`

Urban expansion impact on agriculture: A case study on Hyderabad, India

Thesis submitted to
Jawaharlal Nehru Technological University, Hyderabad
for the award of Degree of

Master of Technology
In
Geo Informatics and Surveying Technology

By
NIDANAMPALLY KEERTHI
Roll. No. 15031D4701

CENTRE FOR SPATIAL INFORMAION TECHNOLOGY
INSTITUTE OF SCIENCE AND TECHNOLOGY JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD-500 072, INDIA

December2017

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY

Kukatpally, Hyderabad – 500 085, Telangana (India)

Centre for Spatial Information Technology

CERTIFICATE

This is to certify that the dissertation entitled "**Urban expansion impact on agriculture: a case study on Hyderabad, India**" submitted by **Ms. NidanampallyKeerthi** to Jawaharlal Nehru Technological University, Hyderabad for the award of the degree of Master of Technology (M.Tech.) is a record of bona fide research work carried out by her under my supervision and guidance. Ms. NidanampallyKeerthi has worked on this topic for about ten months and the dissertation, in our opinion, is worthy of consideration for the award of Master of Technology in accordance with the regulations of the institute. The results embodied in this thesis have not been submitted to any other university or Institute for the award of any Degree or Diploma.

Signature of supervisor

Dr. K. Manjula Vani

Professor, CSIT

IST, JNTUH

DECLARATION

I, **NidanampallyKeerthi**bearing H.T.No. 15031D4701 hereby declare that the project work entitled "**Urban expansion impact on agriculture land: a case study on Hyderabad, India"** is an authenticated work carried out by me at ICRISAT under the guidance of **Dr. K. Manjula Vani (Professor, CSIT, JNTUH)** for the fulfillment of the requirement for the award of the degree of **Master of Technology in Geo Informatics and Surveying Technology.**

Date:

Place: HYDERABAD

NidanampallyKeerthi

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to many people, without whom this dissertation would not have been completed.

First, I would like to acknowledge **Dr. K. ManjulaVani** (Professor, CSIT) and **Dr. Gumma. K. Murali Krishna** (Senior Scientist, ICRISAT) their extensive help in helping me with the methodologies and suggestions. I extend sincere thanks for their inspiring guidance, constant interest, suggestions, and encouragement throughout the course of these investigations.

I owe my heartiest thanks to **Mr. Irshad AMohammed** (Lead Scientific Officer, ICRISAT) and**Mr. Ismail Rafi** (DBA, ICRISAT) for their suggestions and support to carry out this work successfully. I would also like to express my sincere gratitude to **Dr. Anthony M Whitbread** (Research Program Director, Innovation Systems for the Drylands).

I sincerely acknowledge to International Crops Research Institute for the Semi-Arid Tropics(ICRISAT) for providing the infrastructure and the datasets. Working for ICRISAT gave me an opportunity to work on this project that lead to M. Tech dissertation.

Perhaps my greatest good fortune has been to have my friends like **PranayPanjala**and **D. Yellamanda**who helped me with this work. I express my gratitude to all whose names have not been mentioned individually but have helped me directly or indirectly in this work.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Capital cities of the states of India have become centers of development and growth due to industrial concentration and source of employment for migrants. Infrastructure development is a major attraction for migrant labor. Apart from these the natural growth of the urban sprawl has much to contribute from the suburban villages and towns changing their role as suppliers to the urban population. The land use in these peri-urban areas has not only changed to be a supply link but also ready to be merged into the sprawl. The major goal of this study was to investigate the land use changes in urban and peri-urban Hyderabad and its influence on land use and land cover changes using Landsat 8 data and IRS-P6 data along with ground information. The main source of wastewater was the Musi River, which collects large volumes of city discharges while it runs through the city. During the period 2005 – 2016, the wastewater irrigated area within the environs of the Musi River, increased from 15,553 to 20,573 hectares with concurrent expansion of the city boundaries from 38,863 to 80,111 hectares. Opportunistic shifts in land use, especially related to wastewater irrigated agriculture, was a response to the demand for fresh vegetables and easy access to markets, exploited mainly by migrant populations. While the wastewater irrigated agriculture contributes to income security of the marginal groups, it supplements the food basket of many city dwellers. The IRS-P6, Landsat 8 data and advanced methods such as spectral matching techniques are ideal for quantifying urban expansion and associated land use changes, and are useful for urban planners and decision makers alike.

`

CHAPTER 1

INTRODUCTION

Hyderabad is currently ranked the sixth largest urban agglomeration in India. It consists of the surrounding 12 municipalities from Rangareddy and Medak districts and the Secunderabad cantonment along with the Osmania University and others to be called the Greater Hyderabad Municipal Corporation (GHMC). Physically located in the Musi Sub-Basin (11,000 km^2), which is part of the Krishna river basin. Rapid development and economic growth of the city has attracted people from all over the country, increasing the city's population to around 7.7 million (Census of India, 2011).

Urban agriculture is recognized as a significantly contributing to greenspaces and food security. It is significant contribution of food supply to the cities and sustainability of cities in several including socially, economically and environmentally so ultimately it is important to support poor urban households. Growing population and developments in the cities have been affected natural resources and natural diversity and shrinking agriculture areas. These changes challenge urban developers and the service sectors, also the urban water demand has grown exponentially, within the last two decades. The water supply within the city limits has been inadequate to supply the growing needs due to illegal occupation of fresh water lakes by real estate developers, and piped imports from more remote sources has become a necessity. The land under agriculture within city has been diminishing with infrastructure development, while more and more people have been migrating from the rural areas in search of employment and better wages, which will only further stress the service industry. Several studies have been analyzed expansion of urban areas and other land use / land cover changes by using different satellite imagery. Alqureashi et, al. was analyzed expansion of urban growth and land cover changes in five middle east cities by using object based image analysis. Cao et, al was conducted study on urban expansion and impact on land use pattern by using radar graph and gradient-direction method and land scape matrices. Gumma et al., was conducted study on expansion of urban areas and waste water irrigated areas in Hyderabad, India. Most of the above studies was used Temporal Landsat imagery. Many studies have been studies on how to map agricultural areas using advanced techniques in satellite image analysis. However, mapping of urban agriculture areas including fragmented irrigated areas proved to be a challenge due to the diverse range of

`

irrigated plot sizes, crops and water sources used by farmers. The utilization of Landsat symbolism ended up being quick, cheap and effective in mapping small irrigated zones.

Growing population pressure and its associated problems, such as the increasing demand for land and trees, poor institutional and socio-economic settings, and unfavorable government policies, such as absence of land tenure security and poor framework advancement, have been the significant main thrusts behind the LULC changes. Subsequently, uncommon consideration should to be given to the presentation of savvy land asset uses and management practices, secure land ownership systems, controlled populace development, and coordinated environmental rehabilitation programs. The existing tree plantation practices should be encouraged by promoting the planting of indigenous tree species, rather than eucalyptus trees, to enhance ecological harmony.

1.1 Aim

The aim of this study was to investigate the land use changes in urban and peri-urban Hyderabad and its influence on land use and land cover changes using Landsat 8 data and IRS-P6 data along with ground information.

1.2Objective

The main objective of this study was to investigate the land use changes in urban and peri-urban Hyderabad and its influence on land use and land cover changes using Landsat 8 data and IRS-P6 and MODIS 250 m 16-bit timeseries data, combined with ground survey data. Monitoring of agricultural areas is very difficult to capture with single-date imagery. Therefore, the specific methodological contribution of this study relates to the use of unsupervised classification with clusters identified based on bi-spectral plots with high-resolution Google Earth images, spectral profiles, and ground survey data in combinedapproach. The aim in developing an approach based on analyzing high-resolution and coarse-resolution temporal imagery with advanced techniques was to help monitor agriculture and other LULC changes, to understand spatially how urban sprawl influences food security and sustainability in the city of Hyderabad.

1.3 Study Area

1.3.1 Location:

The study area of Hyderabad city and environs extend from 17010/-17050/N and 78010/-78050/ E. The Hyderabad Urban Development Area (HUDA) is around 1907 sq.km. The HUDA area is divided into 29 planning zones (11 zones inside municipal limits and 18 zones in the non-municipal limits or peripheral areas). The city is located around 580m above Mean Sea Level (MSL). It experiences a minimum temperature of 11.60C and a maximum of 40.50C with an average annual rainfall of 73.55 cms. The city is situated centrally between the other metropolises of Mumbai, Chennai and Bangalore and is well connected by road, rail and air.

Hyderabad is in central Telangana and is spread over an area of 260 km^2. The city lies in the Deccan Plateau and rises to an average height of 536 m over the ocean level. The city lies at 17.366° N scope and 78.476° E longitude. Hyderabad is honored with a one of a unique landscape – awesome rock formation which are around 2,500 million years of age; among the most seasoned and hardest rocks on the planet. Rough and sloping areas around the city are under devastation for urbanization. Rock edges and hillocks weathered into pleasant adjusting shapes are a piece of the Deccan Shield area. Rey and Pink Granites are among the world's oldest. Crops are commonly grown in the surrounding paddy fields. The city's soil type is mainly red sandy with areas of black cotton soil. Hyderabad falls in the seismic zone-II [1] and is seismically minimum presented to earthquakes.

The highest point in the city is Banjara Hills. The shape level falls gradually from west to east making pretty much a trough near the Musi River which passes through the city. This regular element has encouraged water supply by gravity. Height inside city shifts between 672mts in Banjara Hills and 456mts in Old City. Adjacent Southern Border satellite towns like Shadnagar have a normal rise of around 650mts consistently.

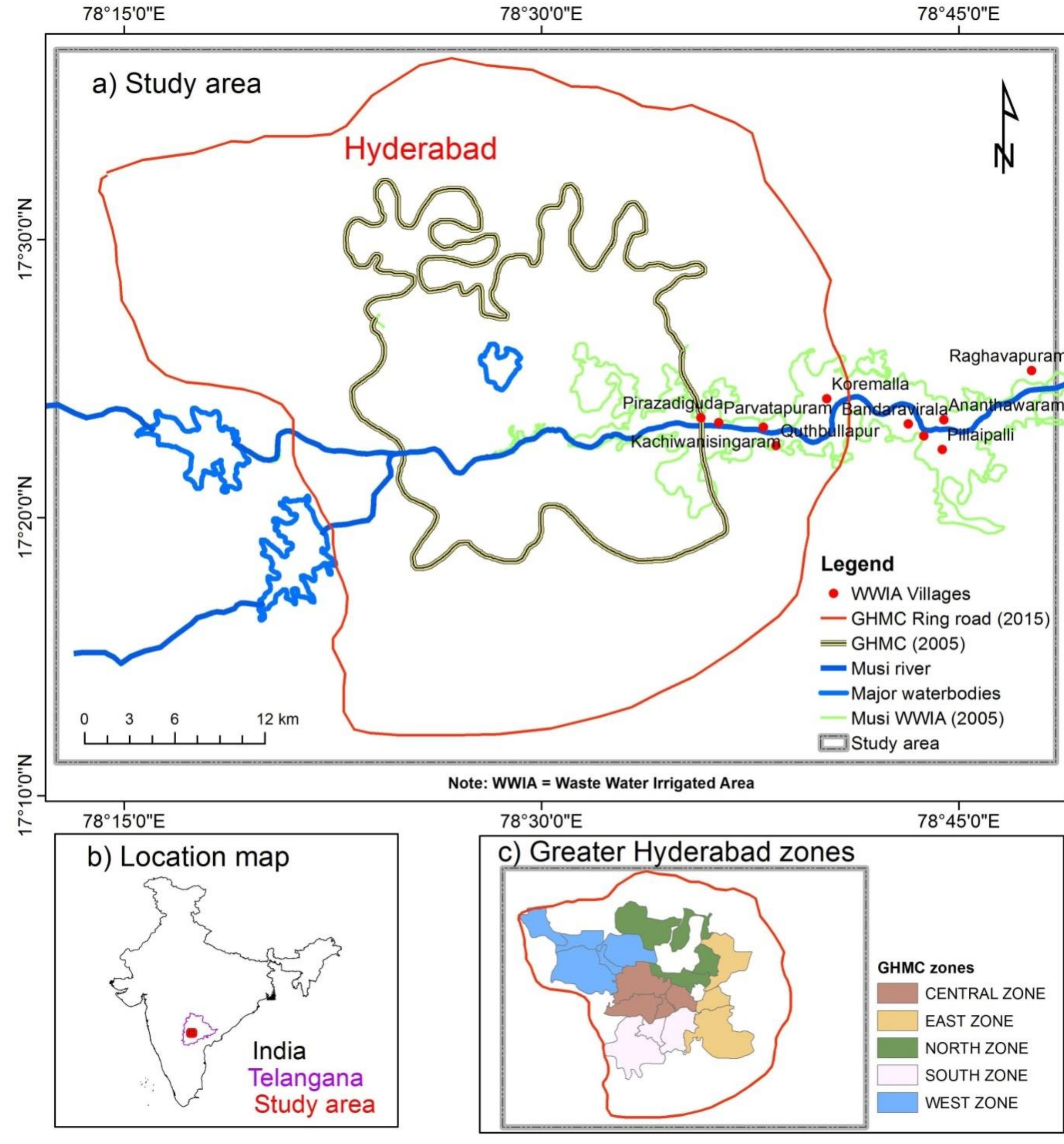

Figure 1.1 Study area showing with different features a) Greater Hyderabad Municipal Corporation (GHMC); b) location map of study area and c) GHMC zones

The original city of Hyderabad was established on the banks of river Musi and has developed over hundreds of years on the two banks of the river. Presently known as the historic "Old City", home to the Charminar and Mecca Masjid, it lies on the southern bank of the river. The city center saw a move toward the north of the river, with the development of numerous administration structures and landmarks. Hyderabad and Secunderabad are called as 'Twin cities' as they are firmly connected with each other. An artificial lake, known as the Hussain Sagar Lake, isolates the two urban communities. The fast development of the city, alongside the development of Secunderabad and neighboring regions has brought about a huge and crowded metropolitan area.

The Musi stream starts from Anantagiri Hills (found 70 km south west of Hyderabad) and joins Krishna River near Wazirabad in Nalgonda district. There are two dams built on it - Osman Sagar and HimayatSagar. Both these reservoirs constitute the major drinking water sources for Hyderabad city. These dams also prevented the city from flooding that encountered till the early decades of 20th century. Musi River was called Muchukunda River in pre-historic days. A few bridges cross the river; the oldest, called "PuranaPul"(literally meaning old bridge) was built during the 16th century by the QutbShahi sultans of Golconda.

Founded in the late 16th century on the banks of Musi River, the city is in the central area of the Deccan Plateau characterized by hard rocky and undulating topography. Hyderabad metropolitan region is isolated into three zones in view of the power of financial activity and its association with the city: (a) "the metropolitan center" inside a span of 10 - 13 km from the center city, (b) "the peri-urban zone" up to 26 km range and (c) "the rural hinterland" up to 64 km. (Map 3.7) The Hyderabad Urban Development Authority (HUDA) was set up in 1975 to regulate urban development in an area of about 1554 square km extending far beyond the limits of the municipal corporation, which then covered 171 square km. The HUDA was envisioned as administrative instead of an executing organization and was required to work autonomously of the state government. The jurisdiction of the HUDA now stretches out over an area of 1865 sq.km excluding Secunderabad Cantonment. The decadal development rate of Hyderabad Urban Agglomeration (HUA) was a high of 43% and 67% amid eighties, individually. Be that as it may, it boiled down to 31% amid 1991-2001. Its population has gone up from 2.55 million out of 1981 to 4.3 million out of 1991 and to 5.7 million of every 2001. With around 5.7 million population (firmly behind Bangalore) according to 2001 evaluation, the development of Hyderabad city has happened at a substantially quicker rate in the peripheries over the most recent few decades than in the metropolitan center. As needs be, numerous new exercises are developing in the outskirts with the active support of both the state and the private sector. These trends have significant implications for land use, urban planning, and policies in the coming years. The city has also acquired national and international image in recent years with the growth of software technology and efforts by the state government. 54 Map 3.7 Hyderabad land use map Much of the spatial expansion in the last two decades in the HUA has occurred in the surrounding municipalities. These towns recorded a high development rate of 71% in 1990's as compared with just 18.7% by the center city. A few of these towns have been developing at high rates from eighties onwards. 55 Together, their offer of population in the HUA has expanded from around 23 to 30% while there is a comparing decrease in that of the center city. These towns give a more prominent extension to statistic development since they represent a high extent of the area of HUA, and are having generally low densities an investigation based on remote sensing data uncovered that the developed area of Hyderabad city has expanded by around 136% during 1973-96, that is from 245 sq.km in 1973 to 355 sq.km in 1983, and from 522 sq.km in 1991 and to 587 sq.km in 1996. The urban sprawl (built-up area) has occurred at an annual rate of 3.77% during 1973-83, 4.95% during 1983-91 and 2.37% during 1991-96. Rural land to the extent of around 128 sq.km was changed over to private, business, institutional and modern purposes during this period. It was additionally observed that the urban developed area has expanded from 49.3 to 62.4% of the total land area during 1988 to 1999.This developed area has expanded at a considerably higher rate (44.5%) in the surrounding municipalities than that in the center city (2. 7%).There is an increase in the open space/playground/recreational area from 6.3 to 12.2 sq.km during this period. Though this appears as an encouraging sign, what is disturbing is that it is either the lakebeds or the parks that are converted into open spaces. The area under dense vegetation/plantations/garden has come down by 6.4% from 40.33 to 37.73 sq.km in the municipalities. Whatever little area was under rain-fed agriculture in core city in 1988 has disappeared by 1999. The area under this category has come down by 45% in the municipalities. Much of this decline has occurred in the municipalities especially along the Old Bombay Highway and ‘Hi-Tech City’ area in Serilingampally, Kukatpally, Qutbullapur, L.B. Nagar and Rajendranagar municipalities. Forest categories do not exist in the core city area. There is no change in their area put together in the municipalities and they constitute only about 11% of their area. 56 There is a substantial decline in the share of wastelands (scrub land) from 20.1 to 13.4% and in the barren rocky areas. It is significant to note that the area under water bodies (reservoir/tank) has come down by 8.6% from 22.79 to 20.84 sq.km. This decline has been steeper in the municipalities (12.0%) than that in core city (3.0%).

The condition of drinking water facility in the peripheries of Hyderabad city presents a depressing scenario. The towns with lower figures for latrines also have high percentage of households with open or no drainage category. Even where toilet facilities exist to a certain extent, there are no proper drainage facilities. (With extracts from Ramachandriah, Demographic Characteristics, Changing Land Use and Basic Amenities in the Periphery of Hyderabad City)

1.3.2 Climate:

Hyderabad has a one of a kind combination of a tropical wet and dry climate that borders on a hot semi-dry climate (Köppen climate classification BSh).

The climate of Hyderabad remains genuinely warm through most parts of the year and does not get much precipitation in the rainfall. With the beginning of winters in North and focal parts of India, temperatures hardly descend in the long stretches of December and January and the evenings turn out to be very cool in and around the Hyderabad city. During the mid-year months, the mercury goes as high as 42 °C while in winters the base temperature may come down to as low as 12 °Cajun to November are the months of monsoons, accompanied by rains. During the Monsoons, also the temperature goes down at times. In this way, almost a year the weather and climate of Hyderabad will be moderate and you can visit the Hyderabad city whenever in the year however the best season to visit Hyderabad is between October– February. Hot steppe type climate beats Hyderabad, Telangana district in which Hyderabad is in the hottest part of the State during summer and coldest in winter. The mean daily temperature varies from 30 °C to 36 °C from April to June and from 20 °C to 24 °C in the months of December and January.

The mean maximum temperature ranges between 39 °C and 43 °C in May. After the withdrawal of the monsoon, the maximum temperature rises slightly due to increased insulation. The mean minimum temperature is 13 °C to 17 °C in December and January, but it rises to 26 °C to 29 °C in May. The base temperature falls quickly after October, and less than 10 °C was recorded on individual days. The climate is charming from November to February. The late spring a long time of April and May are awkward because of abusive heat. The period from July to September is warm, humid and awkward.

1.3.3 Rainfall

More than 75 per cent of the rainfall is received during the south-west monsoon season, i.e., from June to September, July being the month when it rains. September is the month, when there are rains. The south-west monsoon sets in by the 7th of June. Its advent is sudden and the rainfall increases from less than 5 per cent (of the annual) in May to 15 per cent in June.

1.3.4 Humidity

Humidity during the monsoon season is high surpassing 75% from July to September. In the dry months of March, April and May, humidity is also low with a typical of 25 to 30%. June to October is the period when the greater part of the sky is secured with clouds, while just around 1/4 of the sky is clouded from January to March. Half of the days in July and August have overcast skies. About 10 to 13 days in the months of January, February and March, the skies are free from clouds in clear weather.

Recent Temperature Increases:

As per India Meteorological Department, the summer months of April and May 2009 recorded the hottest temperatures since 1901, with mean most extreme temperatures drifting as often as possible at around 42 °C with greatest temperature touching 45 °C.

1.3.5 Population:

Hyderabad has an expected population of 8.7 million with a population density of 18,480 individuals for every square kilometer (47,000/sq. mi). The Greater Hyderabad Municipal Corporation (GHMC) was made in 2007 to direct the city framework of the 18 "circles" of the city. This increased the area of Hyderabad from 175 square kilometers to 650 square kilometers, and the population developed by 87%. The GHMC has a population of 10 million, which makes it the sixth most crowded urban agglomeration in India. The GHMC's population has developed from 7.7 million of every 2011, indicating generous growth. Alluded as Hyderabadi, the occupants of Hyderabad are prevalently Telugu and Urdu talking individuals, with minority Bengali, Gujarati, Marathi and distinctive communities show here. Discussing about population, to look at the population of Hyderabad in 2017, we need a glance at the population of the previous 5 years. They are according to the following:

2012 – 6.9 Million

2013 – 7.3 Million

2014 – 8.2 Million

2015 – 8.9 Million

2016 – 10.2 Million

Looking at the population of Hyderabad from the year 2012-16, it has been noticed that there has been an increase of 3.3 Million in the past 5 years. Therefore, it has been seen that every year the population increases by 0.66 Million. Hence, the population of Hyderabad in 2017 is forecasted to be 10.86 Million. So, the population of Hyderabad in the year 2017 as per estimated data is 10.86 Million. Hyderabad'spopulation density is 18,480/km. The city is one of the quickest developing metropolitan regions in India, which has prompted numerous issues as far as livelihood and basic services. There has been an expansion in Hyderabad's slum population, which is credited to insufficient urban organizing and more prominent country to urban migration. There has been a 264% expansion in the population of slums in and around the city in the most recent decade, with 30% of the inhabitants acknowledged to live in a slum in the year 2014.

CHAPTER 2

LITERATURE REVIEW

Murali Krishna Gummaet al concentrated to explore land utilize changes in urban and peri-urban Hyderabad and their impact on wastewater irrigated rice utilizing Landsat ETM+ data and spectral matching strategies. The primary wellspring of water system water is the Musi River, which gathers an extensive volume of wastewater and storm water while going through the city. From 1989 to 2002, the wastewater inundated zone along the Musi River expanded from 5,213 to 8,939 ha with simultaneous development of the city limits from 22,690 to 42,813 ha and diminished desolate lands and range lands from 86,899 to 66,616 ha. Opportunistic shifts in land use, especially related to wastewater irrigated agriculture, were a response to the demand for fresh vegetables and easy access to markets, exploited mainly by migrant populations. While wastewater irrigated agriculture contributes to income security of marginal groups, it also supplements the food basket of many city dwellers. Landsat ETM+ data and advanced methods such as spectral matching techniques are ideal for quantifying urban expansion and associated land use changes, and are useful for urban planners and decision makers alike.

Doygun H1 et alstudied-onEffects of urban sprawl on agricultural land: a case study of Kahramanmaraş, Turkeyto quantify areal loss of olive groves due to urban sprawl of the city of Kahramanmaraş, Turkey. Spatial changes were analyzed by interpreting the digitized data derived from a black-white monoscopic aerial photograph taken in 1985, panchromatic IKONOS image of 2000 and two pan-sharpened Quickbird images of 2004 and 2006. Data obtained revealed that the area of olive groves decreased by 25% from 460.55 ha in 1985 to 344.46 in 2006, while the number of parcels increased from 170 to 445. Of the total areal loss, 60% was due to building constructions, with the rest being due to clear-cut for new residential gardens composed of exotic plants, new buildings, or new roads. Rapid population growth, increased land prices due to urban expansion, and abandonment of agricultural practices to construction of multi-story buildings were the main causes of the process that transformed the olive groves into urbanized areas. Results pointed to an urgent need to (1) revise the national and municipal land management practices, (2) balance the gap between the short- and long-term economic benefits that urban and community development plans ignore, and (3) monitor land-use changes periodically by using high resolution satellite images.

Murali Krishna Gummaet al has studied to research the adjustments in rice-growing area over 10 years (2000– 2009) utilizing remote-sensing techniques in blend with financial data and national statistics. Temporal rice area and land-utilize changes in Nepal were mapped utilizing MODIS (MOD09A1) 500 m time-series data and spectral matching techniques (SMTs). This examination presents mapped horticultural cropland change identified over a huge area, where fluffy order correctness's extend near 67% and 91% for different rice classes, with a precision of 82% for field-plot data. The MODIS-inferred rice areas for the regions were very related with national statistical data with R2 estimations of 0. 9918.We observed a significant decline (13%)in rice cultivated area in 2006 compared with the average over the remaining years. The higher reduction in rice area was mainly restricted to the rainfed districts of the eastern, central, and mid-western regions due to severe drought incidence, particularly in 2006. The area under the rainfed rice ecosystem keeps on prevailing, recording the largest sharing among rice classes over every one of the years from 2000 to 2009. The utilization of remote-sensing techniques is a quick, practical, and solid measure to screen changes in rice cultivated area over drawn out stretches of time and estimate the decrease in area developed because of climatic stress, for example, drought. Reinforced with methods and information in socioeconomics, these techniques could be used for mapping agricultural land-use changes, production planning, and targeting. Agricultural research and development institutions in Nepal can use these techniques for better planning, regular monitoring of land-use changes, and technology transfer

Bolca M[1], Turkyilmaz B, Kurucu Y, Altinbas U, Esetlili MT, Gulgun B et al studied on Determination of impact of urbanization on agricultural land and wetland land use in Balçovas' delta by remote sensing and GIS technique. Because of their intense vegetation and the fact that they include areas of coastline, deltas situated near big cities are areas of greet attraction for people who wish to get away from in a crowded city. However, deltas, with their fertile soil and unique flora and fauna, need to be protected. For the use of such areas to be planned in a sustainable way by local authorities, there is a need for detailed data about these regions. In this study, the changes in land use of the Balova Delta, which is to the immediate west of Turkey's third largest city Izmir, from 1957 up to the present day, were investigated. In the study, using aerial photographs taken in

1957, 1976 and 1995 and an IKONOS satellite image from the year 2005, the natural and cultural characteristics of the region and changes in the coastline were determined spatially. Through this study, which aimed to reveal the characteristics of the areas of land already lost as well as the types of land use in the Balçova delta and to determine geographically the remaining areas in need of protection, local authorities were provided with the required data support. Balçova consists of flat and fertile wetland with mainly citrus-fruit orchards and flower-producing green houses. The marsh and lagoon system situated in the coastal areas of the delta provides a habitat for wild life, birds. In the Balçova Delta, which provides feeding and resting for migratory birds, freshwater sources are of vital importance for fauna and flora. The settlement area, which in 1957 was 182 ha, increased 11-fold up to the year 2005 when it reached 2,141 ha. On the other hand, great losses were determined in farming land, olive groves, forest and in the marsh and lagoon system. This unsystematic and rapid urbanization occurring in the study region is not only causing the loss of important agricultural land and wetland, but also lasting water and soil pollution.

Gumma et al has studied to map the rice areas of six South Asian nations utilizing moderate-resolution imaging Spectro radiometer (MODIS) time-arrangement data for the day and age 2000 to 2001. South Asia represents just about 40% of the world's collected rice area and is additionally home to 74% of the population that lives on under $2.00 a day. The number of inhabitants in the area is becoming faster than its capacity to deliver rice. Thus, accurate and timely assessment of where and how rice is cultivated is important to craft food security and poverty alleviation strategies. We used a time series of eight-day, 500-m spatial resolution composite images from the MODIS sensor to produce rice maps and rice characteristics (e.g., intensity of cropping, cropping calendar) taking data for the years 2000 to 2001 and by adopting a suite of methods that include spectral matching techniques, decision trees, and ideal temporal profile data banks to rapidly identify and classify rice areas over large spatial extents. These methods are used in conjunction with ancillary spatial data sets (e.g., elevation, precipitation), national statistics, and maps, and a large volume of field-plot data. The resulting rice maps and statistics are compared against a subset of independent field-plot points and the best available subnational statistics on rice areas for the main crop growing season (kharif season). A fuzzy classification precision evaluation for the 2000 to 2001 rice-map product, in view of field-plot data, demonstrated accuracies from 67% to 100% for singular rice classes, with a general exactness of 80% for all classes. Most of the blending was inside rice classes. The determined physical rice area was exceedingly corresponded with the subnational statistics with R2 estimations of 97% at the district level and 99% at the state level for 2000 to 2001. These outcomes propose that the strategies, methodologies, calculations, and data sets we utilized are perfect for quick, exact, and extensive scale mapping of paddy rice and to generate their statistics over vast areas.

Gumma et al research was to delineate farming areas and clarify strategies and conventions utilizing remote sensing. Landsat Enhanced Thematic Mapper (ETM+) data and time-game plan Moderate Resolution Imaging Spectro radiometer (MODIS) data were used to diagram country areas and furthermore other land use/land cover (LULC) classes, for Ghana. Temporal varieties in the normalized difference vegetation index (NDVI) design acquired in the LULC class were utilized to recognize irrigated and non-irrigated areas. To start with, the temporal varieties in NDVI design were observed to be more predictable in long-term irrigated crops than with brief span rainfed trims because of more guaranteed water supply for irrigated areas. Second, surface water accessibility for irrigated areas is subject to shallow burrowed wells (on waterway banks) and burrowed outs (in stream bottoms) that influence the planning of yield sowing and development stages, which was thusly reflected in the occasional NDVI design. A choice tree approach utilizing Landsat 30 m one time data combination with MODIS 250 m time-arrangement data was received to order, gathering, and name classes. At long last, classes were tried and checked utilizing ground truth data and national statistics. Fuzzy classification exactness evaluation for the irrigated classes shifted near 67 and 93%. An irrigated area got from remote sensing (32,421 ha) was 20– 57% higher than irrigated areas announced by Ghana's Irrigation Development Authority (GIDA). This was a direct result of the vulnerabilities engaged with elements, for example, (a) nonattendance of shallow irrigated area statistics in GIDA statistics, (b) non-clearness in the irrigated areas in its utilization, a work in progress, and potential for improvement in GIDA statistics, (c) errors of omissions and commissions in the remote sensing approach, and (d) comparison involving widely varying data types, methods, and approaches used in determining irrigated area statistics using GIDA and remote sensing. Extensive field campaigns to help in better classification and validation of irrigated areas using high (30 m) to very high (<5 m) resolution remote sensing data that are fused with multi temporal data like MODIS are the way forward. This is especially true in accounting for small yet contiguous patches of irrigated areas from dug-wells and dug-outs.

Doygun H[1], Alphan H, KuşatGurun Det al aimed at quantifying changes in urban area of the city of Kahramanmaraş (K.Maraş) between 1948 and 2006, and analyzing suitability of existing land use (LU) to the land potential. Urban change information was derived from two black-white monoscopic aerial photographs, and IKONOS and the Quick Bird images acquired in 1948, 1985, 2000 and 2006, respectively. Quick Bird image and soil map with 1:25,000 scale was used to analyze suitability of the current LU pattern to the land potential. The findings showed that the urban area of Kamara's has expanded approximately 13 times during the past six decades. According to current LU and the soil map, productive and moderately productive soils were largely (73.2%) allocated for agricultural activities, which means that there was a strong consistency between the agricultural LU type and the land capability. However, widespread agriculture on the non-productive soils, and urbanization on the fertile agricultural lands were assessed as unsuitable from sustainable LU viewpoint. Considering this phenomenon, it is possible to say that rapid urban expansion has a growing pressure on the fertile agricultural soils. Monitoring LU changes, particularly urbanization, and developing effective LU plans based on the land capability were determined as the most important approaches to encourage sustainable use of land.

Kurucu Y[1], Chiristina NK et al has determined agricultural land loss and environmental pollution caused by industrialization and urban sprawl using the Geographical Information System (GIS) and Remote Sensing technique (RS). Remotely sensed data is the most powerful tool for monitoring land use changes and GIS is the best way to store and reproduce various kinds of integrated data. Considering the rapid increase of population, the loss of fertile agricultural soils is a very dangerous situation for the future of the country. Thus, people are living in the cities in (with adverse) conditions of insufficient drinking water, infrastructure problems, inadequate landscape and many unsolved (extreme) environmental problems. During the last 36 years, unplanned urbanization and industrialization have led to the use of agricultural areas for non-agricultural purposes in the Torbali (Izmir) region, which has the most fertile soils of the Aegean Region. Within this study, a database was created on the parameters of land loss and environmental pollution by means of field observation, interpretation of satellite images (ASTER), aerial photos (1/25.000 scale), topographic map, soil map, and 1/5.000 scale cadastral map. Results of previous researches and the archives of Torbali municipality were used as ancillary data. In the research, urbanization and industrialization of the town was studied by (using) GIS and RS between 1965 and 2001. Since 1965, 4,742,357 m2 agricultural land, mostly of first and second land use capability classes, has been lost due to unplanned urban and industrial developments. Urbanization and industrialization involved an area of which 58% was being used as irrigated lands, 25 % rain feed (rain fed lands) and 17 % for olive growing.

Gerald F. Winfieldet al examinedthe relationship between urbanization and agriculture. With heavy migrations from rural to urban areas in the United States, there have been significant changes in land utilization. Land converted to urban uses is increasing, though it has little effect on total crop production. The technological transformation of agriculture has had much larger effects and has operated as a push-pull on the cityward movement of people as farm functions have moved to the city. Energy and chemical fertilizers now come from urban bases, with large numbers of urban people working for farmers. Yields per acre and per farm worker have risen sharply so that needs for agricultural products are fully met. Urbanization and rising buying power have moved Americans up the food chain. The demand for expensive animal products grows. These forces have resulted in a dramatic escalation of solid waste production in cities and on farms. Urbanization and transformed agriculture have exploded the organic matter cycle. The nitrogen thrown away in farm and urban organic wastes in the United States each year equals 137 percent of the nitrogen in all chemical fertilizers. In contrast, China keeps her organic matter cycle intact and feeds a population four times as large as ours on an equal cultivated area. Future planning must meet the challenge of wasteful land utilization, the over shift of population to cities, and the problems of restoring the organic matter cycle.

C. H. Shankar Raoet al witnessed that fast urban advancement and expanding land utilize changes because of expanding population and financial development in selected landscapes is being witnessed recently in India and other developing countries. The estimation and checking of these lands utilize changes are essential to comprehend land utilize cover dynamics over various spatial and temporal time scales for compelling land management. Today, with rapid urbanization and industrialization, there is increasing pressure on land, water and environment, particularly in the big metropolitan cities. Urban sprawl may be defined as the scattering of new development on isolated tracts, separated from other areas by vacant land (Ottensmann,1977). It is additionally regularly depicted as leapfrog development (Gordon and Richardson, 1977) as saw in all the real urban communities over the world. Urban sprawl has been condemned for inefficient utilization of land assets and energy and large-scale infringement onto the agrarian lands. There are numerous issues related with divided transformation of agricultural land into urban utilize. The urban areas are extending every which way bringing about huge scale urban sprawl and changes in urban land utilize. The spatial example of such changes is plainly seen on the urban edges or city fringe provincial areas, at that point in the city focus. Unintentionally this is bringing about increment in the developed area and related changes in the spatial urban land utilize designs causing loss of profitable agriculture lands, forest cover, different types of greenery, loss in surface water bodies, exhaustion in ground water aquifers and expanding levels of air and water pollution. Further, it is generally concurred that fragmentation of land utilize is likewise unsafe to biological conservation. There have been lot of debates on how to confine urban sprawl and conserve agricultural land resources (Bryant et al., 1982; Ewing, 1997; Daniels, 1997). There is a demand to constantly monitor such changes and understand the processes for taking effective and corrective measures towards a planned and healthy development of urban areas. In the recent times, Remote sensing data is being widely used for mapping and monitoring of urban sprawl of cities. The spatial patterns of urban sprawl over different time periods, can be systematically mapped, monitored and accurately assessed from satellite data along with conventional ground data. In the present study 'Entropy Approach' for studying the urban sprawl patterns of Hyderabad over different time scales has been attempted in the present investigation. Further, the utilization the GIS for evaluating the urban sprawl patterns at different land utilize sites, viz., business, industrial, residential sensitive and mixed zones is likewise endeavored.

CHAPTER 3

SATELLITE DATA

3.1. Data and Methods

Three Landsat pictures accessible from the Earth Explorer http://earthexplorer.usgs.gov/, were utilized for investigation. These pictures were accessible for the rainy season (kharif) of 1989, 2002 and 2013 (Table 1). The digital numbers (DN values) were converted into reflectance to normalize the multi date effect (Thenkabail et. al., 2004).

Table 1.Characteristics of satellite data used in this study

Sensor	Spatial (meters)	Bands	band range **(µm)**	Irradiance **(**W m-2sr-1 mm-1**)**	Potential application
IRS-P6	23.6	2	0.52-0.59	1857.7	Water bodies and capable of differentiating soil and rock surfaces from vegetation
		3	0.62-0.68	1556.4	Sensitive to water turbidity differences
		4	0.77-0.86	1082.4	Sensitive to strong chlorophyll absorption region and strong reflectance region for most soils.
		5	1.55-1.70	239.84	Operates in the best spectral region to distinguish vegetation varieties and conditions
Landsat 8	30	1	0.43 - 0.45		

		2	0.45 - 0.51		Water bodies and capable of differentiating soil and rock surfaces from vegetation
		3	0.53 - 0.59		Sensitive to water turbidity differences
		4	0.64 - 0.67		Sensitive to strong chlorophyll absorption region and strong reflectance region for most soils.
		5	0.85 - 0.88		Especially important for ecology because healthy plants reflect it
		6	1.57 - 1.65		Particularly useful for telling wet earth from dry earth, and for geology: rocks and soils that look similar in other bands often have strong contrasts in SWIR.
		7	2.11 - 2.09		

3.2Image Normalization

The main purpose of this procedure is to normalize the multi-date effect [18,19] of Landsat images for better classification. Different period data have different radiometric resolutions [20](see Thenkabail *et al.*, 2004, 2002), hence their respective digital numbers (DNs) carry different levels of information and cannot be directly compared. Therefore, they were converted to absolute units of radiance (W m^{-2} sr^{-1}μm^{-1}), then to apparent at-satellite reflectance (%), and finally to surface reflectance (%) after atmospheric correction. Details on these conversions are provided due to the uniqueness of the sensors involved.

3.2.1. IRS-P6 data

IRS-P6 is an Earth perception mission inside the IRS (Indian Remote-Sensing Satellite) arrangement of ISRO (Indian Space Research Organization), Bangalore, India. The general goals of the IRS-P6 mission (ResourceSat-1) are to give proceeded with remote sensing data benefits on an operational reason for coordinated land and water resource management. IRS-P6 is the continuation of the IRS-1C/1D missions with considerably enhanced capabilities

DN to Radiance: The IRS-P6 data is 8 bit DNs were converted to radiances using the equation:

Spectral radiance is computed using the following equation:

$$R = \frac{(DN \times Gain)}{255}$$

Radiance to reflectance: A reduction in between-scene variability can be achieved through a normalization for solar irradiance by converting spectral radiance, as calculated above, to planetary reflectance or albedo [18,20](Markham and Barker, 1985; 1987). This joined surface and climatic reflectance of the Earth is registered with the following formula:

$$\rho_p = \frac{\pi L_\lambda d^2}{ESUN_\lambda \cos\theta_S} \quad ,$$

Where ρ_p is the at-satellite exo-atmospheric reflectance, L_λ is the radiance (W m^{-2} $sr^{-1}\mu m^{-1}$), d is the earth to sun distance in astronomic units at the acquisition date (see [27], $ESUN_\lambda$ is the mean solar exo-atmospheric irradiance (W m^{-2} $sr^{-1}\mu m^{-1}$)or solar flux (Neckel and Labs, 1984; Gumma et. al, 2017), and θ_S is solar zenith angle in degrees (i.e., 90 degrees minus the sun elevation or sun angle when the scene was recorded as given in the image header file).

3.2.2 Landsat 8 data

Standard Landsat 8 data items gave by the USGS EROS Center comprise of quantized and aligned scaled Digital Numbers (DN) speaking to multispectral picture data obtained by both the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). The items are conveyed in 16-bit unsigned whole number configuration and can be rescaled to the Top of Atmosphere (TOA) reflectance as well as brilliance utilizing radiometric rescaling coefficients gave in the item metadata document (MTL record), as quickly portrayed beneath. The MTL record additionally contains the thermal constants expected to change over TIRS data to the at-satellite shine temperature.

While the TIRS groups were intended to permit the utilization of split-window surface temperature recovery calculations, (for example, the utilization of split window techniques for atmospheric correction and recovery of surface temperature esteems), it is prescribed that clients cease from depending on band 11 data in quantitative investigation of the TIRS data because of the bigger adjustment vulnerability related with this band.

Since the dispatch of Landsat 8 of every 2013, thermal energy from outside the normal field of view (stray light) has influenced the data gathered in TIRS Bands 10 and 11. This change all through every scene and relies on brilliance outside the instrument field of view, which clients can't right in the Landsat Level-1 data item. Band 11 is fundamentally more polluted by stray light than Band 10. It is suggested that clients avoid utilizing Band 11 data in quantitative examination including utilization of Band 11 in split-wind surface temperature recovery algorithms.

3.2.3 Conversion to TOA Radiance

OLI and TIRS band data can be changed over to TOA spectral radiance utilizing the radiance rescaling factors gave in the metadata document:

$$L_\lambda = M_L Q_{cal} + A_L$$

where:

L_λ = TOA spectral radiance (Watts/ (m2 * srad * μm))
M_L = Band-specific multiplicative rescaling factor from the metadata

(RADIANCE_MULT_BAND_x, where x is the band number)

(RADIANCE_ADD_BAND_x, where x is the band number)
Q_{cal} = Quantized and calibrated standard product pixel values (DN)

A_L = Band-specific additive rescaling factor from the metadata

3.2.4 Conversion to TOA Reflectance

OLI band data can likewise be changed over to TOA planetary reflectance utilizing reflectance rescaling coefficients gave in the product metadata document (MTL record). The accompanying condition is utilized to change over DN esteems to TOA reflectance for OLI data as follows:

$$\rho\lambda' = M_\rho Q_{cal} + A_\rho$$

where:

$\rho\lambda'$ = TOA planetary reflectance, without correction for solar angle. Note that $\rho\lambda'$ does not contain a correction for the sun angle.

M_ρ = Band-specific multiplicative rescaling factor from the metadata (REFLECTANCE_MULT_BAND_x, where x is the band number)

Q_{cal} = Quantized and calibrated standard product pixel values (DN)

A_ρ = Band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x, where x is the band number)

The following equation is used to convert DN values to TOA reflectance for OLI data

$$\rho\lambda' = M_\rho Q_{cal} + A_\rho$$

Where: $\rho\lambda'$ is the TOA planetary reflectance (without correction of solar angle), M_ρ is the Band specific multiplicative rescaling factor from the meta data, A_ρ is the Band specific additive rescaling factor from the meta data and Q_{cal} is the quantized and calibrated standard product pixel values (DN)

TOA reflectance with correction for the sun angle is then:

$$\rho\lambda = \frac{\rho\lambda'}{\sin(\theta_{SE})}$$

Where: $\rho\lambda$ is the TOA planetary reflectance, $\rho\lambda'$ is the TOA planetary reflectance (without correction of solar angle) and θ_{SE} is the local sun elevation angle provided in the metadata (SUN_ELEVATION).

3.3 Ground survey datasets:

Ground survey data were collected during October 13-26, 2005 for 172 sample sites covering major land use/ cover classes and its fraction in the study area (Figure 1). In addition, ground truth observations were made extensively, while driving, by marking manually on topographic maps (1: 50,000) obtained from the Survey of India for further reference. The Geocover 2000 (https://zulu.ssc.nasa.gov/mrsid/) products were also used as additional information in class identification.

The approach we adopted was to look for contiguous areas of homogeneous classes within which we can sample (an approach like sampling for leaf area index, See Thenkabail *et al.*, 2003). A large contiguous information class constituted our sampling unit, within which we sample a representative area of 250 m by 250 m. The emphasis was on "representativeness" of the sample location in representing one of the classes to ensure precise geolocation of the pixel. Class labels were assigned in the field. Classes have the flexibility to merge to a higher class or break into a distinct class based on the land cover fractions observed at each location. The precise locations of the samples were recorded by a Garmin GPS unit. The sample size varied from 5-15 samples for each category. It is ideal to have at least 15 samples per category, which was not feasible due to limited resources. Class labels were assigned in the field.

At each location the following data were recorded: a) Land use/land cover (LULC) classes : crop type and other land use and land cover; b) Land cover types (% cover): trees, shrubs, grasses, built-up, water, fallow lands, weeds, different crops, sand, snow, rock, and fallow farms; c) Crop types: for Kharif, Rabi, and summer seasons; d) Cropping pattern: for Kharif, Rabi, and summer seasons; e) Cropping calendar (sowing to harvesting the crop): for Kharif, Rabi, and summer seasons; f) Irrigated, rainfed, supplemental irrigation at each location; and Digital photos hot linked @172 locations;

CHAPTER 4

METHODOLOGY

4.1 Flowchart

An overview of the comprehensive methodology for mapping land use / land cover areas including urban areas using Landsat 8 and IRS-P6 data presented in Figure 2.

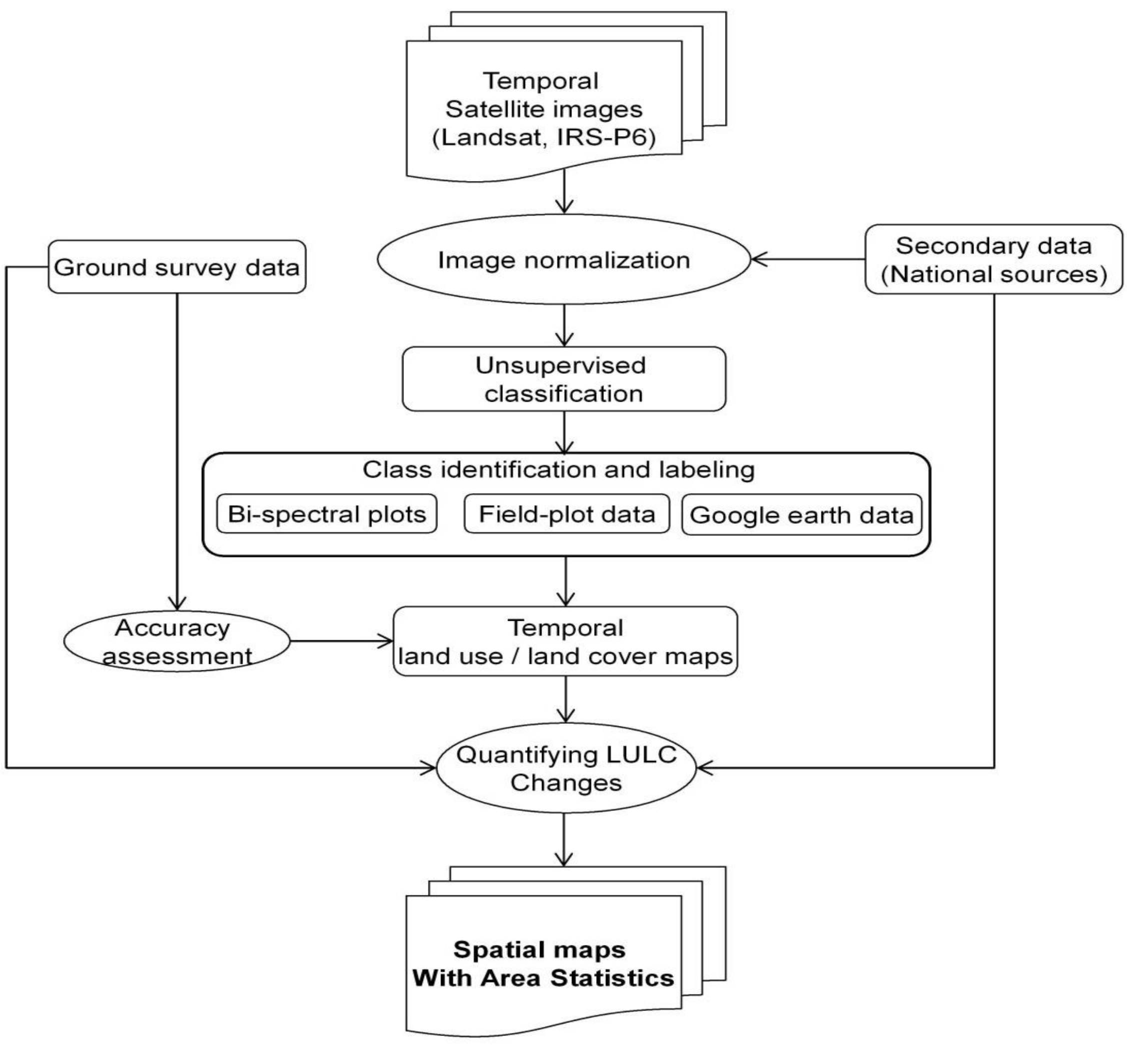

Figure 4. 1. Overview of the methodology for mapping Urban areas along with other land use / land cover areas using Landsat data (Gumma et al, 2017).

4.2 Software used

Software used for the research:

I. Land use/Land cover Mapping
   - ERDAS Imagine 14
   - Google Earth Pro
   - MODIS (250 m resolution) time series NDVI multi-spectral data

II. Geospatial Analysis
   - ArcGIS 10.4.1

III. Analysis and Report writing
   - Microsoft Excel and Word

4.3Classification methods

Methodology starts with normalization of IRS-P6 and Landsat images. Main purpose is to normalize the multi-date effect of images for better classification through reflectance values. In this process, the digital number of the pixels were first converted to radiance and then converted to reflectance using the equations given in. The meta-data needed for normalization are available in the header files.

A comprehensive methodology for mapping crop land areas using IRS-P6 and MODIS 250m data was adopted. The MODIS time series images were first converted into at-satellite reflectance and made single composite. MFD composite was then classified using unsupervised ISOCLASS cluster K-means classification with a convergence value of 0.99 and 50 iterations, yielding 50 classes followed by successive generalization. Unsupervised classification was used instead of supervised classification to capture the range of variability in phenology over the image across the study area. Initial grouping of classes based on decision tree algorithms, decision tree was applied to the 50 NDVI signatures that resulted from the unsupervised classification to group them into a manageable number of distinct classes. The decision tree is based on monthly NDVI thresholds at different crop growth stages in the season. The months and threshold volumes were picked in view of crop calendar from local specialists, field observation and in addition distributed rice crop development stages. crop strength class distinguishing proof and marking depended on MODIS

NDVI time-arrangement plots, perfect spectra, ground-truth data, and high-determination pictures (Google Earth). Perfect spectra were created utilizing time arrangement symbolism with exact recorded plot data of same sort of land use at spatially dispersed areas. The conventions included gathering class spectra based on class similarities and additionally contrasting them and perfect/target spectra, protocols for class identification, and naming with the utilization of substantial volumes of ground-truth data and high-resolution symbolism. After rigorous classification process, most of the classes were identified except some mixed classes. The processes were followed by resolving mixed classes through specifying GIS spatial analysis with DEM. Once the classes were identified, we combined the similar classes by visual matching using spectral correlation coefficient within the classes using spectral correlation coefficients. The spectral correlation coefficient is a combination of signature shape and magnitude.

Accuracy assessment was performed based on intensive field-plot information through error matrix.Error matrix based on a theoretical description given by [26], to generate an error matrix. The columns of an error matrix contain the field-plot data points and the rows represent the results of the classified rice maps [27]. The error matrix is a multi-dimensional table in which the cells contain changes from one class to another class [28]. The 81 points with major land use / land cover and irrigation types observations used for the classification accuracy assessment.

4.3.1 Mapping land use / land cover areas

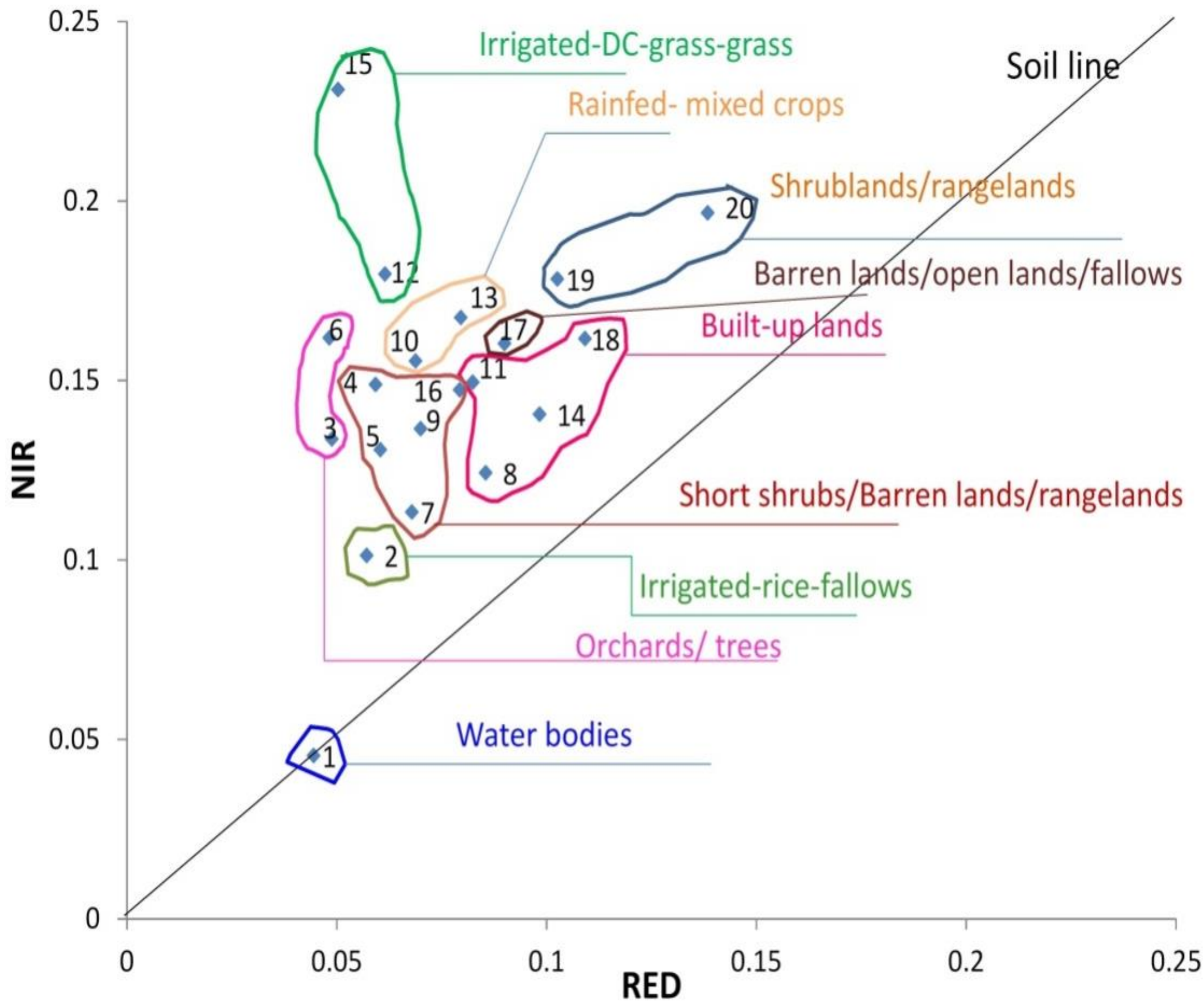

Figure 4. 2.Single date Bi-spectral plot of unsupervised classes. Unsupervised classes were plotted by mean class reflectance in red and NIR bands (Gumma et al, 2017).

The 100 unsupervised classes are plotted taking mean class reflectance in MODIS band 1 (red) and band 2 (NIR). The classes are shown in brightness-greenness-wetness (BGW) feature space and their preliminary class names identified for further investigations during ground truthing. Like Figure shown above TC SDs were plotted for each of the 42 dates.

CHAPTER 5
RESULTS AND DISCUSSION

The state government of Andhra Pradesh's spurt to establsih themsleves as one of the best IT hubs in the country during the 90's led to a process of changing policies for facilitation of such infrastructure and facilities along with its allied sectors. By 2001 the city was the largest urban agglomeration in India. Figure 5 explicitly portrays the observed changes in the urban sprawl of Hyderabad using IRS-P6 (2005, 2008, 2011) and Landsat imagery (2014, 2016). Built-up lands constituting housing and other buildings have doubled their occupation of land from 38,863 ha to 80,111 ha, especially at the cost of water bodies and rainfed croplands which have decreased to half (37,902 ha in 2016) of 2005 (72,817 ha). It can also be observed that there is a drastic increase in the built-up land in the west zone and East zones due to the expansion of IT sector in the former and industrial sector in the later zones.

Seasonal water bodies are the most exploited in the western, central and southern zones to built-up land. This has changed the temperature profile of the city and also ringing a bell towards drinking water crisis as well as groundwater recharge at no cost. Similarly is the case with rainfed croplands which have become miniscule due to urban expansion, specifically in the west zone, east zone and the north zone. Irrigated croplands have increased from 2005 to 2011 but decreased in 2016 due to low rainfall. The River Musi is the zone of waste water irrigated agriculture which ahs also incraesed steadily from 2005 to 2016. An important result in this land use change study is the increase in irrigated agriculture in the form of vegetable gardens using watsewater from the River Musi catering to the urban population. After the formation of Hyderabad Metropolitan development authority (HMDA) with a new master plan, many conservation measures have been laid out to sustaing dringking water sources such as Himayath sagar, Osmana sagar and Manjeera.

Table 5. 1. The 5-land use land cover areas for year 2005, 2008, 2011, 2014 and 2016.

	Area (Ha)				
LULC#	**Y2005**	**Y2008**	**Y2011**	**Y2014**	**Y2016**
01. Water bodies	12535	3584	5417	5694	2283
02. Built-up lands	38863	62000	68560	74131	80111
03. Irrigated-croplands	15553	14589	19966	19510	19678
04. Rainfed-croplands	72817	69601	53361	46815	37902
05. Other LULC	161635	151562	154288	155445	161583

5.1 LULC Classified Images

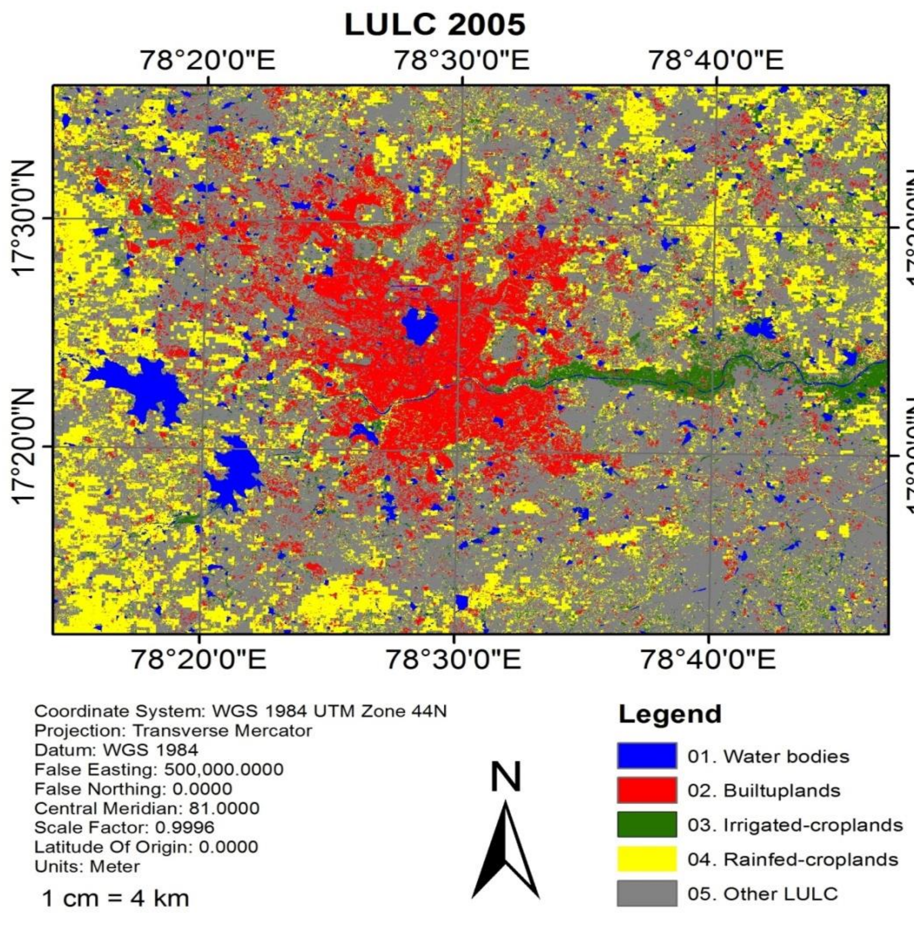

Figure 5. 1. LULC classes based on Landsat, IRS-P6 for 2005.

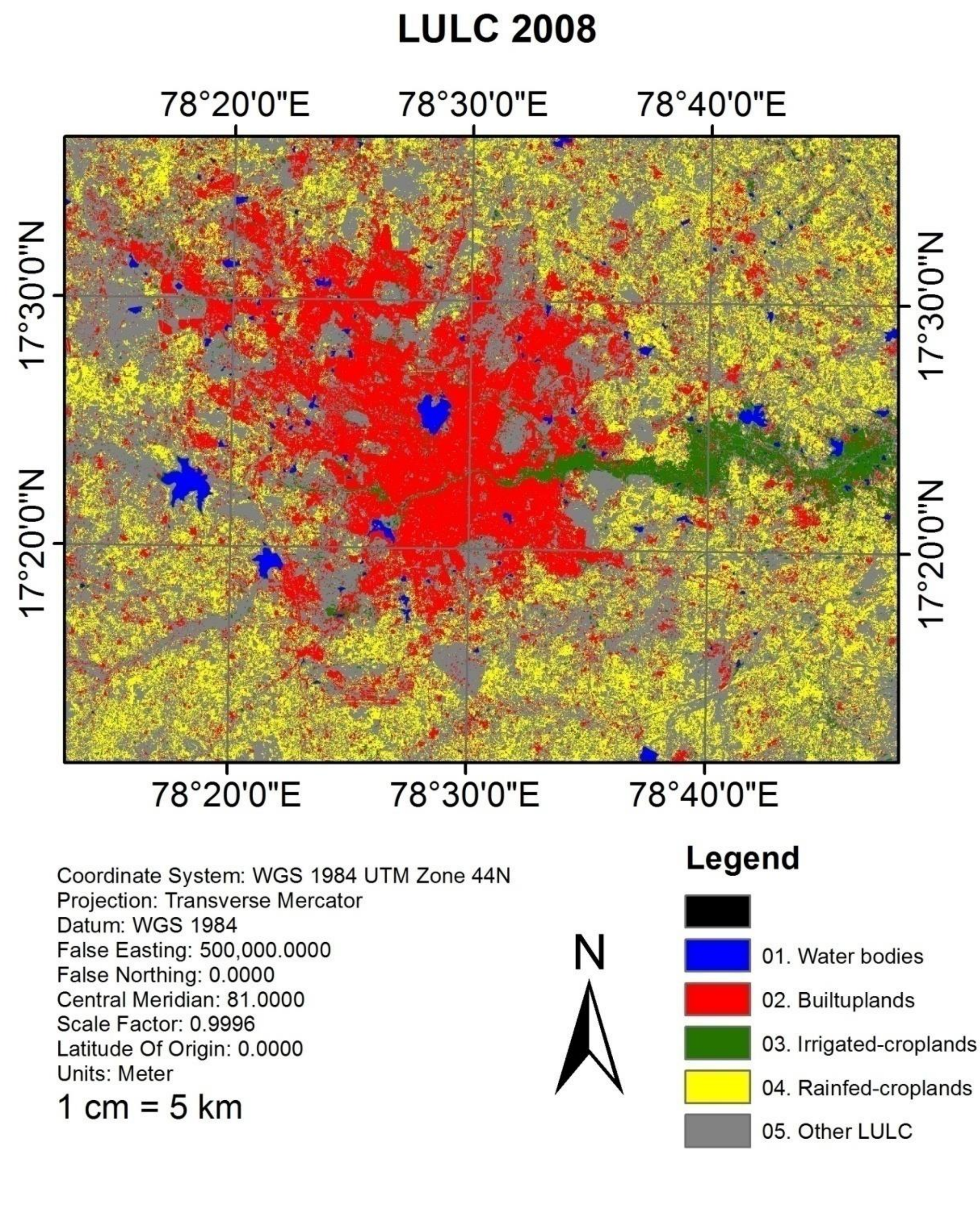

Figure 5. 2. LULC classes based on Landsat, IRS-P6 for 2008.

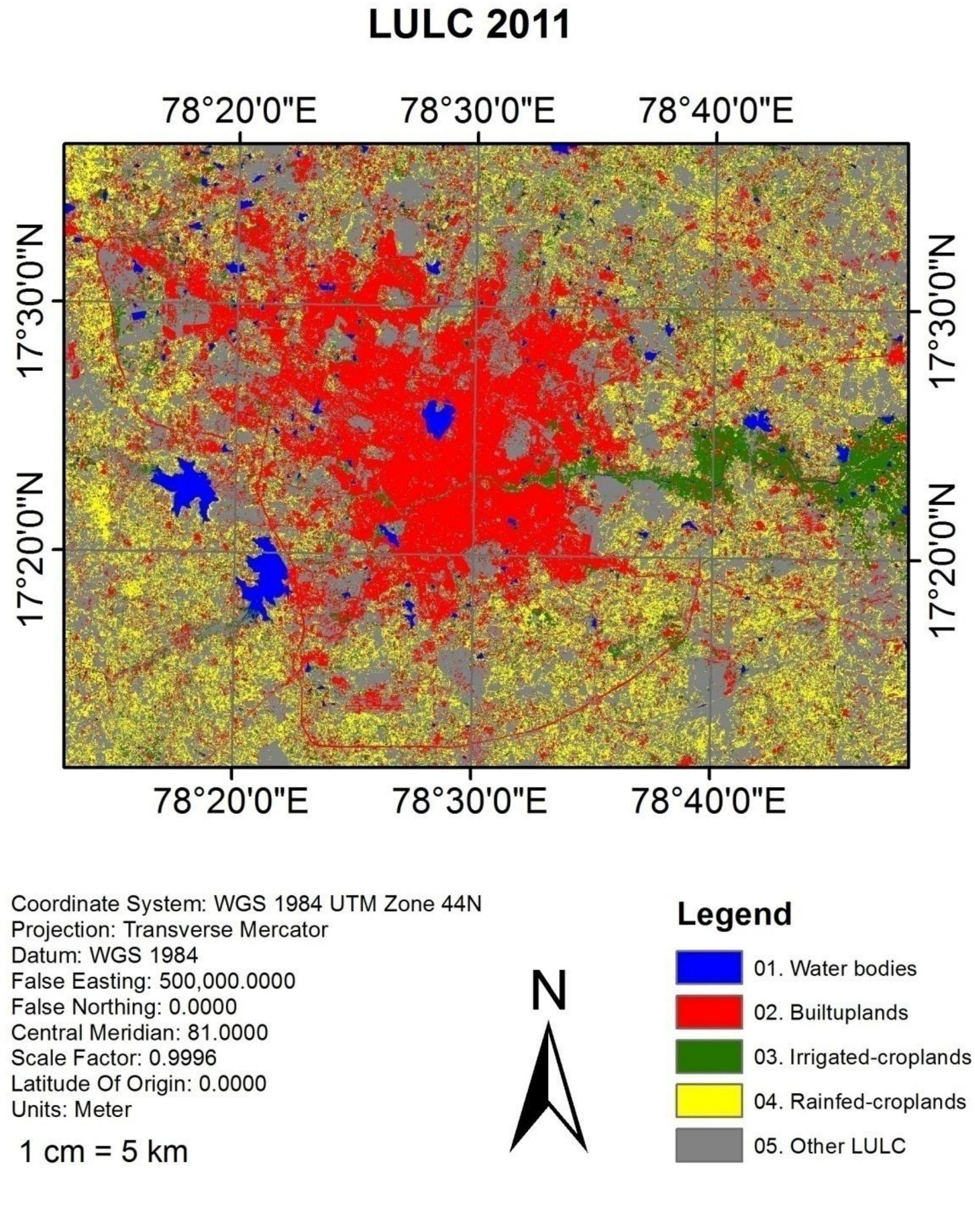

Figure 5. 3. LULC classes based on Landsat, IRS-P6 for 2011.

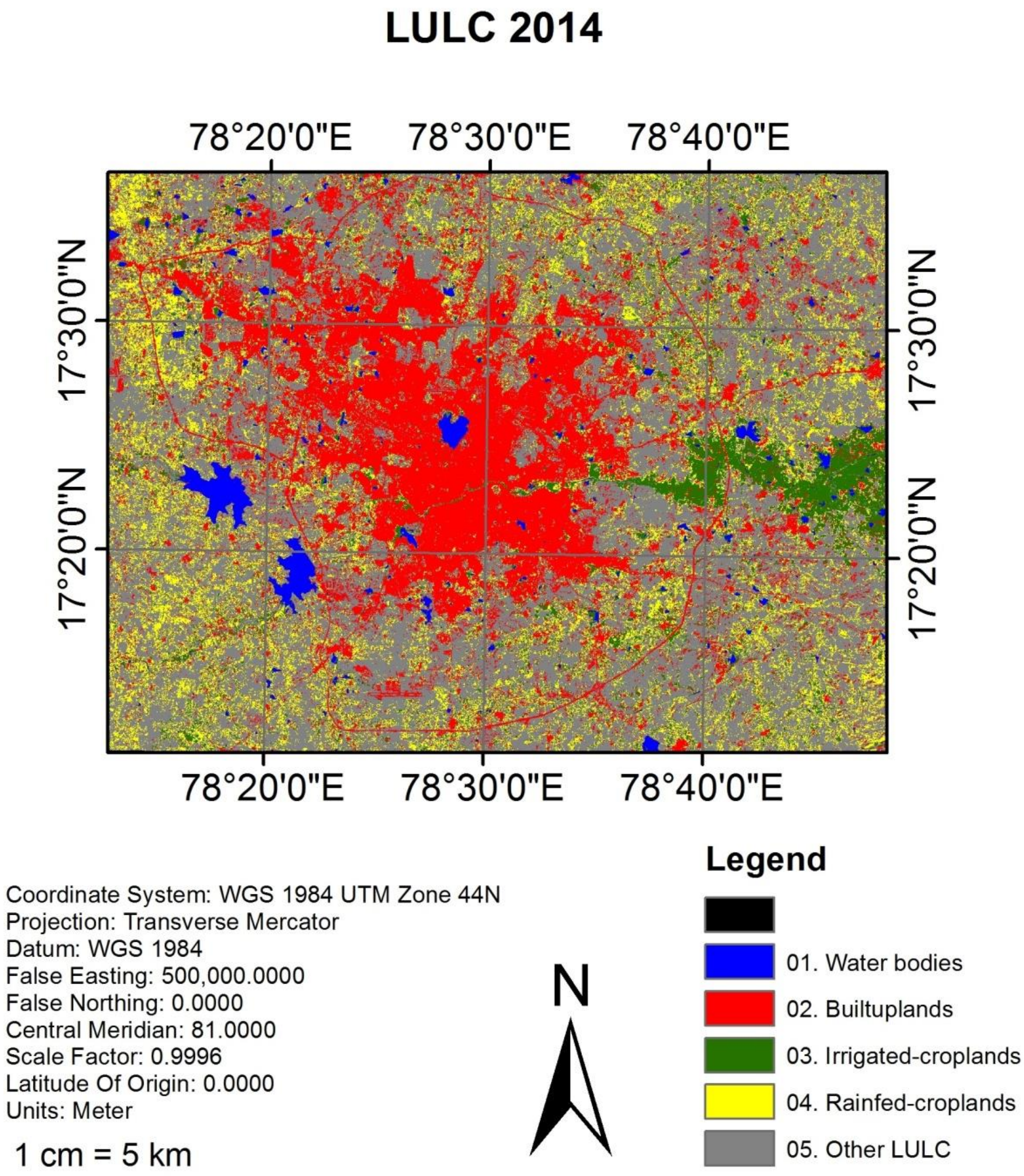

Figure 5. 4.LULC classes based on Landsat, IRS-P6 for 2014.

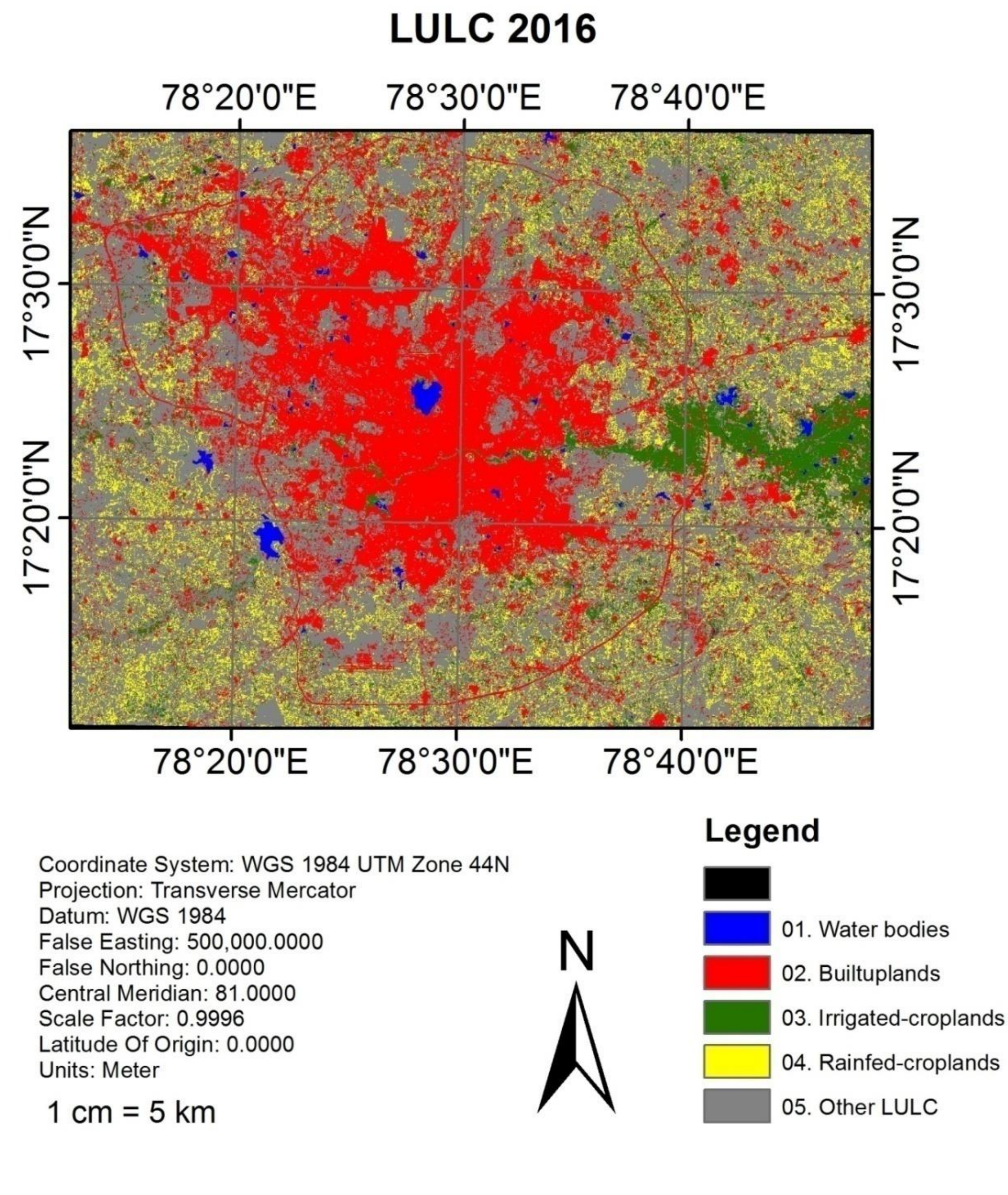

Figure 5. 5. LULC classes based on Landsat, IRS-P6 for 2016.

5.2 Accuracy assessment

Accuracy assessment was performed based on additional ground survey data (which was not used in classification), also performed individual years. Tables 3,4 and 5 shows the error matrices for the study area during 2005, 2011 and 2016.Accuracy assessment was performed through error matrix whether a known LULC class is classified as same class or another crop. This process was done using sixty fourlocations of ground survey observation points and they are summarized in Table 3. Each of the ground survey points refers to one of five classes. The user accuracy varied from 71% to 100% across five classes, with an overall accuracy of 81% for the year 2005, 83% for the year 2011 and 86% for the year 2016. So, if we combine all crop classes into one class, the accuracy of rice mapping will be very high (about 95%). So, the uncertainty of about 15% is due to the inter-mix among the various LULC classes. Therefore, accuracy will be very high between crop land and non-crop lands classes. The built-up areas and water bodies' classes generally have higher classification accuracies than the other LULCirrigated/rainfed classes (Tables 3,4, and 5)

Table 5. 2. Accuracy assessment based on ground survey data for the LULC classed of 2005.

Classified data	Reference data (Ground survey data)									
	01. Water bodies	02. Built-uplands	03. Irrigated-	04. Rainfed-croplands	05. Other LULC	Row Total	Number Correct	Producers Accuracy	Users Accuracy	Kappa
01. Water bodies	11	0	0	0	0	11	11	100%	100%	100%
02. Built-uplands	0	6	0	0	0	6	6	75%	100%	100%
03. Irrigated-croplands	0	0	3	0	1	4	3	50%	75%	72%
04. Rainfed-croplands	0	0	1	10	1	12	10	67%	83%	78%
05. Other LULC	0	2	2	5	22	31	22	92%	71%	54%
Column Total	11	8	6	15	24	64	52			

Table 5. 3. Accuracy assessment based on ground survey data for the LULC classed of 2011.

Classified data	Reference data (Ground survey data)									
	01. Water bodies	02. Built-uplands	03. Irrigated-croplands	04. Rainfed-croplands	05. Other LULC	Row Total	Number Correct	Producers Accuracy	Users Accuracy	Kappa
01. Water bodies	9	0	1	0	0	10	9	100%	90%	88%
02. Built-uplands	0	12	0	0	0	12	12	100%	100%	100%
03. Irrigated-croplands	0	0	5	1	1	7	5	71%	71%	68%
04. Rainfed-croplands	0	0	0	4	2	6	4	44%	67%	61%
05. Other LULC	0	0	1	4	20	25	20	87%	80%	68%
Column Total	9	12	7	9	23	60	50			

Table 5. 4. Accuracy assessment based on ground survey data for the LULC classed of 2016.

Classified data	Reference data (Ground survey data)									
	01. Water bodies	02. Built-uplands	03. Irrigated-croplands	04. Rainfed-croplands	05. Other LULC	Row Total	Number Correct	Producers Accuracy	Users Accuracy	Kappa
01. Water bodies	8	0	0	0	0	8	8	80%	100%	100%
02. Built-uplands	0	12	0	0	1	13	12	100%	92%	91%
03. Irrigated-croplands	1	0	7	0	0	8	7	70%	88%	85%
04. Rainfed-croplands	0	0	0	1	0	1	1	20%	100%	100%
05. Other LULC	1	0	3	4	31	39	31	97%	79%	62%
Column Total	10	12	10	5	32	69	59			

Table 5. 5. Land use / land cover changes from 2005 to 2011.

		Land use / land cover (2005)				
		01. Water bodies	02. Built-up lands	03. Irrigated-croplands	04. Rainfed-croplands	05. Other LULC
Land use / land cover (2011)	01. Water bodies	5011	0	126	94	186
	02. Built-up lands	1212	38863	1500	7792	19180
	03. Irrigated-croplands	1790	0	4265	5620	8278
	04. Rainfed-croplands	1114	0	2302	17292	32604
	05. Other LULC	3406	0	7358	42010	101367

Table 5. 6. Land use / land cover changes from 2005 to 2016.

		Land use / land cover (2005)				
		01. Water bodies	02. Built-up lands	03. Irrigated-croplands	04. Rainfed-croplands	05. Other LULC
Land use / land cover (2011)	01. Water bodies	2012	0	71	60	140
	02. Built-up lands	1345	38863	2033	9727	28130
	03. Irrigated-croplands	1890	0	4361	5339	8069
	04. Rainfed-croplands	1126	0	1709	11874	23155
	05. Other LULC	6161	0	7376	45801	102114

5.3.Urban expansion and other changes

A five year change analysis (Figure 6) shows similar changes, where there is transformation from one type of land use to another, such as built-up areas mushrooming from anyother type of land useespecially the rainfed croplands. A significant increase in the irrigated area is either due to underground water or waster water from the R. Musi. It can also be seen that the sprawl is expanding beyond the Outer Ring Road (Nehru ORR) which was supposed to regulate the increasing heavy transport traffic.

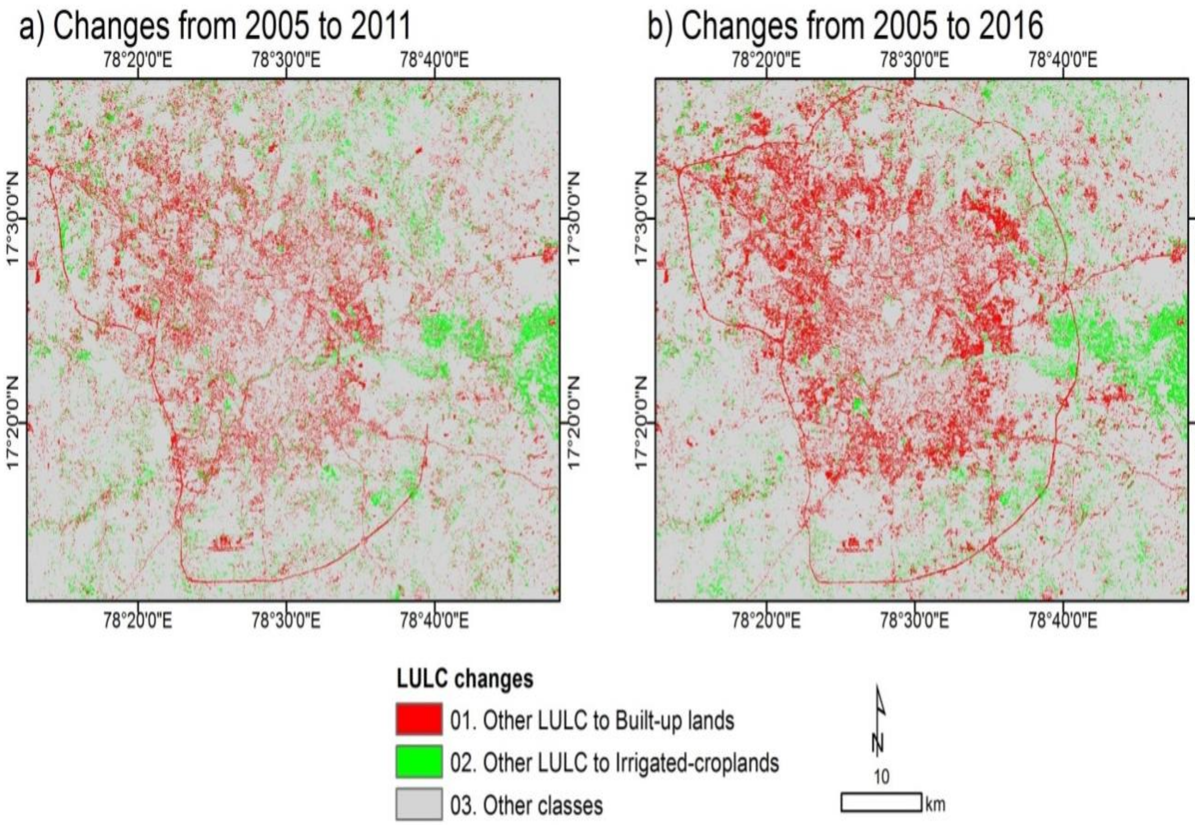

Figure 5. 6. The 5 LULC classes based on Landsat, IRS-P6 and MODIS time series data for 2005, 2008, 2011, 2014 and 2016 (Gumma et al 2017).

Table 5. 7. Land use / land cover changes in area from 2005 to 2011 & 2005 to 2016.

LULC changes	Area (ha)	
	2005-2011	2005 to 2016
01. Other LULC to Built-up lands	29684	41235
02. Other LULC to Irrigated-crop	15688	15297
03. Other classes	256221	245062

5.4. Grid wise area calculation:

Areas of Lulc classified maps for the years 2005,2008,2011,2014,2016 are obtained by dividing into 35 grids. Each grid specified area of water bodies, built up lands, Irrigatedcroplands, rainfedcroplands, other lulc has been calculated using Arc Gis and are given below.

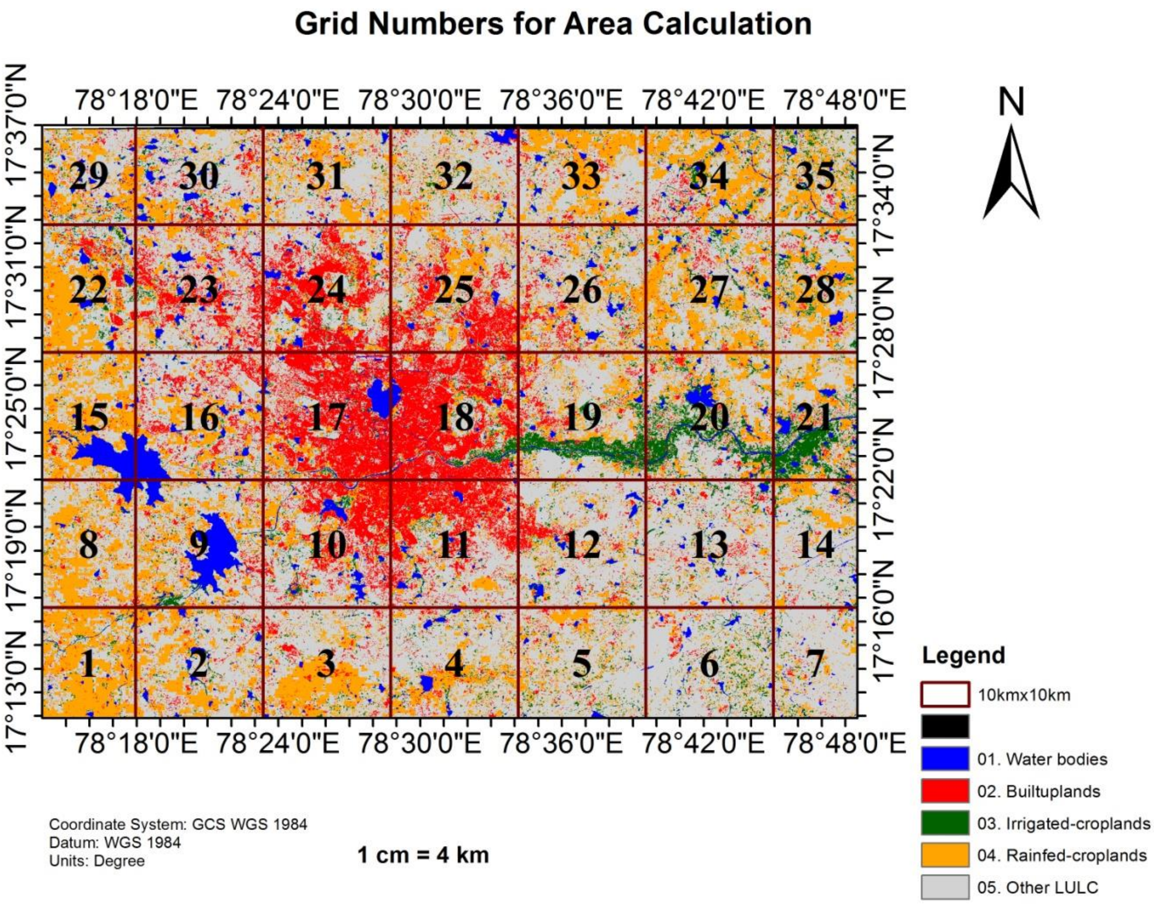

Figure 5. 7. Grid wise numbered LULC map

`

Table 5. 8. Water bodies grid wise area for the years 2005,2008,2011,2014,2016

wb05	wb08	wb11	wb14	wb16
186	1	12	13	0
305	8	27	99	12
123	8	25	31	2
323	14	22	34	2
345	121	3	143	8
248	16	17	45	9
125	8	15	19	3
236	39	71	121	4
1582	307	1265	1189	380
474	236	217	227	103
241	64	90	81	60
291	51	73	96	51
246	16	32	133	34
147	32	46	47	25
1085	188	411	630	2
873	496	539	582	190
597	393	411	366	352
300	157	127	135	123
183	61	59	48	[illegible]
512	248	258	216	138
355	202	202	196	181
363	95	175	150	66
414	159	197	155	87
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
195	58	26	25	1
334	33	116	157	48
439	86	252	213	71
176	17	76	42	12
210	73	173	89	48
185	15	26	31	14
270	51	49	48	10
144	16	11	9	0

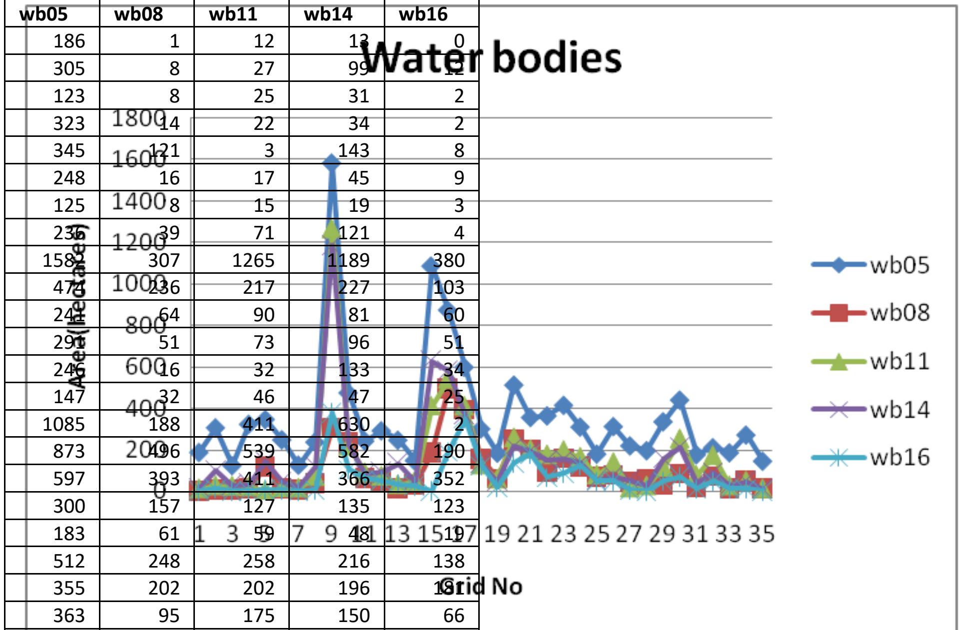

Figure 5. 8. Water bodies grid wise area variation in the years 2005,2008,2011,2014,2016

Table 5. 9. Built-up lands grid wise area for the years 2005,2008,2011,2014,2016

BU05	BU08	BU11	BU14	BU16
302	571	655	490	531
451	742	939	798	851
626	1284	1382	1195	1267
459	783	1017	1107	1193
388	662	889	1139	1242
288	549	657	663	707
138	241	374	349	354
334	877	750	644	704
553	1521	1560	1324	1539
2792	4200	4523	4952	5283
3559	4925	4896	5670	6006
828	1354	1639	2097	2358
548	1093	1186	1529	1646
204	332	525	519	541
321	614	1017	852	921
1386	3017	3311	3429	4043
5229	6479	6829	7233	7361
5523	6495	7168	7617	7722
789	1577	1939	2537	2915
484	809	1153	1082	1146
225	335	425	385	392
752	1495	1987	2057	2326
2142	4248	4255	4876	5555
3486	4984	5213	5782	6123
2704	3806	4238	4478	4787
848	1727	1853	2460	2862
543	971	1161	1285	1414
252	447	717	735	779
376	916	1043	963	1042
599	1681	1502	1830	2010
429	1097	1163	1402	1569
423	789	889	995	1125
326	508	612	636	711
409	608	856	790	843
135	256	216	208	220

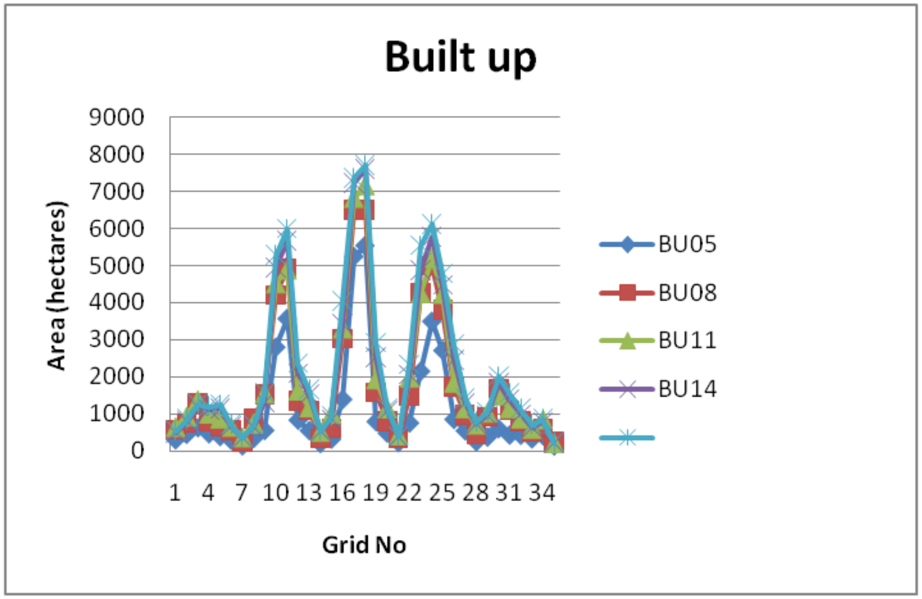

Figure 5. 9. Built-up land grid wise area variation in the years 2005,2008,2011,2014,2016

.

Table 5. 10. Irrigated croplands grid wise area for the years 2005,2008,2011,2014,2016

ic05	ic08	ic11	ic14	ic16
262	132	505	632	608
260	147	351	396	393
276	193	418	306	302
357	183	392	530	542
404	220	563	682	697
630	370	392	562	563
210	301	232	276	284
220	147	227	211	196
403	194	474	338	348
420	414	430	236	253
243	162	391	274	252
348	211	468	537	521
407	319	384	484	490
306	410	810	886	941
212	223	490	417	416
241	210	311	175	167
283	440	258	216	210
541	794	472	242	241
1493	1680	1221	1039	1051
1802	2505	2408	3076	3136
1414	2071	2620	2842	2900
422	281	709	436	431
263	215	360	160	155
298	248	363	128	122
250	156	432	234	224
414	247	738	771	774
547	344	419	577	579
430	190	118	125	131
311	203	409	372	378
268	207	409	260	267
231	220	490	421	421
258	180	533	377	381
170	144	582	553	561
461	352	476	602	604
489	273	100	127	128

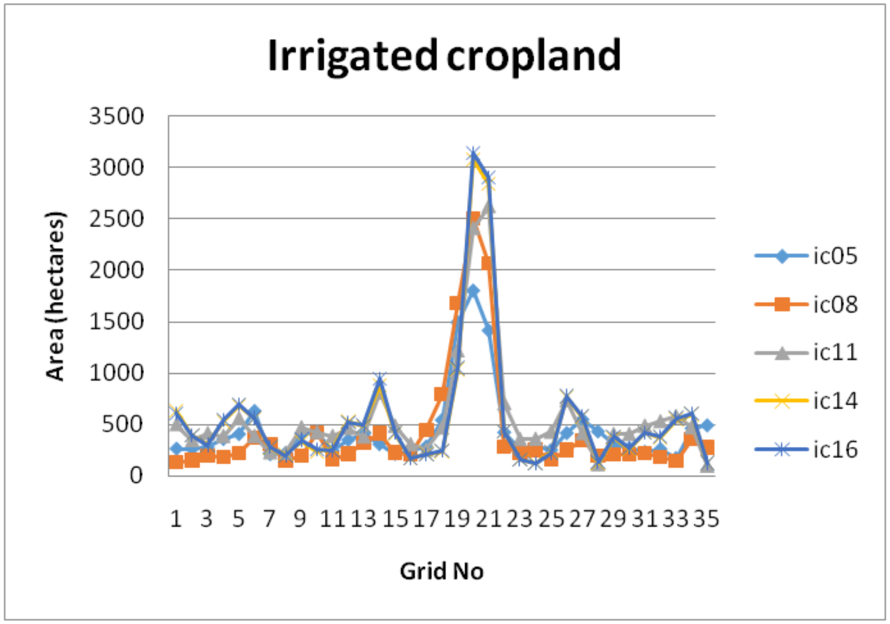

Figure 5. 10. Irrigated cropland grid wise area variation in the years 2005,2008,2011,2014,2016

Table 5. 11. Rainfed Croplands grid wise area for the years 2005,2008,2011,2014,2016

rc05	rc08	rc11	rc14	rc16
6152	3178	2865	2568	2018
3082	3510	2667	2064	1968
3023	3213	2280	1547	1654
2205	2995	2145	1556	1591
1616	3501	2667	1401	1752
885	3203	2600	1800	2094
750	1803	1620	1581	1249
3991	2478	2666	2490	1759
2351	2237	1557	1509	1280
1290	730	690	766	264
1043	1133	1115	716	460
1237	2115	2227	1616	1078
875	2997	2400	1341	1569
965	2397	938	841	1117
4407	2482	2149	2029	1562
1943	1379	938	1071	386
716	120	145	422	33
751	40	65	309	47
1702	1958	1448	1050	992
1888	1973	1534	1410	1050
1386	1223	748	724	673
4392	1083	1541	2581	799
1179	1195	926	844	436
1114	627	544	594	253
1917	972	714	1128	478
2183	2552	1327	1419	1065
3259	3063	2129	1410	1461
2128	2257	1154	1095	1260
2640	1787	1987	1959	1220
1486	1488	1001	782	899
1866	1771	1138	998	814
1369	2044	1310	1401	1044
2731	2138	1654	1662	1160
2626	2361	1480	1122	1278
1592	1556	917	949	1085

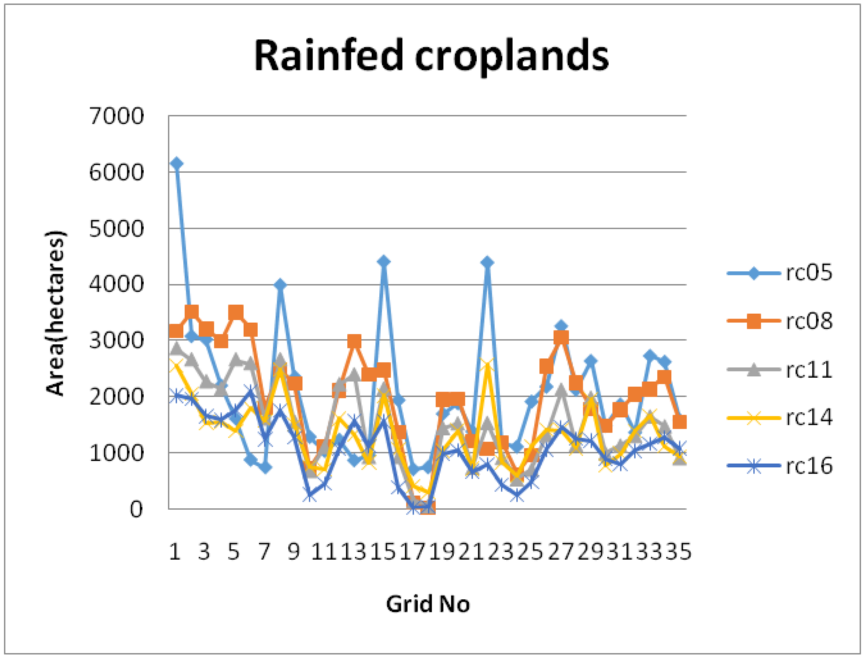

Figure 5. 11. Rainfed Croplands grid wise area variation in the years 2005,2008,2011,2014,2016

Table 5. 12. Rainfed Croplands grid wise area for the years 2005,2008,2011,2014,2016

otl05	otl08	otl11	otl14	otl16
2642	5663	5509	5842	6387
5445	5137	5559	6187	6320
5496	4845	5438	6464	6317
6197	5566	5965	6313	6212
6786	5036	5417	6175	5840
7489	5401	5873	6469	6166
5004	3891	3999	4023	4353
4759	6000	5827	6075	6878
4648	5278	4683	5178	5991
4562	3957	3678	3356	3634
4450	3254	3046	2797	2759
6831	5805	5130	5190	5528
7459	5110	5532	6047	5795
4601	3069	3914	3953	3616
3511	6028	5469	5607	6635
5092	4433	4436	4278	4749
2708	2101	1891	1296	1579
2418	2046	1701	1229	1399
5364	4255	4863	4857	4554
4844	3994	4176	3745	4059
2841	2406	2233	2089	2084
3602	6576	5119	4307	5909
5532	3714	3793	3495	3296
4321	3550	3245	2885	2908
4479	4524	4065	3634	3990
5770	4922	5470	4804	4774
rid4958	5100	5801	6199	6066
3214	3282	4207	4246	4056
3473	4190	3591	3695	4458
4342	3668	3982	4064	3904
4431	4024	4283	4287	4335
4873	4043	4240	4285	4549
3719	4321	4256	4251	4686
3365	3754	4273	4575	4402
2294	2563	3414	3370	3230

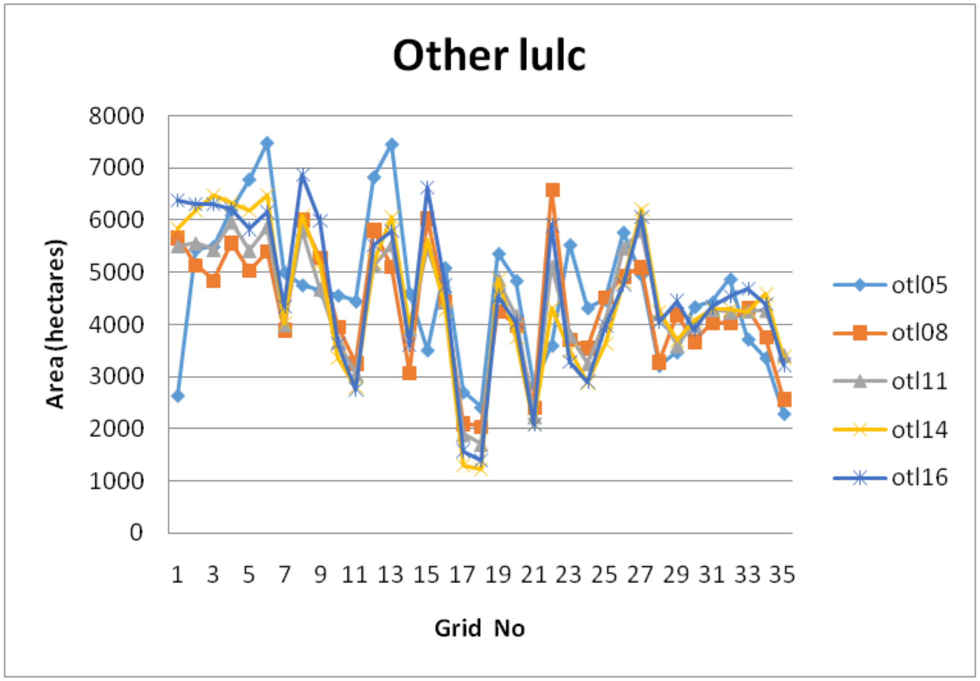

Figure 5. 12. Other lulc grid wise area variation in the years 2005,2008,2011,2014,2016

`

CHAPTER 6

CONCLUSION

This paper analyzed urban expansion along with other land use land cover changes by using IRS-P6, landsat-8, Modis time series data with ground-survey data. Land use class identifications were done based on bi-spectral plots and ground survey data, also classes were compared with high resolution google Earth high resolution imagery. The major land use / land cover classes were mapped with error matrix accuracy between 80 and 86%.

Present study demonstrates significant strengths in using IRS-P6 23.6 m and Modis data along with ground survey data in identifying fragmented and minor crop land areas with irrigation sources, such as waste water irrigation and rainfed agriculture. However, fragmented mixed cropland areas are better mapped using IRS-P6 data in fusion with time-series coarser resolution data.

There is a large juxtaposition of land uses due to increased urban sprawl in the city of Hyderabad. 92% of the 3000 lakes around the city are extinct now. The satellite image analysis proves the point (Table 6& 7). Of the 12534-ha total area under water bodies in 2005, around 1900 ha is converted to agriculture along with 1210 ha to built-up land until 2011 and 3016 ha to agriculture along with 1345 ha to built-up land until 2016. In consequence of the lost water bodies 2302 ha is converted to rainfed agriculture from irrigated area along with 1500 ha to built-up land until 2011 and 1709 ha to rainfed agriculture along with 2033 ha to built-up area until 2016.Also, a consistent increase in built-up land from all other land uses is reflected in the rainfed croplands too. Rainfed croplands lost around 7792 ha until 2006 and 9727 ha until 20011 apart from the increase in built up land from other land use/ land cover. Another important conclusion from this study is that the rainfed areas have consistently decreased from 2005 to 2011 to 2016 and irrigated areas have not changed during the same time.

The methodology developed in this study is useful in understanding the change dynamics of land use from one to many types of land and many to one type of land use. The application of remote sensing to socio-economic research adds a spatial dimension in terms of locational importance of socio-economic factors to the biophysical environment. In this study, the expansion of the sprawl being uniform around the central core, the most important loss to the city is its water bodies and balancing the act is the irrigated agriculture (waste water) from the Musi River. Apart from the vegetable and fruit supply from the peri-urban area, there is no evidence of the dynamics of staple food crops which feed the peri-urban population. The increased built-up area from 2005 to 2016 is totaled to 11,760 ha which is lost from agricultural land. The consequential reduction in the food production is irreversible and this burden is shifted to the surrounding area in its land use pattern. Also, its impact on the urban weather profile in terms of expanded heat islands and temperature differences is another important dimension.

REFERENCES

1. **Alqurashi, A.; Kumar, L.; Sinha, P.,** Urban land cover change modelling using time-series satellite images: A case study of urban growth in five cities of saudi arabia. *Remote Sensing* **2016**, *8*, 838.
2. **Ambast, S.K.; Keshari, A.K.; Gosain, A.K.,** Satellite remote sensing to support management of irrigation systems: Concepts and approaches. *Irrigation and Drainage* **2002**, *51*, 25-39.
3. **Bastiaanssen, W.G.M.; Molden, D.J.; Thiruvengadachari, S.; Smit, A.A.M.F.R.; Mutuwatte, L.; G., J.***Remote sensing and hydrologic models for performance assessment in sirsa irrigation circle, india*; International Water Management Institute: **1999**.
4. **Biggs, T.W.; Thenkabail, P.S.; Gumma, M.K.; Scott, C.A.; Parthasaradhi, G.R.; Turral, H.N.,** Irrigated area mapping in heterogeneous landscapes with modis time series, ground truth and census data, krishna basin, india. *International Journal of Remote Sensing* **2006**, *27*, 4245-4266.
5. **Cao, H.; Liu, J.; Fu, C.; Zhang, W.; Wang, G.; Yang, G.; Luo, L.,** Urban expansion and its impact on the land use pattern in xishuangbanna since the reform and opening up of china. *Remote Sensing* **2017**, *9*, 137.
6. **Congalton, R.G.,** A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment* **1991**, *37*, 35-46.
7. **Congalton, R.G.; Green, K.,** Assessing the accuracy of remotely sensed data: Principles and practices. In *New York: Lewis.*, **1999**.
8. **Deelstra, T.; Girardet, H.,** Urban agriculture and sustainable cities. ***Bakker N., Dubbeling M., Gündel S., Sabel-Koshella U., de Zeeuw H. Growing cities****, growing food. Urban agriculture on the policy agenda. Feldafing, Germany: Zentralstelle für Ernährung und Landwirtschaft (ZEL)* **2000**, 43-66.
9. **Draeger, W.C.,** Monitoring irrigated land acreage using landsat imagery: An application example. In *ERIM Proc. of the 11th Intern. Symp. on Remote Sensing of Environment*, United States, **1977**; pp 515-524.

10. **Guderyahn, L.B.; Smithers, A.P.; Mims, M.C.,** Assessing habitat requirements of pond-breeding amphibians in a highly urbanized landscape: Implications for management. *Urban Ecosystems* **2016**, *19*, 1801-1821.
11. **Gumma, M.K.; Gauchan, D.; Nelson, A.; Pandey, S.; Rala, A.,** Temporal changes in rice-growing area and their impact on livelihood over a decade: A case study of nepal. *Agriculture, Ecosystems & Environment* **2011**, *142*, 382-392.
12. **Gumma, M.K.; Nelson, A.; Thenkabail, P.S.; Singh, A.N.,** Mapping rice areas of south asia using modis multitemporal data. *Journal of Applied Remote Sensing* **2011**, *5*, 053547.
13. **Gumma, M.K.; Thenkabail, P.S.; Hideto, F.; Nelson, A.; Dheeravath, V.; Busia, D.; Rala, A.,** Mapping irrigated areas of ghana using fusion of 30 m and 250 m resolution remote-sensing data. *Remote Sensing* **2011**, *3*, 816-835.
14. **Gumma, M.K.; Thenkabail, P.S.; Muralikrishna, I.V.; Velpuri, M.N.; Gangadhararao, P.T.; Dheeravath, V.; Biradar, C.M.; Acharya Nalan, S.; Gaur, A.,** Changes in agricultural cropland areas between a water-surplus year and a water-deficit year impacting food security, determined using modis 250 m time-series data and spectral matching techniques, in the krishna river basin (india). *International Journal of Remote Sensing* **2011**, *32*, 3495-3520.
15. **Gumma, M.K.; Van Rooijen, D.; Nelson, A.; Thenkabail, P.S.; Aakuraju, R.V.; Amerasinghe, P.,** Expansion of urban area and wastewater irrigated rice area in hyderabad, india. *Irrigation and drainage systems* **2011**, *25*, 135-149.
16. **Gumma, M.K, Mohammad, I., Nedumaran, S., Whitbread, A., Lagerkvist, C.,** 2017. "Urban Sprawl and Adverse Impacts on Agricultural Land: A Case Study on Hyderabad, India." *Remote Sensing* 9 (11):1136.
17. **Gumma, M.K.; Deevi, K.; Mohammed, I.; Varshney, R.; Gaur, P.; Whitbread, A.** 2017,. Satellite imagery and household survey for tracking chickpea adoption in andhra pradesh, india. *International Journal of Remote Sensing*, *37(8)*, 1955-1972.
18. **Jensen, J.R.,***Iintroductory digital image processing: A remote sensing perspective, third edition, prentice hall, up- per saddle river, n.J., 544p.***2004**.
19. **Markham, B.L.; Barker, J.L.***Landsat mss and tm post- calibration dynamic ranges, exoatmospheric reflectances and at-satellite temperatures*; Earth Observation Satellite Company, Lanham, Maryland, Landsat Technical Notes, 1, August.: **1986**.
20. **Mougeot, L.J.,** Urban agriculture: Definition, presence, potentials and risks. *Growing cities, growing food: Urban agriculture on the policy agenda* **2000**, 1-42.

21. **Ozdogan, M.; Woodcock, C.E.; Salvucci, G.D.,** Monitoring changes in summer irrigated crop area in southeastern turkey using remote sensing. *Proceedings of the **2003**IEEE International Geoscience and Remote Sensing Symposium, IGARSS, 3(21–25)* **2003**, 1570–1572.
22. **Parece, T.E.; Campbell, J.B.,** Geospatial evaluation for urban agriculture land inventory: Roanoke, virginia USA. *International Journal of Applied Geospatial Research (IJAGR)* **2017**, *8*, 43-63.
23. **Scheffers, B.R.; Paszkowski, C.A.,** The effects of urbanization on north american amphibian species: Identifying new directions for urban conservation. *Urban Ecosystems* **2012**, *15*, 133-147.
24. **Sakthivadivel, R.; Thiruvengadachari, S.; Amerasinghe, U.; Bastiaanssen, W.G.M.; Molden, D.** *Performance evaluation of the bhakra irrigation system, india, using remote sensing and gis techniques*; International Water Management Institute: Colombo, Sri Lanka., **1999**.
25. **Thiruvengadachari, S.; Sakthivadivel., R.***Satellite remote sensing for assessment of irrigation system performance: A case study in india. Research report 9. Colombo, sri lanka: International irrigation management institute.*; **1997**.
26. **Thenkabail, P.S.; Enclona, E.A.; Ashton, M.S., Hyperion, ikonos, ali,** etm_ sensors in the study of african rainforests. *Remote Sensing of Environment* **2004**, *90*, 11.
27. **Thenkabail, P.S.; Enclona, E.A.; Ashton, M.S.; Legg, C.; De Dieu, M.J., Hyperion, ikonos, ali,** and etm+ sensors in the study of african rainforests. *Remote Sensing of Environment* **2004**, *90*, 23-43.
28. **Thenkabail, P.S.; GangadharaRao, P.; Biggs, T.; Gumma, M.K.; Turral, H.,** Spectral matching techniques to determine historical land use/land cover (lulc) and irrigated areas using time-series avhrr pathfinder datasets in the krishna river basin, india. . *Photogrammetric Engineering and Remote Sensing* **2007**, *73*, 1029 -1040.
29. **Van Rooijen, D.J.; Turral, H.; Wade Biggs, T.,** Sponge city: Water balance of mega-city water use and wastewater use in hyderabad, india. *Irrigation and drainage* **2005**, *54*.
30. **Velpuri, N.M.; Thenkabail, P.S.; Gumma, M.K.; Biradar, C.B.; Noojipady, P.; Dheeravath, V.; Yuanjie, L.,** Influence of resolution in irrigated area mapping and area estimations. *Photogrammetric Engineering & Remote Sensing* **2009**, *75*, 1383-1395.