Chapter 2 Land Use Land Cover

Land covers an area of about 29.2% of the surface area of the earth and is one of the most important and '***finite***' natural source for materials required by all living organisms (Nagamani and Ramachandran, 2003). It provides a platform for all human activities such as agriculture, industry, forestry, energy production, settlement, recreation and water storage. This human interference and its interaction with natural resources such as land have given rise to the term – 'Land Use'. In order to fulfill man's needs the land use has become more and more complex over time. The concern about land use, however, has increased since the industrial revolution (i.e. since 18th century) during which major changes took place in agriculture, transportation, manufacturing, mining and technology sectors (Brandão *et al.*, 2010). This revolution had brought about a profound effect on the social, economical and cultural condition of people and thus the phase of alteration in the pattern of land use began (Goldewijk and Ramankutty, 2004; Martinez, 2005; Brandão *et al.*, 2010).

The term 'land use' (LU) has been sometimes used interchangeably with term 'land cover' (LC) in many land use land cover (LULC) and change detection studies (Green *et al.*, 1994; Dimyati *et al.*, 1996; Heikkonen and Varfis, 1998). But, both the terms are quite distinct from each other. Their differences are well described in many documents (Anderson *et al.*, 1976; Campbell, 1981; Di Gregorio and Jansen, 2000). In simple terms, Land use describes how the land is used where as the land cover specifies what covers the surface of the earth. For example land use includes agricultural land, urban, wildlife management area and recreation area where as land cover include water, grassland, deciduous forest, snow and bare soil. For better understanding, the precise definitions of land use and land cover are given below.

2.1 <u>DEFINITIONS</u>

2.1.1 LAND USE

The word 'Land use' was originally defined by Sauer (1919) as "the use to which the entire land surface is put". In 1959, Albert Guttenberg defined land use as a key term in the language of City planning. According to Clawson and Stewart (1965) land use referred to man's activities on land which were directly related to the land. Vink in 1975 had described land use of an area as "the result of human controls over the land resources in a relatively systematic manner". In 1989, NRSA had given the definition of Land use as man's activities and varied uses which were carried out over land. Jolly and Torrey (1993), described Land use as "varying activities executed by humans to exploit the landscape". Turner and Meyer (1994) briefly described land use as "the human employment of land". Skole (1994) expanded it further and stated that "Land use itself is the human employment of a land-cover type, the means by which human activity appropriates the results of net primary production (NPP) as determined by a complex of socio-economic factors". According to Turner *et al*., (1995) "Land use involves both manner in which biophysical attributes of land are manipulated and the intent underlying that manipulation – the purpose for which the land is used". In a similar way, Meyer (1995) described land use "as the way in which, and purpose for which, human beings employ land and its resources" (Meyer, 1995). The Food and Agriculture Organization (FAO) in 1995 had described it as "concerned function or purpose for which land is used by local human population and can be defined as the human activities which are directly related to land, making use of its resources or having an impact on them". Campbell (1996) defined land use as the use of land by humans, usually with emphasis on functional role of land in economic activities. Longley (2001) referred "land use" to human activities that takes place on or make use of land e.g. residential, commercial, industrial etc. Sherbinin (2002) stated land use is the term used to describe human uses of land, or immediate actions modifying or converting land cover. Konecny (2003) defined land use as "a land right related category of economically using land". According to Jensen (2005) land use is "how land is used by human beings". Zubair (2006) and Chrysoulakis *et al*., (2004) described land use as "intended employment of land management strategy placed on the land cover by human agents, or land managers to exploit land cover" and reflects human activities such as industrial zones, residential zones, agricultural fields, grazing, logging, and mining among many others.

Most of the above definitions of land use mostly refer to the urban or developmental aspect of land. Chapin and Kaiser (1979) have however explained the term land use from other perspective. They had defined land use on the basis of utilization of the land resources and its surface. According to them, "At territorial scales involving large land areas, there is a strong predisposition to think of land in terms of yields of raw materials required to sustain people and their activities". At these scales, 'land' is a resource and 'land use' means 'resource use'. They analyzed land, based on production potential of its soils and its sub mineral content and their emphasis was more on potential use of the land's surface for allocation of various activities. This connotation of the term "land use" is implicit in several other texts dealing with land use in the context of urban and regional analysis and planning (Hoover and Giarratani, 1984). So, in a nutshell, "***land use is the expression of man's management of ecosystems in order to satisfy some of his requirements***".

The land use is thus being shaped under influence of two broad sets of forces – human needs and environmental features and their processes. Neither of these forces remain stable; but are in a state of continuous flux. The magnitude of change in land use varies with time as well as geographical area. A change in land use pattern mostly involves a shift in the land use such as, urbanization, deforestation, agricultural practices etc. Most of the land use transformations result in irreversible changes in resource quality which limits future options for biodiversity conservation and arable agriculture (O'Connor and Kuyler, 2009). These changes are sometimes time beneficial and sometimes having detrimental impacts on the environment. The latter is the chief causes of concern as it impinges variously on human well-beings and their welfare (Briassoulis, 2000).

2.1.2 LAND COVER

Land cover has been described in different ways by different scientists. One of the earliest descriptions of land cover states it as "The vegetational and artificial constructions covering land surface" (Burley, 1961). In 1989, NRSA defined land cover as an assemblage of biotic and abiotic components on earth's surface which was one of the most crucial properties of earth system. Meyer and Turner (1994) stated that "land cover is the physical, chemical, or biological categorization of the terrestrial surface, e.g. grassland, forest, or concrete, whereas land use refers to the human purposes that are associated with that cover, e.g. raising cattle, recreation, or urban living". In a similar way Moser (1996) described land cover as a type of vegetation that covered land surface, but had subsequently broadened it to include human structures, such as buildings or pavement, and other aspects of the physical environment, such as soils, biodiversity, and surfaces and groundwater. Cihlar (2000) related land cover to composition and characteristics of land surface elements. Longley (2001) related land cover to physical materials on surface of a given parcel of land. Geist and Lambin (2002) described land cover as the biophysical earth surface whereas land use was shaped by human, and their socio-economic and political influences on land. Sherbinin (2002) described land cover as the natural vegetative cover types that characterize a particular area. Konecny (2003) described it as the physical appearance of the earth's surface. According to Jensen (2005) land cover was the 'bio-physical materials' found on the land. Lillesand *et al.*, (2007) related land cover to type of feature present on surface of the Earth. Sudhakar and Rao (2010) defined land cover as assemblage of biotic and abiotic components on Earth's surface and as one of the most crucial properties of the earth system. Other researchers have defined land cover as attributes of the earth's land surface captured in the distribution of vegetation, water, desert and ice and immediate subsurface, including biota, soil, topography, surface and groundwater, and it also included those structures created solely by human activities such as mine exposures and settlement (Baulies and Szejwach, 1998; Lambin *et al.*, 2003; Chrysoulakis *et al.*, 2004).

Land cover plays an important role at the national as well as global level. According to Turner *et al.*, (1994) there are three different ways in which it is very important. Firstly, the land cover is important in regulating the hydrological cycles, maintaining energy budgets and at the time of predicting weather and climatic conditions (DeFries *et al.*, 2002). Secondly, it plays an important role in balancing carbon cycle by maintaining level of atmospheric CO_2 and their by the effect of green house (Houghton, 1999; IPCC, 2000; Janetos and Justice, 2000). Lastly, land cover act as an indicator for various ecosystem services and also as an important source for food, fuel, timber, fiber and shelter for all living beings.

Land cover is thus the composition and characteristics of land surface elements and provides key environmental information. This information is very crucial for many scientific, resource management and policy purposes and for a range of human activities. Land cover variation ranges at spatial scales from local to global and at temporal frequencies of days to millennia (Cihlar, 2000). Changes in land cover are mainly due to either conversion or modification (Skole, 1994; Turner *et* al., 1995). A conversion involves a change from one cover type to another whereas modification involves alterations of structure or function without a wholesale change from one type to another. This modification may involve changes in productivity, biomass or phenology (Skole, 1994). Changes in land cover are results of either natural processes such as climatic variations, volcanic eruptions, changes in river channels or the sea level, etc or anthropogenic. However, now a day, most of changes in land cover are due to human actions such as uses of land for production or settlement (Turner *et al*., 1995). According to Meyer and Turner (1996), land use deliberately and inadvertently alters the land cover. Thus, land use and land cover are closely linked with each other and have profound effect on the lives of people as well as natural resources (Dale *et al.*, 1998). There are several causes for land use and land cover changes. One of the main causes of the change in land use land cover (LULC) is competition between different stakeholders in developing and using areas to achieve their respective objectives. Another cause of land use land cover change is rapid population growth which is a serious issue in developing countries (Ehrlich and Ehrlich, 1990; Cohen, 2003). This rising population requires more and more land to fulfill its various requirements such as land for settlements, for economic activities, for agriculture etc. All these demands are fulfilled at the cost of the land of forest, agriculture and wetland area (Yang and Liu, 2005). Hence, adequate information on these changes, their spatial distribution and their periodic monitoring is necessary for making future development plans (Dhinwa *et al.*, 1992).

2.2 IMPORTANCE OF LAND USE LAND COVER

Growing demands on land have resulted in a crisis of land mismanagement (Varghese *et al.*, 2010). To carry out optimal land use planning, it is necessary to have information on existing land use patterns and changes in the land use through time. Accurate, meaningful and current data on land use are essential if public agencies and private organizations are to know what is happening, and to make sound plans for their own future action (Clawson and Stewart, 1965). Land use and land cover information is required by federal, state and local agencies for water- resource inventory, flood control, water-supply planning, and waste-water treatment (Anderson *et al.*, 1976). It is needed to assess the environmental impact resulting from the development of energy resources, to manage wildlife resources and minimize man-wildlife ecosystem conflicts. It is also required in order to make national summaries of land use patterns and changes for national policy formulation, to prepare environmental impact statements and assess future impacts on environmental quality (Anderson *et al.*, 1976). Mapping land use land cover change is very important for planning and management activities in order to guide future trends of human activities and land use land cover change in a better way (Forkuor and Cofie, 2011).

Knowledge of land use land cover change for an area is thus not only important but a pre-requisite for planners and authorities to overcome the problems of haphazard and uncontrolled development, deteriorating quality of environment, loss of prime agricultural lands, destruction of important wetlands and loss of fish and wild life habitat (Anderson *et al*., 1976; Forkuor and Cofie, 2011).

2.3 METHODS USED TO STUDY LAND USE LAND COVER

It is crucial to use each and every bit of available land in the most rational way in order to improve economic condition of an area without any further damage to the environment. This requires detailed knowledge about land use practices, time series land use pattern changes and its effects on environmental processes and systems (Chaurasia, 1996). The knowledge about land use can be gained by two different methods:

1. Conventional land-survey methods
2. Geo-spatial techniques

2.3.1 CONVENTIONAL METHODS

This mainly includes land surveys which were dominating in the era when technique such as remote sensing had not yet developed. At that time local planning, agencies prepared maps with help of observation and enumeration during field surveys (Avery, 1968). Generalized maps used to be developed directly in the field, with few features in detailed form to furnish specific illustration of the application. This land use information derived from agricultural inventory was carried out at individual plot level and available in the form of statistical records without any reference to spatial locations. The major problem that came during the application and interpretation of these data sets was lack of standardization. Every data set showed variation in the definition of categories and method of collection. Another large difficulty came at time of aggregation of available data because of the use of different classification systems. These land use maps which were prepared for specific area with specific objective and without any coordination with other agencies, resulted in the duplication of efforts with little or of no value (Sudhakar and Rao, 2010). Other than this, conventional techniques also have limitations on the assessment, monitoring, modeling and prediction of land use changes. In fact according to Olorunfemi (1983), monitoring changes and time series analysis is quite difficult with traditional method of surveying.

An additional issue in this method was field work, which had many constraints. During early periods, mapping a large and varied territory pose a number of logistical questions such as the costs of map production, costs of field work which increased with the variety of habitats that need to be surveyed, requirement of the different type of vehicles (such as car, boat, airplane) and the shear remoteness of some areas (i.e. poor accessibility). All this required sizable funds (money) and time which became the main limitations in the conventional method (Ferreira *et al.*, 2012).

These limitations in the traditional approach have been largely overcome by adopting geospatial tools and techniques.

2.3.2 GEOSPATIAL TECHNIQUES

Geospatial methods mainly comprise of remote sensing and geographical information systems (GIS). They have created opportunities for better evaluation of land use changes and their impacts on ecosystems worldwide (Nosakhare *et al.*, 2012).

2.3.2.1 Remote Sensing

The seeds of remote sensing were sown in 1858, when the first remotely-sensed photograph was taken for a village near Paris (Goldewijk and Ramankutty, 2004). Several experiments were later conducted using rockets, kites, pigeons etc. but during World War I and II, aerial reconnaissance technology improved greatly and moved beyond visible photography to use infrared. Remote sensing now additionally employs thermal infra-red, radar and microwave radiation.

The use of panchromatic, medium-scale aerial photographs to map land use has been an accepted practice since 1940s. In the mid-1940's, Francis J. Marschner began mapping major land use associations for entire United States, using aerial photographs taken during the late 1930's and the early 1940's. The different land use classes were identified manually using a WILD stereoscope and transparent overlays (Vanacker, 2003). Marschner produced a set of State land use maps at the scale of 1: 1,000,000 from mosaics of aerial photographs and then compiled a map of major land uses at 1: 5,000,000 (Marschner, 1950). Thus, interpretation of large-scale aerial photographs had been used widely to understand land use (Avery, 1968) and to prepare an inventory of Nation's land resources and thereby used effectively to complement surveys (Anderson *et al.*, 1976).

In 1959, satellite based remote sensing was born, with the first space photograph taken by Explorer 6 satellite (Goldewijk and Ramankutty, 2004). Landsat 1 launched in 1972 was the first satellite to monitor earth's natural resources on regular basis. Since then, remote sensing techniques have proved to be of immense value in mapping and monitoring the various natural environments across varied spatial and temporal scales (Gibson and Power, 2000). In case of inaccessible area, this technique is perhaps the only method of obtaining data on a cost and time effective basis (Rao *et al.*, 1996; Roy and Girija, 2008). Over a period of time, a numbers of techniques have been developed using satellite images to detect land use change that have taken place. The synoptic viewing capability of this technique gives better monitoring facility. The ability to perform this task is improved with availability of better temporal (repetitive coverage at very short interval of time) and spatial resolution data. With the advancement in the different resolutions of different satellites and sensors such as Landsat Multi Spectral Scanner (MSS)-80 m, Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+)-30 m, Indian remote sensing satellites (IRS) series with varying spatial resolutions such as 73 m, 36.5 m to 23.5 m, Cartosat 1 with 2.5 m, IKONOS (PAN) and Quick bird (PAN) with 1 m and Cartosat 2 with less than 1 m a large amount of data is now available which has the potential for land use and their change studies over a wide area. Along with this, enhanced spectral resolution in satellite data has increased visual as well as digital interpretation accuracy. Apart from this, the satellite images offer the most current and unbiased baseline information compared to statistics, topographic maps or conventional land use maps (Gupta, 2001). These unique capabilities have therefore been widely used in detecting and monitoring land use change in various environments such as rural, urban and coastal area (Shepard, 1964; Robinove *et al.*, 1981; Jensen and Toll, 1982; Fung, 1990; Rao *et al.*, 1999; Batty and Howes, 2001; Gonzalez, 2001; Chen, 2002; Shi *et al.*, 2002; O'Hara *et al.*, 2003; Ruiz-Luna and Berlanga- Robles, 2003; Herold *et al.*, 2003; DeFries and Pagiola, 2005; Thu and Populus, 2007; Giri *et al.*, 2008).

2.3.2.2 Geographic Information System (GIS)

A geographic information system (GIS) is a computer data system that is capable of capturing, storing, analyzing and displaying geographically referenced information (Folger, 2011). GIS technique allows users to create interactive queries, analysis of spatial information, data editing, and representation of maps and results of these operations (Schröder, 2010). This technology can be used in various domains viz., for scientific investigations, resource management, asset management, archaeology, environmental impact assessment, urban planning, cartography, criminology, marketing etc. (Schröder, 2010). It is a very useful tool in mapping, monitoring coastal resources and in assessing changes in coastal environmental caused by human activities and interference of human (Hadjimitsis *et al.*, 2005; Sunday and Ajewole, 2006). Geographic information systems (GIS) has been used in combination with Remote sensing to analyze land use and land cover changes (Ehlers *et al.*, 1990; Treitz *et al.*, 1992; Harris and Ventura, 1995; Samant and Subramanyan, 1998; Sobrino and Raissouni, 2000; Weng, 2001; Yang and Lo, 2002; Stathopoulou *et al.*, 2004; Mundia and Aniya, 2005; Navalgund *et al.*, 2007; Sreenivasulu and Bhaskar, 2010; Areendran *et al.*, 2013). By understanding the driving forces of land use development in the past, managing the current situation with modern GIS tools and modeling the future, one is able to develop plans for multiple uses of natural resources and nature conservation (Prakasam, 2010). Thus, GIS techniques provide flexible environment for retrieving, analyzing and displaying digital data from various sources that are essential for change detection and database development (Weng, 2002; Sunday and Ajewole, 2006).

2.4 <u>LITERATURE REVIEW</u>

2.4.1 GLOBAL PERSPECTIVE

Since, the dawn of civilization, humans have altered the surface of earth while acquiring valuable resources such as food, fiber and water. These alterations of the landscape and their consequences have been noted for a long time. Greek philosophers like Plato and Aristotle, Roman emperors such as Hadrian had reported about the deterioration of natural vegetation and erosion of fertile land (Goldewijk and Ramankutty, 2004). However, records on analysis of changes in land use are available only from the beginning of the 18^{th} centuary. It was Thomas Malthus in 1798 who first articulated that "land is a finite resource with limited carrying capacity to support the high growth rates of the human population" (Brandão *et al.*, 2010). J. H. von Thunen, a north German estate owner in 1826 for the first time studied the spatial layout of various crops and other land uses of his estate and developed a more general model or theory of how rural land uses should be arranged around a market town (Briassoulis, 2000).

In 1930, a world census of agriculture was conducted for the first time in which data on agricultural land was collected at the national level by FAO. In the beginning, this organization conducted surveys at interval of 10 years. But, since

1961, the surveys were conducted on a yearly basis (Goldewijk and Ramankutty, 2004). During 1970s, New York state office of planning coordination had developed a LUNR (Land Use and Natural Resources) Program, in which 50 categories of land use information were derived from hand drafted maps which were compiled from aerial photographs of 1967-70 (Anderson *et al.*, 1976). With time, increase in knowledge and awareness among the scientific community made land use and land cover change a key issue of global environmental change. With rising concerns the scientific research community was called to carry out a substantive study of land use changes during the conference on the Human Environment in 1972 at Stockholm. A similar meet was conducted after 20 years in 1992 at United Nations Conference on Environment and Development (UNCED). Later a number of national, regional and global projects were initiated such as the US National Land cover data set, the Countryside survey series in the UK, the European CORINE land cover mapping, the International Land use and land cover change core project- run jointly by International Geosphere and Biosphere Programme (IGBP) and International Human Dimension Programme (IHDP) which set up the research agenda and promoted research activity for land use land cover changes from the mid- 1990s (Turner *et al.*, 1995; Lambin *et al.*, 1999; Fisher and Unwin, 2005). In 2008, National Oceanic and Atmospheric Administration (NOAA) started the Coastal Change Analysis Program (C-CAP) that produced a national standard geospatial database to track coastal land use land cover change. They identified changes in more than 500 categories and generated two date C-CAP LULC change detection products which provided detailed information for coastal managers and community planners. Apart from these, some national organizations such as U.S. Department of Agriculture in U.S.A., Fundação Instituto Brasileiro de Geografiae e Estatística (IBGE) in Brazil, Directorate of Economics and Statistics in India collected sub-national data on the land use at roughly five-to-ten year intervals (Goldewijk and Ramankutty, 2004).

A number of studies have been carried out worldwide showing the importance, documenting changes and modeling different land uses over a period of time. Besides studying land use changes and their drivers and impacts, modeling and prediction are also major aspects in the study of land use dynamics. Modeling and prediction play an important role in management activities and are very important in order to balance developmental activities in different areas in a sustainable way. A numbers of studies pertaining to land use land cover change and their modeling have been carried out the world over. A summary of the important studies has been described in Table 2.1. As the current study pertains to changes in land use and land cover in coastal areas, the major emphasis of the summary will remain on coastal studies.

Year	Researcher/ Organization	Major findings or remarks
1919 1937	Sauer, C.O. Salter, L.A.	Described different land use classes and their importance and application. Discussed issues of rural land-use planning in the Northeastern industrial region of United States.
1950	Stamp, L.D.	Worked on cultural landscape of Britain and produced a series of land utilization maps.
1959 1961 (1977)	Guttenberg, A.Z. Burley, T.M. (Dickinson & Shaw)	Proposed multiple land use classification system based on the site development, its actual use and economic activity at the site. Defined land use and land cover and given equation of land use as Land use = Land cover + Land utilization.
1970	Thrower, N.J.W.	Prepared first inventory of land use for the Southwestern United States by employing satellite imagery.
1972	Orning and Maki	Generated land use map of Minnesota as a part of Minnesota land management information system. This map was prepared from aerial photographs taken in spring of 1968 and 1969 and identified nine land use categories.
1972	Chapin, F.S.	Discussed need for assembling and summarizing land-use data. Highlighted the need for construction of systematic procedures for keeping an account of changes.
1974	Stevens *et al.*	Along with other researchers of Maps and Survey Branch of the Tennessee Valley Authority in conjunction with the Marshall Space Flight Centre and Oak Ridge National Laboratories had prepared land use data which was referenced to 1:24,000 topographic maps.
1976	Anderson *et al.*	Proposed a land use and land cover classification system for the use of remotely sensed data. This classification system was developed to meet needs of federal and state agencies for an up-to-date overview of land use and land cover throughout the country. They developed a system which could be used uniformly wherein categorization at first and second level could be perceived from satellite and aircraft remote sensors. This system was widely used by many researchers throughout the world to delineate land uses classes.
1985	Ross, J.	Used a Geographic information system in order to detect land use change on Omaha's (the United States) Urban fringe. He developed a land use change geographic information system (LUCGIS) to test feasibility of automated approach for monitoring the changes. He reported high accuracy of computerized method of detecting change as compared to conventional methods.

Year	Researcher/ Organization	Major findings or remarks
1993	FAO	Formulated guidelines for land–use planning intended for people engaged in making land-use plans. They provide an overview of land-use planning for administrators and decision-makers.
1994	Ojima *et al.*	Studied the global impact of land-use change wherein they established a link between human activities and land use and land cover change.
1994	Houghton, R.A.	Studied worldwide extent of the land-use changes. Analysed changes for last several millennia, last century, last decade and next several decades, with a major emphasis on forests and deforestation. Particular emphasis on tropical forests where the land use changes were most dramatic.
1994	Richards and Flint	Carried out extensive research on land use changes in Asia during the period 1880-1980. This study covers an area of 8 million km^2 and 13 countries (India, Sri Lanka, Bangladesh, Myanmar, Thailand, Laos, Cambodia, Vietnam, Malaysia, Brunei, Singapore, Indonesia and Philippines) wherein main emphasis was given on the change in the forest, wetland and net cultivated area.
1997	Paola and Schowengerdt	Demonstrated the use of neural networks as an alternative to statistical multispectral classification techniques for remote sensing image classification. The approach presented both unique challenges and abilities to study the land use and land cover classification.
1999	Allen *et al.*	Applied GIS based methodologies for analysis, modeling and prediction of coastal land-use change. They used 20 variables and developed spatial multivariate logistic model for predicting the possibilities of land-use change for Murrells Inlet, South Carolina and its vicinity.
1999	Metternicht	Devised methodology for computing amount of changes using remotely sensed technologies and fuzzy modeling.
1999	Verburg *et al.*	Used CLUE (the Conversion of Land Use and its Effects) model to model near future land use changes based on actual and past land use conditions in Ecuador.
2001	Bocco *et al.*	Described a method to quickly map terrain at 1:250,000 and 1:50,000 levels. The maps were used as a basis for land evaluation and land use planning in the state of Michoacan, central-western Mexico.
2001	Messina and Walsh	Used cellular automata model and GIS techniques to describe, and explore the consequences of land use and land cover change (LULCC) in Ecuadorian Amazon.
2002	Seto *et al.*	Estimated land use changes and incorporated area estimates in a socio-economic analysis of the factors that influenced land-use changes across Pearl River Delta, China.
2002	Dahdouh-guebas *et al.*	Studied the land use changes with help of remote sensing and GIS technology wherein the emphasis was given to the area of mud flats which has undergone the change from mangrove to the shrimp farming around the Pambala-Chilaw Lagoon complex.

Year	Researcher/ Organization	Major findings or remarks
2002	Yang and Lo	Used a time series of Landsat MSS and TM images to extract land use/ cover change data of the Atlanta, Georgia metropolitan area in the United Stated over the past 25 years as a component of Project ATLANTA (Atlanta Land-use Analysis: Temperature and Air-quality).
2003	Mapedza *et al*.	Analyzed land cover changes of Mafungabusi Forest, Zimabawe using aerial photography from 1976-1996 with Geographic Information System (GIS).
2003	Vanacker *et al*.	Proposed a methodology to investigate effect of land-use or cover change on slope movement susceptibility by incorporating specific hydrologic parameter estimates, which vary according to a specific land-use pattern, in a simple process-based slope stability model.
2004	Goldewijk and Ramankutty	Studied land use changes across the world during past 300 years.
2004	Rogan and Chen	Discussed remote sensing technique in detail from its evolution to the steps in detecting and monitoring changes in land cover and land use.
2004	Lomba *et al*.	Used GIS technologies in analysis of vegetation data in order to survey and evaluate sand dune habitats in Mindelo Ornithological Reserve, a highly humanized coastal area in North-western Portugal.
2004	Mendoza *et al*.	Used a genetic synthesis of unsupervised neural network ART2 (Adaptive Resonance Theory) to map land use/land cover changes for the year 2002 and 2003 for the northern Mato Grosso State, using images from Terra/ASTER, with visible, near (VNIR) and middle (SWIR) infrared bands.
2005	Muttitanon and Tripathi	Used Landsat TM data and supervised classification to detect land use land cover changes in coastal areas of Ban Don Bay, Surat Thani, Thailand.
2005	Yang and Liu	Developed hierarchical classification and spatial reclassification techniques to map land use and land cover of Pensacola Bay of Gulf of Mexico. This spatio-temporal dynamics of estuarine land-use and land-cover changes was studied by using post-classification comparison and GIS overlay techniques.
2005	Mundia and Aniya	Used integrated remote sensing and GIS technology approach to map spatial dynamics of land use/land cover changes and identify the urbanization process in Nairobi city.
2006	Filatova and Veen	Studied land use changes along coast of Netherlands. They described motives for changes at macro and micro level and presented an agent based model (ABM) to simulate land use change in coastal zone area based of human behavior.
2006	Houet and Hubert-Moy	Studied land use and land cover changes and modeled using cellular automation to project landscape trajectories.
2006	Sunday and Ajewole	Evaluated socioeconomic and environmental implications of changing pattern of land cover associated with Lagos Costal Zone. They observed and predicted (2002-2027) rapid and continuing land cover change in Lagos coastal area.

Year	Researcher/ Organization	Major findings or remarks
2006	Yagoub and Kolan	Evaluated and quantified land use land cover changes of Abu Dhabi, UAE from 1972-2000 using multi-temporal LANDSAT satellite data and digital change detection techniques.
2007	Lovanna and Vance	Modeled temporal and spatial dimensions of a 10,000-mile square swath in central North Carolina. Changes were studied using a database that linked five satellite images spanning 1976-2001 to a suite of socioeconomic, ecological and GIS-created explanatory variables.
2007	Nelson and Robertson	Used global land cover (GLC) datasets, GLC 2000 and GeoCover LC with differing resolutions (1 km versus 30 m) and indicated their potential in economic analyses of the determinants of land use.
2008	Haque *et al.*	Studied change in land use pattern and its causes along the Sylhet, Bangladesh using LANDSAT TM and SPOT images of and GIS technique.
2008	Richardson and Al-Tahir	Used remotely sensed images to undertake a detailed, spatially explicit inventory of local trends in land use and land cover changes in Trinidad and Tobago over 30 years. They investigated the causes and consequences of land use/land cover change and its correlation with socio-economic data was examined to better understand factors influencing changes and to determine sustainability of past and present land use practices and management.
2008	Zubair, A.O	Studied land use and land cover changes in Ilorin, Nigeria from 1972 to 2001 with remote sensing and GIS technologies.
2009	Henriques and Tenedorio	Used GIS for analysis of land use changes and cellular automata for simulation of land use changes in coastal area of Maputo city, Africa.
2009	Simões *et al.*	Proposed a bottom-up approach for modeling coastline evolution with integration of land use cover. They used cellular automata and artificial neural network system to develop the model.
2009	Yuan *et al.*	A combination of several techniques was used to test ability of automated artificial neural network system to perform Land-Use/Land-cover (LU/LC) classifications of a Landsat Thematic Mapper image.
2010	Le *et al.*	Applied the Land Use Dynamics Simulator (LUDAS) framework to a mountain watershed in central Vietnam for supporting the design of land-use policies that would enhance environmental and socio-economic benefits.
2011	Ellis *et al.*	Quantified and assessed geospatial land-use and land-cover changes in two coastal counties of Albama using nine Landsat images from 1974-2008. The emphasis was given on determination and analysis of decadal-scale urban expansion using remote sensing software.
2011	Canisius *et al.*	Used 15-m resolution multi-temporal Landsat Enhanced Thematic Mapper Plus (ETM+) panchromatic data to extract information on seasonal land use/ land cover pertaining to agriculture water use. They applied hybrid approach to process the high resolution data quickly and efficiently.

Year	Researcher/ Organization	Major findings or remarks
2011	Robertson and King	Compared pixel and object based classifications of Landsat Thematic Mapper (TM) data for mapping and analysis of land use land cover change in the mixed land use region of eastern Ontario for period 1995-2005.
2012	Almeida *et al*.	Used SAR images to monitor both urban and rural domains. They developed an alternate cognitive approach for classifying land cover and land use using airborne SAR images. They developed a hierarchical semantic network and fuzzy logic in InterIMAGE (an open source object-based platform), for the interpretation of remote sensing images.
2012	Nosakhare *et al*.	Derived land use-land cover data by supervised classification of Landsat TM 5 satellite image for the lower Eastern Shore watershed and coastal Bays of Maryland.
2012	Huang *et al*.	Studied transitions among agriculture, natural built up area for coastal watershed of southeast China using Landsat Thematic Mapper satellite images and GIS.
2012	Patarasuk and Binford	Studied extent of change in road network and its effect on land cover in Lop Buri area of Thailand using Landsat TM (1989 and 1998) and ETM+ (2006) satellite images.
2012	Ferreira *et al*.	Used remote sensing for mapping of major intertidal and shallow sub-tidal habitats in Tanzania/ Mozambique and discussed its subsequent applications in coastal management.
2013	Adams *et al*.	Developed a new strategy where they integrated climate change adaptation in to the land-use plan of the city Cartagena (USA). Also integrated other planning instruments and policies, to increase resilience to the impacts of climate change.
2013	Kolios and Stylios	Investigated land use and land cover changes in a coastal area of Preveza in north-western Greece. They used Landsat images and their characteristics were classified in to five classes. Used vegetation indices and different band combinations along with a series of different classifiers in order to achieve high classification accuracy for land-use changes.
2013	Li and Nadolnyak	Specified a theoretical model to show how flood risk on the coast, influences the timing of agricultural land conversion. An empirical analysis was conducted using survival analysis to explore impacts on land development. The model examined explanatory variables that influenced the time to conversion of agricultural land to developed (residential and commercial) uses.
2013	Antso *et al*.	Studied land use and trends of development of land cover pattern in different parts of Estonia's coast using aerial photographs and orthophotos at 1:10,000 scale. They studied relationships of natural and man-induced processes and their cumulative impacts on evolution of coastal land cover pattern in Estonia.
2013	Kurt, S.	Determined changes in land use in Black Sea coastal regions of Istanbul between 1987 and 2007 using landsat satellite images to bring out changes in land use dynamics.

Year	Researcher/ Organization	Major findings or remarks
2013	Mialhe *et al.*	Combined conventional method (ground survey and interviews) with remote sensing analysis to characterize and quantify the nature, origin and scale of the environmental and social impacts caused by the intrusion of aquaculture in Tumbes, Northern Peru.
2013	Yeshaneh *et al.*	Studied land use and land cover changes of Koga catchment in North western Ethiopia with aerial photographs, Landsat MSS, TM and ETM images and ASTER images. They identified driver of land use/land cover changes and assessed implications of the changes.
2014	Alqurashi and Kumar	Used post classification change detection technique to determined changes from 1986 to 2013 using Landsat satellite images of Makkah and Al-Taif regions of Saudi Arabia.
2014	Brink *et al.*	Studied land cover dynamics in East Africa region with help of Architect Graphical User Interface (GUI) classification using medium resolution Landsat and DMC Deimos imagery.
2015	Sanger *et al.*	Defined relationships between coastal development, its concomitant land use changes and associated increase in nonpoint source pollution loadings. They studied ecological condition of tidal creek ecosystems including consequences of creek impairment to human populations and coastal communities throughout the South eastern region of US coast.
2015	Qiang and Lam	Studied and modeled land use land cover changes in lower Mississippi river basin in southeastern Louisiana, USA using artificial neural networks and cellular automata.

Table 2.1 A summary of studies of land use land cover changes at global level

2.4.2 NATIONAL PERSPECTIVE

Land use study is not a new concept for India and considerable work has been carried out on land use land cover and their changes. The earliest Indian records pertain to the preparation of sketches, compilation and codification of laws and rules for the land carried out during the Mauryas (321-184 B.C.) and Harsha (606-647 A.D.) (Chauhan, 2007). In 1540-1545 A.D. Pathan Sultan Sher Shah Suri had introduced a systematic land-tax rule for which he measured and classified land in terms of Kabuliyat and Patta (an instrument for settlement of the revenue). Later, during the British rule (1888-1940), land records for every piece and parcel of land were prepared under the C.S. Record-of-Rights Act. After, Independence, in 1953 all the C.S. Records and maps were revised under the provisions of the West Bengal Estate Acquisition Act, which was also known as RS Operation and the RS Records and Maps Act. The main objective for carrying out these all exercises was to collect revenue from public. During this period maps were prepared through conventional survey methods (Anon, 2011g).

In 1948 during the post independence period, the Survey of India (SOI) had introduced photogrammetric method for mapping. They had started use of aerial photographs for survey purposes which was later augmented in 1954 with the acquisition of stereo plotting instruments (Nag and Sengupta, 2007). With this advancement, the procedure of mapping become more accurate and thus mapping of different natural resources become possible at a national level. In 1958 the All India Soil & Land Use Survey (later renamed as Soil & Land Use Survey of India) was established, which became the premier institution in the field of soil survey and land resource mapping of the country. Prior to the development of remote sensing technology, this organization had conducted land use surveys through conventional method. Looking at the development scenario and the haphazard planning activities in the country, National Land Use Conservation Board (NLUCB) was established in 1985 in order to monitor and to optimize the use of land for development of planning activities (Roy and Giriraj, 2008). Over the years, various Central/State Government Departments, Institution/Organizations etc have made their efforts in publishing maps, reports and statistical data. These include the Survey of India (SOI), Indian Space Research Organisation (ISRO), Space Application Centre (SAC), National Atlas and Thematic Mapping Organization (NATMO), National Bureau of Soil Survey and Land Use Planning (NBSS and LUP), All India Soil and Land Use Survey (AIS and LUS), Central Arid Zone Research Institute (CAZRI), Ministry of Agriculture, Settlement Survey and Land Records, Revenue Department, National Sample Survey, State Land Use Boards, Town and Country Planning Organization (TCPO) and other local agencies are noteworthy (Nayak *et al*., 1991; Roy and Giriraj, 2008; Roy *et al*., 2015) .

Realizing the need for an up to date nationwide land use/land cover data and their maps by several departments in the country, a land use/land cover classification system (with 24 categories up to Level-II, suitable for mapping on 1:250,000 scale) was developed by NRSA, DOS taking in to consideration the details obtained from the satellite imagery and existing land use classification adopted by NATMO, CAZRI, Ministry of agriculture, Revenue department, AIS and LUS. NRSC had completed district-wise land use land cover analysis using satellite data for period of 1988-89 for the Planning Commission of India. Besides this, LULC mapping on 1:50K scale was carried out as a part of Integrated Mission for Sustainable Development (IMSD) project, covering 25% area of the country (Ravisankar *et al*., 2013). Another project namely, National (Natural) Resources Information System (NRIS) which was in continuation of IMSD had covered 17 states and the Integrated Resources Information System for Desert areas (IRIS-DA) covered parts of four states- Rajasthan, Gujarat, Karnataka and Haryana (Ravisankar *et al.*, 2013). Multi-date satellite data was analyzed in order to identify and map details of crop land in Kharif and rabi seasons, the area under doubled crop (during Kharif and rabi seasons), fallow lands, different types of forest, degradation status, wasteland, water bodies etc to delineate land use/land cover categories. This task was accomplished by NRSA in the collaboration of Regional Remote Sensing Centres (RRSSC's) and other institutions. They have studied 442 districts and used hybrid methodology i.e., visual (for 247 district) as well as digital (168 district) techniques for demarcating the land use/land cover categories (Roy and Giriraj, 2008). Thus, almost the entire country was surveyed under different projects with major emphasis on analysis of land use land cover pattern.

With the launching of satellite IRS P6 with sensor AwiFS, rapid assessment of Land Use/Land Cover becomes possible on the scale of 1:250K. In this case identification of different categories was possible up to level II classes of land use classification (Nagaraja *et al.*, 2004). This was initiated annually in 2004-05 wherein cropped area during kharif, rabi and zaid seasons were assessed along with area under doubled/triple crops and at the end of the year net sown area was estimated. Till date such eight cycles have been completed and the data is made available to users through the Bhuvan portal (Ravisankar *et al.*, 2013).

Besides these major organizations, many researchers have worked individually as well as in collaboration with these institutes for mapping of land use and land cover pattern and their changes across India. Most of the works on land use land cover analysis in India were initiated following Dudley Stamps land use survey of U.K. i.e. in the beginning of 1940s. It was at the 1940 session of the Indian Science Congress held at Madras that Prof. S.P. Chatterjee pointed out the necessity of undertaking the land use survey in India on the district of 24 Parganas, Bengal in 1945. Since then many workers had worked on the aspect of land use land cover changes emphasizing their importance, changes and modeling aspects. The Table 2.2 indicates some of the major LULC studies conducted in India. While important inland studies have been mentioned, the emphasis remains on coastal regions.

Year	Researcher/ Organization	Major findings or remarks
1947	Dayal, P.	Analysed the agriculture geography of Bihar wherein he discussed the influence of soil and climatic elements on land utilization, pressure of population on land and nature of land utilization.
1947	Rao, V.L.S.P.	Emphasized techniques of soil survey for analysis of land use in the Godavari Region.
1952	Chatterjee, S.P.	Undertook detailed land utilization survey in Howrah district and prepared 1200 land use maps at the scale of 1:3690 covering 813 villages.
1959	Rao, V.L.S.P.	Emphasized the important role of geographers in land use planning.
1960	Shafi, M.	Described land utilization in the eastern Uttar Pradesh.
1968	Roy, B.K.	Documented rural land use pattern in Azamgarh, Uttar Pradesh.
1974	Singh, J.	Developed an agricultural atlas of India- a Geographical analysis.
1981	Rai *et al.*,	Studied land use and soil erosion around Shillong Region.
1989	NRSA	Carried out land use/land cover studies for India at National Remote Sensing Agency (NRSA).
1989	Singh, A.	Developed a variety of procedures for change detection based on comparison of multi temporal digital remote sensing data for the first time in India.
1997	Palaniyandi and Nagarathinam	Mapped land use land cover classes in Thiruvallur area of Chengai, Tamil Nadu using Landsat 5 TM and IRS 1A LISS II images.
1998	Samant and Subramanyam	Utilized Landsat TM imageries to study land use change in Bombay (Mumbai).
1999	Brahme, S.	Discussed several conversions responsible for diversion of land use pattern in India and thereby degradation of the environment.
2001	Ghosh *et al.*	Carried out an assessment of land use/land cover dynamics and shoreline changes of Sagar island using IRS-1B LISS II satellite data. Their study described trend of geomorphic changes and changes in land use pattern of estuarine island in response to the natural and anthropogenic activities over a period of 30 years.
2002	Jorge *et al.*	Studied driving forces affecting the use of coastal resources and economic development and urbanization on coastal land use and land cover.
2003	Nagamani and Ramchandran	Studied land use land cover and their changes using Landsat TM, IRS LISS II and III satellite data and computer aided GIS techniques for the period of 1990 to 2002 for Pondicherry.
2004	Saxena *et al.*	Analyzed of IRS-1D (LISS-III) and derived land use/land cover information and allied shoreline and fluvial surfaces information for Kakainada Bay along the east coast of India. They also developed the Environmental sensitivity index (ESI) for the coastal area and Reach Sensitivity Index (RSI) for inland riparian areas.
2004	Ghosal and Sarkar	Analyzed land use land cover changes for part of Burdwan, Hooghly and Howrah districts of West Bengal, using IRS-1D, LISS II satellite data. They used supervised digital classification in order to delineate surface land cover areas.

Year	Researcher/ Organization	Major findings or remarks
2005	Shamsudheen *et al.*	Studied land use land cover changes with IRS 1D LISS III and used the supervised classification method in order to demarcate various land use land cover features and their changes for Kumta taluka of Uttar Kannada district of Karnataka.
2007	Murali *et al.*	Studied land use changes around the coast of Pradip, Orissa using IRS 1D LISS III (1999, 2000, 2001, 2002 and 2003) and IRS P6 LISS III (2004 and 2005) satellite images.
2008	Roy and Giriraj	Reviewed land use and land cover analysis in the Indian context. They emphasized the need of land use land cover study as a necessary step for an interdisciplinary research program.
2009b	Mukherjee *et al.*	Analyzed changes that occurred in land use land cover over a time span from 1990 to 2005 using Landsat Thematic Mapper TM and IRS-1C data for Batala region of Punjab.
2009	Joshi and Nagare	Studied land use changes of the Pravara River Basin, (Maharashtra) over the past few decades and evaluated causes that were responsible for these changes. They also predicted the possible future implications associated with these changes.
2009	Guha *et al.*	Emphasized the importance of geomorphological mapping for urban planning and development using Korba city (Chhattisgarh) as a case study. They used IRS P6 LISS IV data to delineate various geomorphological units and used GIS technique to integrate geomorphological and geological information.
2010	Prakasam, C.	Studied land use and land cover changes in Kodaikanal region of Western Ghats in Tamil Nadu state of India over 40 years from 1969-2008 using Landsat satellite data.
2010	Muthusamy *et al.*	Studied land use/cover changes through exploratory analyses, land cover classification and change detection analyses conducted on multi temporal Landsat satellite data of 1977, 1991 and 2006.They studied these changes for Cuddalore coastal zone along the southeast coast of Tamil Nadu state.
2010	Sreenivasulu and Bhaskar	Studied land use/ land cover for Devak catchment, Jammu (J&K) for the years 1958, 1979, 1990 and 1998. They prepared maps using visual interpretation of IRS 1A LISS IIB2 (1990) and IRS 1C, LISS III (1998) satellite images and Survey of India topographic maps.
2010	Santhiya *et al.*	Analyzed Land use for Chennai coast over stretch of approximately 125kms from Pulicat Lake (North) to Kovalam Creek (South). They used SOI topographic sheets and IRS-LISS III satellite data to detect changes.
2011	Maiti and Bhattacharya	Carried out change detection analysis for a 113km long coastal stretch in West Bengal and Orissa using Landsat MSS and ETM+ data. Analyzed change within and between three broad categories viz, land, water and wetland.

Year	Researcher/ Organization	Major findings or remarks
2011	Nagarajan and Poongothai	Analyzed the nature and extent of Land use/ land cover changes of the study area in the past 25 years from 1972-2007 for Manimuktha sub-watershed of Vellar basin, Tamil Nadu, India. They used SOI topographic maps and IRS 1C, LISS III satellite images for land use classification and identified major components that promotes for trend in land use from 2003 to 2007.
2011	Arunachalam *et al*.	Studied land use/land cover pattern of coastal region of Nagapattinam (Tamil Nadu) using IRS P6 LISS III data and correlate them with water level, electrical conductivity of ground water and rainfall pattern during the period of study.
2011	Anil *et al*.	Studied Land use/ land cover and change detection from parts of South west Godavari District, Andhra Pradesh using SOI topographic sheets and Landsat ETM and IRS 1D LISS III satellite images.
2012	Kumar, P.	Analyzed impact of economic driver on land use changes by combining socio-economic data and Landsat TM (1986, 1996), IRS 1A LISS I (1989), IRS 1D LISS III (2001) and IRS P6 LISS III (2004) satellite images for Sundarban area of Indian Bengal.
2012	Samanta *et al*.	Studied geomorphology of coastal features and mapped land use changes for between January 1999 and March 2001 for Tiswadi taluka of Goa state using IRS-1C data.
2012	Visalatchi and Raj	Carried out a study on Land use and land cover changes, shoreline changes, geomorphology and geology using remote sensing and GIS using IRS P6 LISS III data for coastal area of Tuticorin district, Tamil Nadu.
2012	Datta and Deb	Assessed changes in land use/land cover (LULC) pattern for the period 1975-2006 with spatial emphasis on the extent and condition of Sunderbans mangroves by using multi-temporal Landsat images. They examined dynamics of landscape change and suggested guidelines towards better management of those vulnerable coastal ecosystem.
2013	Kumaravel *et al*.	Monitored land cover changes in parts of East cost of Tamil Nadu and Pondicherry Union Territory using IRS 1D (2000) and Cartosat 1 (IRS P5) multi-temporal Indian Remote Sensing Satellite data.
2013	Jana and Bhattacharya	Assessed coastal erosion vulnerability around Midnapur-Balasore coast, eastern India using Landsat TM, MSS and ETM+ satellite images. They divided the area in to four categories where in four phenomenon of erosion-accretion, population density, land uses were studied from 1972 to 2010. They calculated imminent collapse zone (ICZ) which showed that maximum values were around artificial structures and anthropogenic activities.

Year	Researcher/ Organization	Major findings or remarks
2013	Mondal *et al.*	Mapped dynamics of land utilization and its changing patterns of Purba Medinipur District of West Bengal. They studied land use changes and examined relation between economic development and change of land use and checked degradation of bio-diversity due to land use change. They analyzed levels of regional development considering social, economical and demographical indicators and recommended balanced regional agricultural development.
2013	Muthusankar *et al.*	Studied possible inundation limit in south east coast of India using various physical, geological and satellite imageries such as Landsat MSS, TM, ETM and IRS P6 LISS III. They signified application of GIS in identifying the exposed areas and prepared coastal risk hazard map for the vulnerable areas in Nagapattinam region of SE coast of India.
2014	Gowthaman *et al.*	Studied land use land cover changes around Rameshwaram Islands of east coast of India with help of visual interpretation technique and using IRS 1D, IRS P6, LISS III dataset.
2015	Roy *et al.*	Developed decadal (1985-1995-2005) land use and land cover database for India using Landsat TM, MSS, IRS 1B LISS I, Resourcesat 1 LISS III satellite images and using onscreen visual interpretation technique.

Table 2.2 A summary of studies of land use land cover changes at national level

2.4.3 STATE PERSPECTIVE

In Gujarat the earliest record of the land record system dates back to 1573. During this period under the rule of Akbar, Raja Todarmal, a land settlement pattern architect started the first land record system with details of land use and ownership. The prime interest behind this was collection of revenue (Chauhan, 2007). In 1989, Iyengar studied the common property land resources in Gujarat where in data on land use, livestock and human population up to taluka level for time period of 1961-82 was studied. This study was mainly based on the census data and data from the Directorate of statistics, Agriculture department, Government of Gujarat. Brahmabhatt *et al.*, in 2000 studied land use land cover changes using multi-temporal satellite data in the Mahi Right Bank Canal (MRBC) command area in Kheda district of Gujarat State. They studied the relation between the MRBC and land use land cover changes and their impact on the environment. Integrated Coastal and Marine Area Management (ICMAM) (2002) generated critical habitat information system for Gulf of Khambhat. They used satellite data for year 1987 and 1998 to generate various maps such as land use land cover, geomorphology, geology etc. for the gulf of Khambhat area (Anon, 2002). In 2005, Chauhan and Nayak used Survey of India topographic maps to derive historical information (1970-1972) and IRS LISS III sensor to derive recent information (1999-2002) on the land use land cover changes in Hazira area near Surat, Gujarat. They studied drivers and rate of land use/land cover changes in time and space along this coastal region. They modeled these changes using cellular automata and characterized the development of Hazira (Chauhan and Nayak, 2006). Nagabhatla *et al.*, in 2007 used geospatial tools to overcome the sustainability concern for wetland ecosystem. They studied wetlands at the global level and at regional scale. In regional scale they studied Gujarat and Tamil Nadu state with datasets viz. the national wetland inventory data from SACON (30 m) and Global Irrigated Area Map (GIAM-500 m data). They prepared a wetland map of Gujarat region which revealed a wetland area of 3.2 million hectares. In 2008 Parida *et al.* assessed the suitability of MODIS data for examining the temporal variation of surface temperature for different vegetation types between 2000 and 2004 for the Gujarat state. They correlated surface temperature dynamics with local land use types. A similar kind of study was carried out by Nayak and Mandal in 2012. They studied the impact of land-use and land-cover changes on temperature trends for 37 years (1973-2009) over western India. The impact of land use land cover changes on temperature trends over western India were estimated using 'observation minus reanalysis' method which suggested that reduction in forest area and subsequent increase in agriculture area were major cause of warming of this region by 0.06 °C per decade. Gujarat Ecological Commission (GEC) (2011) had created ecological profile of coastal talukas around Gulf of Khambhat wherein they conducted field surveys in ecologically important sites to collect data on important biological parameters at the taluka level (Anon, 2011c). They gathered available secondary data on the ecological condition of the region and later this primary as well secondary data was organized in GIS domain in order to understand the trends and state of different parameters of sustainable development. Sharma *et al.*, (2011) studied flood induced land-cover changes using remote sensing technique. They used LISS III satellite data for year 2004, 2005 and 2006 and different digital classification systems (unsupervised ISODATA, supervised maximum likelihood classifier and fuzzy rule based) to prepare land cover maps for Anand, Vadodara and Kheda districts of Gujarat state. Sharma *et al.*, (2013) studied the spatio-temporal variation in urbanization of Surat city. They studied relationship among various environmental variables using Landsat TM satellite images. Mahapatra *et al.*, (2013) studied impact of sea level rise on land use land cover of Dahej coast of Bharuch district. They used resourcesat-1 (P6), LISS

IV(16th February, 2006) and Cartosat-1 PAN (28th February, 2006) for mapping land use land cover categories of Dahej and its surrounding area. Mishra *et al.*, (2014) studied flood induced land use land cover changes in Anand, Vadodara and Kheda districts of Gujarat state. Thakkar *et al.*, (2014) mapped land use land cover classes in a heterogeneous landscape of a Khan-Kali watershed of Dahod district. They used IRS–R2 LISS III dataset and performed supervised classification using maximum likelihood classification (MLC) algorithm. Palchoudhuri *et al.*, (2015) developed a socio-economic index for modeling land use and land cover changes in Narmada river basin. In this study they had included Madhya Pradesh, Chhatisgarh, Gujarat, Maharashtra and Rajasthan states covering 54 districts and 331 talukas. They used secondary data regarding economy, education, health parameters and infrastructure to develop this index.

The literature survey thus indicated that little work has been carried out so far for the coastal talukas of Bharuch district and studies pertaining to the land use changes were very few. With several parts of coastal Bharuch undergoing high rates of development and industrialization, it was decided to take up study on the spatio-temporal changes in the area using multi spectral and multi temporal satellite data.