CHAPTER 1

INTRODUCTION

(1.1) Eco-city - An introduction:

The world is increasingly urban. The number of urban residents is expected to grow continuously, especially in some of the developing Asian countries like India. Some 1.1 billion people are anticipated to move into Asian cities in coming decades **(Kallidaikurichi and Yuen, 2010)**. This includes 11 megacities, each with a population exceeding 10 million, for example, Beijing, Shanghai, Kolkata (Calcutta), Delhi, Jakarta and Tokyo. With the exception of Tokyo, the rest cities are in developing countries. Such expanding urban population will require a whole range of infrastructure, services, housing and jobs, including land. This is expected to threaten agricultural land supply, increase the traffic volumes and pressure on the environment. These trends are very unsustainable for the country and the rest of the planet. Today, most Asian cities are characterized by the following unsustainable trends **(Lehmann, 2010)**:

- A high number of inefficient older parts of the city which are in need of regeneration, with mature housing estates desperate for rejuvenation;
- An existing building stock which is out-dated and not energy-efficient;
- Structural problems, e.g. expansion of large shopping malls, but lack of noncommercial, catalytic, mixed-use, socially sustainable city projects;
- High carbon energy supply due to burning fossil fuels for generating energy
- Inefficient water, waste and transport operations accompanied by population growth

Such unsustainable practices are leading to the higher energy prices and increased emissions of carbon dioxide (CO_2). Traditional urban environmental issues such as urban pollution, traffic congestion and inappropriate waste collection are also the results of rapid urbanization and climate change. The environmental conditions are more degraded in the developed world and are getting worse in developing world, especially in the fast growing economies of China and India. The global shift of manufacturing industries from advanced nations (since the oil crisis in the mid-1970s) to developing countries is also transferring sites of industrial and household wastes, and carbon emissions to the developing world **(Randolph, 2004; Jayne, 2006; Roberts *et al.*, 2009; Dicken, 2005)**. There is an urge to use domestic consumption as means to support such high rate economic growth of cities and their more rapidly rising urban population. In addition, low levels of environment-led technologies, management and civic awareness in environmental protection all contribute to the urgency for action. This urgency has generated a need for reconsideration of the priorities for the future of cities in developing countries like India. There is a need to direct urban development towards minimizing the use of land, energy and materials, and deterioration of the natural environment while maximizing human well being and quality of life. In such situation, implementation of planning process which promotes sensitive urban development for preserving the open space for developing green areas and the ecological integrity of land and water becomes essential. This can be achieved through Eco-city planning.

An eco-city planning considers the city as a single integrated system (holistic approach) and not as a combination or result of many sectoral developments planned in isolation. The eco-city protects and even improves the environment. It is conceptualized as a city that decreases environmental burden/stress, improves living conditions and helps in achieving sustainable development. “Eco” in "eco-city" means the harmonious relationship between people and their natural and social environment while "City" means a self organizing and self-regulating symbiotic system, i.e., an integral organic body made up of nature, the city and people **(Linan *et al.*, 2004)**. It is also referred to as a 'sustainable city' or a 'green city' or "clean city" **(Modak, 2004)**. It is determined by the human ecological values and it is the inevitable trend of urban development in future, being a sustainable development mode of human living. It suggests an ecological approach to urban design, management and towards a new way of lifestyle. Eco-cities are designed with consideration of socio-economic and ecological requirements dedicated to the minimization of inputs of energy, water and food, and waste output of heat, air pollution, etc. so as to create an attractive place to live and work.

(1.1.1) <u>History of Eco-city:</u>

The idea of ecological cities or Eco-cities arose in the 1980s from new urbanism and was initially discussed mainly by German Scholars. New Urbanism is the integration of an array of related concepts including ecology, community design and planning for a livable and walkable environment. It emerged in the 1980s as a strategy with new typologies in land use to deal with the ecological weakness arising from the massive scale of postwar sprawling suburbanization. The earlier Eco-city concepts were focused primarily on the urban metabolism (→ circles of energy, water, waste, emissions, etc.) as well as the protection of the environment within an urban context **(Hahn, 1988)**. The German definition of an Eco-city is an environmentally, socially and economically responsible city. This definition corresponded to the global strategy for sustainable development set out by the **World Commission on Environment and Development (1987)**.

The term "eco-city" was traced to Richard Register's **(1987)** book, "*Eco-city Berkeley: Building cities for a healthy future*." Register's vision of the eco-city was a proposal for building the city like a living system with a land use pattern that supports the healthy anatomy of the whole city, enhances biodiversity, and makes the city's functions resonate with the patterns of evolution and sustainability. Some of the strategies implemented to manage this balance included:

- Building up instead of sprawling out,
- Giving strong incentives not to use a private four wheelers,
- Use of renewable energy and green tools to make the city self-sustaining

Since then, several similar themes such as "eco-neighbourhoods", "urban eco-village" and "eco-communities" emerged, all emphasizing ways of making the city more environment-friendly and sustainable **(Roseland, 1997; Barton, 2000)**.

(1.1.2) <u>Eco-city In India:</u>

In the year 2002, the Eco-city Project was initiated by the **Central Pollution Control Board (CPCB)** with the grants-in-aid from the **Ministry of Environment and Forest (MoEF)**, Government of India in partnership with the **German Technical Co-operation (GTZ)** under the India-German Environment Programme on **"Advisory Services in Environmental Management" (ASEM)** as a part of the X Plan activities. The Eco-city Project was an innovative and proactive measure intended to be implemented in a phased manner, starting with initial project coverage of small to medium towns. The Eco-city programme was conceptualized for improving environment and achieving sustainable development through comprehensive urban improvement system employing practical, innovative and non-conventional solutions.

The Eco-city Project in India aimed to ameliorate the existing environment, addressing mainly to those aspects that are causing the environmental damage. The review on various aspect of the project was carried out by G.**Sandhya K. and Joshi, 2009.** The focus of the project was to control pollution, improve environmental quality, protect environmental resources like rivers and lakes, improve sanitary conditions, improve the needed infrastructure and to create aesthetic environs in the chosen towns. This project anticipated to pave a way for transforming the identified **project towns (Table 1)** into places that are clean, orderly and sustainable.

Table 1: Towns identified for coverage under the X Plan

Sr.No.	Town	State
1.	Rishikesh	Uttaranchal
2.	Mathura	Uttar Pradesh
3.	Vrindavan	Uttar Pradesh
4.	Bharatpur	Rajasthan
5.	Baidyanath Dham (Deoghar)	Jharkhand
6.	Vapi	Gujarat
7.	Shillong	Meghalaya
8.	Puri	Orissa
9.	Ujjain	Madhya Pradesh
10.	Tirupati	Andhra Pradesh
11.	Thanjavour	Tamil Nadu
12.	Kottayam	Kerala

(1.1.3) <u>The specific objectives of the Eco-city project were:</u>

- To identify the environmental problems/hotspots in the selected towns
- To identify priority environmental improvement projects through participatory approach;
- Designing and detailing the prioritized environmental improvement projects
- To create landmarks that shows visible environmental improvement.

- To improve environment by increasing green belts, urban green spaces in the city
- To protect environmental resources (water bodies, forest etc.)
- To plan development activities compatible to environment
- To improve infrastructure-water, electricity, transportation
- To improve sanitary conditions-sewerage, garbage, storm water, etc.

(1.1.4) Criteria for selection of the towns/cities covered under the Eco-city Project were as followed:

- Size of the town/city
- Cultural/historical/heritage/tourism importance
- Environmental Improvement Needs
- Scope for public-private partnerships and private investment
- Generators of economic momentum/urbanization
- Public participation in decision-making process
- Regional distribution of towns

(1.1.5) Following are few towns described in which Eco-city program was implemented by government of India:

(1) <u>Vrindavan:</u>

Eco-city plan of Vrindavan addressed several issues like, improvement of sanitary conditions including solid waste management and drainage system, improvement of traffic and transportation system, development of tourist friendly routes, and improvement of environmental quality. **Plate 1** is showing the part of town where project was implemented along with the location of eco-zone, transportation route and green belt. Trained manpower was also introduced in the Vrindavan Nagar Palika Parishad to fulfill all these objectives and to improve urban management and planning.

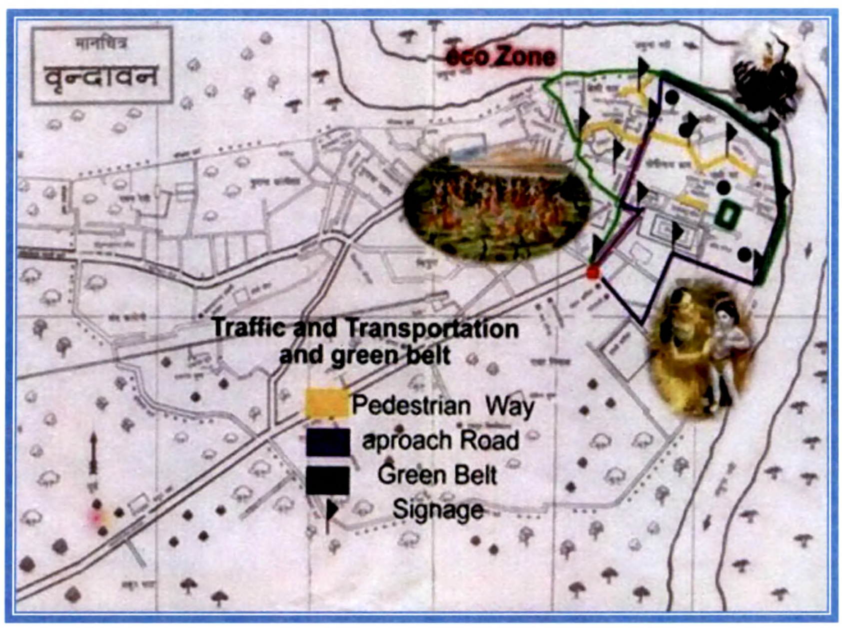

Plate 1: Vrindavan Eco-city plan

(2) <u>Kottayam</u>:

The Kottayam Municipality (Kerala) implemented 'Eco-city' programme to renovate Kacheri Kadavu Boat Jetty Canal and Rejuvenate Munda River which were severely degraded because of siltation, weed growth and disposal of domestic waste **(Plate 2)**. The municipality carried-out the following activities:

- Removal of weeds and vegetations in the Jetty canal and river
- Dredging activity was done in the canal (upto 1100 m) and river (upto 600 m).
- Construction of Sitting steps and retaining wall
- Renovation of parking area.

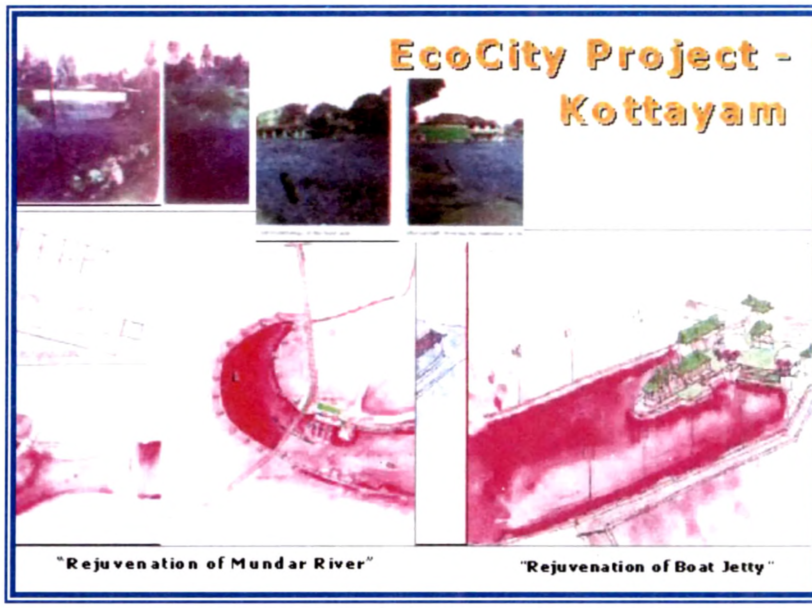

Plate 2: Eco-city plan Kottayam

(3) <u>Kancheepuram (Tamil Nadu)</u>:

To propagate the environmental friendly concept Department of Environment has prepared an "eco-city plan" for Kancheepuram Town through **National Environment Engineering Research Institute (NEERI)**, Chennai. The overall objective of the programme was to incorporate environment considerations into urban planning and prepare an Environmental Management plan for improving the environment quality. Specific objectives of the project were:

- To map the environment profile of study area and to identify the environmental pollution hotspots.
- To prepare an environment management plan that include rehabilitation and mitigation measures
- To recommend guidelines for environmentally compatible land use planning.

(4) <u>Tirupati :</u>

Eco-city project of Tirupati was a joint mission of the Tirupati Municipality and **Participatory Employment Net (PEN)**, India in collaboration with **GTZ-ASEM**, **United Nations Development Program (UNDP)**, **Global Environment Facility (GEF)** and **Small Grants Program (SGP)**. The activities carried out were:

- The storm water drains in the Northern, Southern and Western sides of the temple were covered
- Narasimh Theertha tank was connected with Koneru pond through the pipeline to bring the fresh water to the pond
- Cleaning and de-silting of drains in the core area of the Koneru was done **(Plate 3)**
- The core area of the town around Govinda Raja Swami temple was improved

Koneru , Before

Koneru with Water ,after implementation of Eco-city Programme

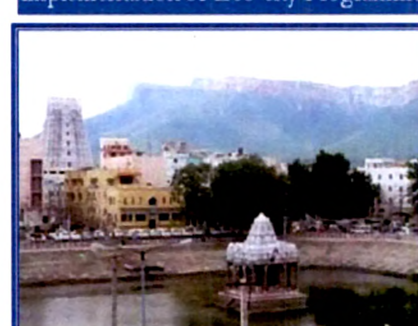

Plate 3: Koneru pond of Tirupati before and after implementation of Eco-city Program

(5) Puri:

The project concentrated on the areas surrounding Lord Jagannath Temple, Grand Road, the religious tanks and commercial and old residential areas near the temple **(Plate 4)**. The main results expected to be achieved from the Eco-City Project were:

- Improved environmental quality
- Improved condition of traditional water bodies
- Improved sanitary conditions by efficient management of solid waste and drainage system
- Improved management of traffic and transportation system

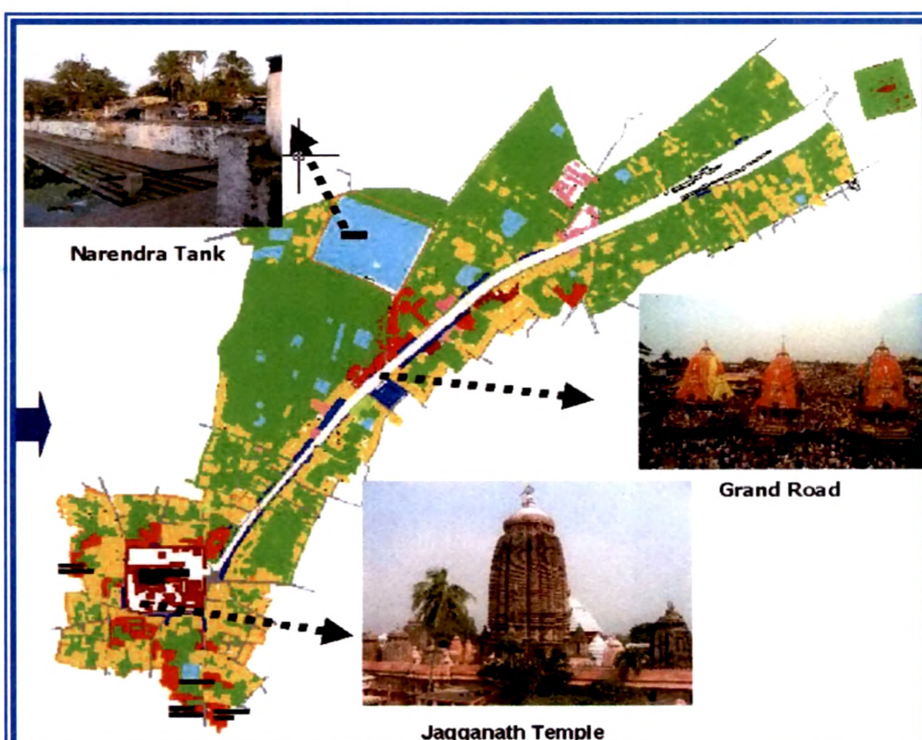

Plate 4: Map showing the locations of Eco-city project implementation in Puri

(6) Ujjain:

The Project on Ujjain focused on Mahakal Temple area including Harsidhhi Temple, Bada Ganapati Temple, Rudra Sagar and Old Residential areas. The main results expected to be achieved from the Project were:

- Revival of Rudra Sagar by improving the water quality of the pond **(Plate 5),**
- Improvement in sanitary conditions including solid waste management and drainage
- Improvement in environmental quality and traffic management

Plate 5: Rudra Sagar Lake of Ujjain

(7) Eco-city of the Magarpatta (Pune):

It is the first city of its kind in the India and has been built considering all the aspects of the Eco-city construction. Everything is within walking distance, to live, work, study, play and shop **(Magar, 2009)**. There is a presence of abundant greenery surrounding residential areas of the city **(Plate 6)**. Magarpatta City is an effort to restore life's harmony, completeness, balance and fulfillment in the living process.

Plate 6: Residential View of the Magarpatta City

(8) <u>Lavasa (Pune): A Dream city</u>

Lavasa lake city is being developed by Hindustan Construction Company (HCC) near Pune within the Western Ghat ranges **(Karunakaran, 2007)**. This sustainable town aims to reduce the environmental stress and enhance residents' quality of life. This will be achieved by minimizing the commute time. This Eco-city will try to attain the balance between urbanism and environmentally friendly surroundings to have a unique way of life as can be seen in **Plate 7**. Life in this city has been envisioned as energetic yet calm, aspirational yet affordable, hi-tech yet simple and urban yet close to nature.

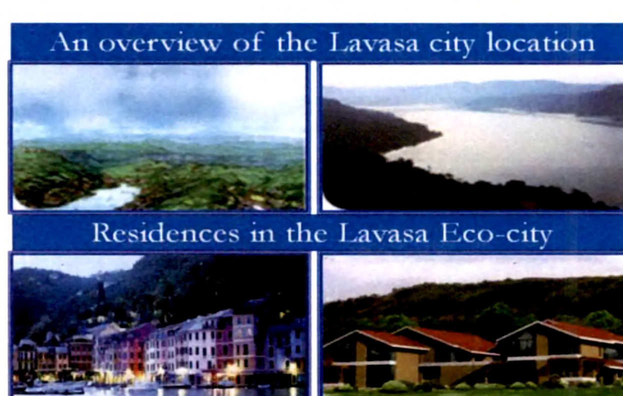

Plate 7: Eco-city of Lavasa

(1.1.6) Vadodara as an Eco-city:

The cities are the major sources of air pollution, water contamination and depletion of supply, excessive fossil fuel consumption, the consumption of materials made from non-renewable resources; and, of the depletion of agricultural land through low density sprawl and expansive waste management (**Steward and Kuska, 2008; Breheney, 1992**). As a consequences environment quality of some cities of developing countries like India is degrading constantly due to wasteful use of resources. This is proving to be costly to present and future generations. Same is the case with Vadodara city also. The city is growing very rapidly consuming all the natural resources most importantly the land. To make the best use of resources and to prepare the ground for the improvement and the development of Vadodara city there is a call for preparing a sound strategic plan. This can be achieved by implementing an Eco-city plan for the city. This plan will aim to attain a balance between the development of the urban areas and protection of the environment by decreasing the environmental damages and depletion of nonrenewable resources.

For preparing the eco-city plan different steps to be carried are mentioned below:

- To generate thematic maps based on various themes, viz. Transportation network, Water body, Gardens, Greenbelts, Population density and slope map of the city.
- To carry out land use change analysis,
- To perform suitability analysis of Urban Green Space (UGS)
- To perform Land Suitability Analysis (LSA) and
- To perform Air Pollution Tolerance Index (APTI) of various plants

Each of these points is discussed separately in different sections.

(1.2) Different types of Maps:

Maps are universal medium for communication, easily understood and appreciated by most people, regardless of language or culture. A map is a set of points, lines and areas that are specified both by their location in space with reference to a coordinate system and by their non-spatial attributes. They are an effective way of presenting a great deal of information about objects and spatial relationships of objects. Incorporated in a map is the understanding that it is a "snapshot" of an idea, a single picture, and a selection of concepts from a constantly changing database of geographic information. They are one means by which scientists distribute their ideas and pass them on to future generations **(Merriam, 1996)**.

Maps can be classified into two main groups: general purpose maps and thematic maps.

(1.2.1) General purpose maps:

General purpose maps are often used for reference purposes and can exhibit a variety of information including physical land features and political boundaries. The most common type of general purpose map is a topographic map. A topographic map is simply a two-dimensional representation of a portion of the three-dimensional surface of the earth. Topography in the topographic map is the shape of the land surface. Topographic maps represent existing condition of the land surface. They are often used as reference maps, and typically display both natural land features (such as coastlines and water bodies) as well as political boundaries. They are the tools used in geologic studies because they show the configuration of the earth's surface.

(1.2.2) Thematic maps:

Thematic map is a simple map made to reflect a particular theme about a geographic area. They are referred to as graphical essays that portray spatial variations and interrelationships of geographical distributions of various objects present on the earth surface. Thus, a thematic map is defined as a two dimensional scale model of a part of the surface of the earth, using symbols to represent certain objects and phenomenon. The term "thematic map" is very widely and loosely applied and is used not only for maps showing a general purpose theme such as "soil" or "landform", but for much more specific properties such as the distribution of the value of the soil pH over an experimental field, the variation of the incidence of a given disease in a city, or the variation of air pressure shown on a meteorological chart. A useful and attractive thematic map successfully combines the mapped data with physical and political elements that constitutes the base map. They help in classifying an area on a particular theme and identifying regions within that area where intervention is required. For example, a thematic map plotting the ground water levels in a given area can be used to design a geo-morphology map **(Upadhyay, 2005)**. These maps concentrate on the spatial variations of a single phenomenon or the relationship between phenomena. They portray the structure of a given distribution and may be used to characterize a wide variety of terrain characteristics. In these maps different tone, colors, and shading patterns are used to convey the different values assigned to each predefined polygonal area. They portray physical, social, political, cultural, economic, sociological, agricultural and many other aspects of a city, state, region, nation, or continent.

Thematic maps serve three primary purposes:

- They provide specific information about particular locations.
- They provide general information about spatial patterns.
- They can be used to compare patterns on two or more maps.

Thematic mapping began in 1686 with Edmund Halley. His maps dealt with sailing and navigation, but were more specialized and went beyond the subject of coastlines and places. One of those early thematic maps showed trade winds of the world **(Cuff and Mattson, 1982)**. In Roman times, the Agrimensores or land surveyors, were an important part of the government, and the results of their work may still be seen in vestigial form in the landscapes of Europe today **(Dilke, 1971)**. The decline of the Roman Empire led to the decline of surveying and map making. Only in the eighteenth century did European civilization once again realize the value of systematic mapping of their lands. National government bodies were commissioned to produce topographical maps of whole countries. These highly disciplined institutes have continued to this day to render the spatial distribution of the features of the earth's surface, or topography, into map form. During the last 200 years many individual styles of maps have been developed, but there has been a long, unbroken tradition of high cartographic standards that has continued until the present. In the twentieth century, the demand for maps of the topography and specific themes of the earth's surface, such as natural resources, accelerated greatly which led to introduction of various cartographic techniques for generation of maps more quickly. Stereo aerial photography and remotely sensed imagery were used by photogrammetrists to map large areas with great accuracy. The same technology had also given the earth resource scientists- the geologist, the soil scientist, the ecologist, the land-use specialist enormous advantages for reconnaissance and semi-detailed mapping. The resulting thematic maps provided useful information about status of various resources. These maps also helped in estimating the land requirements for producing food and supporting populations.

There are five techniques for thematic mapping which are used most often:

(1.2.2.1) Choropleth map:

The first and most commonly used technique of preparing a map is a Choropleth map. A Choropleth map is a thematic map in which areas are shaded or patterned which shows the measurement of the statistical variable being displayed on the map, such as population density or per-capita income. These maps are particularly suited for charting phenomena that are evenly distributed within each enumeration unit (set area). Choropleth techniques are used when the derived data are obtained from raw data such as population densities. Both quantitative and qualitative information can be expressed as a Choropleth map, i.e., areas of equal value separated by boundaries and typical examples are soil maps, land use maps or maps showing the results of censuses. These maps portray quantitative data as a color and can show density, percent, average value or quantity of an event within a geographic area.

(1.2.2.2) Proportional or graduated symbols map:

These maps represent data associated with point locations such as cities. Data is displayed on these maps with proportionally sized symbols to show differences in occurrences. Circles are most often used with these maps but squares and other geometric shapes are suitable as well. The most common way to size these symbols is to make their areas proportional to the values to be depicted with mapping or drawing software. **Plate 8** shows distribution of different plants according to their size which is an example of proportional symbol map.

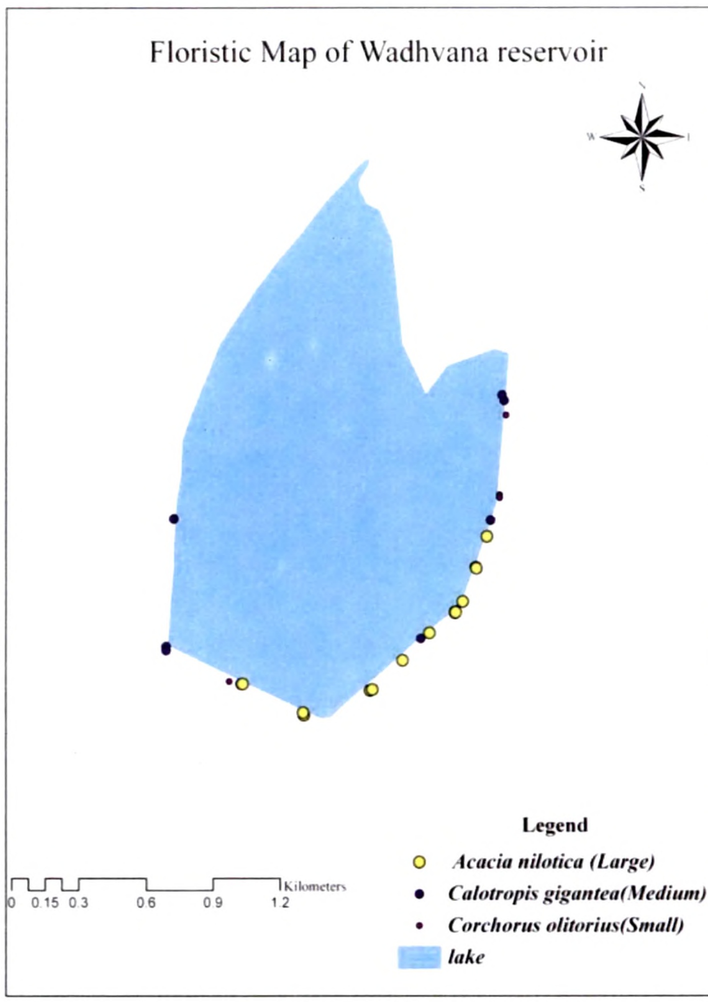

Plate 8. Map showing distribution of different plants according to their size.

(1.2.2.3) <u>Isarithmic or contour map</u>:

In these maps third variable is represented in two dimensions by colour or by contour lines, indicating gradations. It uses isolines to depict continuous values. Data for these maps is gathered via measureable points (e.g. weather stations) or is collected by area (e.g. tons of corn per acre by state). Contour lines are used to determine elevations and are lines on a map that are produced from connecting points of equal elevation (elevation refers to height in feet, or meters, above sea level). There is a high and low side in relation to the isoline in these maps. For example in elevation, if the isoline is 500 feet (152 m) then one side must be higher than 500 feet and one side must be lower. These lines showing different levels of contour have following general characteristics like:

1. They do not cross each other, divide or split.
2. Closely spaced contour lines represent steep slopes, conversely, contour lines that are spaced far apart represent gentle slopes.
3. They trend up valleys and form a "V" or a "U" where they cross a stream.

In most maps, contour lines are generally darker and are marked with their elevations. The contour interval is stated on every topographic map and is usually located below the scale. **Plate 9** shows the contour map of Gujarat.

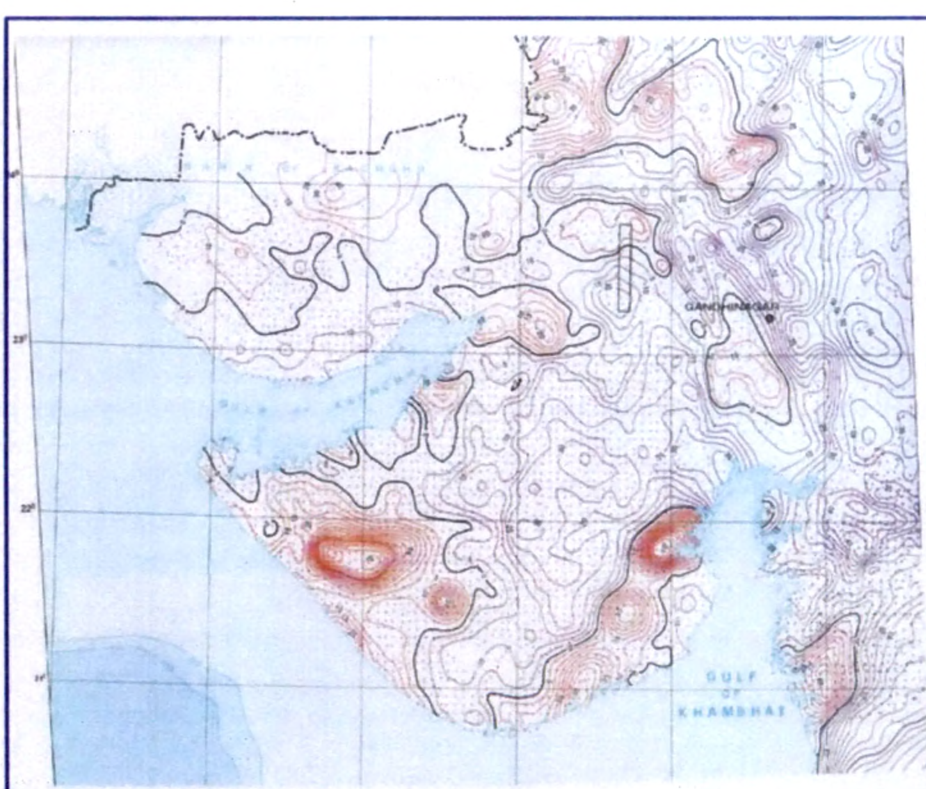

Plate 9: Contour map of Gujarat*

*Source:http://isr.gujarat.gov.in/gravity2.shtm

(1.2.2.4) Dot map:

These maps use dots to show the presence of a theme and display a spatial pattern. Dot density maps are particularly useful for understanding global distribution of the mapped phenomenon and comparing relative densities of different regions on the map. On these maps, a dot can represent one unit or several, depending on what is being depicted within the map e.g. the dot map given in **Plate 10** is depicting floristic composition of Wadhwana reservoir wherein each dot represents a specific type of plant species.

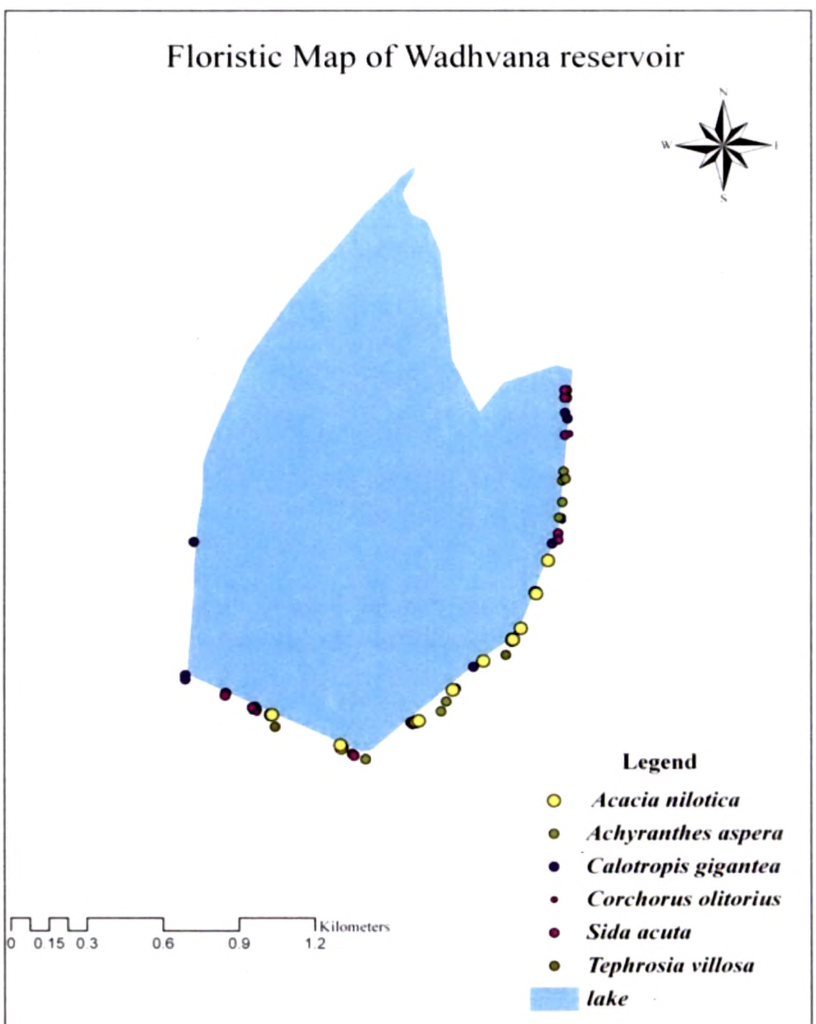

Plate 10: Floristic map of Wadhwana Reservoir

(1.2.2.5) <u>Dasymetric map</u>:

This method of thematic mapping uses aerial symbols to present data spatially. It is a compromise between the Isopleths map and Choropleth map because it utilizes standardized data and at the same time places the symbols by taking into consideration actual changing densities within the boundaries of the map. This map utilizes the ancillary data. It is superior to Choropleth map in relaying statistical data within areas of interest. This map corrects the error, termed "ecological fallacy", that may occur with Choropleth mapping. Dasymetric maps are not widely used because of the limited options for producing them with automated tools such as GIS. Researchers in various fields of science are trying to make dasymetric mapping techniques more easily applicable with modern technology. These maps are becoming more prevalent in developing fields, such as conservation and sustainable development.

(1.2.3) <u>Importance of Thematic maps</u>:

The urban ecosystem constitutes of various components like, water bodies, vegetation, built-up areas, etc. Mapping spatial distribution of these components becomes essential for designing a sound development plan. Thematic maps provide accurate and updated information of spatial distribution and present condition of these various resources. This information plays a vital role in formulation of planning, management and monitoring programs at local, regional and national level. Intense conflicts between socioeconomic development and environmental protection for these resources have increased the attention paid to sustainable urban development **(Rees, 1992; Rees, 1997; Pickett *et al.*, 2001; Pickett *et al.*, 2004),** especially in developing countries like India. This is because megacities of the country are grappling with the complexity of balancing urbanization with preservation and maintenance of supplies of these resources **(Arreguin, 1996; Goldenstein, 1998; Robles *et al.*, 1999; Baykal *et al.*, 2000; Ren *et al.*, 2003)**. Updated information of these resources acquired in the form of thematic maps is a foundation to develop an Eco-city. In such situation, eco-city development becomes an imperative and healthy process towards sustainable development within the carrying capacity of local ecosystem in which generation of thematic maps play a fundamental role.

(1.2.4) <u>Designing the thematic maps</u>:

Designing a thematic map requires a balance of number of factors in order to effectively represent the data. It is necessary to consider a number of key map design elements while designing a thematic map which include the frame of reference, the projection used, the features to be mapped, the level of generalization, annotation used and symbolism employed. All these design elements are presented in a legend which is a key for linking the non-spatial attributes to the spatial entities. Non- spatial attributes may be indicated visually by colour, symbols or shading. Spatial accuracy, aesthetics, quirks of human visual perception and their presentation are also taken into account while generating these maps. Definition of thematic maps depends upon the requirement of the users who will read the maps. For example, a political scientist might prefer having information mapped within clearly delineated state or town boundaries (Choropleth maps) whereas a state biologist could certainly benefit from natural boundaries of resources like water bodies, vegetation, etc. being on a map.

(1.2.5) Role of Remote Sensing (RS) and Geographical Information System (GIS) in generation of thematic maps:

Satellite RS offers varied advantages and has been widely accepted as a technique for urban thematic mapping. Compared to more traditional mapping approaches, mapping using satellite imagery has the advantages of low cost, large area coverage and repetitivity. Consequently, land-use information products obtained from satellite imagery such as land-use maps and data have become essential tools in many operational programs involving land resource management. The increasing availability of satellite imagery with significantly improved spectral and spatial resolution has offered greater potential for more detailed thematic mapping. Recent studies have demonstrated that the higher information content of imagery data combined with the improvement in image processing power result in significant improvement in classification accuracy. Products derived from RS are also important for GIS database development because they provide spatial information that can be incorporated directly into GIS **(Lee, 1991)**.

GIS is defined as a set of tools for collecting, storing, retrieving, transforming, and displaying geographically referenced spatial data with its corresponding attribute information. It is responsible for a major shift in techniques used for generating thematic maps. It comprises of computer hardware, software, digital data, people, organizations, and institutions for collecting, storing, analyzing, and displaying georeferenced information about the Earth **(Nyerges, 1993)**. GIS has two kinds of data bases:

1. Specific characteristic of a location called spatial data, and
2. Attribute data (Statistics of written text tables and so on)

The spatial data is classified into two categories i.e., raster data and vector data. The vector-based GIS, gives an attribute value for each predefined polygon using which the system is instructed to shade or colour the interior of each polygon appropriately. On the other hand the raster-based system is typically more complex. It often uses colour to code different contour line values and other attributes. It aids in generating precise map and integrate them as different themes. Thus, it has a database of multiple information layers that can be manipulated to evaluate relationships among the chosen elements in the different layers of typology. Application of RS-GIS technology therefore has several advantages as are enlisted below:

1. Make existing maps quickly and cost effectively for specific use and needs.
2. Makes map production possible in situations where skilled staff is unavailable.
3. Allows experimentation with different graphical representations of the same data.
4. Facilitates map making and updating when the data are already in digital form.
5. Facilitates analysis of data that demand interaction between statistical analysis and mapping.
6. Aid in generating maps which are difficult to be made by hand, e.g. 3-D maps or stereoscopic maps.
7. Aid in generating maps in which selection and generalization procedures are explicitly defined.

Thus, wide applicability of this technique has been exploited by several workers and in the present study for understanding land use change analysis of Vadodara city.

(1.3) Land use change analysis: An Overview

There are many problems confronting most contemporary cities in the recent time particularly among the less developed countries around the world. These problems have been recognized to be the product of lack of urban planning by the authority in-charge as well as individual members of the society **(Chandrasekar, 2010)**. The understanding of relationship between urban population and urban development using different methodologies has therefore become imperative. This is because expansion of human settlement and its accompanying activities especially the rapid urbanization plays an important role in changing the land use at both global and local scale. Land use is referred to the way in which, and the purposes for which, humans employ the land and its resources **(Meyer, 1995).** The land use pattern of a region is an outcome of several factors and their utilization by man in time and space. These factors driving land use changes are called as 'development attractors.' Such attractors also exist in one of the cities of India, i.e. Vadodara city of Gujarat state. The city has witnessed a rapid urban development during past few decades resulting into enhanced land use change, parallel to the increased population and economic growth. The city has expanded in all directions, resulting in large-scale changes in the land use. According to the projections made by VUDA, the city is expected to have a population of 21, 15,000 by 2021**(Dash and Kumar, 2010)**. Such rapid population growth due to urbanization and industrialization processes would definitely increase the pressure on land making proper land use planning imperative.

The term "Planning" stresses mainly on assessment of future and making provisions for it. In order to achieve proper urban planning and to check haphazard development, it is necessary that authorities associated with the urban development generate planning models. These models should help in utilizing every bit of the available land in most rational and optimal way. They should aid in selection, planning and implementation of land use schemes to meet the increasing demands of the city. Such models require data on present and past land use information of the area and pattern of changes with respect to urban settlements and other local resources **(Chaurasia *et al.*, 1996)**. It is subtle to acquire such volumetric information using conventional ground methods. Such methods are labor intensive, time consuming and are done relatively infrequently. The maps produced using these techniques soon become outdated with the passage of time, particularly in a rapid changing environment. Therefore, in order to use land optimally, it is not only necessary to have the information on existing land use but also a technique to monitor the dynamics of land use resulting out of both changing demands of increasing population and forces of nature acting to shape the landscape. According to **Olorunfemi (1983)**, monitoring changes and time series analysis is quite difficult with traditional method of surveying. At this point the advanced remote sensing techniques have proved to be of immense value for gathering all the possible information in quick and cost-effective manner. It aids in both preparing accurate land use maps and monitoring changes at regular intervals of time. The potential of remote sensing to detect the growth of urban land use changes and determination of statistics has already been demonstrated by several workers **(Li *et al.*, 2011; Chen and Xie, 2000; Saleh and Al Rawashdeh, 2007)**. Integration of such spatially retrieved data into Geographic Information Systems further has improved the analysis of the land use dynamics **(Sreenivasulu and Bhaskar, 2010)**. These systems integrate different spatial and statistical data relevant in understanding the changes. Such integration and organization of information on land use in these systems give the planners a broad view of the current situation. It aids in taking proper land related decisions for shaping the way in which land can be used and the built environment can be managed as it assesses the future more accurately. This has become a need for Vadodara city as it is facing the grave problem of both urbanization and industrialization.

In the recent years, Vadodara city has experienced significant growth in Information technology (IT) and IT Enabled Service (ITES) industries like the software and electronics. Demand for the Processing industries and other allied industries contribute about 41% share of the total industries because of the increasing demand related to plastics, and pharmaceuticals. Vadodara has nine Industrial Estates (I.E.) located dispersed in all the four corners of the city *viz.*, Makarpura I.E., Baroda I.E. (BIDC Gorwa), Sardar Patel (I.E.) (Ajwa Road), Baroda Ind. Co.Op. Estate (Chhani Road), Patel I.E. (Yamuna mill Road), Sahajanand I.E. (Atladra Road) and R.C. Patel Estate (Akota). Apart from these VUDA have industrial complexes like Nandesari, Ranoli, Bajwa and Undera **(VUDA report)**. Such industrial growth has brought in the population inflow from nearby rural areas resulting into a complex phenomenon of urban sprawl. This phenomenon has both environmental and social impacts and is measured in terms of Shannon's Entropy (S.E.) **(Barnes *et al.*, 2002; Sun *et al.*, 2007, Leta *et al.*, 2001; Yeh and Li, 2001; Sudhira *et al.*, 2004)** and urban sprawl index (U.S.I).

S.E. determines the distribution of built-up as a function of the area of built-up within a defined spatial unit **(Jat *et al.*, 2007).** The change of entropy identifies whether land development (sprawl) is of more dispersed or compact pattern. The U.S.I. developed by **Yuan *et al.*, 2005** on the other hand also is an important index providing information on the degree of sprawl in a city. Other indicators along with S.E. and U.S.I. determining the sprawl are the Land Consumption Rate (L.C.R.) and

Land Absorption Coefficient (L.A.C.). These indicators provide good input in the understanding of the land use change both at spatial and temporal scale. L.C.R. is a measure of compactness of the city indicating a progressive spatial expansion of urban area. Land absorption coefficient (L.A.C) on the other hand, is a measure of consumption of new urban land by each unit increase in urban population **(Fanan *et al.*, 2011, Sharma *et al.*, 2011).**

In the present study land use changes in Vadodara city have been measured over a period of 129 years. Estimation of different urbanization related parameters for Vadodara city have also been attempted. These changes have been assessed at two different levels, i.e. Vadodara Urban Development Authority (VUDA) level and Vadodara Municipal Seva Sadan (VMSS) level. VUDA covers the entire city and adjoining village areas while VMSS covers urbanized area of the city.

(1.4) Analysis of Urban Green Space:

Analysis of the Urban green space is segregated into three different parts, i.e., Suitability analysis, economic evaluation and assessment of impact of various biophysical and socio-economical parameters on UGS.

(1.4.1) Part 1: Suitability of Urban green space:

Urban areas presently cover about 4% of global land area. More than 50% of the global population currently live in cities and it is expected to increase to 70% (or 6.4 billion people) by 2050 (**Kasih, 2009**). These areas are multiplex ecological system made up of three subsystems i.e., social, economic and natural (**Haung and Chen, 2002**). The green spaces present in these areas are termed as Urban Green Spaces (UGS). These spaces are the foundation of the natural system in a city and the principal part of the natural productivity in the urban structure. They are the base for developing a city into Eco-city. **Wu (1999)** has described this as the area covered with the natural or man-made vegetation in the built-up areas. Landscape features like parks, public gardens, squares, traffic circles, sport fields, fallow lands, and family gardens as well as individual street trees form a component of the 'urban forest' **(Pauleit, 2003; Colding, 2007)**. UGS are managed intensively by different agencies or people. They provide many amenities for city dwellers like, aesthetic enjoyment, recreation, with an access to clean air and quiet environment. They also absorb atmospheric carbon, maintain a certain degree of humidity in the atmosphere, regulate rainfall, moderate the temperature, restrain soil erosion, produce vitamin "G" for health and form the basis for the conservation of flora. Conservation of the UGS therefore acts as a backbone for natural ecological network and support the sustainability of the cities. They act as the link between residential and industrial areas. The different social, economical and environmental benefits accrued from these areas in the urban region makes them very significant. Rapid urbanization and the accelerated urban sprawl are leading towards the conversion of these areas into a largely artificial environment like urban built-up, industries, etc. made up of concrete and asphalt. Increased built-up area results into the several regional environmental and climatic changes **(Landsberg, 1981; Oke, 1987; Oke *et al.*, 1992)**. It has already been proved that the urban temperature rises because surface covered with vegetation gets replaced by artificial facilities of impervious cover of asphalt and concrete **(Lee, 1993; Kato, 1996; Gallo *et al.*, 1996; 1999)**. As cities grow in both population and physical size, the urban-rural difference in atmospheric and surface temperature also increases **(Kalnay and Cai, 2003, Voogt and Oke, 2003)**. This difference in temperature leads to generation of urban heat island (UHI) effect. However, many researchers have proved that UGS and UHI are inversely proportional i.e., higher the amount of UGS, the lower the intensity of UHI **(Wu and Zhang, 2008)**. The role of UGS becomes very significant in such circumstances. It plays a very significant role in maintaining the temperature in the urban settings. Despite of this fact there is a total apathy towards the management of vegetation in many cities. Similar situation prevails in Vadodara city also wherein areas allotted for UGS are not maintained properly. They are getting converted to concrete jungles. In addition, no new areas are being allotted for development of UGS.

Above facts emphasize the need for not only developing green areas in the city but also to identify suitable sites in the city where these areas can be planned, managed and sustained. This can be accomplished using suitability analysis technique. This technique helps in determining the fitness of given tract of land for a defined use **(Steiner *et al.*, 2000)**. It is the process to determine whether the land resource is suitable for the given specific use by estimating the suitability level of that area in terms of all different parameters. It is an important analytical method for ecological planning. Several methods exist for suitability analysis viz., sieve mapping, landscape unit method, grey tone method and computer based Geographical Information System (GIS) method. GIS method has been used for this work because GIS in combination with remote sensing provides precise information about the present status of various parameters used for suitability analysis. In addition, spatial statistics algorithms within GIS help in accurate, consistent, unbiased assessment of UGS. This aids in determining the UGS suitability as it takes into account various parameters viz., vegetation, temperature, land use, transport, water body, population density, slope, location of greenbelts and gardens for the suitability analysis **(Tajima, 2003)**. All these parameters have been discussed separately in the following sections.

(1.4.1.1) <u>Vegetation</u>:

The spatiotemporal distribution of vegetation is a fundamental component of the urban environment. From the view of ecological balance, environmental protection and improvement, allocation of certain areas for UGS is prerequisite. It plays an active role in terms of ecological benefit. Acquiring information on the condition and distribution of areas with and without vegetation is in the centre unit which using conventional technique is a difficult task. Satellite data enables the retrieval of such information through various algorithms in the form of various indices. In the present study one of such indices viz. Normalized Difference Vegetation Index (NDVI) has been utilized to understand vegetation status. This index identifies the photosynthetic affinity or 'greenness' of the vegetation through the reflective proprieties of the chlorophyll and mesophyll layers within the plants in the NIR and red part of the EM spectrum. In case of photo-synthetically active vegetation, low red reflectance is observed along with very high NIR reflectance producing a NDVI, approaching the value of +1 and vice versa approaching the value -1.

Per capita vegetation and change in vegetation was assessed based on the quantification of vegetation by this method which proved to be a key input. Per capita green space is an index to assess the green space system in accordance to the population status. According to the International minimum standard suggested by World Health Organization (WHO) and adopted by the publications of United Nations Food and Agriculture Organization (FAO) the minimum area allotted for UGS should be 9 sq.m. per city dweller. Except for Gandhinagar and Chandigarh most Indian cities are far behind in their per capita urban forest availability **(Chaudhry *et al.*, 2011)**. Same is true for the Vadodara city also. Ward wise estimation of Per capita vegetation can provide an exact idea of availability of vegetation per city dweller which would help in identifying potential sites for developing UGS in different wards of the city.

(1.4.1.2) Temperature:

Land surface temperature a component which is also sensitive to vegetation and soil moisture has become a preliminary cause for converting urban areas in UHI. Utility of satellite thermal image for understanding such temperature changes is frequently used in recent years. LST changes for Vadodara city has been taken up as an important component for suitability analysis **(Eliasson, 1992; Dousset and Gourmelon, 2003; Bartholy *et al.*, 2003).**

(1.4.1.3) Land use:

Land use gets changed constantly by human activities from the past to the present and it is one of the most visible causes of ecosystem change **(Singh, 1996; Weng, 2001)**. This makes it necessary to construct accurate and up-to-date data on land use for correct assessment and management of urban environment and climate **(Assefa, 2004)**. Mapping the existing land use also provide a significant input for suitability analysis because it expresses the human impact, and influences the feasibility of developing UGS. It provides an idea about presence of open space in the city for developing the UGS and has been considered as an important input for site suitability analysis.

(1.4.1.4) Transport:

Importance of information on transportation for site suitability analysis is in the terms of road accessibility as it provides link between the settlements and UGS. The distance of UGS from the road has a significant impact on the character of UGS, due to noise, movement, pollution and the physical presence of the corridor. According to **Davies *et al.* (2008),** the total length of the road network act as a strong negative predictor of extent of green space and needs to be considered as a good input for suitability analysis for identifying potential sites for UGS development.

Elevation and slope are the two main topographic factors that control the distribution and patterns of vegetation. Availability of the ground water in the urban areas has a very significant effect on the growth of vegetation. Population density is one of the reasons for underdevelopment of UGS. Location of green belts and gardens provide the information on their present status of same in a specific ward. These theme layers therefore have been considered for the suitability analysis.

(1.4.2) Part 2: Economic valuation of Urban Green Space (UGS):

Not only identification but economic evaluation of the UGS is also essential for the sustenance of the existing UGS. It is a prerequisite for the Eco-city planning. It has been noted that the appreciation of Urban Green Spaces changes with each society (Jim, 2004). It is related with societal changes and depends on the historical context. Their lack of value, expressed in financial terms, prevents these UGS from being properly considered in the cost-benefit analysis of public urban planning policies. One of the main reasons for this is that there is no market to represent these green spaces or in other words, there exists no representation of the green spaces within the market prices of houses (**Hanley and Spash, 1993; Shechter, 1995; Callan and Thomas, 2000; Lange and Schaeffer, 2001**; **Willis *et al.*, 2001**). In the absence of market price the remnant UGS gets shrunk in size and gradually gets encroached by urban development and sprawl **(Lockeretz, 1989; English *et al.*, 1990; Leiva and Page, 2000)**. Besides this, the UGS are being overexploited in order to meet housing demand because of fast population growth **(Cohen, 1996; Bateman and Willis, 1999; Thompson *et al.,* 2001).** Estimation of their economic value in urban settings in such cases becomes mandatory. Economic valuation of any resource can be expressed in terms of direct or indirect economic benefit **(G. Sandhya K. and Malhi, 2011)** and for UGS these benefits are not direct. From an economic point of view; these services are public goods without a market price. Economists use two broad methods to evaluate such open spaces, i.e. by way of stated and revealed preference approach. The revealed preference approach stresses on the market choices that individuals make to reveal their underlying preferences and to estimate their values for goods and services **(Freeman, 1993)**. Example of this approach is hedonic price model in which the value is indirectly obtained by the influence exercised by the environment on the market price of another good. It enables the 'price' of amenities for which markets do not exist, such as open spaces and urban parks, to be inferred from observing and analyzing the price of goods from which markets do exist, for example housing **(Dunse *et al.*, 2007)**. Using this methodology the private benefit of UGS can be analyzed. Benefits produced by UGS make a neighborhood nice place to live, and these benefits are reflected in the prices of surrounding properties. Hence, the amenity of UGS can be valued in terms of money based on the price people pay for such benefits in their housing. This approach was applied for UGS valuation of Vadodara city for which real estate prices were taken into account. In this valuation GIS provided the descriptive framework for location of properties. One of the most basic advantages provided by GIS was the position of properties on a local map in terms of their geographic coordinates **(Din *et al.*, 2001)**. It also provided a means of organizing very large datasets spatially which helped in assessing UGS **(Pauleit and Duhme, 2000; Dwyer and Miller, 1999)**. In addition, spatial statistics within a GIS provided a consistent display of UGS along with their importance in adding the valuation to the property in a fast and efficient manner. It also aided in measuring the price difference of houses located in nice, safer, cleaner communities relative to similar homes located in less desirable communities. These price differentials provided an estimate of the value placed on UGS **(Comrey and Lee, 1992)**.

(1.4.3) Part 3: Assessment of impact of various biophysical and socioeconomic parameters on Property Value (P.V.) at VMSS level

The value of the UGS affected by various biophysical parameters like LST, NDVI, Normalized differential building Index (NDBI) and Building density (B.D.) and socio-economical parameter like population density (P.D.). It was therefore essential to assess impact of these parameters on the value of Property Value. At the same time UGS also influences both the biophysical and socioeconomic variables in and around the dwellings which is reflected in housing property prices. To explain this relationship and the impact created by biophysical and socioeconomic parameters, remote sensing and GIS based approach has been used in the present work.

(1.5) Land suitability analysis and Air Pollution Tolerance Index (APTI) for Eco-ward planning:

Sustainable use of resources can be achieved by implementing the **Land suitability analysis (LSA)** while preparing an Eco-city plan. The aim of LSA is to determine the suitability of land for alternative, actual or potential, land uses that are relevant to the area under construction. It provides information on the constraints and opportunities for the use of the land and therefore, guides decisions on optimal utilization of land resources **(FAO, 1983).** It predicts land performance, both in terms of the expected benefits from and constraints to land uses, as well as expected environmental degradation due to these uses. In the qualitative and quantitative context, LSA allows planner to allocate major land uses, including residential, industrial, office/retail, and green space etc. based on the local need for land. This helps in improving the existing situation of the city **(Tan and Lebron, 2011)**. The environmental condition can be further improved by understanding the effect of pollution on various plants of the city. This can be understood by two methods, i.e., Active and passive bio-monitoring. In this study active bio-monitoring method was adopted **(Klumpp *et al.*, 2003)**. **Singh and Rao (1983)** have developed the Air Pollution Tolerance Index (APTI) from leaf parameters to evaluate the tolerance level of plant species to air pollution. This index is based on four biochemical properties of leaves, i.e., ascorbic acid content **(Lee *et al.*, 2007),** total chlorophyll content **(Flowers *et al.*, 2007)**, relative water content **(Rao, 1979)** and leaf extract pH. Plant sensitivity and tolerance to air pollutants varies with these parameters. The APTI of plants present in the three selected wards of the Vadodara city was carried out to evaluate their tolerance level. The results will help in suggesting different plants in different wards for converting them to Eco-ward.

(1.6) Need of development of Vadodara as an Eco-city:

There is an urgent need for studying the environmental condition of the Vadodara city and nearby areas because of rapid urbanization. Developing Vadodara city as an Eco-city will help in decreasing environmental stress, improving living conditions and in achieving sustainable development through a comprehensive urban improvement system involving planning and management of land and its resources. Urban degradation will get reduced when environmental considerations will be adequately getting incorporated into plans (Master Plans). The eco-city proposal will have positive contribution to sustainability, quality of life and health, and planning and designing of built environment of Vadodara city. Implementation of environmental improvement measures will prove as a major step in eco-city development. This process will not only benefit the citizens of Vadodara through renewed and effective management, but will also help in formulating the policies for future development.

Keeping these facts in mind the following objectives has been designed for the study:

(1.7) Objectives:

- **Generation of different thematic maps required for Eco-city planning.**
- **Monitoring of land use changes in the city over past two decades.**
- **Suitability analysis for Urban Green Space identification in different areas of the city for proposed changes.**
- **Eco-city/Eco-ward plan generation and recommendations.**