35.0	12.5	47.5	15	100
4	Bangalore South	47.4	10.5	12.1	30	100
5	Channapatana	66.7	8.3	25.0	0	100
6	Kanakapura	60.7	25.0	19.3	0	100
7	Maddur	85.2	13.0	2.0	0	100
8	Magadi	76.9	0.0	23.1	0	100
9	Malvalli	100.0	0.0	0.0	0	100
10	Mandya	71.3	7.8	20.9	0	100
11	Mysore	67	8.6	3.3	20.73	100
12	Pandavapura	100.0	0.0	0.0	0	100
13	Ramanagara	59.6	0.0	18.1	22.20	100
14	Srirangapatana	100.0	0.0	0.0	0	100

The private ownership of houses is usually a common feature in rural areas, however in urban areas like Bangalore, Mysore, Ramanagara, the percentage was 30-40 percentage, while in and around smaller towns and rural areas, the house ownershipwere mostly private.

The dimension of houses are also



SIZE OF THE HOUSE:

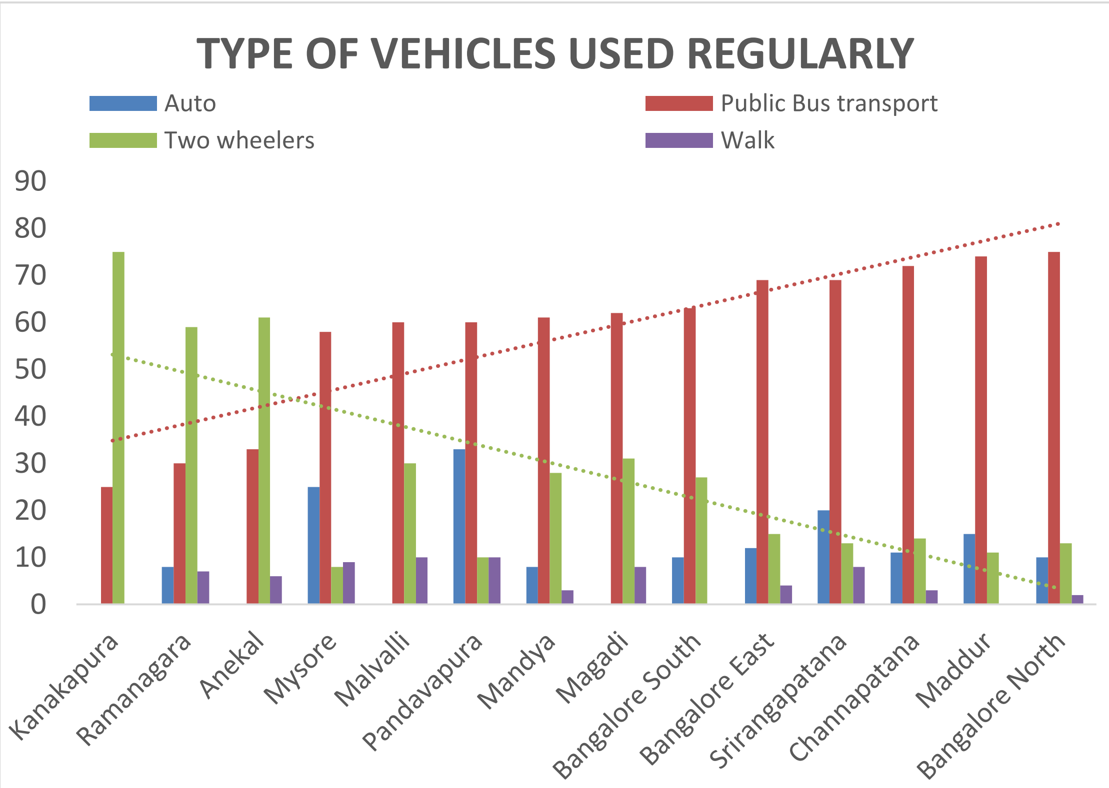


House Site Dimension					
Name of the village	29x30 percentage	30x40 percentage	40x60 percentage	50x8 percentage	total
Anekal	27.8	61.1	11.1	0.0	100
Bangalore East	26.9	53.8	19.2	0.0	100
Bangalore North	45.0	47.5	7.5	0.0	100
Bangalore South	84.2	15.8	0.0	0.0	100
Channapatana	19.4	77.8	2.8	0.0	100
Kanakapura	25.0	58.3	16.7	0.0	100
Maddur	18.5	57.4	16.7	7.4	100
Magadi	38.5	38.5	23.1	0.0	100
Malvalli	30.0	40.0	30.0	0.0	100
Mandya	32.8	39.1	18.8	9.4	100
Mysore	36.8	51.3	7.9	3.9	100
Pandavapura	26.7	50.0	20.0	3.3	100
Ramanagara	33.3	55.6	11.1	0.0	100
Srirangapatana	28.2	53.8	17.9	0.0	100

TYPE OF VEHICLES USED REGULARLY:

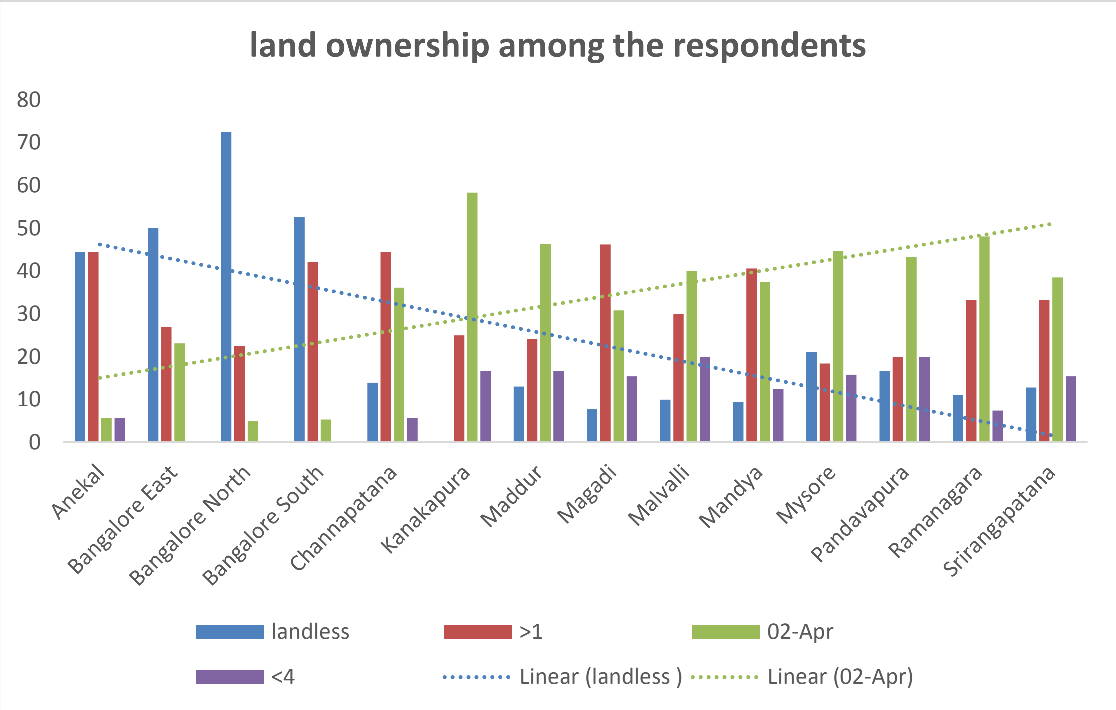
The survey has shown that majority of respondents primarily depend upon public bus transport for their mobility and the second important type of mobility is with the two wheelers. Auto rickshaw is the third important vehicle used for short distances. Bangalore's dependence on two wheelers and auto rickshaw is comparatively more than

PERCENTAGE OF HOUSE HOLD MEMBERS USING DIFFERENT TYPE OF VEHICLES						
	Name of the village	Auto	Public Bus transport	Two wheelers	Walk	Total
1	Anekal	0	33	61	6	100
2	Bangalore East	12	69	15	4	100
3	Bangalore North	10	75	13	2	100
4	Bangalore South	10	63	27	0	100
5	Channapatana	11	72	14	3	100
6	Kanakapura	0	25	75	0	100
7	Maddur	15	74	11	0	100
8	Magadi	0	62	31	8	100
9	Malvalli	0	60	30	10	100
10	Mandya	8	61	28	3	100
11	Mysore	25	58	8	9	100
12	Pandavapura	33	60	10	10	100
13	Ramanagara	8	30	59	7	100
14	Srirangapatana	20	69	13	8	100



PERCENTAGE OF HOUSEHOLDERS OWNING AGRICULTURAL LAND IN DIFFERENT SIZES

PERCENTAGE OF HOUSEHOLDERS OWNING AGRICULTURAL LAND IN DIFFERENT SIZES						
	Name of the village	landless	>1	2-4	<4	total
1	Anekal	44.4	44.4	5.6	5.6	100
2	Bangalore East	50.0	26.9	23.1	0.0	100
3	Bangalore North	72.5	22.5	5.0	0.0	100
4	Bangalore South	52.6	42.1	5.3	0.0	100
5	Channapatana	13.9	44.4	36.1	5.6	100
6	Kanakapura	0.0	25.0	58.3	16.7	100
7	Maddur	13.0	24.1	46.3	16.7	100
8	Magadi	7.7	46.2	30.8	15.4	100
9	Malvalli	10.0	30.0	40.0	20.0	100
10	Mandya	9.4	40.6	37.5	12.5	100
11	Mysore	21.1	18.4	44.7	15.8	100
12	Pandavapura	16.7	20.0	43.3	20.0	100
13	Ramanagara	11.1	33.3	48.1	7.4	100
14	Srirangapatana	12.8	33.3	38.5	15.4	100



a) The increased feminisation of agriculture is mainly due to increasing rural-urban migration by men, rise of women-headed households and growth in the production of cash crops which are labour intensive in nature. Women perform significant tasks, both, in farm as well as non-farm activities and their participation in the sector is increasing but their work is treated as an extension of their household work, and adds a dual burden of domestic responsibilities.

b) India also needs to improve its management of agricultural practices on multiple fronts. Improvements in agriculture performance has weak linkage in improving nutrition, the agriculture sector can still improve nutrition through multiple ways: increasing incomes of farming households, diversifying production of crops, empowering women, strengthening agricultural diversity and productivity, and designing careful price and subsidy policies that should encourage the production and consumption of nutrient rich crops. Diversification of agricultural livelihoods through agri-allied sectors such as animal husbandry, forestry and fisheries has enhanced livelihood opportunities, strengthened resilience and led to considerable increase in labour force participation in the sector.

RURAL LANDUSE CHANGE AND OCCUPATIONAL STRUCTURE

Occupational structure refers to the percentage of workforce employed in various economic activities. It explains how many of the total working population are employed in agriculture and associated activities and how many of them are involved in manufacturing and service sector which can be identified from the occupational structure. The occupational structure has a characteristic feature of change. It is sensitive for any changes that may occur in the economy. It keeps changingwith the passage of time, changing technology and with changing land use pattern. India'srural population is grounded to agriculture as its main occupation and it employs the broadest spectrum of working population, contributing directly or indirectlyto this occupation. Agriculture occupation not only includes cultivators and agriculture laborers but it encompasses all other related activities, including animal husbandry, trade and commerce, financial and service sector, and a whole lot of other supporting agencies into this business.Although employment in Agriculture has been falling all over the world, due to increasing value added labour and services, but the Indian scenario does not seem to have made any drastic change. However it is important to compare the characteristics and status of Indian agriculturewith that operating globally.Agriculture plays a significant role in the overall socio-economic fabric of India. The present study attempts toinvestigate the changes in occupational structure in over a period of 30 years in the Mysore – Bangalore Infrastructure Corridor.

Karnataka in general and the southern maidan in particularis considered as the food basket for the state. Even before independence; irrigation facilities were development and increasing land under agriculture was facilitated. Mysore Bangalore infrastructure Corridorregion is the chief centre of social economic and political activity of this region and urban growth is concentratingchiefly, at the two ends of the corridor.The growth is enormously as a result of the process of industrialization, urbanization and the growth of tertiary service sector especially since the past three to four decades. There is a growing speculation that large amounts of fertile land is drifting away from agriculture thereby leading to unemployment of the agriculture labour in large numbers. Urbanization and urban development has made several non-compromising change in land use and such land exploitation schemes haveserious consequences on regional development. The changes in agriculture land use has serious implication on occupation structure. Especially rural labour which is strongly connected to agriculture are directly at risk to their livelihood.

The changes in occupational structure can effect regions in three ways. The regional economy can drift towards more backwardness, or the region could spring into a highly potential region with a diversified economy by shifting the man power to more productive occupation, and lastly it cancause increase in regional stress on water resources, desertification, and land degradation which can cause major threats to agriculture and environment.

Rising industrialization and urbanization in Bangalore -Mysore regions is creating this corridor as one of the busiest urban corridors in south India, which calls for huge land to manage the swelling traffic plying between the two metropolises.

The present study will examine the occupational changes based on two majorcharacteristics.

- Changes in occupational structure based on the irrigation pattern.
- Changes in occupational structure based on the distance from the corridor

IMPACT OF LANDUSE CHANGE ON OCCUPATIONAL STRUCTURE

The economy of Mysore Bangalore corridor was primarily based on Agriculture. However the growth and expansion of urban areas along this belt has resulted in the ingestion of surrounding fertile agricultural land into non-agricultural uses causing a great hindrancetonot only agricultural land, but also on agricultural production and occupational structure of this region. This belt has spatial variations primarily with respect to its irrigation potential. In view of this difference we can be divide the belt into two distinct sections.

1. High irrigation Zone: The region covering Mysore, Shrirangapatana, Mandya and Maddur have a very high proportion of irrigation. River Cauvery which flows through this region has been the source of irrigation. The average percentage of irrigation in this region is ranging between 50- 60%, the farmers are usually having 100% certainty of irrigation availability. The main crops grown are sugar cane, and rice with high yielding crops which is returns three crops annually.

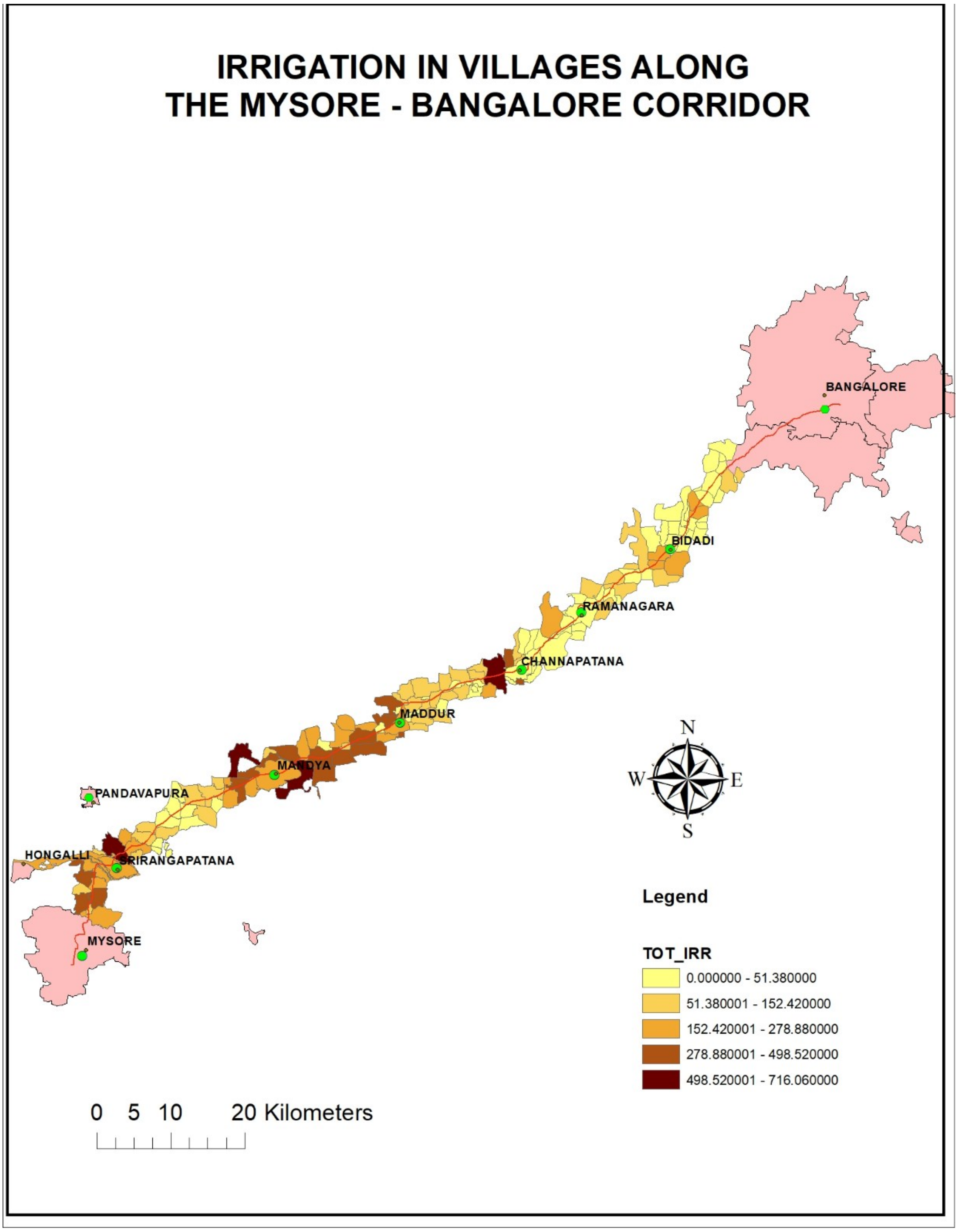
2. Low irrigation Zone:The amount of irrigation facility in this region is lesser and it is found chiefly beyond Maddurupto Bangalore where the percentage of irrigation to the total geographical area falls drastically between 20 – 0 %. Farmers in channapatana, Ramanagara mainly depend on rain-fed water for irrigation. This region is a part of "Eastern Dry Zone"

Ramanagara district is located in the southern part of Karnataka. It is situated on the north by Bangalore rural &Tumkur districts of Karnataka state; on the East Bangalore Urban district; on the South east Tamil Nadu state; on the south Chamarajanagara district; on the southwest Mandya district of the Karnataka state. The uplands are often bare or covered with low scrub jungles and the low lands are dotted with series of irrigation tanks. It represents an uplifted peneplain at an elevation of 900 meters. The surface has been dissected on the western and southern parts of the study unit giving rise to a broken and rugged topography. In the west, the terrain is rugged and broken and is composed of a succession of hills and valleys intersected by rocks and rapid streams with sandy beds. In the south, the hills get closer. The lands are covered with denser vegetation and the general level declines as one moves south towards the Cauvery. Its average elevation is 800 meters above the mean sea level.

The drainage of Ramanagara radiates from high grounds in radial pattern. Ramanagara district has Cauvery, Arkavati, Shimsharivers. However tanks play a vital role in Ramanagara district economy. At present, some of the streams are highly polluted to an extent that they are no more streams but drains of household sewage and let outs of industrial waste. In some cases the streams are cut off or blocked by constructions which often lead to urban floods during the heavy rains.

The state has also started to focus on the fields of information technology and biotechnology. Telangana is one of top IT exporting states of India. There are 68 Special Economic Zones in the state.[3]

Telangana is a mineral-rich state, with coal reserves at SingareniColleries.[4]



IRRIGATION IN VILLAGES ALONG
THE MYSORE - BANGALORE CORRIDOR
BANGALORE
BIDADI
RAMANAGARA
CHANNAPATANA
MADDUR
MANDYA
PANDAVAPURA
HONGALLI
SRIRANGAPATANA
MYSORE
N
W
E
S
Legend
TOT_IRR
0.000000 - 51.380000
51.380001 - 152.420000
152.420001 - 278.880000
278.880001 - 498.520000
498.520001 - 716.060000
0 5 10 20 Kilometers

Census year	irrigation	Total villages	Total cultivators	Total agricultural laborers	Total other workers	Total marginal workers	Total main workers	Total non workers
1981	100 - 80	9	2088	1856	706	17	6772	7428
	80 - 60	19	6187	5649	2251	291	14314	20501
	60-40	21	7767	6622	1595	389	16192	25307
	40 - 20	19	4059	2502	2177	928	8807	14316
	20 - 0	101	24574	16366	61909	2793	107411	226400

Census year	irrigation	Total villages	Total cultivators	Total agricultural laborers	Total other workers	Total marginal workers	Total main workers	Total non workers
1991	100 - 80	3	430	451	47	70	1037	1394
	80 - 60	12	4412	4480	552	1046	11073	15549
	60-40	24	11698	11324	1070	1307	26847	33802
	40 - 20	17	6322	5421	653	1221	14742	18536
	20 - 0	117	29066	25147	38999	5677	170628	311790

Census year	irrigation	Total villages	Total cultivators	Total agricultural laborers	Total other workers	Total marginal workers	Total main workers	Total non workers
2001	100 - 80	5	407	597	2876	269	4010	5201
	80 - 60	21	3619	1221	6616	1418	11955	18318
	60-40	21	4635	1723	28539	5266	36321	59185
	40 - 20	19	3605	2268	20277	4444	30878	53306
	20 - 0	76	27419	21705	66390	16932	118534	194318

Census year	irrigation	Total villages	Total cultivators	Total agricultural laborers	Total other workers	Total marginal workers	Total main workers	Total non-workers
2011	100 - 80	6	301	621	3705	654	5627	6451
	80 - 60	21	4289	8524	10354	2755	19542	36214
	60-40	21	5684	2882	30609	5978	41550	64840
	40 - 20	19	43215	3221	21277	4834	34695	57961
	20 - 0	112	42010	35175	109127	19071	192541	345264

1981 OCCUPATIONAL STRUCTURE

The workers have been classified by the census of India into various categories of occupations belonging to the rural areas. To start with the classification begins with main workers and non workers. The main workers are further subdivided into 1. "cultivators" and "agricultural laborers", and other workers, and marginal workers. The non workers are all those people who do not involve any kind of occupations. They chiefly depend upon the Main workers for all kind of expenditures. They are also called as dependent population. But the most important socio economic phenomena which is evolving in this region is that there is a general occupational change in the study area. In order to understand the various occupations which are undergoing changes are all due to the land use changes. In order to understand the changes in a more better way we can observe the average number of people engaged in various activities.

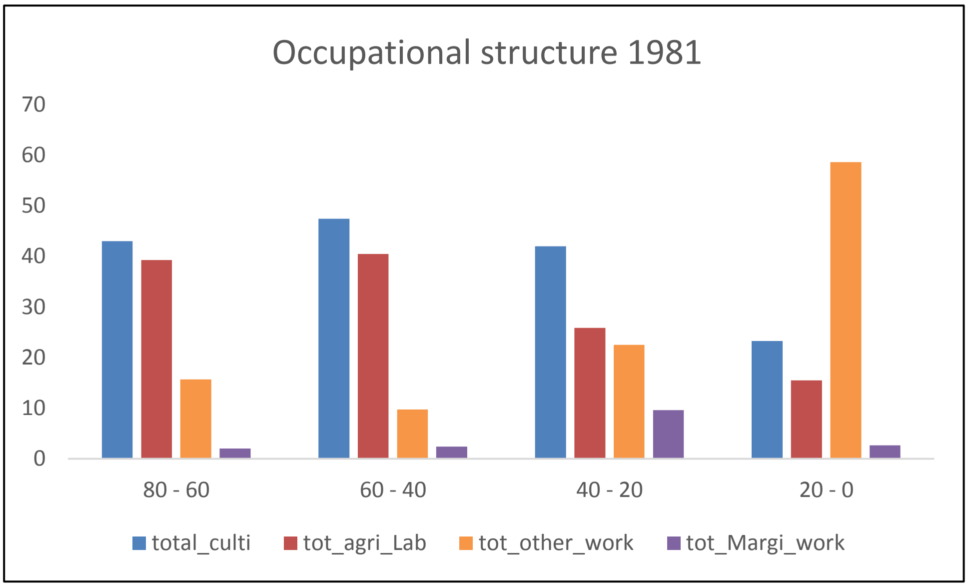
The following is the table which gives a simple distribution of the average annual number of people who are appointed in different type of economic activities. The following table gives the average number of people working in different activities in each village

Total villages	1981	T_culti	T_Agri_Lab	T_Other_Work	T_Margi_Work	T_MAIN_WORKERS
19	80 - 60	326	297	118	15	753
21	60 - 40	370	315	76	19	780
19	40 - 20	214	132	115	49	509
101	20 - 0	243	162	613	28	1046

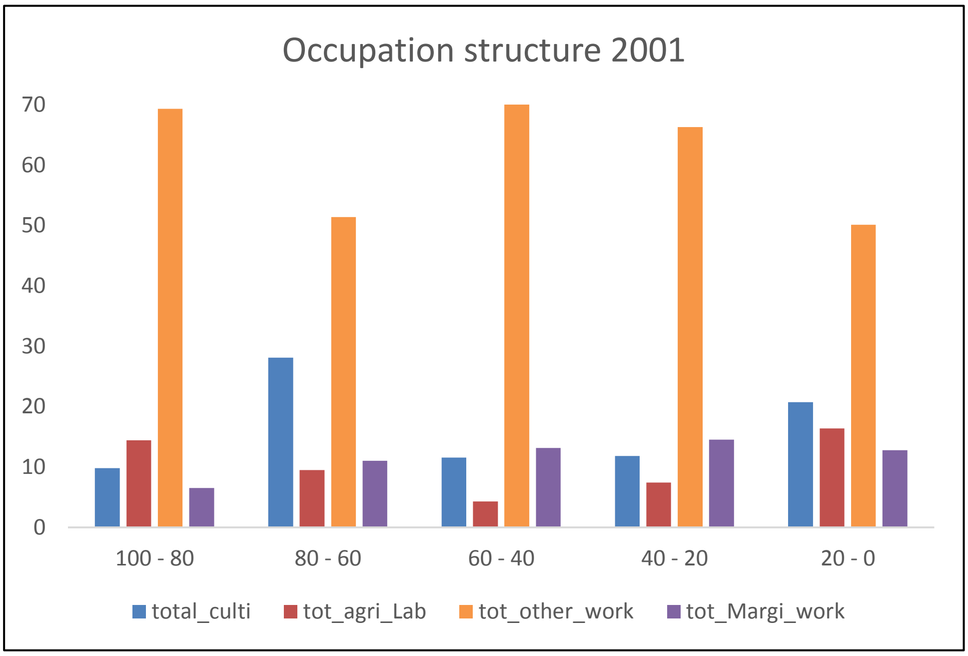
This table illustrates the concentration of people in different villages. For the sake of critical analysis the village lining along the road were selected. There were atleast 160 villages which were spread over the Mysore– Bangalore corridor. The entire strip of land containing villages were classified. And thepercentage of workers in different categorywere calculated with respect to irrigation.

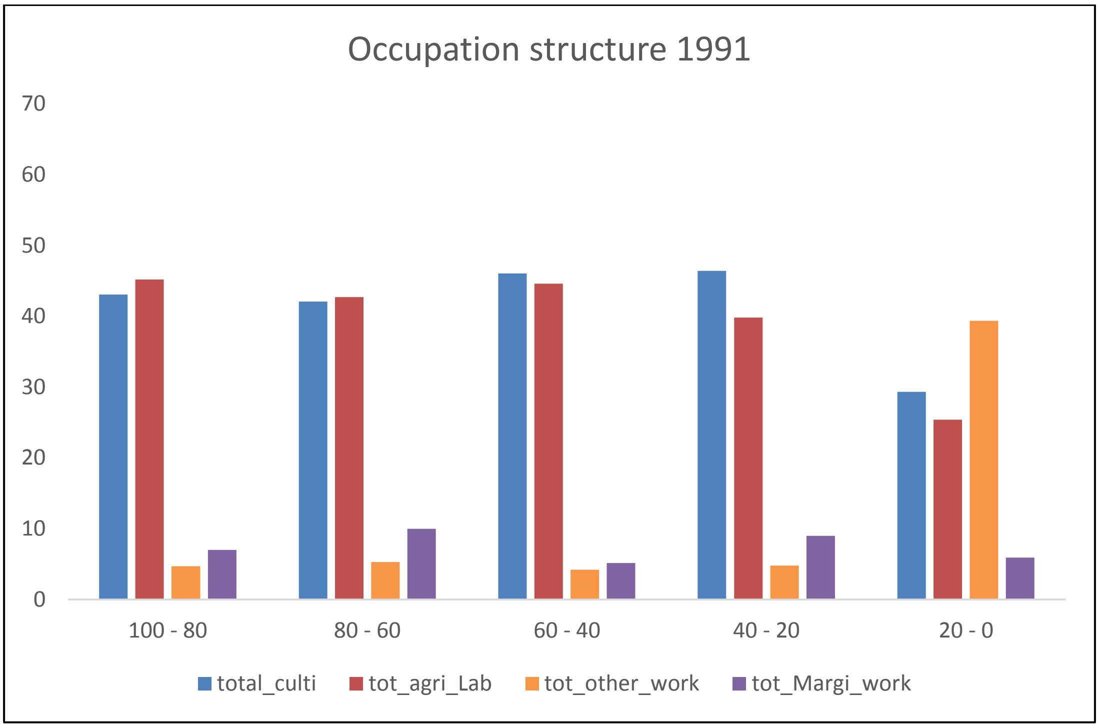
From this table it can be understood that the number of cultivators in 1981 census were that is the highest concentration of pople are found within tatk population.

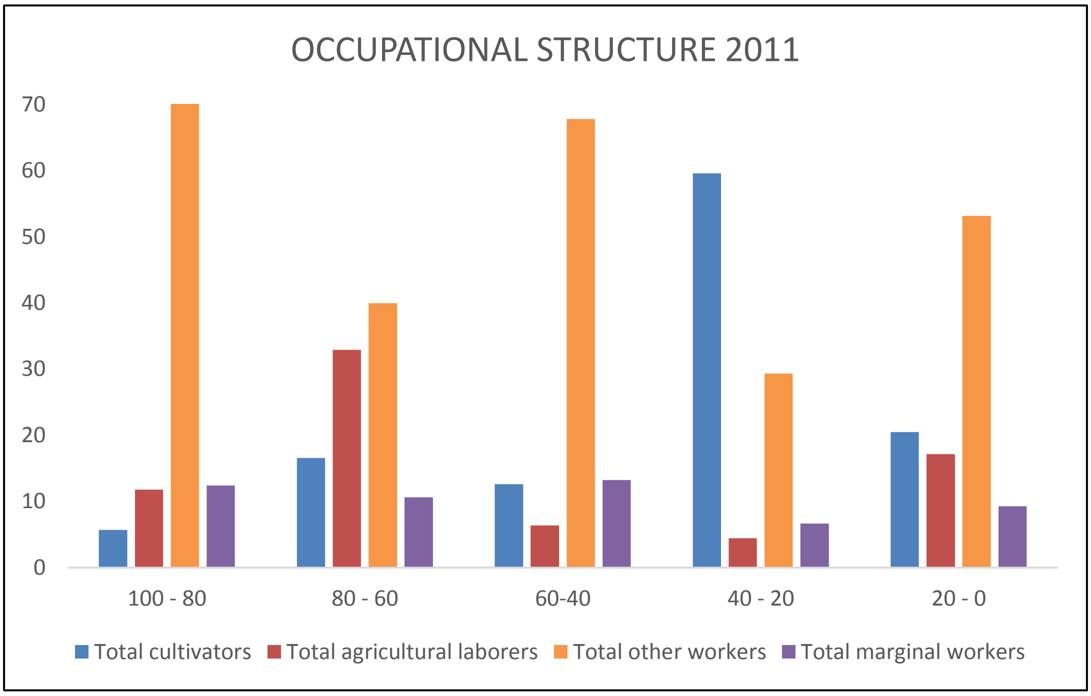
	total_culti	tot_agri_Lab	tot_other_work	tot_Margi_work
80 - 60	43	39	16	2
60 - 40	47	40	10	2
40 - 20	42	26	23	10
20 - 0	23	15	59	3



ot_main_workers	total_non_workers
753	1079
757	1205
780	753
509	2242
1046	







100-80	Total cultivators	Total agricultural	Total other	Total marginal	Total main	Total non

		laborers	workers	workers	workers	workers
1981	232.0	206.2	78.4	1.9	752.4	825.3
1991	143.3	150.3	15.7	23.3	345.7	464.7
2001	81.4	119.4	575.2	53.8	802.0	1040.2
2011	50.2	103.5	617.5	109.0	895.0	1075.2

80-60	Total cultivators	Total agricultural laborers	Total other workers	Total marginal workers	Total main workers	Total non workers
1981	325.6	297.3	118.5	15.3	753.4	1079.0
1991	367.7	373.3	46.0	87.2	922.8	1295.8
2001	172.3	58.1	315.0	67.5	569.3	872.3
2011	204.2	405.9048	493.0476	131.1905	930.5714	1724.476

60-40	Total cultivators	Total agricultural labourers	Total other workers	Total marginal workers	Total main workers	Total non workers
1981	369.9	315.3	76.0	18.5	771.0	1205.1
1991	487.4	471.8	44.6	54.5	1118.6	1408.4
2001	220.7	82.0	1359.0	250.8	1729.6	2818.3
2011	270.7	137.2421	1457.587	284.6865	1978.575	3087.611

40-20	Total cultivators	Total agricultural laborers	Total other workers	Total marginal workers	Total main workers	Total non workers

1981	213.6	131.7	114.6	48.8	463.5	753.5
1991	371.9	318.9	38.4	71.8	867.2	1090.4
2001	189.7	119.4	1067.2	233.9	1625.2	2805.6
2011	227.4	169.5526	1119.86	254.4561	1826.083	3050.623

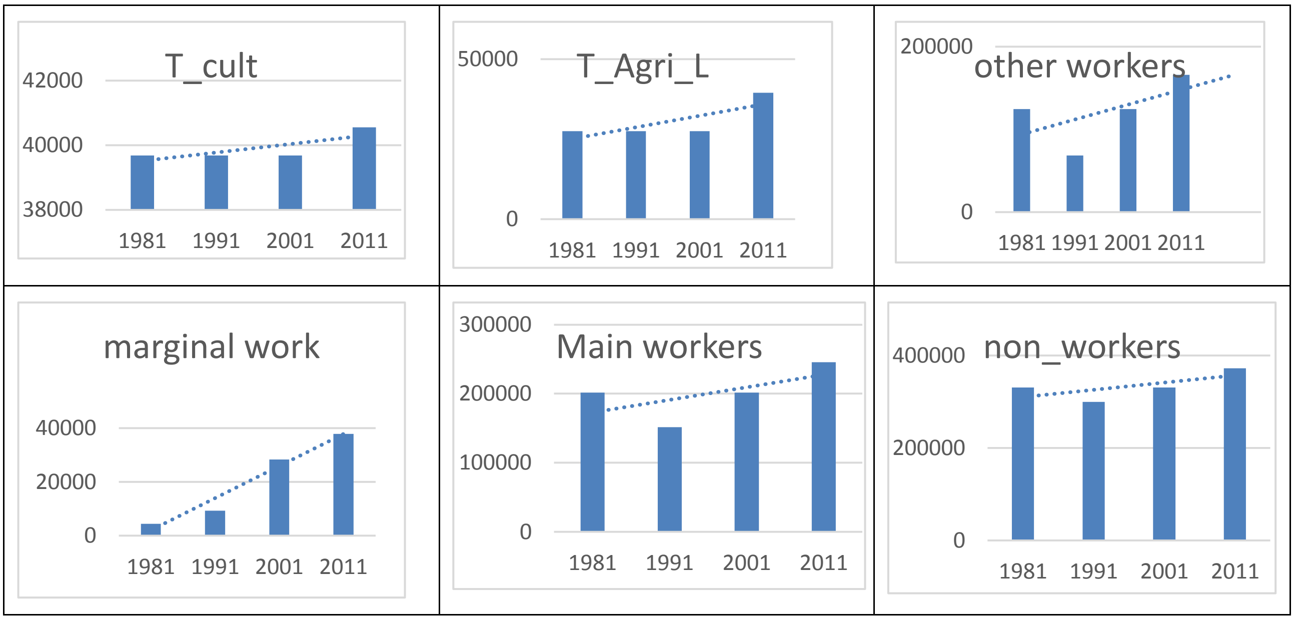
20-0	Total cultivators	Total agricultural laborers	Total other workers	Total marginal workers	Total main workers	Total non workers
1981	243.3	162.0	613.0	27.7	1063.5	2241.6
1991	248.4	214.9	333.3	48.5	1458.4	2664.9
2001	360.8	285.6	873.6	222.8	1559.7	2556.8
2011	375.1	314.0625	974.346	170.282	1719.116	3082.714

OCCUPATIONAL STRUCTURE:

Occupational pattern of the people living in the villages just along the road has changed tremendously during the past four decades i.e., 1981 -2011.

	villagers	T_cult	T_Agri_L	other workers	Mwork	non_work	marginal work
1981	172	44675	32995	68638	151408	299197	4418
1991	172	51943	46823	41321	224336	381071	9321
2001	172	39685	27514	124698	201698	330328	28329
+2011	172	40555	28702	165954	245460	372299	34581

OCCUPATIONAL PATTERN OF PEOPLE IN THE VILLAGES ALONG THE MYSORE – BANGALORE CORRIDOR



The most phenomenal changes observed are that the changes are not significant in terms of the growth in the number of cultivators nor the number of agricultural laborers. However there is a significant growth in the number of marginal workers and other workers. This indicates that the population is beginning to drift away from the main stream agriculture. It can be presumed that if the occupational change continues in the same manner the number of cultivators and agriculture laborers may diminish to an extent that people would prefer mostly non agriculture jobs.

It was assumed that irrigation would make a difference in the nature of the occupation pattern. Hence the data was further filtered to find out the problems related to these issues whether jointly or singularly.

QUESTIONNAIRS USED FOR THE DATA COLLECTION

Questionnaire survey for Household in the Village

Name of the Village:
Name of the Householder
Date of Survey
HouseholdInformation
1) How many Male are there in the Family?
a) 0 b) 1 c) 2-4 c) > 5
2) How many Female are there in the Family?
a) 0 b) 1 c) 2-4 c) > 5
3) Children between the ages 0-5?
a) 0 b) 1 c) 2-4 c) > 5
4) People between the ages 6-16?
a) 0 b) 1 c) 2-4 c) > 5
5) People between the ages 7-25?
a) 0 b) 1 c) 2-4 c) > 5
6)People between the ages 26-40?
a) 0 b) 1 c) 2-4 c) > 5
7) People between the ages 41-60?
a) 0 b) 1 c) 2-4 c) > 5
8) People with age >60?
a) 0 b) 1 c) 2-4 c) > 5

9) Marital Status of Family members?
a) Pre marital age b) Married c) Unmarried c) Divorcee d) Widow e) Widower
10) Education Level of the Family members?
a) Illiterate b) Primary/middle c)High School d)PUC e) Degree f)Masters g) Professional
11) Size of the Household?
a) Loner b) 2-4 c) 5-7 d)8-10
12) Status of the Residence?
a) Local b) Migrant
13) Mode of travel to Education centers?
a) Bicycle b) Bus c) Two wheelers d) Auto e) By walk
14) Type of Occupation engaged in?
a) Farming b) Teaching C) Coolie d) Manufacturing e)Mining f) Others
15) Monthly Income of the Family?
a) < 5000 b) 5000-10,000 c) 10,000 -20,000 d) > 20,000
16) What kind of crops is used in farming?
a) Ragi b) Paddy c) Sugarcane d) Vegetables e) Fruits f) Dairy g) Poultry h) Others
17) Area of the Land holdings?
a) < 1 acres b) 2-4 acres c) >4 acres
18) Type of House?
a) Single b) Duplex c) Triplex

19) Site dimension of house?	
a) 20*30 b)30*40 c)40*60 d)50*80	
20) House Rent?	
a) <5000 b) 5000-10,000 c)above 10,000 d)Lease	
21) Type of Family?	
a) Single b)Joint	
22) Facility of Drinking water and Electricity?	
a) Available b) Moderately available c) Not available	
23) Type of Irrigation?	
a) Irrigated b)Unirrigated c)Medium Irrigated	
24) Type of Land use?	
a) Agriculture b) Residential c)Commercial d) Vacant e) Non Cultivable barren f) Grazing g) Water body h) Wild bushes	
25) Present changes in Land use?a) Vacant to Agriculture b) vacant to residential c) vacant to commercial d) Agriculture to residential e) Agriculture to commercial f) Agriculture to recreation g) Others h) No change	
26) Probable changes in Future? a) Vacant to Agriculture b) vacant to residential c) vacant to commercial d) Agriculture to residential e) Agriculture to commercial f) Agriculture to recreation g) Others h) No change	

FIELD OBSERVATION WAS ALSO CONDUCTED AND THE FOLLOWING WERE THE CHECK LIST

Field observation of surveyedVillage				
Name of the Village:				
Date of Survey:				
6)	How many Schools?			
b)	0	b) 1	c) 2-4	c) > 5
7)	How many Colleges?			
b)	0	b) 1	c) 2-4	c) > 5
8)	How many Universities?			
b)	0	b) 1	c) 2-4	
9)	How many Professional Institutes?			
b)	0	b) 1	c) 2-4	c) > 5
10)	Number of Banks?			
b)	0	b) 1	c) 2-4	c) > 5
11)	Number of ATM?			
b)	0	b) 1	c) 2-4	c) > 5
27)	Type of Markets?			
b)	Permanent	b) Weekly		
28)	Number of Retail shops?			
b)	0	b) 1	c) 2-4	d) > 5
29)	Number of Whole sale shops?			
a)	0	b) 1	c) 2-4	d) > 5

30)	Number of Grocery shop?			
a)	0	b) 1	c) 2-4	d) > 5
31)	Number of Stationery?			
b)	0	b) 1	c) 2-4	d)>5
12)	Number of Auto service?			
a)	0	b) 1	c) 2-4	d) > 5
13)	Number of Petrol bank?			
a)	0	b) 1	c) 2-4	d) > 5
14)	Number of Restaurants?			
a)	0	b) 1	c) 2-4	d) > 5
15)	Number of Tailor shop?			
a)	0	b) 1	c) 2-4	d) > 5
16)	Number of Barber shop?			
a)	0	b) 1	c) 2-4	d) > 5
17)	Number of Bakery?			
b)	0	b) 1	c) 2-4	d) > 5
18)	Number of Pharmacy?			
b)	0	b) 1	c) 2-4	d) > 5
19)	Number of Clinics?			
b)	0	b) 1	c) 2-4	d) > 5
20)	Number of Primary health centers?			
b)	0	b) 1	c) 2-4	d) > 5

21) Type of Lake?
b) Perennial b) Non perennial
22) How is the lake used?
a) Domestic b) Agriculture c) Recreation d) Fishing
23) How the volume of water changing?
b) Shrinking in size b)Shrinking in depth
24) Why is the lake water reducing?
a) Sedimentation b) Reduction in inflow c) Construction of building and roads
25) How is the lake Protected?
a) Construction of Bunds b) Dredging Less Irrigated ing vegetation
26) Nearest Urban Area?
a) <10km b) 10-20km c) >20km
27) Distance to secondary roads?
a) 0-250 Mts b) 250-500 Mts c) 500-1000 Mts
28) Distance to Major roads?
a) 0-250 Mts b) 250-500 Mts c) 500-1000 Mts d)1000-2000Mts
29) Distance to Highway?
c) 0-250 Mts b) 250-500 Mts c) 500-1000 Mts d)1000-2000Mts

CHAPTER VI

ASSESSMENT AND PREDICTION OF LAND USE AND LAND COVER IN MYSORE-BANGALORE CORRIDOR REGION

Introduction

In recent years, the influence of anthropogenic activities on land use and land cover have been accelerating due to the rapid population growth which undeniably leads to an abundant increase in the demand for land. The land therefore shifts continuously between different categories of land uses, through clearance of forest lands, encroachment of water bodies and greeneries, or transference of agriculture land to non-agriculture thereby adjusting the shifts and balancing the demand and supply accrued through human population pressures.

The land use and land cover studies would provide an explanation to the extent of pressure on land use which becomes useful for policy makers to understand the nature of problems to support in formulation of policies.

The growth of population and their needs are altering the limited resources leading to land use change. In this perspective the information regarding the rate and kind of shift in land use is important for proper management, planning and regularization (Gautam & Narayanan, 1983). There is a significant relationship of LULC on the biodiversity, natural disasters and deforestation. on cropland, forest, wet land and water bodies, leading to severe environmental crisis.

The employment of LULC analysis have been proved in many studies that there is a clear influence of human activities on the land use and land cover in rural areas. The assessment of this study shows that, there is a marked increase of urban area and with a decline in forest and wasteland. Juxtaposed to Ganasri and Dwarakish, the study of (Brink et al., 2014) depicts the pressure of anthropogenic activities on land cover in their study area (Intergovernmental Authority on Development in Eastern Africa), whereby totally 15 million hectares of natural vegetation has been converted to agriculture generating a high rate of anthropogenic impact.

The objective of the present study is to examine the land-use changes related to the Built-up area, Water bodies, Vegetation, Agriculture and Wasteland.

Methodology Sources of data:

- ✓ Satellite data of LANDSAT TM, and OLI TIRS imageries (1999, 2009 and 2019) with 30-metre resolution downloaded from USGS website.
- ✓ The change in LU/LC by supervised classification was conducted.

Analysis:

- ✓ Supervised Classification: Land use Land cover related to Agriculture, Vegetation, Barren land, Built up and Waterbodies.
- ✓ The Satellite images have been georeferenced, and atmospheric corrections have carried out.

Preparation of Satellite images

In the present study the images have been subjected to corrections. The ATCOR module has been used to correct the atmospheric errors in the selected dates of satellite images. Among the several preprocessing software ACTOR is one of the most widely used module in ERDAS software. This software uses the acquisition date of image, type of sensor, solar zenith, solar azimuth, sensor tilt, satellite azim, elevation for the correction of atmospheric errors. The other inbuilt tools in ERDAS have been used to correct the line-start problems, line drop-out, and striping errors in the data. After the correction of atmospheric and radiometric errors in the image the geometric errors have been carried out using the collected ground truth points that collected through Global Positioning Systems.

Land use and land cover classification system

It is necessary to determine which classification technique has to be adopted and followed for the classification of images before starting the analysis. The method suggested by (James R Anderson et al., 1976), is much popular among the land use and land cover researchers (Mundia & Aniya, 2005). As a matter of fact, it has been extensively appropriated and employed on a worldwide basis. Anderson goes further to classify the land use and land cover into four levels notably as Level-I, Level-II, Level-III and Level-IV. The Level-I contains the major classes of LULC like urban or built-up land, agricultural land, forest land, water, wetland, barren land, tundra and perennial snow or ice. These classes are expanded in detail up to the Level-IV, and the detailed Table of Anderson's classification has been given in Appendix.

The National Remote Sensing Agency (NRSA, recently NRSC) has developed a land use and land cover classification system that is suitable for India. This classification system consists of three levels which are similar to Anderson classification to some extent. However, the NRSA classification deals with more details particularly concerning to the Indian scenario. The levels of classification are as follows: Level-I classifies the major LULC like built-up land, agriculture land, forest, waste/barren/uncultivated land, water bodies and others (Appendix). There are several Indian researchers who have followed the NRSA classification (Mondal et al., 2015), for Brahmaputra River Basin along with the method suggested by Anderson, J.R (S. Gupta & Roy, 2012), for Burdwan Municipality, West Bengal. As this present study has been carried out based on the Landsat imagery, the study follows the scheme suggested by NRSA system for the precision of results.

The determination of the levels of classification for the LULC analysis is rooted in the base data that is used for the study. As Anderson suggests, Level-I classification can be analyzed using Landsat imageries, Level-II can be explored using High-altitude data at 40,000 feet (12,400 m) or above (less than l: 80,000 scale). Level-III classification can be analyzed through the Medium-altitude data drawn between 10,000 and 40,000 feet (3,100 and 12,400 m), (1: 20,000 to 1: 80,000 scale) and Level-IV classification can be evaluated using Low-altitude data taken below 10,000 feet (3,100 m) (more than 1: 20,000 scale). The satellite imageries applied for the present study belong to Landsat, which has the spatial resolution of 28.5 m (30m) and through which only the Level-I classification is feasible. The present study on LULC classification has been examined using Level-I classification of NRSA.

Conditions for Accurate Change detection

To obtain higher accuracy of LULC, the base data should be on the similar scale or same spatial resolution. The satellite imageries appropriated in the present study have the identical spatial resolution of 30 meters. Therefore, it is clear that the selected satellite imageries are adequate for the analysis of land use and land cover of study area for varied time periods.

After the preparation of the base data, the supervised classification using the Maximum Likelihood classification is implemented to classify the imageries. The supervised classification is a popular approach which is highly popular in India as well as in other countries (Maktav & Erbek, 2005) for Istanbul, Turkey; (Nori et al., 2008) for El Rawashda forest, Sudan; (Uma & Mahalingam, 2011) for Kanchipuram District, Coastal Stretch, Tamil Nadu, India. The supervised classification performs on the ground of the training samples given by the analyst for each class separately. As mentioned earlier, the present study has adopted the Level-I of the NRSA classification system.

All the satellite images confer to the same season. The dates however have a slight variation which can be accepted to produce satisfactory change detection. The sensors and spatial resolution also are similar to obtain high accuracy results.

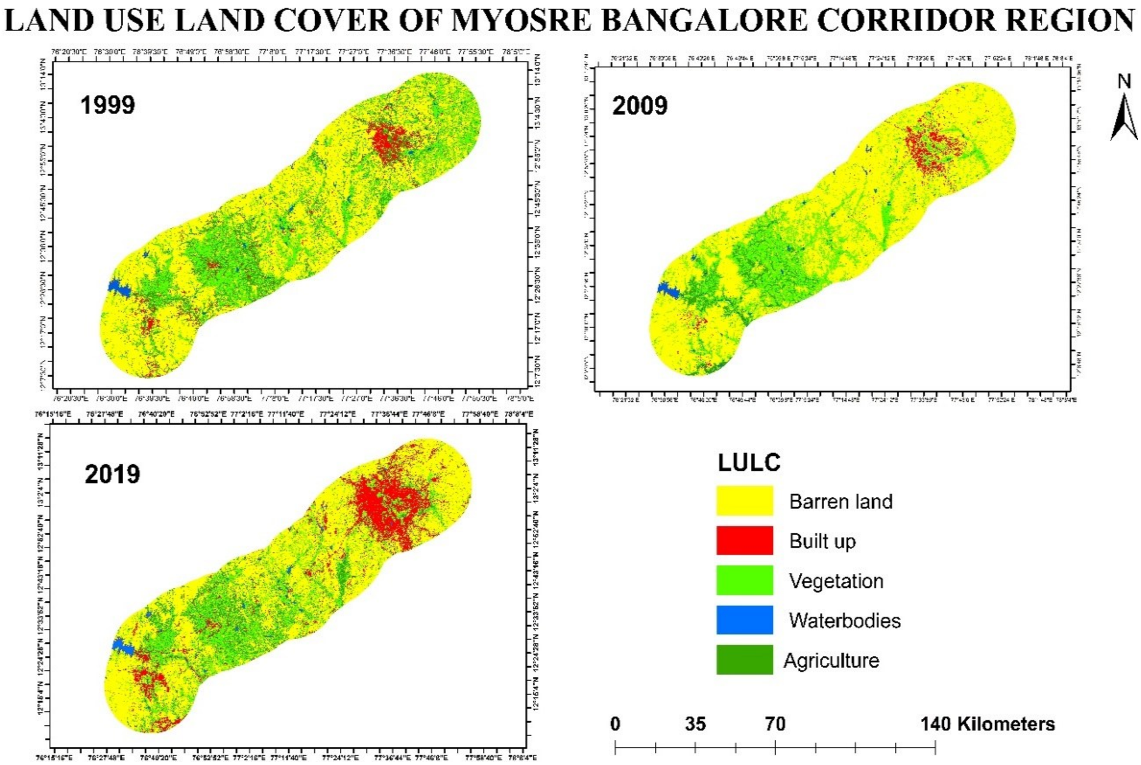
Method for ground truth verification

Ground truth was verified using google earth, field survey and toposheet. The recent satellite image of 2019 was verified by field survey using GPS. While the 1999 and 2009 images were mostly verified using google earth and toposheet for the simple reason because of the appropriate authenticity and reliability of data.

Assessment of Classification Accuracy

The result of classification cannot be accepted without proving the accuracy of the classification, therefore the present study has used the Confusion Matrix and Cohen's Kappa, which is highly accepted and considered by several researchers for the accuracy assessment of LULC studies (Hollister et al., 2004; Kaul & Sopan, 2012). The Confusion Matrix also known as the Contingency Table represents the actual and classified results in a Table form. In this matrix, the classified LULC is in rows and the ground verified samples are in columns.

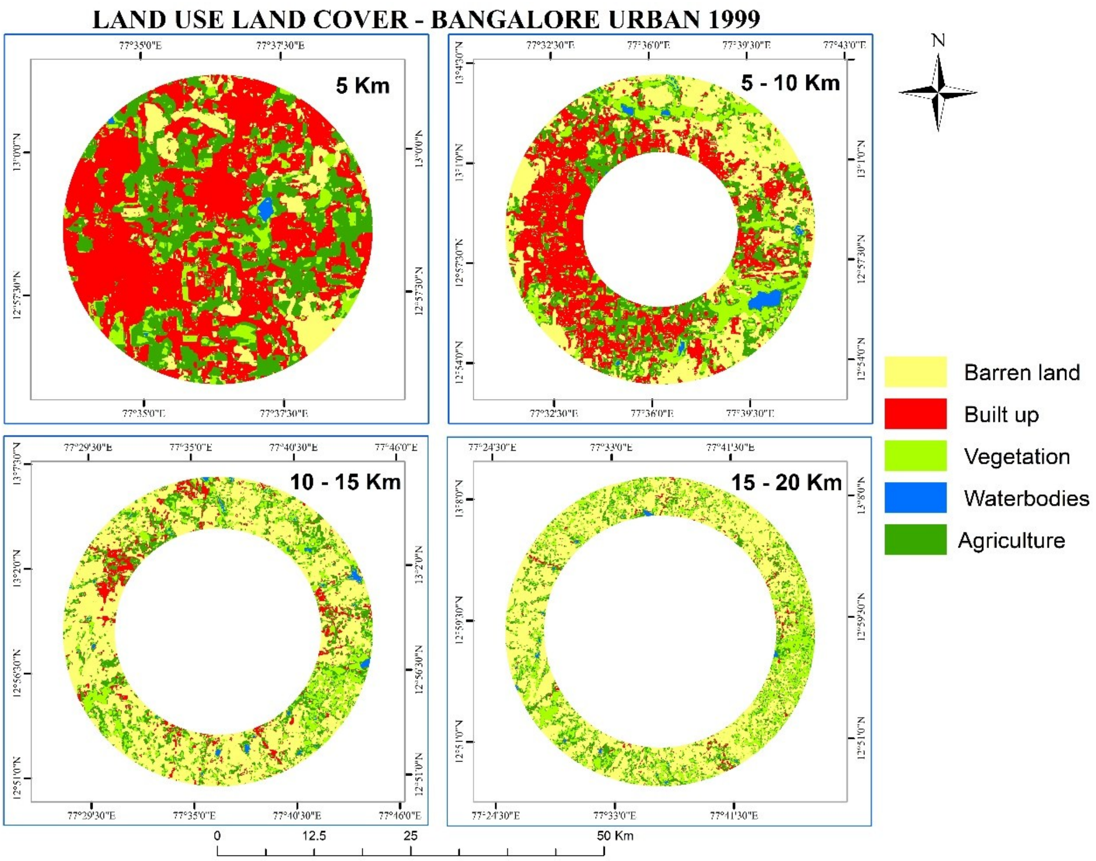
Once the matrix has been framed successfully, the accuracy classification results can be seen through the diagonal values in the matrix. Other than the diagonal values in the matrix table there are wrongly classified sample, the errors placed in rows are commission error while the columns display the omission error. From the error matrix, the user and producer accuracy can be obtained by dividing the number of correctly classified samples by the total number of samples, and the resulting in the column which illustrates the producer accuracy while the user accuracy is demonstrated in the row.

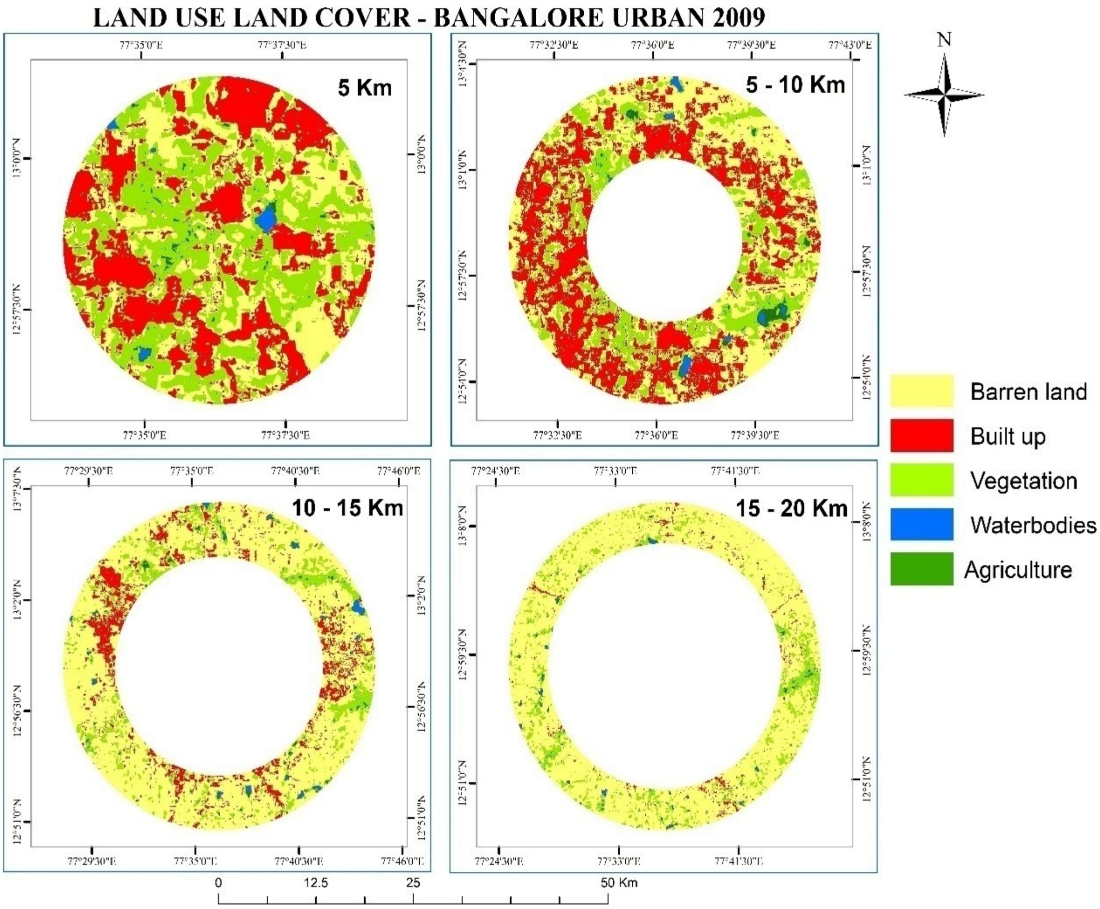


Discussion

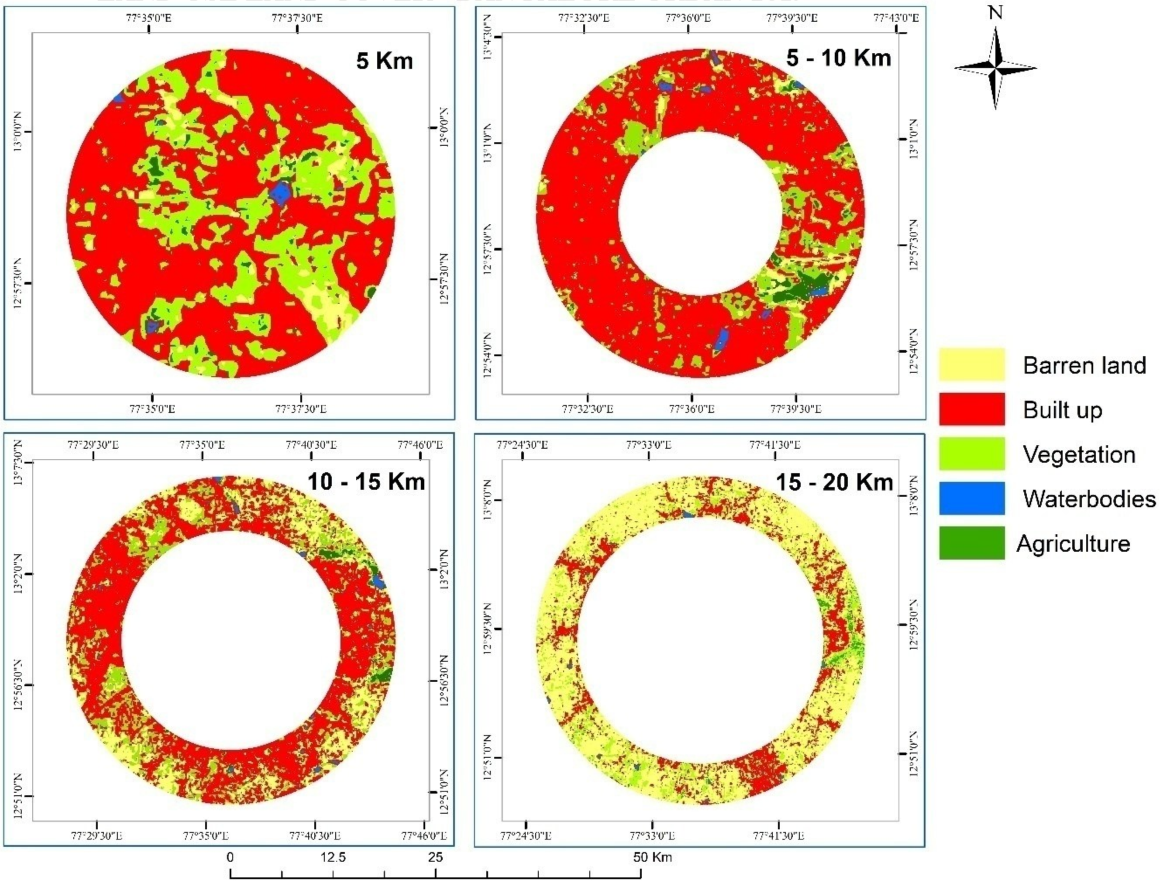
The classified result shows that during 1999, the built- up area was 340.4 Sq. Km; vegetation was 599.17 Sq. Km, barren land was 3036.54 Sq. Km and water bodies were 97.23 Sq. Km. During the year 2001, built-up area increased 646.11 Sq. Km, vegetation was 585.89 Sq. Km, barren land was 2899.54 Sq. Km and water bodies were 95.98 Sq.Km. the change in the area under vegetation from 1999 to 2019 was less than 1%, while the change in agriculture was around 5% decline, built up land also has made a large change to a tune of 13% increase. The landuse has changed in different proportion for different urban centres.

The Bangalore Metropolitan region shows a drastic change

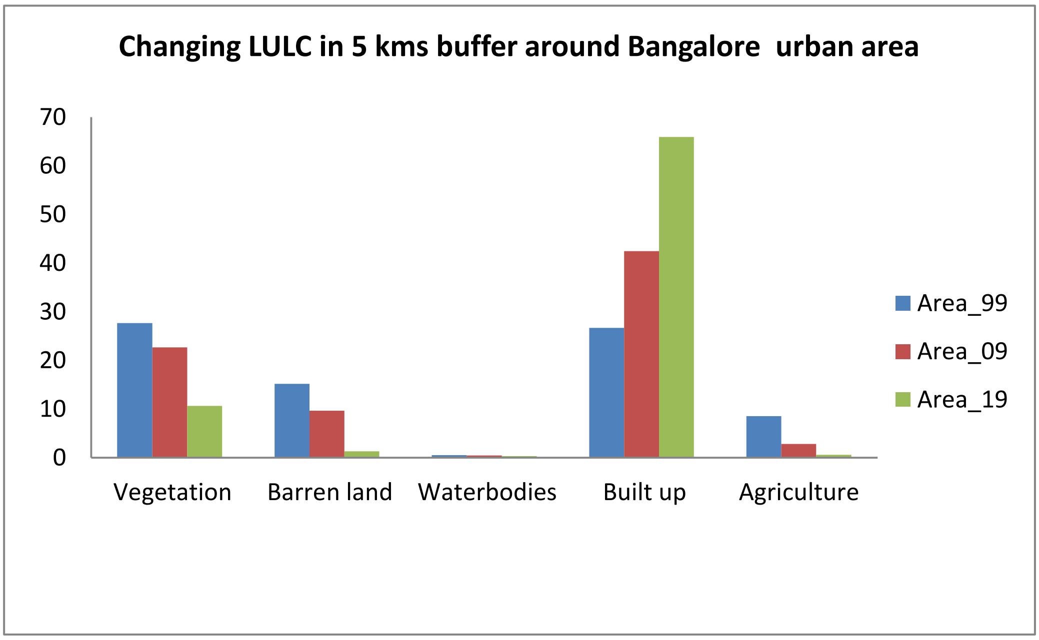


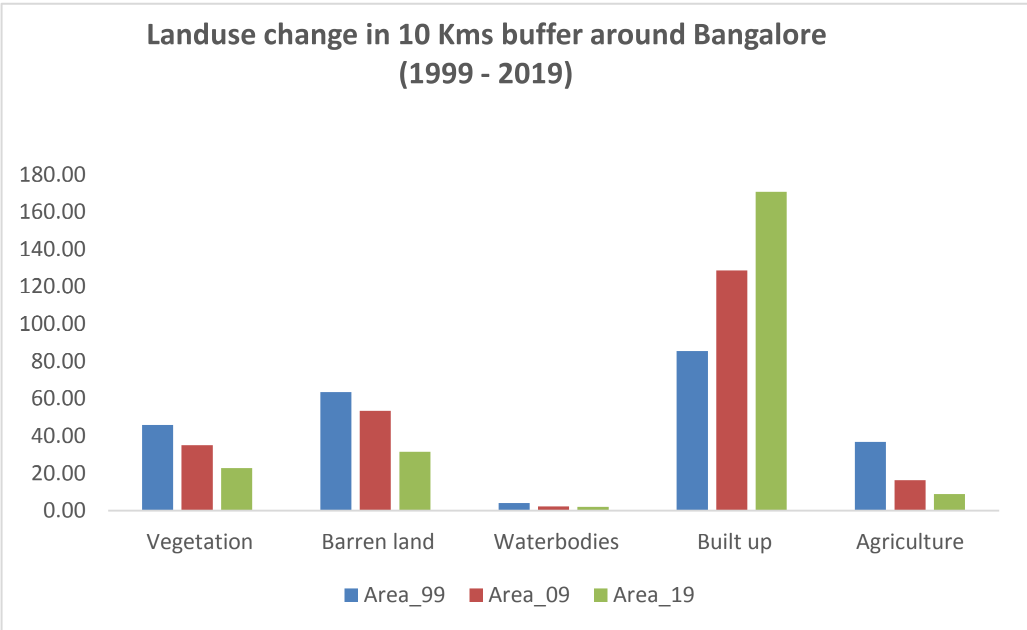

LAND USE LAND COVER - BANGALORE URBAN 2009
5 Km
5 - 10 Km
10 - 15 Km
15 - 20 Km
N
Barren land
Built up
Vegetation
Waterbodies
Agriculture
0
12.5
25
50 Km

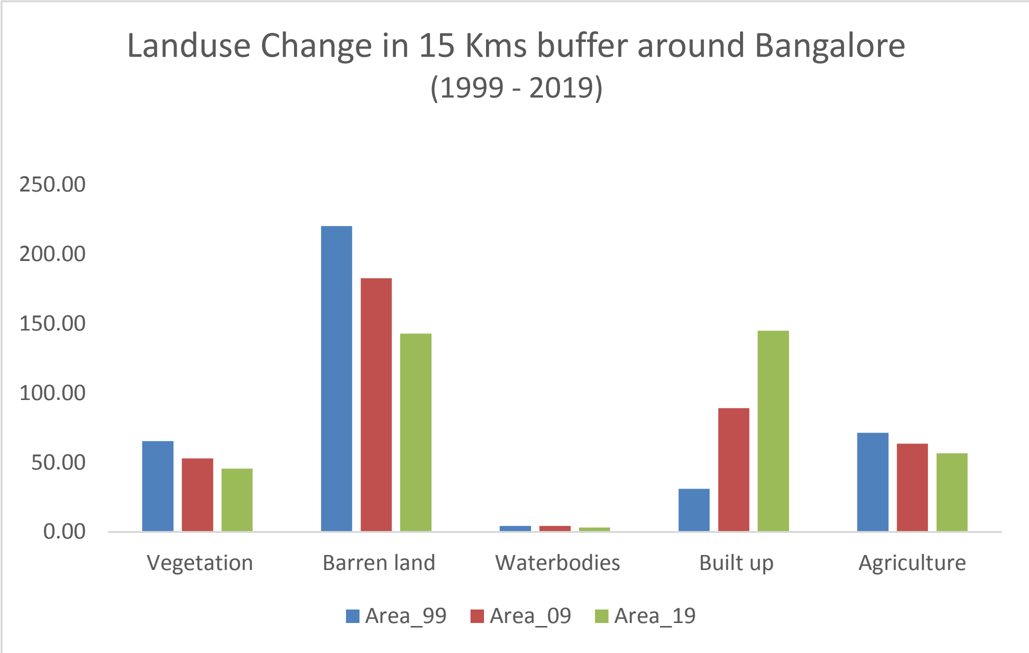
LAND USE LAND COVER - BANGALORE URBAN 2019

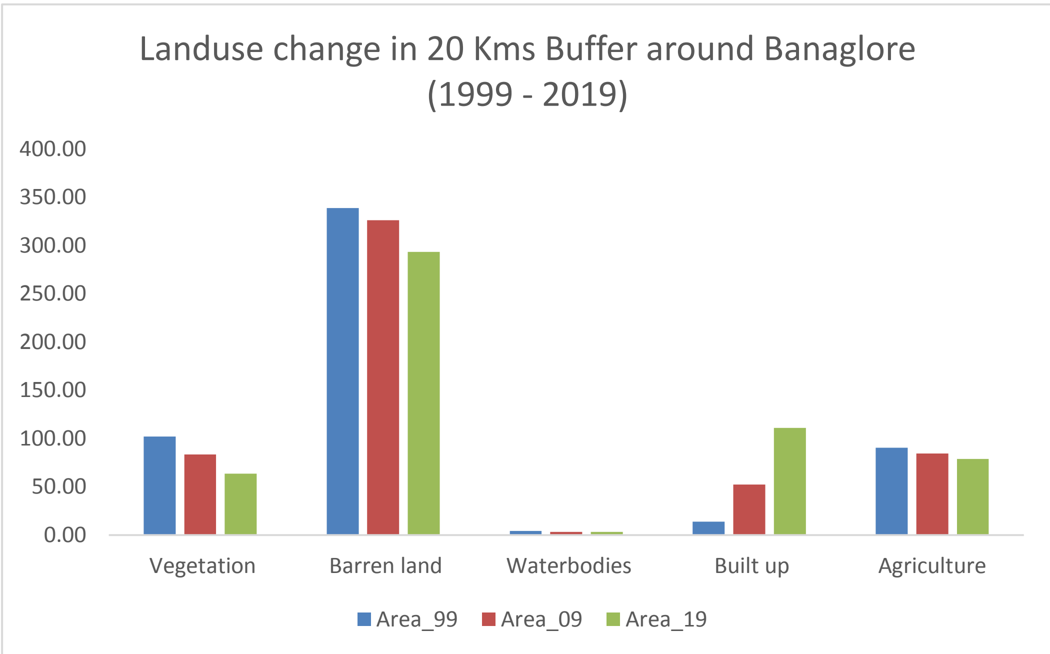


5KM BUFFER	LULC- BANGALORE			Percentage of land use in different categories		
	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	27.68	22.71	10.62	35.23	29.10	13.50
Barren land	15.16	9.65	1.28	19.30	12.37	1.63
Water bodies	0.51	0.44	0.31	0.65	0.57	0.39
Built up	26.7	42.44	65.92	33.98	54.39	83.77
Agriculture	8.52	2.79	0.56	10.84	3.58	0.71
	78.56645	78.029053	78.689946	100	100	100
10 KM BUFFER	LULC- BANGALORE			Percentage of land use in different categories		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	45.89	34.93	22.81	19.48	14.83	9.67
Barren land	63.37	53.50	31.46	26.90	22.72	13.34
Water bodies	4.05	2.16	1.94	1.72	0.92	0.82
Built up	85.39	128.58	170.79	36.25	54.61	72.42
Agriculture	36.87	16.28	8.84	15.65	6.91	3.75
	235.57	235.45	235.83	100	100	100
15 KMS BUFFER	LULC- BANGALORE			Percentage of land use in different categories		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	65.42	52.95	45.59	16.66	13.48	11.60
Barren land	220.43	182.76	142.83	56.13	46.54	36.34
Water bodies	4.40	4.23	3.06	1.12	1.08	0.78
Built up	30.99	89.27	144.96	7.89	22.73	36.89
Agriculture	71.46	63.48	56.55	18.20	16.17	14.39
	392.70	392.70	393.00	100	100	100
20 KMS BUFFER	LULC- BANGALORE			Percentage of land use in different categories		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	101.98	83.36	63.5	18.56	15.16	11.55
Barren land	338.85	326.21	293.371	61.67	59.33	53.34
Water bodies	4.26	3.35	3.177	0.77	0.61	0.58
Built up	13.82	52.41	111.049	2.52	9.53	20.19
Agriculture	90.53	84.50	78.896	16.48	15.37	14.34
	549.44	549.84	549.99	100	100	100

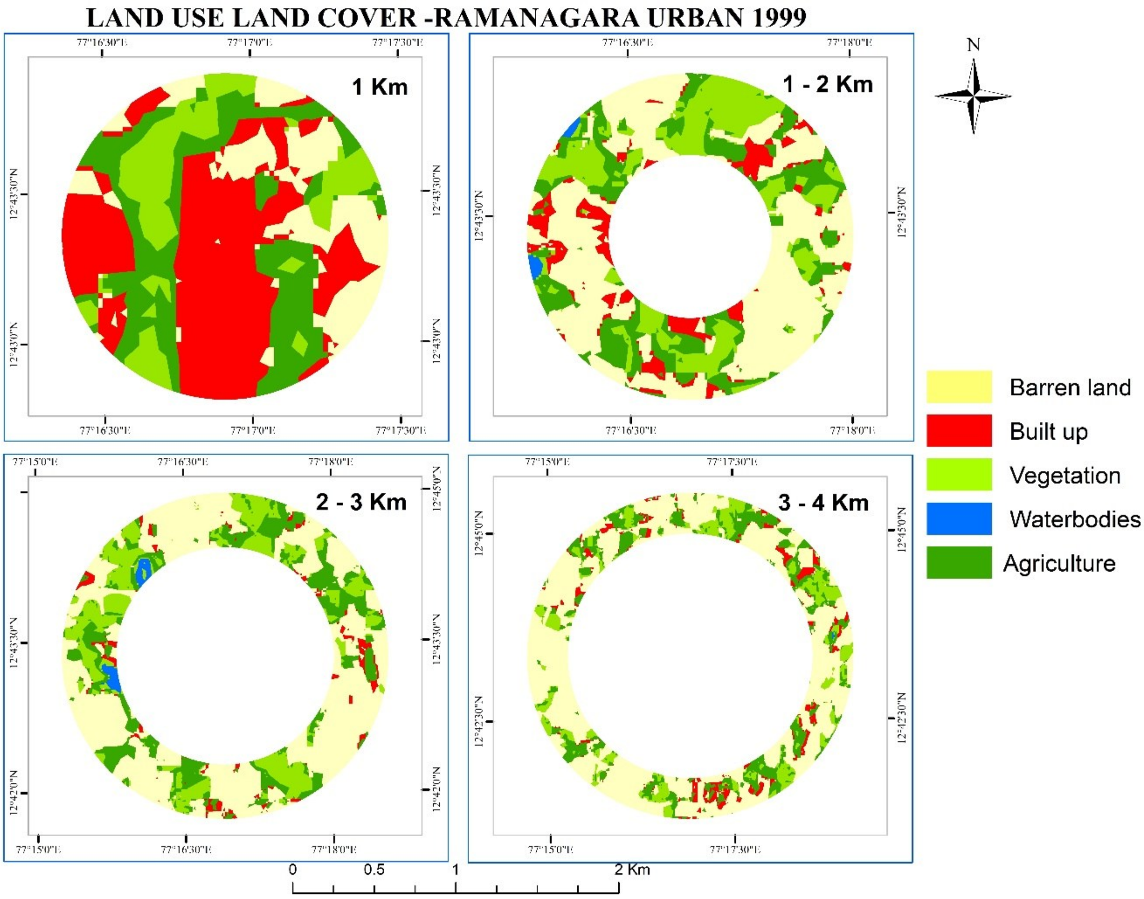

Changing LULC in 5 kms buffer around Bangalore urban area
70
60
50
40
30
20
10
0
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19


Landuse change in 10 Kms buffer around Bangalore
(1999 - 2019)
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19

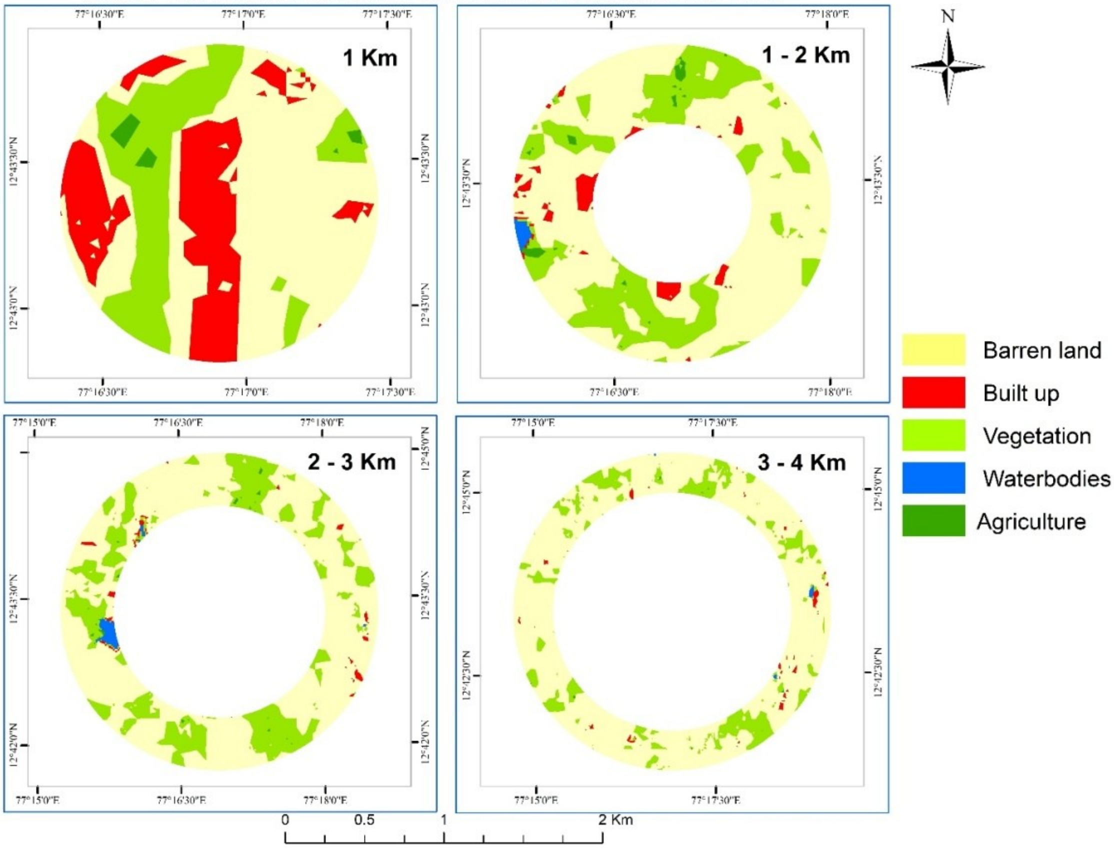

Landuse Change in 15 Kms buffer around Bangalore
(1999 - 2019)
250.00
200.00
150.00
100.00
50.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19


Landuse change in 20 Kms Buffer around Banaglore
(1999 - 2019)
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19

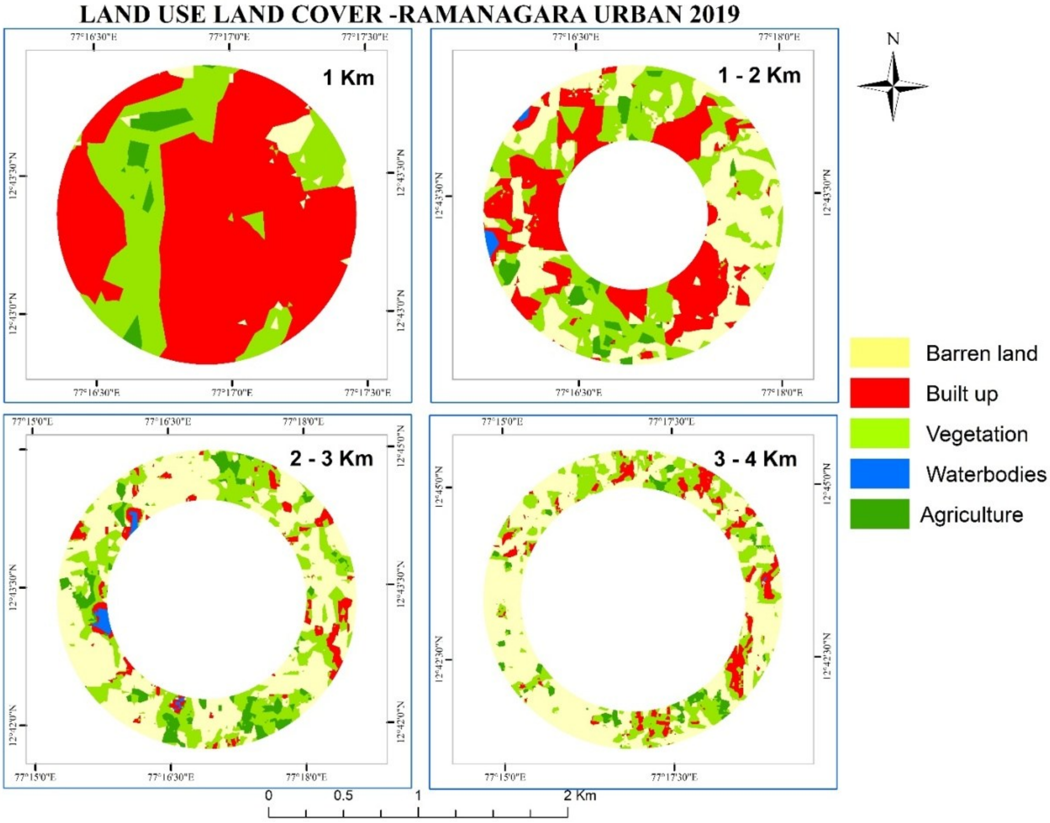
LANDUSE CHANGE IN AND AROUND RAMANAGARA URBAN AREA

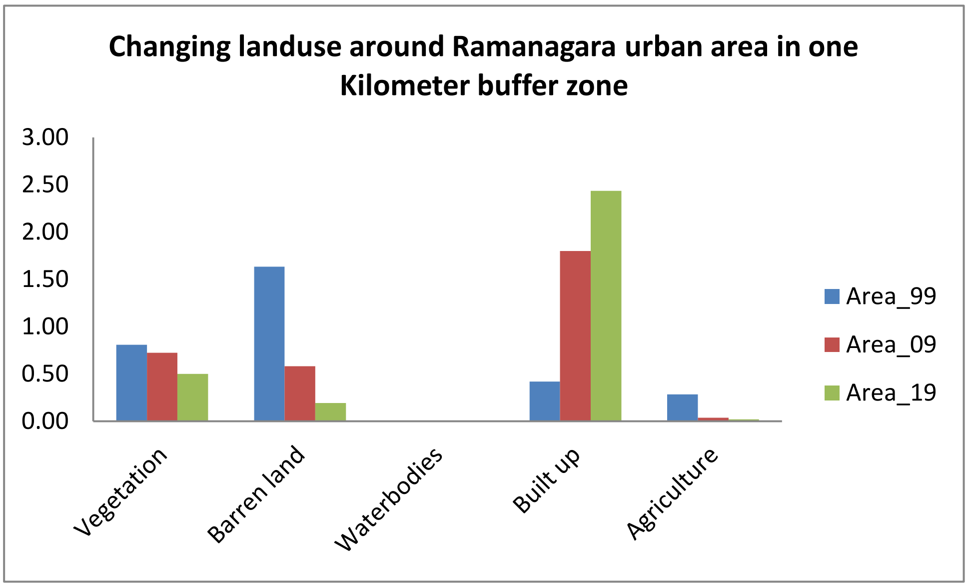


LAND USE LAND COVER -RAMANAGARA URBAN 2009

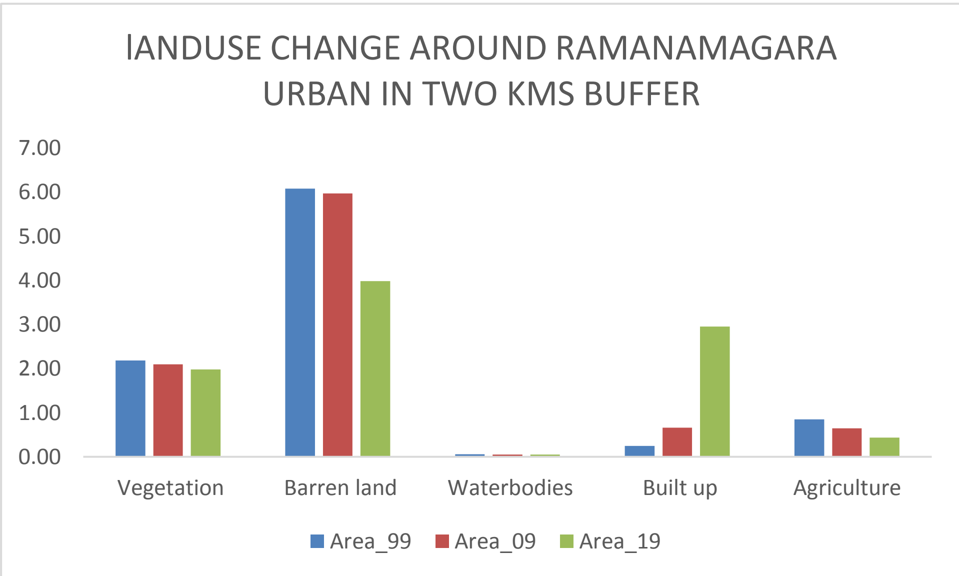


LAND USE LAND COVER -RAMANAGARA URBAN 2019

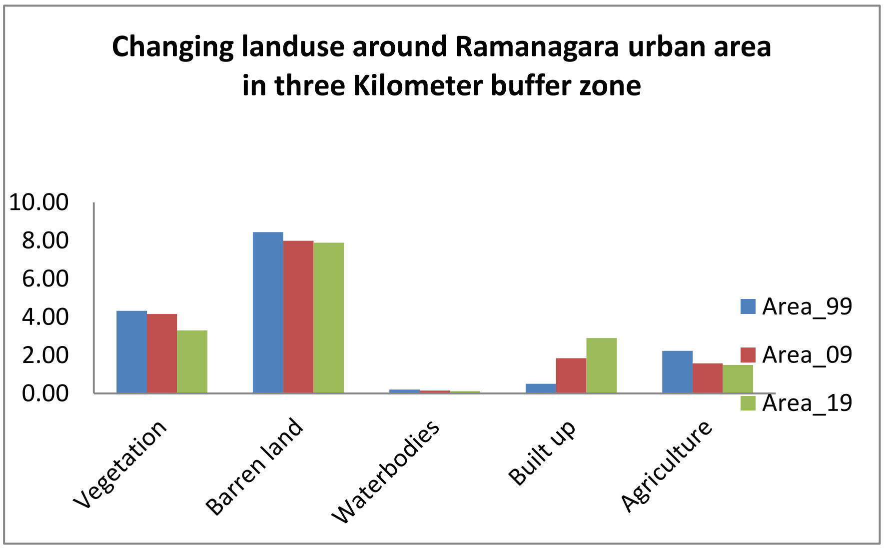


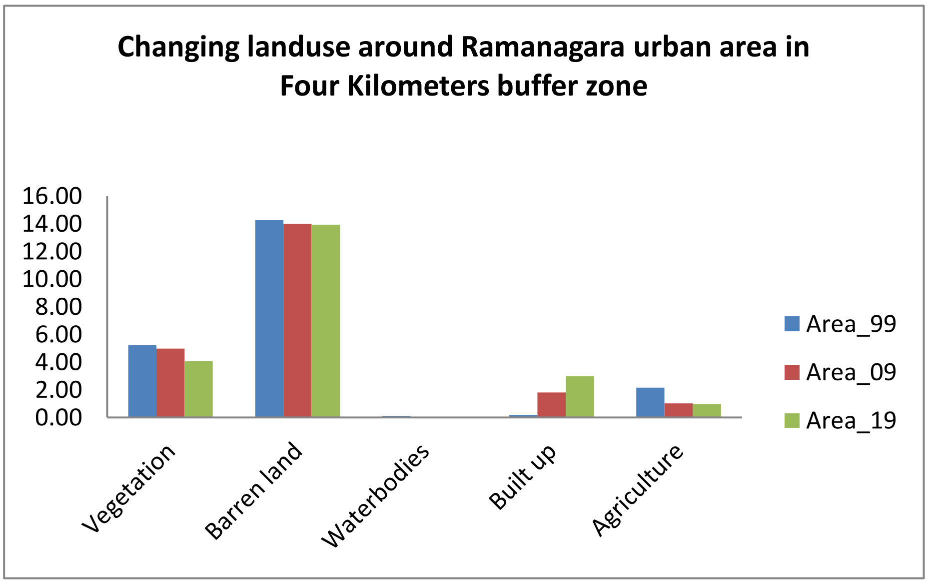


Changing landuse around Ramanagara urban area in one Kilometer buffer zone
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19



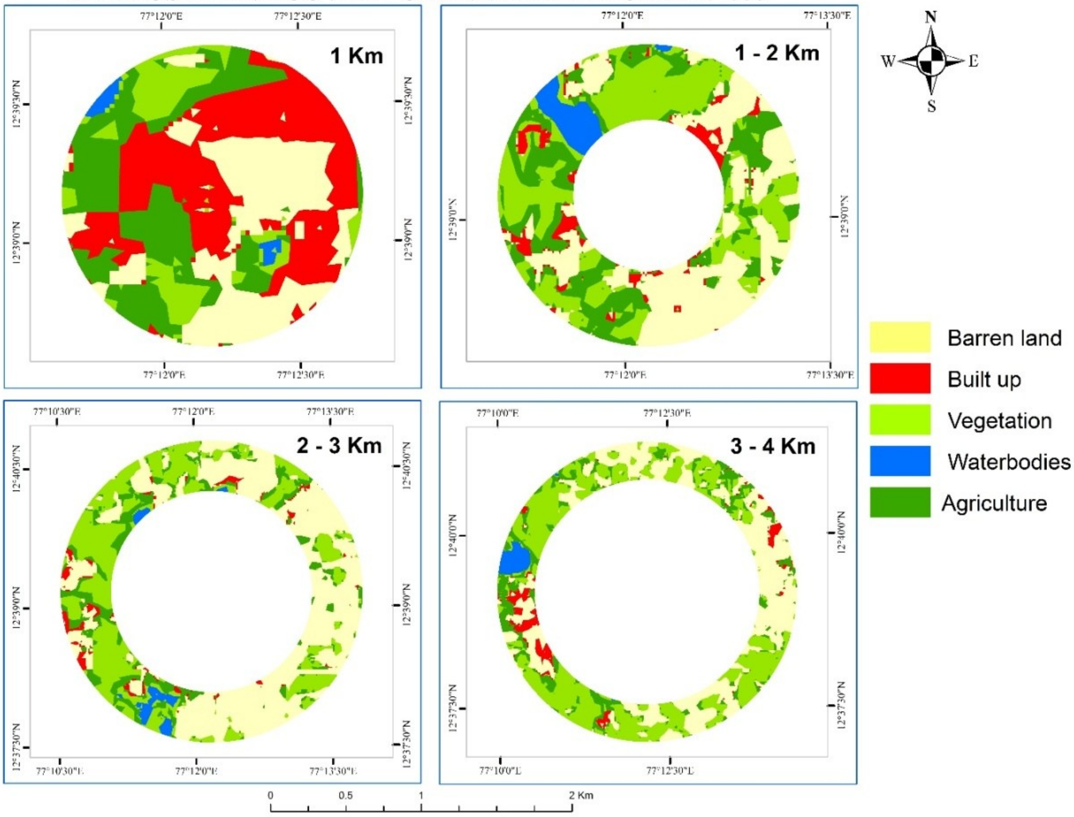
lANDUSE CHANGE AROUND RAMANAMAGARA URBAN IN TWO KMS BUFFER
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19


Changing landuse around Ramanagara urban area in three Kilometer buffer zone
10.00
8.00
6.00
4.00
2.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19

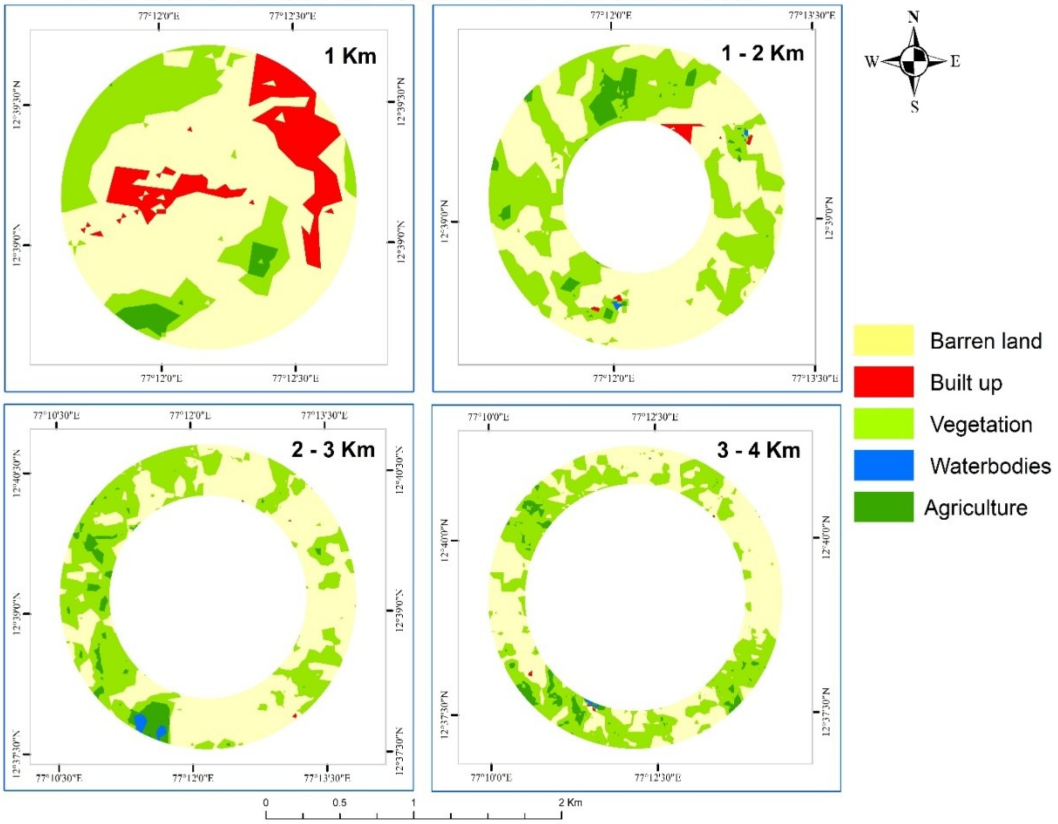

Changing landuse around Ramanagara urban area in Four Kilometers buffer zone
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19

1KM BUFFER	LULC- Ramnagara			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	0.81	0.72	0.50	25.7	23.0	15.9
Barren land	1.63	0.58	0.19	52.0	18.5	6.1
Waterbodies	0.00	0.00	0.00	0.0	0.0	0.0
Built up	0.42	1.80	2.43	13.3	57.3	77.4
Agriculture	0.28	0.04	0.02	9.0	1.2	0.6
total area in Sq. Kms	3.14	3.14	3.14	100.00	100.00	100.00
2KM BUFFER	LULC- Ramnagara			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	2.18	2.09	1.99	23.2	22.2	21.1
Barren land	6.08	5.97	3.99	64.6	63.4	42.3
Waterbodies	0.06	0.05	0.05	0.6	0.6	0.6
Built up	0.25	0.66	2.96	2.6	7.0	31.4
Agriculture	0.85	0.64	0.44	9.0	6.8	4.6
total area in Sq. Kms	9.42	9.42	9.42	100.00	100.00	100.00
LULC- Ramnagara	3KM BUFFER			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	4.33	4.15	3.30	27.53	26.41	21.02
Barren land	8.44	8.00	7.89	53.75	50.89	50.23
Water bodies	0.20	0.15	0.13	1.28	0.99	0.81
Built up	0.50	1.84	2.90	3.20	11.71	18.44
Agriculture	2.24	1.57	1.49	14.24	10.00	9.49
total area in Sq. Kms	15.71	15.71	15.71	100	100	100
LULC- Ramnagara	4KM BUFFER			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	5.24	4.97	4.09	23.8	22.8	18.6
Barren land	14.27	13.98	13.93	64.9	64.1	63.4
Waterbodies	0.12	0.02	0.01	0.5	0.1	0.0
Built up	0.19	1.81	2.98	0.9	8.3	13.6
Agriculture	2.16	1.02	0.98	9.8	4.7	4.4
total area in Sq. Kms	21.99	21.79	21.99	100.00	100.00	100.00

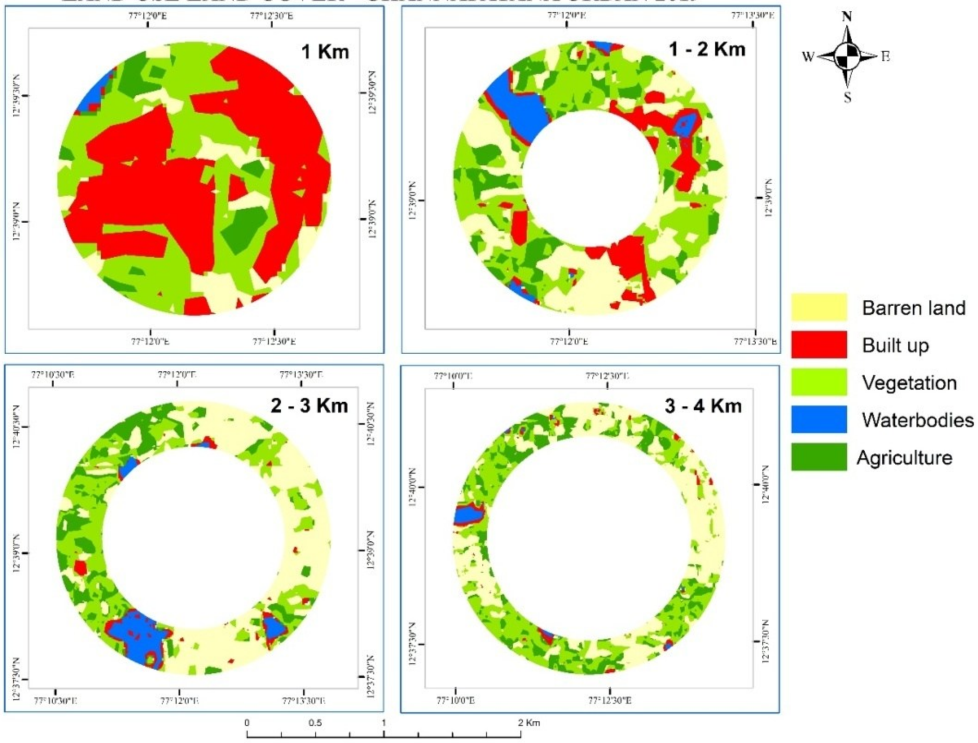
LAND USE LAND COVER - CHANNAPATANA URBAN 1999

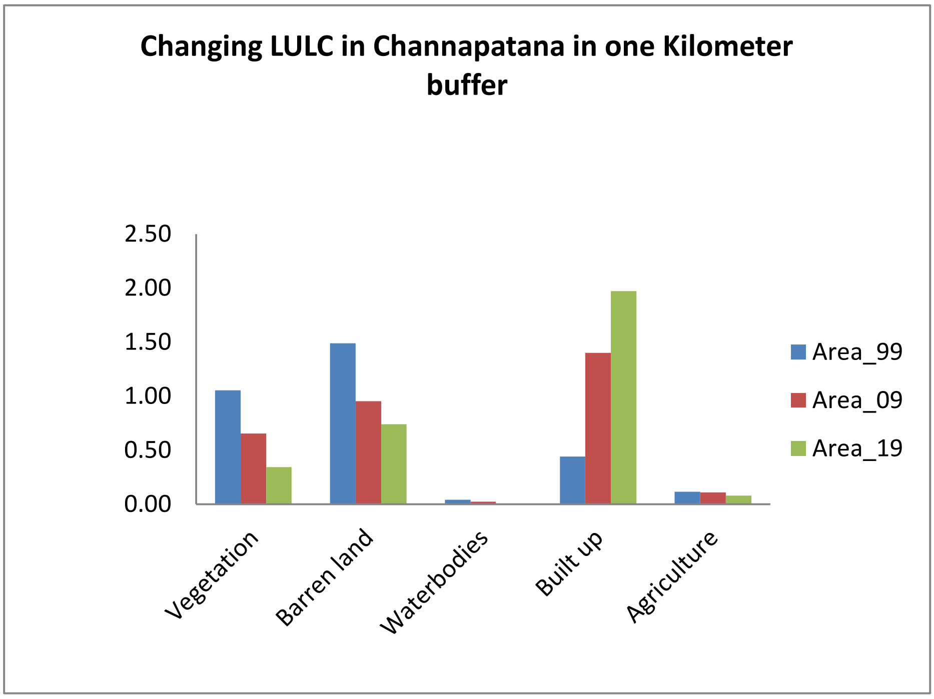


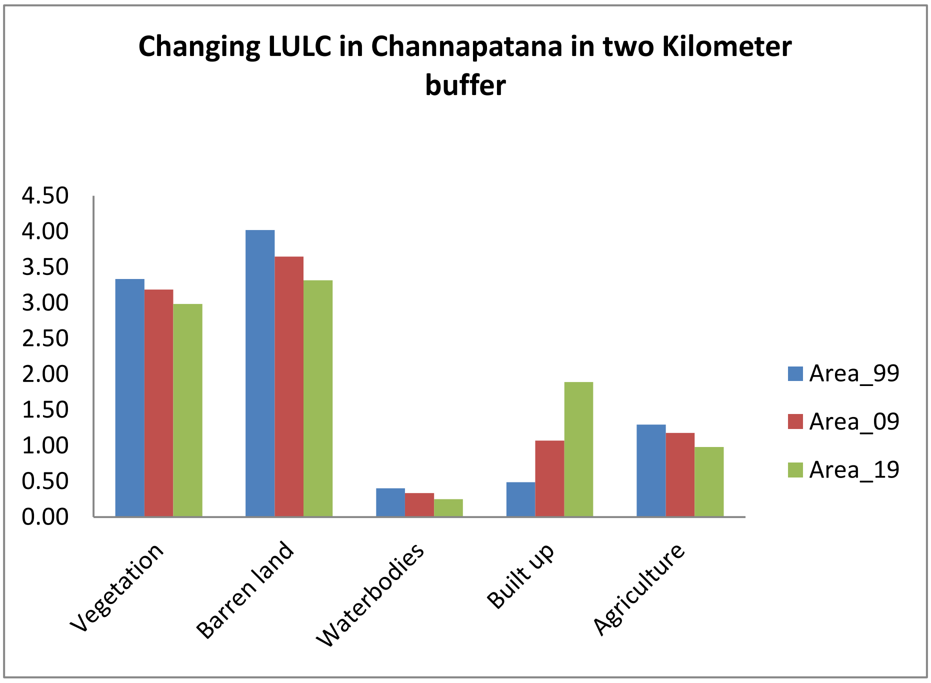
LAND USE LAND COVER - CHANNAPATANA URBAN 2009

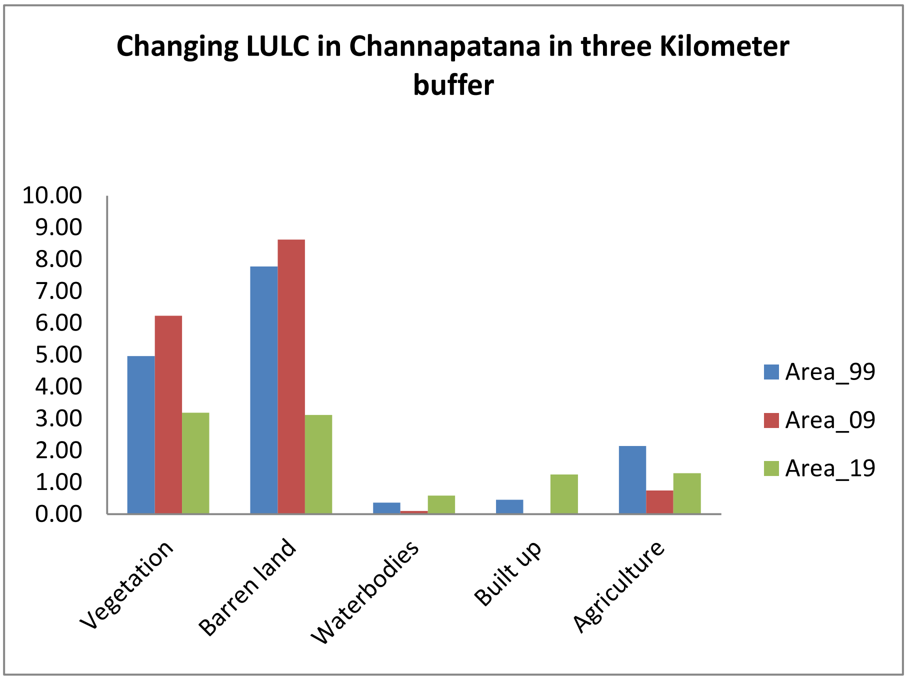


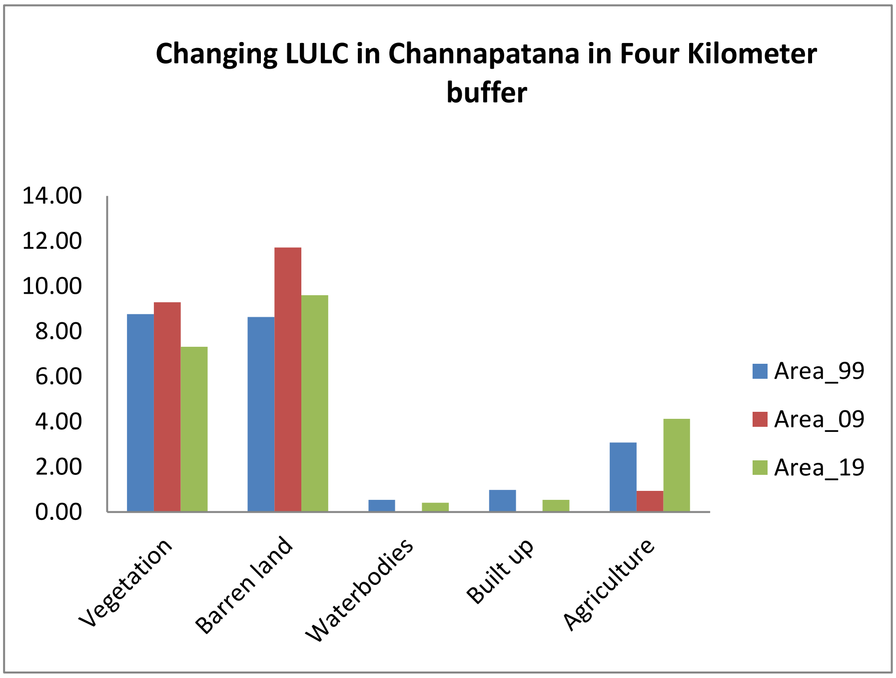
LAND USE LAND COVER - CHANNAPATANA URBAN 2019




Changing LULC in Channapatana in one Kilometer buffer
2.50
2.00
1.50
1.00
0.50
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19

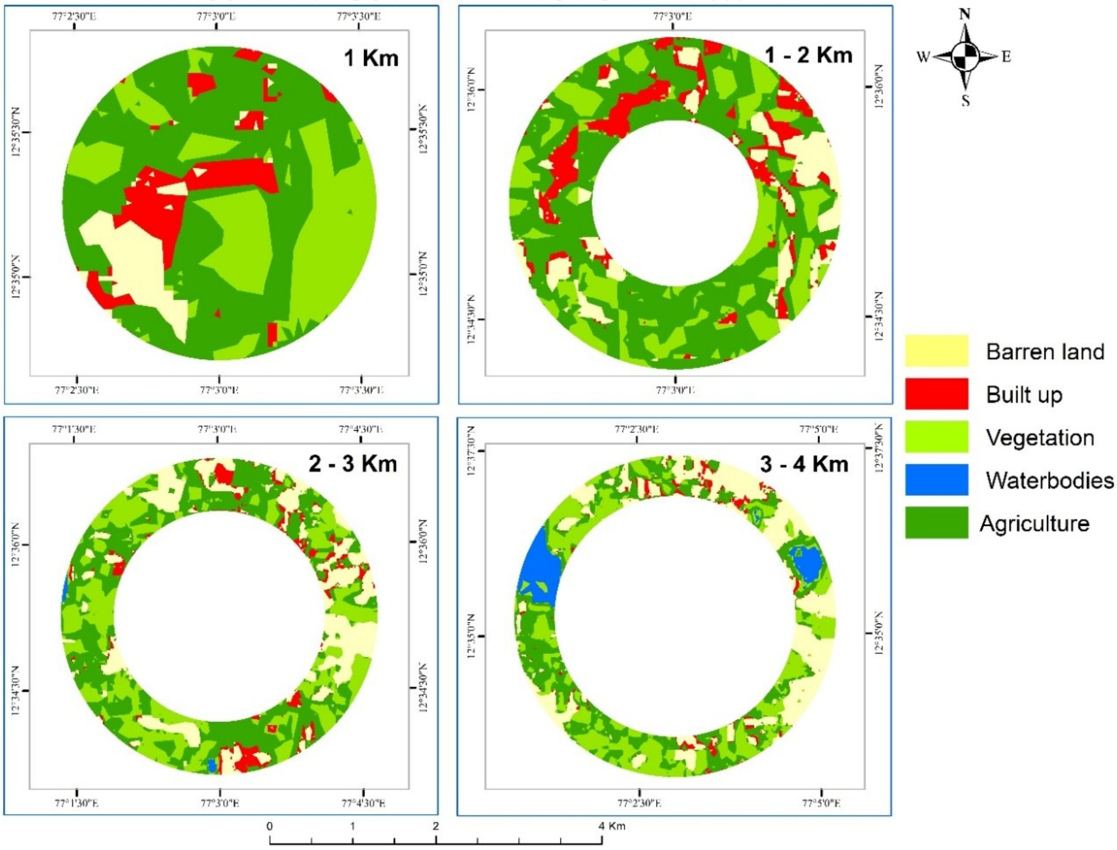

Changing LULC in Channapatana in two Kilometer buffer
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19


Changing LULC in Channapatana in three Kilometer buffer
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19

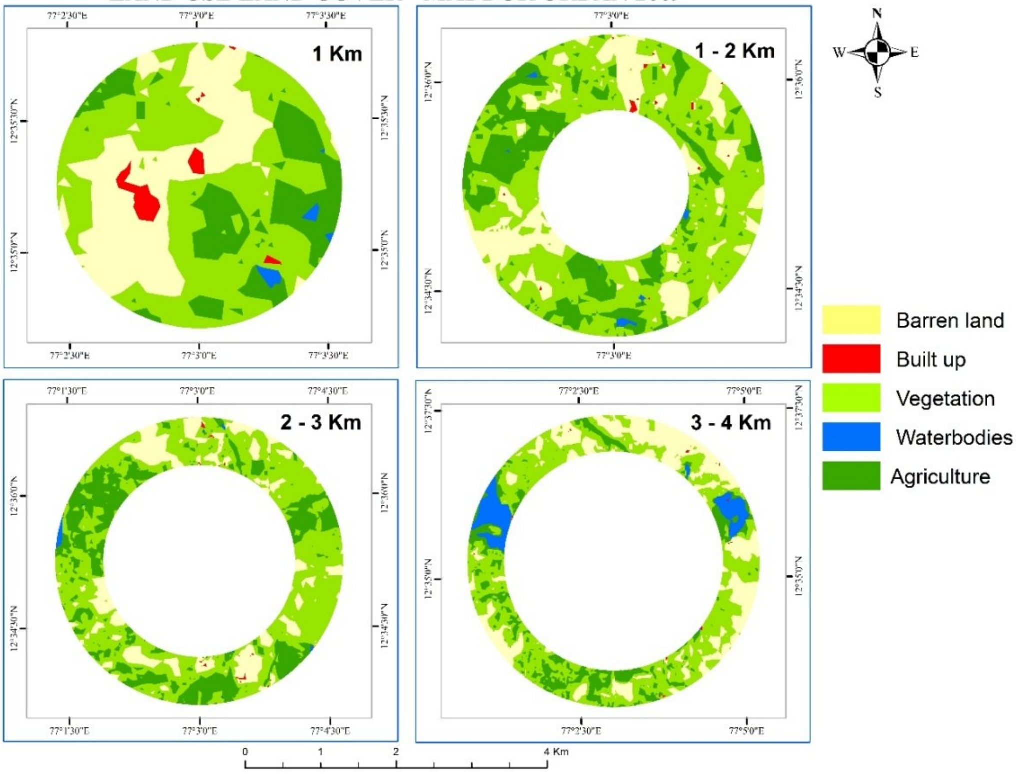

Changing LULC in Channapatana in Four Kilometer buffer
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19

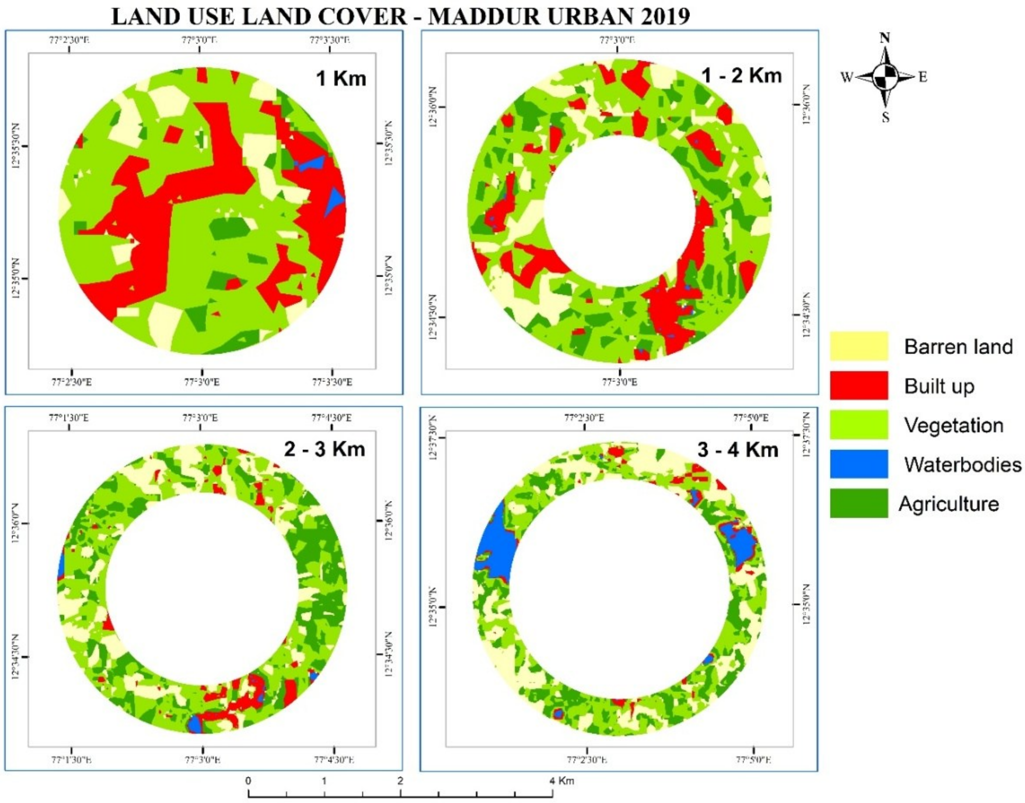
1KM BUFFER	LULC HANNAPATANA			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	1.05	0.66	0.34	33.55	20.85	10.99
Barren land	1.49	0.95	0.74	47.43	30.32	23.59
Waterbodies	0.04	0.02	0.00	1.28	0.78	0.00
Built up	0.44	1.40	1.97	14.02	44.54	62.87
Agriculture	0.12	0.11	0.08	3.72	3.50	2.55
	3.14	3.14	3.14	100	100	100
2KM BUFFER	LULC HANNAPATANA					
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	3.34	3.19	2.98	34.97	33.84	31.68
Barren land	4.02	3.65	3.32	42.15	38.73	35.21
Waterbodies	0.40	0.34	0.25	4.21	3.57	2.65
Built up	0.49	1.07	1.89	5.11	11.38	20.05
Agriculture	1.29	1.18	0.98	13.57	12.49	10.40
	9.54	9.42	9.42	100	100	100
3KM BUFFER	LULC HANNAPATANA					
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	4.97	6.23	3.19	31.62	39.64	33.81
Barren land	7.78	8.62	3.12	49.54	54.88	33.08
Waterbodies	0.36	0.11	0.59	2.31	0.67	6.22
Built up	0.45	0.01	1.25	2.88	0.04	13.25
Agriculture	2.14	0.75	1.29	13.66	4.76	13.64
	15.71	15.71	9.42	100	100	100
4KM BUFFER	LULC HANNAPATANA					
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	8.76	9.29	7.32	39.85	42.26	33.28
Barren land	8.63	11.71	9.60	39.24	53.25	43.65
Waterbodies	0.54	0.03	0.40	2.44	0.13	1.83
Built up	0.98	0.02	0.54	4.46	0.11	2.46
Agriculture	3.08	0.93	4.13	14.01	4.25	18.78
	21.99	21.99	21.99	100	100	100

LAND USE LAND COVER - MADDUR URBAN 1999

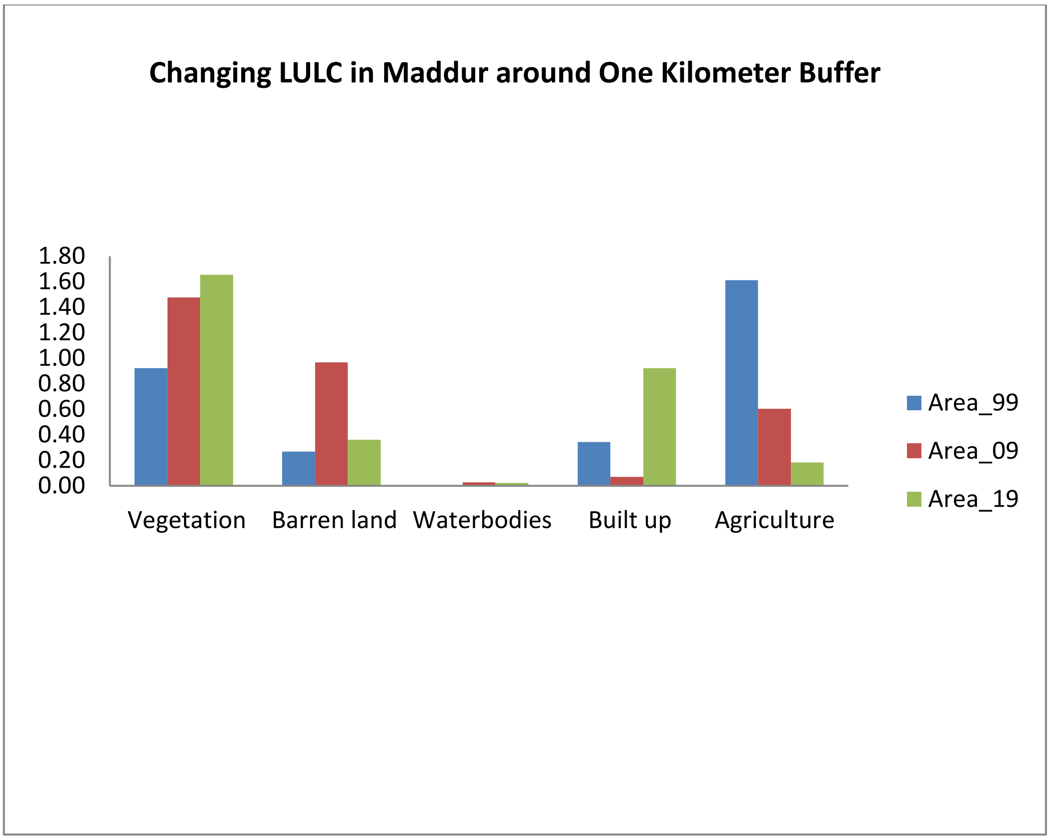


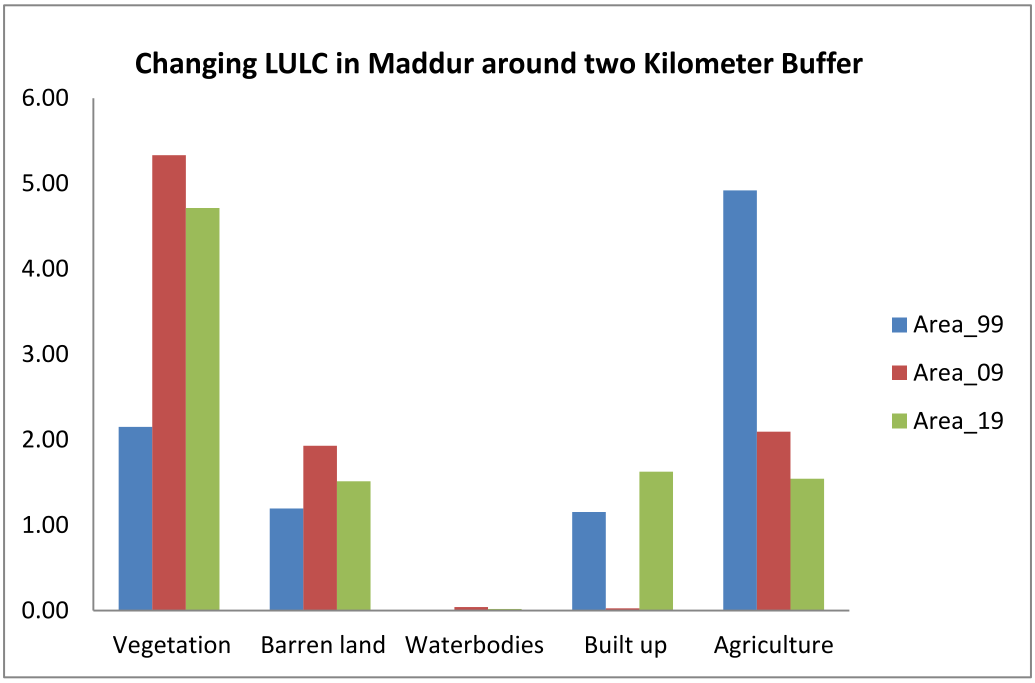
LAND USE LAND COVER - MADDUR URBAN 2009

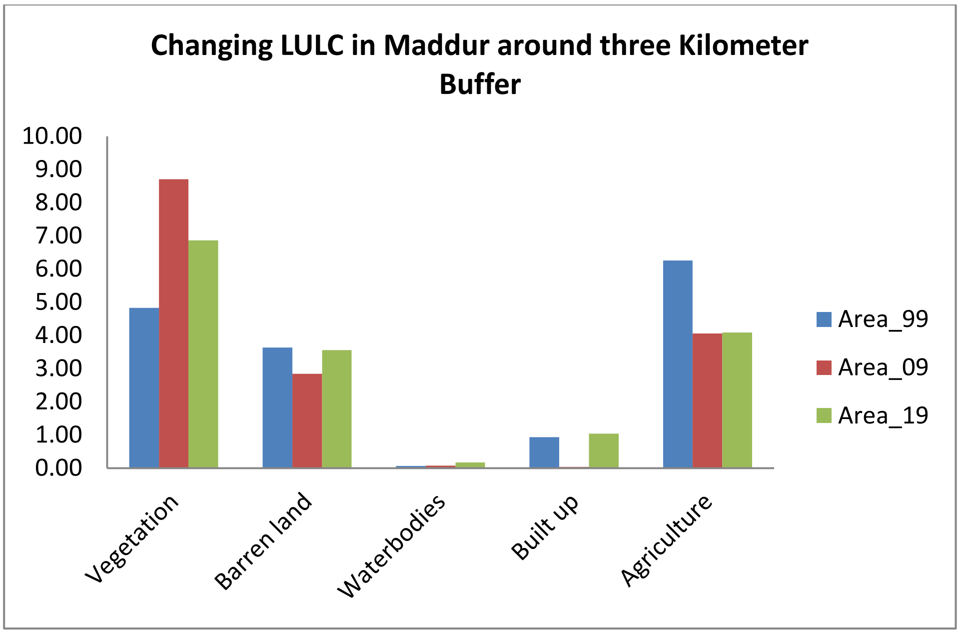


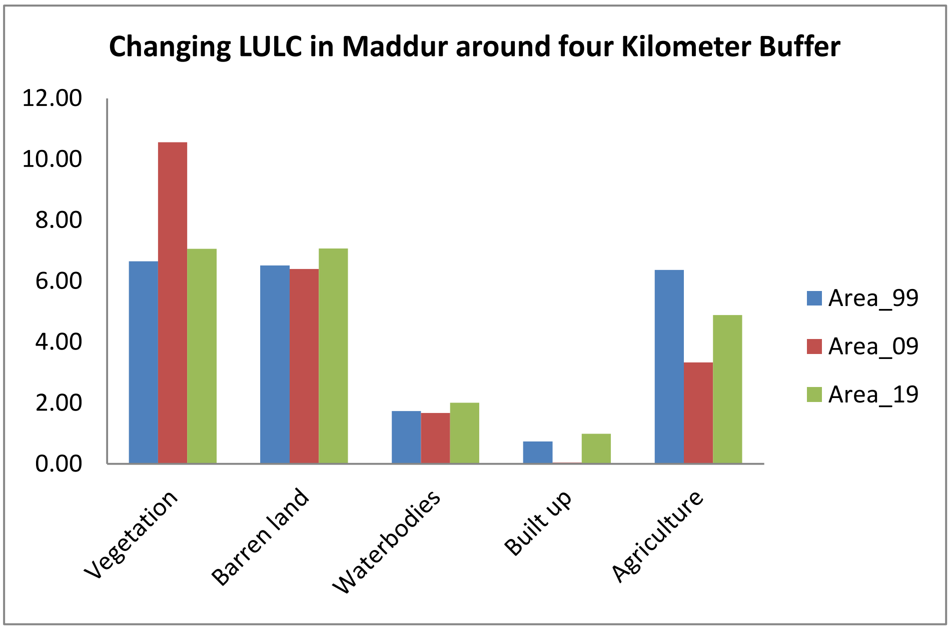


LAND USE LAND COVER - MADDUR URBAN 2019
1 Km
1 - 2 Km
2 - 3 Km
3 - 4 Km
N
S
E
W
Barren land
Built up
Vegetation
Waterbodies
Agriculture
0
1
2
4 Km


Changing LULC in Maddur around One Kilometer Buffer
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19

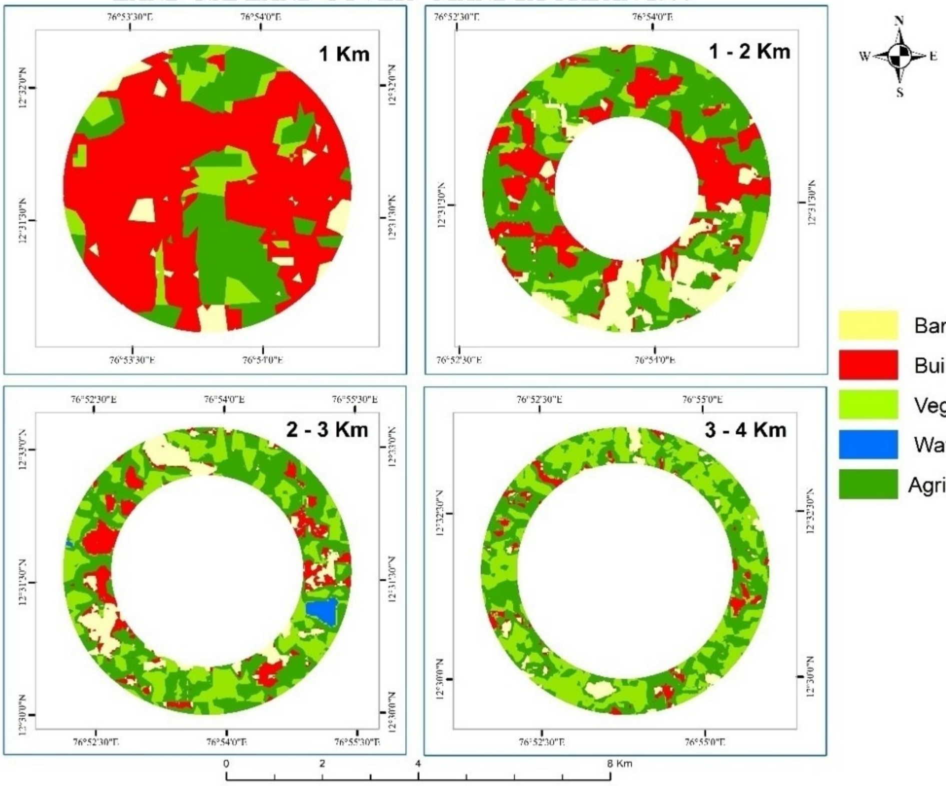

Changing LULC in Maddur around two Kilometer Buffer
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19


Changing LULC in Maddur around three Kilometer Buffer
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19

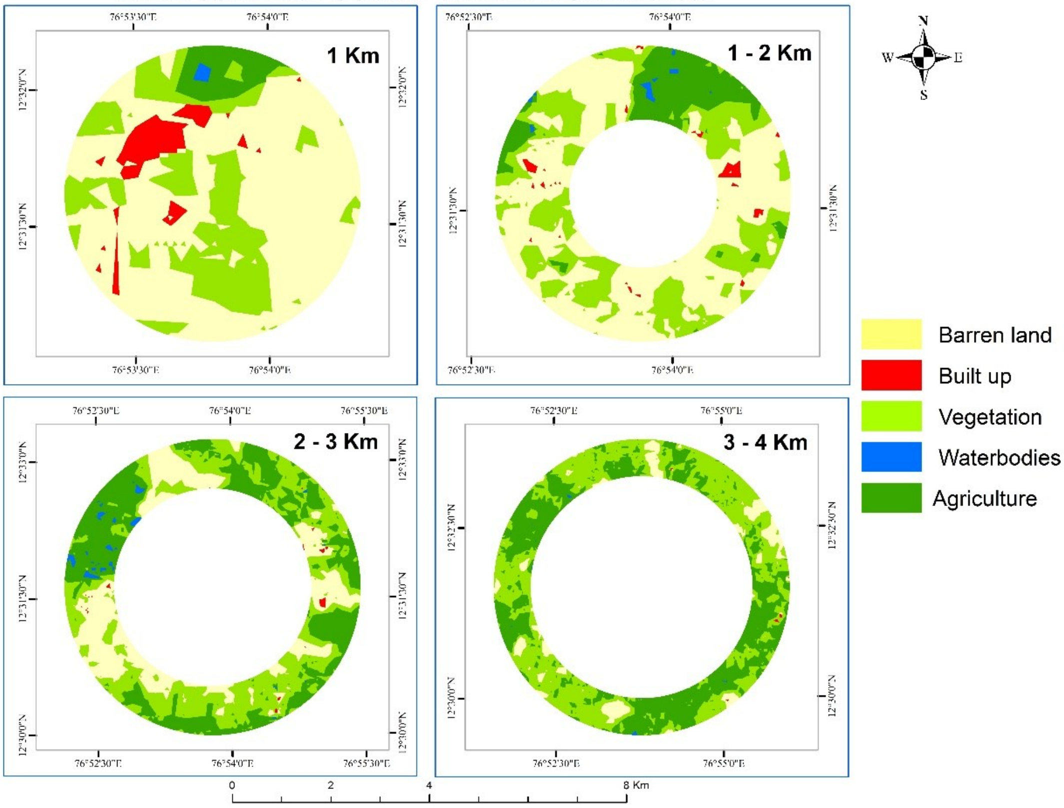

Changing LULC in Maddur around four Kilometer Buffer
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19

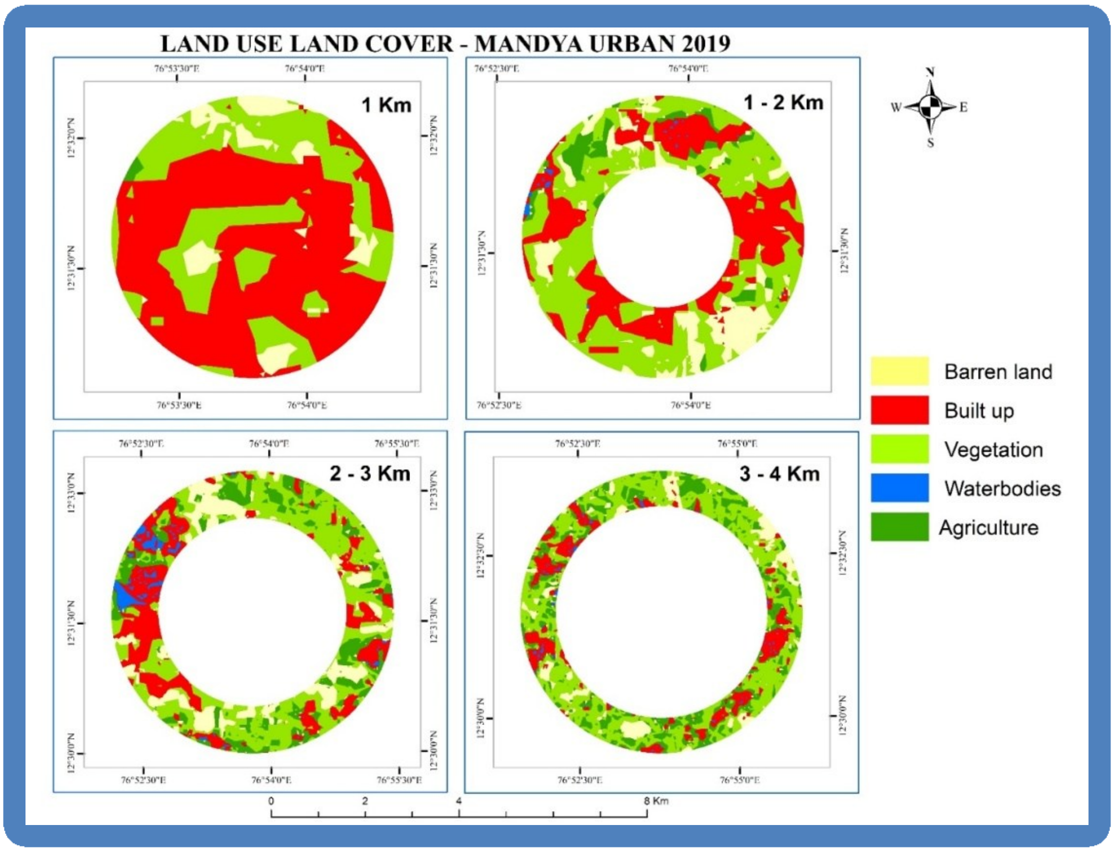
1KM BUFFER	LULC- Maddur			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	0.92	1.47	1.65	29.3	47.0	52.7
Barren land	0.27	0.97	0.36	8.5	30.8	11.4
Waterbodies	0.00	0.03	0.02	0.0	0.8	0.7
Built up	0.34	0.07	0.92	10.9	2.2	29.3
Agriculture	1.61	0.60	0.18	51.3	19.2	5.8
	3.14	3.14	3.14	100	100	100
2KM BUFFER	LULC- Maddur			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	2.15	5.33	4.72	22.8	56.6	50.0
Barren land	1.20	1.93	1.52	12.7	20.5	16.1
Waterbodies	0.00	0.04	0.02	0.0	0.5	0.2
Built up	1.16	0.03	1.63	12.3	0.3	17.3
Agriculture	4.92	2.10	1.55	52.2	22.2	16.4
	9.42	9.42	9.42	100.00	100.00	100.00
3KM BUFFER	LULC- Maddur			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	4.83	8.71	6.86	30.7	55.4	43.7
Barren land	3.63	2.84	3.55	23.1	18.1	22.6
Waterbodies	0.07	0.07	0.17	0.4	0.4	1.1
Built up	0.93	0.03	1.04	5.9	0.2	6.6
Agriculture	6.25	4.05	4.08	39.8	25.8	26.0
	15.71	15.71	15.71	100	100	100
4KM BUFFER	LULC- Maddur			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	6.65	10.55	7.06	30.2	48.0	32.1
Barren land	6.51	6.40	7.06	29.6	29.1	32.1
Waterbodies	1.73	1.67	2.00	7.9	7.6	9.1
Built up	0.74	0.04	0.99	3.3	0.2	4.5
Agriculture	6.36	3.33	4.88	28.9	15.1	22.2
	21.99	21.99	21.99	100	100	100

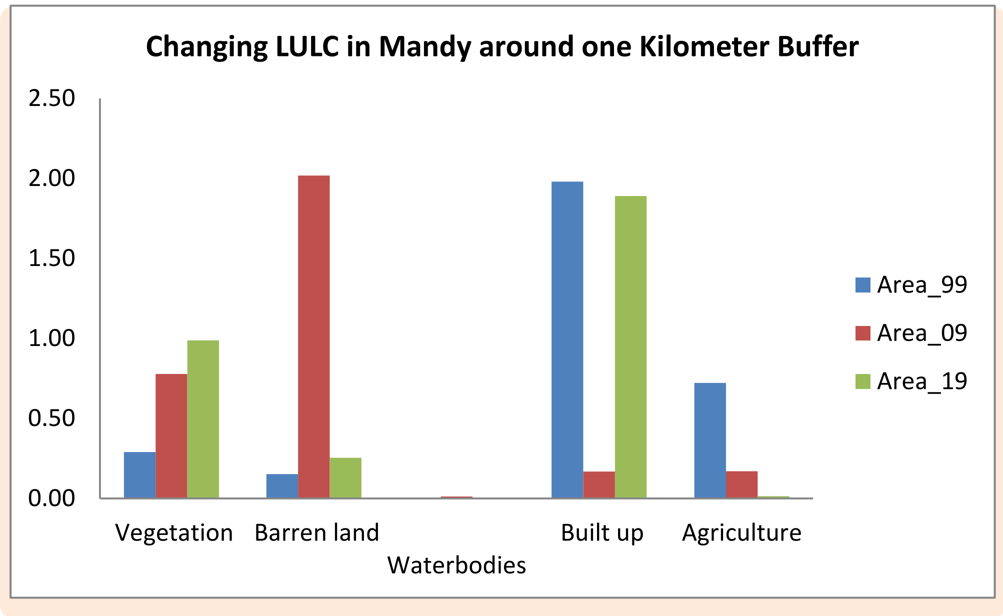
LAND USE LAND COVER - MANDYA URBAN 1999

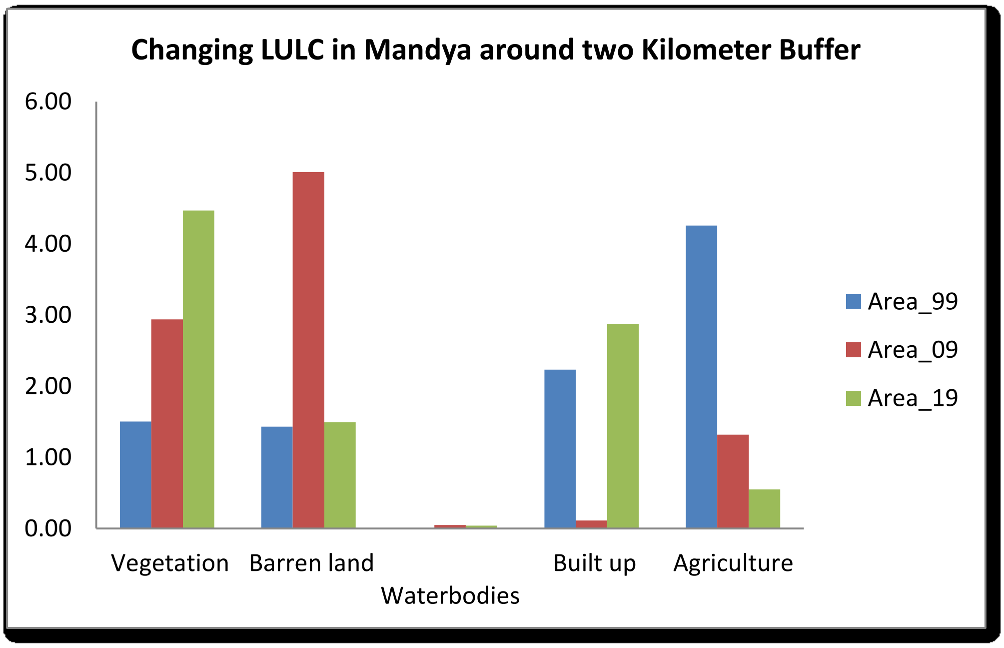


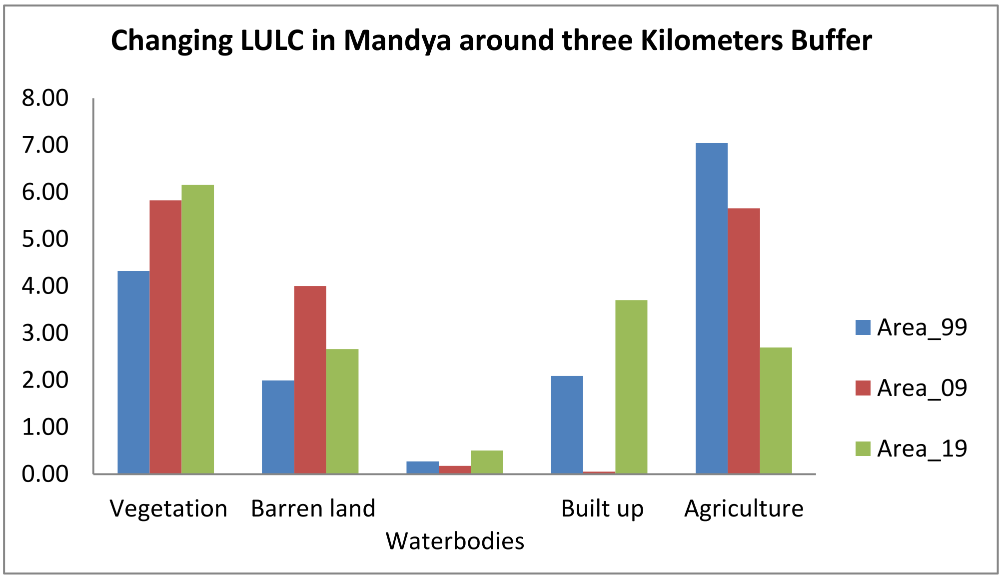
LAND USE LAND COVER - MANDYA URBAN 2009

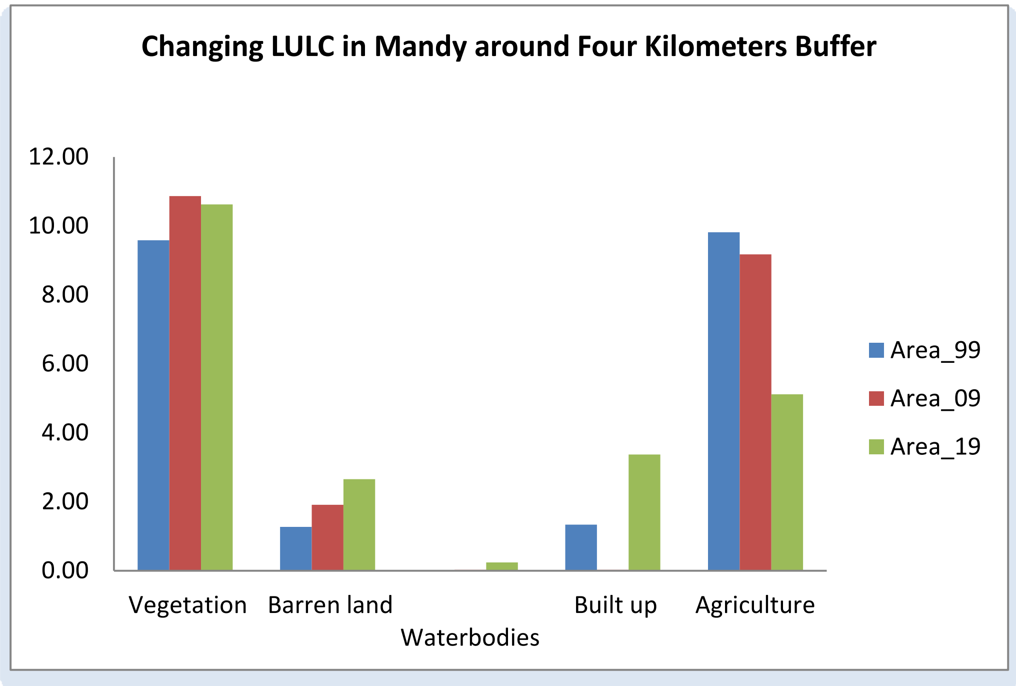



LAND USE LAND COVER - MANDYA URBAN 2019
1 Km
1 - 2 Km
2 - 3 Km
3 - 4 Km
N
W
E
S
Barren land
Built up
Vegetation
Waterbodies
Agriculture
0
2
4
8 Km


Changing LULC in Mandy around one Kilometer Buffer
2.50
2.00
1.50
1.00
0.50
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19


Changing LULC in Mandya around two Kilometer Buffer
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19

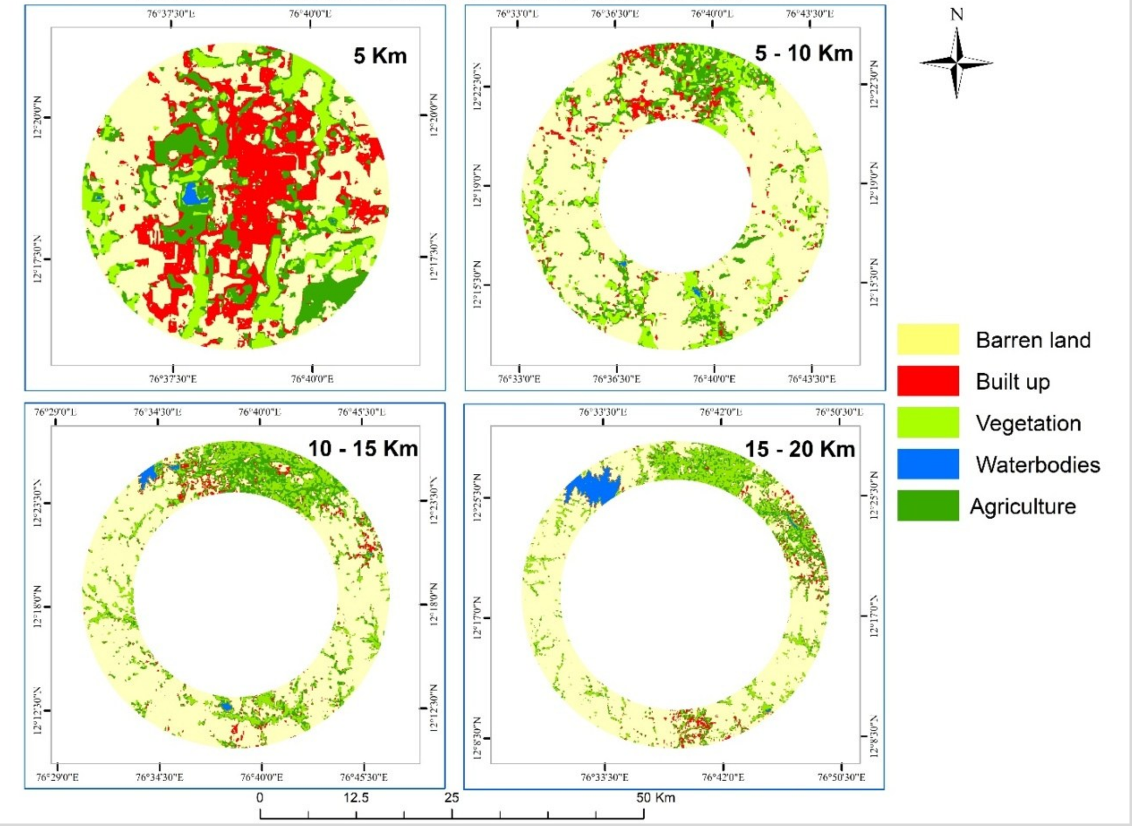




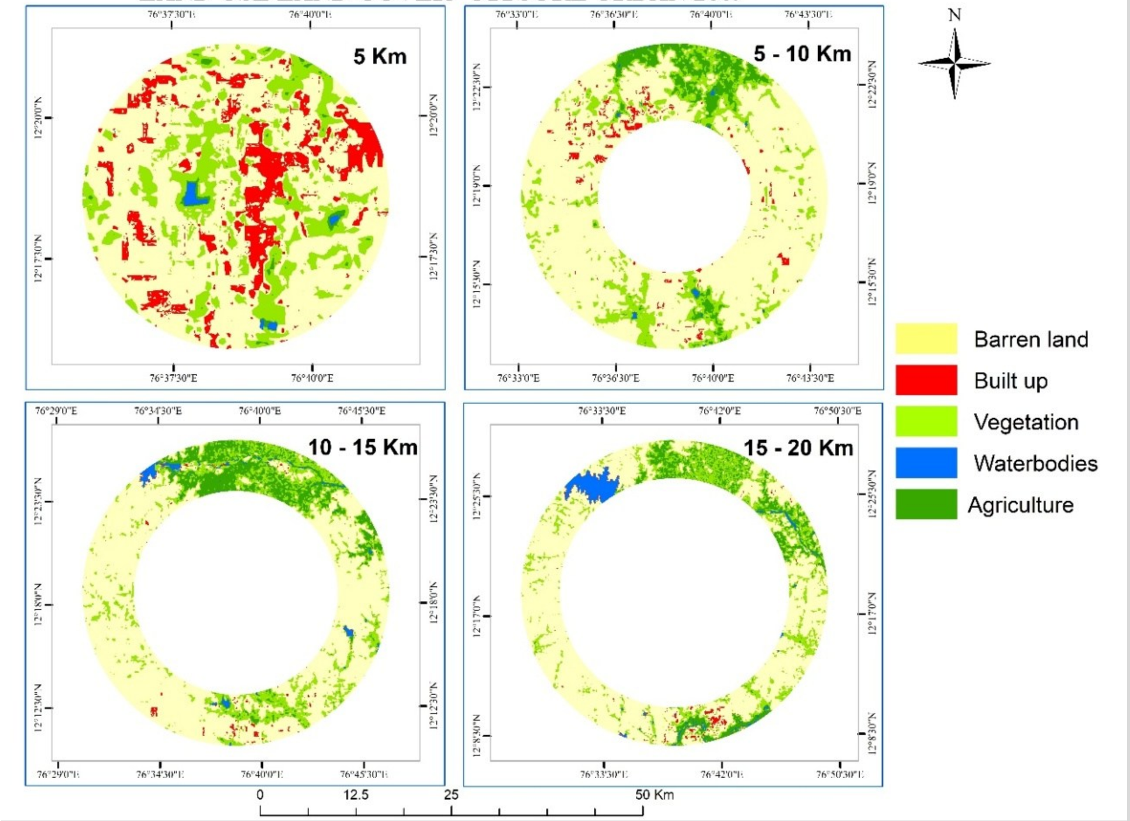
	LULC- Mandya	percentage of area in different

1KM BUFFER				LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	0.29	0.78	0.99	9.2	24.7	31.4
Barren land	0.15	2.02	0.25	4.8	64.2	8.0
Waterbodies	0.00	0.01	0.00	0.0	0.3	0.0
Built up	1.98	0.17	1.89	63.0	5.3	60.1
Agriculture	0.72	0.17	0.01	23.0	5.4	0.4
	3.14	3.14	3.14	100.0	100.0	100.0
2KM BUFFER	LULC- Mandya			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	1.50	2.94	4.47	16.0	31.2	47.4
Barren land	1.43	5.01	1.49	15.2	53.1	15.8
Waterbodies	0.00	0.05	0.04	0.0	0.5	0.4
Built up	2.23	0.11	2.87	23.7	1.2	30.5
Agriculture	4.26	1.32	0.55	45.2	14.0	5.8
	9.42	9.42	9.42	100.0	100.0	100.0
3KM BUFFER	LULC- Mandya			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	4.32	5.83	6.15	27.50	37.09	39.17
Barren land	1.99	4.00	2.66	12.66	25.48	16.94
Waterbodies	0.27	0.17	0.50	1.72	1.11	3.17
Built up	2.09	0.05	3.70	13.29	0.33	23.57
Agriculture	7.04	5.65	2.69	44.83	35.98	17.15
	15.71	15.71	15.71	100.00	100.00	100.00
4KM BUFFER	LULC- Mandya			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	9.58	10.87	10.62	43.6	49.4	48.3
Barren land	1.27	1.91	2.65	5.8	8.7	12.1
Waterbodies	0.00	0.03	0.24	0.0	0.1	1.1
Built up	1.33	0.02	3.36	6.0	0.1	15.3
Agriculture	9.81	9.17	5.11	44.6	41.7	23.2
	21.99	21.99	21.99	100.0	100.0	100.0

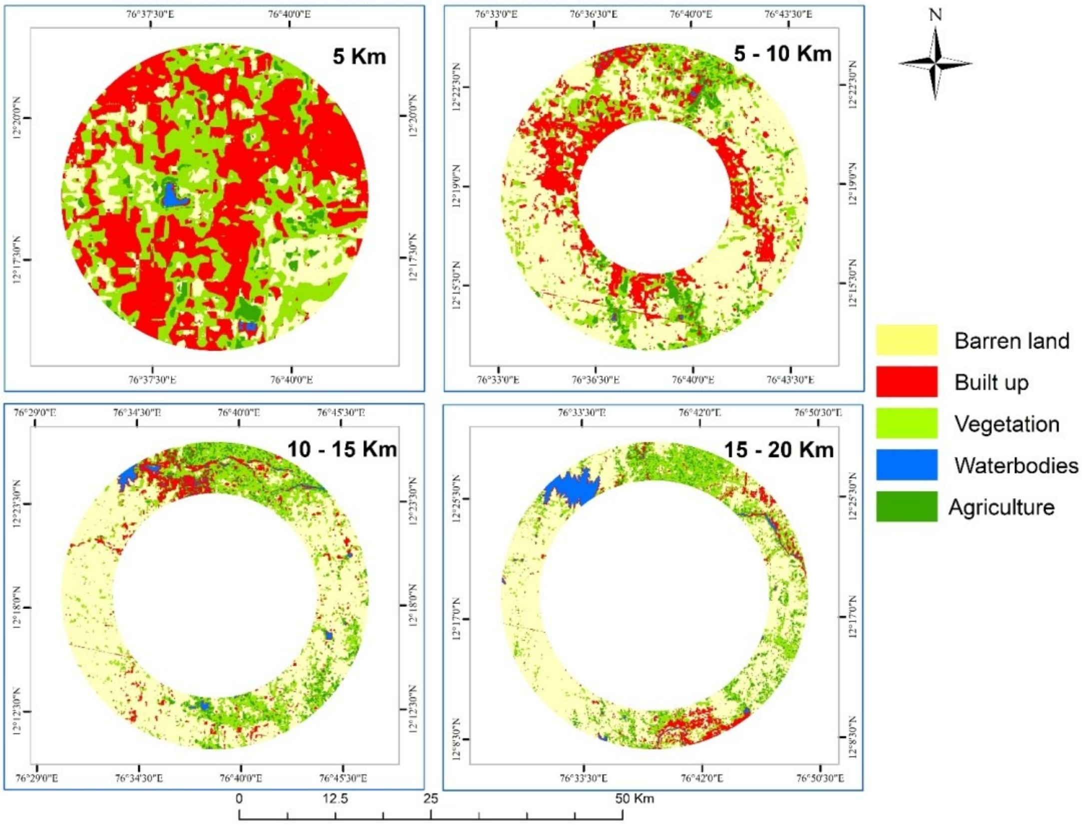
LAND USE LAND COVER - MYSORE URBAN 1999

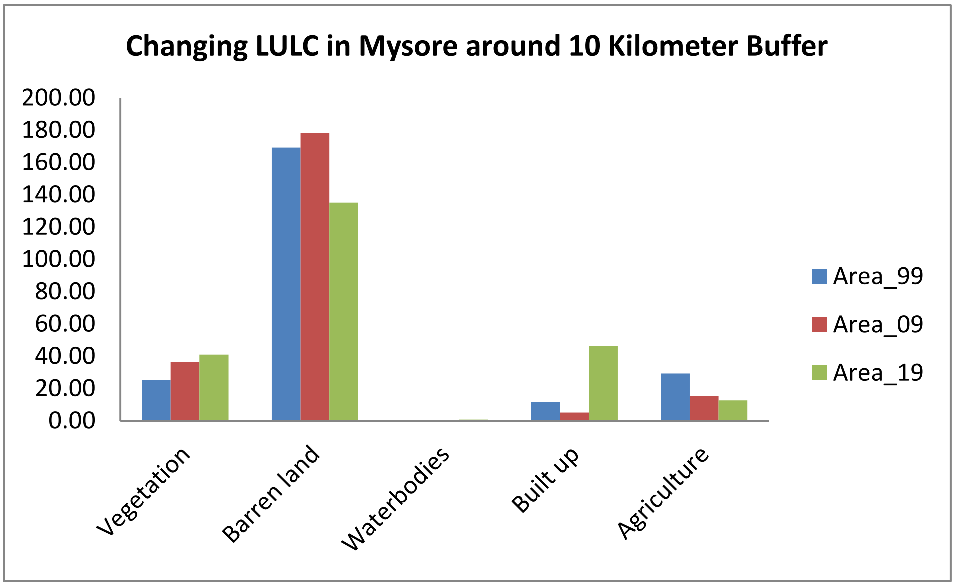


LAND USE LAND COVER - MYSORE URBAN 2009

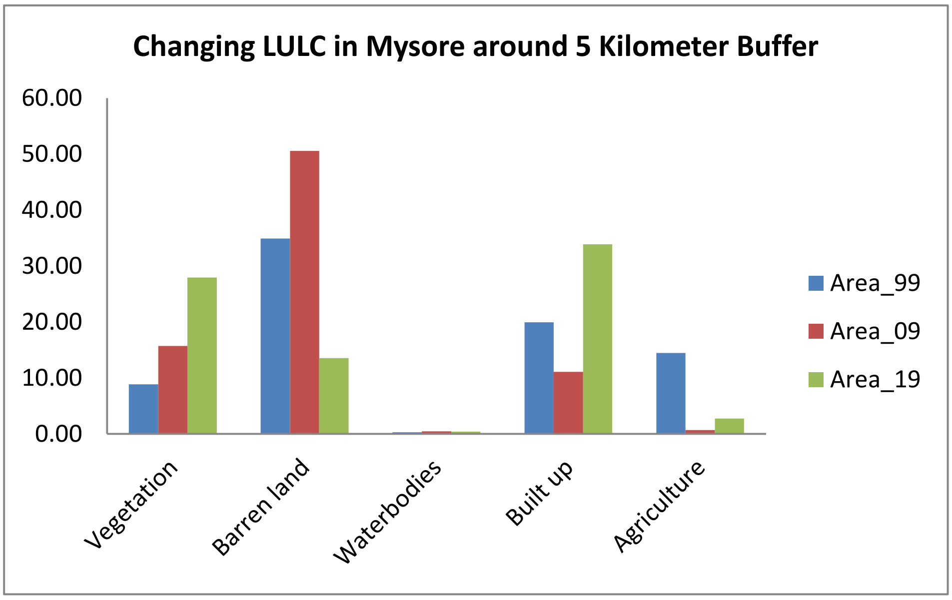


LAND USE LAND COVER - MYSORE URBAN 2019

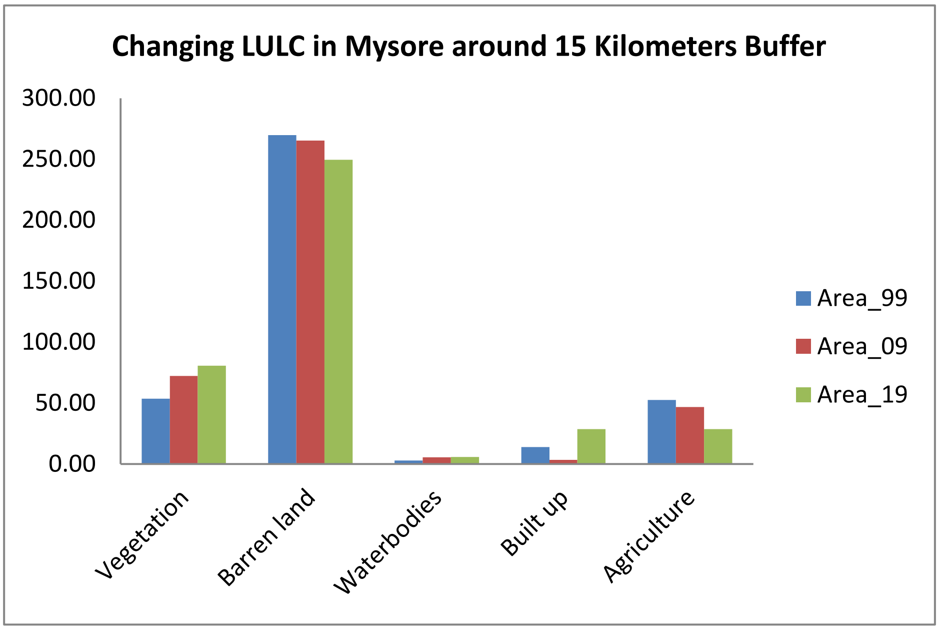


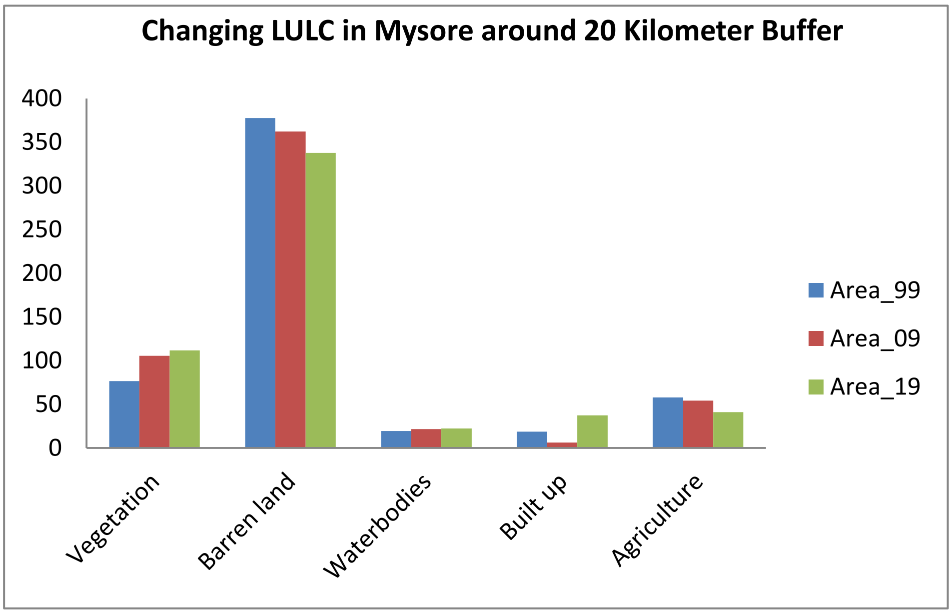


Changing LULC in Mysore around 10 Kilometer Buffer
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19



Changing LULC in Mysore around 5 Kilometer Buffer
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19


Changing LULC in Mysore around 15 Kilometers Buffer
300.00
250.00
200.00
150.00
100.00
50.00
0.00
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19


Changing LULC in Mysore around 20 Kilometer Buffer
400
350
300
250
200
150
100
50
0
Vegetation
Barren land
Waterbodies
Built up
Agriculture
Area_99
Area_09
Area_19

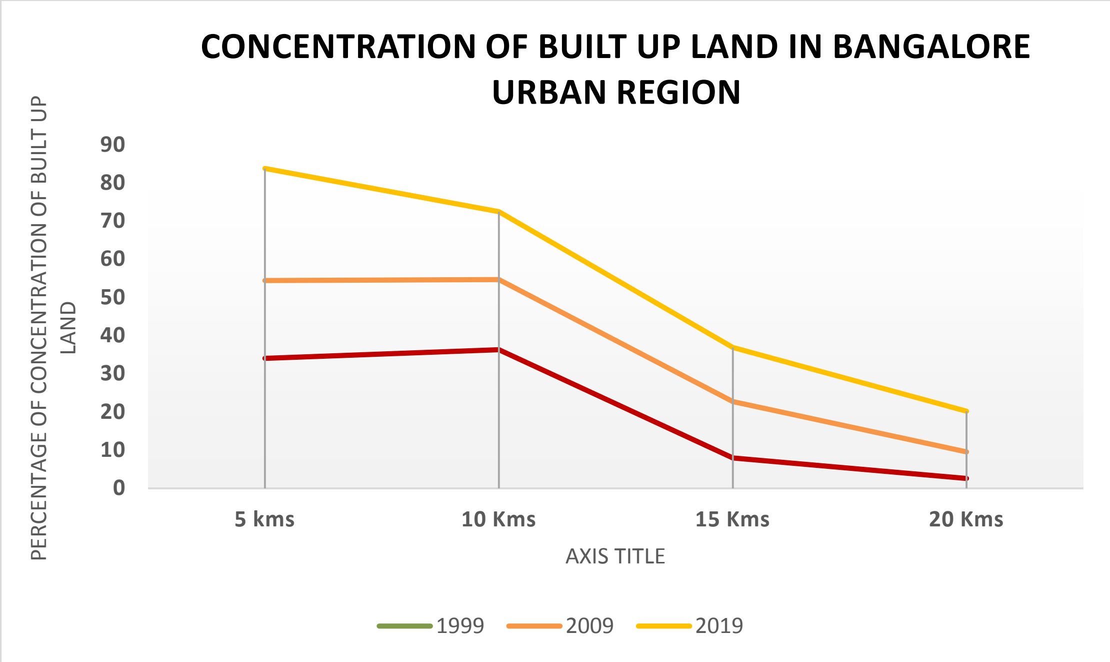
5KM BUFFER	LULC- Mysore			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	8.9	15.7	27.9	11.3	20.0	35.5
Barren land	34.9	50.6	13.6	44.4	64.4	17.3
Waterbodies	0.3	0.5	0.4	0.4	0.6	0.5
Built up	19.9	11.1	33.9	25.4	14.1	43.2
Agriculture	14.5	0.7	2.8	18.4	0.9	3.5
	78.5	78.5	78.5	100	100	100
10KM BUFFER	LULC- Mysore			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	25.3	36.3	41.0	10.7	15.4	17.4
Barren land	169.2	178.2	135.2	71.8	75.6	57.4
Waterbodies	0.3	0.6	0.6	0.1	0.2	0.3
Built up	11.5	5.1	46.2	4.9	2.2	19.6
Agriculture	29.3	15.4	12.5	12.5	6.5	5.3
	235.6	235.6	235.6	100	100	100
15KM BUFFER	LULC- Mysore			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	53.5	72.2	80.5	13.6	18.4	20.5
Barren land	269.6	265.1	249.4	68.6	67.5	63.5
Waterbodies	3.0	5.5	5.7	0.8	1.4	1.4
Built up	14.0	3.3	28.5	3.6	0.8	7.3
Agriculture	52.6	46.6	28.6	13.4	11.9	7.3
	392.7	392.7	392.7	100	100	100
20KM BUFFER	LULC- Mysore			percentage of area in different LULC		
LULC	Area_99	Area_09	Area_19	Area_99	Area_09	Area_19
Vegetation	76.4	105.4	111.8	13.9	19.2	20.3
Barren land	377.4	362.2	337.5	68.6	65.9	61.4
Waterbodies	19.3	21.5	22.3	3.5	3.9	4.1
Built up	18.8	6.3	37.2	3.4	1.1	6.8
Agriculture	58.0	54.3	40.9	10.5	9.9	7.4
	549.8	549.8	549.8	100	100	100

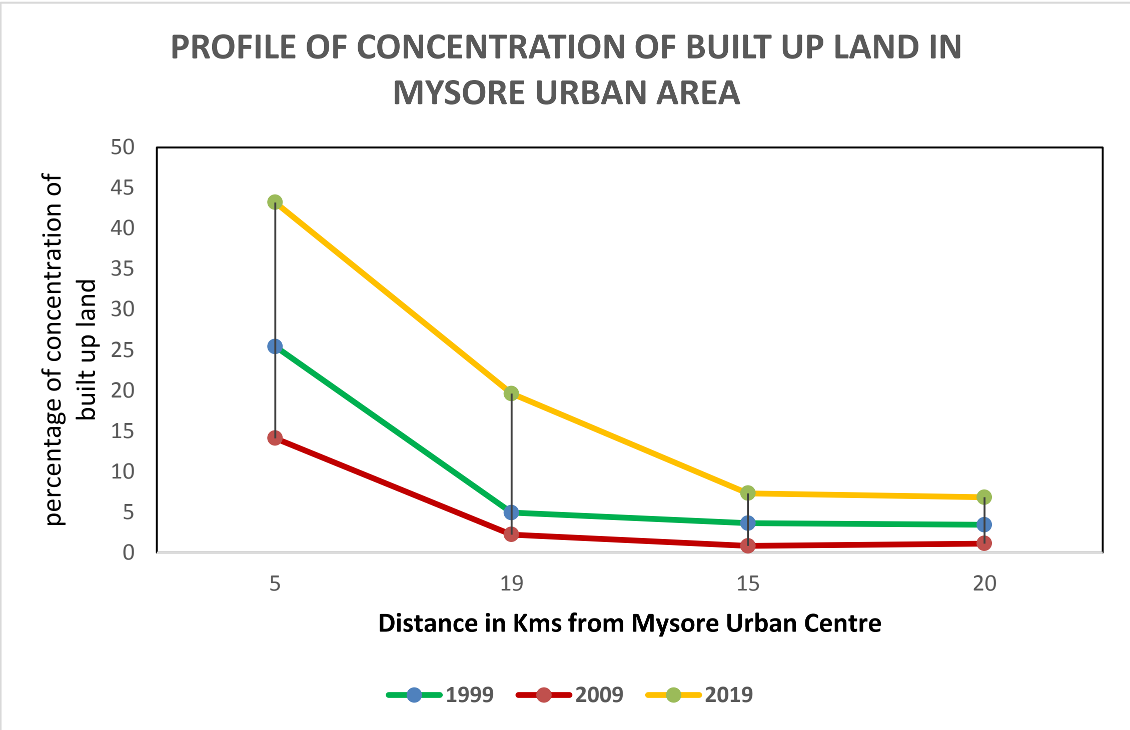
DISCUSSION AND CONCLUSION:

Land is important in all its varied features and in all its forms. Therefore a more logical approach has to be adopted while deciding how to use the land resource. Some Land-use changes are beneficial to man's survival, some remain neutral while some others become very disturbing. Some land uses can be repaired while some may not. Built up Land uses belong to the category where it becomes a permanent sealing of the surface by concrete thereby leading to the stock of impervious category. The land-cover analysis showed that the Bangalore and Mysore urban areas had dense concentration of built up land, Indicative of high impervious surface.

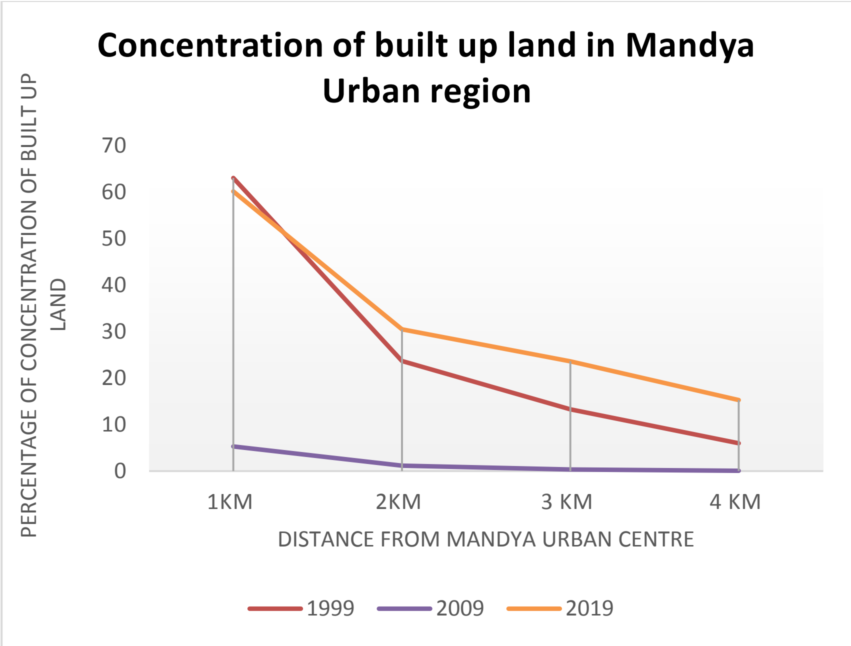
BUILT UP LAND:

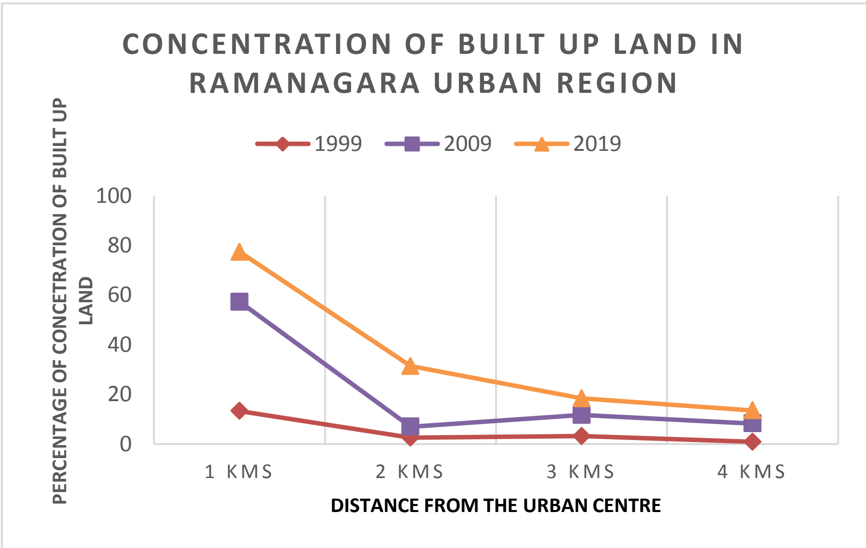
The concentration of built up land has been 33.98%, 54.39% and 83.77 % inside 5 Kms radius buffer around Bangalore from 1999, 2009 and 2019 respectively. The high non porosity of surface has many impacts chiefly to cause the reason for city floods during rainy season on one hand and on the other hand it will increase the temperatures during other times. In the 5 kms radius buffer in Mysore urban region the concentration of built up land was 25.4%, in 1999 and it was 43.2% in 2019. The built up land has shown a drastic decline in the 10 Kms. radius buffer around Mysore with 4.9% concentration in 1999 to 19.6% of the total land area in 2019.





The land-use-change findings for Bangalore showed that the built up land was persistently high even in the 10 Kms. radius buffer with 36.25%, 54.61%, 72.42% during 1999, 2009, and 2019. The 15 Kms radius buffer around Mysore urban area showed rural environment with very low percentage of impermeable areas, and it indicated that this zone was having very low urban – rural intervention 3.6 %, 0.8%, and 7.3% during 1999, 2009, and 2019 respectively.





While comparing the built up pattern in Mandya and Ramanagara it is quite interesting to note that Mandya is expanding faster than Ramanagara . The trend shows that Mandya is generating an outer expansion with a sudden increase in the built up land on the outer zone, which can be associated with the recent spurts taking placing in the corridor development. Ramanagara's built up land use is increasing more inside the inner zone than on the outer zone.

AGRICULTURE LAND USE: Agriculture is the other most important land use and land cover classification.

CHAPTER VII

IMPACT OF URBANIZATION ON ELEVATION AND WATERBODIES

6.1. Introduction

This study is an attempt to understand the changing characteristics of surface elevation and its impact on Water bodies. Streams are the most important part of the natural ecosystem. It is with the availability of water that most of the natural vegetation flourishes creating healthy environments resulting in the regulation of temperature and humidity of any region. In view of the Water bodies occupying central position over the environment it was considered as the most important issue to be highlighted in the context of urban environment.

Urbanization modifies surface features through construction of buildings, roads, bridges and other developmental activities. These surface alterations are of vital importance for human life on Earth. However such features are the major causes in the process of stopping and discontinuing the feeders in filling low-lying swamps, ponds, lakes etc. The lakes and reservoirs across the urban landscape are hence going through environmental crisis which needs to be addressed. There is a great need for these studies especially in the context of urban planning and management. Many a times rivers of higher stream order such as the main river have disappeared due to increase in impervious surface, surface runoff volume, and the lower order streams gradually narrowing down or even disappear due to sedimentation of river channels.

The main objective of this chapter is to identify streams which have disappeared and to find the reason for their disappearance.

6.2. Methodology

- For the Terrain analysis, DEM data were obtained for two periods between 1978 and 2011. The former data were obtained from the Toposheets and the later from Satellite image.

- Topographic Maps: The survey of India Toposheets Number 57 D/11 of scale 1:50,000 with contour interval 20 m was digitized.

- Cartosat 1: Digital Elevation Model (2005 to 2019) developed by ISRO with spatial resolution is 2.5m on the horizontal plane (Downloaded from Bhuvan website)

- The streams and Waterbodies were digitized from 1978 Toposheet and stream network was extracted from 2019 Carto DEM.

6.2.a. Analysis

- ✓ Comparison of 1978 DEM with 2019 DEM, and Field observed data were compared.
- ✓ Derived Slope and Aspect map from 1978 and 2011.
- ✓ Visual image interpretation is carried out to assess the Water bodies disappeared and shrinkage
- Temporal elevation changes were identified using cut and fill tool from

ARCGIS

- ✓ Disappearance and shrinkage of Water bodies with urban expansion.

6.2.b. Data Preparation

In order to determine the changes in elevation, two-time period data was compared with respect to elevation, slope and aspect. These three factors are very important to understand the changing elevation of streams, missing networks in the streams, and also to determine the shrinkage and disappearance of Water bodies as a result of changing elevation.

Before data was obtained using Toposheet 1:50,000 scale of 1978, all the contours with 20-meter interval was digitized. Similarly, the after data was prepared with the help of Cartosat DEM 2019 with 2.5-meter resolution. The elevation, slope aspect was prepared and compared for both the periods.

Streams and Waterbodies have been digitized from the Toposheet of 1978, and for 2019 Waterbodies are digitized from satellite images, then stream and stream orders were extracted by following the process of Fill- Flow Direction –Flow Accumulation- of Hydrological tool in ArcGIS 10.5.

6.3. Urban Expansion

Before knowing the changes in elevation, slope and aspect it is essential to know the urban expansion of the study region. Because urban expansion is one of the major root cause for the changes in elevation. To identify the urban expansion of Mysore Bangalore region Google Earth was used cross referencing historical images for 1981 and 2019

Figure 6.1:

Urban Expansion (1981-2019)

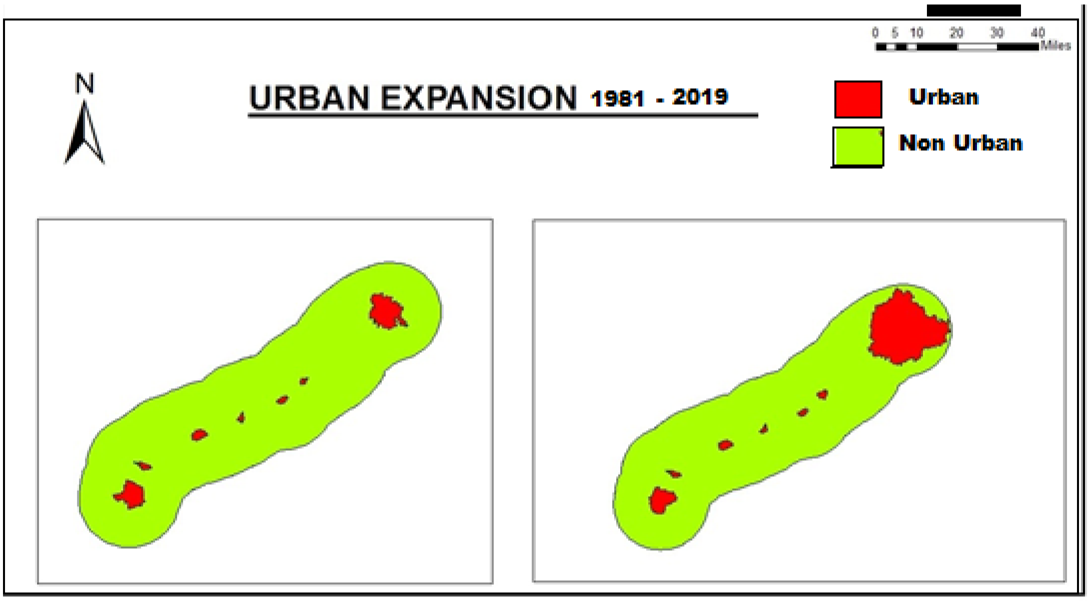


Table 6.1

Urban Expansion (1981-2019)

Urban Centers	Built up in 1981 Area in Sq.Km	Built up in 2019 Area in Sq.Km
Mysore	25.4	43.2
Mandya	23.7	30.5
Maddur	10.9	29.3
Channapatana	3.72	2.55
Ramanagara	2.6	31.4
Bangalore	33.98	83.77

6.6. Elevations

The elevation change generated from Toposheets of 1978 and Cartosat 1 2011 image data. Figure 6.2 and table 6.2, shows that the elevation ranged from 675.33 m to 1025.39 m and that the mean height of the study area was 751.84 m, with a standard deviation of 25.74 m. Whereas in the case of 2011 Carto DEM, the elevation ranged from 675.79 m to 1026.80 m, the mean height was 755.52 m. with a standard deviation of 25.66 m. Chamundibetta recorded the maximum elevation in both periods and the minimum was recorded on the southwest of K. Shetahalli.

Table. 6.3

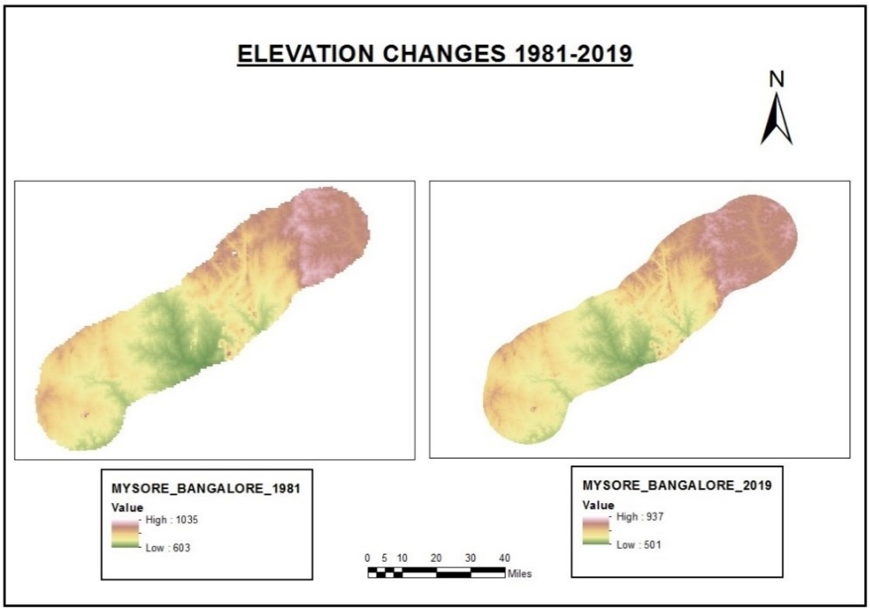
Variations in Elevation (meters) 1978 to 2019

Category	Topographical Sheet	Carto DEM
Max	1025.39	1026.80
Min	675.33	675.79
Mean	751.84	755.52
STD	25.74	25.66

Source: **Scholar's Computation**

Figure 6.2

Elevation Change Detection



To identify the elevation changes in the study areas, two Digital Elevation. Models were used and elevation values of sample points were extracted from elevation maps of 1978 DEM and 2019 DEM. Differences in these two elevation maps of different time periods were compared and the same was represented in (Appendix Table 6.3)

2) Give complete information why there has been a change in elevation, After the field visit and interviewing the respondents, it has been concluded that due to recent construction in the area as a result of urbanization, and silt deposition in lake bed, there has been an increase in elevation.

Figure 6.3:

Sample Location Points

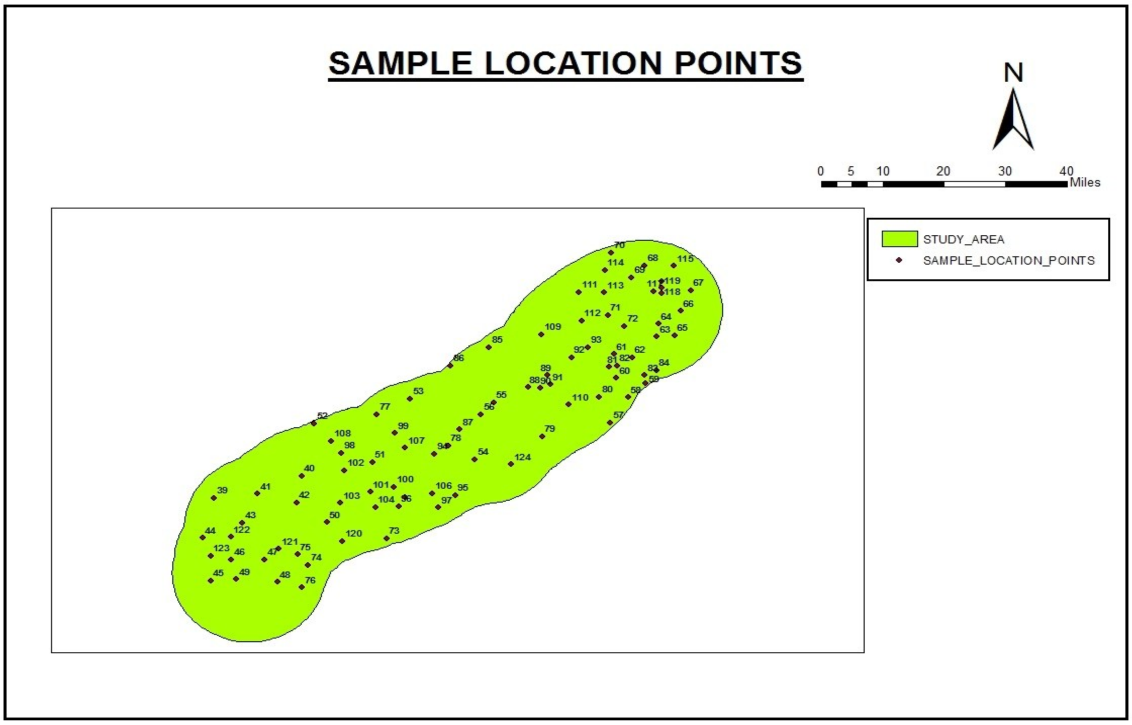


Table 6.4.

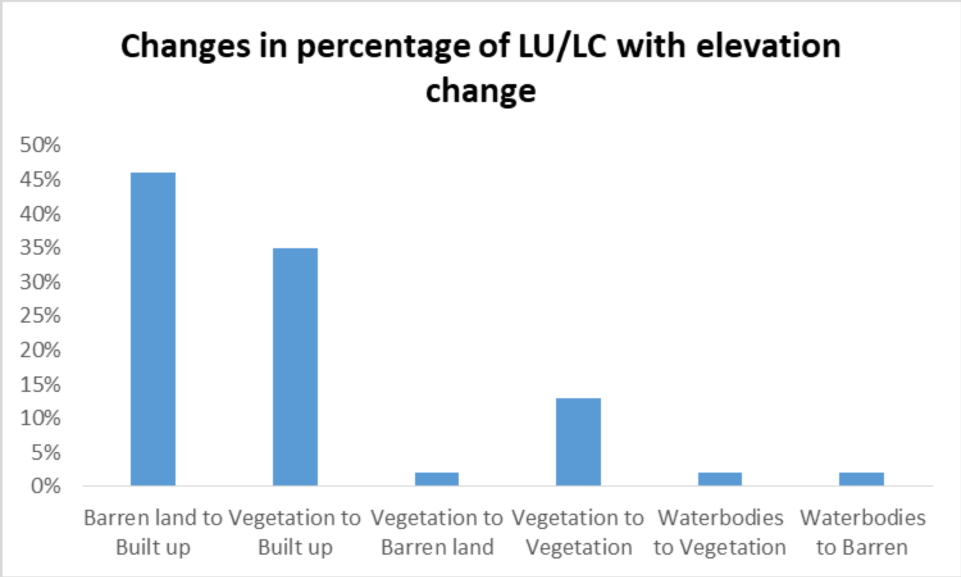
Elevation change between 1978 Toposheet and 2019 Carto DEM and their Land use Change

Change in Land Use Land cover with elevation change(1978-2019)	Total number of locations with elevation change 1978-2019	Elevation change in Percentage(1978-2019)
Barren land to Built up	31	46%
Vegetation to Built up	24	35%
Vegetation to Barren land	1	2%
Vegetation to Vegetation	4	13%
Waterbodies to Vegetation	1	2%
Waterbodies to Barren	1	2%

Source: Verification using Google Earth and Field Observation

Figure 6.4

Changes in percentage of LU/LC with elevation change



The impact of urbanization is very much noticed especially with changes in elevation. The sample location points with maximum change was detected are within 10 km distance and in and around the CBD of Mysore. The only reason for the change is expansion of Built up and other constructional activity like roads bridges as a result of urbanization. Out of 179 settlements, the change was detected for 67 sample location points (Appendix Table 3) out of which 42 sample points are recorded as gained height and in 20 points there was a reduction in height and 5 sample points identified as no change in elevation. From the field visits and by enquiring with the local people and the authorities, the reason identified either for the reduction or increase in the elevation was due to the conversion of Vegetative land and Barren Land to Built-up areas.

6.6.1. Barren land to Built up

There were 31 sample locations (Appendix Table 3) which have changed their elevation due to conversion of Barren land to Built up only. Among that most of the location points identified for increased in elevation. The maximum gain in elevation is observed in North of Mysore (5.51 meters) and South East of Hebbalu (4.96 meters) followed by Hebbadi (4.78 meters) and the minimum gain in elevation is noticed in Middle of Krurbarahalli (1.09 meters) The maximum reduction in elevation is identified in South East of Kythamarnahalli (-5.51 meters) and the least reduction in elevation was identified in East of Metagalli (0.34 meters).Overall 46 % (table 6.3) of the area changed elevation mainly due to Barren land to Built up. There are 20 sample locations with an average of +3.67 meters of elevation shows increase in elevation due to Barren to Built up land. Similarly, in the same category 11 locations with an average of – 3.78 meters of elevation identified with reduction in elevation.

The main reason for the increase in elevation will be the land filling for the building and road construction and also due to upcoming of industrial areas. The excavation of Barren land and the recent construction activity were responsible for reduction in elevation. Under this category most of the sample locations which gained elevation can be identified in and around Mysore urban. Therefore, maximum changes in elevation identified more in Mysore.

6.6.2 Vegetation to Built up

There are 24 sample locations falls under this category where the changes in elevation happened due to conversion of Vegetative cover to Built up are a. Here also the maximum changes identified with increase in elevation. Under this category there are 9 locations identified with an average elevation of + 3.87 meters with increasing height and 8 locations with an average elevation of -2.49 meter with decreasing height. The large amount of loss in Vegetation can be identified (Appendix Table 2) where the changes in elevation was identified due to conversion of Vegetation in to Built up area. This clearly indicates rapid urbanization in the Mysore Srirangapatana region which alters the elevation. The minimum level of increase in elevation identified in South Mysore rural (0.01 meters). Whereas the maximum reduction under this category was identified in South East of Hinkal (-4.81 meters) and the minimum reduction identified in South Alanahalli (-2.76 meters). Altogether 35 % of the area changed elevation mainly due to conversion of Vegetation to Built up (table 6.3).

6.6.3 Vegetation to Barren land

Belagola is the only sample location shows the change in elevation due to conversion of Vegetation to Barren land, where the changes in elevation is identified with reduction in elevation of (-5.23 meters) and accounts a change in elevation of 2%. (table 6.3). Excavation of Vegetation to Barren land mainly due constructional activities for industries probably the reason for the reduction in elevation in this area.

6.6.4 Vegetation to Vegetation

There were 4 sample locations identified under this category with an average elevation of 4.4 meters with increasing height. The maximum change in elevation with increasing height identified in 4 sample locations, in which maximum gain in elevation noticed in (Appendix Table 3) Anagalli with 5.79 (meters) and the minimum gain in elevation identified in Bommur Agrahara (3.01 meters). The maximum reduction in elevation is observed in Ananduru with (-4.48 meters). The urban expansion of Mysore Srirangapatana region is main reason for this conversion of Vegetation to Vegetation with change in elevation of 13% (table 6.3). Therefore, the expansion of urban centers influences the elevation of nearby settlements.

6.6.5 Waterbodies to Vegetation

Ananduru is the only location where the Waterbodies changed to Vegetation among the sample locations. It had lost an elevation of -4.87 meters with 2% due to this land use change.

6.6.6 Waterbodies to Barren land

Srirangapatana shows the elevation change due to conversion of (table 6.3) Waterbodies to Barren land with 2% change. The main reason of land use change was due to urban expansion of this island town. New layouts and roads have emerging up as a result of urbanization which affects the elevation of this region.

There were 5 sample locations which shows no change in elevation during this period. The sample points which are away from the urban areas remain unchanged and few locations are affected less. But the sample locations which are very close to urban centers are greatly affected with elevation changes.

The overall changes in elevation with land use change is shown in the figure 6.4. The maximum change in elevation mainly identified in Barren land to Built up (46%) and secondly change in elevation identified in Vegetation to Built up (35%)

followed by change in elevation with Vegetation to Vegetation land use change (13%).The least level of change in elevation is identified in Vegetation to Barren land (2%), Waterbodies to Vegetation (2%) and Waterbodies to Barren land (2%).

The above land with increased elevation was probably the main reason for water not flowing in to the streams and other reasons were the conversion of Barren land into new layouts, construction of new Buildings, roads along with the improper management of lakes. By observing the sample location points it was identified that maximum change in elevation was observed due to Built up expansion.

6.7 Change in Slope

The Slope tool calculates the highest rate of change in value from that cell to its neighbor cell. Initially the maximum change in elevation over the distance between the cell and its eight neighboring cells has been recognized as the vertical downhill descent from the cell. Theoretically, the tool fits a plane to the z-values of a 3x3 cell neighborhood around handling or the center cell. The slope value of this plane is calculated using the average maximum method. The direction the plane faces is the aspect for the processing cell. Hence the lesser the slope value, the flatter the terrain and likewise, the higher the slope, the steeper the terrain. If there is cell location in the neighborhood with a No Data z-value of the center cell is allocated to the location. At the raster edge, as a minimum three cells (outside the raster extent) comprise No Data as their z values.

The table is derived from the slope maps of 1978 and 2019 (figure). The minimum slope is same in both slope maps and the maximum slope varies from 28.46 º to 29.43 º respectively. The mean value of slope was 1.05° in 1978 and 1.02° in 2011. Only 0.17 º of deviation is identified from 1978 to 2019. When the study has compared to 1978 and 2019 slope map was found that Chamundi hill. The main reason probably behind slope changes in Chamundi hill will be the encroachment of buildings and also due to upcoming of new roads and bridges and other urban infrastructures which have altered the slope of the region. The maximum angle of the slope was recorded in Chamundi Hills in both the periods. The minimum slope angle was recorded in K. Shetahalli.

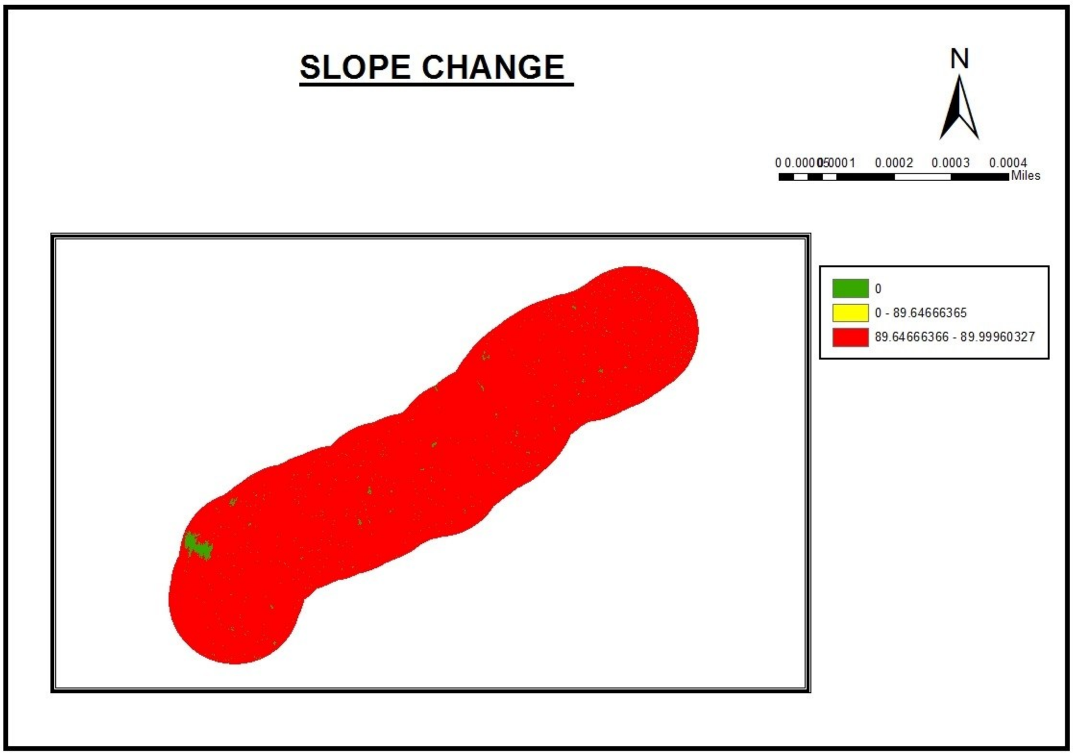
Table 6.4

Variations in Slopes (1978-2011)

Category	Topographical Sheet	Cartosat DEM
Min	0°	0°
Max	28.46°	29.43°
Mean	1.05°	1.02°
STD	1.17°	1.00°

Source: Scholar's Computation

Figure 6.5: Slope Change from 1978 -2011



6.8. Aspect (Direction of Changes in slope)

Aspect identifies the maximum rate of change in value along the down slope direction of each cell to its neighbours derived from a raster surface. Aspect can also be defined as the direction of slope. The compass direction of the aspect is the value of the output raster. It can be understood of as the slope direction. The values of each cell in the output raster specify the compass direction, which the surface faces at that location. It is measured clockwise in degrees from 0 (due north) to 360 (again due north), next full circle. Flat areas have no down slope direction are given a value of -

1.

Table 6.5 is derived from figure 6.6 shows aspect (slope direction), from 1978 and 2019 DEM. Not ample of a change has been identified in the flat area, it was just 0.28 km2, but a lot of change in the direction can be observed in other categories. The flat surface has a minimum slope direction was identified as -1 in both 1978 and 2019. In 1978 (Figure 6.6) most of the flat area was identified in and around the Waterbodies, mainly near the Cauvery river basin and all other small tanks. The flat area is shown in Grey colour where the aspect value is -1, the Red colour area drain towards North (0.22.5º), Orange coloured area drain towards North east (22.5-67.5 º), East draining area are shown in yellow colour (67.5 -112 .5º), South east draining area are shown in green colour (112.5 -157.5 º), South drained areas are shown in Cyan colour (157.5 -202.5 º), light Blue colour areas are drained towards South west (202.5-247.5 º), Royal blue colour area drain towards west (247.5 º-292.5 º) North west drained areas are shown in Magenta colour (292.5-337.5 º) and the North drained areas are shown in Red colour (337.5-360 º).

Table 6.5. Aspect (Changes in Slope Direction) 1978 to 2019

Direction	Toposheet Area (Sq. Km)	Cartosat Area (Sq. Km)	Change
Flat	0.5074444	0.790405	0.28
North	6.944813	6.138373	-0.81
North East	15.893935	15.795841	-0.10
East	18.613192	18.26232	-0.35
South East	14.740396	15.357251	0.62
South	12.451239	14.086755	1.64
South West	12.149414	12.527639	0.38
West	12.548389	10.604445	-1.94
North West	9.715947	10.454476	0.74
North	5.794104	5.341366	-0.45

Source: Image processing and Interpretation

Figure 6.6: Aspect (Slope Direction Change) from 1978 -2019

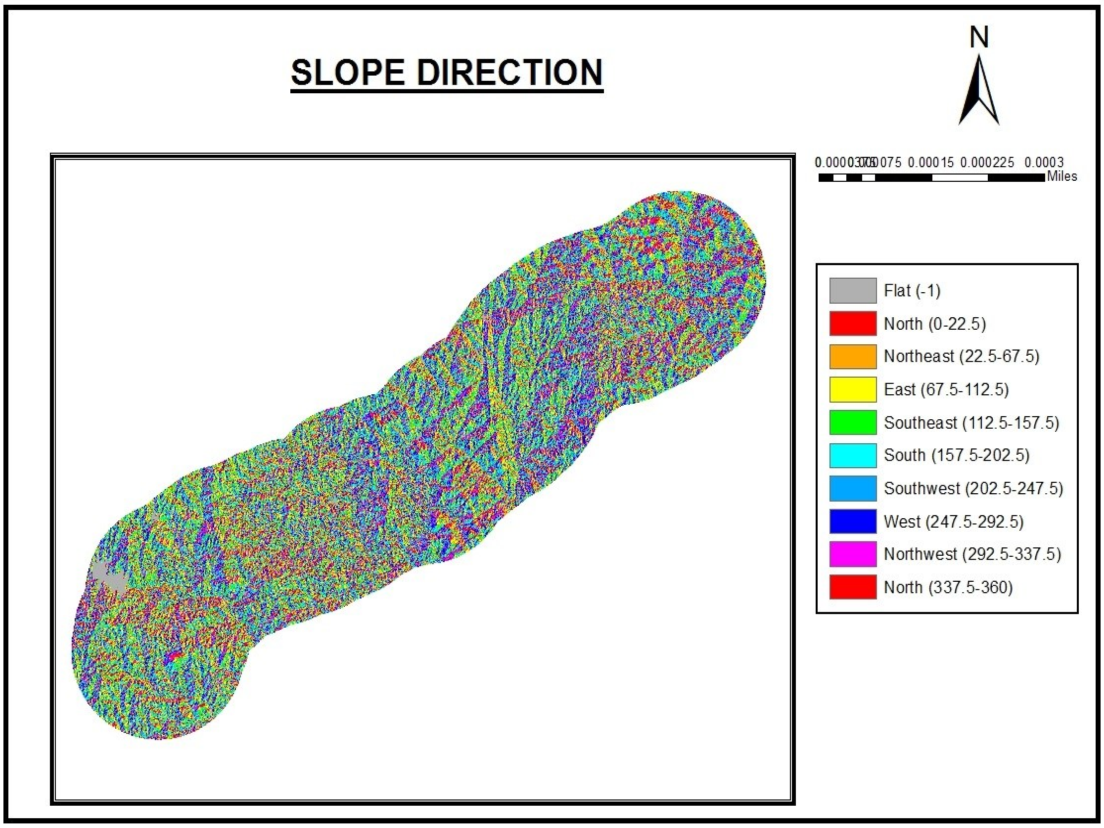
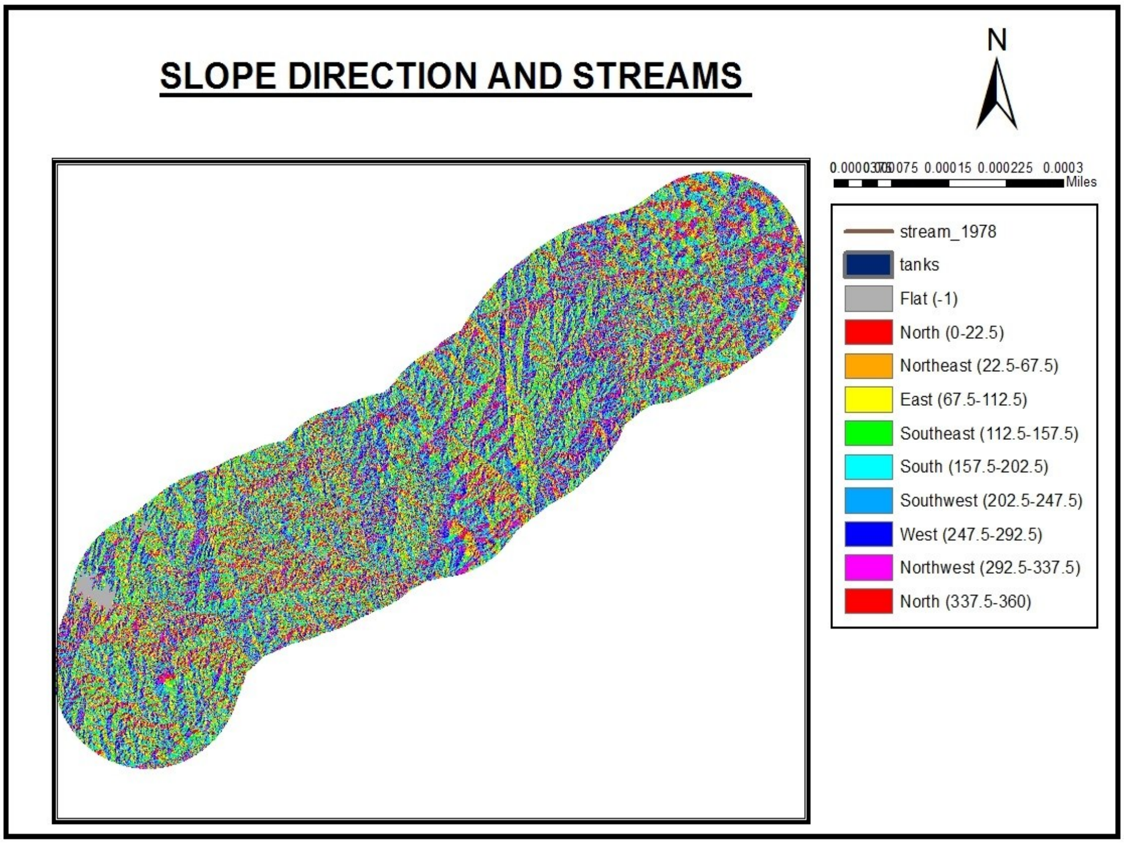


Table 6.5 shows positive change can be detected towards South and negative towards North East and West. The widening of road, new city development plan between Mysore and Nanjangud, is the reason for the aspect of positive change. The aspect of positive change in south direction is more and the difference between two periods was 1.61 km^2 as shown in the map by light blue colour and 0. 62 km^2 towards southeast and 0.38 km^2 towards southwest. The aspect of change in the direction was decreased towards North (-0.18), East (-0.35), Northeast (-0.10), and West (-1.94). The decrease in the aspect towards the North, West and Northwest was due to the alteration gauge from Mysore to Bangalore. Much of the area depicted in red colour aspect towards west is attributed to the industrialization. Hebbalu, Hutagalli, and Belavadi Industrial hubs are located in the West direction and the transformation of thousands of hectares of Barren land into residential layouts by the Karnataka Housing Board. (KHB) near Elwala.

6.9. Slope Direction and Stream Disappearance:

The figure 6.7 shows the slope direction overlapped with the stream. For the comparison Streams and Waterbodies have been digitized from Toposheet of 1978 and the same are extracted from Carto DEM for 2011. From Carto DEM streams and stream orders have been extracted by using Hydrological tool in ArcGIS 10.5. In this map it is easy to identify the changes in stream disappearance and shrinkage as a result of changes in slope direction. Most of the first order streams have been disappeared due to change in slope direction, and this may probably due to the new construction of roads, buildings and other urban infrastructures especially in and around the surroundings of Mysore and Srirangapatana urban area. Mysore-Bangalore Highway is also the main influencing factor on changing slope direction.

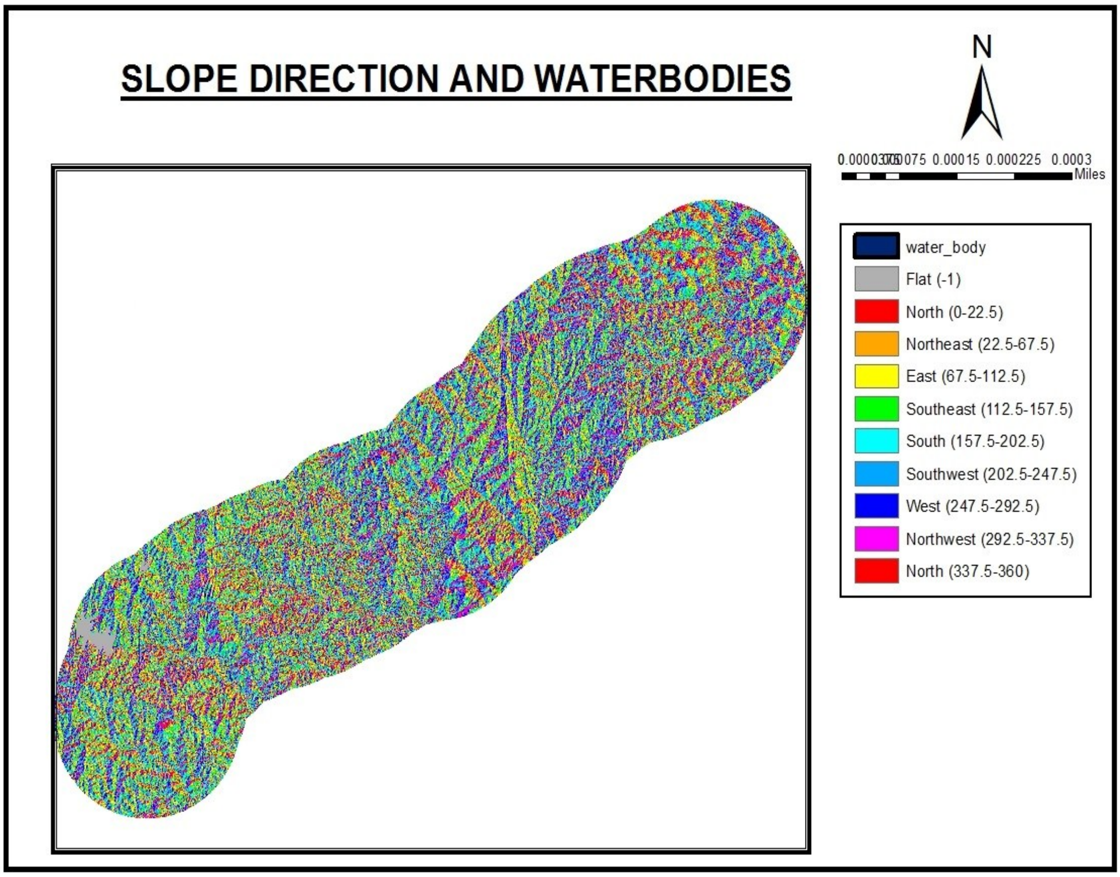
Figure 6.7: Slope Direction and Streams



6.10. Slope Direction and Shrinkage of Waterbodies

The figure 6.8 shows the slope aspect along with Waterbodies. In 1978, small tanks were well connected with streams and slope direction was also supporting the streams to have a steady flow of water to the tanks, whereas in the case of 2011 near Mysore urban area, slope direction had changed, that is the water flowing to the tanks have stopped, where water might have escaped to some other places. Also the rapid expansion of Mysore and Srirangapatana urban area also contributed to the shrinkage Waterbodies like Kukkarahalli, Karanjikere and other Waterbodies of smaller size tanks in the study area, the Cauvery river which is in North also affected due to urban expansion.

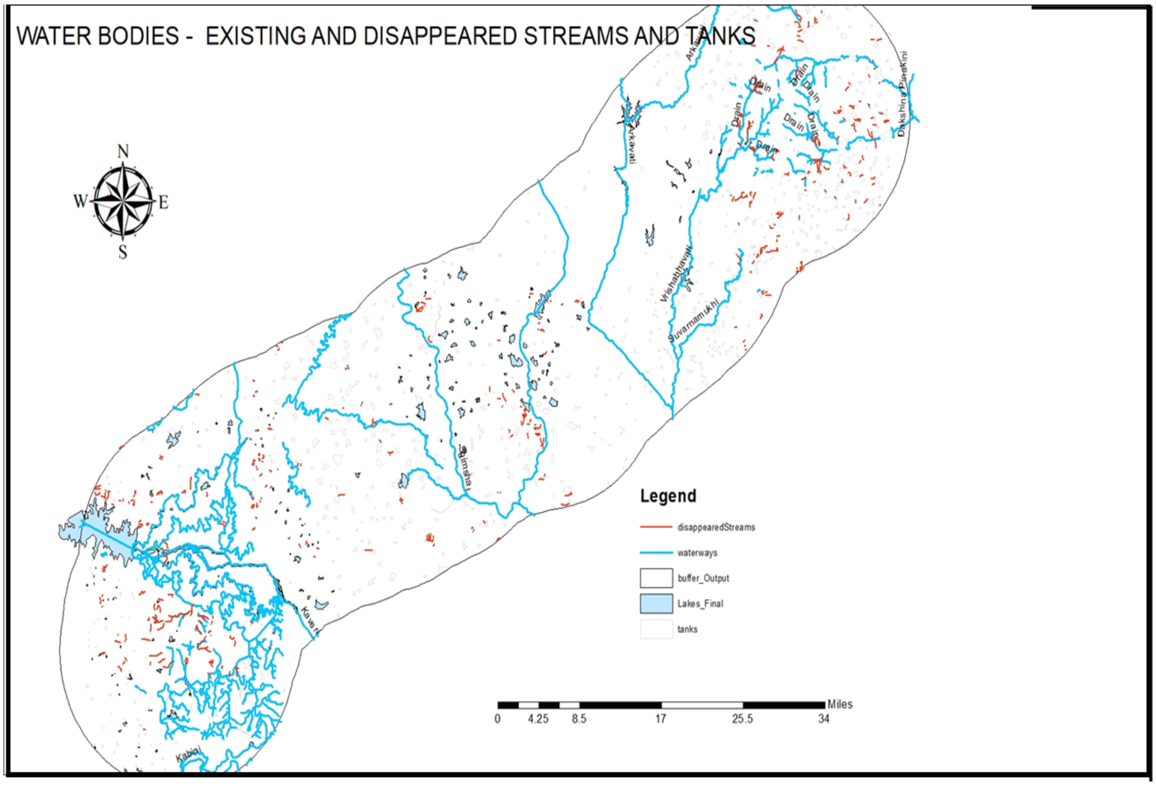
Figure 6.8: Slope Direction and Waterbodies.



6.11. Temporal Changes in Elevation

To know the temporal elevation changes, the Cut and Fill tool has been used. It computes the volume change between two surfaces, and is typically used for the Cu and Fill operations. A cut and fill operation is a technique in which the elevation of surface is modified by the removal or addition of surface material. The Cut and Fill tool, also reviews the areas and volume of change. By taking surfaces of a given location at two different time periods, it classifies regions of surface material removed, surface material addition, and area where the surface has remained unaffected as well. Hence with this tool helps in Elevation change detection as shown in table 6.6 and represented in figure 6.9 was carried out using cut and fill tool in GIS. The table 6.6 shows that for a total area of 760.8 km2 through which it was found that 173.27 km2 area's elevation was decreased, which is concentrated mostly on the West and Northwest of the study area while 587.53 km2 area's elevation was increased and mostly dispersed evenly.

The resulting elevation changes is shown in figure 6.10.and table 6.6 Cut and Fill is Net gain, Net Loss and unchanged areas in terms of elevation. About 80 percent of the land fall in Net gain category is shown in the map in green color. Recent construction of houses, roads and conversion of Barren land in to new layouts and apartments are the main causes for these changes. About 587.53 sq.km of area falls in Net gain class. Soil erosion near the streams and tanks play a major role in this. 83. 87 sq.km area remain unchanged identified in the study area which is Agricultural and Barren land. Most of the 1 (First)and II (Second) order streams came in to Net gain elevation areas, it has become a very big issue for feeding waters to the tanks, as system collapse has occurred. Even though some of the streams got effected maximum in Mysore urban interior where we can see Net loss area is more compared to Net gain. This resulted in stream diversion and disappearance and shrinkage of waterbodies in Mysore Srirangapatana region. The main reason probably due to excavation of elevated Vegetative cover to Built up and also due to Industries.



The disconnected streams were identified in the study area and their local landuse and landcover was detected. It was found that the discontinuity of streams have occurred for the following reasons.

1. Construction of roads.
2. Growth and expansion of settlements.
3. Filling of the tanks and depressed areas.

CONSTRUCTION OF ROADS AND DISCONTINUITY OF STREAMS:

The disconnected streams were over laid upon the settlements layer. Where ever disconnected streams were identified which were intersecting the settlements, such areas were identified and classified as major , medium and minor clusters.

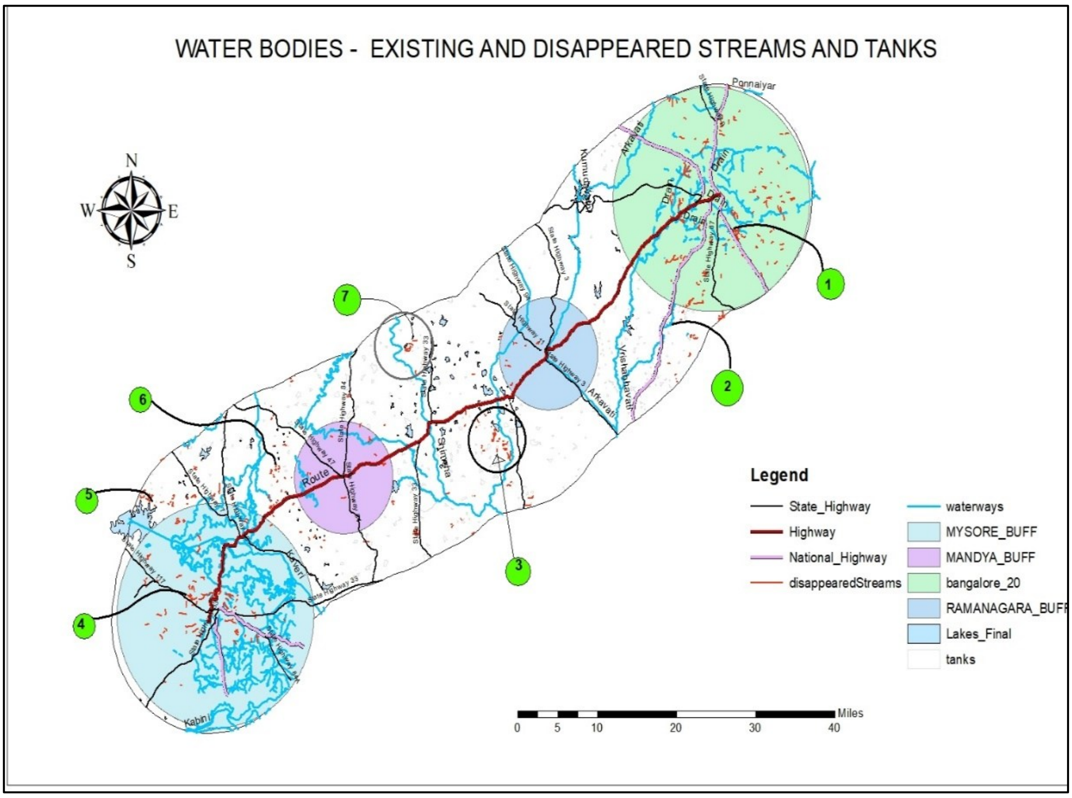


Figure 6.9: Elevation Change Detection with Waterbodies Disappearance 1978-2019

Clusters of disappeared streams were identified as follows:

1. Disappeared streams in Bangalore urban area.
2. Disappeared due to the construction of roads .
3. Disappeared due to the construction of roads.
4. Disappeared streams in Mysore urban area.
5. Disappeared streams due to expansion of settlement (Mysore).
6. Disappeared streams due to settlements and roads.
7. Disappeared streams due to construction of roads and settlement.

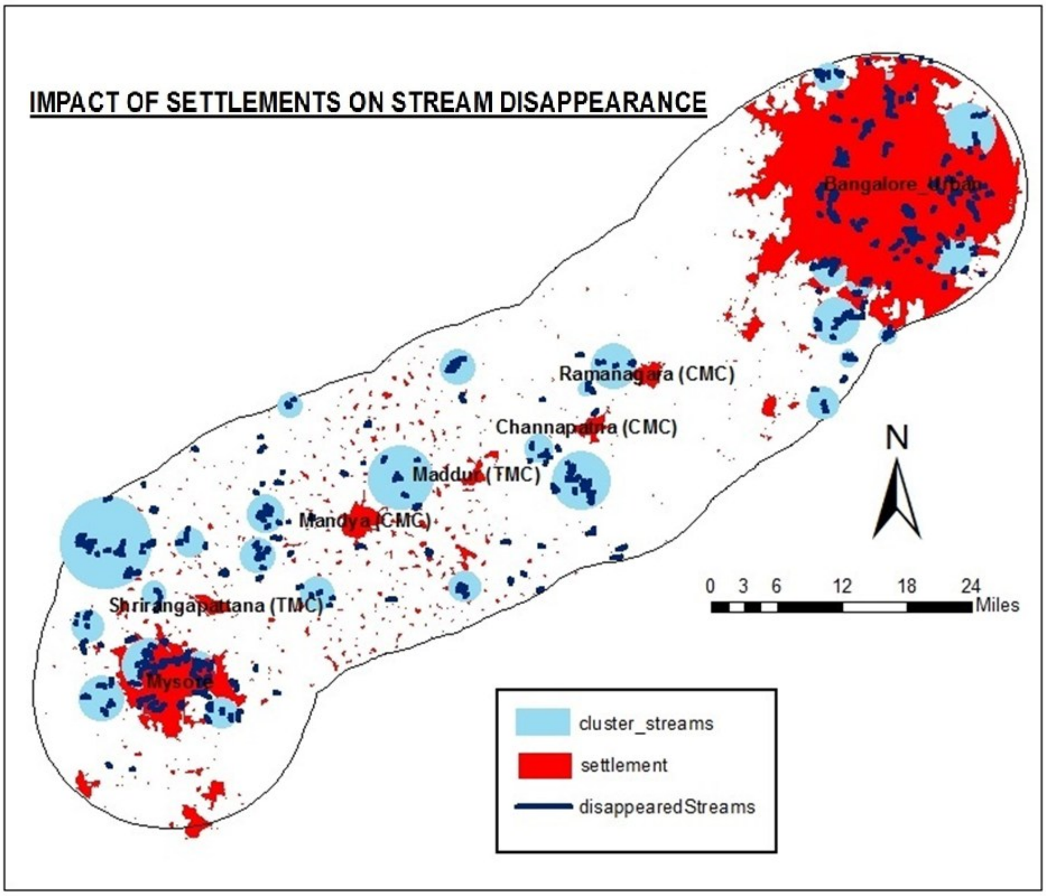


Table 6.8

Settlements forming obstruction to the flow and discontinuity of streams

	Major Clusters	Medium Clusters	Minor Clusters
Mysore	5	0	0
Srirangapatana	0	0	0
Mandya	1	4	3
Maddur	1	1	3
Channapatana	1	2	0
ramanagara	0	1	0
bangalore	4	2	4

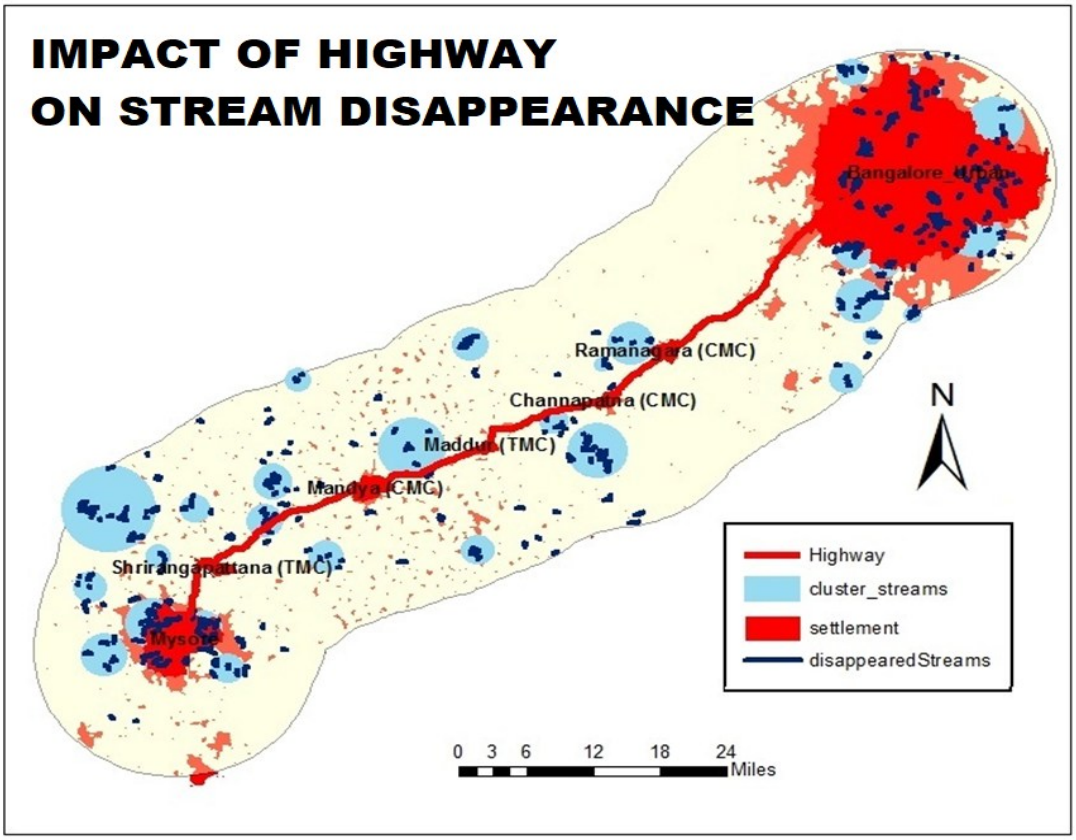
GROWTH AND EXPANSION OF SETTLEMENTS AND DISCONTINUITY OF STREAMS:

The Highway layer was superimposed over the disconnected streams, where ever the disconnected streams were intersecting the highway, they were marked as clusters of different sizes and data was generated with respect to

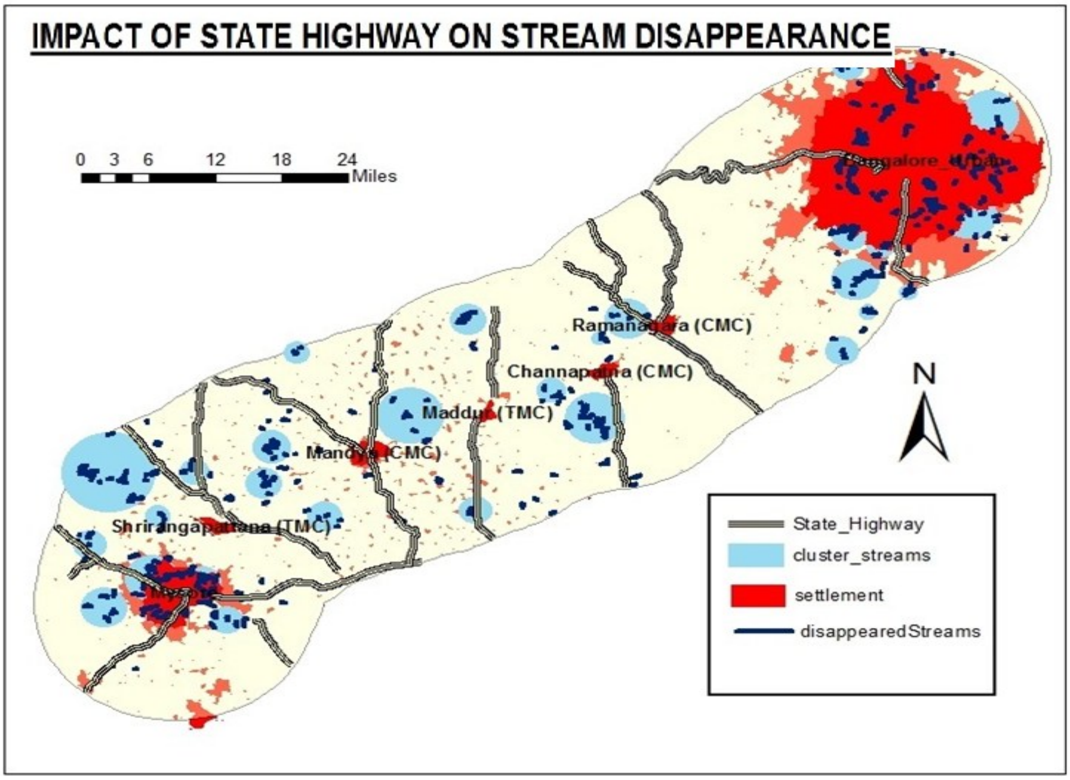
Table 6.9

National Highways obstructing the stream flow and discontinuity

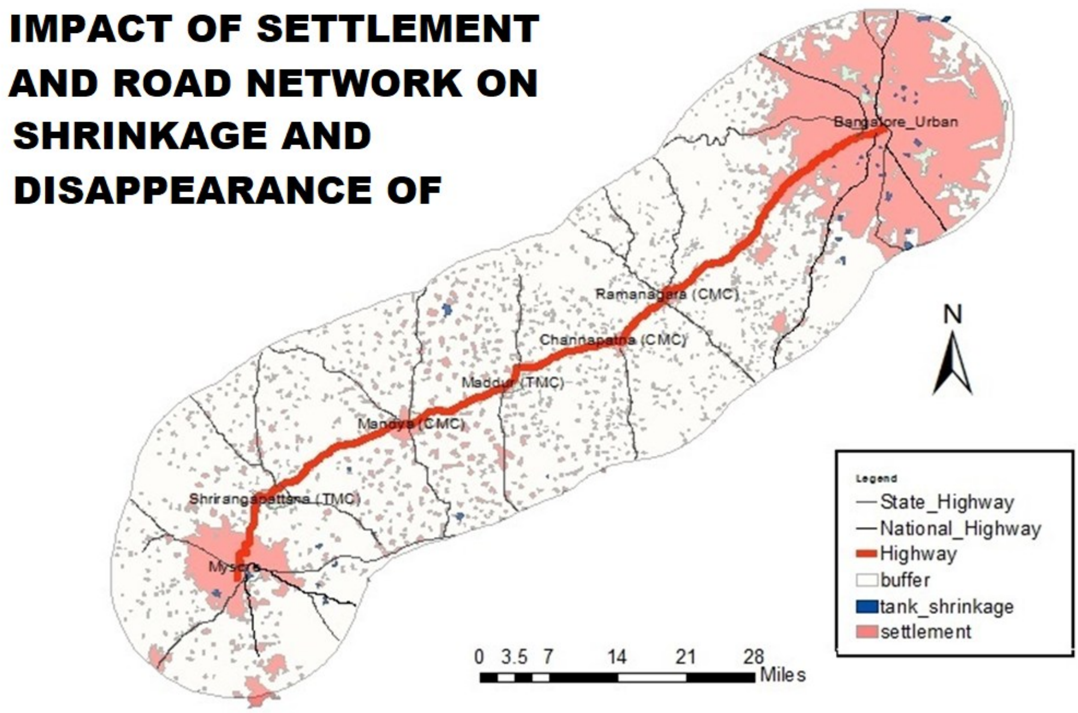
	Major	Medium	Minor
Mysore	5	0	0
Srirangapatana	0	0	0
Mandya	2	0	0
Maddur	1	1	0
Channapatana	1	2	0
ramanagara	1	1	0
bangalore	0	1	



IMPACT OF HIGHWAY
ON STREAM DISAPPEARANCE
Bangalore_Urban
Ramanagara (CMC)
Channapatna (CMC)
Maddur (TMC)
Mandya (CMC)
Shrirangapattana (TMC)
Mysore
N
Highway
cluster_streams
settlement
disappearedStreams
0 3 6 12 18 24
Miles



IMPACT OF STATE HIGHWAY ON STREAM DISAPPEARANCE
0 3 6 12 18 24
Miles
Bangalore_Urban
Ramanagara (CMC)
Channapatna (CMC)
Maddur (TMC)
Mandya (CMC)
Shrirangapattana (TMC)
Mysore
N
State_Highway
cluster_streams
settlement
disappearedStreams



Net Loss	173.27 km^2
Net Gain	587.53 km^2
Unchanged	83.87km^2
Total	**760.8 km^2**

Table 6.6 Elevation Change Detection (Topographical Sheet & Carto DEM)

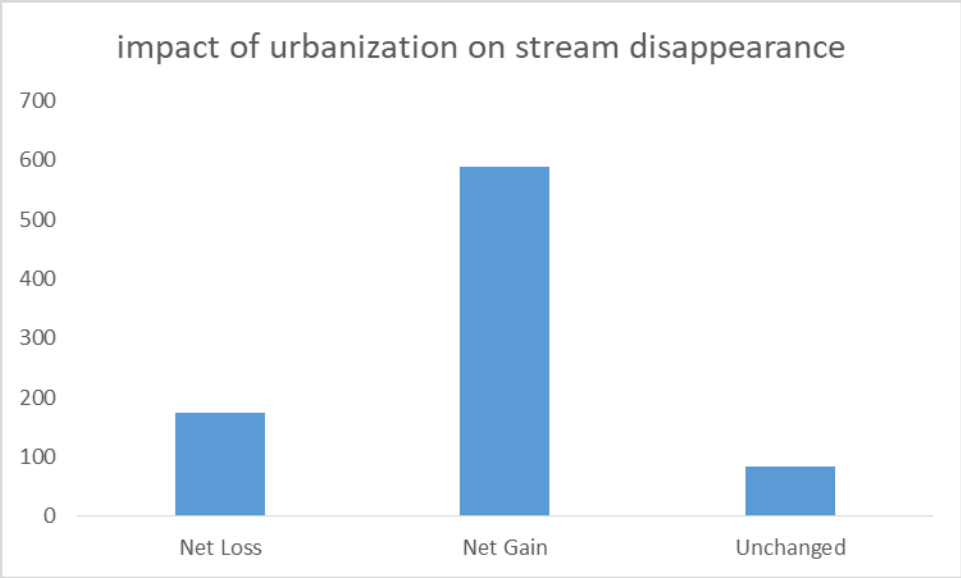


Figure 6.10 Area under Net loss, Net gain and Unchanged Elevations

6.12. Impact of Urbanization on Stream disappearance

Streams are the main source of water to feed both tanks and high order streams, Cauvery river in the study area extent is a seasonal river and only during the rainy season it flows from one tank to another, filling them one after another. But due to the continuous urban expansion in Mysore and Bangalore most of the streams are disappeared and lost its connectivity. Waterbodies in the region also shrunk due to dryness and also because of the encroachment of Built up areas.

The Strahler stream order method of analysis was employed to classify stream orders in the study area. The total number of streams (Table 6.7) decreased from 957 to 880 during two decades. The total number of 955 streams in 1978 had 733 I order streams, 185 II order streams, 32 III order streams, 4 IV order streams 2 V order streams, and 1 VI order streams. Whereas in the case of 2011 with 880 streams I order streams are 666, 175 II order streams, 32 III order streams, 4 IV order streams, 2 V order streams, and 1 VI order streams. When compared with 1978 and 2011, a total number of 77 streams were affected among which 62 streams have disappeared and 7 streams lost its connectivity which belongs to first order, and the 6 streams of second order have vanished and 2 streams lost their continuation. Third, fourth, fifth order streams remain unchanged throughout the period. The figure 6.11 shows affected streams with urban expansion. And can easily identify that with the expansion of Built up, in the interior of the region, most of the streams got disappeared and lost its connectivity. Whereas the streams which were in the outskirts of the urban are affected less. The main reason was due to the continues urban expansion of Mysore, that affects the stream diversion. Where as in Bangalore the streams are not affected much. Most of the streams are affected in Mysore urban area only within 10 km and where most of the area is occupied by Built up. This study on stream orders conveys there will be future threat to all the stream orders in coming years due to urban expansion and that process is still continuing.

Table 6.7 Stream Orders and Disappearance

Sl No	Stream order	No. of Streams in 1978	No. of Streams in 2019	Disappeared Streams	Connectivity lost
1	I Order Steams	733	666	62	6
2	II Order Streams	185	175	7	2
3	III Order Streams	32	32	0	0
4	IV Order Streams	4	4	0	0
5	V Order Streams	2	2	-	-
6	VI Order Streams	1	1	-	-
Total of Streams		**955**	**880**	**77**	

Source: Image processing and mapping of streams in the study area.

ANNUAL ZONAL VANISHED STREAMS :

The study area was divided into 20 buffer zones each with a difference of 1 Kms. Around the Mysore – Bangalore express highway and the pattern of disappearance was analysed.

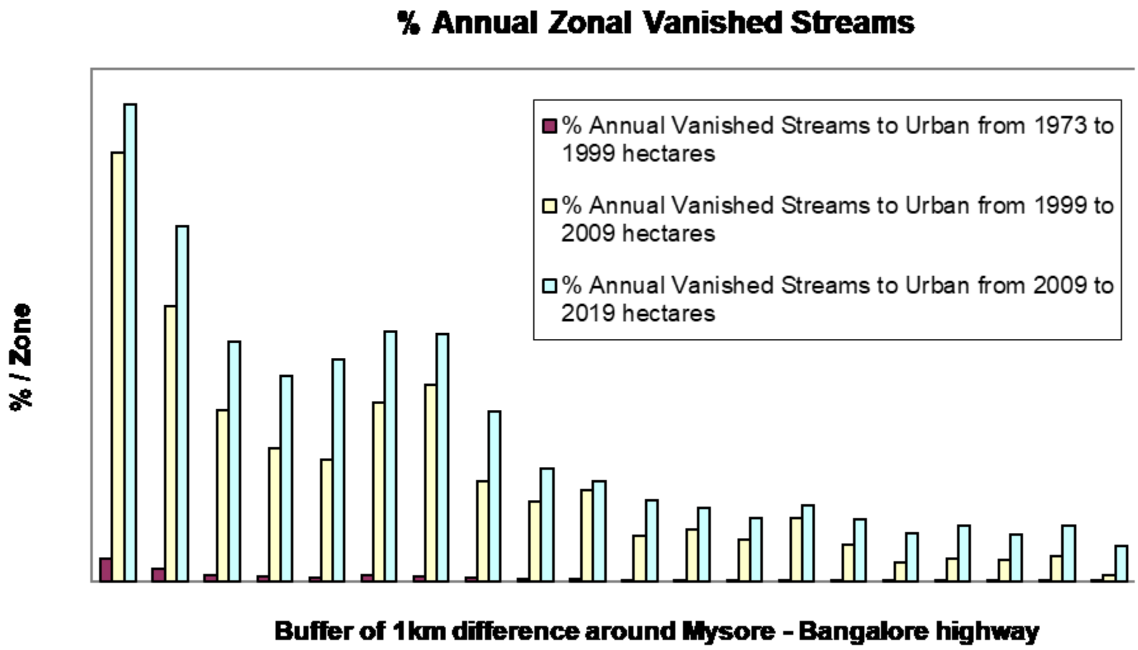
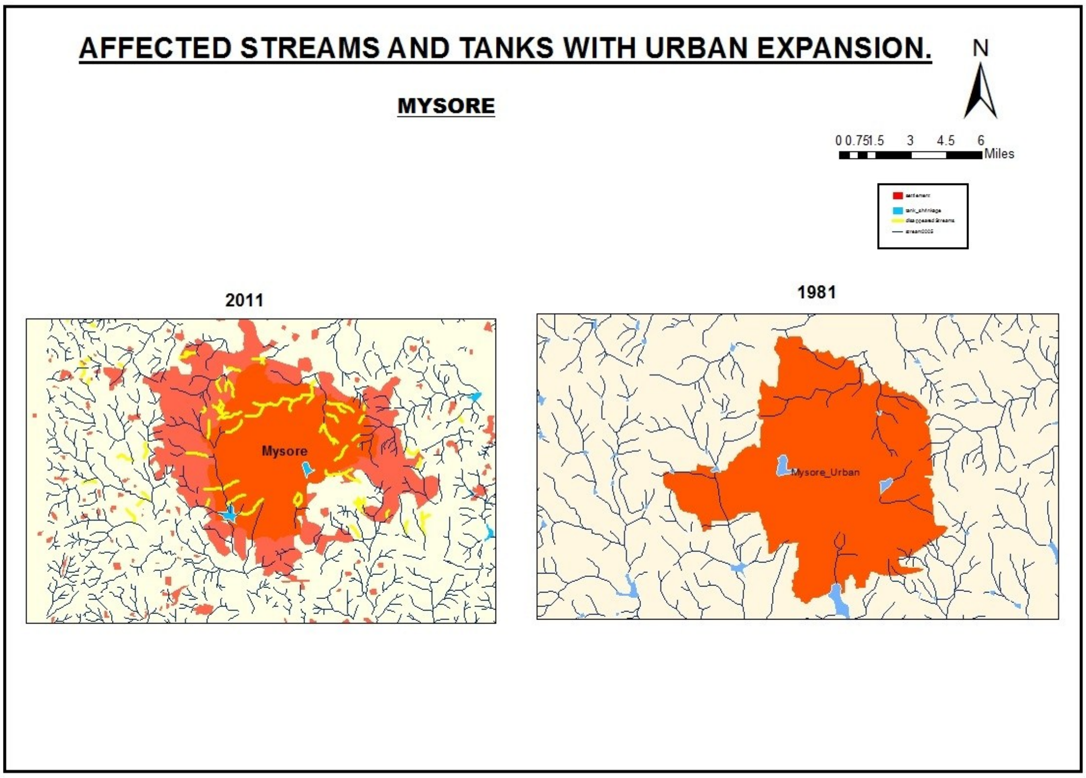


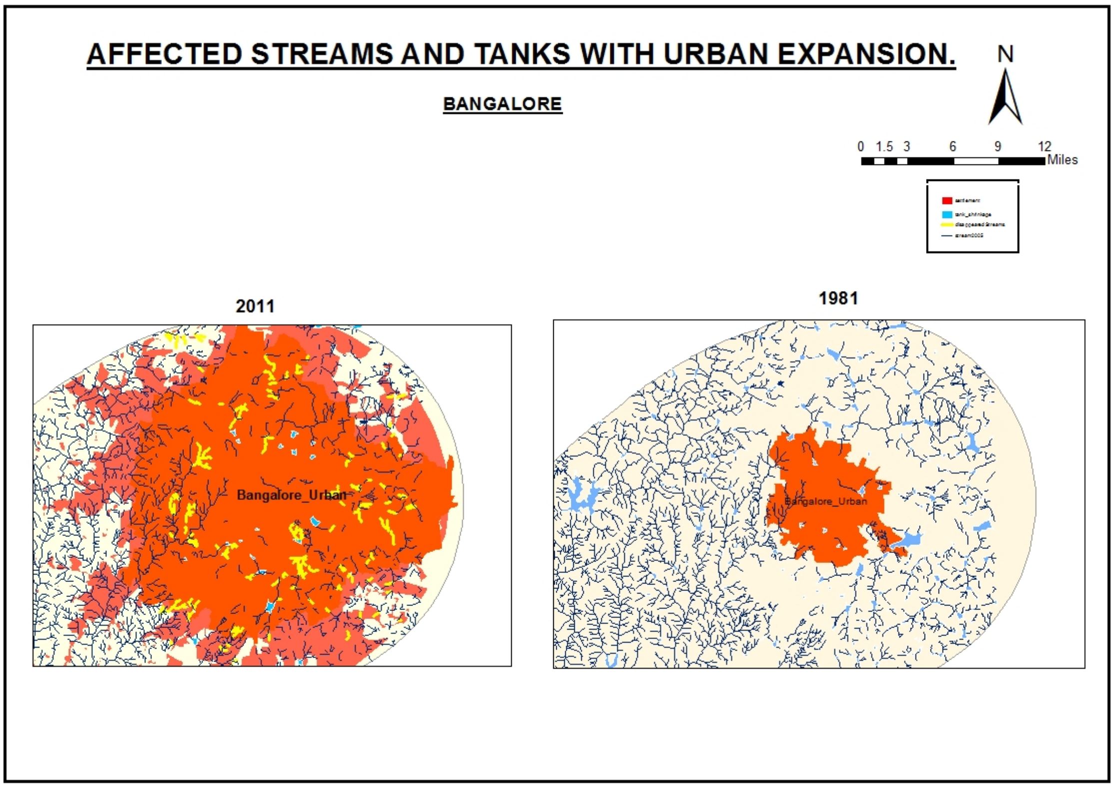
Figure 6.11 Affected Streams with Urban expansion

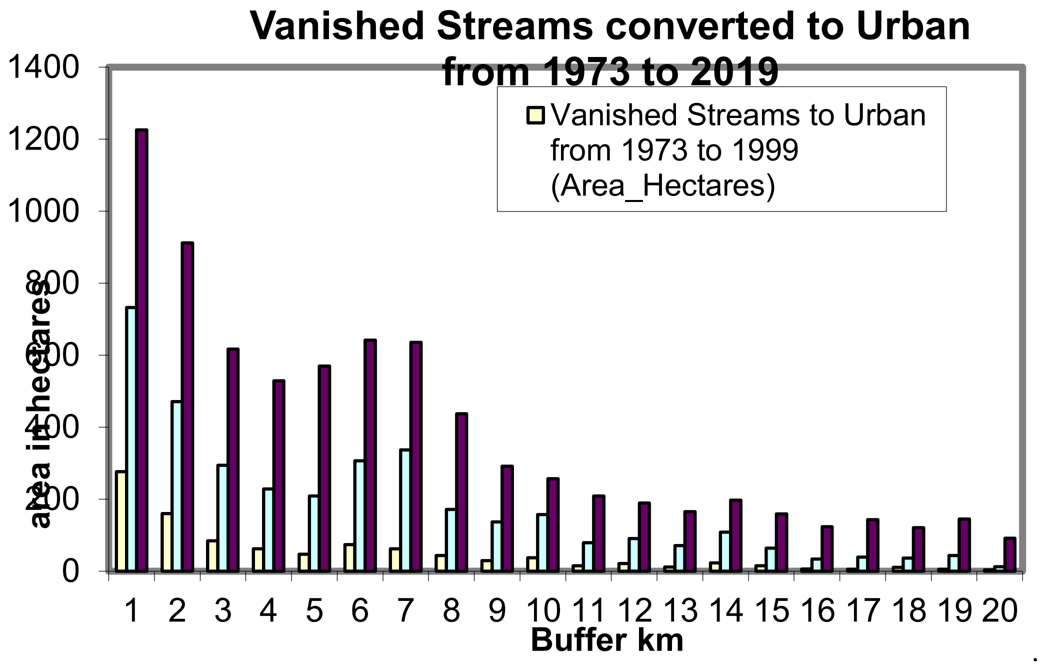


6.13. Impact of Urbanization on Waterbodies shrinkage and disappearance

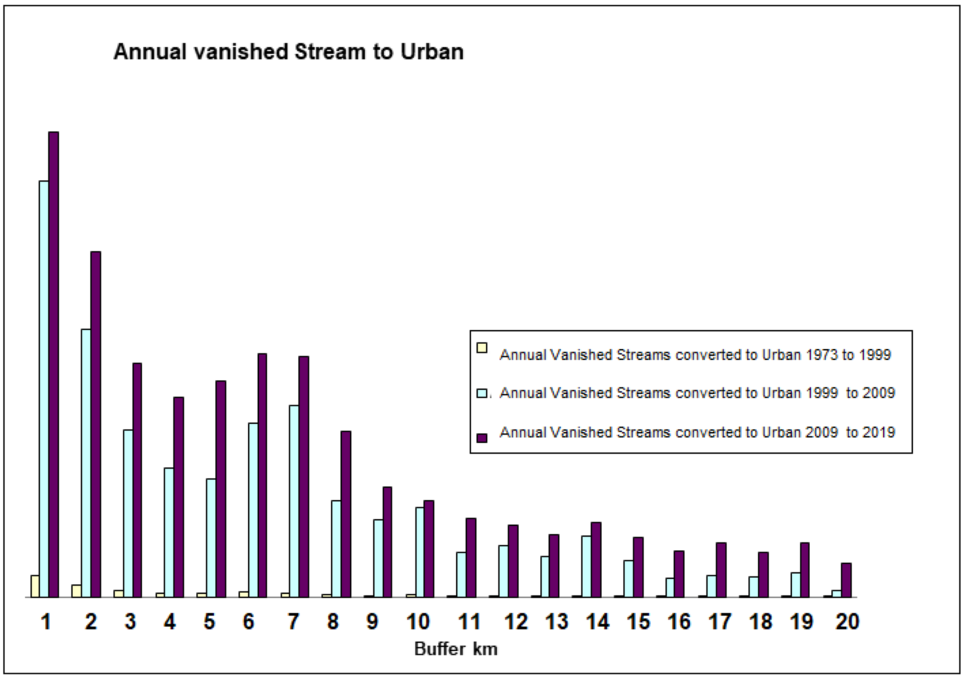
There were 71 tanks in 1978 and three Waterbodies had disappeared by 2011 and thus the number of tanks that existed since 2011 were reduced to 68. The figure 6.12 shows that, affected Waterbodies with urban expansion. Most of the Waterbodies in the two periods were not affected much but area of the Waterbodies shrunk more as encroachments and conversions affected their areal extent. They are Dodakere, Tank in Hinkal and Tank in Hanchya which were very close to the CBD of Mysore had already disappeared. The first two lakes were converted into playgrounds.

Figure 6.12 Affected Water bodies with Urban expansion.

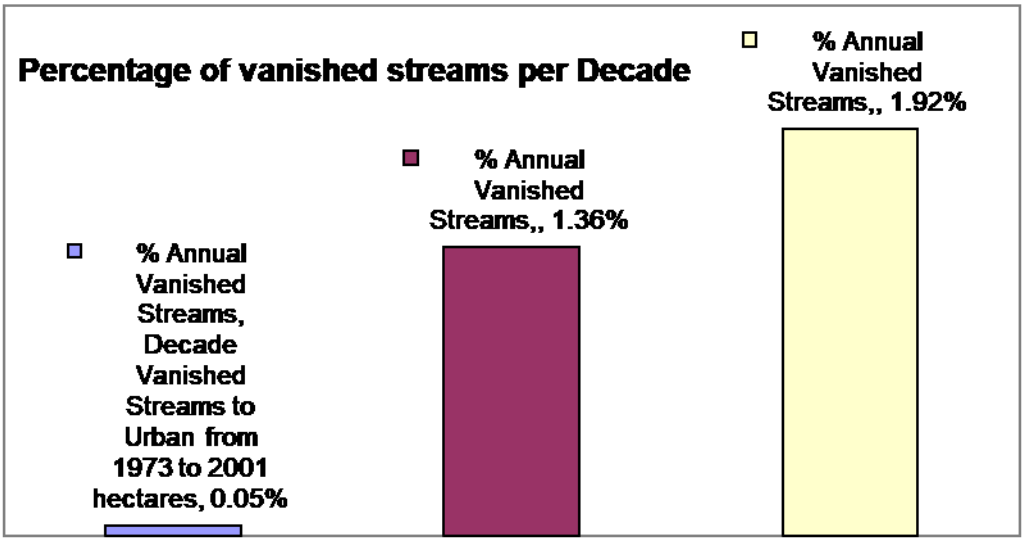




Vanished Streams converted to Urban from 1973 to 2019
Vanished Streams to Urban from 1973 to 1999 (Area_Hectares)
area in hectares
0
200
400
600
800
1000
1200
1400
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Buffer km



Annual vanished Stream to Urban
Area in ha
Annual Vanished Streams converted to Urban 1973 to 1999
Annual Vanished Streams converted to Urban 1999 to 2009
Annual Vanished Streams converted to Urban 2009 to 2019
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Buffer km


Percentage of vanished streams per Decade
% Annual Vanished Streams,, 1.92%
% Annual Vanished Streams,, 1.36%
% Annual Vanished Streams, Decade Vanished Streams to Urban from 1973 to 2001 hectares, 0.05%

Buffer_Km	% Vanished Streams to Urban from 1973 to 1999 hectares	% Vanished Streams to Urban from 1999 to 2009 hectares	% Vanished Streams to Urban from 2009 to 2019 hectares
1	5.05%	13.37%	22.36%
2	2.92%	8.60%	16.65%
3	1.54%	5.38%	11.25%
4	1.13%	4.16%	9.65%
5	0.86%	3.81%	10.39%
6	1.34%	5.60%	11.71%
7	1.13%	6.15%	11.59%
8	0.80%	3.13%	7.98%
9	0.53%	2.50%	5.31%
10	0.68%	2.87%	4.68%
11	0.27%	1.45%	3.80%
12	0.38%	1.65%	3.46%
13	0.21%	1.30%	3.01%
14	0.42%	1.97%	3.60%
15	0.28%	1.17%	2.91%
16	0.12%	0.61%	2.25%
17	0.09%	0.71%	2.61%
18	0.19%	0.67%	2.20%
19	0.09%	0.80%	2.65%
20	0.06%	0.23%	1.67%

Buffer_Km	Water Body_73	Vanished Streams to Urban from 1973 to 1999 hectares	Vanished Streams to Urban from 1999 to 2009 hectares	Vanished Streams to Urban from 2009 to 2019 hectares
1	5480	277	733	1225
2	5449	160	471	912
3	4765	84	295	616
4	4616	62	228	529
5	4914	47	209	569
6	4787	74	307	642
7	4804	62	337	635
8	3761	44	171	437
9	3149	29	137	291
10	2634	37	157	256
11	2374	15	79	208
12	2480	21	90	190
13	2418	11	71	165
14	2734	23	108	197
15	2355	15	64	159
16	1820	6	34	124
17	2556	5	39	143
18	2105	11	37	120
19	1886	5	44	145
20	1444	3	12	91

Table 6.8 List of Affected Waterbodies with Urban Expansion 1978-2019

Table 6.8 List of Affected Waterbodies with Urban Expansion 1978-2019						
Sl No	Name of Village	1978 Area Ha	2019 Area Ha	Changes in LULC of affected Waterbodies	Changes	Changes in %
1	Hinkal 1	2.16	1.58	Built up	0.57	26.62
2	Hinkal 2	0.46	Disappeared	Built up (Disappeared)	Disappeared	Disappeared
3	Bhogadi	6.41	6.23	Vegetation	0.18	2.83
4	Kukkarahalli, Mysuru	50.87	43.21	Built up	7.65	15.04
5	Devanur Kere	4.42	3.31	Vegetation	1.1	25.01
6	Kythamaranahalli Mysuru	2.47	2.43	Built up	0.05	1.83
7	Chamundibetta Devi kere	1.04	0.86	Vegetation	0.18	17.67
8	Karanjikere Mysuru	25.07	19.51	Built up	5.56	22.17
9	Dodakere Dry	39.7	Disappeared	Disappeared	Disappeared	Disappeared
10	Gobi tank	2.05	2.05	No Change	0	0
11	Koorgalli 1	1.95	1.95	No Change	0	0
12	Koorgalli 2	0.45	0.33	Vegetation	0.12	27.44
13	Hebbalu 1	8.39	7.69	Vegetation and Built up	0.7	8.32
14	Hebbalu 2	2.74	1.57	Vegetation	1.17	42.65
15	Basavanahalli 1	1.18	0.82	Vegetation and Built up	0.36	30.47
16	Nagarthahalli	9.28	9.28	Vegetation	0	0
17	Ballahalli	50.62	43.22	Vegetation	7.4	14.62
18	Basavannanagudihundi	11.89	4.9	Vegetation	6.99	58.77
19	Ganigarahundi	2.9	2.33	Vegetation	0.58	19.88
20	Jettihundi	6.4	5.25	Vegetation	1.15	17.99
21	K. Hemmanahalli	1.14	0.94	Vegetation	0.2	17.81

22	Devayyanahundi	67.28	28.68	Vegetation and Built up	38.6	57.37
23	Kergalli	2.91	1.37	Vegetation	1.53	52.73
24	Ajjanahundi	4.68	1.93	Vegetation	2.75	58.73
25	Dasana Koppalu	1.27	1.1	Built up	0.18	13.98
26	Basavanahalli 2	4.01	3.43	Built up	0.58	14.4
27	Belavadi	1.27	1.23	Vegetation	0.05	3.86
28	Kamkarehundi	5.8	4.99	Vegetation	0.81	13.95
29	Kesera	1.16	0.99	Vegetation	0.17	14.73
30	Rammanahalli	0.6	0.6	No Change	0	0
31	Hanchya 1	1.15	Disappeared	Vegetation (Disappeared)	Disappeared	Disappeared
32	Hanchya 2	4.61	3.26	Vegetation	1.35	29.3
33	Tavarekatte	1.12	0.95	Vegetation	0.17	15.33
34	Naranahalli	0.47	0.4	Vegetation and Built up	0.07	14.43
35	Sarakariuthanahalli	1.22	0.95	Built up	0.27	22.12
36	Uttanahalli	3.94	2.85	Vegetation	1.08	27.51
37	Bandipalaya	0.65	0.65	No Change	0	0
38	Dalavayi Kere	53.82	45.12	Vegetation	8.7	16.16
39	Mandakalli	8.95	8.95	No Change	0	0
40	Kalalavadi	9.7	8.91	Vegetation	0.79	8.14
41	Cauvery river	4089.08	4089.08	No Change	0	0
42	Megalapura	1.24	1.11	Vegetation	0.12	10.02
43	Mydanahalli	7.99	7.43	Vegetation	0.56	6.98
44	Elwala	4.18	2.42	Vegetation	1.76	42.14
45	Nagawala	8.38	8.38	No Change	0	0
46	Bommenahalli	7.7	5.27	Vegetation	2.43	31.54
47	Doddamaragowdanahalli	4.31	3.33	Vegetation	0.98	22.77

48	Gubbe Matti	3.37	3.12	Vegetation	0.25	7.48
49	Shettanayakanahalli	6.26	5.68	Vegetation	0.58	9.2
50	Manikyapura	1.35	1.35	No Change	0	0
51	Huyilalu Marshy land	10.08	5.21	Vegetation	4.87	48.31
52	Hampapura	1.15	1.02	Vegetation	0.13	11.33
53	Doddankanahalli 1	38.76	22.69	Wasteland and Vegetation	16.07	41.46
54	Doddankanahalli 2	0.5	0.42	Vegetation	0.08	15.32
55	Harohalli	2.35	2.35	No Change	0	0
56	Varakodu1	9.61	2.57	Vegetation	7.05	73.27
57	Varakodu 2	1.37	1.03	Vegetation	0.33	24.48
58	Varakodu 3	2.33	1.25	Vegetation	1.08	46.24
59	Lake Devambakere	53.84	51.64	Vegetation	2.2	4.09
60	Jantagalli1	34.69	34.69	No Change	0	0
61	Jantagalli 2	6.36	3.74	Vegetation	2.62	41.15
62	Madapura	7.05	5.54	Vegetation	1.51	21.4
63	Koodanahalli	4.14	3.79	Vegetation	0.35	8.41
64	Madaragalli	8.11	7.19	Vegetation	0.92	11.4
65	Sindhuvalli	128.99	124.5	Vegetation	4.49	3.48
66	Pillahalli	36.22	29.78	Vegetation	6.44	17.78
67	Nachanahalli	1.23	1.08	Builtup	0.15	12.04
68	Nachanahallipalya	1.83	1.83	Vegetation	0	0
69	Sathagalli	0.83	0.48	Builtup	0.34	41.57
70	Chikkanahalli	0.35	0.25	Vegetation	0.1	28.79
71	Vijayasripura	2.95	2.77	Vegetation	0.18	6.16

Source: Topographical sheets and image processing 1978 and 2019

In 1978, the total area of the 71 tanks was 4,892.74 ha but it had decreased to 4704.79 ha in 2005, as seen in table 6.8. In figure 6.12 Most Waterbodies were affected mainly inside Mysore urban because of expansion of Built up land. Major portion of the Waterbodies are concentrated towards south of Mysore Srirangapatana region and large amount of aerial shrinkage is identified within this region only. The largest areal change in Waterbodies occurred in Varakodu village, which accounted for 73.27 % of areal change in Waterbodies followed by Basavannanagudihundi accounting for 58.77 % and Ayyajayyanahundi followed by 58.73%. And the least areal change of 1.82 % in Waterbodies occurred in Kythamaranahalli. Kukkarahalli, (15.04%), Karanjilake (22.17%), Devanur (25.01%), Bhogadi (2.83%), Hinkal (26.62%) Chamundibette Devikere (17.67%) were the Waterbodies in Mysore urban which have been shrinking fastly due to Built up expansion and also due to the encroachment of Barren land and Vegetation which is situated in the heart of Mysore. Industrial development will be the other reason for the fast rate of shrinkage in Mysore urban especially towards North West direction. One of the tank in Hinkal totally disappeared from its vicinity due to industrialization of this region. The other waterbodies which are located nearby Industrial areas like Hebbalu and Hinkal are in the future threat of shrinkage or disappearance.

Kukkarahalli kere which is located near to Mysore University campus is facing aerial shrinkage due to the construction activity in and the around lake and also of improper management. Karanjikere one of most tourist attraction of Mysore city losing its area because of the Mysore city expansion. Doddakere which was large Waterbody inside Mysore urban have already disappeared without leaving its footprints.

The largest aerial shrinkage was found interior and towards North west direction. Waterbodies in Ajjanahundi (58.73%), Basavannanagudihundi (58.77%) Devayyanahundi (57.37%) Kergalli (52.73%) Elwala (42.14%) shows high frequency of shrinkage in the region. There are some tanks like Gobi tank, Nagawala, Jantagalli 1, Harohalli, Mandakalli which remain unchanged during this period. Mysore city alone was with more than 50 % of the tanks and three of them, namely, Doddakere, Hanchya 1 and Hinkal 2 already got disappeared in the process of urban expansion and urban land conversion. As the distance from the CBD increased, the encroachment of tank area for building up was gradually decreasing and conversion of tank area into Vegetation was greater. It was either the natural growth of plants or encroachment of tank area for agriculture.

6.14. Conclusion

The change in elevation which has changed the angle of slope and in aspect**.** From the study, it is evident that the process of urbanization, the change in the elevation has been detected and is within 10 km distance in and around the CBD of Mysore. Expansion of Built up area and the upcoming Industrial area are the main reasons. Out of 179 settlements, the change has been detected only in 67 sample points out of which 42 points have been recorded as gain and in 20 points there has been a loss in the elevation. The Industrial hub of Hutgalli, Hebbalu and Koorgalli which are located in the west of Mysore resulted in the decrease of elevation, and also conversion of un- irrigated area in to residential area especially in Elwala. The New City development plan of Mysore Nanjungud has its impact on the increase in the elevation of some of the places to south of Mysore. Streams have disappeared and lost its connectivity wherever the elevation changed. Most of the streams got affected in Mysore urban where elevation increased. This is mainly due to bareness as a result filling of Vegetative cover transforming to Built up land. Three Waterbodies already disappeared from the Mysore urban in the course of time, where other Waterbodies area already started to shrink due to the urban expansion and change in elevation.

There is an urgent need to protect and preserve, water resources for future generations. These Waterbodies are valuable because they are not only tourist attractions but they also act as sustenance to the city as they provide livelihoods to a big population, directly or indirectly. Thus, proper organization is the need of the hour for both maintaining ecological equilibrium as well as sustainability.

So proper administration and planning should be taken to avoid the changes in elevation towards urban center and towards the Northwest due to industrial transformation of land for residential layout. The authorities should take necessary precautions to control the urban expansion in future at least protecting in and around 10 km from CBD, as it is the prime cause for change in the elevation. Restriction should be imposed for land filling as it is the main reason for increase in the elevation as it is noticed that major stream and waterbodies changes happened due to elevation changes by gaining elevation.

Buffer_Km	Water Body_73	Annual Vanished Streams to Urban from 1973 to 1999 hectares	Annual Vanished Streams to Urban from 1999 to 2009 hectares	Annual Vanished Streams to Urban from 2009 to 2019 hectares
1	5480	9.89	183.18	204.24
2	5449	5.72	117.75	152.02
3	4765	3.01	73.64	102.73
4	4616	2.22	57.02	88.14
5	4914	1.69	52.14	94.90
6	4787	2.63	76.65	106.92
7	4804	2.21	84.25	105.86
8	3761	1.57	42.84	72.85
9	3149	1.03	34.19	48.53
10	2634	1.34	39.32	42.74
11	2374	0.53	19.81	34.74
12	2480	0.75	22.62	31.59
13	2418	0.40	17.85	27.53
14	2734	0.83	27.02	32.87
15	2355	0.55	15.99	26.56
16	1820	0.23	8.39	20.59
17	2556	0.17	9.79	23.88
18	2105	0.38	9.19	20.08
19	1886	0.17	10.95	24.16
20	1444	0.11	3.10	15.24

uffer_Km	% Annual Vanished Streams to Urban from 1973 to 1999 hectares	% Annual Vanished Streams to Urban from 1999 to 2009 hectares	% Annual Vanished Streams to Urban from 2009 to 2019 hectares
1	0.18%	3.34%	3.73%
2	0.10%	2.15%	2.77%
3	0.05%	1.34%	1.87%
4	0.04%	1.04%	1.61%
5	0.03%	0.95%	1.73%
6	0.05%	1.40%	1.95%
7	0.04%	1.54%	1.93%
8	0.03%	0.78%	1.33%
9	0.02%	0.62%	0.89%
10	0.02%	0.72%	0.78%
11	0.01%	0.36%	0.63%
12	0.01%	0.41%	0.58%
13	0.01%	0.33%	0.50%
14	0.02%	0.49%	0.60%
15	0.01%	0.29%	0.48%
16	0.00%	0.15%	0.38%
17	0.00%	0.18%	0.44%
18	0.01%	0.17%	0.37%
19	0.00%	0.20%	0.44%
20	0.00%	0.06%	0.28%

CHAPTER VIII

IMPACT OF URBANIZATION ON LAND SURFACE TEMPERATURE

8.1 Introduction

Rapid urban growth and increasing population pressure keeps on altering the physical properties of urban land, resulting in significant variations in urban thermal environments. (S. Li, Zhao, Miaomiao, & Wang, 2010). The urbanization process also plays a significant role in the heating phenomena known as Urban heat island involving both air and surface temperatures in different ways. The Urban heat island has effects on human comfort, air pollution, energy management, urban planning policy and climate changes (Fallmann J. 2016). Infact Land Surface Temperature (LST) images retrieved from satellite sensor thermal observations, supply a scientific support to assess if the urban development model is amenable with the environmental sustainability (Fan, C.,2017). The changes in Land use land cover have different environmental implications and the urbanization that is conversion of natural surfaces to human uses has a great impact on urban climate. The Land Surface Temperature decreases as the albedo of the built up surface increases, (Baldinelli, G.,2017) while the same trend is not followed by air temperature. Reviews on potential strategies to mitigate the urban heat island effects that are applicable in the design phase of urban development (Gago, E.J., 2013) Urban studies essentially require accurate and widespread spatial information to monitor the land use changes and the surface thermal pattern (Xu, Y., 2017). Remote sensing provide data over large areas and suitable image processing and statistical analysis allow to derive spatial parameters useful to detect urban changes and thermal environment. In several studies different analysis has been proposed to infer a relationship between urban land covers land LST changes. And there is a significant role of land use/ land cover changes in the variation of Land Surface Temperatures is restated. With increase in Built up the excess heat from buildings and transportation, industrial and residential areas are trapped and the heat accelerates to higher temperatures in urbanized areas. In urban area the land cover of vegetation has been replaced by concrete materials and reduced the density of vegetation in urban environment which makes the environment hotter. This drastically raises the surface temperatures and thereby affecting the land cover types. So it is essential to know about Land surface temperature and its correlation with different land cover types.

This is the reason that studies on Land surface temperature received worldwide importance. The information obtained by Land surface temperature can provide useful awareness in the study of various sensations including analysis of urban heat islands, detection of thermal anomalies related to earth quakes, drought, forest fire monitoring. Wan, 1999). The studies on Land Surface Temperature has been extended due to the availability of remote sensing database during different periods. This chapter focusses on the changing land surface temperature over different Land uses in Mysore Bengaluru region during 1999 to 2019.

8.2 Land Surface Temperature

LST means the temperature of the surface which we can observe directly or touch it with. From satellite point of view, the surface is whatever it sees when it looks through the atmosphere to ground, it could be snow or ice, roof of the building, leaves of the canopy of a forest. Thus the surface temperature is not the similar as air temperature and it is included in the daily weather report (NASA). LST has a substantial impact on analyzing the environmental problems like urban heat islands (UHI), soil moisture, and vegetation loss which plays an important role in substituting bioprocess of water and energy between land surface and air. (Zareie, S., Khosravi 2016) which are connected to the surface temperature. This finally results in having various land use land cover types or surface properties which have several effects on LST from local to global scales.

The uncontrolled and haphazard urbanization related with poor built up design are the major reason for high level of LST and finally lead to the formation of Urban Heat island in urban centers. The study conducted by Jones P.D (1990) proved that the large extent of built up is the main cause of high temperature level in urban areas, in which vegetation areas are replaced with impervious and high temperature surface of concrete and asphalt. Therefore, these surface absorbs more heat than they reflect it, and this cause surface temperature to rise and in addition to that buildings with large height and the impervious narrow streets can make the air heat which is closed between them.

Urban built up areas had less moisture content and evaporate less water which make the surface temperature high Weng.Q (2007).

8.3 Methodology

The study has been carried out purely on the basis of remote sensing. Landsat Images (1999,2009 and 2019) were downloaded from the official website of US Geological Survey (USGS) were used in order to fulfil this objective. The study area is located in the Landsat path 144 and row 51 and 52, with Universal Mercator Projection(UTM) with in zone 43 North and World Geodetic System (WGS)1974 datum were assigned to the Landsat images.

In addition to that Land Use Land cover classification of 1999 ,2009 and 2019 have been done to extract land cover types over the corresponding periods, a number of land use map for study period were also collected from MUDA in order to verify the accuracy of Classified images.

Table 8.1. Details of Landsat Images used

Respective Year	Data Acquired	Sensor
1999	2/February/1999	LANDSAT 5 TM
2009	1/March/2009	LANDSAT 5 TM
2019	13/March/2019	LANDSAT 8 OLI TIRS

Source: US Geological Survey 2019

8.4 Measurement of Land Surface Temperature (LST)

Recently researchers started using airborne or satellite data to derive LST. This new geospatial technology allows to monitor and derive LST for different periods. These openings facilitate researchers to investigate the relations between land use and land cover changes over LST. Before National Oceanic and Atmospheric administration (NOAA) data was used to derive LST to conduct studies at the regional scale. In recent years, the Landsat Thematic Mapper TM and Enhanced Thematic Mapper (ETM+) thermal Infrared (TIR), have been utilized for small scale studies. Landsat 8 is the new satellite from Landsat series, has given a wide opportunity in remote sensing.

Various types of Land cover indices have also been created in order to investigate the correlations between LST. Among the different indices this study has found NDVI (Normalized Difference Vegetation Index), NDBI (Normalized Difference Built Up Index), NSWI (Normalized Difference Water Index), NDBal (Normalized Difference Bareness Index) which correlate strongly with LST.

In this study LST is derived using LANDSAT 5 and LANDSAT 8. Different types of Land cover indices have also been done in order to investigate the correlations between land cover changes and LST. Among various indices this study has found NDVI (Normalized Difference Vegetation Index) NDBI (Normalized Difference Built up Index) and NDWI (Normalized Difference Water Index) which correlate strongly with LST.

8.5 Retrieval of Land Surface Temperature

The Landsat images of 1999, 2009 which belongs to Landsat 5 TM and 2019 of Landsat 8 OLI TIRS have been used for calculating land surface temperature in Mysore Bengaluru region. From Landsat 5 band number 6 have been used to extract temperature for year 1999 and 2009 and in Landsat 8 band number 10 have been used to extract surface temperature. Band 6 is the thermal infrared channel which records the radiation with spectral range from 10.4 -12. 5µm.from the earth surface and in the case of band number 10 of Landsat 7 is the thermal band the radiation of spectral range from 10.60 -11.19µm.

The impact of diurnal heating cycle over LST is an important and interesting topic to state here, but it cannot be make an attempt here because thermal images of Landsat 5 and 8 do not provide any day and night infrared images in the same day. This is why the reason the variations of LST at overpass time in different years are not able to analyzed. Moreover, absolute temperature is not used for estimation of Land surface temperature.

8.5.1 Retrieval of Land Surface Temperature with Landsat 5

On the grounds of Chen et.al (2002), a two-step procedure was followed to extract brightness of temperature from Landsat 5 TM images in this research.

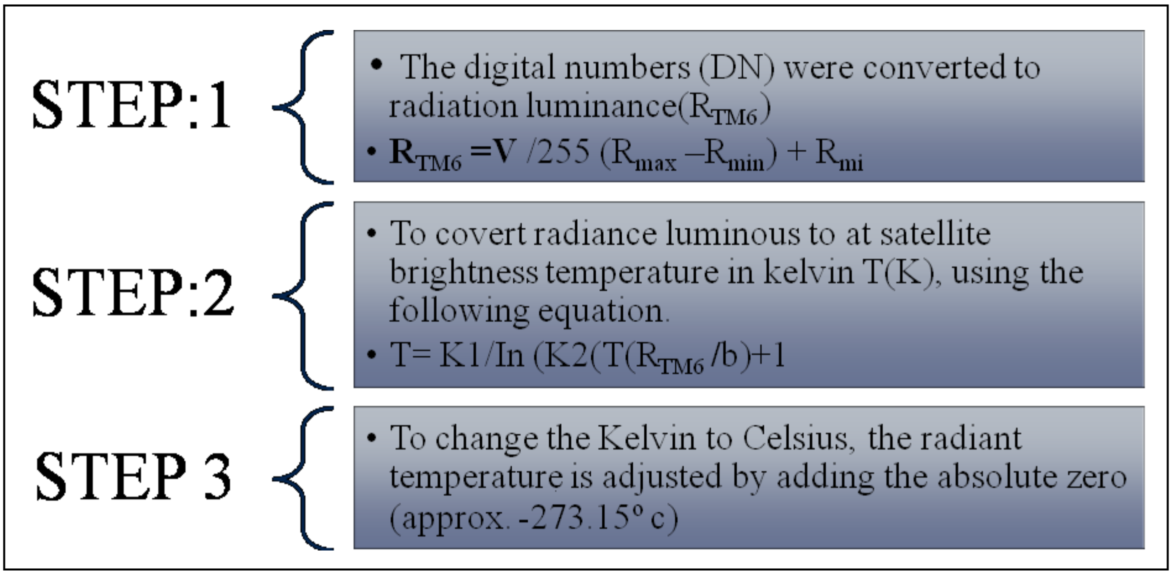


Figure 8.1 Retrieval of LST with Landsat 5

8.5.1.a. Step :1

The digital numbers (DN) of band number 6 were converted to radiation luminance(R_{TM6}) using the following formula

$$\mathbf{R}_{TM6} = \mathbf{V} /255 (R_{max} - R_{min}) + R_{min}$$

In which V represents the DN number of band number 6

R_{max} = 1.896 (mW * cm -^{2} * sr $^{-1}$) R_{min}

= 0.1534 (mW * cm $^{-2}$ * sr $^{-1}$)

8.5.1.b. Step :2

The next step is to covert radiance luminous to at satellite brightness temperature in kelvin T(K), using the following equations.

Where the value of K1= 1260 .56K and K2 is 607.766 ((mW * cm -2 * sr -1

µm -1) which were pre launched calibration constants under a hypothesis of unit emissivity, and b represents the effective spectral range, when the sensor response extent more than 50%, where b= 1.239µm.

$$T = \frac{K1}{In (K2/R_{TM6}/b) + 1}$$

8.5.2 Retrieval of Land Surface Temperature with Landsat 8

OLI and TIRS data can be converted in to spectral radiance using radiance rescaling factors provided in the metadata file.

Retrieval of LST with Landsat 8

Step1

- **Calculation of TOA (Top of Atmospheric) spectral radiance.**
- **TOA (L) =** $M_L * Q_{cal} + A_L$

Step2

- **Conversion of TOA (Top of Atmospheric) to Brightness Temperature.**
- **BT =** $K_2 / (In (K_1/L_\lambda) + 1$

Step3

- **To change the Kelvin to Celsius, the radiant temperature is adjusted by adding the absolute zero (approx. -273.15º c)**

Step4

- **Calculation of NDVI (Normalized Difference Vegetation Index)**
- **NDVI = (Band 5- Band 4)/ (Band5 + Band 4)**

Step5

- **Calculation of Proportion of Vegetation (P_v)**
- P_v **= Square ((NDVI –NDVI** $_{min}$**) / (NDVI** $_{max}$**- NDVI**$_{min}$**))**

Step6

- **Calculation of Emissivity**
- $\varepsilon = 0.004 * P_v + 0.986$

Step7

- **Calculation of Land surface temperature**
- **T = BT/ (1 +λ*BT/c 2) *In(e))**

8.5.2.a. Step 1. Calculation of TOA (Top of Atmospheric) spectral radiance

TOA (L) = $M_L * Q_{cal} + A_L$

Where

M_L = Band specific multiplicative rescaling factor from metadata file

(RADIANCE_MULTI _BAND_x, where x is the band number. Q_{cal} = Corresponds to band 10

A_L = Band specific additive rescaling factor from the metadata file (RADIANCE_ _ADD _BAND _x, where x is the band number.

8.5.2.b. Step 2: Conversion of TOA (Top of Atmospheric) to Brightness Temperature

TIRS band data can be converted spectral radiance to top of atmospheric brightness using the thermal constants provided in the metadata file.

BT = K_2 / (In (K_1/L_λ) + 1

Kelvin (K) to Celsius (ºc) Degrees

Therefore, to change the Kelvin to Celsius, the radiant temperature is adjusted by adding the absolute zero (approx. -273.15º c)

BT = (K_2 / (In (K_1/L_λ) + 1)) – 273.15

Where;

K_1 = Band specific thermal conversion constant from the metadata file

(K1_CONSTANT BAND_x, where x is the thermal band number) K_2 = Band specific conversion constant from the metadata. (K2_CONSTANT BAND_x, where x is the thermal band number) L_λ= TOA

8.5.2.c. Step 3: Calculation of NDVI (Normalized Difference Vegetation Index)

The calculation of NDVI is very much important because, subsequently, the proportion of vegetation which is highly related to the NDVI, and emissivity (e) which is related to the proportion of vegetation must be estimated.

NDVI = (Band 5- Band 4)/ (Band5 + Band 4)

8.5.2.d. Step 4: Calculation of Proportion of Vegetation (P_v) P_v = Square

((NDVI –NDVI $_{min}$) / (NDVI $_{max}$- NDVI$_{min}$))

Usually the minimum and maximum NDVI values can be exhibited directly in the image. The values vary from 1 to -1.

8.5.2.e. Step 5: Calculation of Emissivity

Formula to calculate emissivity as follows

$\varepsilon = 0.004 * P_v + 0.986$

8.5.2.f. Step 6: Calculation of Land surface temperature

T = BT/ (1 +λ*BT/c 2) *In(e))

Where

- BT is the brightness of temperature
- C2 =h*c/s= 1.4388* 10^{-2}Mk =1.4388µ k
- h = Plank's constant 6.626*10^{-24} J s
- s = Boltzmann constant 1.38*10^{-23} J/K
- c = Velocity of light = 2.998*10^{1}m/s

The values of λ for Landsat are listed below

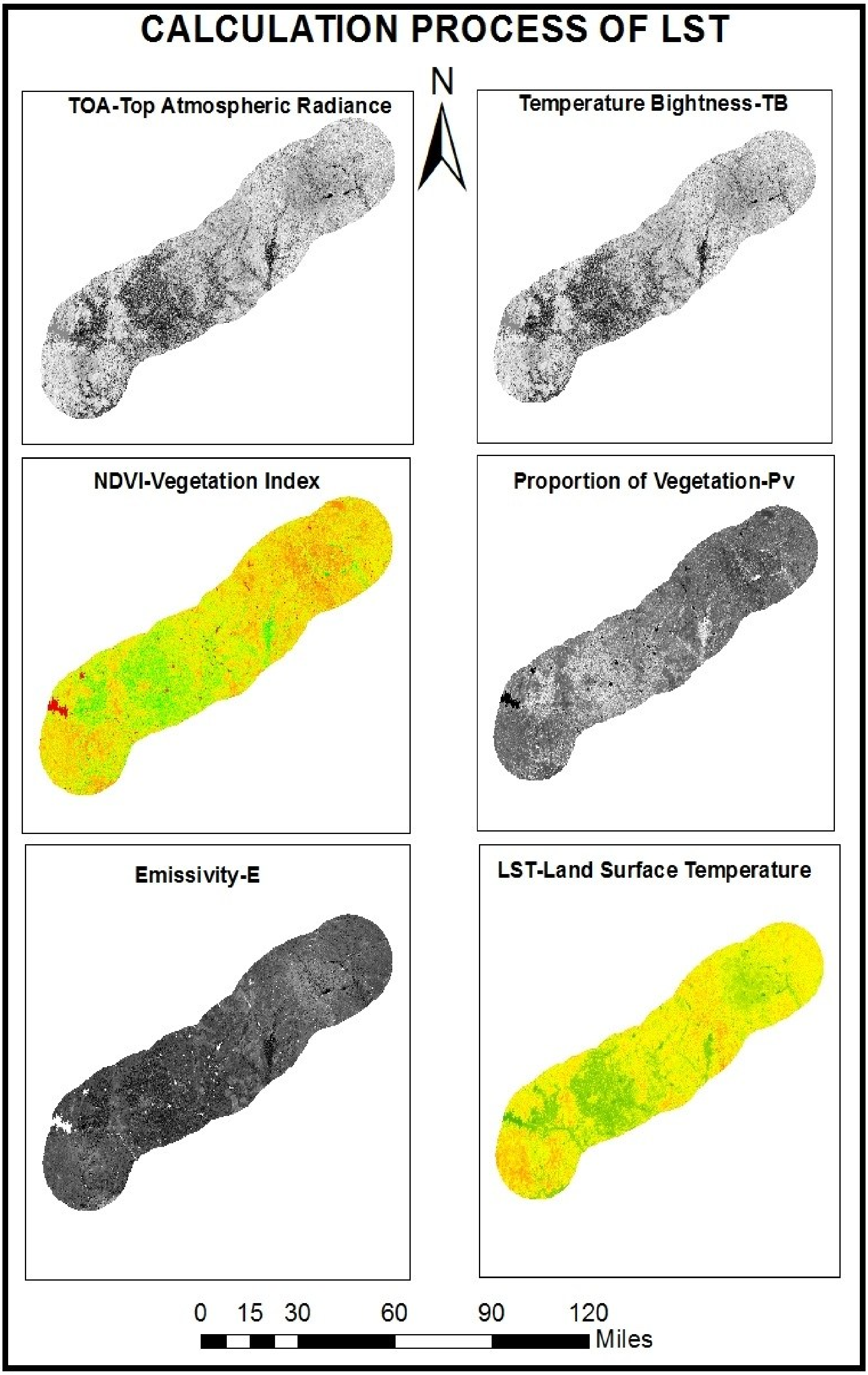
Table 8.2. Centre wavelength of Landsat Bands

Satellite	Band	λ(µm)
Landsat 4-5 ,7	6	11.45
Landsat 7	10	10.7
Landsat 8	11	12

Source US Geological Survey

8.6 Results on LST Calculation

Estimation of LST from satellite sensor based on TIR (Thermal Infrared) measurements gone through radiometric calibration, emissivity, and atmospheric corrections. The Thematic Mapper (TM) for 1999 and 2009 and Operational Land imager (OLI) and Thermal infrared sensor (TIRS) for 2019 have been used for calculation of LST. Thermal band of 6 from Landsat 5 for two years 1999 and 2009 and band 10 for Landsat 8 TIRS were employed to calculate the LST from all the selected periods. The output image of LST contains values of Land Surface Temperature of the region in Degree Celsius. The figure 8.3 shows the following procedure to be followed for the retrieval of LST from thermal images and NDVI images.


CALCULATION PROCESS OF LST
N
TOA-Top Atmospheric Radiance
Temperature Bightness-TB
NDVI-Vegetation Index
Proportion of Vegetation-Pv
Emissivity-E
LST-Land Surface Temperature
0 15 30 60 90 120
Miles

8.7 Spatio Temporal analysis of LST in Mysore Bengaluru region

The spatial variation of LST has been studied over a period of 20 years from 1999 to 2019.The figure 8.4 shows the spatial distribution of LST for three periods. After the retrieval of LST from the above mentioned formulas and it shows the expansion patterns of LST changes in two decades (1999-2009-2019). The result show that the LST ranged from 19.22 º C to 27 º C, 27 to 30 º C, 31 to < 34 º C, 34 to 37 º C,37 to < 40 º C, and > 40 º C. The least temperature experienced in the year 1999 where the minimum temperature ranges from < 27 and the maximum temperature range between 34 to 37 º C. In 1999 major part of the Mysore Bengaluru region falls within the lower temperature zones (< 27 º C to < 37 º C). But in 2009 after 10 years most of the area was found fall in to the mid temperature zones (27 to < 40 º C). This trend gradually continues and finally in 2019 all most major portion of the Mysore Bengaluru region were found to be in high temperature zones which falls in the range > 40 º C. Another noticeable fact that due to the presence Cauvery river in Mysore Bengaluru region, the in and surrounding areas shows low temperature zone in all the periods, but the intensity of low temperature zones come down gradually in the subsequent years.

The high temperature areas have been shown in the shades of red and correspond to Built up areas, open surfaces or barren hill slopes. Whereas the cooler areas are depicted by the shades of green and correspond to Waterbodies, Vegetation, and Agricultural land. Upon analysis it has been identified that the minimum and maximum temperature in the study area has been increasing since 1999.The rapid urbanization leads to increase in the Built up areas which in turn heated up as compared to the surrounding areas leading to urban heat island effect.

Figure 8.4 Spatial Distribution of LST in Mysore Bengaluru region

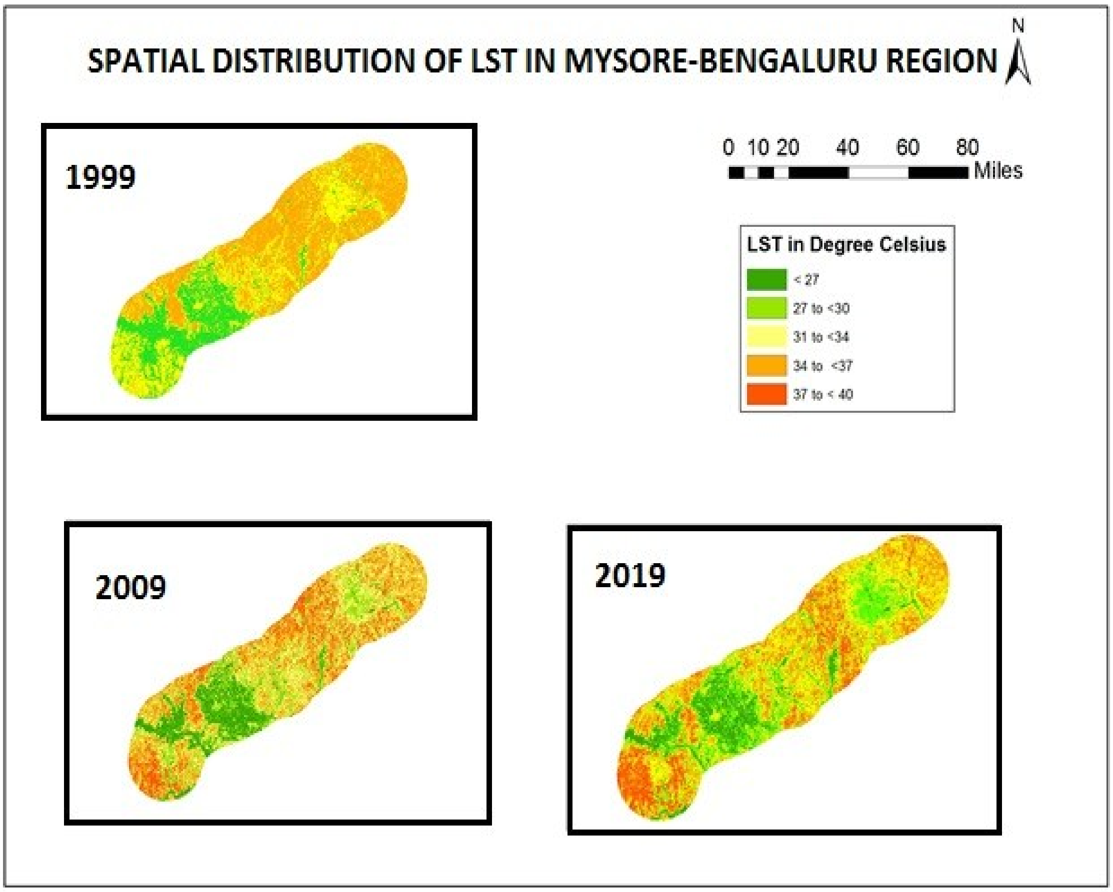


Table 8.3. Spatial Distribution of LST in Mysore Bengaluru region

Distance in Buffers	**Average LST in °C**		
	1999	2009	2019
5 km Buffer	30	34	39
10 Km Buffer	28	30	36
15 Km Buffer	27	29	32

Source: Image processing and Interpretation

8.7.a Spatio Temporal Analysis of LST with 5 km Buffer

The figure 8.4 and table 8.3 shows variation in LST values for each 5 km distance. Within 5 km radiance the average value of LST shows 30°C in 1999, and it gradually shows an increasing trend of 38°C towards 2019. There has been a rise of 4°C in minimum (1999-2009) and 8°C (1999-2019) in the maximum temperature of

20 years. Therefore, it can be said that rapid urbanization of Mysore which was identified with in 5km buffer shows remarkable increase in the Built up area which leads to high temperature values.

8.7.b Spatio Temporal Analysis of LST with 10 km Buffer

Within 10 km (Table 8.3) buffer trend of LST values are getting reduced and the average values of LST range from 28°C in 1999 ,30°C in 2009 and 36°C by 2019. It was identified that as the distance from urban center decreases the impact of LST also decreases. But there has been rise of temperature 2°C in minimum (1999-2009) and 6°C (1999-2019) during this period.

8.7.c Spatio Temporal Analysis of LST with 15 km Buffer

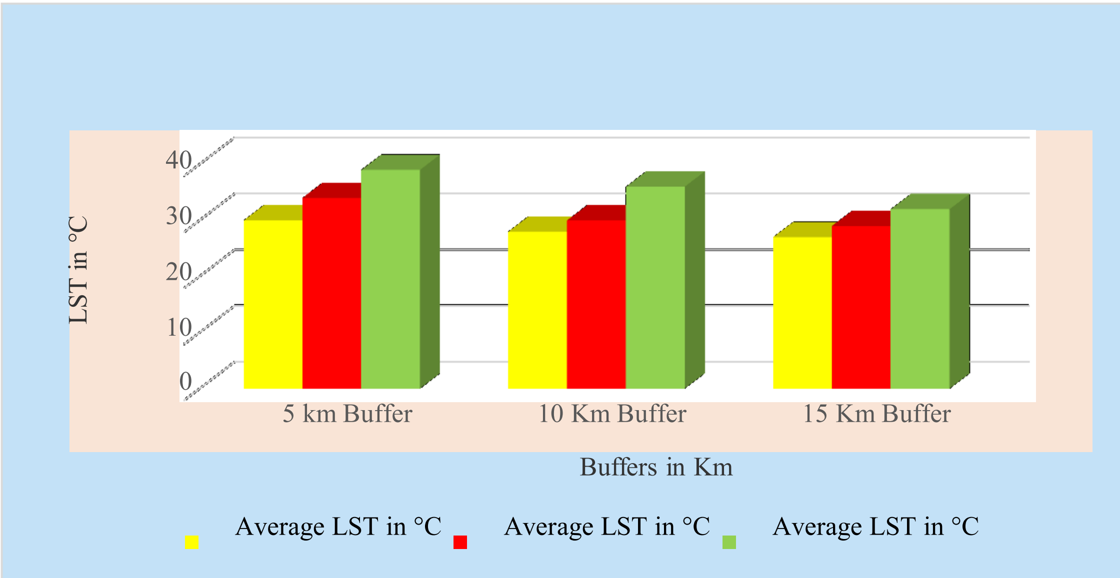
Within 15 km buffer (Table 8.3) LST values shows a minimum level of temperature, due to less impact of urbanization and high concentration of vegetation, and Water bodies. Bengaluru urban falls under this buffer and as it is surrounded by high vegetation concentration around, LST average values in this region show low range when compared to LST values in barren areas. But within this buffer also temperature shows increasing trend with a minimum and maximum of 2 °C during 1999-2009-2019 where there is severe concentration of built up areas. Therefore, it can be said that rapid increase in Built up area from the centre towards outskirts leads to the effect of higher surface temperature. Another feature of temperature distribution in less developed countries is that the imperviousness is not 100% as compared with the developed countries. This leads to the cooling effect of the surfaces due to evaporation leading to lower surface temperatures on the road leading to lower impact on the Urban heating.

However the maximum intensity of Temperature was identified within 5km buffer due to the higher concentration of built up areas and the minimum temperature was noticed in 15km (Figure 8.5). Distance has therefore a strong impact on the distribution of surface temperature. But when compared to LST value for 1999, 2009, and 2019, there has been a rise in temperature in each year. This clearly indicates the impact of urbanization on Land Surface Temperature.

8.8 Comparison of Land Surface Temperature with Land Cover types

In order to examine the effect of temperature on different land cover types, a land use land cover classification is necessary for detection of the nature of temperature over different LU/LC. The land use map which has been already classified for the previous chapter is used. The table 8.4 shows the details of land cover types and the figure 8.6 shows the Land use land cover classifications for three periods in Mysore Bengaluru region. The temperature over different types of land use were taken through sample points over and around different towns and land uses and an average value was derived from the temperatures of different land uses.

Figure 8.5 Spatio Temporal analysis of LST in Mysore Bengaluru region



There is a significant relationship between the LST and land cover types and it is an important signature that is usually used to understand interaction between different surfaces with the local temperature. Various land cover types such as built up areas, Vegetation, Barren land and Water bodies and agriculture were measured using LST image. The temperature distribution showed that there was a significant relationship between land covers and temperature.

Figure 8.6 Land use Land cover classification of Mysore Bengaluru region

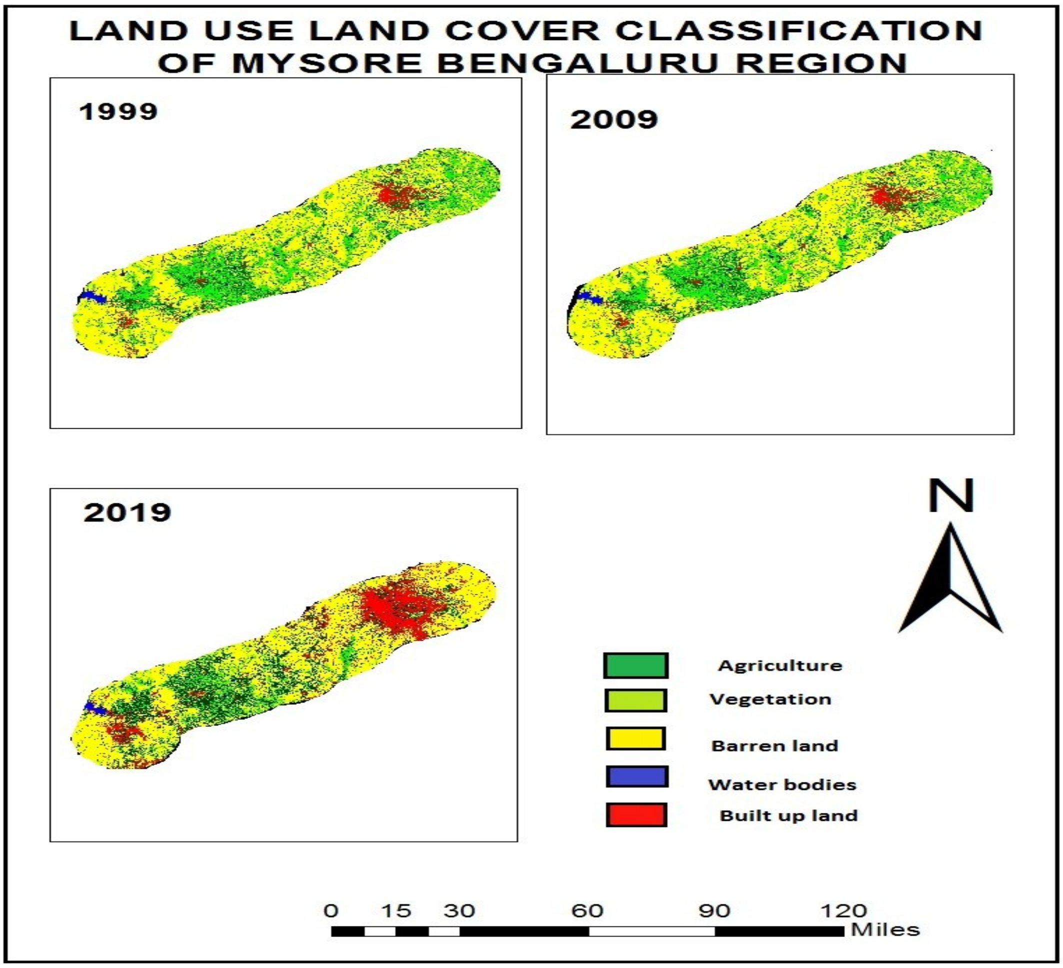


Table 8.4. Details of Land use Land cover Types

Land cover	Description
Vegetation	Trees, Natural Vegetation, Mixed forest , Gardens, Grassland, vegetated lands
Agriculture	Agriculture lands, Irrigated tracts, crop fields
Waterbodies	River, Lakes, Ponds, Canals, Low lying areas, Marshy land and swamps. Seasonal wetlands
Barren land	Fallow land, Construction sites, Excavation sites, Open space, Bare soils, and the remaining land cover types
Built up	All Infrastructure-residential, commercial, mixed use, and industrial use , settlements, villages, Road network, Pavements and other manmade structures

The present study attempts to examine the variation in temperature between different land cover types for 1999,2009, and 2019. The purpose of selecting these decades is to confirm the impact and to study the changing pattern of temperature over different land cover types. LST increased for all land cover types even on Vegetation, again it is an indication of urban warming effect, (Table 8.5). However, in comparison with their level of temperature increase overall Bengaluru region was higher as shown in the figure 8.4. This is probably due to the fact that the urban component experienced a significant growth of imperviousness as a result of development of urban infrastructures like roads, parking lots, sidewalks, concrete grounds which gradually result in high surface temperature on land. Due to the expansion and growth of imperviousness surface the LST was severely affected the temperatures on different land cover types.

Table 8.5. Variation of LST values over Land Cover Types

Land cover types	LST in °C _1999	LST in °C _2009	LST in °C _2019
Vegetation	22	24	26
Agriculture	21	21	24
Water bodies	17	19	21
Barren land	27	27	32
Built up	36	37	42
Parking area	32	34	40
Road Networks	32	37	39
Residential Areas	33	34	37
Industrial Areas	34	36	37

Source: Image processing and Interpretation

The Figure 8.7 shows average LST values over various land cover types in which 15 reference points have been taken as sample points for each land cover types to check LST average value on different Land cover types. LST value is derived to know about the impact of urbanization on surface temperature. The LST value on all Landover types have an increasing trend, which clearly indicates the rapid expansion of Built up as a result of Urbanization for the urban infrastructures like roads, parking area, paly ground, roof tops in Mysore Bengaluru region which give rise to high surface temperatures. The LST value was more over Built up land ranging between 36 ºC to 42ºC whereas the other land cover types have comparatively less temperature with built up also shows the increasing trend in temperature.

8.8.a Vegetation

Most of the Vegetation cover was concentrated over Mysore Bengaluru region. Bangalore region shows more intense Vegetation with coconut plantation and orchards surrounding it, compared to Mysore urban which is chiefly surrounded by its rich agricultural belt. In Figure 8.7 and table 8.5 shows the average value of LST over vegetation which was 22 ºC in 1999, which increased to 24 ºC in 2009 and by 2019 it increased to 26 ºC. however around Bangalore region there is a growing trend of conversion of less irrigated areas into orchards and coconut plantation. However the trend in Mysore is that the areas surround the urban region are becoming barren and left uncultivated.

8.8.b Agriculture

The table 8.5 Agricultural land is considered as the Green belt of the region. Compared to Vegetation cover, Agricultural land shows lesser Land Surface Temperature values, because of higher water content in the soils of irrigated tracts. In 1999 the LST value was 21 ºC and remained stable in 2009, but by 2019 the index value increased to 24 ºC.

8.8.c Waterbodies

Water bodies usually shows inverse temperature values due to the nature of heating and cooling properties. But due to the expansion of Built up land the index value of LST started fluctuating even on Water bodies. In 1999 the LST shows the least values of 17 ºC; in 2009 it slightly raised to 19 ºC; and by 2019 the LST increased to 21 ºC. The maximum concentrated of Water bodies are towards South of the study area. Especially in the Cauvery River and other small lakes in the surrounding areas which shows high variation in LST value. Srirangapatana, as it is an island town, the LST values over Water bodies are very less compared to Mysore urban. But it shows an increasing trend in LST values due to its urban expansion in recent period.

8.8.d Barren land

Barren land are the open spaces, it is observed that the temperatures over the barren lands are ururally very high compared with other land use and land cover. In 1999, surface temperature was low which shows the surface temperature of 27 ºC. By 2009 it reached to 27 ºC and in 2019 it has increased to 32 ºC. This is a clear indication of urbanization, and there by expanding the imperviousness which result in temperature rise.

8.8.e Built up

This is the only land cover which shows high surface temperature rates, throughout the period. It is probably due to the larger extent of imperviousness and, the building materials, narrow roads of Mysore and Bengaluru urban centers, which cause high land surface values over Built up lands. In 1999 the surface temperature was 36 ºC and in 2009 the LST value goes up to 37 ºC and by 2019 it reached its maximum temperature of 38 ºC.

8.8.5.i. Parking Area

Parking area inside Mysore and Bengaluru also shows oscillating LST values where the intensity of Imperviousness is more which convert the incoming solar radiation in to sensible heat. In 1999 the LST value shows 32 ºC and in 2009 it further raised to 34 ºC and finally reached up to 40 ºC.

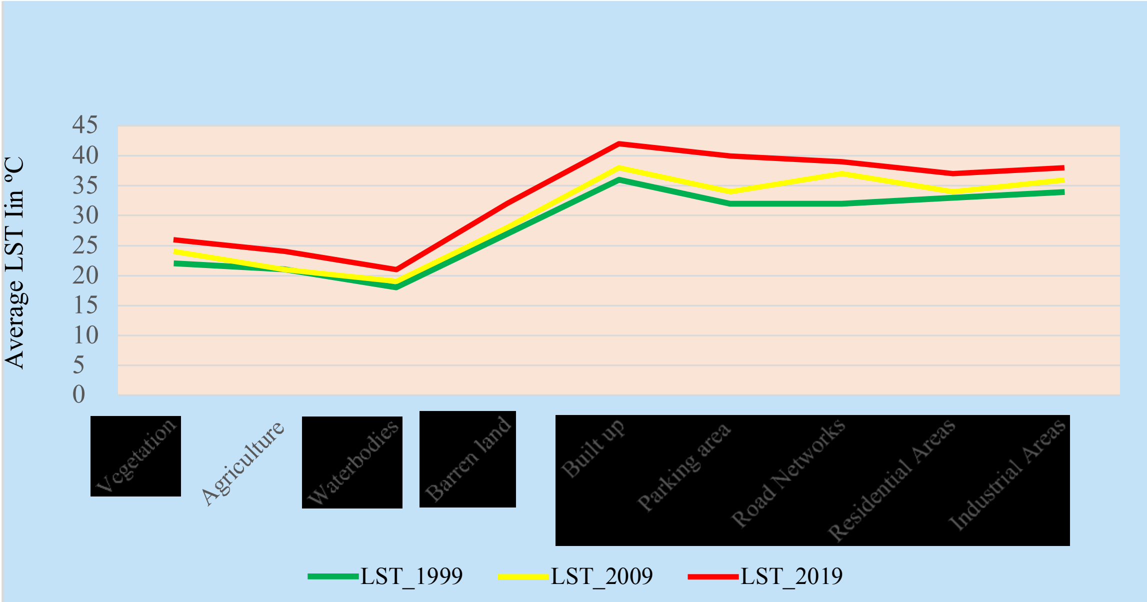
8.8.5. ii. Road Networks

The road networks inside and outside urban area shows average LST value of 32 ºC in 1999 (table 8.5) and as the transportation increase the movement of surface temperature was also high, reached up to 39 ºC by 2019.

8.8.5.iii. Industrial Areas

Industrial area is those which will be in the outskirt of Mysore urban, where the temperature fluctuates (figure 8.7)34 ºC to 37 ºC due to construction materials which effects the surface temperature of the surrounding areas.

Figure 8.7 Variation of average LST over Land use land cover types



8.9. Significance of Different Land cover indices on LST

Four land cover indices (NDVI, NDWI, NDBal, NDBI) were derived in order to quantifiable the relationship between LST and the indices and also their distribution over Land cover types in Mysore Bengaluru region which are explained below one by one. Among the various indices studies have found that Normalized Difference Index (NDVI), Normalized Difference Water Index(NDWI) Normalized Difference Bareness index (NDBaI) Normalized Difference Built up Index (NDBI) correlate strongly with LST.

8.9.a NDVI (Normalized Difference Vegetation Index)

The NDVI classification creates a single band data which mainly characterizes healthy biomass. In LANDSAT 5 Band 3 and 4 are used to derive NDVI. where band 3 is the visible red band (0.63-0.69µm) and Band 4 is the near infrared band (0.76-0.90µm) The output values of this index ranges between -1.0 and 1.0, in which negative values are mainly formed from water, clouds and snow and the positive values near zero are created from rock and bare soil. Table 8.6 shows the estimation of NDVI using Landsat 5 and 8.

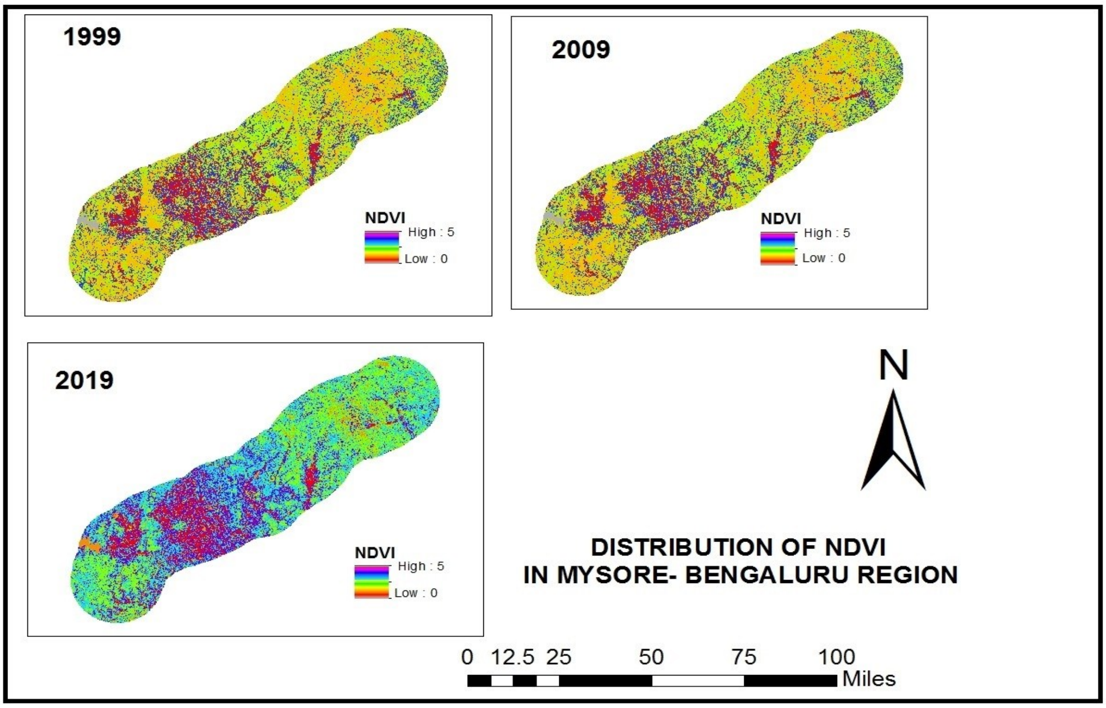
Table 8.6. Estimation of NDVI

NDVI= (NIR-RED)/(NIR+RED) Formula for Calculating NDVI for LANDSAT 5 NDVI= (Band 4- Band 3)/ (Band 4+ Band 3) Formula for Calculating NDVI for LANDSAT 8 NDVI= (Band 5- Band 4)/ (Band 5+ Band 4)

8.9.a.i. Distribution of NDVI in Mysore Bengaluru region

This index helps (table 8.6) to quantify the temporal urban green space dynamics. This index of greenness range from 1 to -1, where 1 represents maximum greenness and -1 represents no greenness. In Mysore Bengaluru region the figure 8.8 shows the maximum greenness observed in Bengaluru agricultural belt for 1999 where the NDVI value reached 1. The least value of greenness recorded more in and around Mysore urban area. But gradually due to rapid urbanization the trend of NDVI gradually decreased to -0.27 in 2009 and further the value of NDVI drop down to -0.10 in 2019.Finally the higher level of LST were found be associated with the lower level of NDVI.

Figure 8.8 Distribution of NDVI in Mysore Bengaluru region



8.9.a. ii. Distribution of NDVI values on Land Use Land Cover:

The table 8.7 shows the distribution of NDVI values over land cover types. This range of NDVI values of different years indicate the increased and decreased level of vegetation intensity in Mysore Bengaluru region between 1999 -2019. In order to find the level of vegetation over each land cover types in Mysore Bengaluru region 15 sample points have been taken from each land cover types and checked the NDVI values of each sample points. The average of NDVI values in each land cover types are shown in the table 8.7 to know the intensity of vegetation during this period.

In 1999 the intensity of vegetation greenness value was 0.3, (Table 8.7 and Figure 8.8) and reference points have been taken randomly in all direction of Mysore Bengaluru region. It is observed that more greenness is found in the northern portion of Mysore Bengaluru region, especially in Bengaluru region. Towards south the intensity of vegetation was comparatively less. By 2009 the average value of greenness on Vegetation reduced to 0.2 and further it declined to 0.17 by 2019. Followed by Vegetation, Agricultural land in Bengaluru shows highest value of NDVI, where Agricultural land was comparatively less towards South of Bengaluru region. Therefore, as the urban expansion proceeds in a higher rate, the intensity of vegetation will be declining.

The figure 8.9 shows the greenness value over Water bodies, and Built up, Barren land was very low when compared to the NDVI values over Vegetation. The greenness value of Water bodies shows the average value between 0.1 to 0.07.and Barren land also had less greenness value during this period ranging between 0.07 to 0.05. Whereas the NDVI values on Built up shows least values where vegetation range between 0.04 in 1999 and declined to 0.01 by 2019.

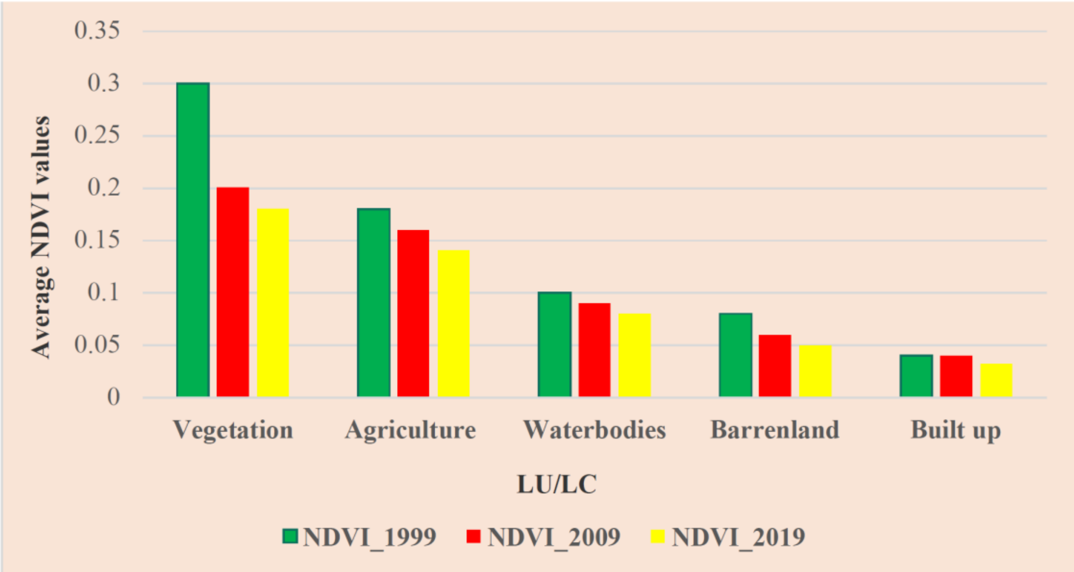
Table 8.7. NDVI values over Land cover types (1999 to 2019)

Land cover	Range of NDVI_1999	Range of NDVI_2009	Range of NDVI_2019
Vegetation	0.3	0.2	0.17
Agriculture	0.17	0.16	0.14
Water bodies	0.1	0.09	0.07

Barren land	0.07	0.06	0.05
Built up	0.04	0.04	0.01

Source: Image processing and Interpretation

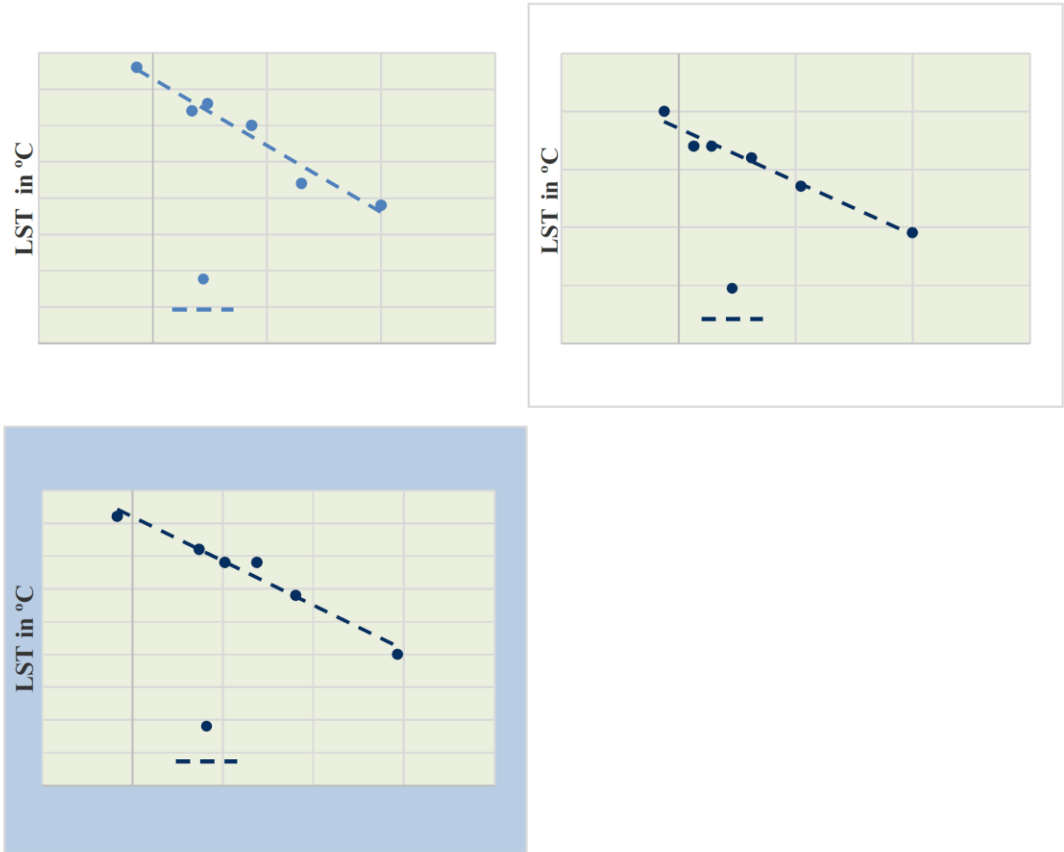
Figure 8.9 NDVI values over Land cover types



8.9.a.iii.Relationship between NDVI and LST

The correlation analysis was conducted between NDVI and LST in order to explore the relationships NDVI and LST. The figure 8.10 presents the relationship between NDVI and LST. In 1999 the NDVI value ranged between -0.07 to +1, which gradually reduced to between -0.06 to +1 in 2009 and further drastically reduced to -0.03 to +0.05 in 2019. Therefore, it can be said that the Vegetation index had a decreasing trend in Mysore Bengaluru region. The correlation results shows a negative correlation between NDVI and LST. As the LST increases the Vegetation reduces due to the high temperatures in the impervious area, which was showing an increasing trend in the future scenarios.

Figure 8.10 Correlation between NDVI and LST



8.9.b. NDWI (Normalized Difference Water Index)

This index is used to differentiate water from dry land and it also implies water content within vegetation. This is most suitable method of water mapping. The table 8.8 shows the estimation of NDWI with Landsat 5 and 8. Water bodies had high absorption and low radiation in the visible infrared wavelengths. NIR near infrared wavelength ranges from 0.741-0.776µm and SWIR – short wavelengths infrared range between 1.627-1.652µm. The output value of NDWI range between -1 to 1. High value of NDWI shows water in blue colour and low value shows in red colour. NDWI rate decrease at the time of water deficit.

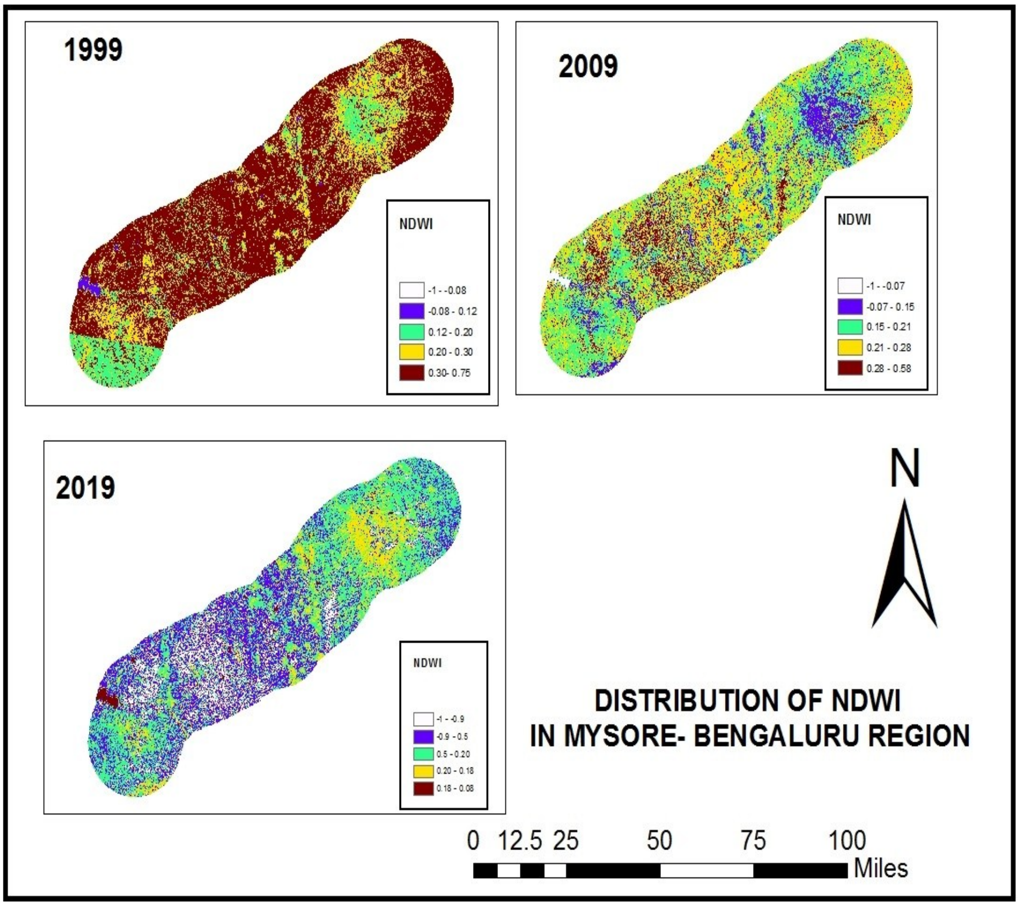
Table 8.8. Estimation of NDWI

NDWI= (NIR-SWIR)/(NIR+SWIR) Formula for Calculating NDWI for LANDSAT 5
NDWI= (Band 2- Band 4)/ (Band 2+ Band 4)
Formula for Calculating NDWI for LANDSAT 7
NDWI= (Band 3- Band 5)/ (Band 3+ Band 5)

8.9.b.i. Distribution of NDWI in Mysore Bengaluru region

Water index is also an important factor which influence LST. The figure 8.11 shows NDWI distribution over Mysore Bengaluru region from 1999 to 2019.In 1999 the value of Water index ranged between -0.9 to + 1, but in 2009 the trend gradually reduced to -0.09 to +0.57 and finally by 2019 the values of Water index further reduced to – 0.09 to + 0.08. The Cauvery river basin in the north of Mysore Bengaluru region shows the highest value of Water index in both time periods of 1999 and 2009, but in 2019 the value still reduced to -0.09 to 0.08 which shows a clear indication of rapid urbanization in Mysore and Bengaluru and also the wide expansion of LST in Mysore Bengaluru region. Therefore, it can be said that NDWI in Mysore Bengaluru region shows a declining trend during this period.

Figure 8.11. Distribution of NDWI in Mysore Bengaluru region



8.9.b. ii. Distribution of NDWI values on Land Use Land Cover

The table 8.9 shows the NDWI values over different land cover types. The reference points of Water index have been taken for all land cover types. In 1999 the average index value (0.21) of water was high in waterbodies especially in Cauvery basin, and the waterbodies like Kukkrahalli and Karanchikere which is located in the heart of Mysore, and also the other waterbodies which is present in Mysore Bengaluru region. By 2009 (Figure 8.12) the index value drops down to 0.19 especially in the Waterbodies which are located in urban centers and also in the Barren land. By 2019 again the value got declined to 0.15, mainly due to the encroachment of Built up. The index value of water was comparatively good in agricultural areas, as this agricultural land is an irrigated tract, which contain certain amount of water content always in the ground.so here the index value normally shows a good average range between 0.16 - 0.11 in Bengaluru agricultural belt. But in other areas of Mysore Bengaluru region which are not agricultural shows less NDWI values. By 2019 this agricultural land shows declining trend to 0.11. The Vegetation cover also have less range of index values of water which shows a range between 0.07 in 1999,0.09 in 2009 and decline to 0.07 towards 2019. Barren land shows minimum value of water Index from 0.02 to 0.07 during this period. Compared to Barren land Built up land shows index value from 0.13 to 0.1 which is having artificial manmade waterbodies in and around the urban area.

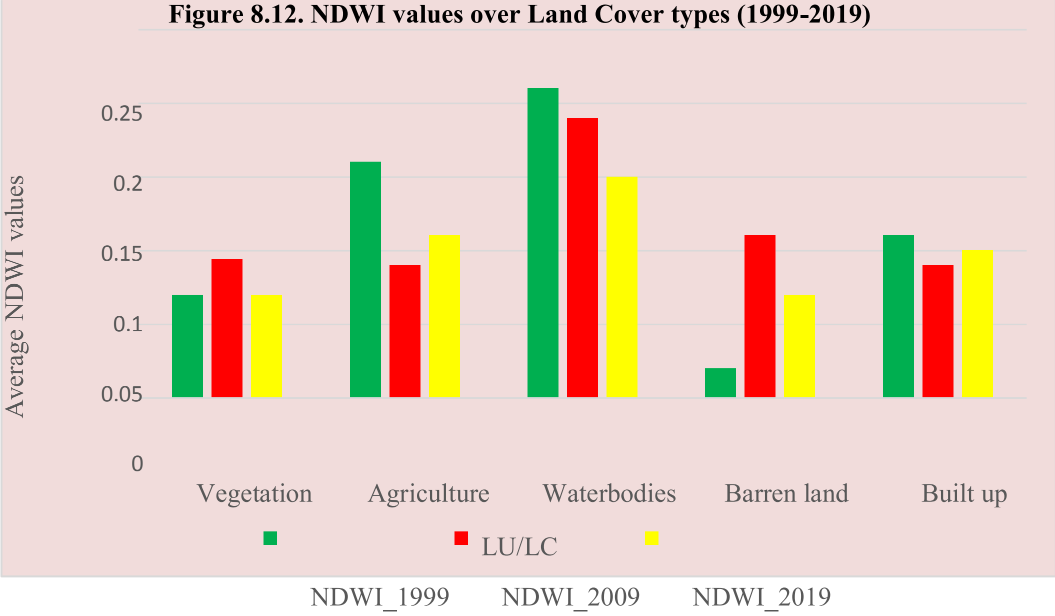
In general, (figure 8.12) all the Land cover types indicate a declining trend of water index value throughout the period, which gives clear indication of Urban expansion for its infrastructures.

Table 8.9. NDWI values over Land Cover Types (1999-2019)

Land cover	NDWI_1999	NDWI_2009	NDWI_2019
Vegetation	0.07	0.094	0.07
Agriculture	0.16	0.09	0.11
Waterbodies	0.21	0.19	0.15
Barren land	0.02	0.11	0.07
Built up	0.11	0.09	0.1

Source: Image processing and Interpretation

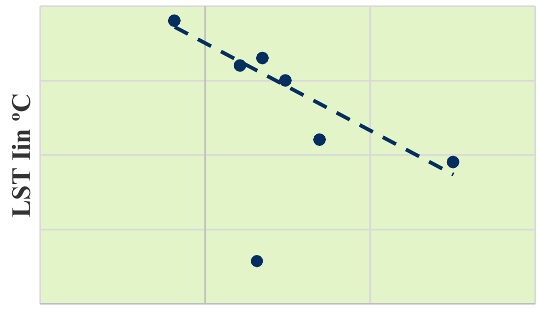
Figure 8.12. NDWI values over Land Cover types (1999-2019)

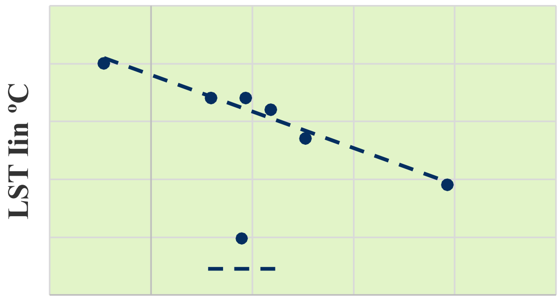


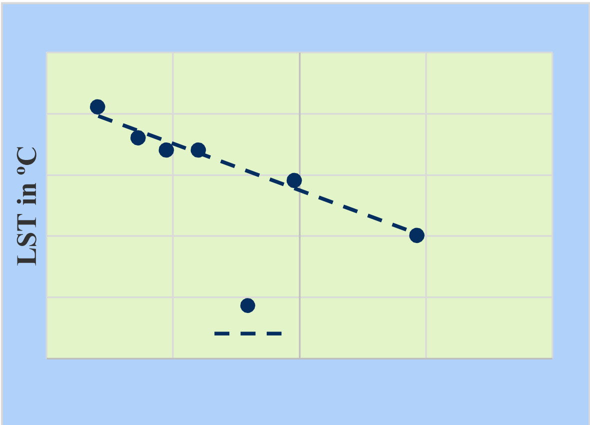
8.9.b.iii. Relationship between NDWI and LST

This figure 8.13 represents a negative correlation between NDWI and LST. The correlation has been calculated for three years (1999,2009 and 2019). The highest value of Water index is recorded +1 in Bengaluru belt due to the presence of Cauvery basin of Mysore Bengaluru region in 1999 and 2009 and gradually the value of Water index got declined to -0.052 to -0.01 in 2019 due to high temperature expansion and also in the rise impervious area in and around Mysore urban. Therefore, it can be said that the NDWI and LST are negatively correlated during this period.

Figure 8.13 Correlation between LST and NDWI







8.9.c. NDBaI (Normalized Difference Bareness Index)

Bareness index is very useful to classify different barren lands, and are very much used to classify various land cover types by setting the appropriate threshold values. It also has been analyzed for delineating water content in vegetation and also to identify the bareness of soil respectively. Estimation of NDBaI as follows. (Table 8.10)

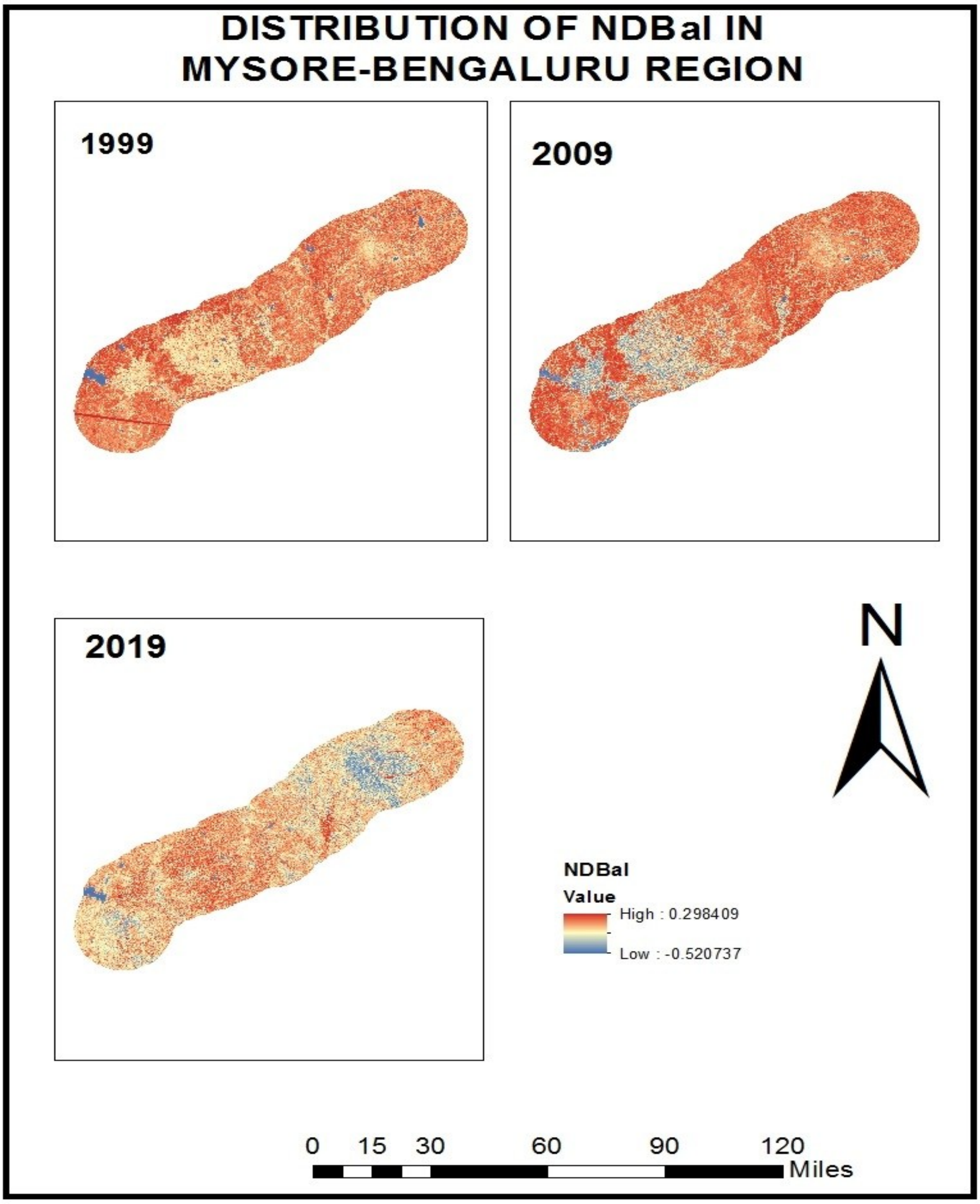
Table 8.10. Estimation of NDBaI

NDBal= (Thermal-SWIR)/(Thermal+SWIR)
Formula for Calculating NDBal for LANDSAT 5
NDBal= (Band 5- Band 6)/ (Band 5+ Band 6)
Formula for Calculating NDBal for LANDSAT 7
NDBal= (Band 6- Band 7)/ (Band 6+ Band 7).

8.9.c.i. Distribution of NDBal in Mysore Bengaluru Region

The figure 8.14 shows the distribution of NDBal over three periods in Mysore Bengaluru region. In 1991 the Bareness index value ranged from -0.97 to +1, but in 2009 the minimum value of bareness declined to -0.91 to and the maximum value remains the same. Gradually the minimum value of bareness declined to the level of -0.37 and also the maximum level declined to further +0.23. There was a sudden decline of Bareness index in 2019 mainly due to the urban expansion of Mysore and also because of development of infrastructures for urbanization. Therefore, it can be said that the Bareness index of Mysore Bengaluru region shows a declining trend for this study period.

Figure 8.14 Distribution of NDWI in Mysore Bengaluru region



8.9.c. ii. Distribution of NDBaI values on Land Use Land Cover

The table 8.11 shows the Bareness index value range between 0.32 to 0.3. In 1999 the maximum bareness value is noticed over fallow land, open space, and wasteland. But by 2009 some extend of barren land is occupied by the land holders for the urban development and the value of bareness index started declining and by 2019 it has declined to the value of 0.3 by 2019. The figure 8.15 shows that when compared to other land cover types the index value over Built up was significantly increasing with the decline of Bareness value from 0.16 to 0.19. Which means the bareness index is getting reduced by the expansion of Built up especially in Mysore and Bengaluru urban and also towards North west of Elwala. Whereas the other land cover types had a declining trend in NDBaI average values.

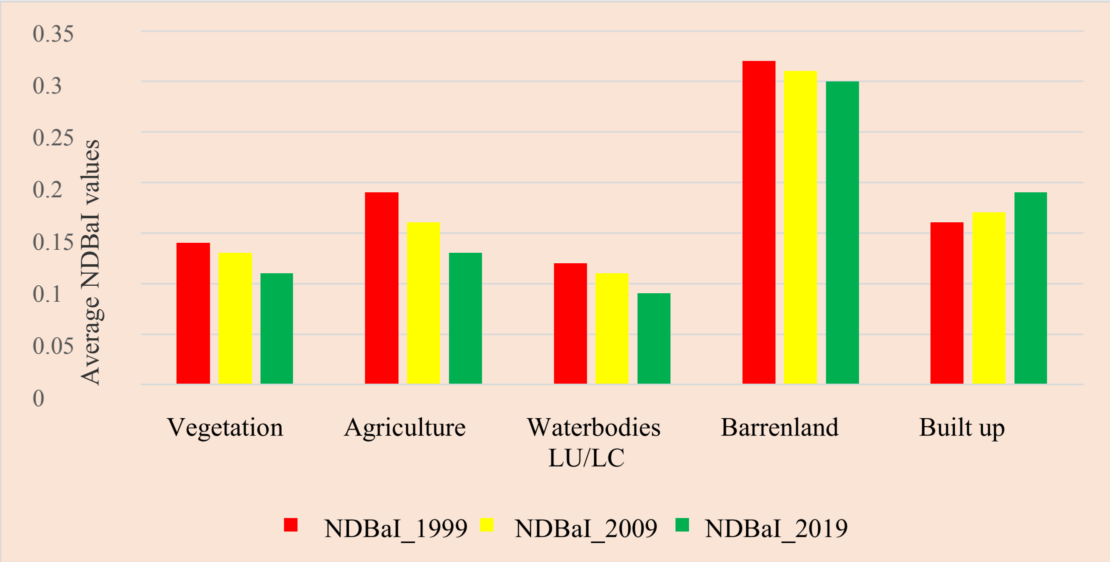
The index value on Vegetation also shows less bareness which ranges from 0.14 in 1999 and reduced to 0.11 by 2019. Whereas the Agricultural land also has normal range of NDBaI values at 1999 which range between 0.19 but reduced to range of 0.13 towards 2019.The index on Waterbodies also similar where the NDBaI values start declining from 0.12 to 0.09 by 2019.Therefore NDBaI values are reducing over all the Land cover types except in the Built up land.

Table 8.11. NDBaI values over Land cover types (1999 to 2019)

Land cover	NDBaI_1999	NDBaI_2009	NDBaI_2019
Vegetation	0.14	0.13	0.11
Agriculture	0.19	0.16	0.13
Waterbodies	0.12	0.11	0.09
Barren land	0.32	0.31	0.3
Built up	0.16	0.17	0.19

Source: Image processing and Interpretation

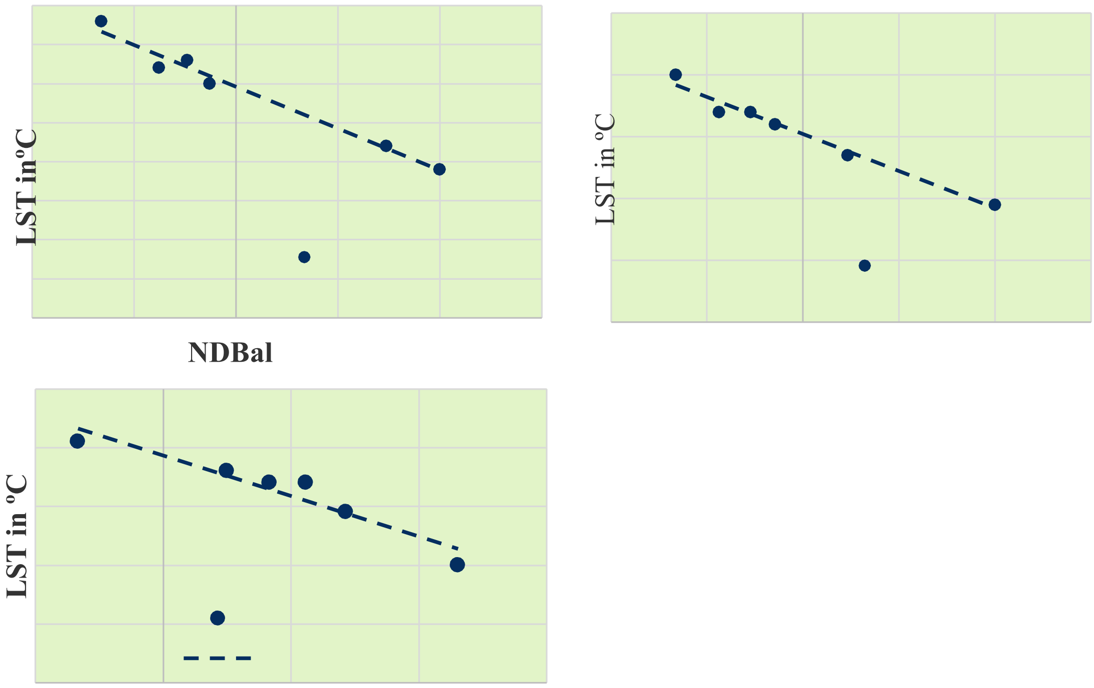
Figure 8.15 NDBaI values over Land cover types.(1999-2019)



8.9.c.iii. Relationship between NDBaI and LST

The relation between the Bareness and LST is very essential to know how the distribution of LST affects the Bareness index. The figure 8.16 presents the relationship between NDBal and LST in two periods. In 1999 the value ranged between -0.97 to 1, but in 2009 the value of bareness declined to -0.91 to +1 and further shows declining trend -0.37 to +0.23 in 2019 which clearly indicates that the LST totally affects the distribution of Bareness by 2019 in Mysore Bengaluru region. Therefore, it can be said that NDBal and LST are negatively correlated.

Figure 8.16. Correlation Between LST and NDBaI



8.9.c. NDBI (Normalized Difference Built Up Index)

This index is used to classify Built up land. NDBI has been used recently as a major indicator to project the extent of Built upland. The output values lie between -1 to +1. The negative value represents waterbodies whereas the highest value represents Built up land. The value for Vegetation in NDBI is low. Table 8.12 shows the estimation of NDBI.

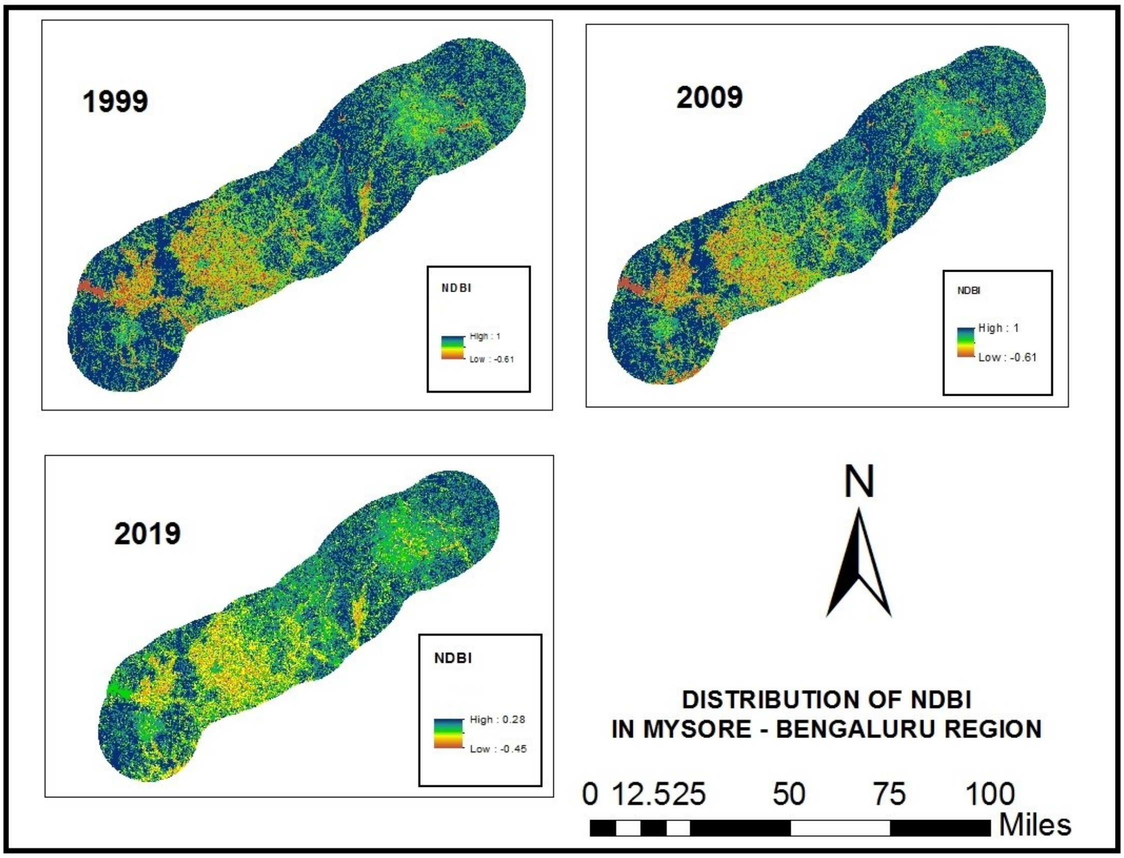
Table 8.12. Estimation of NDBI

NDBI= (SWIR-NIR)/(SWIR+NIR) Formula for Calculating NDBI for LANDSAT 5
NDBI= (Band 5- Band 4)/ (Band 5+ Band 4)
Formula for Calculating NDBI for LANDSAT 7
NDBI= (Band 6- Band 5)/ (Band 6+ Band 5)

8.9.c.i. Distribution of NDBl in Mysore Bengaluru region

Figure 8.17 indicates the distribution of NDBI in Mysore Bengaluru region for two decades (1999-2009-2019). In 1999 the minimum value of index was -0.04 to maximum 0.15, but in 2009 the value of index increased to -0.06 to maximum +0.27. Finally, in 2019 the Built up index drastically increased from minimum +0.26 to maximum +1. This is the only indices which shows significant trend further. This gives a clear indication of booming expansion in Built up land in Mysore and Bengaluru due to rapid urban growth, compared to 2009 the level of Built up gradually raised and by 2019 it reached to its maximum level of expansion towards North west of Mysore Bengaluru region.

Figure 8.17. Distribution of NDWI in Mysore Bengaluru region



8.9.c. ii. Distribution of NDBI values on Land Use Land Cover

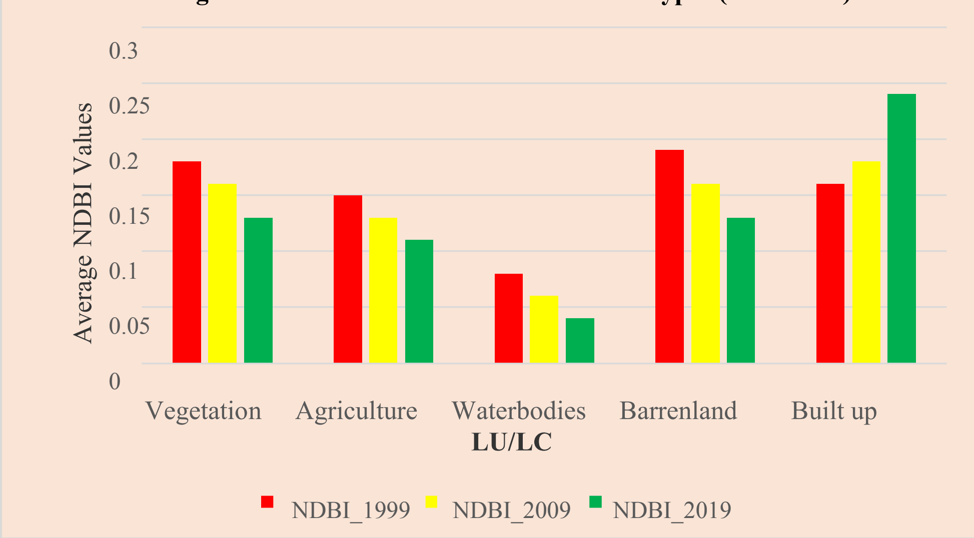
The table 8.13 shows distribution of Built up values over land cover types. Usually index value of Built up shows very lesser values over Land cover types. Figure 8.18 shows the index value over vegetation range from 0.17 to 0.13. In 1999 the index value of Vegetation was 0.17 and by 2009 it declined to 0.16 and finally reduced to 0.13 in 2019, which means the built index value is less significant with vegetation cover. Agriculture area of Bengaluru belt also have very minimum index value range from 0.15 in 1991 to 0.11 in 2019.Waterbodies are the main land cover where the Built up index value is in very less ranges from 0.07 in 1999 to 0.04 by 2019.Barren land is another land cover type which also shows declining trend from 0.19 in 1999 to 0.13. But in Built up land cover the index value shows an oscillating variation throughout the period. This was the only land cover which shows an increasing trend with index value range from 0.16 in 1999 to 0.24 towards 2019.

Table 8.13 NDBI values over Land cover types (1999 to 2019)

Land cover	NDBI_1999	NDBI_2009	NDBI_2019
Vegetation	0.17	0.16	0.13
Agriculture	0.15	0.13	0.11
Waterbodies	0.07	0.06	0.04
Barren land	0.19	0.16	0.13
Built up	0.16	0.17	0.24

Source: Image processing and Interpretation

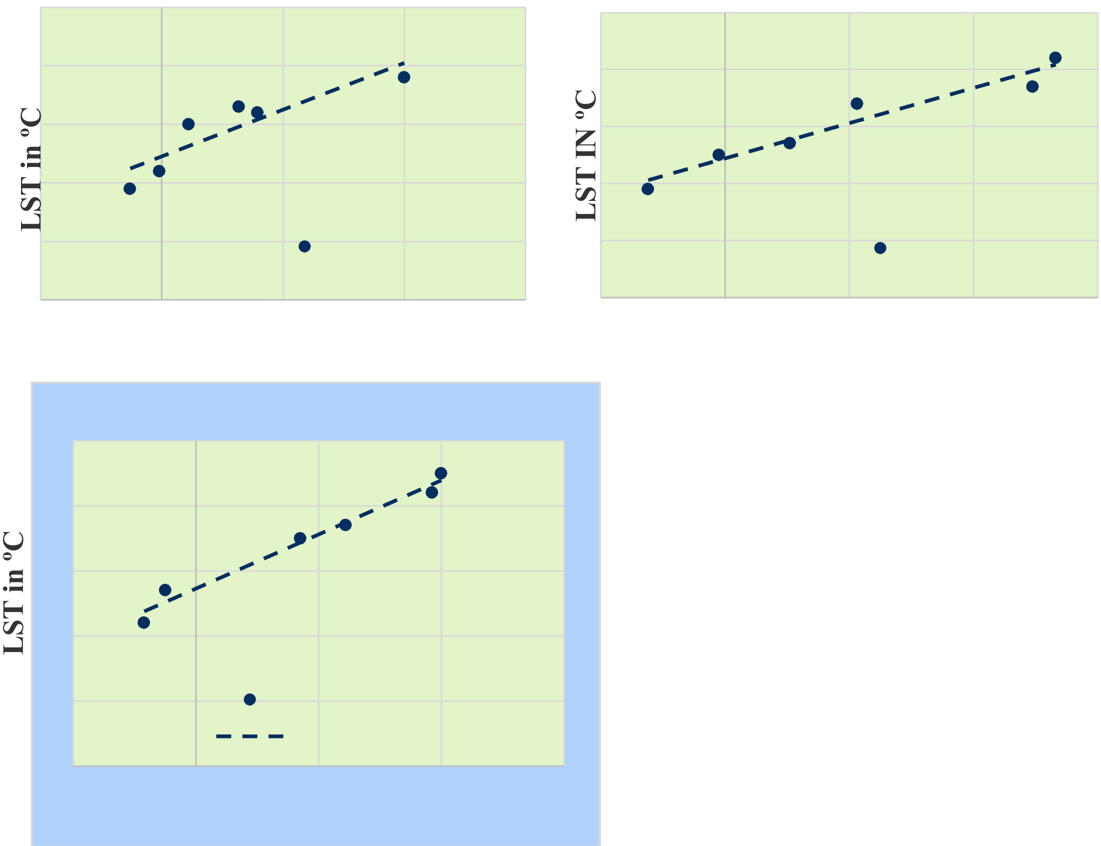
Figure 8.18 NDBI values over Land cover types.(1999-2019)



8.9.c.iii. Relationship between NDBl and LST

This index was more effective in discriminating Built up from other land cover types. Mapping of Built up area is very important because the existence of these land cover types can be useful as an indicator for Urban planning and development. So it is very significant to know the relationship between NDBI and LST. The figure 8.19 indicates correlation between NDBI and LST in Mysore Bengaluru region for two decades. From 1999 to 2019 correlation shows a positive trend in the relationship that is from -0.06 to +0.26 of minimum value and maximum value ranged from +0.15 to 1. Therefore, it can be said that there exists a strong positive correlation between NDBI and LST throughout the period.

Figure 8.19 Correlation Between LST and NDBI

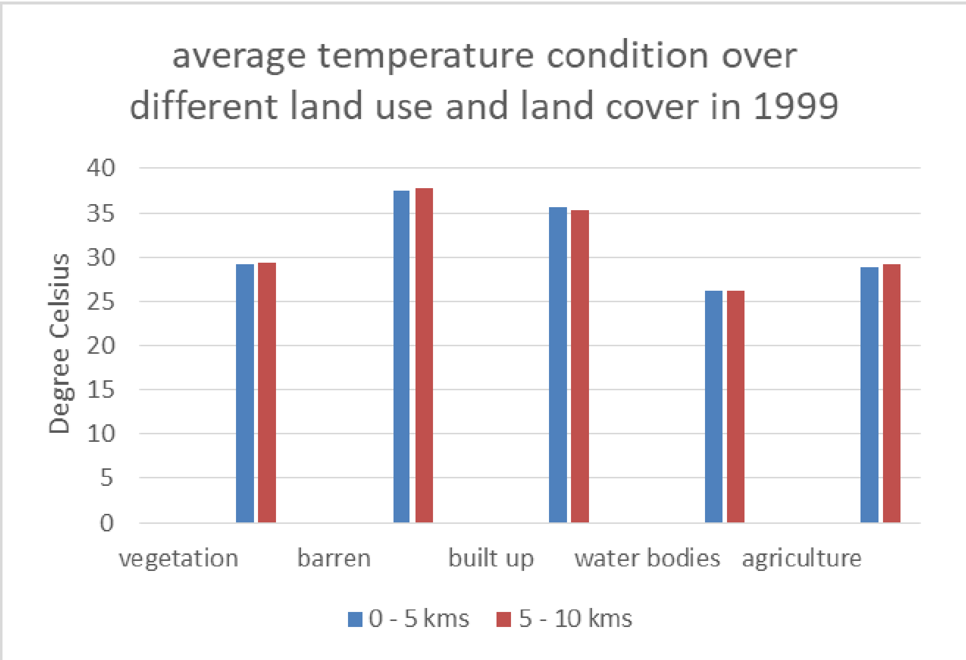


The above explained indices are derived to know their impacts on different land cover types, and the previous studies shows all these indices has very strong relation with surface temperature. The above analysis shows that correlation was conducted for each land cover indices over LST for each time periods (1999,2009,2019) in order to find out relationship during this period. The above mentioned correlation shows that correlation are statically significant and hold over the years in Mysore Bengaluru region. The correlation result of NDVI, NDWI, NDBal with LST is negatively correlated. When the level of LST is increasing the values of NDVI, NDWI, NDBal is getting decreased as well suggesting that the water content in Vegetation, Water and Bareness also got declined. But in the case of Built up index (NDBI), the correlation with LST shows a very high positive correlation, due to the rapid expansion of, Built up, which affects the temperature directly. Therefore, we can say that all four land cover indices had very strong correlation with LST. Among that NDV1, NDWI, NDBal indices are negatively correlated or inversely proportional to LST and only NDBI is positively correlated or directly proportional to LST.

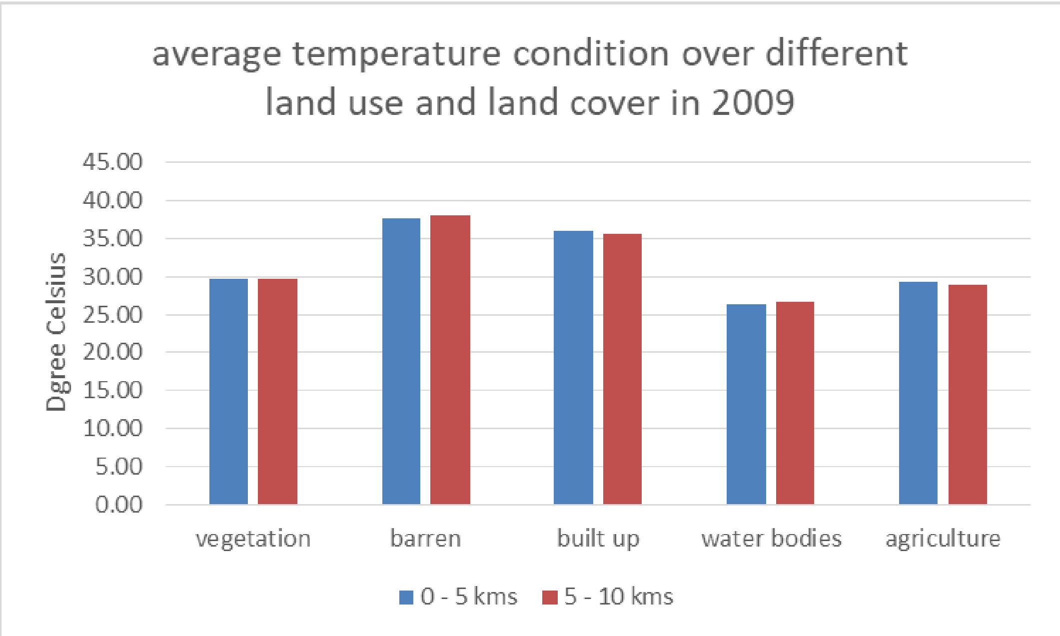
8.10. Conclusion

This chapter attempt to identify the impact of urbanization on Land surface temperature over Mysore Bengaluru region. And also demonstrated a method of deriving land surface temperature (LST) and also observed the relationship of LST with four land cover indices in study area. From the indices we can conclude that the proportion of Built up land doubled between 1999 and 2019.and it reflects that there is a strong positive correlation with LST and landuses. Secondly a significant negative correlation existed between NDVI, NDWI, NDBal with LST which indicates that the is significantly lower over Vegetation, Water, and Bareness. While with and Built up land the LST increases invariably. The changes are mainly negative which can directly be related to the rapid urbanization in the study area. The impact of urbanization has been large in the last decade due to the development for urban infrastructures of this region. Urbanization will be the main drivers for land cover changes and consequently LST, finally most of the Mysore Bengaluru region area is moving towards higher temperatures due to the expansion of Built up, parking areas, sidewalks, concrete ground, road networks narrow buildings for development of urban infrastructures and if the present trend still continues, then almost the entire Mysore Bengaluru region will be converted to Urban Heat Island (UHI) by 2029. However, it is difficult to stop and reverse urbanization process in Mysore Bengaluru region because it contains all the major facilities and services of the place. Growth Management policies like Green belt can be implemented which will consequently help in reducing temperature effect. In addition, policies should not have limited to horizontal Growth management but also to consider vertical Growth Management like building heights which have more influence on temperature in Mysore Bengaluru region. Therefore, Urban city planning should focus more on Urban Greening in the upcoming years in order to prevent the large scale of Land Surface Temperature in Mysore Bengaluru region.

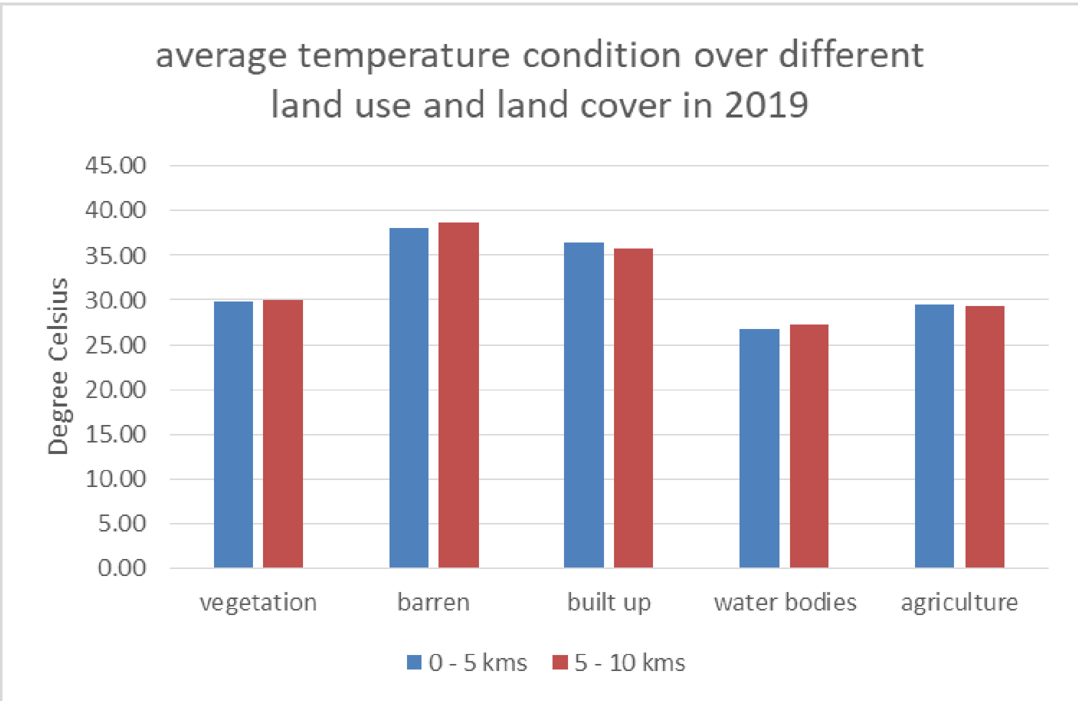
AVERAGE LST TEMEPERATURE OVER DIFFERENT LANDUSE AND LANDCOVER 1999										
	vegetation		barren		built up		water bodies		agriculture	
	0 - 5 kms	5 - 10 kms	0 - 5 kms.	5 - 10 Kms	0 - 5 Kms	5 - 10 Kms	0 - 5 Kms	5- 10 Kms	0 - 5Kms	5 - 10 Kms
Mysore	28.56	29.56	38.78	39.56	33.77	33.89	26.44	26.00	29.11	29.78
Srirangapatana	29.22	29.89	36.44	36.89	36.11	33.78	25.89	25.22	29.89	29.67
Mandya	27.33	27.56	36.00	36.11	34.00	33.78	25.22	26.22	26.56	27.56
Maddur	28.89	28.89	36.78	37.78	34.89	34.00	25.89	26.22	29.11	29.33
Channapatana	30.67	30.00	37.11	37.11	36.22	36.89	26.33	26.22	29.11	29.33
Ramanagara	30.00	30.11	39.00	39.11	37.11	37.00	26.67	27.00	29.11	29.22
Bangalore	30.11	30.11	38.44	38.78	37.89	38.11	26.89	26.78	29.00	29.11
TOTAL	204.78	206.11	262.56	265.33	249.99	247.44	183.33	183.67	201.89	204.00
AVERAGE	29.25	29.44	37.51	37.90	35.71	35.35	26.19	26.24	28.84	29.14

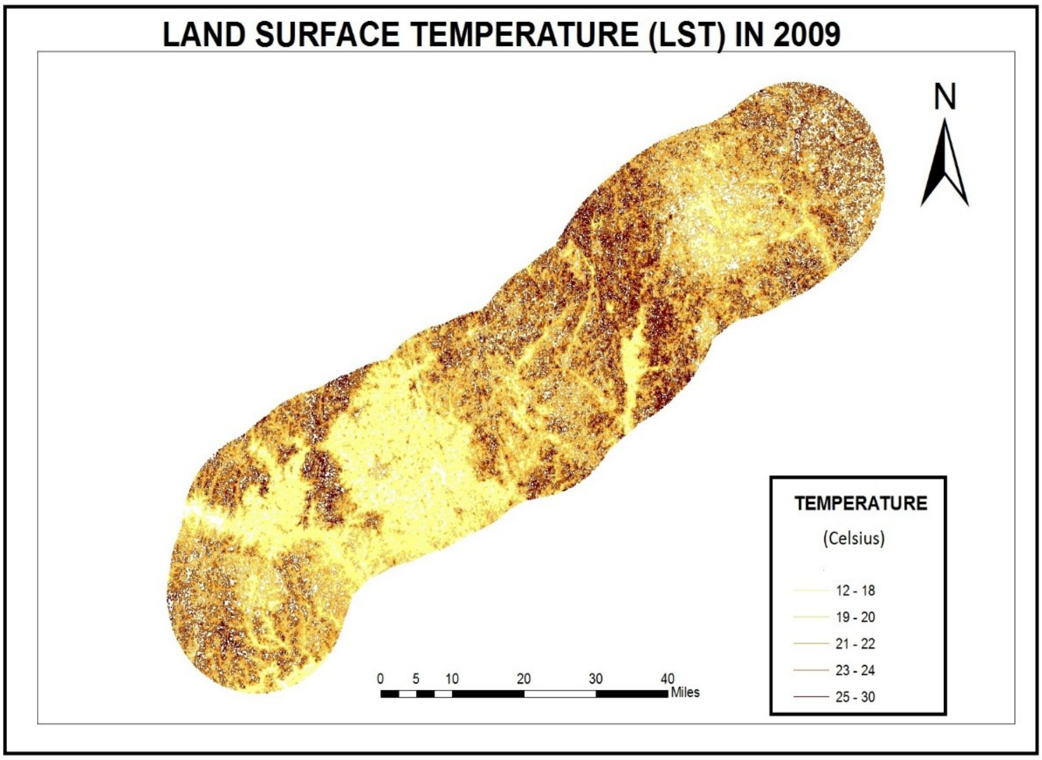


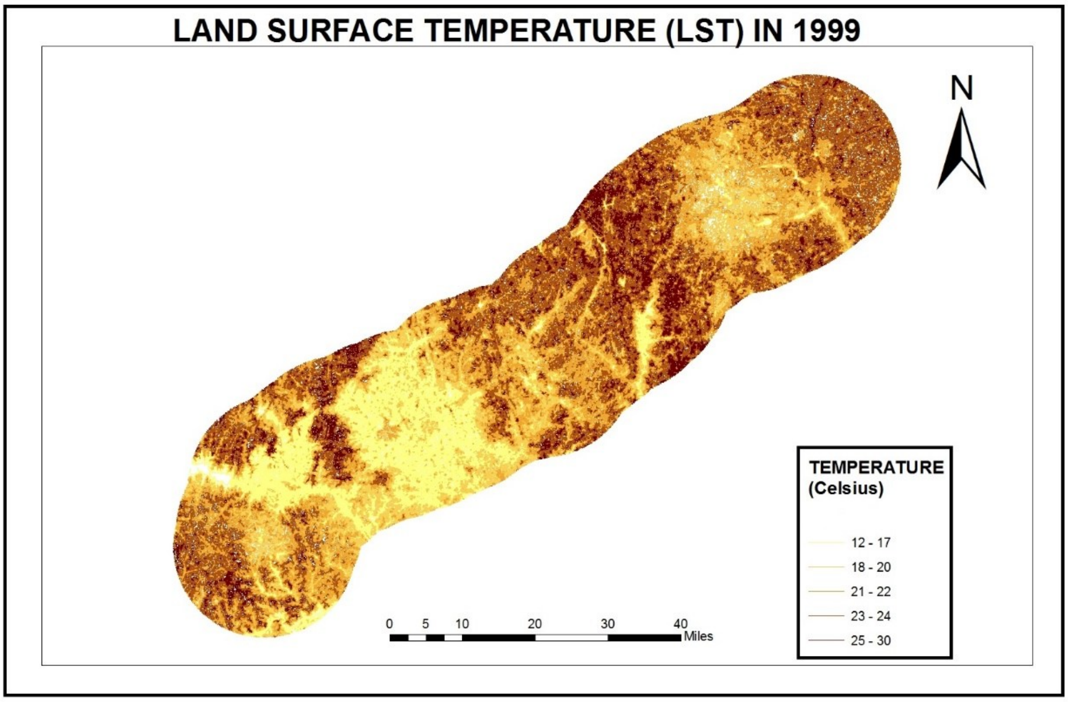
AVERAGE LST TEMEPERATURE OVER DIFFERENT LANDUSE AND LANDCOVER 2009										
	vegetation		barren		built up		water bodies		agriculture	
	0 - 5 kms	5 - 10 kms	0 - 5 kms.	5 - 10 Kms	0 - 5 Kms	5 - 10 Kms	0 - 5 Kms	5- 10 Kms	0 - 5	5 - 10 Kms
Mysore	29.56	30.00	39.67	40.11	34.00	34.00	26.89	26.78	29.67	30.00
Srirangapatana	29.44	29.89	36.89	37.00	36.11	34.22	26.22	25.22	30.67	29.89
Mandya	27.56	27.78	36.33	36.44	34.67	34.22	25.89	26.56	27.00	27.56
Maddur	29.56	29.22	37.44	38.44	35.22	34.11	26.00	26.89	29.56	29.78
Channapatana	31.11	30.00	36.44	37.33	36.44	37.33	27.00	27.33	29.00	29.56
Ramanagara	30.22	30.33	39.22	39.11	37.11	37.33	26.67	27.22	29.33	28.00
Bangalore	30.00	30.56	37.56	38.67	38.00	38.22	26.11	27.22	29.33	28.00
TOTAL	237.08	237.46	301.21	305.27	287.49	285.08	211.17	213.97	233.78	231.75
AVERAGE	29.63	29.68	37.65	38.16	35.94	35.63	26.40	26.75	29.22	28.97

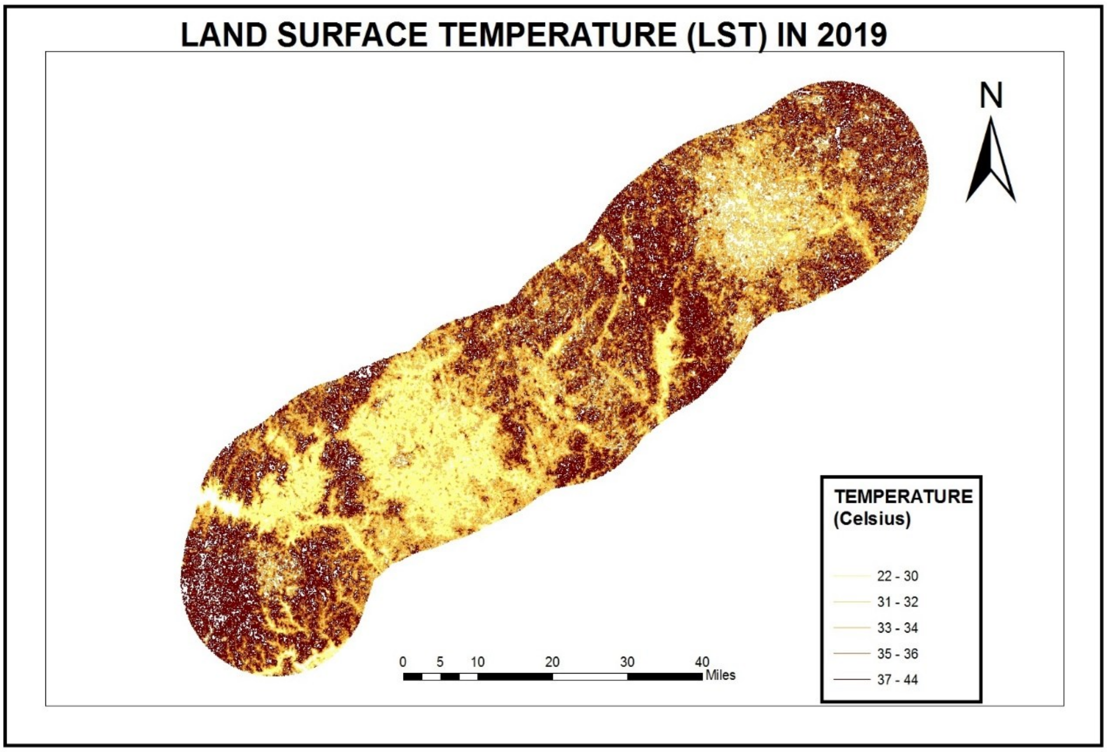


AVERAGE LST TEMEPERATURE OVER DIFFERENT LANDUSE AND LANDCOVER 2019										
	vegetation		barren		built up		water bodies		agriculture	
	0 - 5 kms	5 - 10 kms	0 - 5 kms.	5 - 10 Kms	0 - 5 Kms	5 - 10 Kms	0 - 5 Kms	5- 10 Kms	0 - 5 Kms	5 - 10 Kms
Mysore	29.78	30.33	39.78	40.33	35.22	34.44	27.33	27.33	30.33	30.22
Srirangapatana	29.78	30.00	37.22	37.44	36.33	34.22	25.78	25.67	30.00	30.33
Mandya	27.67	28.00	36.89	37.33	35.22	34.56	26.44	26.89	27.78	28.00
Maddur	29.44	29.67	38.00	39.00	35.22	34.00	26.33	27.67	29.78	30.33
Channapatana	31.11	30.44	37.56	37.78	36.89	37.56	27.67	27.56	29.44	30.00
Ramanagara	30.56	30.56	39.11	39.89	37.89	37.67	27.11	27.67	29.67	28.22
Bangalore	30.56	30.56	38.00	39.44	38.22	38.67	26.78	27.67	29.56	28.22
TOTAL	238.73	239.49	304.63	309.97	291.43	286.98	214.22	217.65	236.06	234.67
AVERAGE	29.84	29.94	38.08	38.75	36.43	35.87	26.78	27.21	29.51	29.33




LAND SURFACE TEMPERATURE (LST) IN 2009
N
TEMPERATURE
(Celsius)
12 - 18
19 - 20
21 - 22
23 - 24
25 - 30
0 5 10 20 30 40
Miles


LAND SURFACE TEMPERATURE (LST) IN 1999
N
TEMPERATURE
(Celsius)
12 - 17
18 - 20
21 - 22
23 - 24
25 - 30
0 5 10 20 30 40
Miles


LAND SURFACE TEMPERATURE (LST) IN 2019
N
TEMPERATURE (Celsius)
22 - 30
31 - 32
33 - 34
35 - 36
37 - 44
0 5 10 20 30 40 Miles

CHAPTER IX

ESTIMATION OF CARBON SEQUESTRATION OVER MYSORE BANGALORE REGION

Introduction:

Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide by vegetation. Carbon sequestration is a mechanism for removal of carbon from atmosphere by storing in the biosphere Chavan and Rasal, It is single method of reducing the amount of carbon dioxide in the atmosphere with the goal of reducing global climate change. The absorption of carbon by the trees for the process of photosynthesis is the major means for controlling atmospheric carbon. With the rapid changes in land use and land cover, there is enormous decline in the overall distribution of land under vegetation and agriculture. Our environmental conditions therefore needs to be protected and monitored time and again to check the status of vegetation potential for atmospheric carbon sequestration. All these land use transformation would inevitably change the region's potential capacity to sequester the carbon dioxide thereby reducing fresh oxygenated atmosphere for the well being of people.

Carbon sequestration (CoS) has been carried out in many studies and a majority of research is directed for estimating different type of forests. However there is still lot of interesting studies on the estimation of CoS over agricultural lands, coconuts plantations, orchards, shrub lands and grass lands which form the basic type of vegetation in the present study area. Estimation of carbon sequestration potential in coconut plantations under different agro-ecological regions and land suitability classes in Sri Lanka by Ranasinghe and others, The study by Kort and Turnock have presented the methodology for shrub carbon. At first the estimation of carbon was calculated, Deb (2018) and others have developed Allometric models for predicting above ground biomass of dominant shrub and tree species grown in semi-arid Bundelkhand region of India. Estimation of carbon sequestration for Indian Mangoes was done by Naresh, K.S., Kasthuri, B.K.V. and George, J.

BIOMASS ESTIMATION AND CARBON SEQUESTRATION FOR INDIAN MANGO						
Scientifi name CO_2 (t/ha)	height (m)	Girth (m)	AGB (Kg/Plant)	C (Kg/Plant)	C (t/Ha)	CO2 (t/ha)
Mango (Mangifera indica)	7.8	0.58	70.76	35.38	5.31	19.48
AGB = Above ground biomass, C = Carbon						

Grasses had the highest plant biomass production (19.80 ± 1.16 Mg ha^{-1} yr^{-1}), followed by cereals (9.44 ± 0.45 Mg ha^{-1} yr^{-1}), fibre (7.90 ± 1.00 Mg ha^{-1} yr^{-1}), legumes (3.29 ± 0.63 Mg ha^{-1} yr^{-1}), and oil crops (3.05 ± 1.16 Mg ha^{-1} yr^{-1}) showing significant differences ($p < 0.05$). Maize (6.3 ± 0.34 Mg C ha^{-1} yr^{-1}) had the highest plant C amongst summer crops, while wheat (2.2 ± 0.35 Mg C ha^{-1} yr^{-1}) had the highest plant C amongst winter crops. In all the studies, crops allocated more C to their shoots than roots yielding root C: shoot C (Rc/Sc) ratios below magnitude. The greatest C allocation to roots was in grasses (Rc/Sc = 1.19 ± 0.08), followed by cereals (0.95 ± 0.03), legumes (0.86 ± 0.04), oil crops (0.85 ± 0.08), and fibre crops (0.50 ± 0.07). There was evidence that high plant C stocks were found in crops grown under carbon rich clayey soils of tropical humid areas. Natural grasses and cereals should be promoted as they appeared to yield greater potential for atmospheric carbon sequestration in plants and soils. Overall, the study evaluated the relative potential of the main crop types to sequester atmospheric C useful in screening of crop types for carbon efficiency and for development of plant C models. In this context, it is of paramount importance to promote coconut-based cropping systems as a strategy to enhance income. Coconut-based cropping systems, involving cultivation of compatible crops specially fruit crops in the interspaces will offer considerable scope for increasing production and productivity per unit area, time and input by more effiient utilization of resources like sunlight, soil, water and labour. In addition, it will be imitator to a forest system and will have large scope for storage of carbon and removal of carbon dioxide from the atmosphere, thus playing a vital role in sustaining the environment Carbon sequestration is a mechanism for removal of carbon from atmosphere by storing in the biosphere (Chavan and Rasal, 4). Soil carbon exchange with *et al.*, 5). It is possible for humans to manage soils in order to accumulate carbon or avoid high losses of it with cultivation (Lal, 7). The present investigation was carried out to quantify the above ground and below ground (soil) and total carbon storage in coconutbased fruit croppings.

Type of agriculture crop	plant biomass production	Carbon stock
Grasses	19.80 ± 1.16 Mg ha^{-1} yr^{-1}	9.9 ± 0.54 Mg ha^{-1} yr^{-1}
cereals	9.44 ± 0.45 Mg ha^{-1} yr^{-1}	5.45± 0.22 Mg ha^{-1} yr^{-1}
fibre	7.90 ± 1.00 Mg ha^{-1} yr^{-1}	4.45 ± 0.5 Mg ha^{-1} yr^{-1}
legumes	3.29 ± 0.63 Mg ha^{-1} yr^{-1}	2.00 ± 0.46 Mg ha^{-1} yr^{-1}
oil crops	3.05 ± 1.16 Mg ha^{-1} yr^{-1}	2.11 ± 0.53 Mg ha^{-1} yr^{-1}
Maize	6.3 ± 0.34 Mg C ha^{-1} yr^{-1}	3.3 ± 0.17 Mg C ha^{-1} yr^{-1}
wheat	2.2 ± 0.35 Mg C ha^{-1} yr^{-1}	1.1 ± 0.17 Mg C ha^{-1} yr^{-1}

THE BIOLOGICAL DIVERSITY OF THIS REGION IS DIVIDED INTO THE FOLLOWING TYPES OF VEGETATION.

1. Scrub vegetation.
2. Irrigated vegetation.
3. Hilly scrub vegetation.
4. Coconut palm vegetation
5. Moderately irrigated vegetation
6. Orchard vegetation

The following diagrams indicate the difference in the vegetation growth during different seasons and month of the year.

The nature of the land cover for different types of vegetations were recorded from the Google Earth Pro and the information were collected related to spatial characteristics.

1. COCONUT PLANTATION SAMPLE PLOTS OF ONE HECTARE

COCONUT DECEMBER 2021

COCONUT APRIL 2021

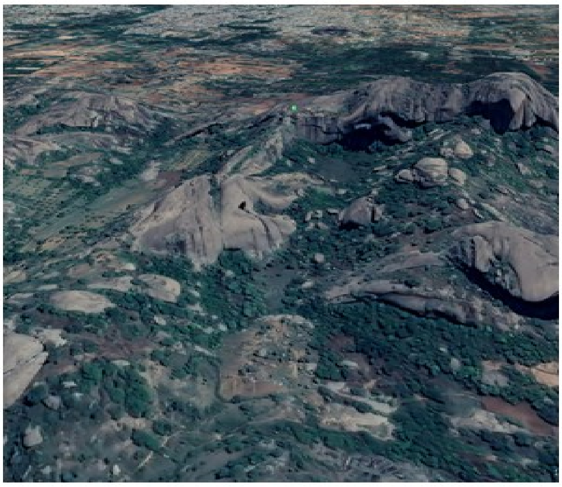
COCONUT PLANTATION SAMPLE PLOTS OF ONE HECTARE							
Sample plots	Total coconut tress/ha	Type of vegetation	LANDUSE FEATURES IN DECEMBER 2021		LANDUSE FEATURES IN APRIL 2021		PERCENTAGE COVER
A	90	tree cover	Not a dense coconut plantation		Not a dense coconut plantation		30
		under growth cover	brown patchy land is visible between tress	Mostly green grass	brown patchy land is visible between tress	dry soil	70
B	162	tree cover	Coconut trees are densely distributed		Coconut trees are densely distributed		70
		under growth cover	visibility of under growth is nil	mostly green grass	visibility of under growth is nil	mostly green grass	30
C	195	tree cover	Coconut trees are densely distributed	tree cover	Coconut trees are densely distributed	Tree cover	80
		under growth cover	visibility of crops is nil	mostly green grass	visibility of crops is nill	mostly green grass	15 5
D	156	tree cover	Coconut trees are MODERATELY distributed	tree cover	Coconut trees are densely distributed	tree cover	50
		under growth cover	visibility of crop LAND	mostly green grass	visibility of crops is nill	mostly green grass	40 10
E	168	tree cover	Coconut trees are MODERATELY distributed	tree cover	Coconut trees are densely distributed	tree cover	60%
		under growth cover	visibility of crops	mostly green grass	visibility of crops	mostly green grass	35%

HIGHLY IRRIGATED DECEMBER 2021

HIGHLY IRRIGATED APRIL 2021

HIGHLY IRRIGATED AGRICULTURE LAND						
sample plots	total plants	December 2021		April-2021		percentage cover
of one hectare		Percentage of land cover	Nature of landuse	Percentage of land cover	Nature of land use	
	200000	100	dense growth	100	dense growth	100
a		100	dense growth	100	dense growth	100
	200000	100	dense growth	100	dense growth	100
b		100	dense growth	100	dense growth	100
	200000	100	dense growth	100	dense growth	100
		100	dense growth	100	dense growth	100
c			dense growth		dense growth	100
	200000	100	dense growth	100	dense growth	100
		100	dense growth	100	dense growth	100
d			dense growth		dense growth	100
	200000	100	dense growth	100	dense growth	100
e		100	dense growth	100	dense growth	100

HILLY SHRUBS DECEMBER 2021



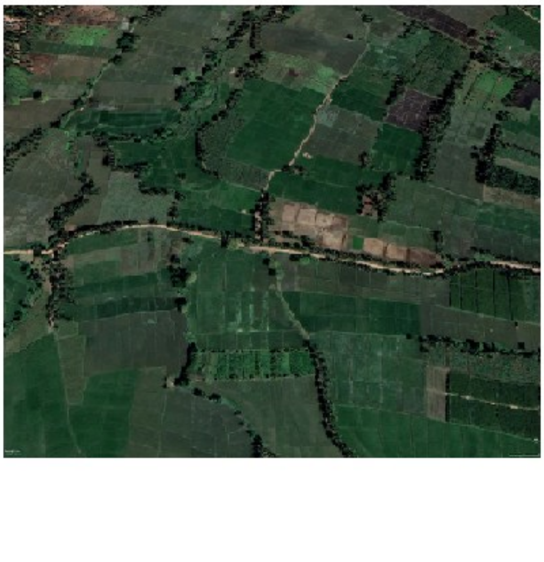
HILLY SHRUBS APRIL 2021

HILLY SHRUBS 2020							
sample plots of one hectare	total trees in one hectare		landuse features in December 2021		landuse features in April -2021		percentage cover
	37	tree cover	60		not dense		60
a		under growth cover/	40	mostly green grass	brown patchy land is visible between tress	dry soil	40
	22	tree cover	40		do		40
b		under growth cover	60	mostly green grass	do	mostly green grass	60
	18	tree cover	20	tree cover	do	tree cover	20
c		under growth cover	80	mostly green grass	do	mostly green grass	60 20
	26	tree cover	40	tree cover	do	tree cover	30
d		under growth cover	60	mostly green grass	do	mostly green grass	40 30
	38	tree cover	60	tree cover	do	tree cover	35%
e		under growth cover	40	mostly green grass	do	mostly green grass	65%

LESS IRRIGATED DECEMBER 2021

LESS IRRIGATED APRIL 2021

MODERATELY IRRIGATED DECEMBER 2021



MODERATELY IRRIGATED APRIL 2021

ORCHARD DECEMBER 2021

ORCHARD APRIL 2021

ORCHARD SAMPLE PLOTS 2021							
sample plots of one hectare	total tress		landuse features in December 2021		landuse features in April-2021		percentage cover
a	130	tree cover	75		dense		75
		under growth cover/	25	mostly green grass	brown patchy land is visible between tress	dry soil	25
b	88	tree cover	70	tree cover	brown patchy land is visible between tress		70
		under growth cover	30	mostly green grass		mostly green grass	30
c	45	tree cover	60	tree cover	coconut trees are densely distributed	tree cover	60
		under growth cover	40	mostly green grass	visibility of crops is nill	mostly green grass	35 5
d	77	tree cover	70	tree cover	coconut trees are densely distributed	tree cover	50
		under growth cover	30	mostly green grass	visibility of crops is nill	mostly green grass	40 10
e	110	tree cover	65	tree cover	coconut trees are densely distributed	tree cover	60%
		under growth cover	35	mostly green grass	visibility of crops	mostly green grass	35%

SHRUBS DECEMBER 2021

SHRUBS APRIL 2021

SHRUB TYPE VEGETATION **2021**							
sample plots of one hectare	scrub type vegetation		landuse features in december 2021		landuse features in april 2021		percentage cover
	45	tree cover	70		not a dense coconut plantation		75
		bushes					
a		grass	25	mostly green grass	brown patchy land is visible between tress	dry soil	25
	52	tree cover	70				70
b		under growth cover	30	mostly green grass		mostly green grass	30
	12	tree cover	20	tree cover		tree cover	20
				mostly green grass			35
c		under growth cover	80			mostly green grass	5
	35	tree cover	70	tree cover		tree cover	50
				mostly green grass			40
d		under growth cover	30			mostly green grass	10
	60	tree cover	65	tree cover		tree cover	70%
e		under growth cover	35	mostly green grass		mostly green grass	35%

STONE QUARRY DECEMBER 2021

STONE QUARRY APRIL 2021

9. METHODOLOGY USED BY THE PRESENT STUDY

9.1 . Land use / Land cover Data collection and preparation

The present study has used Google Earth Pro software to generate the land use cover data for 2006 and 2021. Detailed land use data was digitized at high resolution in visible spectrum and the land uses were classified under the following heads.

TYPE OF COMMON VEGETATION COVER IN THE STUDY AREA:

1. Social forest: the trees along the road sides belong to various varieties but their common features are that their average diameter at breast height is 0.5 meters, average height of the trees are 50 feet. They are perennial trees and belong to the deciduous variety. These trees are planted by the forest department

2. Coconut plantation: the trend in the number of coconut plantation is increasing every year. Their concentration is mostly increasing around Bangalore urban area. The average girth of the diameter is 14 inches and height is 60 feet. They are perennial trees but they shed enormous wood during the rainy season.

3. Shrubs: Shrubs are widely spread over the study area. They area woody plant that generally has multiple stems growing from the same root system. They belong to various species, but most commonly they have a stem diameter of 5 – 10 inches and a height of 6 – 7 feet. These shrubs can be differentiated in the study area as hilly shrubs, and ordinary shrubs. These shrubs are perennial they defoliated during dry season and again foliate during the rainy season.

4. Highly Irrigated agriculture plots are usually used for the cultivation of sugar cane and cereal crops like paddy. They are cultivated at least tree times in a year. The density of the plants in the plot is fully dense.
5. Moderately irrigated plots: the moderately irrigated lands are cultivated two times in a year. One is the monsoon season and the other is during the winter season.
6. Less Irrigation plots: less irrigated crops are cultivated three times.
7. Grasses are commonly and naturally grown by itself. Grasses are commonly grown in vacant lands, shrubs, and hilly shrubs and also in the orchards and coconut plantation as under grown. They commonly grow whenever there are rains and even slight drizzle. At least two times in a year it is seen to grow it grows faster and dry also faster.

SUPPLEMENTARY DATA: The other data collected from google earth were related to the density of the growth of vegetation, and type of trees. The following tables were created by sampling.

SAMPLING OF TREE DATA FROM GOOGLE EARTH: The field sample sites were designed to cover a 1-hectare sample area, where the data was collected for different type of vegetation, viz a vie tree cover and under growth, site attributes, tree species, and tree compositional data including under growth have been taken.

Data have been collected for two period for 2006 and 2021. The sample plots of one hectare were observed for the months of December and April.

Perennial vegetation:

Orchards, Coconut Plantation and Social Forestry come under the perennial vegetation. There are two kinds of biomass estimation carried out in this class of vegetation, such as Tree biomass and Under-Growth biomass. These trees are assumed to have an average age of 15 years. They shed in November – December and new foliage grows in January-February. During the rainy season dense undergrowth usually grows from June _July and remains until Nov_ December and retreat during drier season in January –May. The under growth in Orchards and plantations were calculated based on seasonal changes in atmospheric moisture and temperature condition.

Social forestry is another type of vegetation included in perennial vegetation. It is a protected forest and this type of vegetation runs along the main Highway, and other roads. But in the present scenario the trees along the Mysore – Bangalore Road are subjected for constant deforestation and a forestation in view of widening the road. Therefore their age estimation is made based at previous road expansion (2005).

Non perennial vegetation:

Sugarcane and Paddy are the most widely cultivated crops in the Highly Irrigated areas. The land is constantly cultivated. They have three crops system, kharif, Rabi and summer crop. The moderately irrigated lands have two crops, and the less irrigated lands have a single crop. Shrubs, and hilly shrubs are fallow lands usually covered by grass and shrubs. The estimation of biomass for this class of vegetation was calculated based on phonological cycle and the seasonal changes in atmospheric moisture and temperature.

9.2. METHODOLOGY FOR CALCULATING CO2 SEQUESTRATION

This methodology was designed by the University of New Mexico, and it is very appropriate for the present study hence it is used for the estimation of carbon estimation. The method of calculating CO2 sequestration in the present study has been based on the method suggested by the University of New Mexico. The purpose of accepting this methodology is chiefly due to its simplicity and objectivity in the estimation of CO2 sequestration.

(https://www.unm.edu/~jbrink/365/Documents/Calculating_tree_carbon.pdf)

A key "feature" of a tree is that trees sequester carbon – the process of removal and long-term storage of carbon dioxide (CO2) from our atmosphere.

EcoMatcher and its tree-planting partners estimate that the trees planted sequester CO2 at an average of 25 kilos per tree per year; we use an average of 250 kilos over a tree's lifetime. Please note those are average numbers as multiple different species are being planted.

The rate of carbon sequestration depends on the growth characteristics of the tree species, the density of its wood, the location's conditions for growth, and the plant stage of the tree.

That said, there are ways to estimate a tree's CO2 sequestration, see below[1].

Step 1: Determine the total green weight of the tree

The green weight is the weight of the tree when it is alive. First, you have to calculate the green weight of the above-ground weight as follows:

$W_{above\text{-}ground} = 0.25\ D^2\ H$ (for trees with D<11)

$W_{above\text{-}ground} = 0.15\ D^2\ H$ (for trees with D>11)

$W_{above\text{-}ground}$= Above-ground weight in pounds

D = Diameter of the trunk in inches
H = Height of the tree in feet

The root system weight is about 20% of the above-ground weight. Therefore, to determine the total green weight of the tree, multiply the above-ground weight by 1.2:

$W_{total\ green\ weight} = 1.2 * W_{above\text{-}ground}$

Step 2: Determine the dry weight of the tree

The average tree is 72.5% dry matter and 27.5% moisture. Therefore, to determine the dry weight of the tree, multiply the total green weight of the tree by 72.5%.

$W_{dry\ weight} = 0.725 * W_{total\ green\ weight}$

Step 3: Determine the weight of carbon in the tree

The average carbon content is generally 50% of the tree's dry weight total volume. Therefore, in determining the weight of carbon in the tree, multiply the dry weight of the tree by 50%.

$W_{carbon} = 0.5 * W_{dry\ weight}$

Step 4: Determine the weight of carbon dioxide sequestered in the tree

CO_2 has one molecule of Carbon and 2 molecules of Oxygen. The atomic weight of Carbon is 12 (u) and the atomic weight of Oxygen is 16 (u). The weight of CO_2 in trees is determined by the ratio of CO_2 to C is 44/12 = 3.67. Therefore, to determine the weight of carbon dioxide sequestered in the tree, multiply the weight of carbon in the tree by 3.67.

$W_{carbon\text{-}dioxide} = 3.67 * W_{carbon}$

Step 5 determination of Age:

Ultimately, the growth of each tree is non-linear, and the greatest sequestration stage is in the younger stages of tree growth, depending on rates and peaks of individual species, with the sequestration of CO_2 per year dropping thereafter. CO_2 sequestration can differ even within tree species, with multiple factors such as growth conditions also at play. But while the exact CO_2 sequestration rates may require more accurate measurements to pinpoint, the impact trees can create is undeniable in our global fight against climate change, in addition to the host of localized functions it can fulfil.

CRITERIA FOR THE ESTIMATION OF CARBON SEQUESTRATION							
Non Perennial	Number of plants in one Hectare	Diameter in inches	Height in feet	Age	Growing months	Density in percentage	NO. OF CROPS
Highly Irrigated : Agricultural lands							
Sugarcane	1200	2	6	18 Months		100	1 ½ YRS
Paddy	2000000	0.7	3	3 months	Monsoon crop, Winter crop and summer crops	100	3 crops per year
NO UNDER GROWTH							
Moderately irrigated Agricultural lands							
Cerials: Paddy, Ragi	2000000	0.7	3	3 months	Monsoon crop, Winter crop	90	2 crops per year
vegetables					Summer crop	30	
Rain fed Agricultural Lands Less irrigated agricultural lands							
Ragi , Jowar		0.7	3	3 months	Monsoon crop	90	1 crops per year
Vegetables				3 months	Winter crop	20	2 crops per year
Grass		0.7	3		Summer	30	2 seasons per year
Shrubs							
Hilly shrubs		3	3	Perennial	June – December	10	2 seasons per year
Shrubs		3	3	Perennial	June – December	20	
Grass		0.7	3	3 months		20	2 seasons per year
Orchards	400	15	50	20>	Perennial	50	Perennial

Coconut trees	200	14	60	20>	Perennial	70	Perennial

	CARBON BIOMASS AND CARBON SEQUESTRATION 2006				
landuse	sq_kms	W_GBM KGS	W D BM KGS	WCARBON KGS	WCO2_KGS
COCONUT	265.33	8424.76	6107.9	3054.0	560.4
HILLY SHRUBS	1006.81	221.52	160.6	80.3	294.7
IRRIGATED	354.37	153.09	111.0	55.5	203.7
MODERATELY IRRIGATED	1658.64	14083.79	10210.8	5105.4	18736.7
ORCHARDS	449.24	70755.30	51297.6	25648.8	4706.6
SHRUBS	500.96	4057.78	2941.9	1470.9	5398.4
HILLY SHRUBS	121.4	11.97	8.7	4.3	15.9
STONE QUARRY	123.03	4.61	3.3	1.7	6.1
UNCULTIVATED	830.6	44.85	32.5	16.3	59.7
WATER BODY	275.88	0.00	0.0	0.0	0.0
SETTLEMENT	479.94	0.00	0.0	0.0	0.0

	CARBON BIOMASS AND CARBON SEQUESTRATION 2006				
landuse	sq_kms	W_GBM KGS	W D BM KGS	WCARBON KGS	WCO2_KGS
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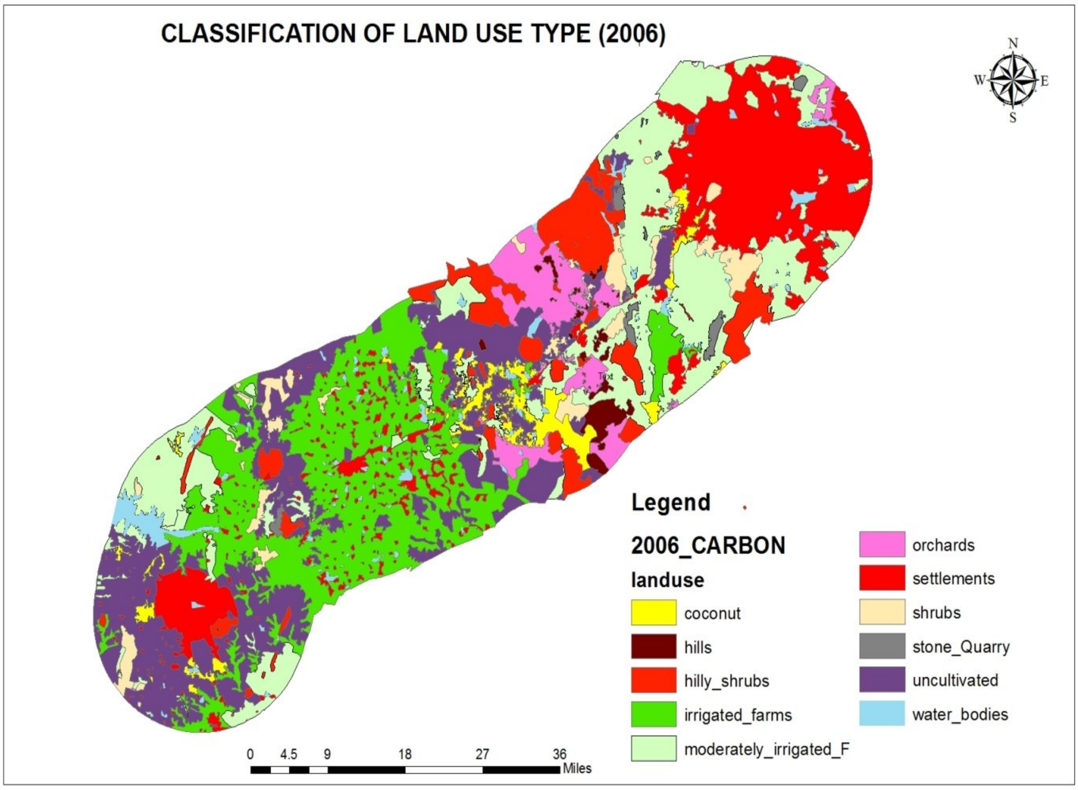
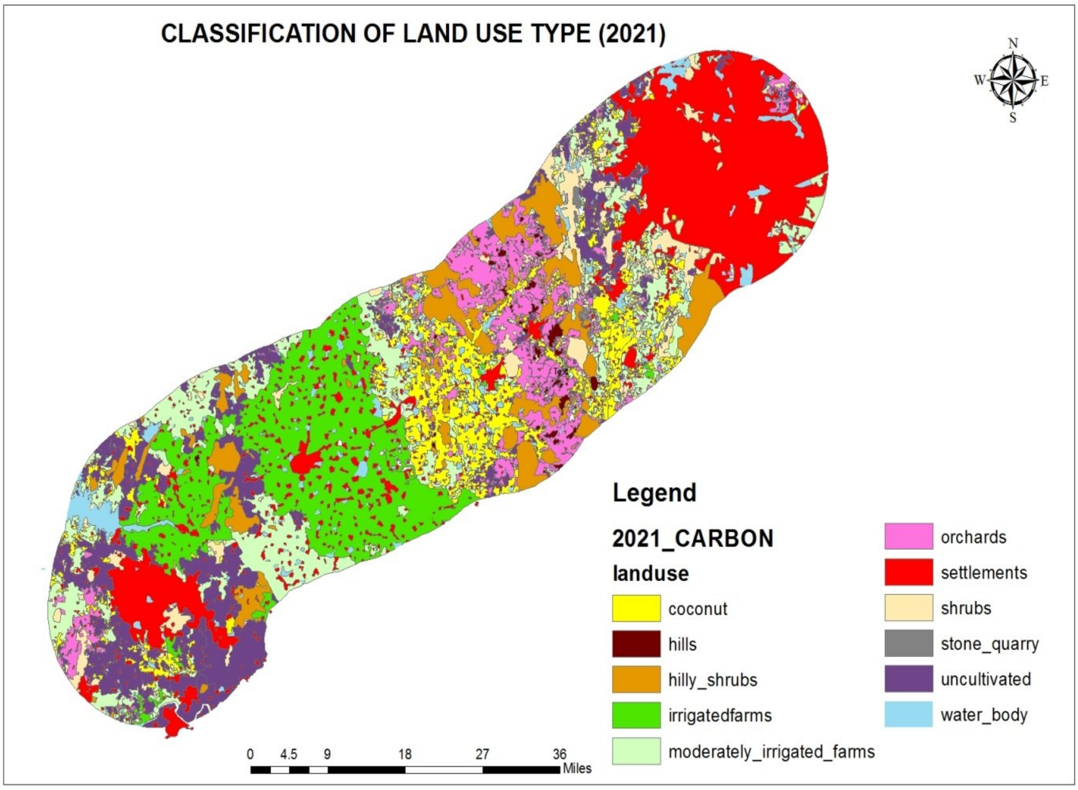
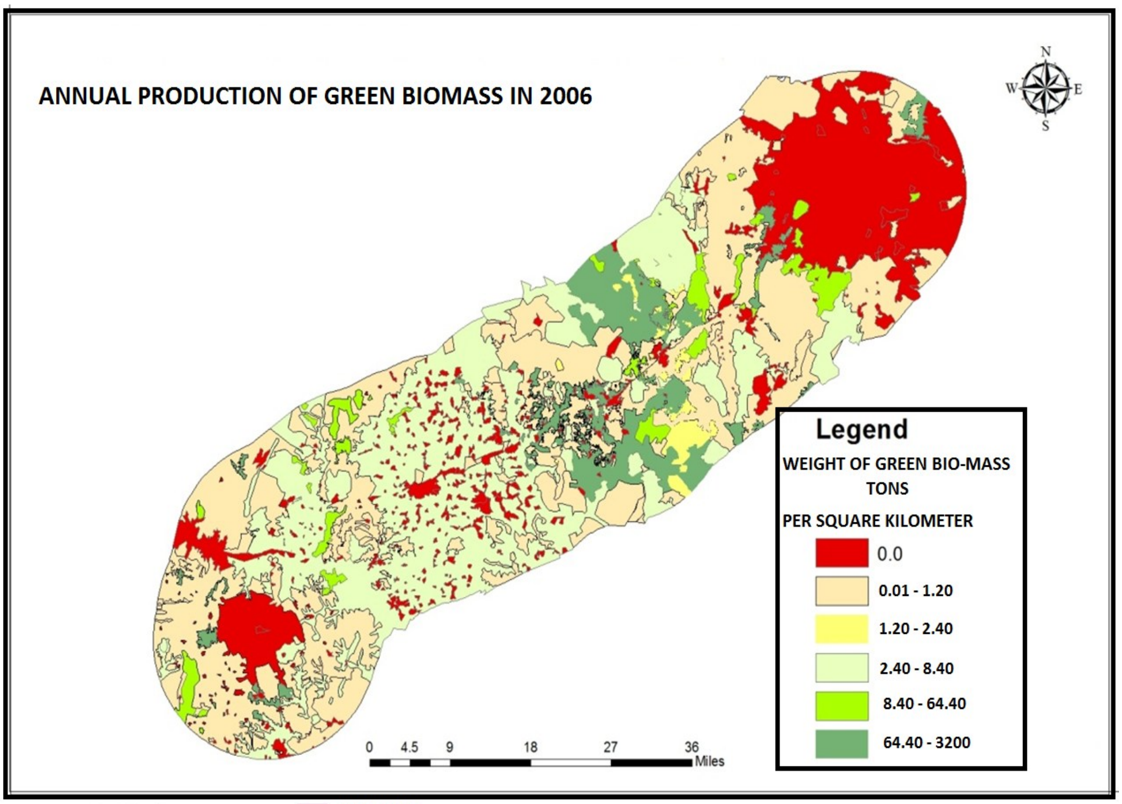
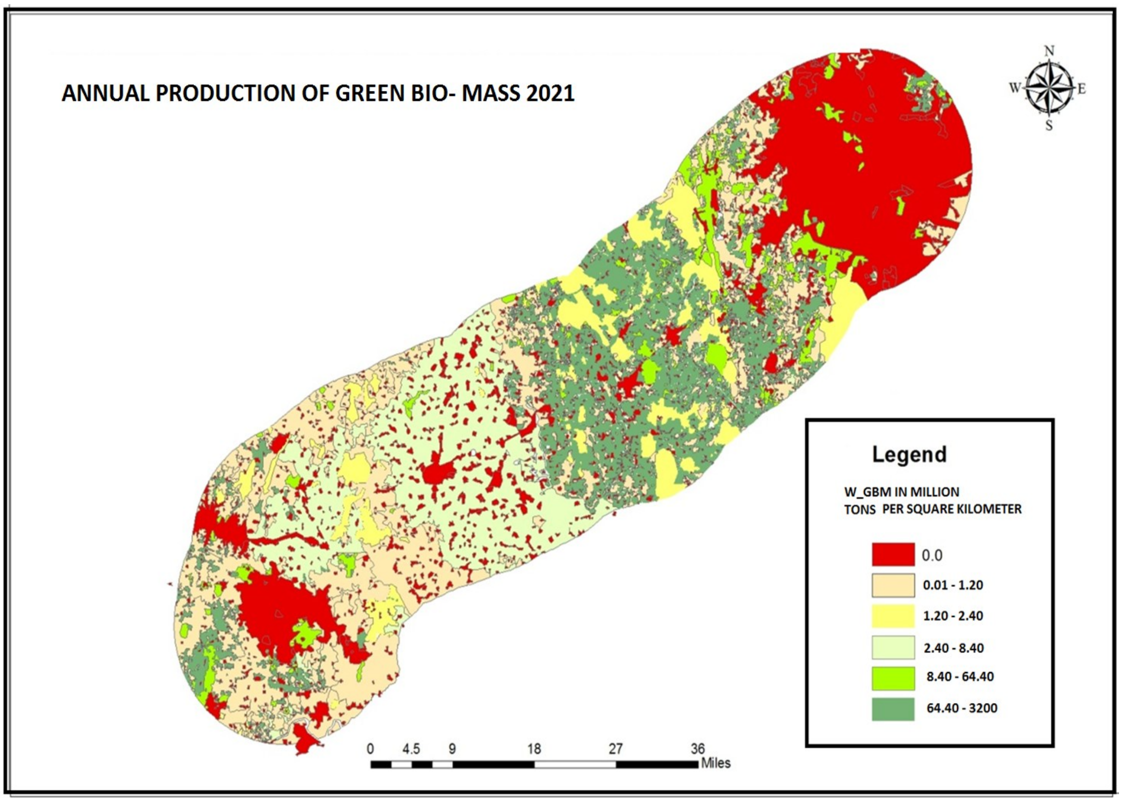
SETTLEMENT	479.94	0.00	0.0	0.0	0.0


CLASSIFICATION OF LAND USE TYPE (2006)
N
W
E
S
Legend
2006_CARBON
landuse
coconut
hills
hilly_shrubs
irrigated_farms
moderately_irrigated_F
orchards
settlements
shrubs
stone_Quarry
uncultivated
water_bodies
0
4.5
9
18
27
36
Miles


CLASSIFICATION OF LAND USE TYPE (2021)
N
W
E
S
Legend
2021_CARBON
landuse
coconut
hills
hilly_shrubs
irrigatedfarms
moderately_irrigated_farms
orchards
settlements
shrubs
stone_quarry
uncultivated
water_body
0
4.5
9
18
27
36
Miles


ANNUAL PRODUCTION OF GREEN BIOMASS IN 2006
N
W
E
S
Legend
WEIGHT OF GREEN BIO-MASS
TONS
PER SQUARE KILOMETER
0.0
0.01 - 1.20
1.20 - 2.40
2.40 - 8.40
8.40 - 64.40
64.40 - 3200
0
4.5
9
18
27
36
Miles


ANNUAL PRODUCTION OF GREEN BIO- MASS 2021
N
W
E
S
Legend
W_GBM IN MILLION
TONS PER SQUARE KILOMETER
0.0
0.01 - 1.20
1.20 - 2.40
2.40 - 8.40
8.40 - 64.40
64.40 - 3200
0
4.5
9
18
27
36
Miles

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Hilly shrubs		3	3	Perennial	June – December	10	2 seasons per year
Shrubs		3	3	Perennial	June – December	20	
Grass		0.7	3	3 months		20	2 seasons per year
Orchards	400	15	50	20>	Perennial	50	Perennial
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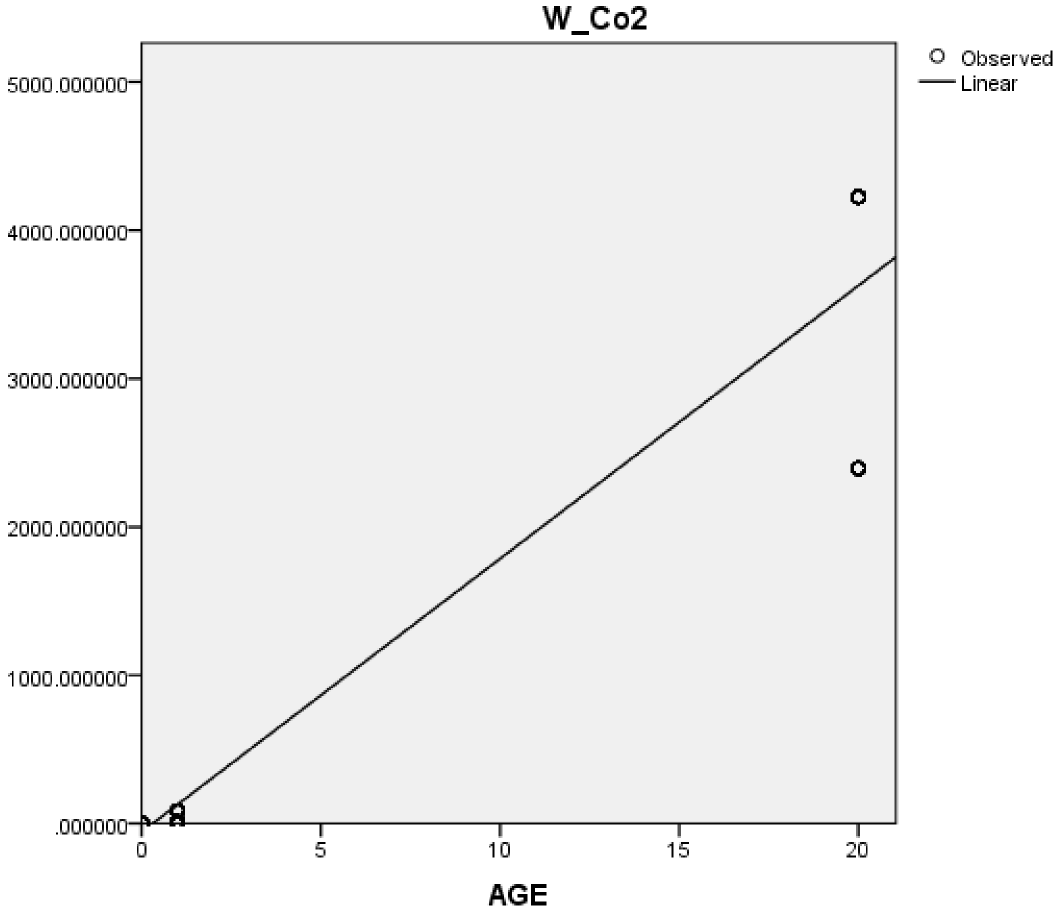
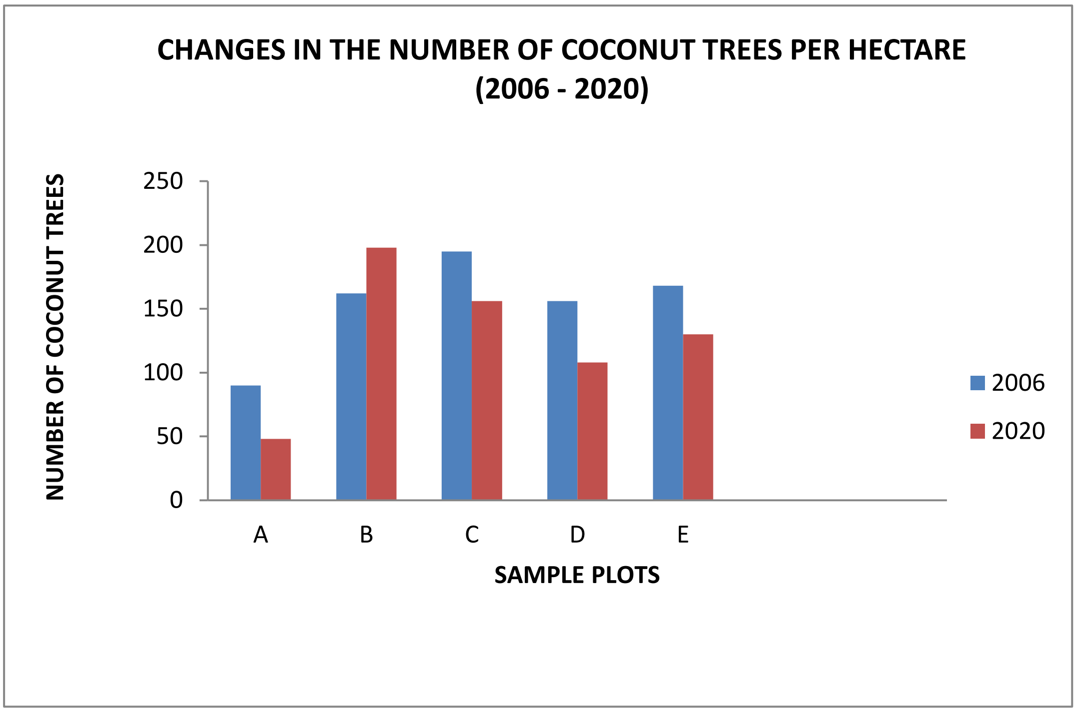


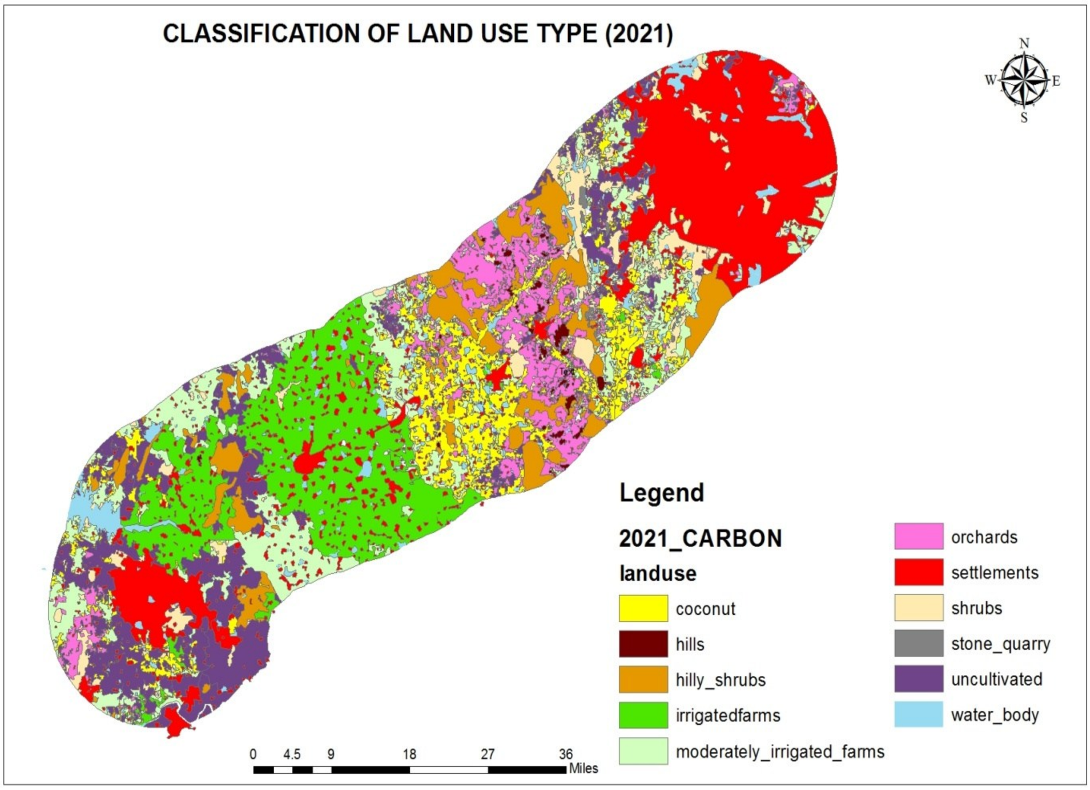
Estimation of carbon sequestration potential in coconut plantations under different agro-ecological regions and land suitability classes, Revised: 06 September 2011 ; Accepted: 16 September 2011

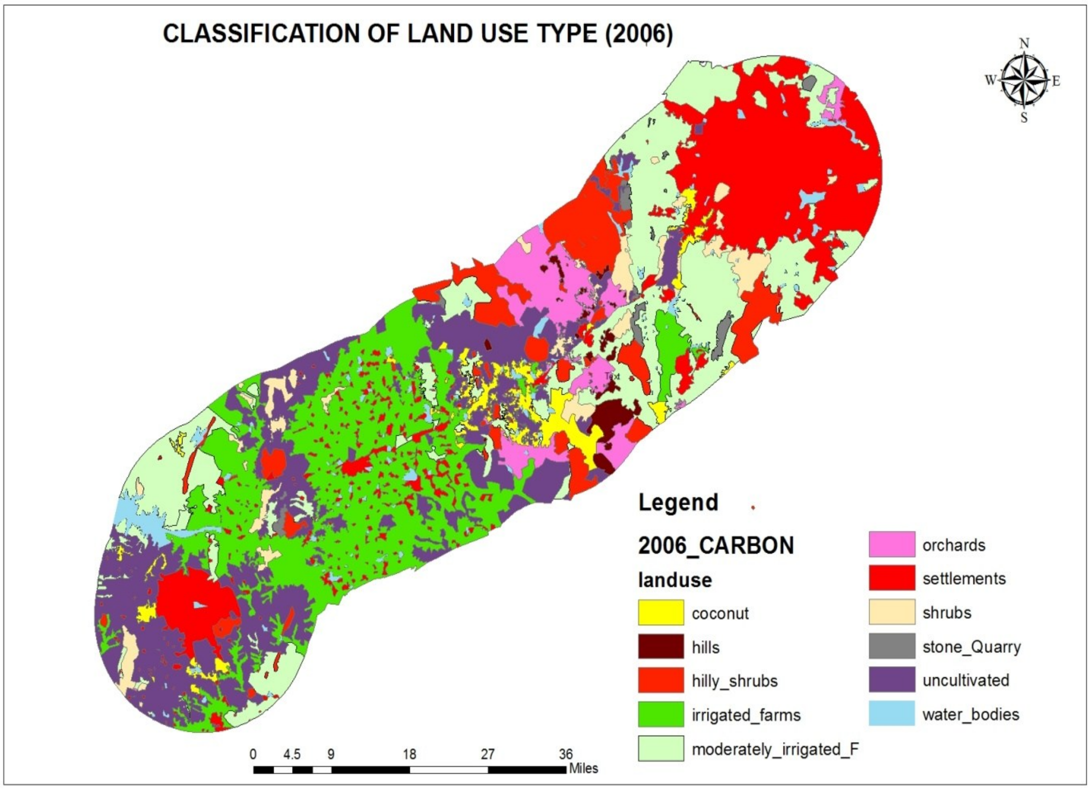
J.Natn.Sci.Foundation Sri Lanka 2012 40 (1):77-93; C. S. Ranasinghe* and K. S. H. Thimothias
Plant Physiology Division, Coconut Research Institute, Bandirippuwa Estate, Lunuwila.

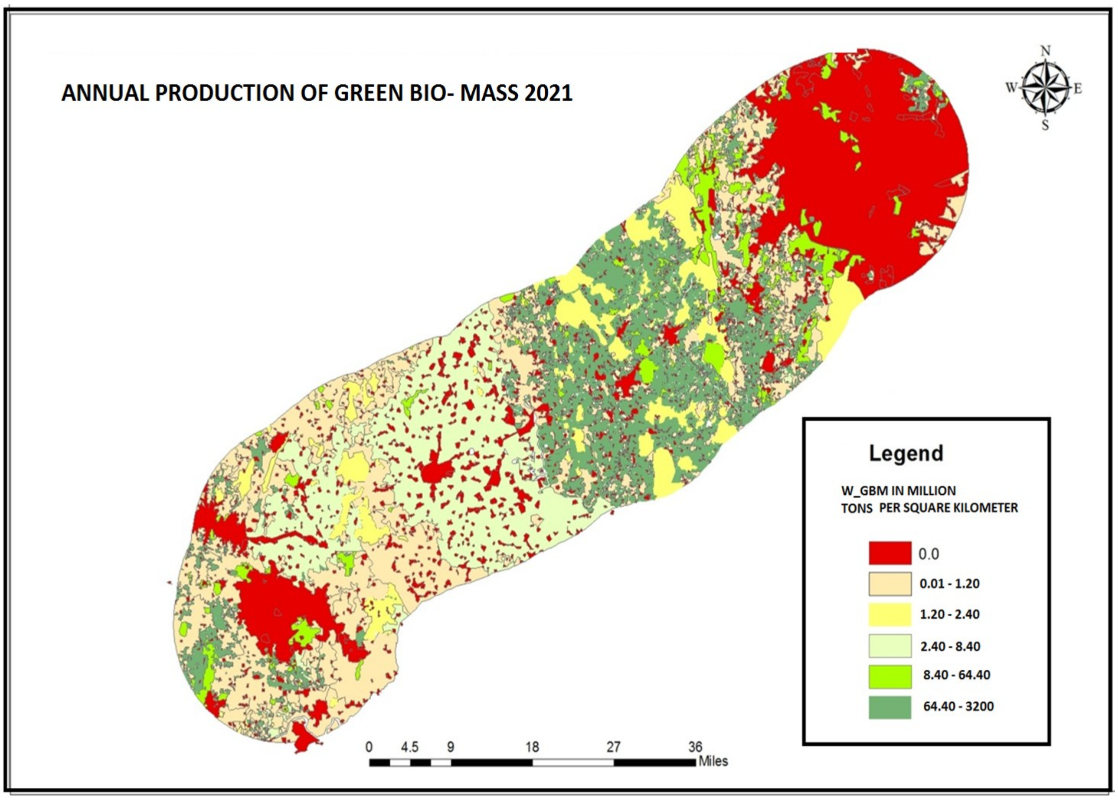
2. Maheswarappa H.P, and Bhat Ravi: Carbon sequestration potential in coconut-based cropping systems, Indian Journal of Horticulture; January 2017, DOI: 10.5958/0974-0112.2017.00004.4,

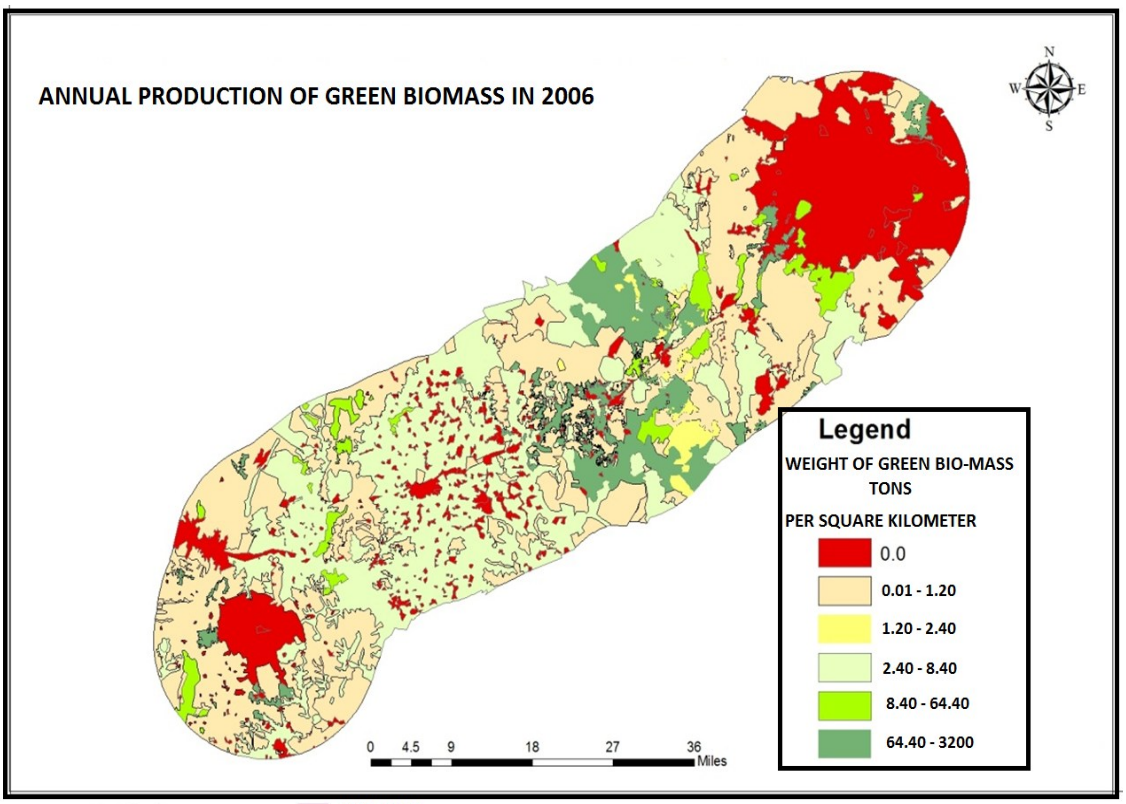
BIOMASS ESTIMATION AND CARBON SEQUESTRATION FOR COCONUT						
Scientifi name CO_2 (t/ha)	height (m)	Girth (m)	AGB (Kg/Plant)	C (Kg/Plant)	C (t/Ha)	CO2 (t/ha)
Coconut (Cocos nucifera)	20.8	0.85	574.57	287.28	51.14	187.67
AGB = Above ground biomass, C = Carbon						

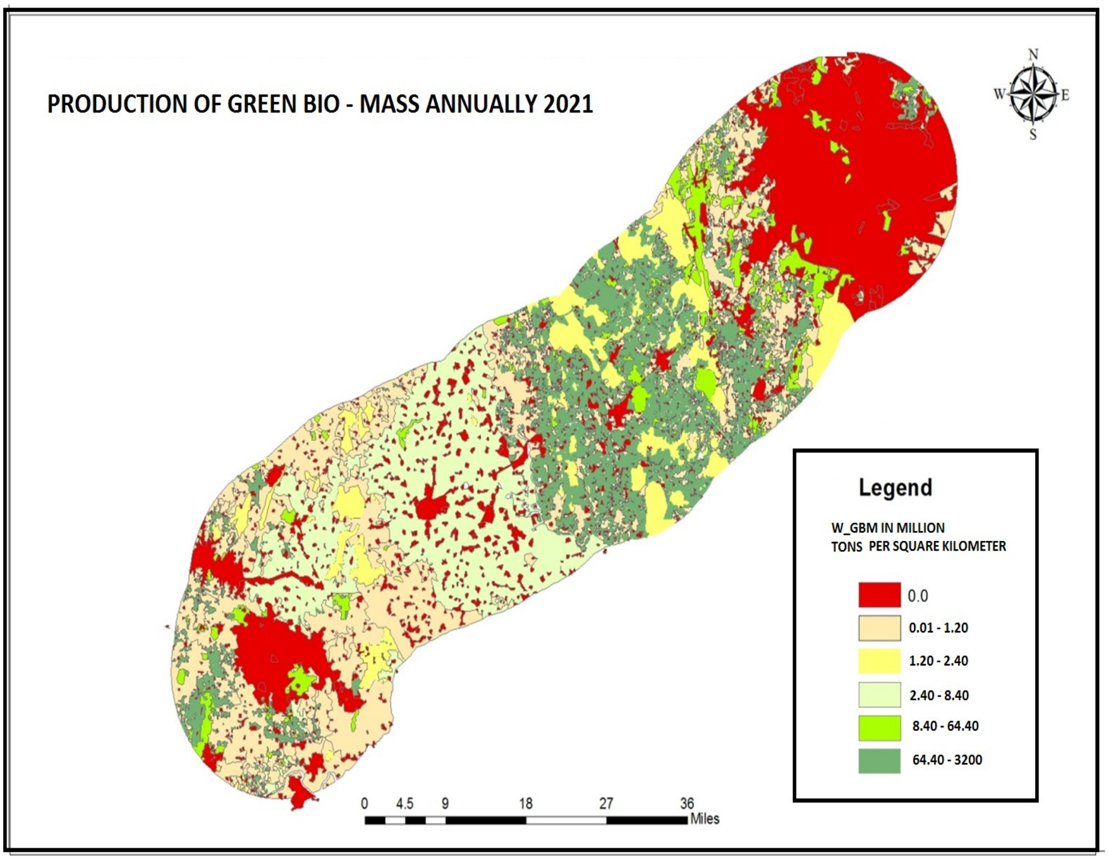


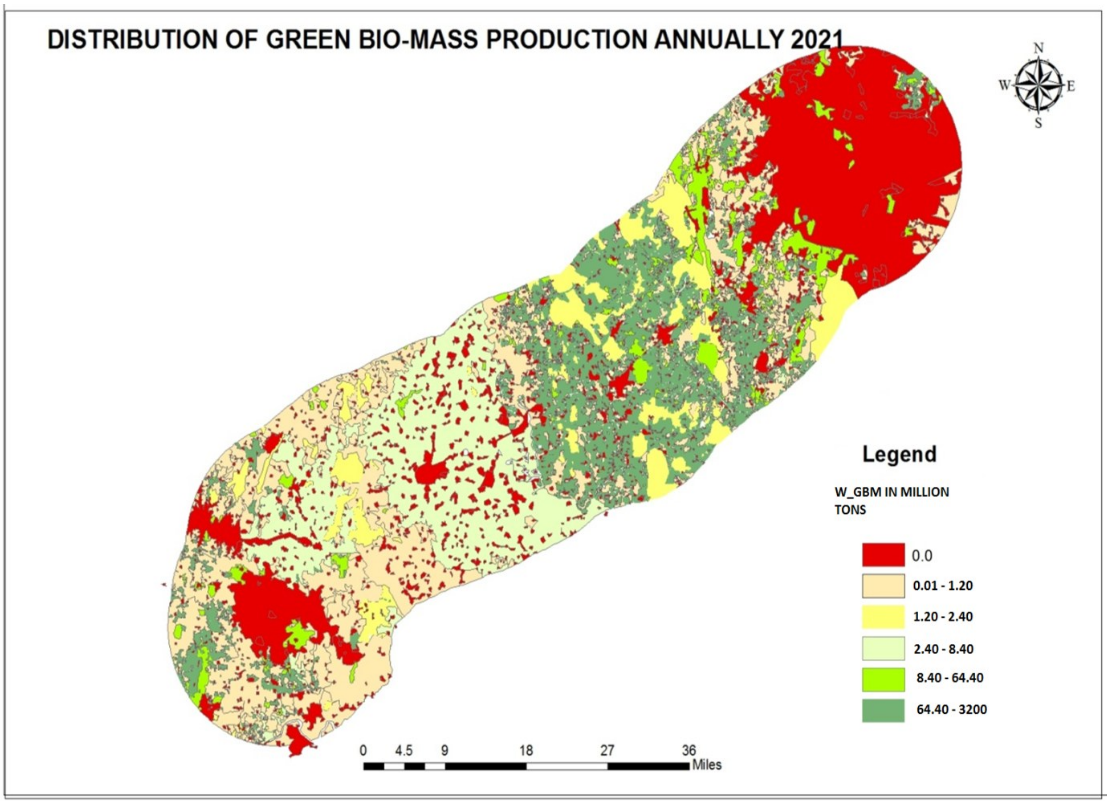

CLASSIFICATION OF LAND USE TYPE (2021)
N
W
E
S
Legend
2021_CARBON
landuse
coconut
hills
hilly_shrubs
irrigatedfarms
moderately_irrigated_farms
orchards
settlements
shrubs
stone_quarry
uncultivated
water_body
0 4.5 9 18 27 36
Miles

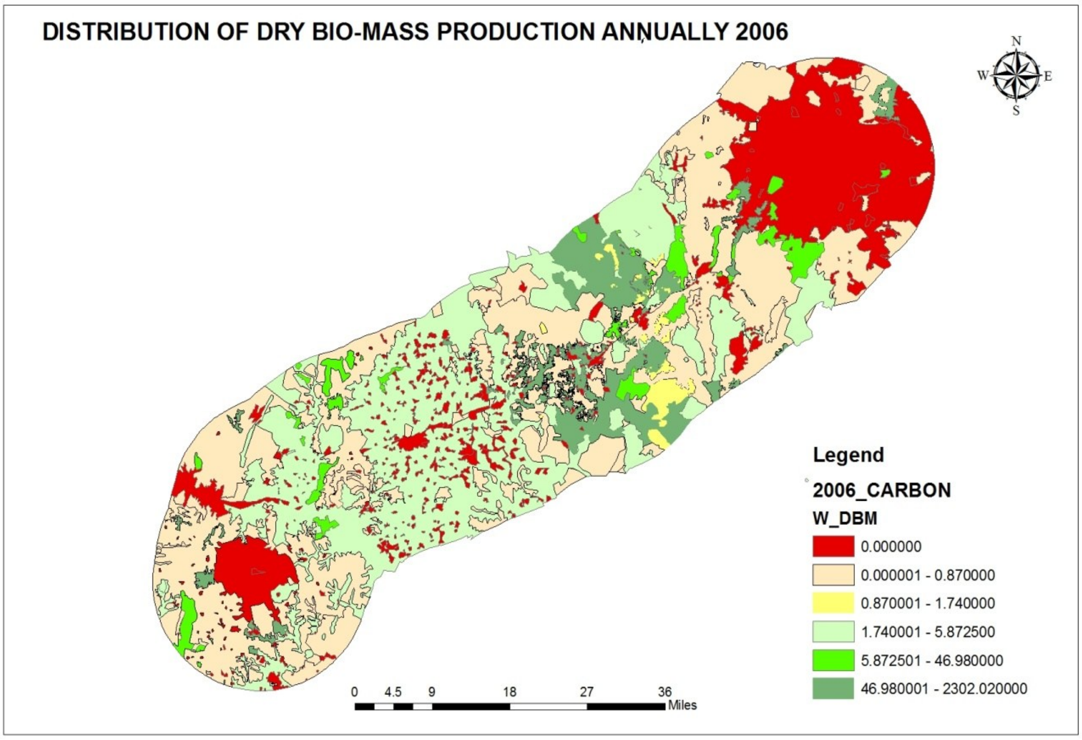

CLASSIFICATION OF LAND USE TYPE (2006)
N
W
E
S
Legend
2006_CARBON
landuse
coconut
hills
hilly_shrubs
irrigated_farms
moderately_irrigated_F
orchards
settlements
shrubs
stone_Quarry
uncultivated
water_bodies
0 4.5 9 18 27 36
Miles

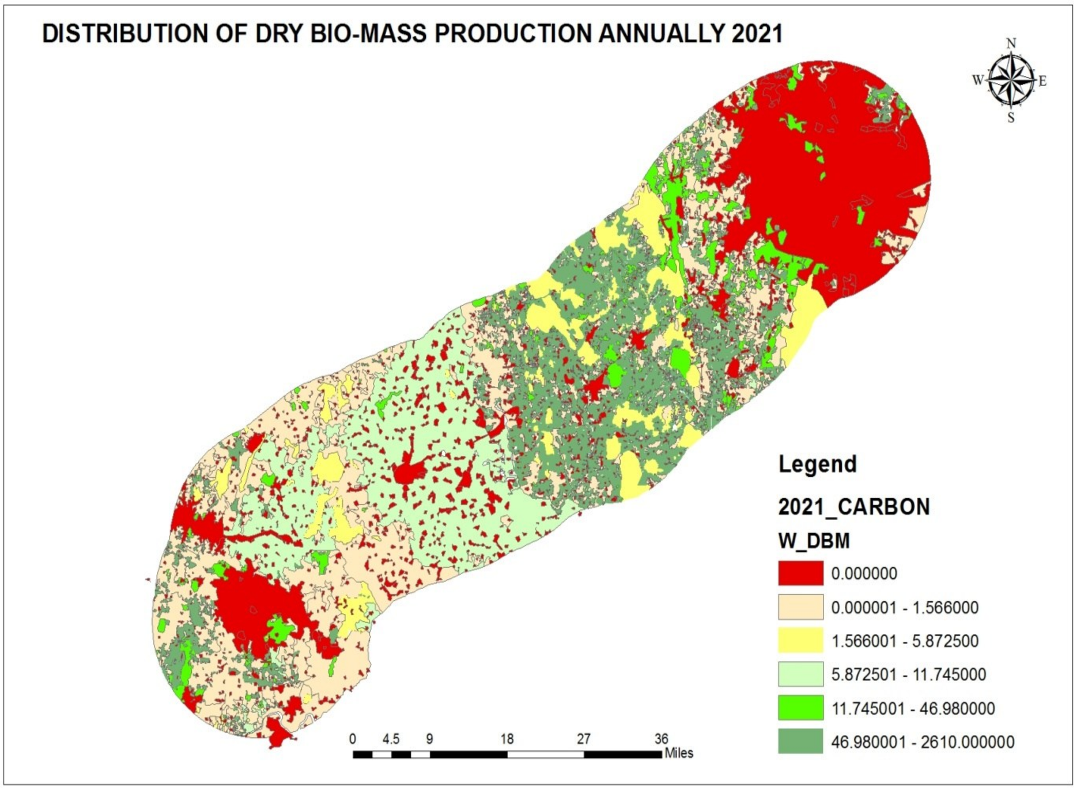

ANNUAL PRODUCTION OF GREEN BIO- MASS 2021
N
W
E
S
Legend
W_GBM IN MILLION
TONS PER SQUARE KILOMETER
0.0
0.01 - 1.20
1.20 - 2.40
2.40 - 8.40
8.40 - 64.40
64.40 - 3200
0 4.5 9 18 27 36
Miles

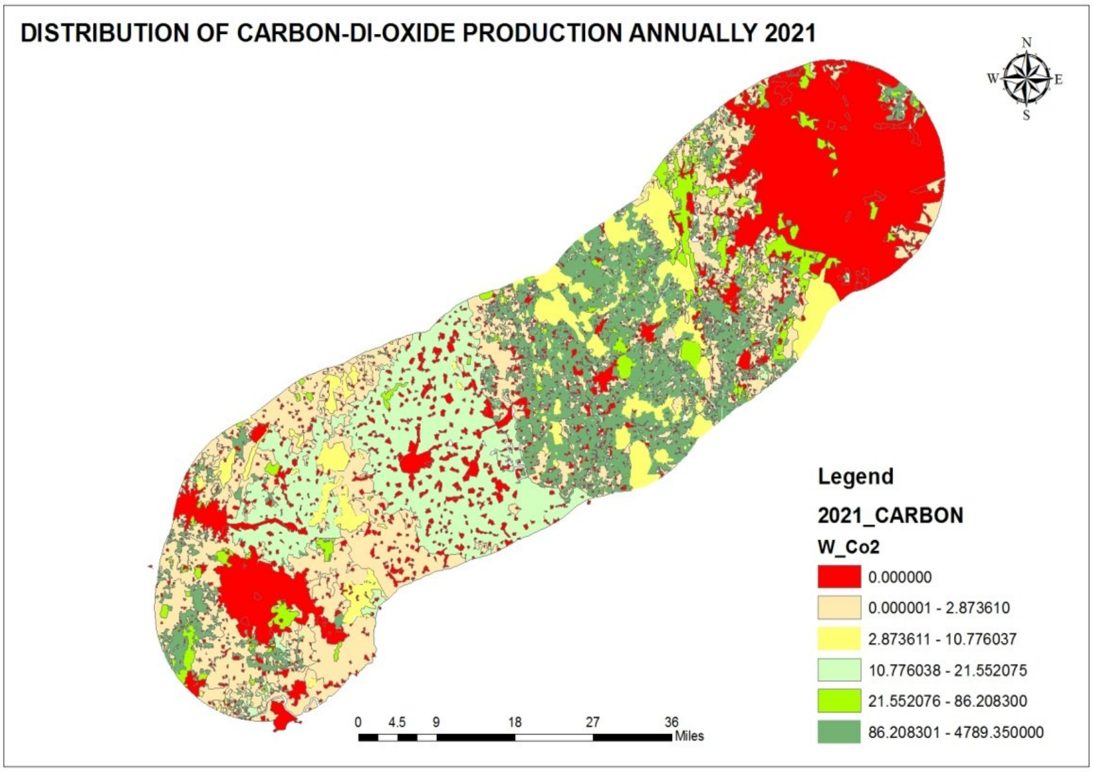

ANNUAL PRODUCTION OF GREEN BIOMASS IN 2006
N
W
E
S
Legend
WEIGHT OF GREEN BIO-MASS
TONS
PER SQUARE KILOMETER
0.0
0.01 - 1.20
1.20 - 2.40
2.40 - 8.40
8.40 - 64.40
64.40 - 3200
0 4.5 9 18 27 36
Miles

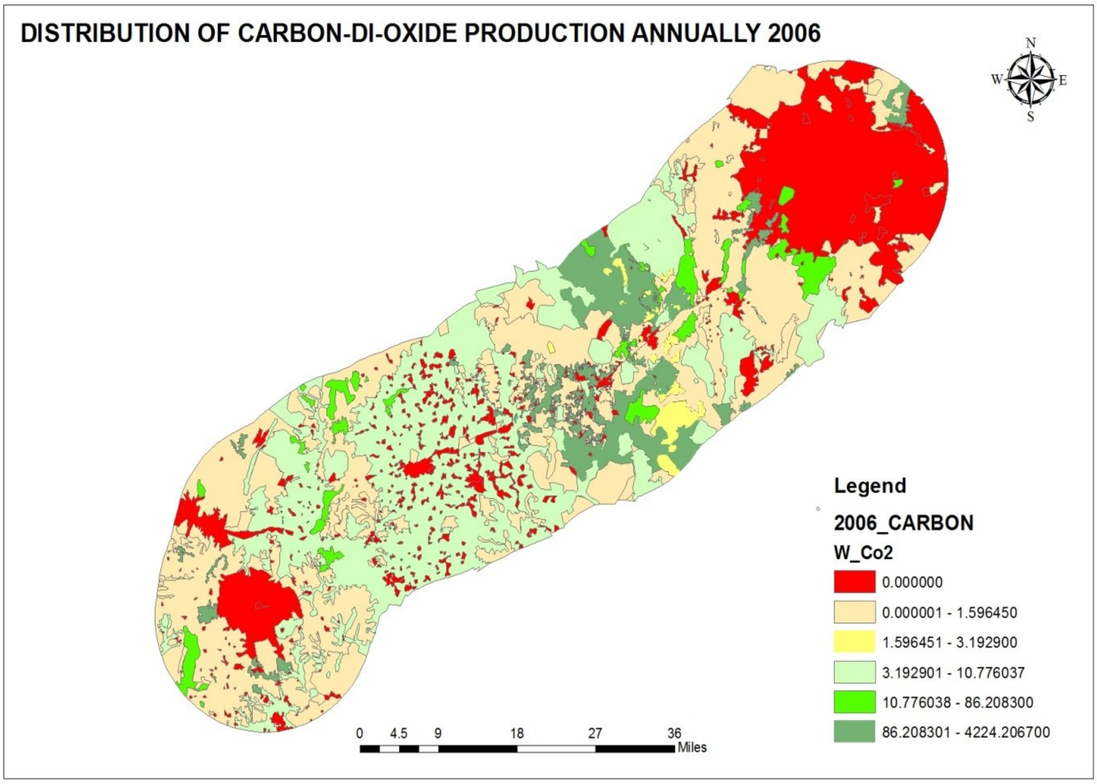

PRODUCTION OF GREEN BIO - MASS ANNUALLY 2021
N
W
E
S
Legend
W_GBM IN MILLION
TONS PER SQUARE KILOMETER
0.0
0.01 - 1.20
1.20 - 2.40
2.40 - 8.40
8.40 - 64.40
64.40 - 3200
0
4.5
9
18
27
36
Miles

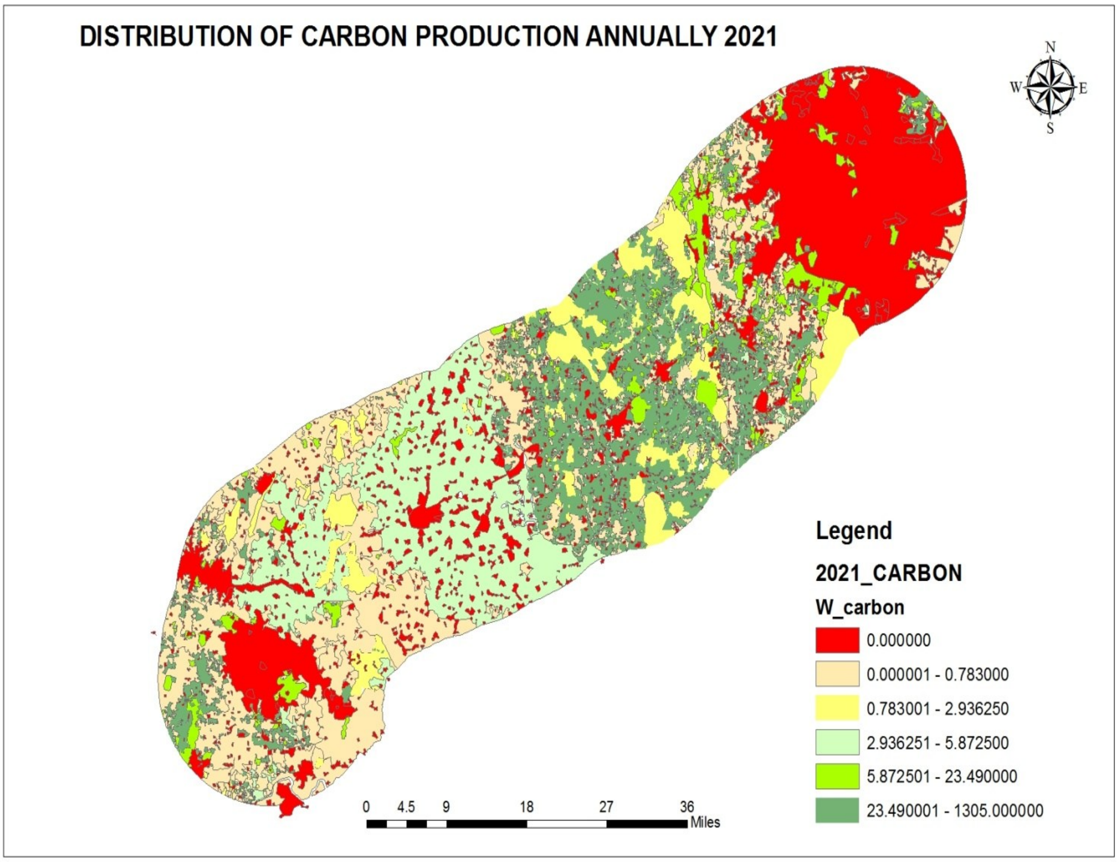

DISTRIBUTION OF GREEN BIO-MASS PRODUCTION ANNUALLY 2021
N
W
E
S
Legend
W_GBM IN MILLION
TONS
0.0
0.01 - 1.20
1.20 - 2.40
2.40 - 8.40
8.40 - 64.40
64.40 - 3200
0
4.5
9
18
27
36
Miles

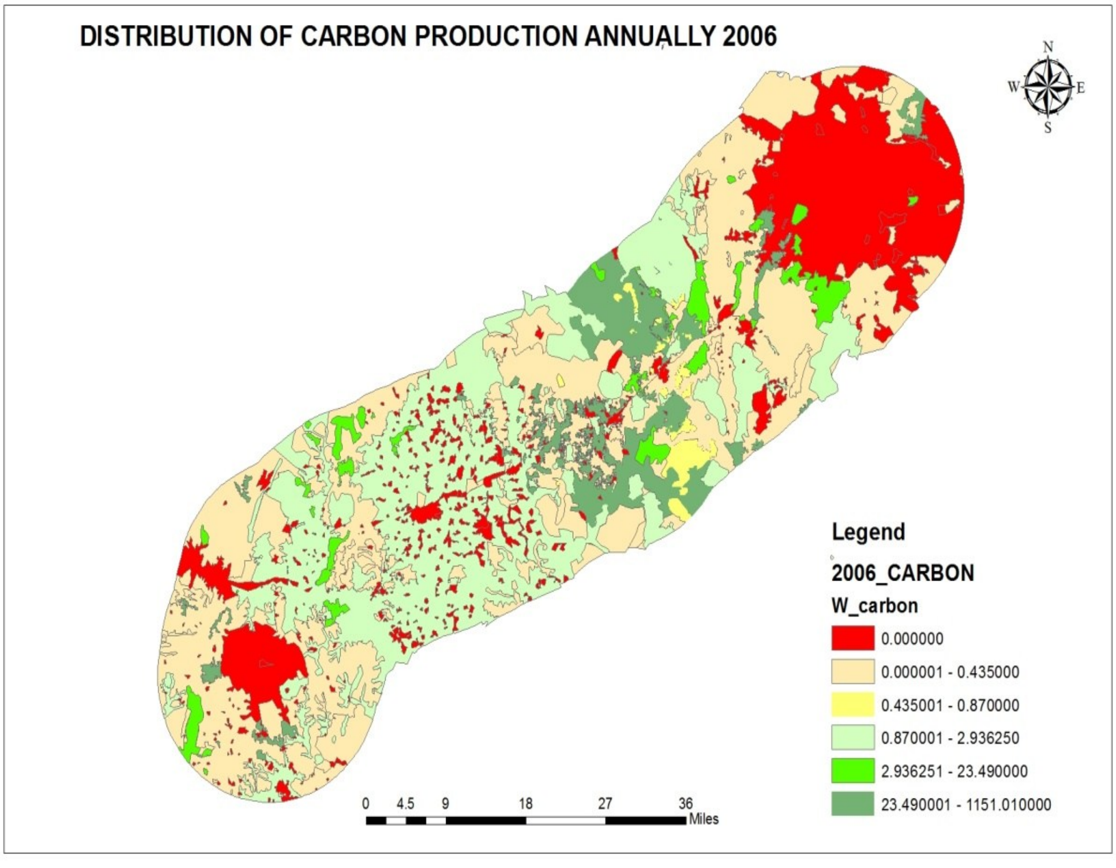

DISTRIBUTION OF DRY BIO-MASS PRODUCTION ANNUALLY 2006
N
W
E
S
Legend
2006_CARBON
W_DBM
0.000000
0.000001 - 0.870000
0.870001 - 1.740000
1.740001 - 5.872500
5.872501 - 46.980000
46.980001 - 2302.020000
0 4.5 9 18 27 36
Miles

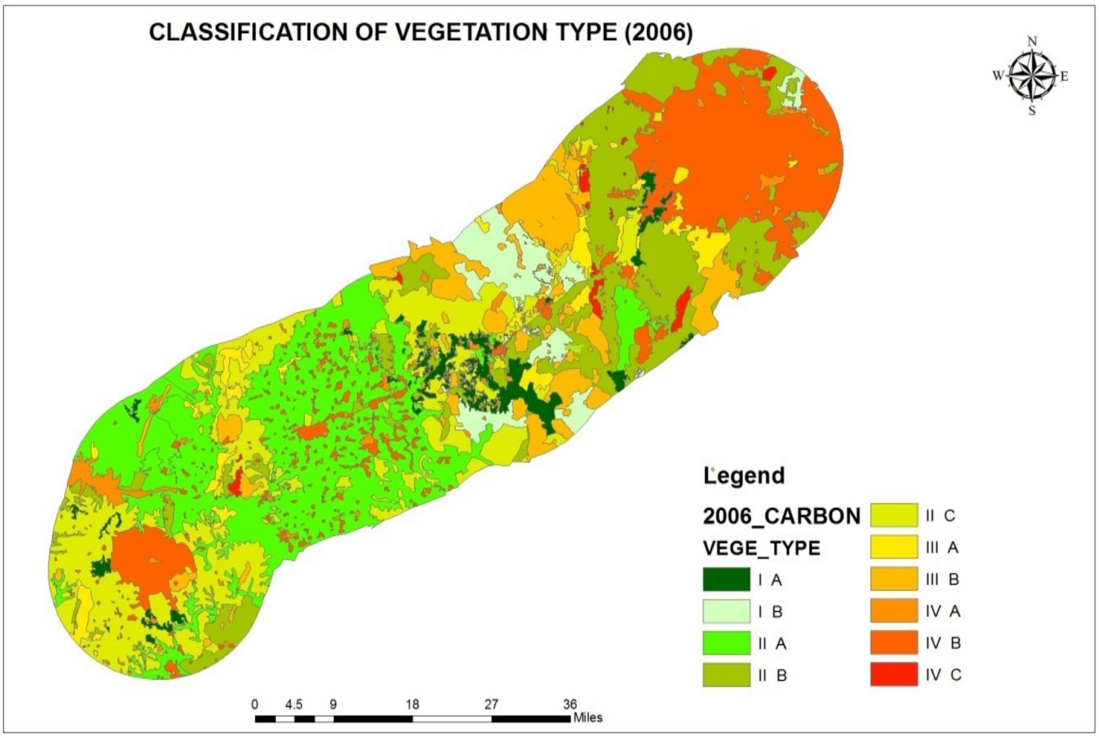

DISTRIBUTION OF DRY BIO-MASS PRODUCTION ANNUALLY 2021
N
W
E
S
Legend
2021_CARBON
W_DBM
0.000000
0.000001 - 1.566000
1.566001 - 5.872500
5.872501 - 11.745000
11.745001 - 46.980000
46.980001 - 2610.000000
0 4.5 9 18 27 36
Miles

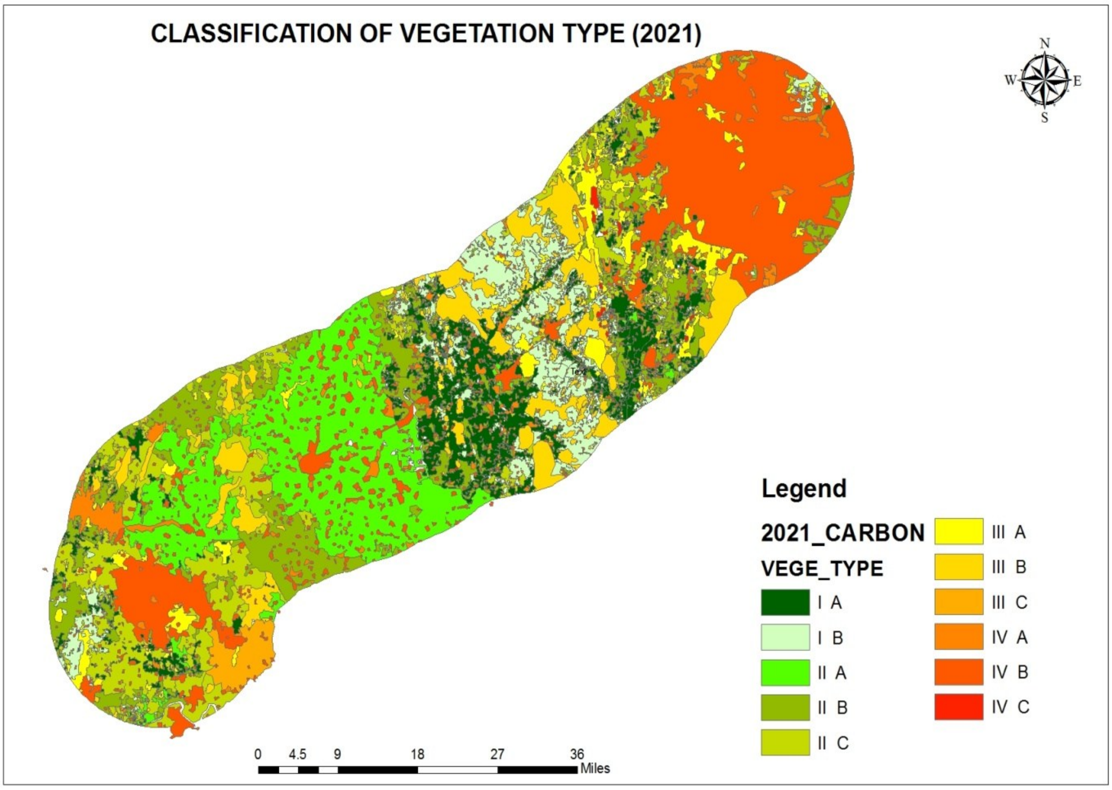

DISTRIBUTION OF CARBON-DI-OXIDE PRODUCTION ANNUALLY 2021
N
W
E
S
Legend
2021_CARBON
W_Co2
0.000000
0.000001 - 2.873610
2.873611 - 10.776037
10.776038 - 21.552075
21.552076 - 86.208300
86.208301 - 4789.350000
0 4.5 9 18 27 36
Miles


DISTRIBUTION OF CARBON-DI-OXIDE PRODUCTION ANNUALLY 2006
N
W
E
S
Legend
2006_CARBON
W_Co2
0.000000
0.000001 - 1.596450
1.596451 - 3.192900
3.192901 - 10.776037
10.776038 - 86.208300
86.208301 - 4224.206700
0 4.5 9 18 27 36
Miles

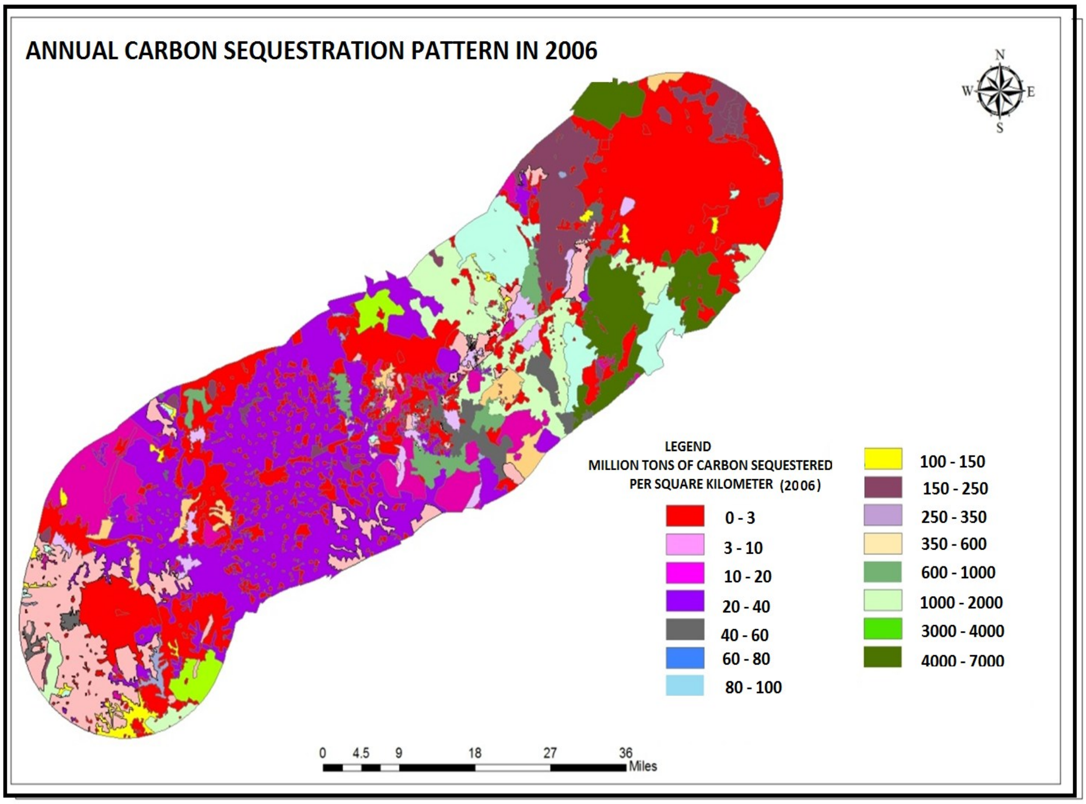

DISTRIBUTION OF CARBON PRODUCTION ANNUALLY 2021
N
W
E
S
Legend
2021_CARBON
W_carbon
0.000000
0.000001 - 0.783000
0.783001 - 2.936250
2.936251 - 5.872500
5.872501 - 23.490000
23.490001 - 1305.000000
0 4.5 9 18 27 36
Miles

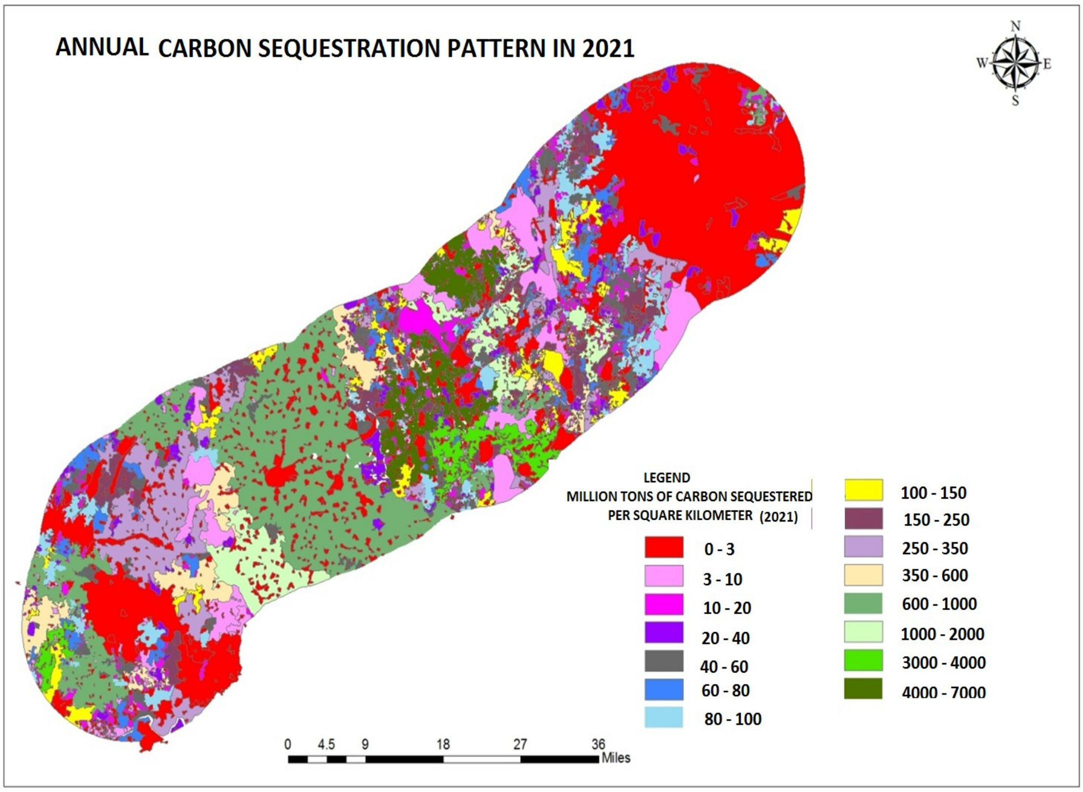

DISTRIBUTION OF CARBON PRODUCTION ANNUALLY 2006
N
W
E
S
Legend
2006_CARBON
W_carbon
0.000000
0.000001 - 0.435000
0.435001 - 0.870000
0.870001 - 2.936250
2.936251 - 23.490000
23.490001 - 1151.010000
0 4.5 9 18 27 36
Miles

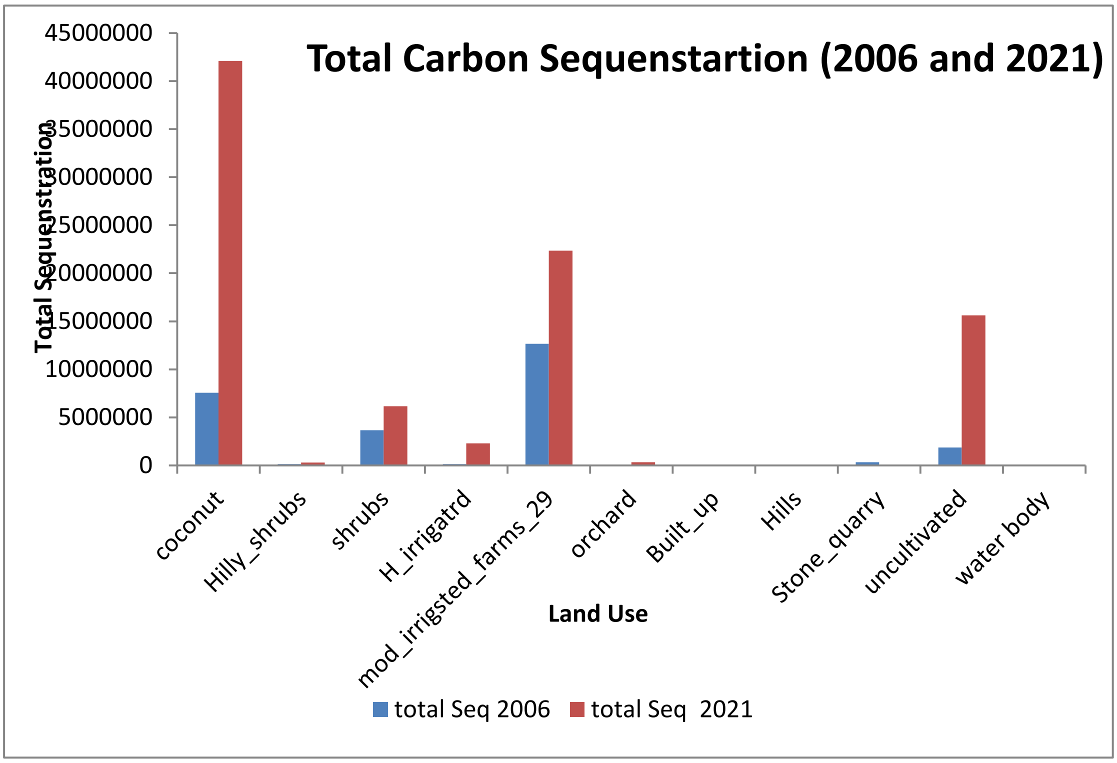

CLASSIFICATION OF VEGETATION TYPE (2006)
N
W
E
S
Legend
2006_CARBON
VEGE_TYPE
I A
I B
II A
II B
II C
III A
III B
IV A
IV B
IV C
0
4.5
9
18
27
36
Miles

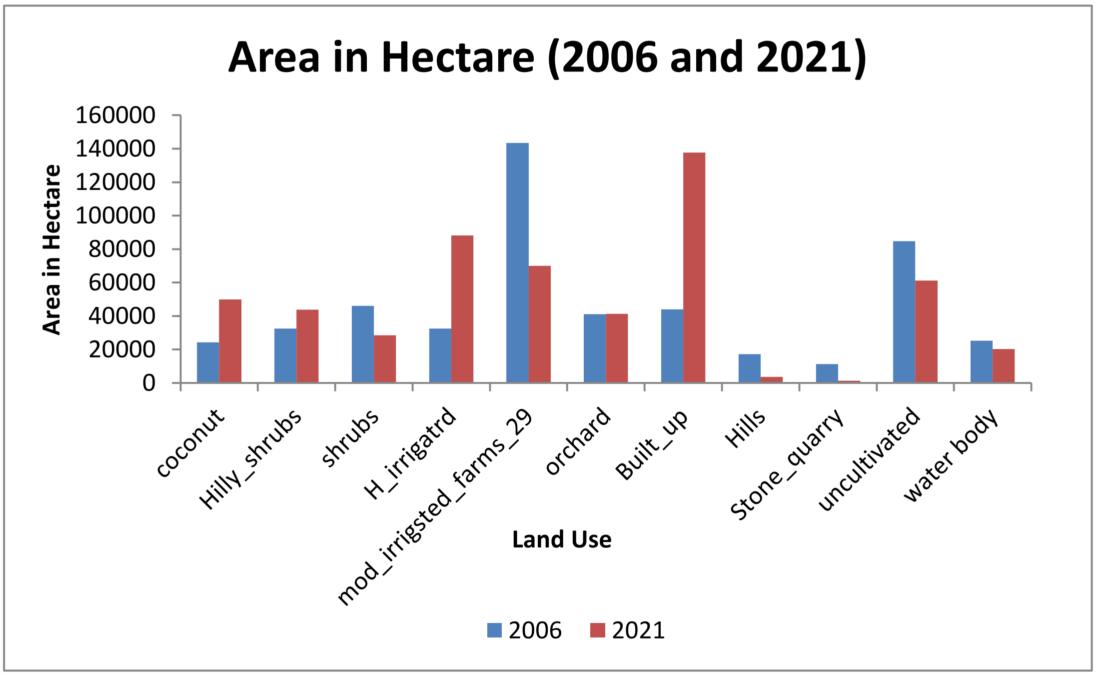

CLASSIFICATION OF VEGETATION TYPE (2021)
N
W
E
S
Legend
2021_CARBON
VEGE_TYPE
I A
I B
II A
II B
II C
III A
III B
III C
IV A
IV B
IV C
0
4.5
9
18
27
36
Miles

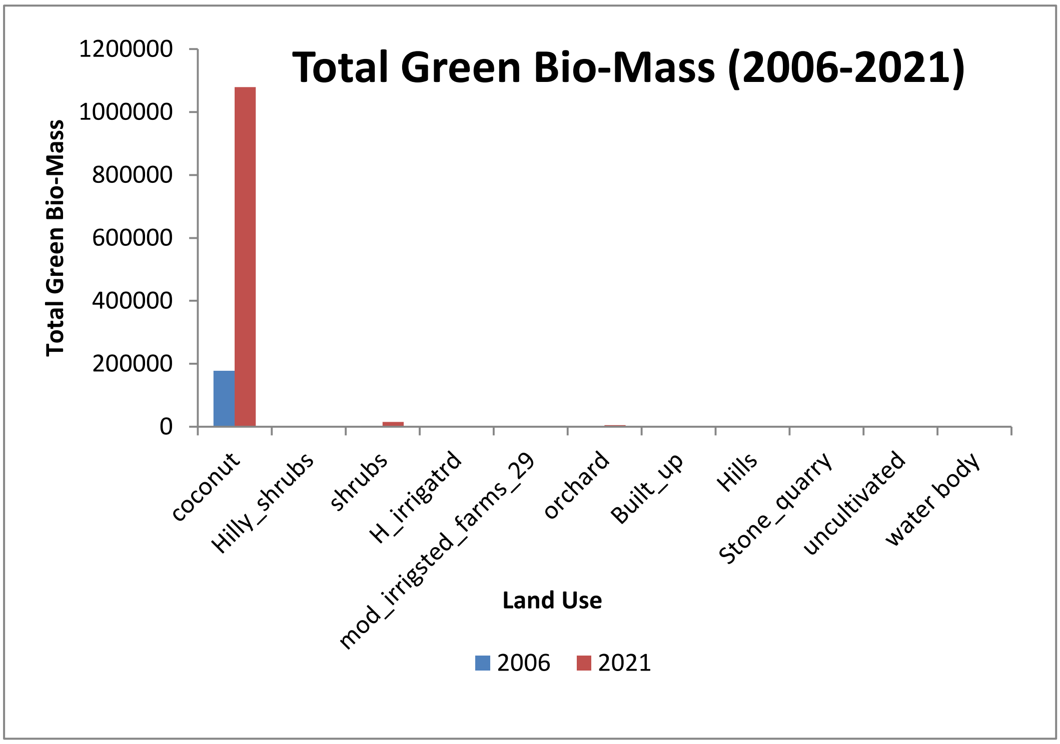
The land use/ land cover

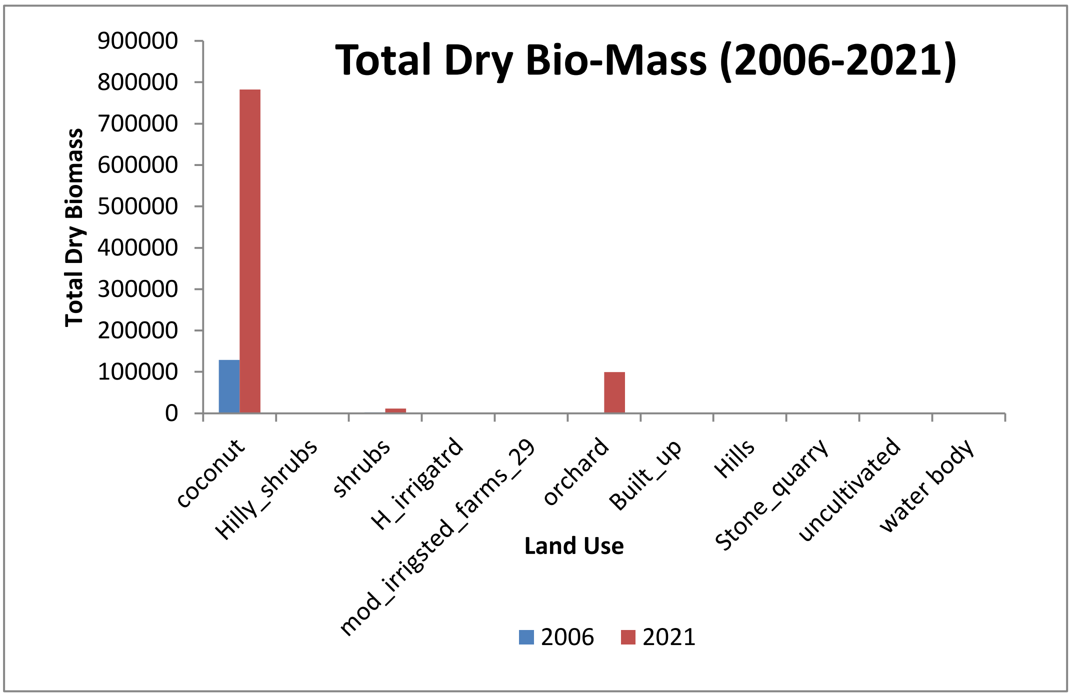


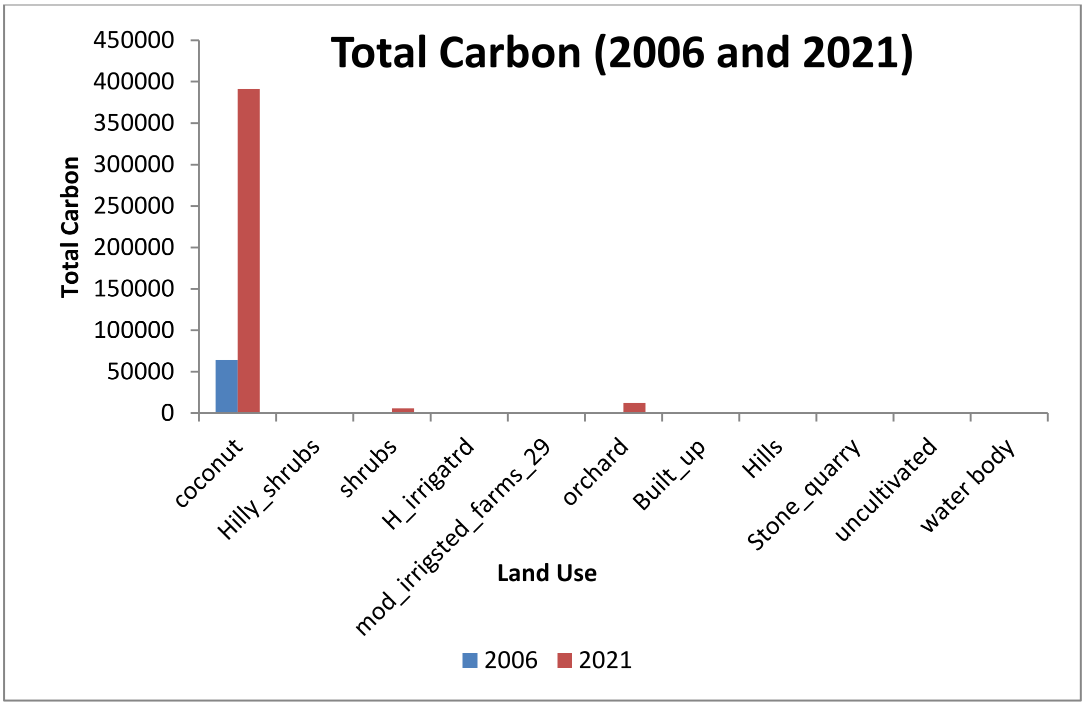



Total Carbon Sequenstartion (2006 and 2021)
Total Sequenstration
45000000
40000000
35000000
30000000
25000000
20000000
15000000
10000000
5000000
0
coconut
Hilly_shrubs
shrubs
H_irrigatrd
mod_irrigsted_farms_29
orchard
Built_up
Hills
Stone_quarry
uncultivated
water body
Land Use
total Seq 2006
total Seq 2021


Area in Hectare (2006 and 2021)
Area in Hectare
160000
140000
120000
100000
80000
60000
40000
20000
0
coconut
Hilly_shrubs
shrubs
H_irrigatrd
mod_irrigsted_farms_29
orchard
Built_up
Hills
Stone_quarry
uncultivated
water body
Land Use
2006
2021


Total Green Bio-Mass (2006-2021)
Total Green Bio-Mass
1200000
1000000
800000
600000
400000
200000
0
coconut
Hilly_shrubs
shrubs
H_irrigatrd
mod_irrigsted_farms_29
orchard
Built_up
Hills
Stone_quarry
uncultivated
water body
Land Use
2006
2021


Total Dry Bio-Mass (2006-2021)
Total Dry Biomass
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
coconut
Hilly_shrubs
shrubs
H_irrigatrd
mod_irrigsted_farms_29
orchard
Built_up
Hills
Stone_quarry
uncultivated
water body
Land Use
2006
2021



CONCLUSION

The carbon sequestration potential of the study area shows a positive resilience towards the rapid alterations in the landuse and land cover. The rapid change and decline in social forestry, and agricultural lands does not show any drastic impact on the carbon sequestration potential of the region. The growth pattern is self sustaining and the reason for the resilient growth and development is the land use adaptation to the new changes occurring over the land use. The situation especially around Bangalore Metropolitan region the less irrigated and rough terrain which used to be under utilized and uncultivated are generally converted into coconut plantation and orchards. This has led to a greater area under vegetation. Coconut is considered to be one of the tree type which has a very high potential of carbon sequestration.

Secondly, the area under agriculture has also increased from 2006 to 2021. The source of irrigation is generally through bore-wells which has brought thousands of hectares of land under cultivation. The growth of cereals has a very high potential for carbon sequestration. Since these crops are growing at a fast rate, they have a very high rate of sequestration.