CHAPTER 4

RESULTS

(4.1) Thematic map generation:

The provision of basic services and infrastructure in many developing metropolitan areas is still in its infancy. Therefore, making existing cities and new urban development more ecologically based and livable is an urgent priority in the global push for sustainability. Changing urban development from its present unsustainable forms and patterns is a very challenging process. Not only does the urban pattern, transportation systems, water, waste and energy technologies have to change, but also the value systems and underlying processes of urban governance and planning needs to be reformed to reflect a sustainable agenda. Clean water, transportation infrastructure, solid waste management and pollution control are well accepted as essential elements for such a change. In addition, up to date and recent information on various resources of the city is required. The thematic maps generated in present work have provided accurate information about the existing status of all these elements of Vadodara city. Thematic maps of different component generated for this city have been briefly explained separately.

(4.1.1) Thematic layer of Transportation Network of Vadodara city:

Transport is the single biggest issue for urban environmental debates **(Jenks *et al.*, 1996)**. In Vadodara, the inefficiency or lack of urban transport services and infrastructure is one of the major impediments to economic growth and urban productivity. Every day more and more vehicles are being added to the Vadodara transport network. Many of the citizens are having more than one vehicle. Increasing motorization, poorly operating public transport services, inadequate road maintenance, insufficient bikeways and walkways, poor traffic management, lack of enforcement, transport education and culture are contributing factors to congestion, road accidents, and air pollution. The morning and evening traffic congestion leads to loss of work and time, increased fuel consumption and emissions, and high accident rates. The form of cities is the reflection, to a large extent of the transport technologies that were dominant at different stages of their development **(George, 1996)**. Looking to present city structure and major arteries linking the city with the region gives a sound network but with few flaws and so it still need to be strengthened for future requirements and developments. For example location of railway station and bus stand in the same area has created heavy conjunction though both gives sound link off the city with the region, state and other parts of the country. Total length of the paved and unpaved roads of the city is 711 km. As per the estimate of the VMSS, the road network accesses 70 % of the city area and more than 80 % of the population. All these facts make necessary the study of transport system of the Vadodara city. Moreover, Vadodara city is well connected with the adjacent areas by National highway (NH) 8 and State Highways **(Plate 13)**. Major roads leading to the other cities are Savli road, Godhra road, Waghodia Road, Ajwa Road, Dabhoi Road on eastern side and Jambusar, Gotri road on the western side **(Table 7)**. Broad gauge railway line passing through the city is also an important link to different regions. A narrow gauge railway line towards Dabhoi and Jambusar also connects a good network for the nearby small cities.

Table 7: Different roads of Vadodara city

Location	Road
East - Western Area	• Vinoba Bhave Road, connecting Tilak Marg, Salatwada, Nagarwada, Bhutdi zampa upto Champaner gate, north of the walled city; • R.C.Dutt Road, Tilak Marg, Raopura road connecting Jubilee baug, Nyay Mandir, Mandvi,Panigate and further east to Waghodia road and Ajwa road; • Indira avenue diversion from Tilak road at the Vishwamitri river bridge, Jawaharlal Nehru Marg, Dandia Bazar upto Nyay mandir; • Rajmahal Road from Laxmi Vilas palace to Nyay Mandir • Vishwamitri Road between Padra Road in the western side of the river; and • Jawaharlal Nehru Road and east to Dabhoi road Via Lalbaug
Western area	• V.S.Marg • R.C.Dutt Road • Jetalpur Road • Gotri Road • Padra Road
Around the central city	• Ring road along the Padra road in the west, Vikram Sarabhai Marg, Subhash Bridge, University Road, Harni Road, Waghodia Road to Tarsali and via Makarpura GIDC to Padra Road Junction
Northern – Southern area	• Fatehgunj road in the west side of Sayajigunj • Long Road connecting Baucharaji road, Prof. Manek Rao Road, R.V. Desai Road upto Pratapnagar • Link connection Godhra Road State Highway with Harni Airport and southwards to Bank road; and • Gendigate road, Pratapnagar Road up to the railway crossing

Vadodara which is predominantly administrative, business and industrial city in recent years is facing a rapid development and population increase resulting into traffic congestion and parking problems. Some of the city areas like, area within four gates, Raopura, Dandia Bazar, Chowkhandi, and Bhutdizampa have become overcrowded. During the peak hours they suffer from the heavy traffic creating chaos thereby requiring special attention. A large number of people have to commute from the eastern part of the city to different direction and in the evening to return to their residence. Thus, a proper road network planning becomes imperative to avoid large volume of traffic and undue delay. This leads to high rates of traffic accidents and excessive strain on the public transit during the peak hours. This situation exhibits the urgent requirement of well developed and proper transportation network in the city.

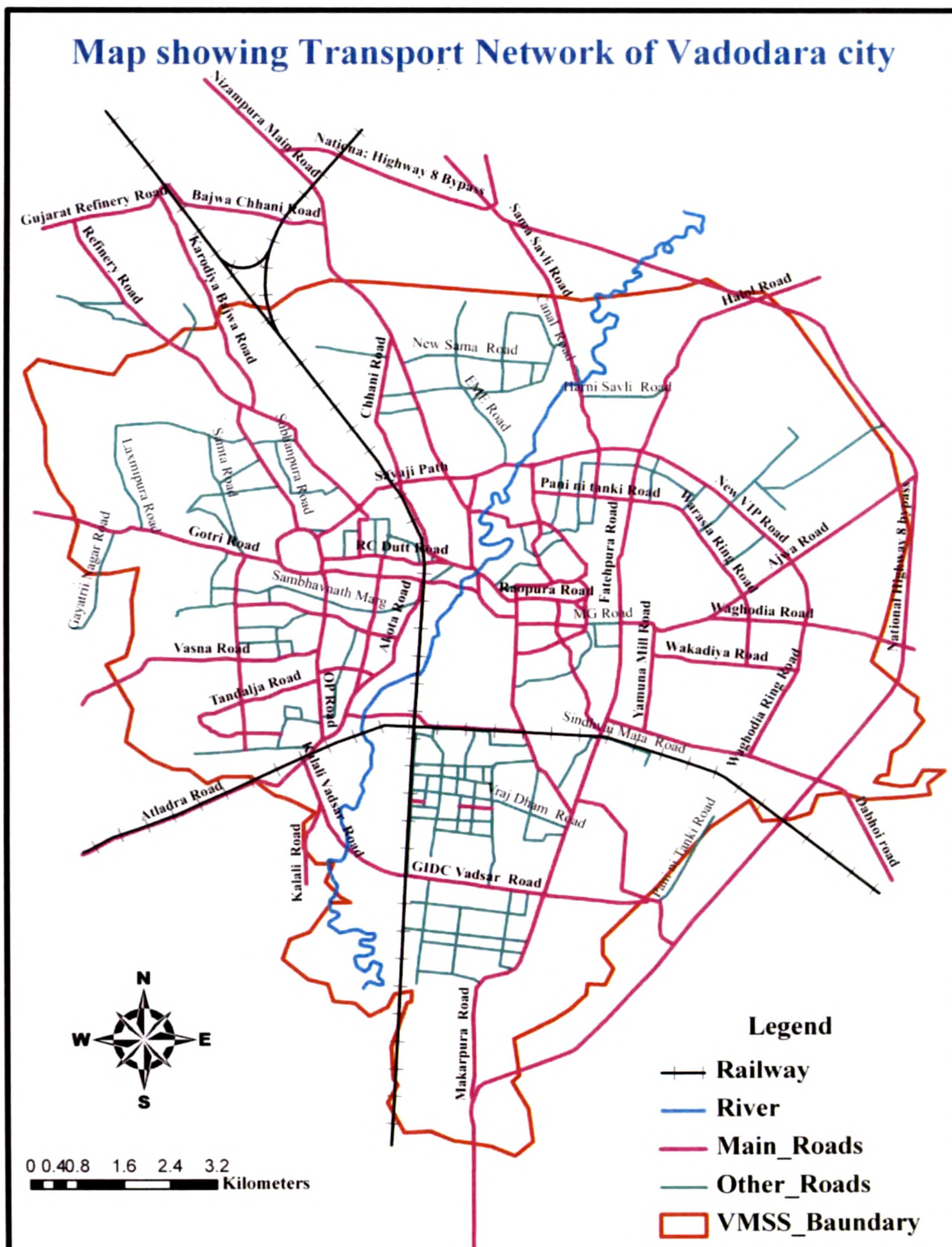


Plate 13: Transportation network of the Vadodara city

(4.1.2) Thematic layer of Water body of Vadodara city:

Freshwater resources are fundamental to agriculture, food production and human development. While freshwater supplies are clearly limited, for most people water scarcity is caused by competition between water uses and by political, technological and financial barriers that limit their access to water **(Falkenmark and Lundqvist, 1998)**. The UN Environmental Programme reports that "if present trends continue, 1.8 billion people will be living in countries or regions with absolute water scarcity by 2025, and two thirds of the world population could be subjected to water stress **(UNEP GEO-4 2007)**." Every city needs enough water for its population and industries, and hence it needs water resources. Accelerated urban growth, increasing poverty and low investment in water supply is contributing to water shortages in many cities. Drainage and infilling of wetlands through the process of illegal urbanization means natural loss of water storage areas and reduction in groundwater recharge, reducing dry season flows and the options available for coping with drought. In such situation mapping the water resources becomes essential because a sustainable urban water system is a basic feature of an eco-city. The eco-city approach to urban management combines water with environmental management and focuses on long-term urban sustainability. Its purpose is to make water treatment more sustainable and protect the quality of drinking water sources.

From the thematic layer it is clear that, many water bodies exist as a part of the hydraulic network of the city. Some of them like Sursagar in the heart of the city are provided with built walls **(Plate 14)**. Eastern part of the city has good number of water bodies some of which are located in the vicinity of gardens **(Plate 15).** The quality of water in all lakes is not suitable for human consumption. There is no aquatic life, barring some stray cases. Weed growth is abundant. Lakes provided with stoned walls are found to be in dilapidated conditions and require major repairs or replacement. Slums have also developed on the banks and in some cases, even the tank bed is encroached upon. The garbage dumping has further degraded the environment leading to unhealthy living conditions for the slum dwellers and people in the vicinity. Some of the lakes like Gorwa lake, Harni pond, etc. are now acting as breeding grounds for mosquitoes. Lakes, which served the basic needs of society and provided a healthy environment, are in disuse and are turning into health hazards. It is therefore, imperative to preserve and revive these water bodies and also protect the water quality.

The Vadodara branch canal of the Sardar Sarovar Project, running on north and east boundary is a perennial canal and is a recent addition to the hydraulic system. The lakes are an integral part of the hydraulic system of Vadodara city and have influenced the development of the city so far. The Vishwamitri river passes across Vadodara City.

Plate 14: Sursagar lake of Vadodara city

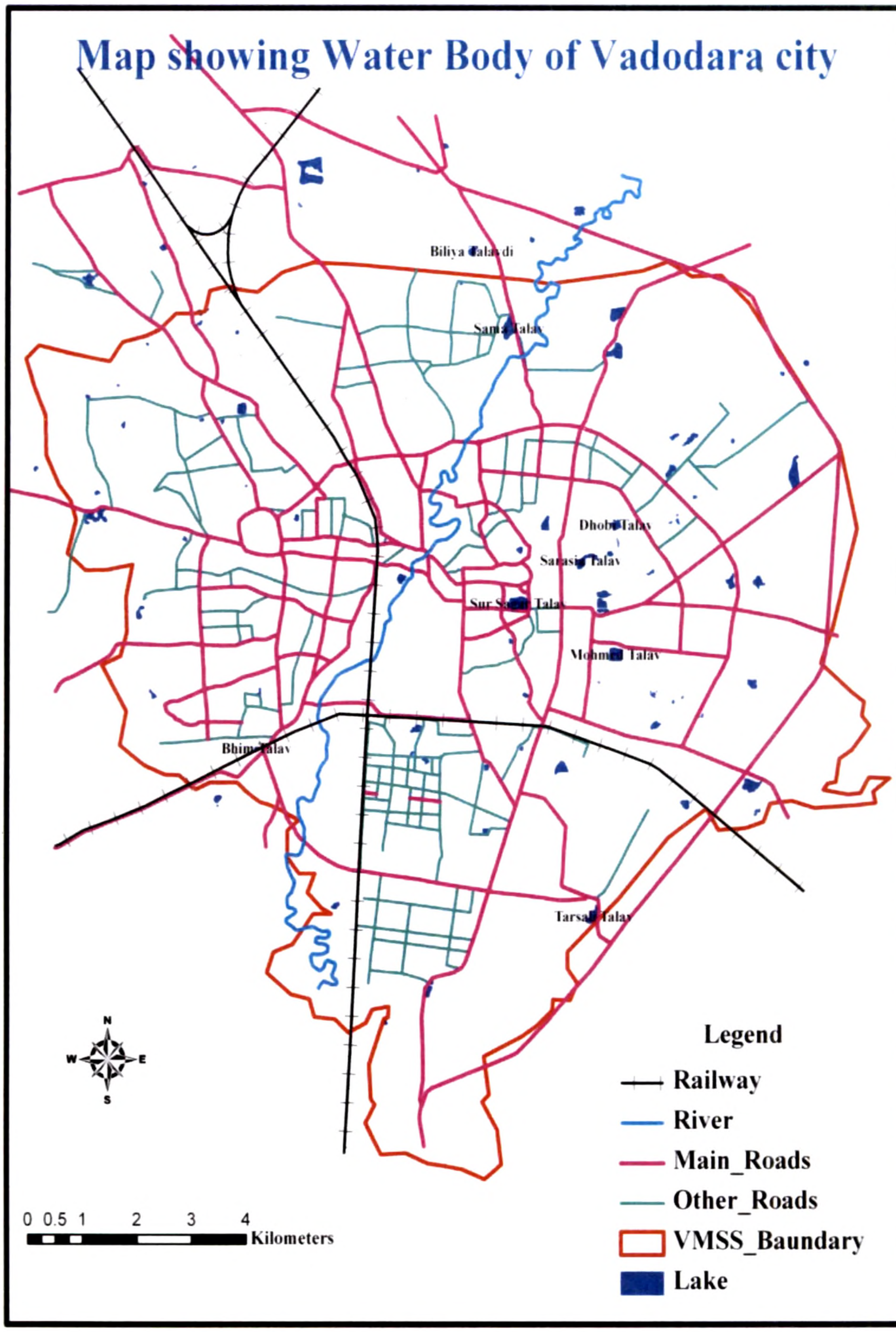


Plate 15: Map showing different water bodies of Vadodara city

(4.1.3) Thematic layer of Gardens of Vadodara city:

Vadodara is known as the "city of gardens" due to presence of many gardens in the city. These gardens have been set up for recreation by VMSS (Vadodara Mahanagar Seva Sadan). Gardens of the city have been expanding from time to time, under successive gardeners to its present state. These parks and gardens are of great importance; as they act as the great green lungs that make city fit to live in. These are profusely green, with plantations of major plants, shrubs and herbs. They play a very important role in preserving the biodiversity of the urban ecosystems. They serve not only to retain precipitation, recharge the water tables, clean the air, and provide wildlife habitat but also act as wind breaks and cool and refresh the summer breeze. **Table 8** shows the list of the gardens present in the city. Total 51 gardens have been reported from the city covering the area of 400 ha. The largest garden of the city is Sayaji garden located in the Sayajigunj area while the smallest one is the Navi Dharti garden which is situated in the Navi Dharti area. Few new gardens have also been reported during the survey of the city of which three are located in the Manjalpur and one each in Akota, Maneja, Subhanpura and Gajrawadi. Some of these gardens like, Sayaji Garden, Suryanarayan Baug, Kevda baug, etc. are located along the roadside while some of them like Makarpura baug, Tarsali housing baug are located in between the residential areas. These gardens are located all around the city and provide many amenities to the people living in near vicinity **(Plate 16). Plate 17** shows photographs of various gardens of the city.

Table 8: List of the gardens present in the city

Sr. No.	Name of the Garden	Area (Ha)	Location
1.	Sayaji Garden	113.00	Sayajigunj
2.	Suryanarayan Baug	0.36	Raopura
3.	Jubilee Baug	3.00	Nr.Amdavadi Pole
4.	Lal Baug	9.31	Nr.Lal railway crossing
5.	Varasia Baug	2.20	Sant Kanvar Society
6.	Chandan Baug	1.00	Shankar Baug soc. Manjalpur
7.	Makarpura Baug	1.06	Nr.Makarpura Village
8.	Maneja Baug	0.14	Nr. Maneja Village
9.	Market Baug	0.33	Nr.Khanderao Market
10.	Kevda Baug	0.26	Nr. Shiya Baug
11.	Sardar Baug(Vadi)	6.06	Nr. Sarabhai Chemicals
12.	Hirak Baug	0.11	Nr. Railway Station
13.	Akota Baug	5.00	Nr. Akota water tank
14.	Shankar tekri Baug	1.24	Nr. Technical College
15.	Maharishi Baug	2.20	Fatehgunj
16.	Channi Jicon Baug	-	Nr. Channi
17.	V.I.P Trikon Baug	0.20	VIP Road
18.	Harni Housing Baug-1	0.64	Nr. Harni Atithi Gruh
19.	Harni Housing Baug-2	0.64	Nr. Harni Housing
20.	Moti Baug	0.10	Rajmahal Road
21.	Navapura Baug	0.60	Bh. Navapura Market
22.	Azad Baug	0.92	Opp. Moti Tambudivad
23.	Sarasiya Baug	2.74	Mohammed Lake wadi
24.	Shantinagar housing board	0.10	Tarsali
25.	Danteshwar	1.00	Danteshwar Village
26.	Tarsali Housing Baug 1-2	0.30	Tarsali Housing
27.	Tarsali Sewage Baug	2.20	Tarsali pumping Station
28.	Gajrawadi Baug (Shashtri Baug)	-	Gajrawadi
29.	Khaswadi Smashan Baug	4.18	Bahucharaji Road
30.	Ramnath Smashan Baug	1.07	Gajrawadi
31.	Navroji Baug	0.11	Sayajigunj Police Station
32.	Pratapgunj Statue Baug	0.10	Pratapgunj
33.	Premanand Hall Baug	0.10	Mahammed lake wadi
34.	Panigate Gruh Baug	-	Panigate
35.	Hariomnagar Baug	0.18	Gotri Road
36.	Wadi Sewage Baug	3.00	Gajrawadi
37.	Jambua Baug	2.00	Jambua Village
38.	Ajwa Garden	100.00	Nr. Ajwa lake
39.	Nimeta Garden	25.00	Nr. Nimeta Filteration
40.	Navi Dharti Baug	0.03	Navi Dharti,Nagarwada
41.	T.P.12 Baug	0.33	Ellora Park
42.	T.P.7 Baug	-	-
43.	T.P 11\2	-	Nr. Sama crossing
44.	Saii Udhyan	4.40	Manjalpur
45.	Dr.Hedgevar Udhyan	11.00	Sama,Bhadrannagar
46.	Veer Sankar udhyan	-	New Sama Road
47.	Shantinagar Plot-1	-	Shantinagar Tarsali
48.	Shantinagar Plot-2	-	Shantinagar Tarsali
49.	Sharadnagar Plot-1	-	Sharadnagar Tarsali
50.	Sharadnagar Plot-2	-	Sharadnagar Tarsali
51.	Sharadnagar Plot-2	90	Sharadnagar Tarsali

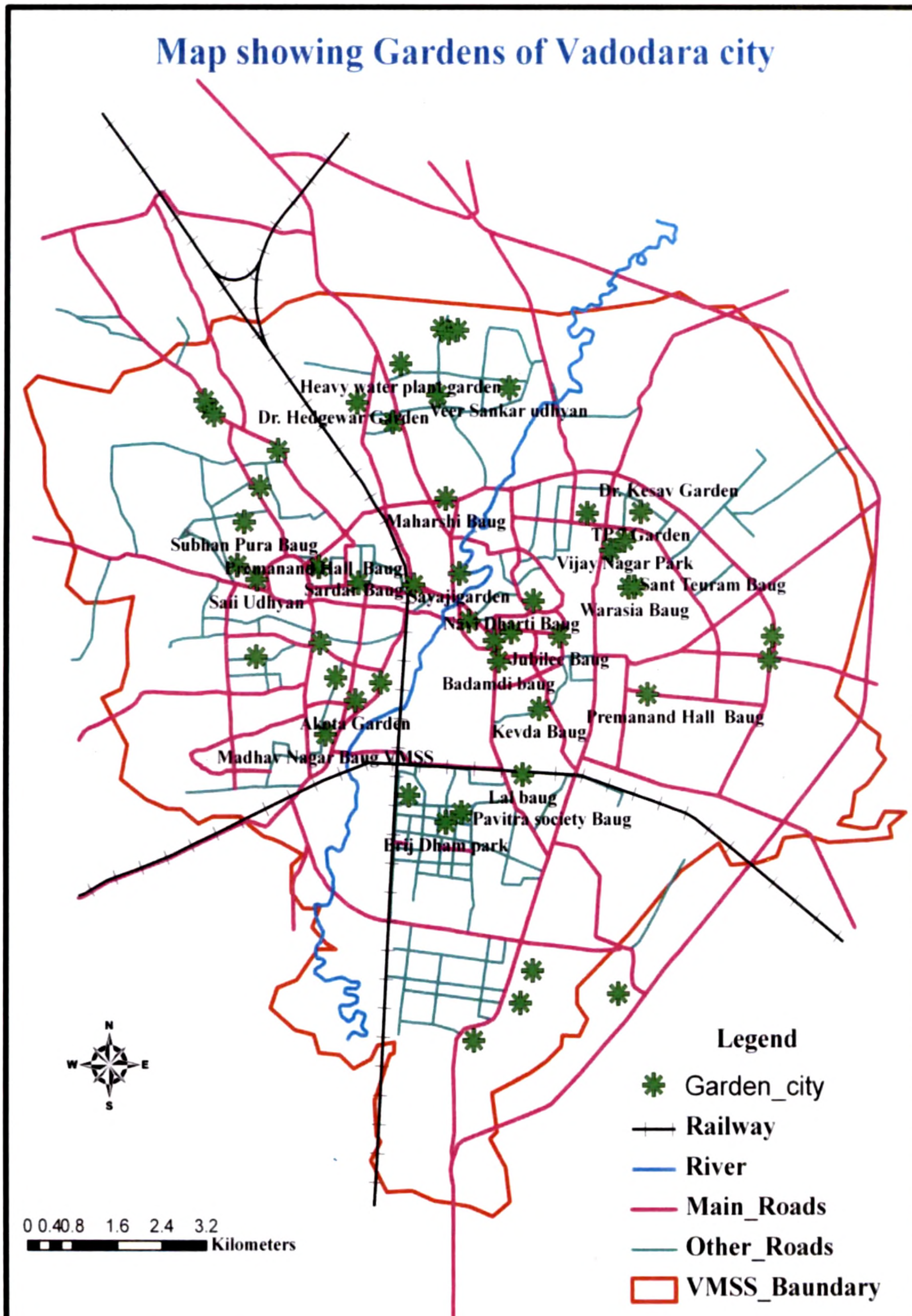


Plate 16: Map showing different Gardens of Vadodara city

T.P 7 Udhyan, Karelibaug

Maharshi Arvind Udhyan, Fatehgunj

Hirak Baug, Sayajigunj

Vijay Nagar Garden, Vijay Nagar

Sant kanvarram Baug, Gajrawadi

Sardar Baug, Race course

Plate 17: Photographs of different Gardens of Vadodara city

(4.1.4) <u>Thematic layer of Greenbelts of Vadodara city</u>:

A Greenbelt (GB) refers to a physical area of open space, e.g., forest, or other green space, that surrounds a city or metropolitan area, and it is intended to be a permanent barrier to urban expansion. **Plate 18** shows different Greenbelts of the city. Any type of development is strictly regulated or prohibited on GB land. It is an important part of complex urban ecosystem services including: flood control, air filtration, carbon storage and erosion prevention. The GBs are gaining greater importance day by day as the urbanization is degrading the environment very rapidly. GBs also connect urban dwellers with nature and so it is imperative that all cities should earmark certain areas for the GB development to bring variety to the built-up city and a healthy environment to the urbanities **(Sharma and Roy, 1999)**. These GBs also play an important role in sustainable development, i.e. Eco-city planning. Planning, management and development of GB therefore become imperative. Vadodara city has 19 GBs identified by V.M.S.S. (Vadodara Mahanagar Seva Sadan). The total area encompassing the GBs is approximately 20344 sq.m.**(Table 9)**. These GBs are located either along the road side or in between residential areas depending upon the area alloted. As less as only 37% of them are fuctional and performing the functions of reducing the pollution and restricting urban sprawl. Few of the GBs were not reported during the survey of the city and few of them were lacking any type of vegetation. Hence, such GBs were categorised as non-functional GBs. Few selected green belts as observed on ground are shown in **Plate 19**.

Table 9 : Important Green belt Areas of City

Plot	T.P no.	Location	Area (Sq. m.)	Status
234	1	Guru Prasad Society Near Akota Playground	3114	Functional
127	4	Varishta Nagrik Mandal Bapod	379	Non-functional
281	5	New V.I.P road New Snehal Printing Press	1766	Non-functional
961	3	Relok youth Club and Charitable trust	474	Non-functional
401	3	Senior Citizen Bapod	564	Non-functional
234	3	Near Kailash Society Bapod	595	Non-functional
428\1	3	Near Prabhat Society Vaghodia Road (GB transformed into Garden)	1841	Functional
248	3	Near Uma Society Vaghodia	1179	Non-functional
498-499	3	Chandanben Vithaldas Parekh Bhavan	-	No location available
272	19	Vallabh Foundation Trust Manjalpur	3201	Functional
42	19	Yogi Foundation Trust Swami Narayan Mandir Manjalpur	192	Non-functional
133	19	Yogi Foundation Trust Swami Narayan Mandir Manjalpur	352	Non-functional
180	5	Lokseva Federation	500	Non-functional
303	2	Behind Natubhai Circle Race cource circle	925	Functional
146	9	Near Dhanlaxmi Society Karelibaugh	1036	Functional
33	9	Mangal Jyot Society Karelibaugh	1160	Functional
353	9	Near R.R.Park Society	1253	Functional
50	7	Sangam Chaar Rasta Harni	929	Non-functional
10	4	Vaghodia Road	884	Non-functional

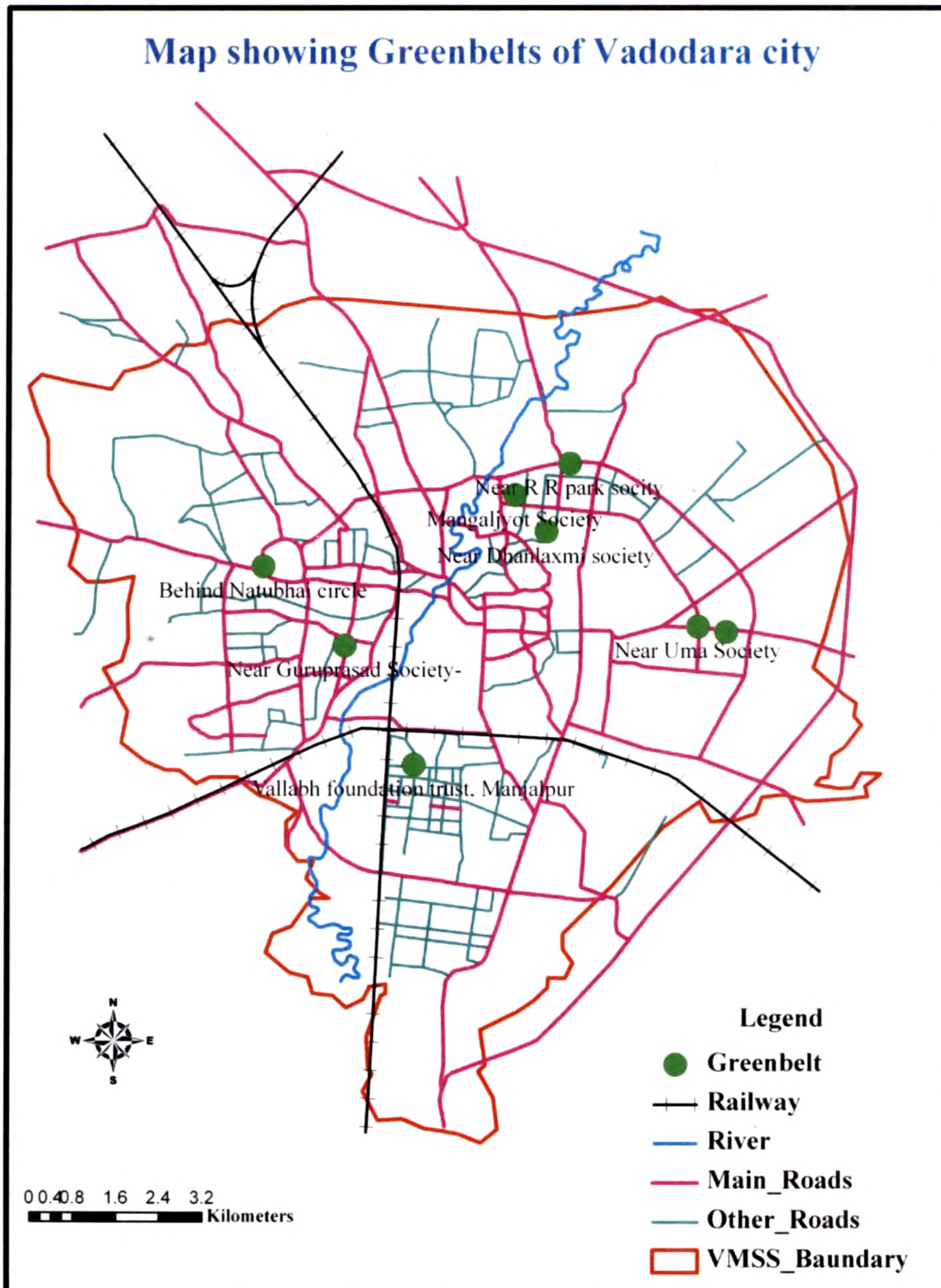
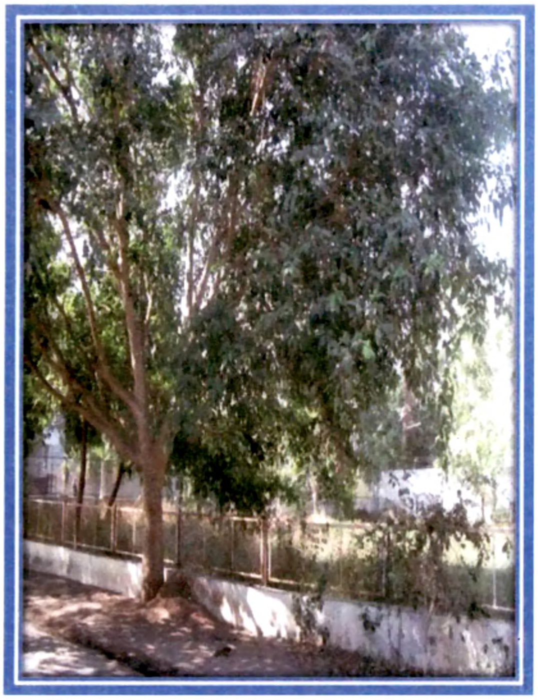
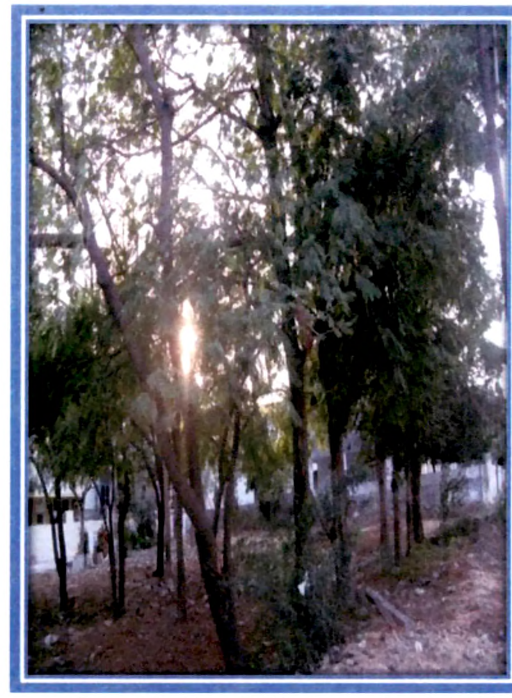


Plate 18: Map showing different Greenbelts of Vadodara city



Greenbelt at Guruprasad Society



Greenbelt at R.R. Park Society

Greenbelt at Mangaljyot society

Greenbelt at Near Prabhat Society

Plate 19: Photographs of different Greenbelts of Vadodara city

(4.1.5) Thematic layer of Population density of Vadodara city:

At any level of development, human impact on the environment is a function of population size, and the environmental damage caused by the technology used to produce what is consumed. Widespread poverty, environmental conditions, the use of natural resources along with economic and social development is closely linked to population growth and distribution. In spite of covering only 1.5% of the total land area of the earth, 50 % of the global population currently lives in cities and it is expected to increase to 70% in 2050 **(De and Soni, 2009).** The urban population in India is 285 million, which is 10 per cent of world and 21 per cent of Asia **(Singh and Manoj, 2009)**. Such magnitude of urban population growth for a developing country is a direct indicator of the degree of spatial concentration of people, industries, commerce, vehicles, energy consumption, water use, waste generation, and other environmental stresses. This leads to unsustainable patterns of consumption and production which is responsible for depleting natural resources and causing environmental degradation. The understanding of demographic trends of the Vadodara city becomes important as the development of city into an eco-city is highly influenced by socioeconomic conditions and population density **(Hald, 2009)**. The city is the third most populated town in the Gujarat after Ahmedabad and Surat. It is one of three towns with a population of over 1 million and the 16th most populous city of India. The city has developed as one of the major industrial and commercial centers of Gujarat. The population of Vadodara city has increased from 1, 03,790 in the year 1901 to 16, 66,703 in the year 2011 **(Figure 7)**.

It was difficult to trace the demographic trends of the city prior to the 1901 Census. According to 1901 census the population of Vadodara was 1,03,790 **(Table 10).**

Around 1902, the city faced a locust invasion, resulting in a heavy loss of agriculture output. Plague followed by famine in 1906, made the conditions very abject. These factors declined population by 4.66 % from the year 1901-1921. The third decade was a transitory period in the population history of city due to increased population during this time. The highest change in population was observed in the year 1981 at both VMSS and VUDA level. The reason behind such increase was rapid industrialization during this time. The trend of growth set during the first three decades of the post-Independence era, continued during the last two decades of 1981-1991 and 1991-2001. Rapid urban-rural migration during these decades resulted into the rapid increase in population. The population increased by 5,88,147 during this time.

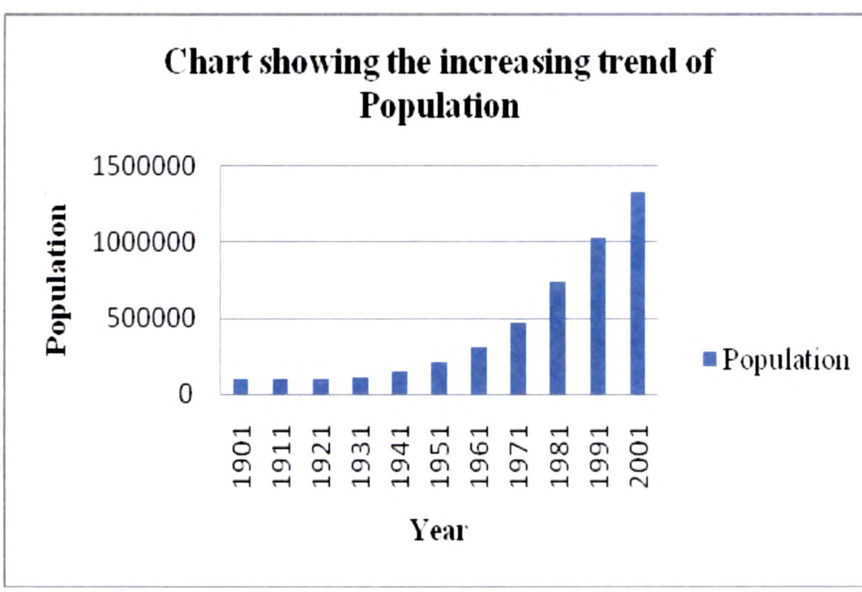


Figure 7: Chart showing the increasing trend of population

Table 10: Population statistics of Vadodara city

Year	Population	% Change VMSS	% change VUDA
1901	1,03,790	-	-
1911	99,345	-4.28	-
1921	94,712	-4.66	-
1931	1,12,860	19.16	-
1941	1,53,301	35.82	-
1951	2,11,407	37.90	-
1961	3,09,487	46.50	36.80
1971	4,67,487	50.94	45.80
1981	7,34,473	57.10	49.77
1991	10,21,084	39.02	21.97
2001	13,22,620	40.00	34.05

The change in population density of different wards of Vadodara city exhibited that the City ward (No. 1) was having the highest density in both the years. The second highest density was reported by Raopura and Sindhvai Mata Road wards in the years 1991 and 2001, respectively **(Plate 20).** The lowest population density was reported by Gajrawadi ward in both the years. The City ward showed decline in population from the year 1991 to 2001. It was partly because of high cost of land in the inner city and partly because the inner city is being commercialized and many residential buildings are being converted into shops and other buildings. Added to this is the wards have become congested due to high residential building density affecting environment condition of these wards. Increasing vehicular traffic has made the situation worse due to heavy pollution load. New residential colonies are coming up in the wards like Panigate, Subhanpura, Sindhvai Mata road, etc. These areas are developing away from the congested core around the periphery of the city. More citizens prefer to live in these areas with good environment condition.

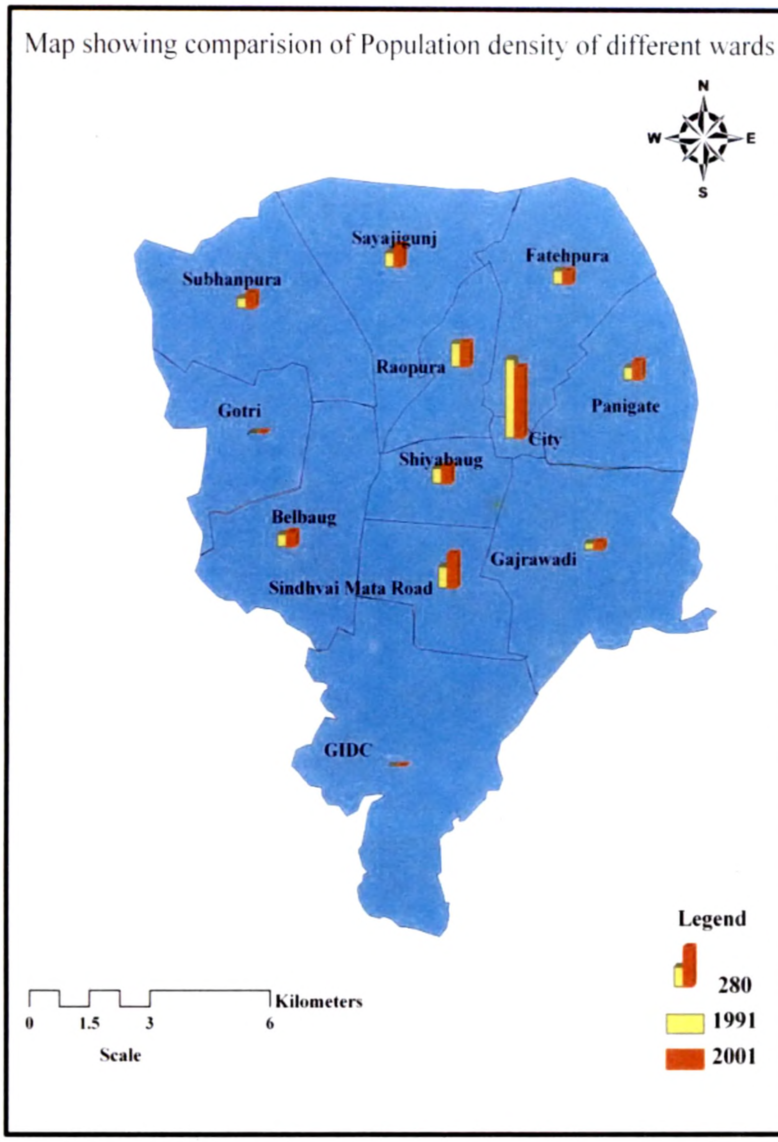


Plate 20:Map showing the Population density of different wards in the year 1991 and 2001

(4.1.6) <u>Contour and Slope of Vadodara city</u>:

Contour and Slope map of Vadodara city explained the terrain characteristics of the city. The results showed that the highest peak in the Vadodara city was reported in Fatehpura area with the elevation of 43 m while lowest peak was observed in GIDC area with elevation of 26 m **(Plate 21)**. The slope map generated from the information of contour map exhibited that the city has a relatively flat terrain. The city showed gentle slope ranging from 0.001 to 0.87 %. The contour lines were found be spaced evenly indicating a uniform and gentle slope in the northern parts of the city while they were spaced closely indicating the steeper slope in the southern side of the city. The high percent of slope value was seen in GIDC ward while areas like Subhanpura, Gotri etc. showed lower percent values of slope **(Plate 22)**.

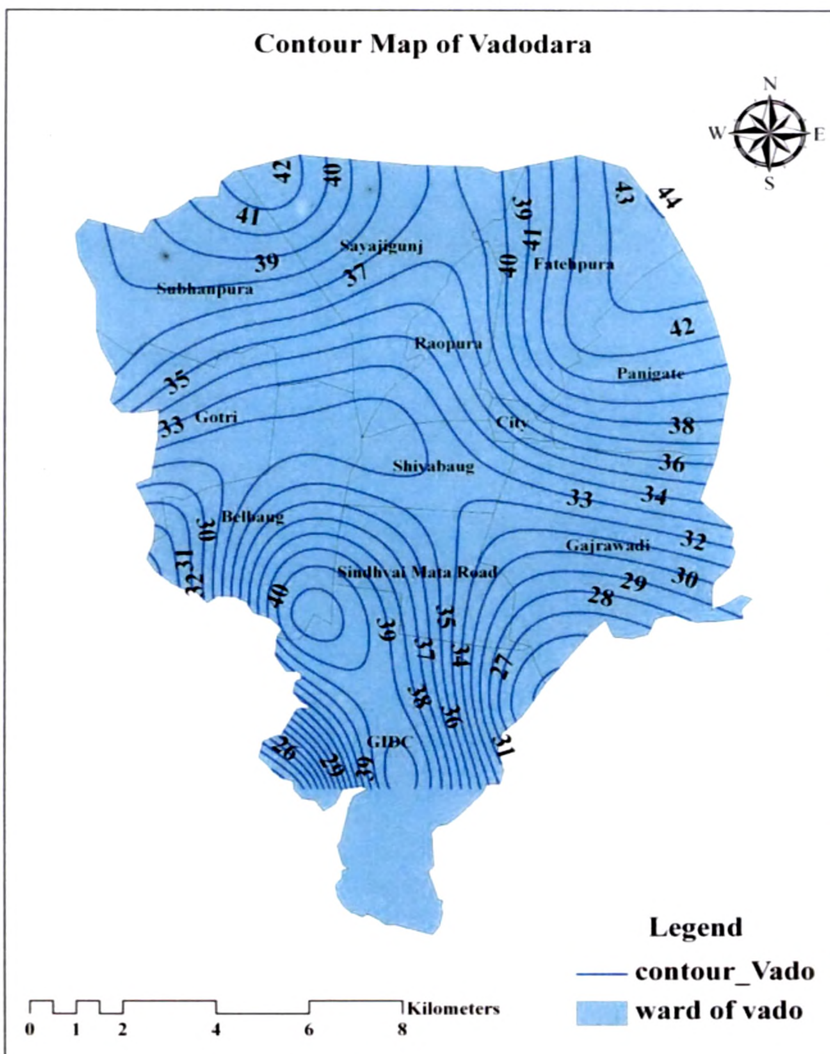


Plate 21: Contour map of Vadodara city

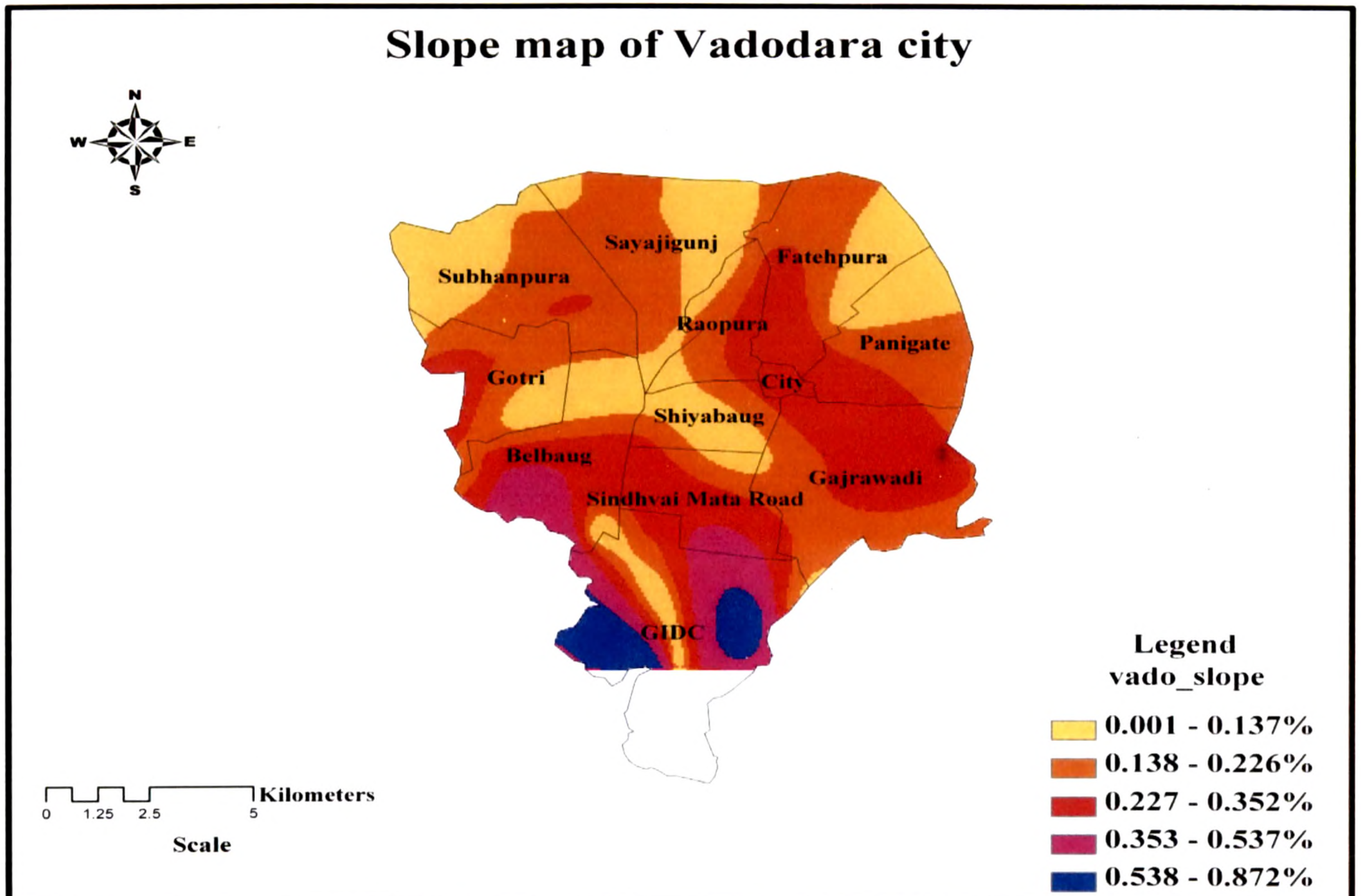


Plate 22: Slope map of Vadodara city

(4.2) Land use change analysis:

The change in any form of land use is largely related either with the external forces or with the pressure built up within the system. It has been noted that these changes lead to very unfavorable secondary effects on fragile natural environment. Many shifting land use patterns driven by a variety of social causes have resulted in land use changes that have affected biodiversity, water, trace gas emission and other processes. These processes also affect climate and biosphere (**Riebsame *et al.*, 1994**). Assessment of such spatial and temporal changes in land use pattern in Vadodara city has proved to be very effective in understanding changes occurring not only in land use but also in evaluating the environmental degradation. It has become a central component in formulating the current strategies for Vadodara city. The results have shown that in past few years the city has spread itself encroaching nearby areas enhancing the consumption of various natural resources. During earlier years, the development was along the four axes of Mandvi (the city centre, Wall city) and the municipal limits of the city covered only 22.68 km^2 in 1960. With increasing development more residential areas were required to accommodate the teeming inflow of people and the city began to grow rapidly outside the city wall. It expanded outwards in the west and northwest directions. In June 1964 this led to expansion of VMSS limit by 3.5 fold, covering an area of 72.44 km^2. With passage of time, industrial and commercial activities developed along the major arterial roads running on north-south and east-west direction of the city. This further accelerated the development of new residential colonies. The city in turn got a new extended structural form. This again induced the expansion of city administrative limits. It increased gradually to 97.22 km^2, 108.22 km^2 and 149.72 km^2 in the years

1973, 1975 and 2003, respectively. The city witnessed tremendous growth and distinct changes in the land use since it has been planned to be developed into an industrial hub.

Estimation of the dynamic process of the spatial and temporal characteristics of land use changes for study area was carried out at two different levels, i.e. VUDA (1880 to 2006) and VMSS (1880 to 2009). Overlay analysis of the thematic maps of different years brought out when the changes has occurred? and which type of land has been transformed into what? Land use changes detected in each class at VUDA and VMSS levels have been discussed separately.

(4.2.1) <u>Agriculture:</u>

Among all the resources agriculture is one of the prime and most important for the survival of the mankind. The proportion of land area under agricultural use in India (46%) is much large compared to world (11%) **(Kushwaha, 2008)**. Same is the case with Gujarat state which has 45% of total area of land under agriculture land use. In order to meet the food requirement of increasing population, there is a further need to increase the land under the agriculture. However, in view of rapidly growing cities, the change of agriculture land to other forms is increasing rapidly. Every year, some land at the outskirts of the city which is under cultivation gets degraded due to urbanization. Some of this arable land goes for the industrial developments while other for the infrastructure development leading to lowering in agricultural productivity **(Basawaraja *et al.*, 2011)**. The encroachment on arable land due to urban sprawl and probable consequences in terms of reduction in total arable fertile land have already been demonstrated by several workers **(Olson, 1996; Mohan, 2010)**. It has been observed that the growth of cities and progress of industries and services sectors increases the demand for conversion of agricultural land use. In other words, the agricultural land use changes are basically urban-induced negative changes **(Bryant and Greaves, 1978)**. This has been proved by the results obtained for the Vadodara city. In Vadodara also area occupied by various crops like Cotton, Bajra, Tobacco, Pulses, Wheat, Paddy, Maize, Sugarcane etc. have reduced drastically.

(4.2.1.1) VUDA level (1880-2006):

The change statistics for the agriculture class from the year 1880 to 2006 showed that the area decreased by 132 km^2 at Vadodara Urban Development Authority (VUDA) level. Since the data for these years were procured from different sources except for the year 2000, no categorization was done in agriculture class **(Plate 23)**. In case of data for 2000, two sub-classes of agriculture were identified viz. Crop land and Fallow land. These classes also exhibited distinct decreasing trend **(Table 11)**. In Vadodara city the highest reduction in agriculture land was observed during the years 1960 **(Plate 24)** to 1980 **(Plate 25)**. The reduction of -7.1 % can be attributed to the construction activities carried out on prime agricultural land on account of urban expansion and industrialization **(Table 12)**. From the year 1980 to 2000, only 10.15 km^2 area of agriculture was converted to other land uses with annual rate of change of -1.42% **(Plate 26)**. The reason behind this was the slower rate of urban sprawl during these years. The area covered by Fallow land was more compared to crop land in the year 2000 **(Plate 27)**. In the year 2006, agriculture land decreased by 5.42 % with the annual rate of change of -0.32%. This decrease was due to discontinuation of agricultural activities in expectation of conversion to urban areas due to expanding VMSS limits **(Plate 28)**.

Table 11: Land use classification of VUDA area

Sr. No.	Level – I	Level - II	Level-III	Land Use Code	1880 km^2	1960 km^2	1980 km^2	1996 km^2	2000 km^2	2006 km^2
1.	Built - Up	Built Up(Urban)	Residential	01-01-00-00	9.14	42.69	58.87	63.03	73.79	100.33
	Built - Up	Built Up(Rural)		01-02-00-00	-	-	29.93	29.93	29.93	36.35
2	Agriculture Land			02-00-00-00	704.85	663.24	616.12	612.54	605.97	573.1
	Agriculture Land	Crop Land		02-01-00-00	-	-	-	-	152.34	-
	Agriculture Land	Fallow		02-02-00-00	-	-	-	-	453.63	-
3	Water Bodies	River		07-01-00-00	6.76	6.76	6.76	6.76	6.76	6.76
	Water Bodies	Canal		07-02-00-00	-	-	-	-	3.3	3.3
	Water Bodies	Lakes		07-03-00-00	-	5.1	2.27	1.69	1.35	1.25
	Water Bodies	Tanks		07-04-00-00	-	2.96	2.96	2.96	2.96	2.96

Table 12: Percent change in different land use classes of VUDA area

Sr. No.	Level – I	Level - II	Level-III	Land Use Code	1880-1960 %	1960-1980 %	1980-1996 %	1996-2000 %	2000-2006 %
1	Built - Up	Built Up(Urban)	Residential	01-01-00-00	367.06	37.90	7.06	17.07	35.96
	Built - Up	Built Up(Rural)		01-02-00-00	-	-	0	0	21.45
2	Agriculture Land			02-00-00-00	-5.9	-7.1	-0.58	-1.07	-5.42
	Agriculture Land	Crop Land		02-01-00-00	-	-	-	-	-
	Agriculture Land	Fallow		02-02-00-00	-	-	-	-	-
3	Water Bodies	River		07-01-00-00	0	0	0	0	0
	Water Bodies	Canal		07-02-00-00	-	-	-	-	0
	Water Bodies	Lakes		07-03-00-00	-	-55.49	-25.5	-20.1	-7.4
	Water Bodies	Tanks		07-04-00-00	-	0	0	0	0

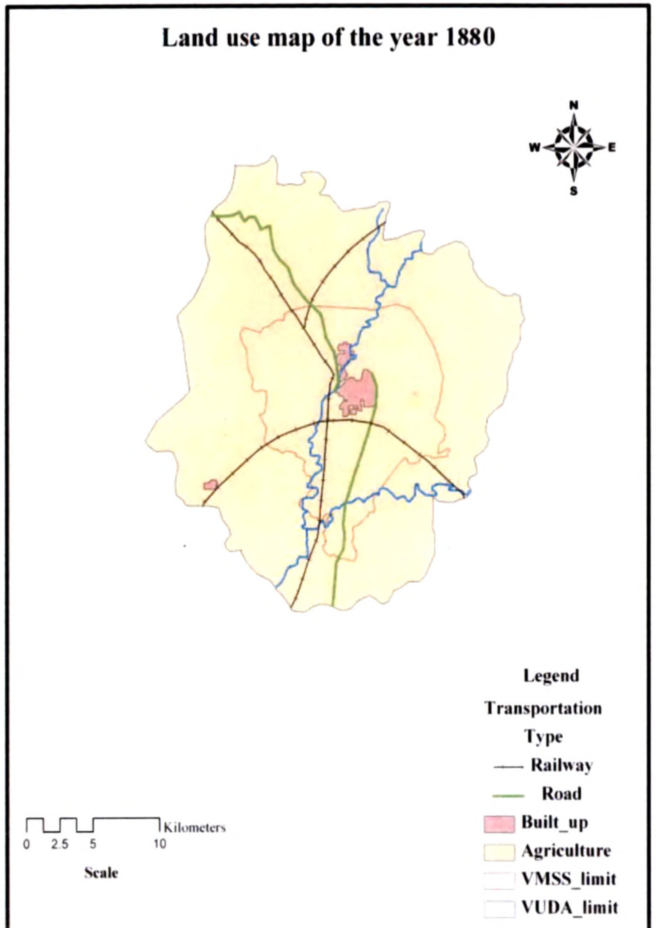


Plate 23: Map showing the land use of year 1880

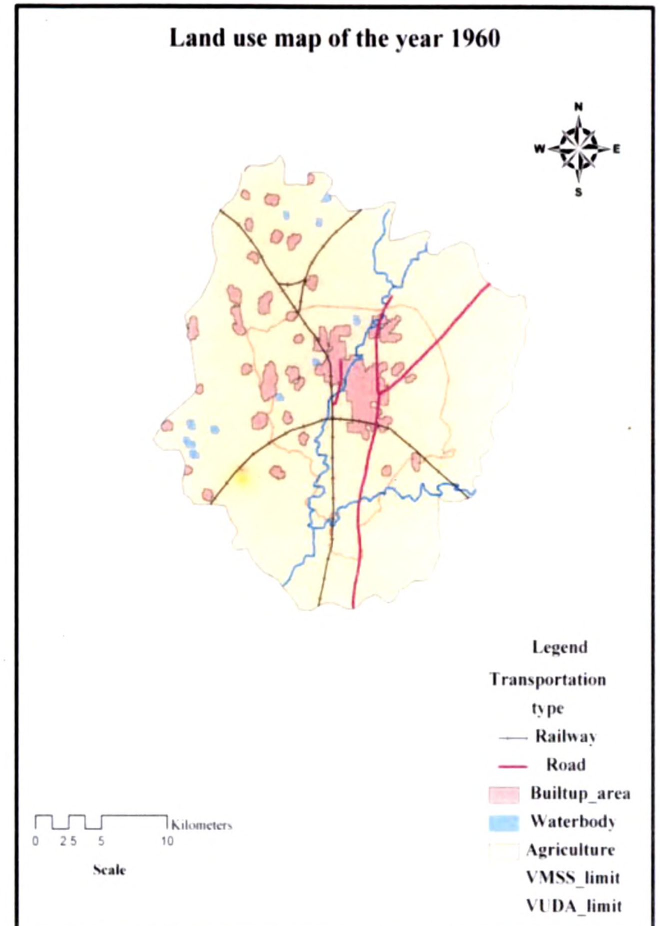


Plate 24: Map showing the land use of year 1960

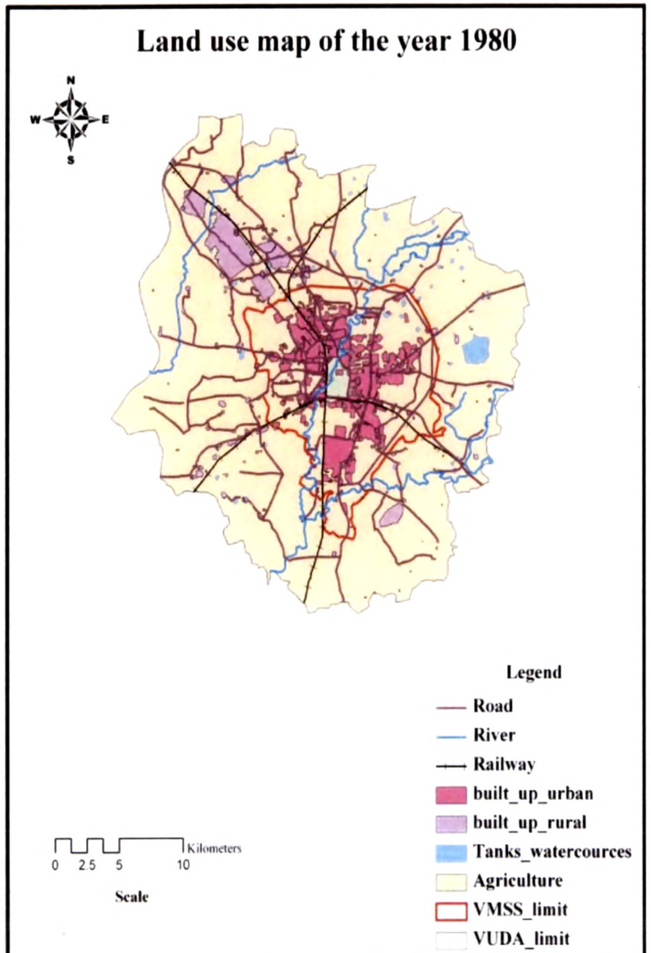


Plate 25: Map showing the land use of year 1980

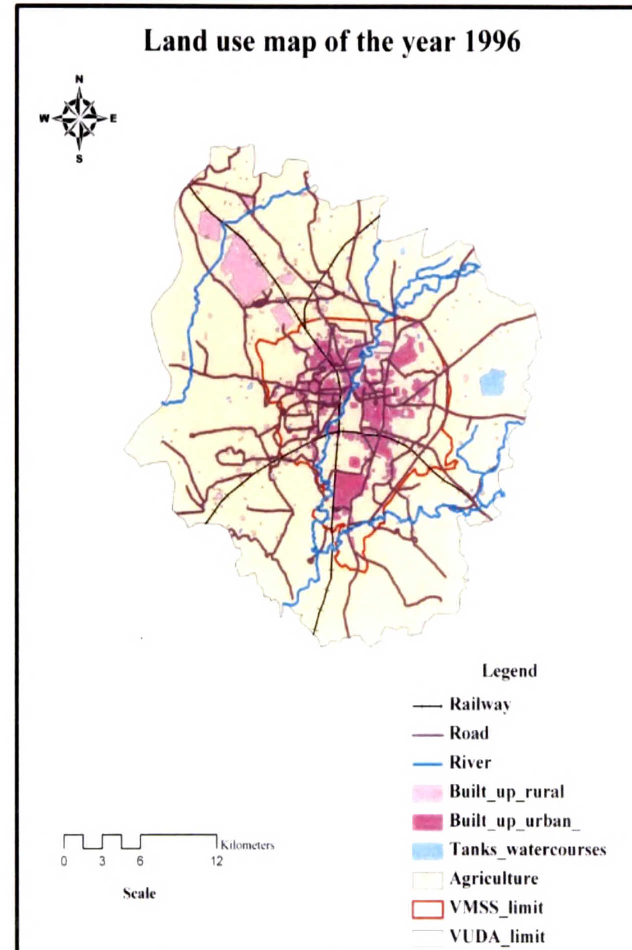


Plate 26: Map showing the land use of year 1996

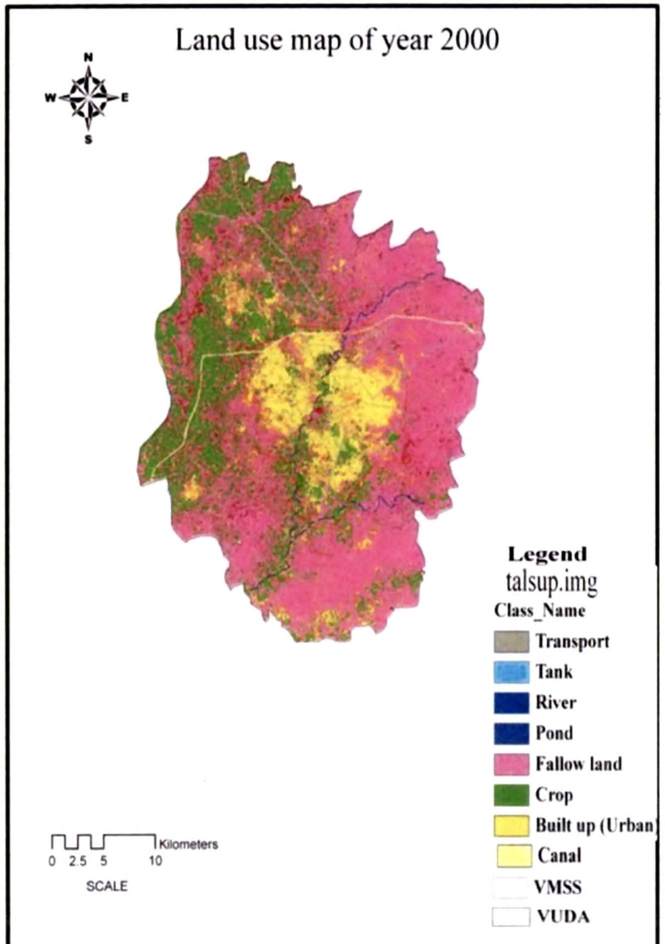


Plate 27: Map showing the land use of year 2000

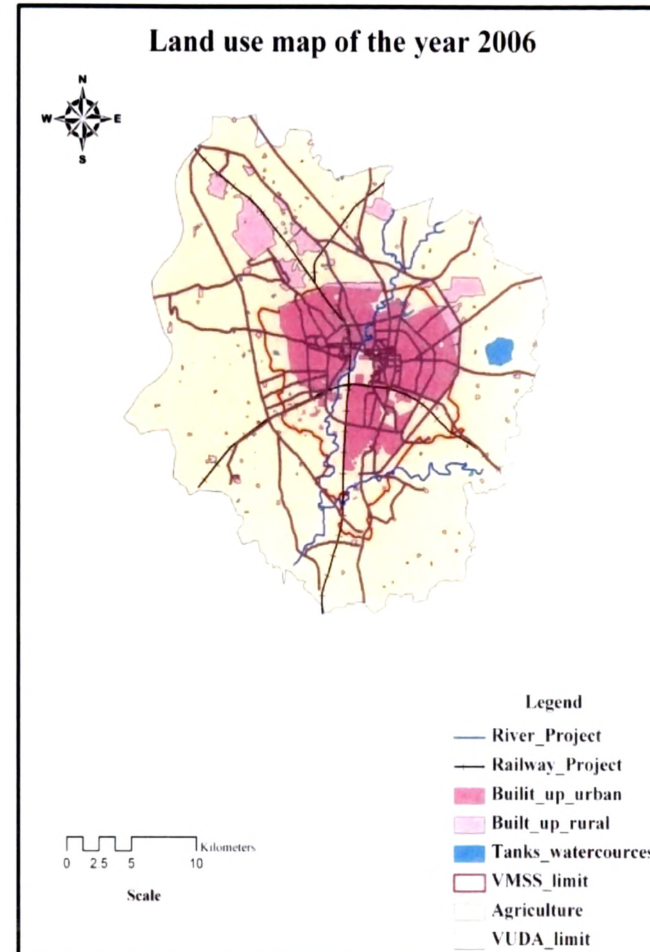


Plate 28: Map showing the land use of year 2006

(4.2.1.2) VMSS level (1880-2009):

Vadodara Mahanagar Seva Sadan (VMSS) covers the entire city area or urban area. The area occupied by agriculture reduced very rapidly from the year 1880 to 2009 **(Table 13).** In the year 1880 almost entire area of Vadodara Municipal Seva Sadan (VMSS) was occupied by the agriculture land which reduced significantly by 24.62% in the year 1960 (**Table 14).** Most of the industries established during the years 1960 to 1980 were beyond the VMSS limit which is apparent from the low annual rate of change (-6.6%) in agricultural land. The highest decrease of 77.53% in agriculture land was observed between the years 2000 to 2006. This decrease was attributed to the conversion of agriculture land into residential and commercial areas to meet the demand of increasing population. The classified output of 2009 was categorized into crop land and fallow land covering an area of 1.2 km^2 and 2.51 km^2, respectively **(Plate 29)**.

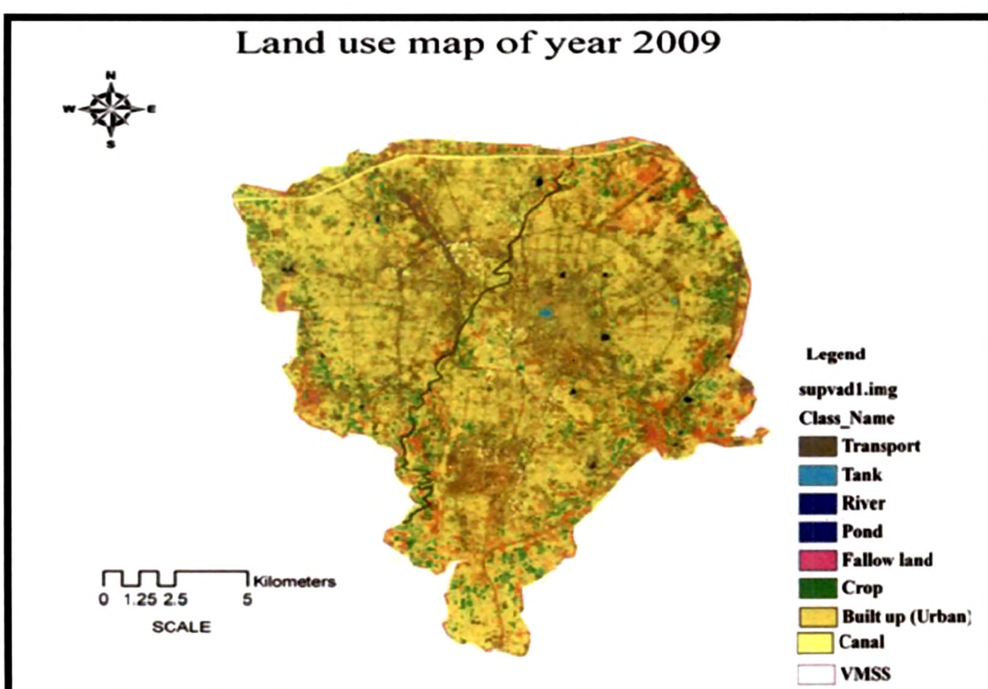


Plate 29: Map showing the land use of year 2009

Table 13: Land use classification of VMSS area

Sr. No.	Level – I	Level - II	Level-III	Land Use Code	1880 km^2	1960 km^2	1980 km^2	1996 km^2	2000 km^2	2006 km^2	2009 km^2
1.	Built - Up	Built Up(Urban)	Residential	01-01-00-00	9.14	42.69	74.58	77.32	102.45	138.61	145.6
	Built - Up	Built Up(Rural)		01-02-00-00	-	-	-	-	-	-	-
2	Agriculture Land			02-00-00-00	140.58	105.96	70.79	68.27	47.13	10.59	3.71
	Agriculture Land	Crop Land		02-01-00-00	-	-	-	-	15.12	-	1.2
	Agriculture Land	Fallow		02-02-00-00	-	-	-	-	32.00	-	2.51
3	Water Bodies	River		07-01-00-00	2.9	2.9	2.9	2.9	2.9	2.9	2.9
	Water Bodies	Canal		07-02-00-00	-	-	-	-	1.05	1.05	1.05
	Water Bodies	Lakes		07-03-00-00	-	0.97	0.42	0.39	0.34	0.32	0.30
	Water Bodies	Tanks		07-04-00-00	-	0.1	0.1	0.1	0.1	0.1	0.1

Table 14: Percent change in different land use classes of VMSS area

Sr. No.	Level – I	Level - II	Level-III	Land Use Code	1880-1960 %	1960 - 1980 %	1980 - 1996 %	1996 - 2000 %	2000 - 2006 %	2006 - 2009 %
1	Built - Up	Built Up(Urban)	Residential	01-01-00-00	367.06	74.7	3.67	32.5	35.29	5.04
	Built - Up	Built Up(Rural)		01-02-00-00	-	-	-	-	-	-
2	Agriculture Land			02-00-00-00	-24.62	-33.19	-3.55	-30.96	-77.53	-64.96
	Agriculture Land	Crop Land		02-01-00-00	-	-	-	-	-	-
	Agriculture Land	Fallow		02-02-00-00	-	-	-	-	-	-
3	Water Bodies	River		07-01-00-00	0	0	0	0	0	0
	Water Bodies	Canal		07-02-00-00	-	-	-	-	0	0
	Water Bodies	Lakes		07-03-00-00	-	-56.7	-7.1	-12.82	-5.88	-6.25
	Water Bodies	Tanks		07-04-00-00	-	0	0	0	0	0

(4.2.2) Water Bodies:

Cities and towns of India are getting deficient in the quality of services they provide. Rapid urbanization in India has led to a tremendous pressure on urban infrastructure systems like water supply, sewerage and drainage, solid waste management, transport, etc. This situation was visualized even in Vadodara city.

(4.2.2.1) VUDA level (1880-2006):

Many water bodies existing within the Vadodara Urban Development Area (VUDA) limit have changed during the span of five decades. No records were found for the year 1880. Water body class was categorized into four sub-classes, viz. River, Canal, Lakes and Tanks. The area under river and tanks did not exhibit any changes, whereas a distinct change was noted in the lakes from the year 1960 to 2006 **(Table 11).** A rapid decrease of 55.49 % in area under the sub-class lakes was noted from the year 1960 to 1980 **(Table 12)**. The reason for which was the occurrence of three consecutive drought years of 1965, 1966 and 1967. From the years 1980 to 1996, a decrease of 0.58 km^2 was noted due to their conversion into settlements, waste lands, etc. A very small difference of 0.1km^2 was observed from the year 2000 to 2006. The Narmada canal was constructed in the year 2000 and since then this class came into existence covering an area of 3.3 km^2.

(4.2.2.2) VMSS level (1880-2009):

The area occupied by water body decreased in Vadodara Maha Seva Sadan (VMSS) from the year 1880 to 2009 **(Table 13)**. No change was observed in the area occupied by the sub-classes; river and tanks from the year 1960 to 2009. In the year 1960 the area occupied by lakes was 0.97 km^2 which decreased to almost half in the year 1980 **(Table 14)**. A continuous decreasing trend was observed from the year 1996 to

2009. The reason behind such fluctuation in the area can be attributed to occurrence of eutrophication in many lakes of the city like Gorwa Lake, Mohamed Lake, etc. **(Plate 30)**. In addition to this problem, these lakes were also misused for dumping untreated waste water mixed with substantial amount of solid waste (**Dey *et al.*, 2006**). Perennial pond of Harni of the city shrunk due to encroachment by the people residing in near vicinity. Sursagar Lake situated in the middle of the city is also facing stinking problem. In addition to this, many wetlands of the city have disappeared in last few decades. The reason for this was lack of control over construction activity and improper planning.

Plate 30: Lake with vegetation growth on the periphery

(4.2.3) Built-up land:

Urban built-up areas are the regions which contain structural information about the urbanized land, including buildings and open space. These areas are also often referred to as "impervious surfaces" **(Yang *et al.*, 2003**). These impervious built-up lands have significant impacts on the ecosystem, hydrologic system, biodiversity, and local climate which can result in the negative aspects such as the urban heat island phenomenon. This was also proved by the results obtained for Vadodara city in which the urban built-up area has increased several folds at both the levels.

(4.2.3.1) <u>VUDA level (1880-2006):</u>

This class was classified into two sub-classes urban built-up and rural built-up except for the years 1880 and 1960. The change in this class as observed over a period of 126 years was notable on all sides except the northern region. The eastern spread was predominantly residential though it had industrial component in it. The open areas, close to the outskirts of the city mostly turned into big townships, new colonies, and apartment complexes **(Desai, 2009)**. The southern spread had well marked large sized Industrial estates and emerging residential complexes. On the western side, residential use was quite pronounced. The change detection results revealed that from the 1880 to 1960 the built-up area increased by 33.55 km^2 **(Table 11)**. Between the years 1980 to 2000 the area occupied by rural built-up remained the same but it increased in the year 2006 **(Table 12)**. Due to rapid industrial development, area occupied by Urban built-up increased by 4.16 km^2 from the year 1980 to 1996. The urban built-up area increased by 10.76 km^2 from the year 1996 to 2000, due to higher rate of urbanization experienced by the city. An increase of 26.54 km^2 with annual rate of change of 0.06 % was observed from the year 2000 to 2006. Such high rate of urbanization led to conversion of agriculturally productive land into residential and other uses **(Balogun *et al.*, 2011)**.

(4.2.3.2) <u>VMSS level (1880-2009):</u>

At the VMSS level, from the two sub-classes, i.e. Urban built-up and rural built-up, the change in only one sub-class of urban built-up was analyzed for 129 years. The highest change in the built-up area was observed from the year 1880 to 1960 **(Table 13)**. This increase was attributed to development of many industries during this time. The area under this class increased significantly from the year 1960 to 1980 occupying almost half of the VMSS area. Further increase in the urban built-up area was due to development of new residential colonies around the erstwhile villages of Gorwa, Gotri, Sama, Nizampura, Harni, Jetalpur, Akota, Makarpura, Tarsali and Maneja, which surrounded the old city. These areas were then gradually included in the municipal area. From the year 1980 to 1996 increase of only 2.74 Km^2 was observed in area covered by this class. During the last decade the area under this class increased very exponentially occupying majority area under VMSS boundary. The area increased by 45.15 km^2 between the years 2000 to 2009.

(4.2.4) <u>Transportation Network:</u>

The transport infrastructure of many larger and medium sized cities of India has expanded considerably and it is expected to grow by 2.6 times by 2016 in larger and medium sized cities of India **(Nagdeve, 2002)**. In recent years the pressure on urban transport has increased substantially because of high rate of urbanization in the country **(Anonymous, 2011).** The number of vehicles on roads has increased considerably which has resulted into increased environmental degradation due to high rate of air and noise pollution. The cities are confronting with the twin challenges. The first challenge is of providing adequate road space for future use. The second is of improving the poor condition of existing roads due to the neglect of maintenance over the years. Most of the cities of the country are facing urban transport problems for last many years, affecting the mobility of people and economic growth of the urban areas. One of such cities is Vadodara in which the transportation length has increased very rapidly.

(4.2.4.1) VUDA level (1880-2006):

Transportation class of the city was segregated in two sub-classes, i.e., railway and road network. No change was observed in length of the railway during 126 years. But, significant increase was observed in the length of road network. It increased approximately five folds from the year 1880 to 2006. The highest increase of 348.7 km in the road length was observed during the years 1960 to 1980. This increase can be attributed to the rapid industrial development during this time. Such highly developed road network helped in establishing better communication with other parts of state which resulted into heavy traffic load on the roads of the city. From the year 1980 to 2000 only 13.88 km were added into this class showing slower rate of expansion of road network. From the year 2000 to 2006 the road length increased by 21.74 km with annual rate of change of 0.27 % **(Figure 8)**.

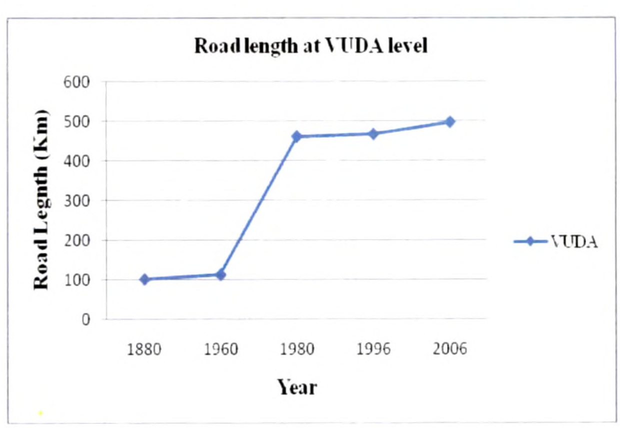


Figure 8: **Chart showing increasing road length at VUDA level**

(4.2.4.2) VMSS level (1880-2009):

No change was observed in rail length at this level also but road length increased five times during 129 years from the year 1880 to 2009 **(Figure 9)**. Infrastructural activity, like construction of new-bypass roads and ring roads has contributed to this increase. Highest increase in the road length was observed during the year 1960 to 1980 at this level also. This has resulted into the increased vehicular traffic on the roads which led to environment degradation due to higher consumption of fossil fuels. Further, as high as 87.17 km was added into the road network from the year 1980 to 2009. Despite of such development, current road designs do not adequately provide for facilities such as footpaths and cycle tracks. The available road space is getting encroached by commercial establishments, street vendors, and on-street parking due to poor enforcement of the existing regulations. These problems are due to inadequate transport infrastructure and its sub-optimal use; lack of integration between land use and transport planning. **Plate 31** shows the Station road which is one of the busiest roads of the city.

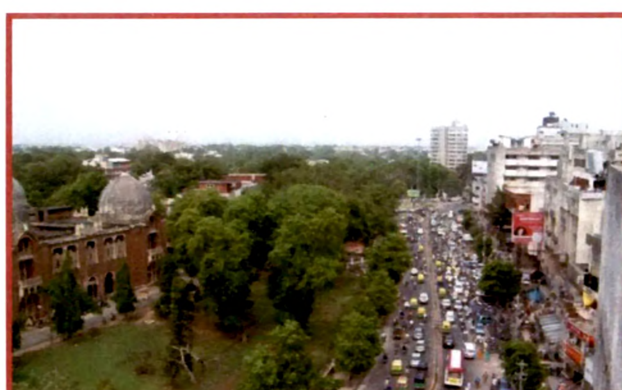


Plate 31: Station road of the city

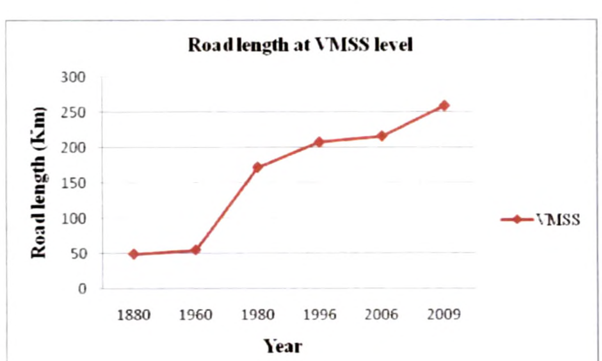


Figure 9: Chart showing the increasing road length at VMSS level

(4.2.5) Validation of results:

Accuracy assessment was performed using the random stratified sampling method for classified output of the years 2000 and 2009. The results exhibited the classification accuracy of 86% with kappa coefficient 0.80 in the year 2000 while for the year 2009 it was 95% with Kappa coefficient of 0.93.

(4.2.6) Urban sprawl analysis:

Urban sprawl analysis was performed using four different parameters, i.e. entropy, U.S.I., L.C.R. and L.A.C. Out of these parameters entropy was calculated at VMSS level whereas U.S.I, L.C.R. and L.A.C. were calculated at VUDA level. All these parameters are discussed separately.

(4.2.6.1) Entropy:

Entropy calculation is based on area computation which is best facilitated by the integration of spatial measurement facility correspondingly offered by remote sensing and GIS. It is a good indicator for identifying and monitoring urban land development i.e., dispersion and concentration of built-up areas. It helps in understanding the nature of urban sprawl of the city. In this context, entropy values calculated for each dataset of Vadodara city from the year 1880 to 2009 varied from 0.43 to 0.64 **(Table 15)**. The value of Log N where n=5, which is 0.6989 was taken as the reference value as it was treated as a critical limit or threshold for expansion of an area. As evident from the results the pattern manifested by built-up area of the city was dispersed distribution from the city center. In the earlier years the urban development was concentrated within Mandvi area of the city which got confirmed by the low entropy value of 0.43 in the year 1880. The expansion of built-up area from a city centre led to increase in the entropy value to 0.47 in the year 1980 which was lower than the Log N value. This indicated the concentrated nature of urban sprawl. The entropy value decreased in the years 1996 and 2000 indicating less fragmentation of the city explaining the homogenous distribution of built-up areas due to rapid growth. As a result, the space became very limited and built-up areas became concentrated within the VMSS limits. Similar results were observed by **Verzosa and Gonzalez (2010)** for Baguio City of the Northern Philippines. In the year 2006 the entropy value increased very significantly to 0.64 approaching the Log N value. This high value of entropy can be attributed to the increased urban sprawl and more dispersed development. This implied massive movement of residents from congested built up centre to outskirts of the city. Increasing trend of the entropy has also been observed by **Joshi and Bhatt (2011)** at Vadodara taluka level. In the year 2009 the value again decreased to 0.63. This estimation of Shannon entropy confirmed the dispersed development of urban built-up. In addition to this, entropy showed strong negative correlation (r^2 = -0.9) with total vegetation in the corresponding years which supported the fact that increasing disorder in the urban areas led to the degradation of vegetation in the city.

Table 15: Entropy values of different years

Year	Log N	Entropy
1880	0.6989	0.43
1960	0.6989	0.47
1980	0.6989	0.60
1996	0.6989	0.59
2000	0.6989	0.58
2006	0.6989	0.64
2009	0.6989	0.63

Investigation of entropy values for succeeding years aided in monitoring the progression of a random component, i.e. the built-up sprawl. The measurement of the difference in entropy between (t) and t+1 showed the degree of dispersal of this. The results showed that highest difference in entropy, i.e., 0.13 was observed between the years 1960 to 1980, corresponding the high degree of dispersion **(Figure 10).** The lowest difference of -0.009 was observed between the years 1980 to 1996 indicating the concentrated pattern of urban sprawl.

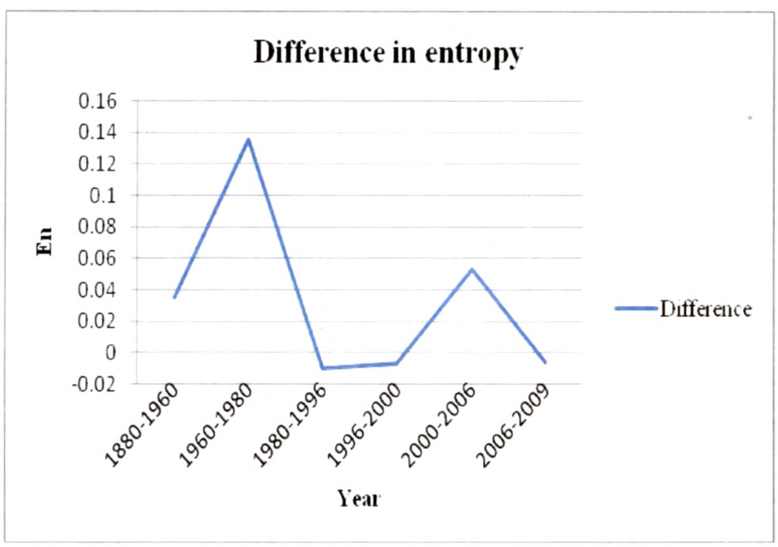


Figure 10: Chart showing difference in entropy in various years

(4.2.6.2) U.S.I.:

U.S.I value estimated to determine the urban sprawl pattern of the city fluctuated between the years 1880 to 2006 (**Table 16**). The U.S.I. value was 0.009 between the years 1880 to 1960 which indicated sparse development pattern. The value decreased by 0.001 during the years 1960 to 1980 indicating slow urban expansion rate due to increased population growth. The value decreased very rapidly by 0.007 between the years 1980 to 1996 due to low urban expansion during these years. The U.S.I. increased rapidly to 0.012 from the year 2000 to 2006, due to addition of 2220.67 ha of built-up areas into the city. The correlation analysis was carried out between the U.S.I. and NDVI values to understand the relationship between the two. A correlation value of (r^2= -1) indicated the urban induced negative effect of USI on the growth of vegetation of the city.

Table 16: U.S.I. of the study area

Year	Urban Expansion (ha)	Population growth	U.S.I
1880-1960	3354.67	3,54,182	0.009
1960-1980	4611.30	5,46,000	0.008
1980-1996	415.61	3,56,000	0.001
1996-2000	1075.58	3,99,000	0.002
2000-2006	3296.25	2,63,000	0.012

(4.2.6.3) L.C.R. and L.A.C:

Land Consumption Rate (L.C.R.) was constant whereas Land absorption rate (L.A.C.) differed slightly from the years 1880 to 1980. The span of 1996 to 2006 observed changes in both the components **(Table 17)**. A distinct drop in L.C.R by 0.006 and an increase in L.A.C. by 0.013 was seen in the year 2000 **(Figure 11)**. This implied that something was responsible for the decline in L.C.R. of the urban areas of the city which has ultimately decreased the consumption rate. L.A.C and L.C.R. between the years 1880 to 2006 as such exhibited inverse relation having negative correlation of -0.3.

Table 17: L.C.R. of the study area

Year	Area (A) (ha)	Population (P)	L.C.R. (A/P)
1880	914.85	1,01,818	0.009
1960	4269.51	4,56,000	0.009
1980	8880.81	10,02,000	0.009
1996	9296.42	13,58,000	0.007
2000	10372.00	17,57,000	0.006
2006	13668.25	20,20,000	0.007

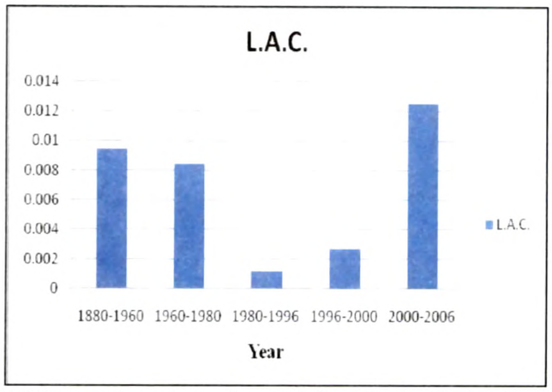


Figure 11: Chart showing change in L.A.C. of the study area

(4.3) Analysis of Urban green space (U.G.S.):

Urban green space analysis was carried out in terms of finding out suitable locations for its development and its economic relations with property surrounding it and its impact on various biophysical and socioeconomic parameters. Hence the results are also explained in three different sections viz., (1) Suitability analysis, (2) Economic evaluation and (3) Assessment of Impact of various biophysical and socio-economic parameters.

(4.3.1) Suitability analysis:

Urban expansion usually goes without considering the effect of ecological and environmental problem. In most of the cases urban sprawl fails to take up agriculture and green space planning which leads to unsustainable urban development. In recent years therefore planning for green spaces has been made imperative. Introduction of more green areas in the city is compulsory. Suitability analysis for UGS system has become prerequisite to identify potential sites for their development which will aid in developing city into an Eco-city. The selection of such potential sites for UGS is usually based upon a specific set of local criteria and the relationship of different factors to ensure that most benefits of UGS are attained by the community. These factors are simple characteristics of land that are grouped as attributes **(Pease and Coughlin, 1996)**. In the present study integration of different themes, i.e. Slope, Land use, transportation, water body and ground water status which generated were based on various natural and social factors which aided in generating a precise map exhibiting potential sites in Vadodara city for UGS development. UGS suitability analysis was carried out purely on the basis of different heterogeneous parameters viz. at level 1, i.e., land is suitable for developing it into an UGS or not. This section explains the vegetation status and temperature as other themes already have been explained in earlier sections of this chapter.

(4.3.1.1) <u>Vegetational Status:</u>

NDVI aided in the generating the vegetation status of different wards of the city for the years 2000, 2007 and 2009 **(Plates 32, 33 and 34)**. Vegetation of a city plays a significant role in moderating the physical stresses which are typical of the urban environment. A decreasing trend in total vegetation of eight wards was noted except for the Panigate and Gajrawadi ward of the city **(Plate 35)**. These two wards exhibited variations from the year 2000 to 2009. In case of Panigate the vegetation increased in the initial years i.e. from 2000 to 2007 but in the later years rapid decrease was observed. Gajrawadi ward on the other hand had a decreasing trend in the initial years but exhibited a significant increase in the later years i.e. from year 2007 to 2009 **(Plate 36)**. As the City ward is densely built commercial ward, it showed negligible amount of vegetation in all the years. These findings indicated that the urban sprawl has occurred in land covered by vegetation in one or other form.

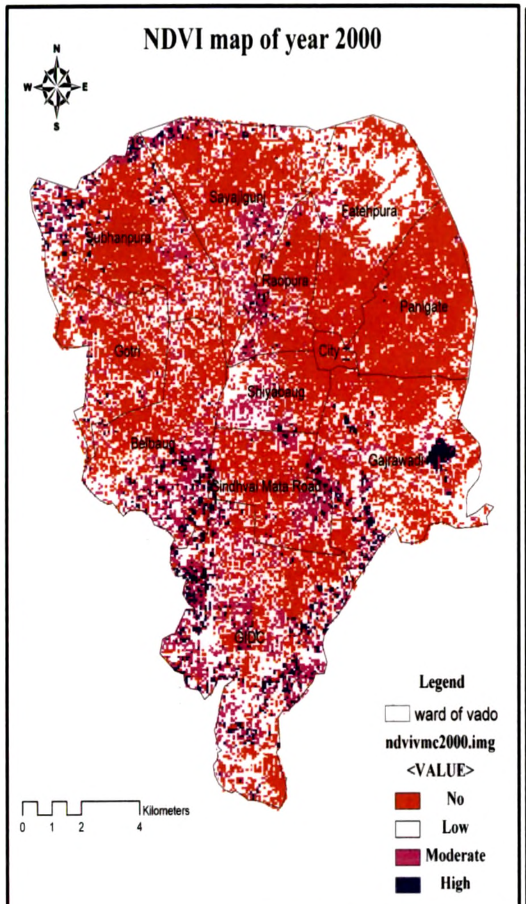


Plate 32: NDVI map of Year 2000

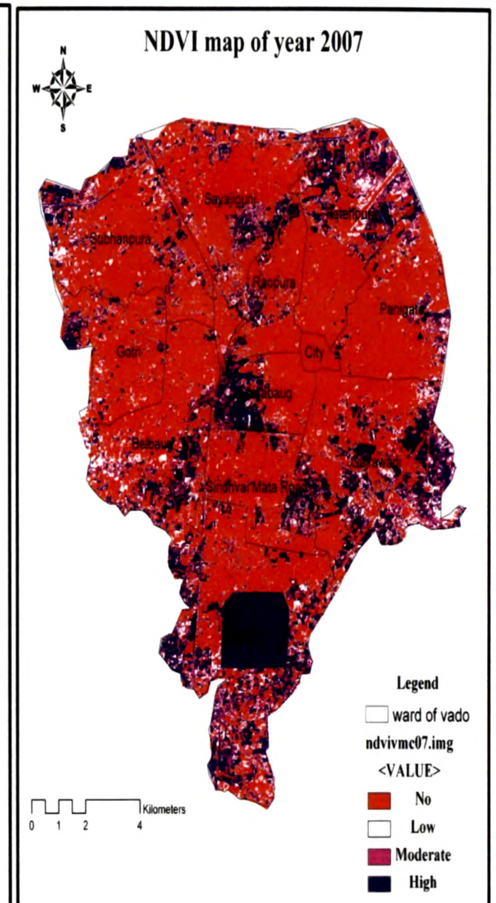


Plate 33: NDVI map of Year 2007

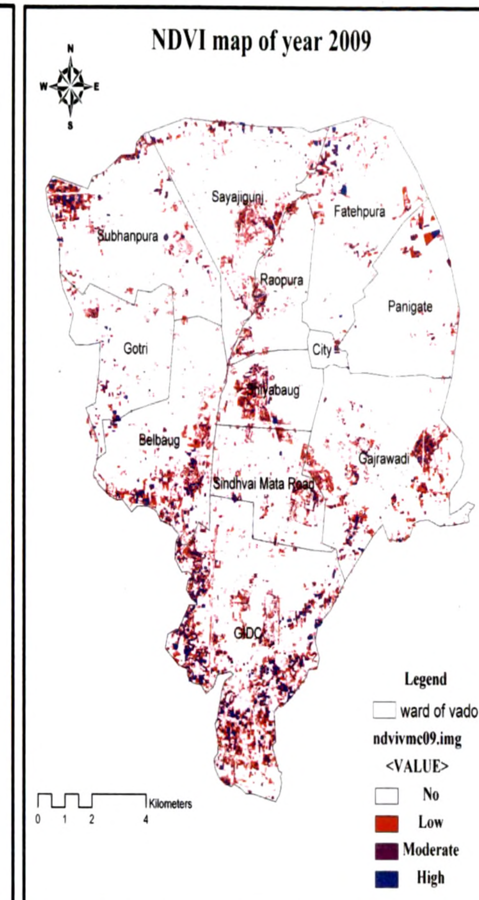


Plate 34: NDVI map of Year 2009

The NDVI values exhibited the strength of vegetation **(Mukherjee and Banerjee, 2005).** To analyze the changes in vegetation more precisely, different classes of the vegetation was identified based on the NDVI values. Based on these values four different classes were identified, *viz.*, pixels with values ranging from -0.34 to -0.17 were categorized as areas without vegetation, from -0.17 to 0.01, 0.01 to 0.022 and 0.022 to 0.38, were considered as low, moderate and high vegetation classes, respectively. **Table 18** revealed the ward-wise distribution of area occupied under different vegetation classes in different years. It was observed that the area occupied by high vegetation was less when compared to the areas having moderate and low vegetation. This indicated lack of dense greenery in Vadodara city. Area with high vegetation varied from 1.6 ha to 104.9 ha in the year 2000. Area under this class increased in all the wards in the year 2007 except for the City ward. After 2 years, i.e. in the year 2009 this area reduced in all wards except for City ward in which an increase of 0.22 ha was observed. Areas under moderate vegetation class showed a distinct decreasing trend in all the wards in all the years except for wards like City, Panigate and Fatehpura. These three wards are very congested wards and no space was available to built new buildings and hence, no encroachment of vegetation observed in these wards. Area occupied by low vegetation also decreased in all the years in all the wards except the Gajrawadi ward in which increase was observed from the year 2007 to 2009.

Table 18: Ward wise change in high, medium, low and total vegetation

Ward No.	Ward Name	Total area of Ward (ha)	2000					2007					2009				
			H (ha)	M (ha)	L (ha)	T. Veg. (ha)	T.P. (%)	H (ha)	M (ha)	L (ha)	T. Veg. (ha)	T.P. (%)	H (ha)	M (ha)	L (ha)	T. Veg. (ha)	T.P. (%)
1	City	94.73	1.6	4.21	5.46	11.30	11.92	0.00	1.09	0.81	1.91	2.01	0.22	1.98	1.17	3.37	3.55
2	Fatehpura	1419.88	5.0	236.75	473.4	715.21	50.37	76.45	242.86	277.39	596.70	42.08	8.41	28.43	76.39	113.23	7.99
3	Gajrawadi	1909.78	104.9	437.37	549.91	1092.24	57.19	36.15	71.41	76.89	184.44	27.66	8.81	72.17	177.27	258.26	13.49
4	Sindhvai Mata	894.20	24.25	280.88	159.23	464.38	51.93	29.22	91.15	117.76	238.13	26.63	2.20	29.61	70.03	101.83	11.38
5	Shiyabaug	630.91	7.67	251.36	125.38	384.42	60.93	73.14	141.92	81.16	296.22	46.95	5.02	38.24	71.77	115.03	18.23
6	Sayajigunj	1693.89	41.09	497.49	348.83	887.43	52.38	42.19	180.96	260.12	483.27	28.73	6.12	46.77	212.59	265.47	15.14
7	Belbaug	1427.03	76.47	525.38	323.14	925.00	64.81	66.33	199.32	261.69	527.33	35.77	14.24	67.90	175.16	257.3	17.57
8	Raopura	666.63	12.42	201.85	101.66	315.93	47.39	36.15	71.41	76.89	184.44	27.66	0.86	18.95	43.98	63.79	9.56
9	Panigate	1267.98	1.93	51.48	188.39	241.81	19.07	16.18	89.82	154.86	260.87	20.75	1.95	19.24	48.98	70.17	5.56
10	Subhan-pura	1577.84	63.5	411.73	322.82	798.10	50.58	41.83	124.53	227.86	394.22	24.95	5.08	28.20	85.55	118.83	7.54

H= High vegetation
M= Moderate Vegetation
L= Low Vegetation
T.Veg. = Total vegetation
T.P. =Total percent

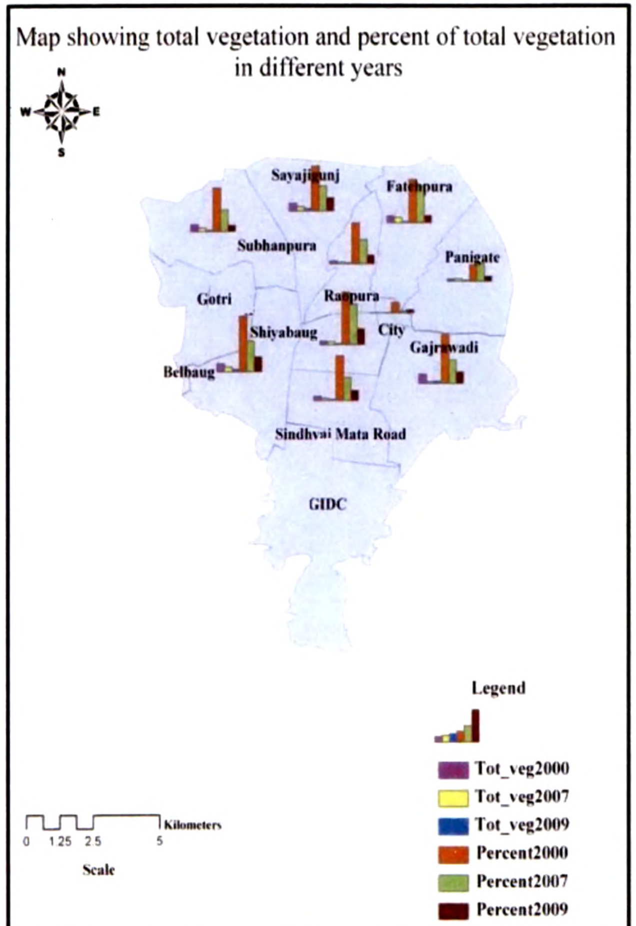


Plate 35: Map showing total vegetation and percent of total vegetation in different years

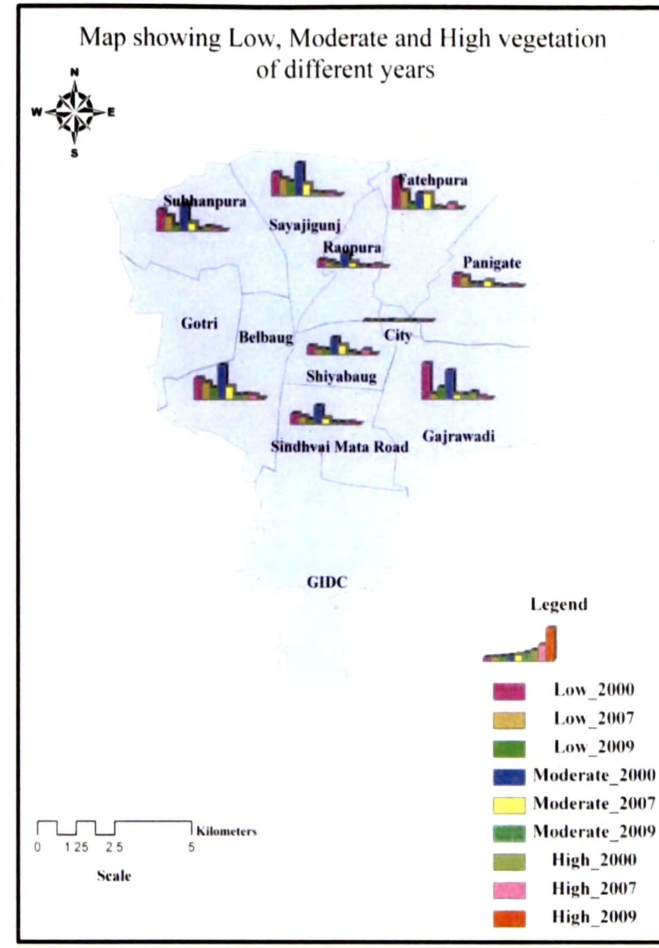


Plate 36: Map showing Low, Moderate and high vegetation of different years

(4.3.1.2) **<u>Per capita change in Vegetation:</u>** The Per capita vegetation in the year 2000, 2007 and 2009 showed a distinct decreasing trend in the availability of the per capita vegetation in different wards **(Plate 37)**. Ward No. 1, City ward showed the lowest values of per capita vegetation in all the years. The reason behind this is that this ward was densely populated and showed negligable amount of vegetation and hence resulted into the lower values of per capita vegetation. This fact proved the negative correlation of vegetation and population density ($r = -0.11$) indicating a very high anthropogenic pressure on vegetation of this area. Same observation was also made by **Faryadi and Taheri (2009)** for some regions of Tehran. The highest per capita vegetation was reported by Gajrawadi ward in the year 2000 and 2009 while by Fatehpura ward in the year 2007. Fatehpura ward is one of the greenest ward of the city due to presence of ample of vegetation in this ward. Results also proved the fact that vegetation was not properly distributed in different wards of the city.

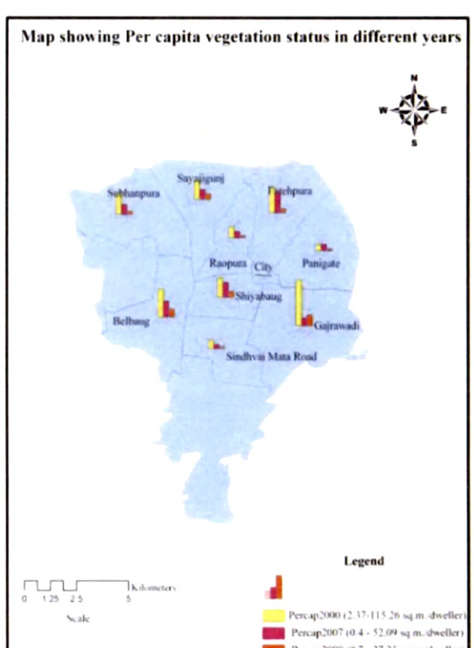


Plate 37: Ward wise Per capita vegetational status in different years

(4.3.1.3) Temperature:

The Land Surface Temperature figures as retrieved for the Vadodara city from Landsat ETM+ data ranged between 27 °C to 50 °C. The temperatures for the entire city area was categorized in three classes viz. temperature values ranging from 27 °C to 35 °C, 36 °C to 42 °C and 43 °C to 50 °C were categorized into areas with low, medium and high temperature, respectively **(Plate 38)**. The majority parts of the city had medium temperature values corresponding to the high building densities. Eastern parts of the city i.e. some parts of Fatehpura ward, Panigate ward and Gajrawadi ward showed slightly higher temperatures. Areas with vegetation, mostly along the banks of Vishwamitri river showed low temperatures revealing the impact of vegetation of temperature. A negative correlation between temperature and vegetation has already been proved by **Carlson *et al.* (1994)** and **Weng *et al.* (2004)**.

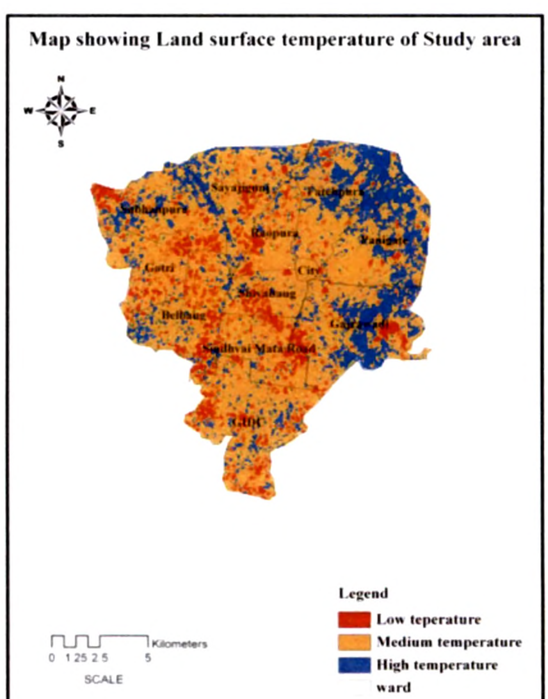


Plate 38: Map showing temperature profile of Vadodara city

(4.3.1.4) Identification of Suitable sites:

Suitability for UGS was carried out using parameters like transportation network, slope, ground water, water body and land use of the study area. The results revealed that 98 % area of the city was found not to be suitable for the green space development **(Plate 39)**. Areas which were suitable were the existing green spaces, vacant areas and government reserved areas. The highest suitable area has been observed in Sayajigunj ward. This may be due to the presence of ample of open spaces and government offices in this ward. The City ward showed the lowest area under the suitable sites corresponding to the low availability of open space **(Table 19)**. It was noted that parameters like P.D., L.S.T and slope influenced the suitability of an area negatively while parameters like Per capita vegetation, Gardens, water body and green belts influenced the suitability positively. Suitable sites identified for the city are more accessible and available for the public to use and in a location which will be accessible to current and potential new users.

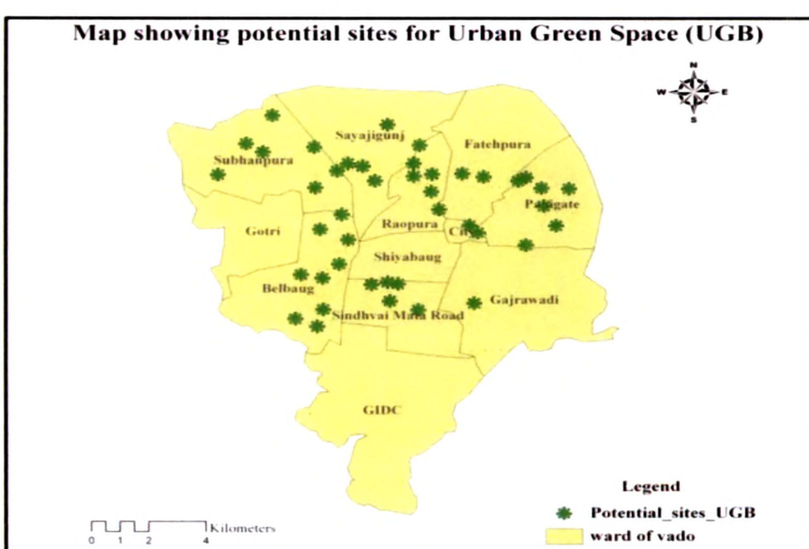


Plate 39: Map showing the potential sites for Urban Green Space development

Table 19: Status of various suitability factors in different wards

Ward No	Ward Name	Population Density	Per Capita Vegetation	Vegetation Change	Land Surface Temp (LST)	Open space	Slope	Gardens	Greenbelts	Water body	Potential site (ha)
1	City	Very High	Low	Decreased	Medium	Very low	Medium	0	0	3	0.06
2	Fatehpura	Low	Medium	Increased	High	Low	Low	6	1	5	1.58
3	Gajrawadi	Low	Medium	Increased	High	Medium	Medium	1	0	7	3.41
4	Sindhvai Mata Road	Medium	Very High	Decreased	Medium	Low	Medium	4	1	3	1.77
5	Shiya Baug	Low	Low	Increased	Low	High	Low	2	0	3	0.66
6	Sayajigunj	Low	Medium	Decreased	Medium	High	Low	11	0	1	4.76
7	Belbaug	Low	Low	Decreased	Low	High	Medium	5	1	1	4.16
8	Raopura	Medium	Medium	Decreased	Medium	Medium	Low	5	2	2	2.22
9	Panigate	Low	Low	Increased	High	Low	Medium	2	2	3	1.84
10	Subhanpura	Low	Low	Decreased	High	High	Medium	8	0	3	3.25

(4.3.2) Economic valuation of Urban Green Space (UGS):

The results for economic valuation of the UGS brought out that areas like Sama (Amar Complex), Gotri, southern part of O.P road and Atladra showed houses with lower property prices **(Table 20)**. Such low values of the houses were due to the absence of vegetation as proved by slight positive correlation between vegetation and property price (r^2 = 0.283). In recent years citizens has become more aware of benefits green surroundings around their houses as exhibited by positive correlation. This correlation may increase to higher side with passing years. Areas with moderate value of NDVI like, Akota, Ellora park, Gotri, and Hari Nagar showed moderate property prices. The high property prices were seen in the areas like Kareli Baug, Alkapuri, etc. attributing to the high NDVI values of these areas. Interestingly, areas like Sama and O.P. road were having houses categorized into all the three classes as their prices were differing with the varying distance from the densely vegetated areas.

Table 20: Comparison between vegetation and Property price

Low Price (1000-2000) (Rs/Sq Mt.)	**NDVI**	**Moderate Price (2000-3000) (Rs/Sq Mt.)**	**NDVI**	**High Price (3000 and above) (Rs/Sq Mt.)**	**NDVI**
Gotri, near jakat naka	No Veg.	Shree nagar soc,Akota	No Veg.	Akota,Villa	Moderate Veg.
O.P. Road	No Veg.	O.P.Road,Apt	No Veg.	Akota House	High Veg.
Atladra,Apt	Low Veg.	Ellora Park	Low Veg.	Alkapuri,Chikuvadi apartment	High Veg.
Sama,Amar complex	No Veg.	Gotri,Narayan gardens	Low Veg.	Kareli baug, Villa	Moderate Veg.
Villa,O.P Road	No Veg.	Hari Nagar	No Veg.	Alkapuri Apt	High Veg.
Navapura	Low Veg.	Nizam pura, house	Moderate Veg.	Alkapuri House	High Veg.
Ajwa,Jay Yogeshwar Township	No Veg.	O.P. Road, bunglows	Low Veg.	Kareli baug,Harish nagar	High Veg.
Raopura	No Veg.	Subhan pura	Moderate Veg.	Manjalpur,Ranchod Nagar	High Veg.
Dutta Nivas	No Veg.	Tandalja	Low Veg.	Kareli baugh, House	High Veg.

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

In this study, the impact of various biophysical and socio-economic parameters on the property price was analyzed. Six biophysical and socio-economic parameters were considered for assessing the impact out of which status of LST and NDVI of the city has already been described earlier in this section.

NDBI index describes the spatial pattern of urban impervious surfaces. It was used in this study to extract the built-up land from the urban area of the city **(Plate 40)**. The values of this index were classified into four different classes, viz. No, Low, Moderate and High built-up land. The areas with high vegetation either showed negative values or very low positive values for this index. Wards like Panigate, Subhanpura, and Gotri showed higher values of NDBI while wards like Sindhavai mata Road, Belbaug showed moderate values of the same.

Mapping of Building Density (B.D.) gave the idea about the quantitative distribution of built up areas in different wards of the city **(Plate 41)**. Wards like Subhanpura, Panigate, etc. showed high B.D. corresponding to higher values of NDBI of these wards while wards like Belbaug, Gajrawadi etc. showed moderate value of the B.D. as NDBI values of these wards were found to be moderate.

The impact of various parameters was analyzed at two different levels, i.e., impact of individual parameters and impact integrated parameters. It has been described separately in the following sections:

(4.3.3.1) Assessment of Impact considering Individual Components:

Impact of individual parameters on property price was assessed using correlation analysis between six different components viz. NDVI, NDBI, Property price, Building density, Population density and LST (**Table 21**). It was observed that property price had a positive correlation with NDVI. This fact has already been proved in the earlier section. The reason can be attributed to willingness of citizens to pay more prices for the properties located in green environment. NDBI and LST had a negative correlation with property price. This is because the increasing builtup area and temperatures deteriorates the environmental condition around the property. Interestingly, some high populated areas of the city like Mandvi was having the high property values despite of high population density (r^2=0.546 at 0.01 level of confidence) and building density. This area is highly commercialized area which compelling the citizens to reside there due to easier availability of the amenities despite of high property prices.

Table 21: Correlation Matrix

Parameters	NDBI	NDVI	PP	PD	LST	Building density
NDBI	1.0	-0.438*	-0.158	0.006	0.441*	0.235
NDVI	-0.438*	1.0	0.283*	-0.050	-0.203	-0.173
Property price (PP)	-0.158	0.283*	1.0	0.546**	-0.255	0.344
PD	0.006	-0.050	0.546**	1.0	0.241	0.184
LST	0.441*	-0.203	-0.255	0.241	1.0	0.058
Building density	0.235	-0.173	0.344	0.184	0.058	1.0

*. Correlation is significant at the 0.05 level (2-tailed)
**.Correlation is significant at the 0.01 level (2-tailed)

(4.3.3.2) Assessment of Impact considering Integrated Components:

The integration of these six correlating components at different level of significance, using principal component analysis (PCA) enhanced the precision regarding the understanding of specific component influencing value of property price.

Percentage of variance of each PC is shown in **Table 22.** Maximum variance of 60.95% of the data was seen in the PC1 and PC2. **Table 23** illustrates the loading of variables of the first two components. The loading above 0.71 is high; 0.63 is very good; 0.55 is good; 0.45 is fair and 0.32 is poor. These ranges of loadings for interpreting component weights are already given earlier workers **(Li and Weng, 2007)**. The PC1 is highly influenced by NDVI followed by LST, Building density, Population density and property price. This indicated that as compared to other parameters vegetation has major impact on the property price. PC2 is characterized by NDBI, building density and property price.

Table 22: The percentage of variances and principal Components loading matrix

Components	Initial Eigen values		
	Total	% of Variance	Cumulative %
1	1.921	32.025	32.025
2	1.736	28.928	60.953
3	0.968	16.138	77.091
4	0.689	11.478	88.570
5	0.490	8.171	96.740
6	0.196	3.260	100.00

Table 23: Component Matrix

Components	Component	
	1	2
NDVI	0.805	0.175
LST	-0.721	-5.4E-02
Buld. Den.	-0.497	0.783
NDBI	-3.26E-02	0.802
Pop. Den.	0.685	0.162
Property price	0.192	0.648

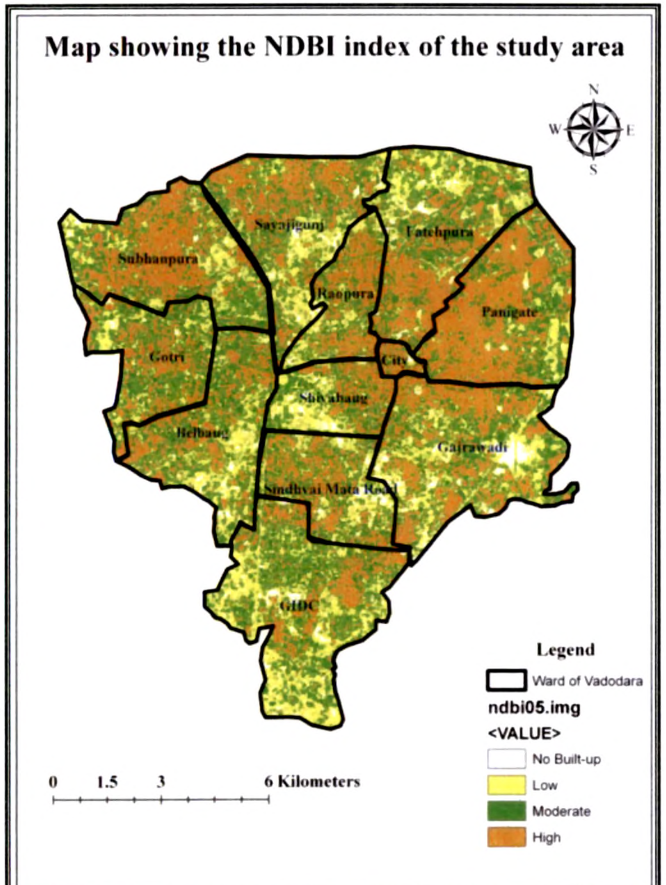


Plate 40: Map showing NDBI of Vadodara city

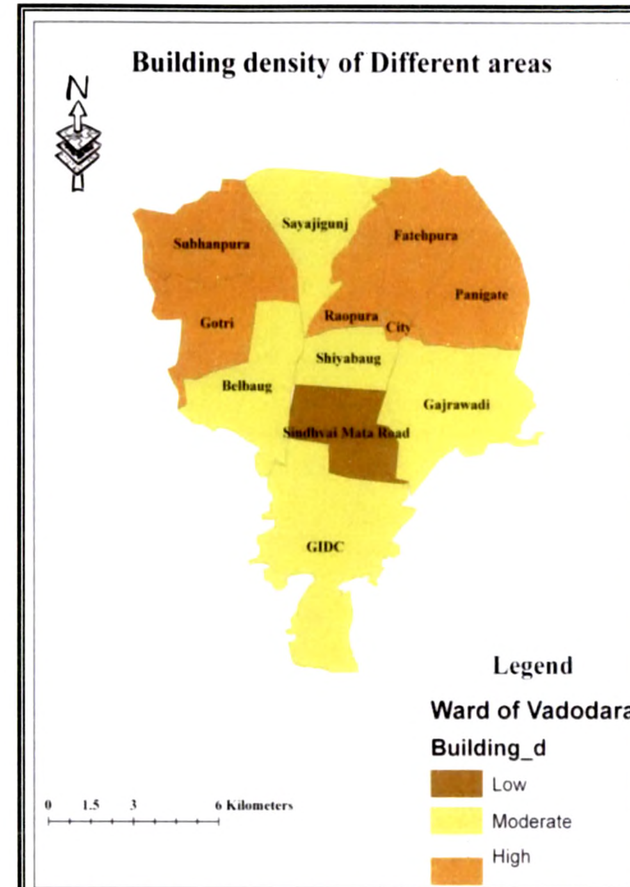


Plate 41: Map showing the building density of Vadodara city

(4.4) Eco-city plan generation:

An eco-city is the city which is in balance with nature. It aims to minimize the required inputs of energy, water and food, its waste output of heat and finally the gases such as carbon dioxide and methane that cause atmospheric and water pollution. To achieve this, the ecological approach of sustainable utilization of resources must be implemented. This implies that instead of using traditional environmental technologies more eco-friendly technologies should be utilized for utilizing the resources. For this Eco-city guidelines and objectives should be woven together with local requirements **(Gaffron *et al.*, 2005)** in which the suitability analysis can play a vital role. Hence, at first instance land use suitability analysis was carried out for the selected wards. Ward-wise explanation of the results is presented in the following sections.

(4.4.1) Ward No. 1- City Ward:

Landuse suitability analysis (LSA) carried out for converting Ward no. 1 into an Eco-ward is based mainly on physical constraint at Level 1, i.e., land suitable for built up and conservation purpose only. Based on the different parameters LSA analyzed the fitness of land of this ward for urbanization. The physical constraints become progressively greater from highly suitable to not suitable class. The area occupied by the highly suitable class generated by all the models for this ward was the least **(Table 24)**. Output generated by Model No.4 was considered for further development as it was based on the Land use. In this model the area occupied by highly suitable, moderately suitable, less suitable and not suitable classes was 2.91%, 18.44%, 65.04% and 13.59%, respectively **(Plate 42)**. Maximum area occupied by the highly suitable, moderately suitable and less suitable class is already covered by high–density buildings. These buildings are associated with commercial activities, which in turn pose excessive traffic pressure on the roads leading to high emission of pollutants. This increased building density has deteriorated the environmental condition. Major sub-arteries of roads of this ward lack the capacity of catering the needs of these densely populated areas. Approximately 7% of the area occupied by moderately suitable class is covered by open space. 5% area of the area occupied by not suitable class is also covered by buildings and remaining area is covered by water body. This water body is eutrophicated due to anthropogenic activities **(Plate 43)**. Available vegetation is very less **(Plate 44)**.These facts revealed a need for significant improvement in the ward and therefore, this ward was taken up for developing it into the eco-ward.

Table 24: Area covered by different classes of suitability in City ward

Ward Name	Model	Highly suitable (km^2)	Moderately suitable (km^2)	Less suitable (km^2)	Not suitable (km^2)
City	1	0.02	0.42	0.43	0.16
	2	0.03	0.35	0.48	0.17
	3	0.02	0.47	0.47	0.07
	4	0.03	0.19	0.67	0.14

Plate 43: Lake showing the eutrophication due to *Eicchornia crassipes* (Mart.) Solms.

(4.4.1.1) Air Pollution Tolerance Index (APTI) estimation: APTI of the different plants of this ward when estimated suggested that the plants were attenuating the air pollution in various parts of the ward. The results revealed that APTI differed based on various biochemical parameters of tree species, i.e., pH, AA, TCh and RWC. The highest pH value was exhibited by *Ficus bengalensis* L. while that of *Ficus religiosa* L. was the lowest **(Table 25).** *Ficus bengalensis* L. also exhibited the highest value of AA content when compared to other plants of the ward. *Alstonia scholaris* L. R. Br. reported the highest TCh content with lowest RWC while *Caesalpinia pulcherrima* (L.) reported the lowest TCh content with the highest RWC content. APTI estimated using these parameters showed that *Ficus bengalensis* L. was having the highest APTI value while that of *Ficus religiosa* L. was the lowest. Tolerance level of each plant was determined based on the APTI value of all the plants. Results exhibited that out of five plants examined, one plant was tolerant, two were intermediately tolerant and two were moderately tolerant. *Ficus bengalensis* L. seemed to be the most tolerant plant and can be utilized for road side plantation.

Table 25: APTI values of different plants in City Ward

Plants	pH	AA (mg/g)	TCh (mg/g)	RWC %	APTI	Tolerance Level
Azadirachta indica **A.Juss.**	5.1±0.8	4.18±0.56	0.4±0.09	85.71 ±0	10.85±0.59	MT
Caesalpinia pulcherrima **(L.) Sw**	7.75±0.05	2.57±1.27	0.3±0.008	100±0	12.03±1.01	MT
Alstonia scholaris **L. R. Br.**	7.9±0	4.45±0.13	0.72±0.002	61.16±0	9.71±0.10	IT
Ficus bengalensis **L.**	6.05±0.65	6.31±0.39	0.41±0.014	84.24±0	12.3±0.16	T
Ficus religiosa **L.**	4.5±0	4.96±0.38	0.55±0.02	64.73±0	8.9±0.19	IT

T=Tolerant, **MT**=Moderately Tolerant, **IT**=Intermediate Tolerant, **S** = Sensitive

(4.4.1.2) Eco-ward generation:

Planning based on the suitability analysis has encouraged the understanding of spatial settlement patterns of the ward to provide easy access to basic necessities such as workplaces, schools, health care, places of worship, goods and other services, and leisure, thereby reducing the need to travel. Land Suitability Analysis (LSA) along with the suggestions from the participants of questionnaire survey played a major role in converting City ward into an Eco-ward.

Output of Model 4 showed that highly suitable class of this ward was seen near Mandvi gate which at present is covered with buildings. In addition, majority of the area categorized into moderately suitable, less suitable and not suitable classes are the completely built up areas. For converting this ward into the Eco-ward, renovation of these existing buildings is recommended. This will give various environmental, economic and social benefits. This will attract residents of all ages and classes back, to live in these inner-city residential centers. For renovation of these buildings modular prefabrication of entire building elements, such as add-on balconies or double-skin front wall systems are recommended. As suggested by various participants, large commercial buildings, office complexes, hotels etc. of the ward situated in the highly suitable category are recommended to develop rainwater-harvesting systems in the buildings (**Anonymous, 2004**). This will increase the availability of water in this ward. Questionnaire survey revealed that residents of this ward were facing many environment related problems due to lack of greenery. Establishment of gardens or other green vegetation on the roof top will not only improve the surroundings of the ward but also provide insulation and filter the rainwater. This helps in reducing the energy consumption **(Plate 45)**. To improve the condition further, more vegetation can be introduced in between the building gaps by planting small plants. Transportation is one of the important planning elements which can be used to improve the present condition in the ward. This can be achieved by coordinating land-use and transport.

The existing roads of the Ward i.e., M.G.Road, Gendigate Road and Hathikhana are narrow with buildings on both sides. In addition, the footpaths of these roads are covered by the local vendors and patharavalas. As revealed from LSA, there is no available space for widening. This has lead to generation of heavy traffic on the roads. Many participants complained that due to the soft attitude of the controlling authority and indifference towards law enforcement agencies, vehicles are parked haphazardly **(Plate 46)**. This creates traffic jams and pedestrians face great inconvenience. No parking space is available in the entire area for four-wheelers except for one private pay and park facility in the Nazar baug palace ground. Many participants felt that there is a lack of greenery in the ward. Therefore, there is need to increase the vegetation of the ward which will also help in reducing the pollution level. Plantation of small shrub like *Alstonia scholaris* L. R. Br. along both the side of the roads is recommended as no space is unavailable for tree plantation. The road towards the Panigate i.e., Panigate road is somewhat wider with ample of open space available on both side of road as revealed from the LSA. Hence, plantation of shrubs and trees in the middle of the road and along the road side are recommended as suggested by participants. There is a need of comprehensive effort to deliver new public transportation options while upgrading and enhancing the efficiency of existing services. More CNG-based Auto-rickshaws and city buses should be introduced into the public transport systems to decrease dependency on the private transport as suggested by the participants. Many participants felt that the roads were unsafe for them. Therefore, encouragement of the use of an optimal combination of modes of transport, including walking, cycling and private and public means of transportation, through appropriate pricing is required.

Plate 46: Photograph showing the unorganised parking of vehicles

The open spaces present in the ward which is occupied by the moderately suitable class can be used for the further building development. These buildings should be eco- buildings developed using the eco-friendly material. Some sites for parking can also be suggested in the open spaces of this moderately suitable class.

Some area of the less suitable class was seen to be covered by open spaces. These lands have to be protected and conserved in the form of natural landscape or can be converted in the garden.

Major part of non suitable class was seen to be covered by water body which needs rejuvenation. Plantation of trees around it is recommended. This will help in attenuating the pollution and will add to the beautification of the water body. In addition, pollution tolerant trees with high APTI values like, *Ficus bengalensis* L., *Azadirachta indica* **A.Juss., etc.** can be planted in the compound of Nazar baug palace of the ward which is situated in the category of non-suitable class. The broken and dilapidated tree guards of the road side trees should be removed or replaced.

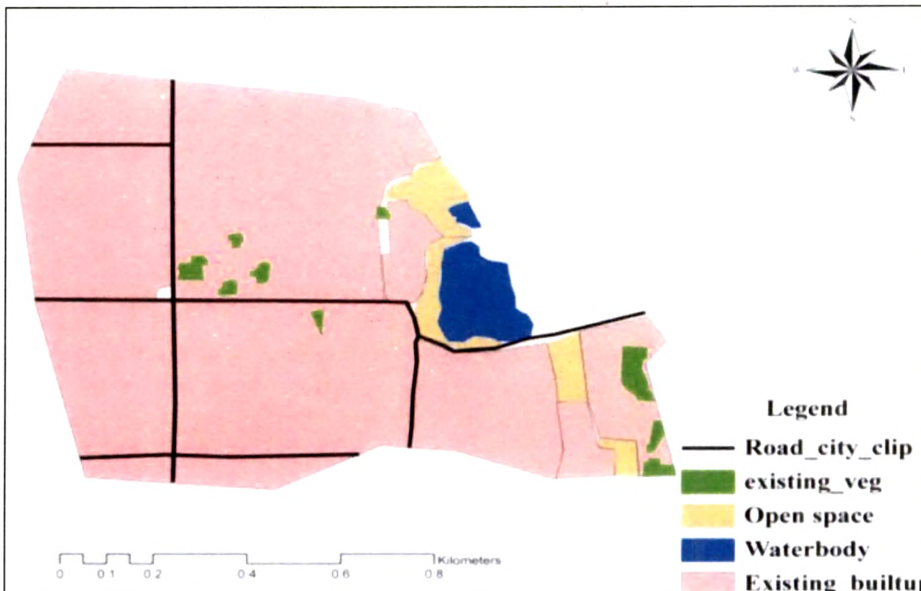


Plate 44: Map showing Existing situation of Ward No. 1

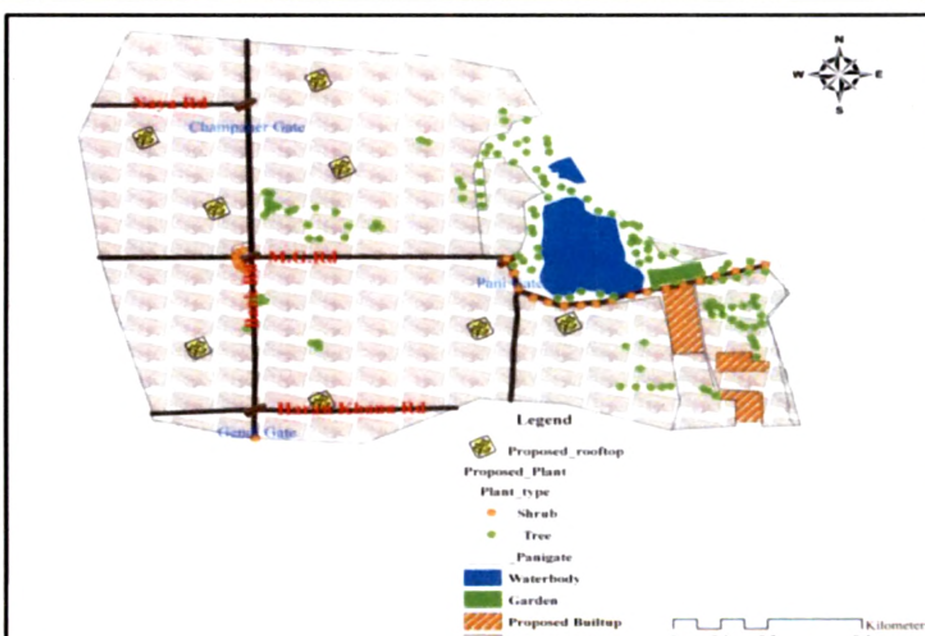


Plate 45: Map showing Eco-ward plan of Ward No. 1

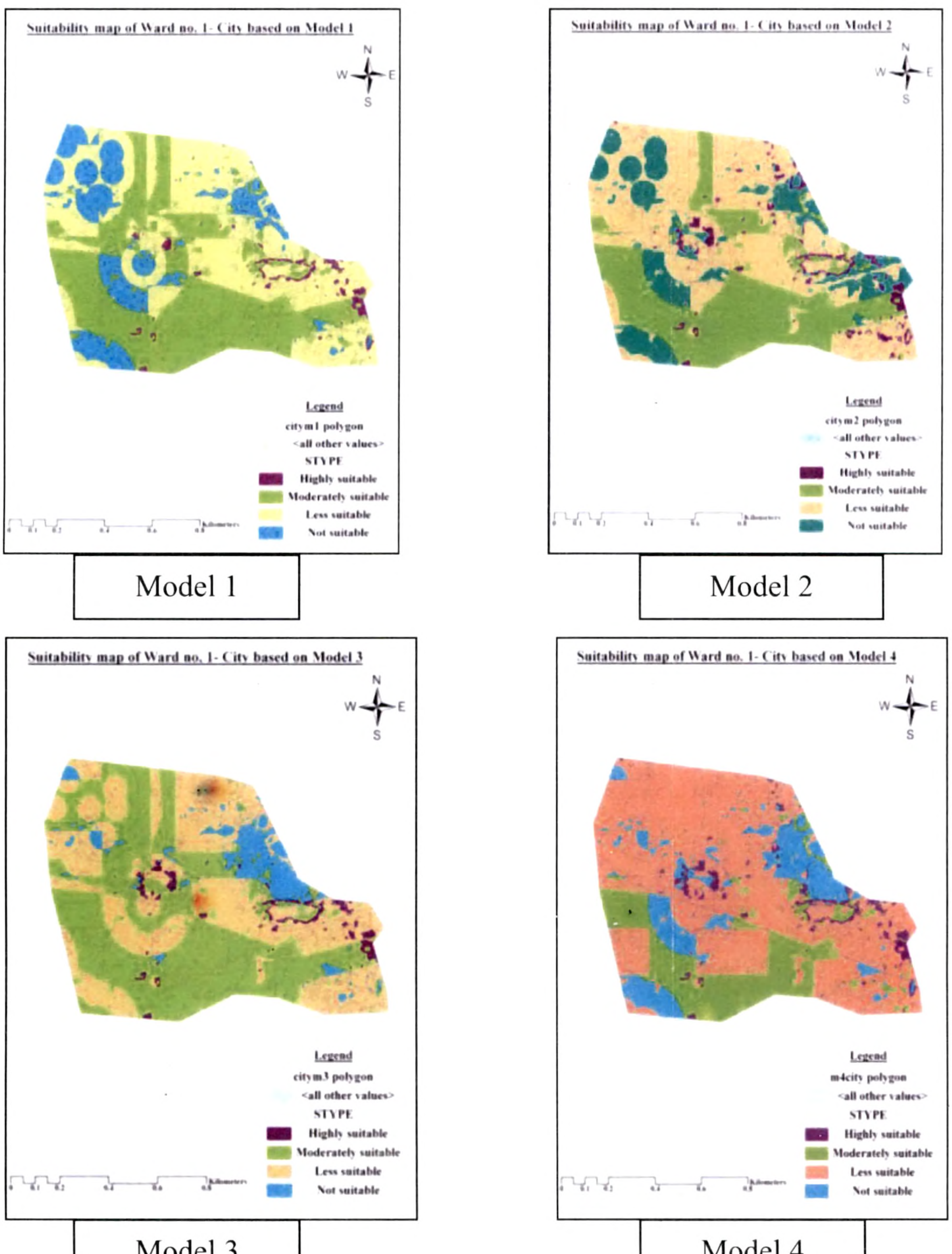


Plate 42: Suitability map of Ward No.1 based on different models

(4.4.2) Ward No.5 Shiyabaug:

Land use suitability maps obtained using USAP module for this ward showed that various suitability classes generated by 4 models differed in terms of area occupied by each class **(Table 26).** The output of Model no. 4 showed 33.33% of the entire ward to be non-suitable class which is mostly occupied by Rajmahal compound **(Plate 47)**. Part of non-suitable land is covered by SRP campus. Highly suitable, moderately suitable and less suitable classes covered 11.85, 27.08 and 27.72 % of the area of the ward, respectively. All these classes are almost covered by buildings with few play grounds and gardens **(Plate 48)**. This ward is characterized by the presence of good amount of vegetation with many recreation areas and water bodies. It is highly residential with scattered commercial activities.

Table 26: Area covered by different classes of suitability in Shiyabaug ward

Ward Name	Model	Highly suitable (km^2)	Moderately suitable (km^2)	Less suitable (km^2)	Not suitable (km^2)
Shiyabaug	1	1.32	1.52	3.08	0.32
	2	0.73	2.34	2.8	0.37
	3	1.5	1.45	1.2	2.09
	4	0.74	1.69	1.73	2.08

(4.4.2.1) Air Pollution Tolerance Index (APTI) estimation:

Estimation of APTI of different plants revealed that it differed based on different biochemical parameters. The pH value of various plants varied from 5.9±0 to 6.7±0. The Ascorbic acid content varied from 1.29±0.21 mg/g in *Azadirachta indica* A.Juss. to 20.081±1.47 mg/g in *F.bengalensis* L. *Pithecellobium dulce* (Roxb.) Benth. showed the highest TCh content while *Alstonia scholaris* L. R. Br. showed the lowest

TCh content. The RWC of the plant varied from 43.035±4.57 % in *Delonix regia* (Boj.) Raf. to 92.695±3.04% in *Mangifera indica* L. The APTI estimated using these parameters revealed that *Ficus bengalensis* L. showed the highest APTI value while that of *Delonix regia* (Boj.) Raf. was the lowest. Tolerance level estimation of different plants showed that out of the nine plants analyzed two plants were tolerant, one was moderately tolerant, five plants were intermediate tolerant while one plant was found to be sensitive **(Table 27)**. The results implied that *F. bengalensis* L. and *F. religiosa* L. plants can be planted in this ward to attenuate the air pollution and improve the environmental condition of the ward.

Table 27: APTI values of different plants in Shiyabaug Ward

Plants	pH	AA (mg/g)	TCh (mg/g)	RWC %	APTI	Tolerance Level
***Azadirachta indica* A.Juss.**	6.2±0	1.29±0.21	0.60±0.08	83.75±3.75	9.25±0.24	IT
***Caesalpinia pulcherrima* (L.) Sw**	6.7±0	1.52±0.16	0.50±0.01	88.60±2.56	9.95±0.14	IT
***Alstonia scholaris* L. R. Br.**	6.3±0	4.39±0.19	0.24±0.02	79.73±9.15	10.84±0.78	IT
***Pithecellobium dulce* (Roxb.)Benth.**	5.9±0	7.08±1.68	0.85±0.13	83.33±16.67	13.09±2.70	MT
***Ficus bengalensis* L.**	6.6±0	20.08±1.47	0.39±0.02	87.85±10.3	22.82±0.04	T
***Ficus religiosa* L.**	6.4±0	15.33±6.54	0.37±0.06	77.38±4.6	18.17±4.99	T
***Mangifera indica* L.**	5.9±0	4.06±0.68	0.48±0.08	92.69±3.04	11.86±0.77	IT
***Polyalthia longifolia* (Sonn.)Thw.**	6.6±0	4.46±1.7	0.38±0.05	79.82±8.69	11.10±2.08	IT
***Delonix regia* (Boj.) Raf.**	6.7±0	4.67±1.87	0.69±0.2	43.03±4.57	7.71±0.82	S

T=Tolerant, MT=Moderately Tolerant, IT=Intermediate Tolerant, S = Sensitive

(4.4.2.2) Generation of Eco-ward plan:

Questionnaire survey for this ward revealed that Ward No. 5 is having good environmental conditions with good amount of vegetation. This ward has proper planning and therefore a few inputs are required to convert this ward into Eco-ward. This was also proved by the output generated from the Land Suitability Analysis (LSA).

Highly suitable class present in this ward is covered almost by both old and new residential buildings. Many buildings are used for commercial purpose also. Old buildings which are present in the ward can be improved by modular prefabrication of entire building elements, such as add-on balconies or double-skin front wall systems. New buildings should apply the innovative integration of greenery into buildings, rooftop gardens, increased practice of recycling, water collection and storage and the use of solar energy as suggested by participants of questionnaire survey. The various roads of the ward include Makarpura-Lalbaug Road, R.V. Desai road, Tagore road, etc. Majority of the participants were not satisfied with road sweeping and other cleanliness maintained in their vicinity. Therefore, there is need for further improvement in general cleanliness maintained in the ward. Makarpura-Lalbaug road is wide with divider in the middle which lacks any kind of vegetation. Plantation of shrubs on divider is suggested to improve the vegetation status of the ward. This will reduce the pollution level of the ward. Plantation of trees like, ***Azadirachta indica*** **A.Juss.,** ***Polyalthia longifolia*** **(Sonn.)Thw., etc.** along both the sides of roads can also improve the status as suggested by participants. There is presence of ***Alstonia scholaris*** **L. R. Br.** on both the side of R.V.Desai road but they are not maintained properly. Plants are growing out of the tree guard which needs to be removed or replaced. This is necessary for generating the sound eco-ward plan.

As low as 2 % area of less suitable class is covered by recreational areas including play grounds and gardens. However, many participants do not visit gardens very frequently. Therefore, plantation of suitable trees like, ***Pithecellobium dulce*** **(Roxb.)Benth.,** ***Ficus bengalensis*** **L.,** ***Ficus religiosa*** **L., etc.** in periphery of these play grounds and gardens is recommended **(Plate 49)**. This will decrease the noise pollution and will enhance the aesthetic value of the play grounds which will attract more citizens by providing them with Vitamin G which is a basic concept of Eco-ward planning. Various gardens namely; Badamdi baug, Kevda baug, Khanderao market and Lal baug present in this ward are providing many amenities to the people. These gardens are having positive effects on the people living in the nearby vicinity. Many participants felt that Kevda baug need improvement as it is not maintained properly. Almost 10% area of non-suitable class is occupied by two water bodies of the ward. As suggested by many participants these water bodies need improvement. The one present near the Kashi Vishwanath temple is suffering from the eutrophication. The whole water body is covered with the vegetation due to which it has become shallow which creates the problem of flooding on main road during monsoon season. Therefore, cleaning of this water body is recommended. Siddhnath Lake present on R.V.Desai road is also not in proper condition and needs improvement.

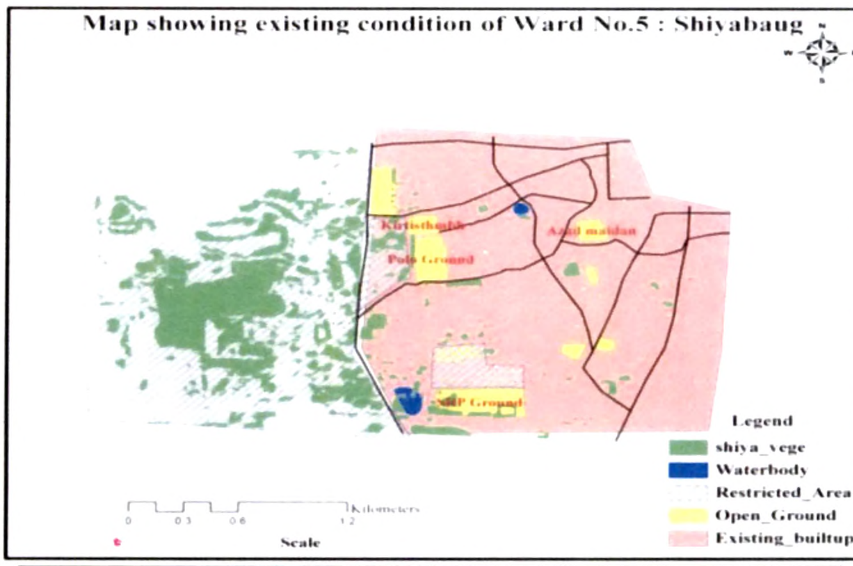


Plate 48: Map showing existing condition of Ward

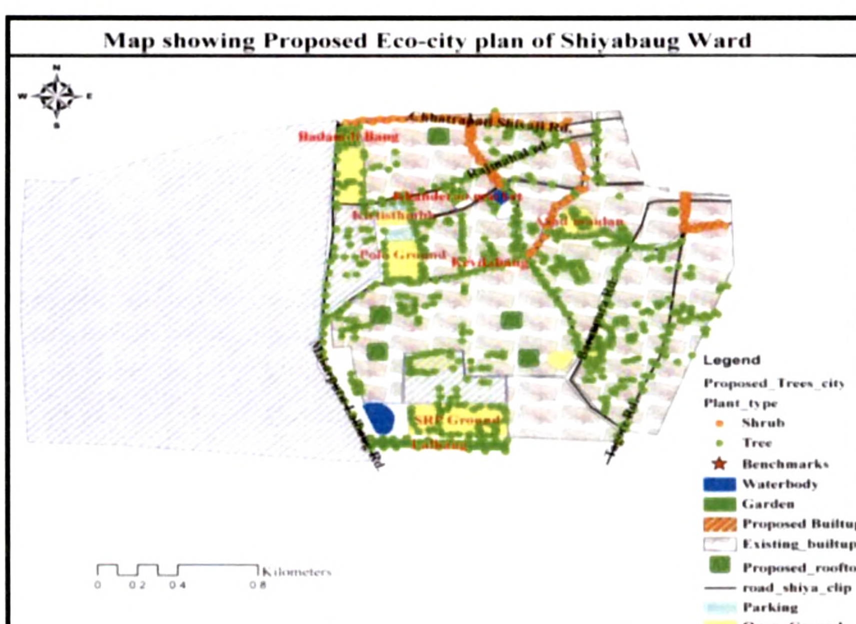
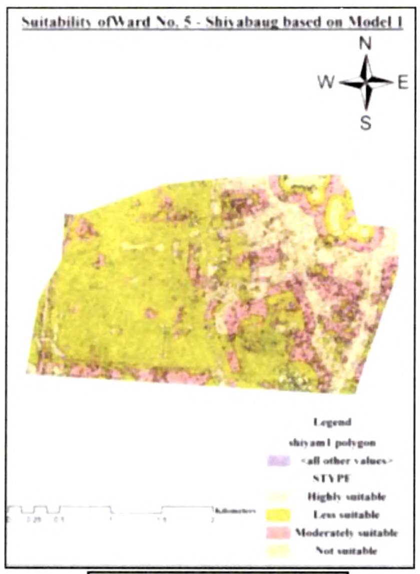
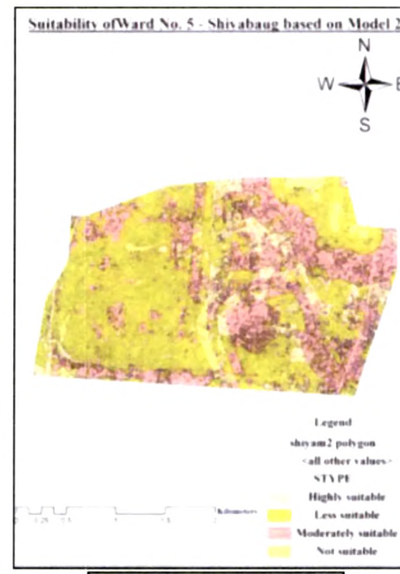


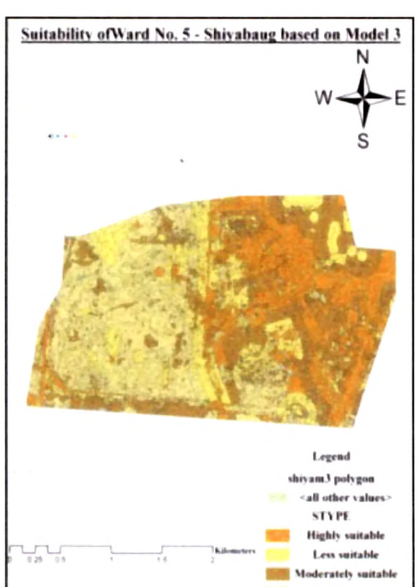
Plate 49: Map showing Eco-ward plan of Ward No.



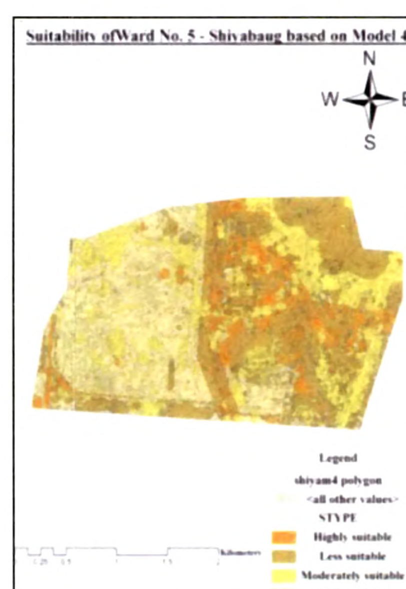
Model 1



Model 2



Model 3



Model 4

Plate 47: Suitability map of Ward No.5 based on different models

(4.4.3) <u>Ward No.9: Panigate Ward:</u> Land Suitability Analysis (LSA) for this ward showed that different land suitability classes differed in terms of area depending upon different models **(Table 28).** Various suitability classes like highly suitable, moderately suitable, less suitable and not suitable occupied 9.8, 58.71, 23.05 and 8.4 %, of the total area of ward, respectively **(Plate 50).** Most of the existing built-up area of the ward was categorized under highly suitable, moderately suitable and less suitable class. 1% of highly suitable area was occupied by open space which can be utilized for further development. Almost whole area under the category of not suitable class was occupied by agriculture, water body and open space. All these landscape should be preserved and should not be utilized for built up areas. This ward also showed the presence of scattered vegetation with agriculture fields **(Plate 51).**

Table 28: Area covered by different classes of suitability in Panigate ward

Ward Name	Model	Highly suitable km^2	Moderately suitable km^2	Less suitable km^2	Not suitable km^2
Panigate	**1**	3.03	5.84	2.57	0.83
	2	4.16	4.19	3.16	0.76
	3	1.21	7.30	3.07	0.69
	4	1.22	7.31	2.87	0.87

(4.4.3.1) <u>Air Pollution Tolerance Index estimation</u>:

Estimation of APTI of this ward showed that different components of the APTI, i.e. pH, AA, TCh and RWC, varied substantially in different plants **(Table 29).** The pH value was the highest in the *Alstonia scholaris* L. R. Br. while it was the lowest in *Mangifera indica* L. Total chlorophyll content varied from 1.33±0.29 to 0.24±0.68 (mg/g) in various plants. Ascorbic acid content and RWC of *Mangifera indica* L. was as high as 18.97±0.06 (mg/g) and 88.56±1.9 %, respectively which imparted it the highest APTI value. The lowest APTI value was of ***Caesalpinia***

pulcherrima **(L.) Sw.** Tolerance level estimation of the nine plants of this ward showed that one of them was Tolerant. two were moderately tolerant, two were intermediate tolerant and one was sensitive plant. *Mangifera indica* L. was having the highest APTI value in this ward and was graded as Tolerant plant. This plant can be utilized for the roadside plantation. The lowest APTI value was of *Caesalpinia pulcherrima* (L.) Sw. and was graded as sensitive plant. This plant should not be utilized for plantation because it will not be able to survive in the polluted environment. Various other plants like *F. bengalensis* L. and *Polyalthia longifolia* (Sonn.)Thw. can also be utilized for planting in various gardens and greenbelts of the ward.

Table 29: APTI values of different plants in Panigate Ward

Plants	pH	AA (mg/g)	TCh (mg/g)	RWC %	APTI	Tolerance Level
Azadirachta indica **A.Juss.**	6.9±0	6.2±0.04	0.86±0.31	67.93±4.78	11.36±0.70	IT
Caesalpinia pulcherrima **(L.) Sw**	5.9±0	5.08±1.46	0.74±0.23	44.99±1.66	7.71±0.95	S
Alstonia scholaris **L. R. Br.**	7.25±0	9.35±0.032	0.63±0.03	70.74±4.5	14.10±0.46	IT
Pithecellobium dulce **(Roxb.)Benth.**	5.9±0	6.7±2.02	0.54±0	78.14±7.56	12.39±2.13	IT
Ficus bengalensis **L.**	6.6±0	12.47±4.27	0.24±0.68	76.21±2.56	16.98±2.19	MT
Ficus religiosa **L.**	5.9±0	8.04±3.84	0.40±0.09	78.25±.22	12.87±3.09	IT
Mangifera indica **L.**	5.4±0	18.97±0.06	0.5±0.79	88.56±1.9	22.67±1.64	T
Polyalthia longifolia **(Sonn.)Thw.**	6.6±0	14.40±2.69	0.65±0.19	79.13±0.87	17.98±1.70	MT
Delonix regia **(Boj.) Raf.**	5.9±0	8.31±1.77	1.33±0.29	59.47±2.58	11.22±0.63	IT

T=Tolerant, MT=Moderately Tolerant, IT=Intermediate Tolerant, S = Sensitive

(4.4.3.2) Generation of Eco-ward plan:

The Land Suitability Analysis (LSA) results of the Panigate ward revealed that improvement at several levels is required to convert this ward into eco-ward. Almost whole area occupied by highly suitable class was found to be present along the roadside of the ward. This area is already covered by existing built up. It is recommended that these existing buildings should develop roof top gardens along with rain water harvesting system to improve their microclimatic condition. Few of the main roads of the ward like Ajwa, Waghodiya and Waghodiya ring road showed the presence of open space on both the sides of road. Some area of this open space is covered by trees but they are not properly managed. Plantation of more pollution tolerant trees like ***Mangifera indica*** **L.,** ***Ficus bengalensis*** **L.,** ***Polyalthia longifolia*** **(Sonn.)Thw., etc.** in rows along the roadside is recommended. This will reduce the pollution level of the ward and will improve the environmental condition. As suggested by the participants broadening of these roads is also recommended to avoid the traffic jam in this ward. The traffic rules should be followed properly because many participants felt that roads are unsafe for them. Many participants of questionnaire survey complaint about the road-side illegal encroachments which covered half of the space on busy roads. This has to be removed for the convenience of travelling and walking people. This will encourage people to go by walk to nearby areas which is one of the major objectives of eco-ward planning. Majority of participants were not satisfied with road sweeping and cleanliness maintained in the ward. Garbage bins present along the roadside are inadequate and people dump their waste on road side leading to stench and breeding ground for mosquitoes. More dustbins should be placed to keep the surroundings clean and healthy. Along with that frequency of door to door waste collection need to be increased as suggested by many participants.

Open space present in the highly suitable area is recommended for future construction activity **(Plate 52)**. New buildings to be developed in this ward have to should follow sustainable architecture and green design. Ample of green space should be kept in between the new buildings as the questionnaire survey revealed lack of greenery in the ward. Care should be taken to conserve the existing vegetation while developing these buildings. In addition, new buildings should be provided with the facility of recycling the waste water. This type of arrangement will avoid the water waste by enhancing the availability.

The built-up area of the ward has reached up to agriculture fields present along the NH8 passing through the ward which are located under the category of non-suitable class. These fields need to be protected from encroachment. Plantation of more trees is proposed in the open space present in the compound of leprosy hospital. This will help patients to improve their health and feel close to the nature. Establishment of gardens and green belts on open spaces which are covered under the category of non-suitable class is recommended. The presence of four water bodies covered under the non-suitable class is improving the micro-climate (Gehl, 1971). All these water bodies should be connected with each other which will reduce problem of flooding during monsoon. Plantation of suitable shrubs and trees along the periphery of these water bodies is recommended. This will enhance the beauty of the water bodies.

LSA along with the suggestions from the participants of questionnaire survey played a major role in converting various wards of Vadodara city into Eco-wards. Same methodology can also be applied for the generation of Eco-city plan for the city. Various other measures which are saving energy, decreasing pollution and improving the environmental conditions can also be applied to develop the city in balance with nature.

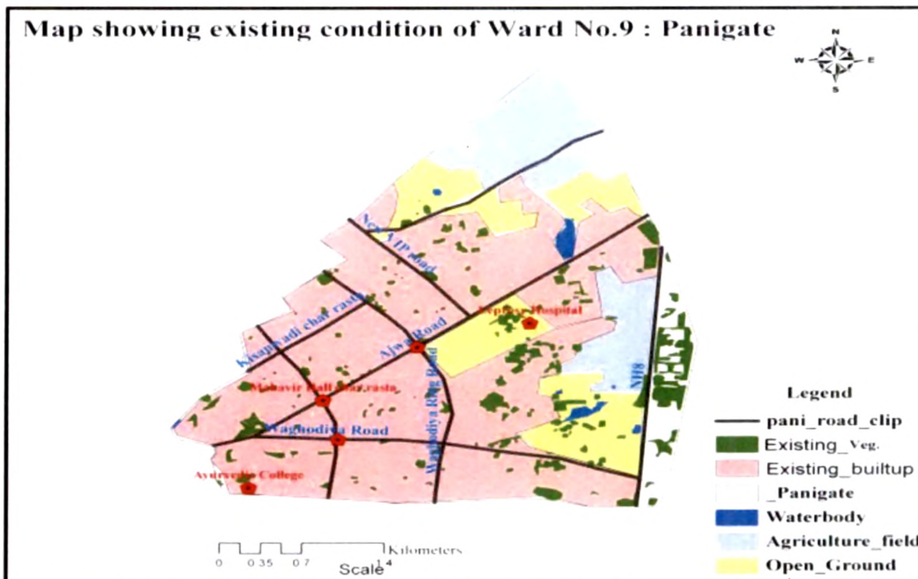


Plate 51: Map showing existing condition of Ward No. 9

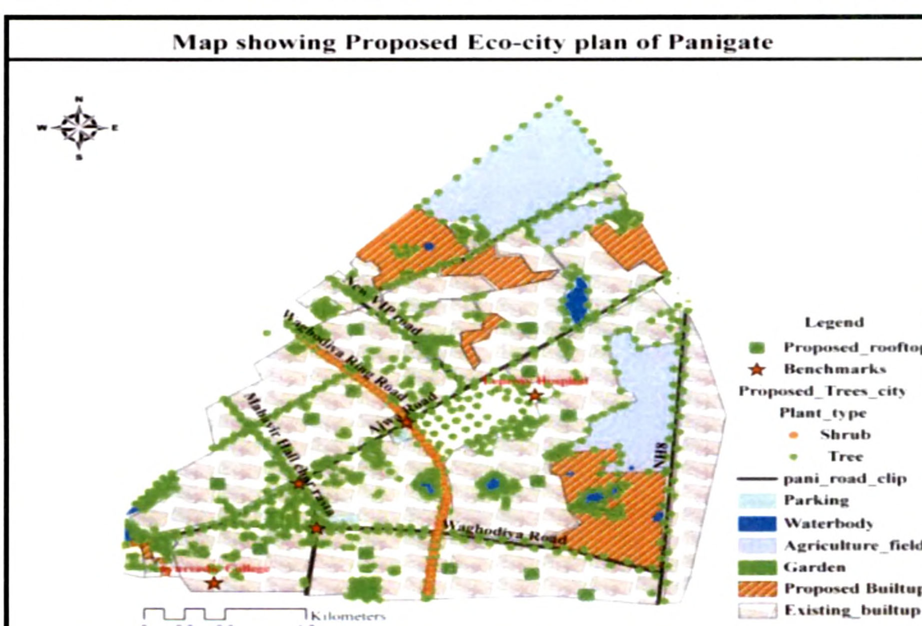


Plate 52: Map showing Eco-ward plan of Ward No. 9

Results

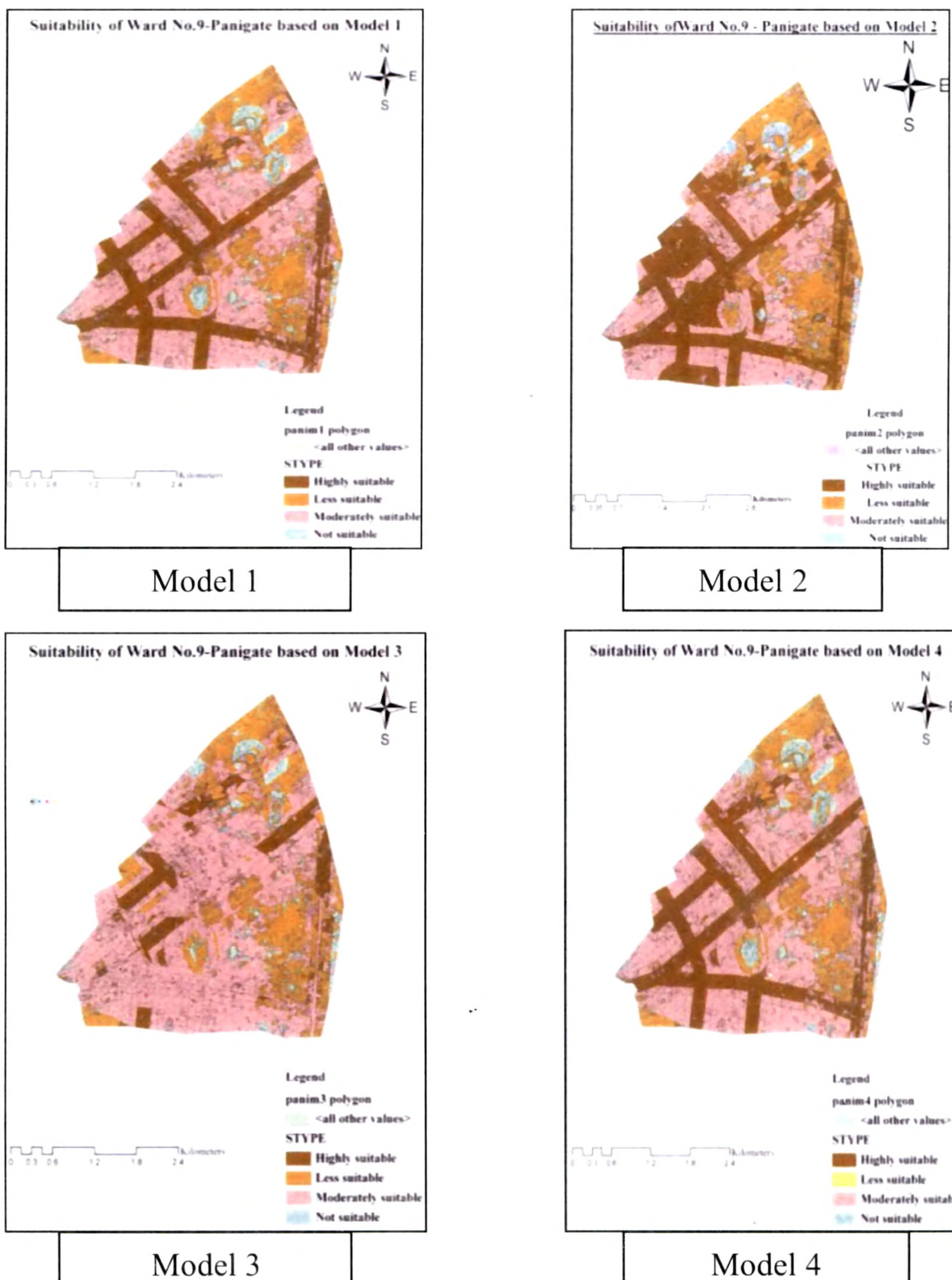


Plate 50: Suitability map of Ward No.9 based on different models

(4.4.4) <u>Converting the existing city into an Eco-city</u>:

In recent times cities have become places of environmental degradation and wasteful use of resources, which is proving to be costly to present and future generations. Vadodara city is also facing the problems of air quality pollution, green house gases, unsustainable consumption and of inadequate sanitation and water supply. Realizing the urgency of the situation this study has been taken up to propose the changes to be carried out to convert Vadodara city into an Eco-city. The aim of Eco-city development is to control environmental damages, depletion of nonrenewable resources and rising levels of pollution in cities. Eco-city tries to achieve a balance between the development of the cities and protection of the environment along with providing various basic services like employment, shelter, social infrastructure and transportation in the cities. Municipal corporations of developing cities like Vadodara with limited budget cannot invest in incremental changes. Modifying existing cities like Vadodara into an Eco-city require lesser changes. Precise changes can be proposed by performing the Land Suitability Analysis for the city. Open space redevelopment within existing cities can be proved as an excellent strategy to transform unusable or damaged land into functional and profitable area. Existing cities are able to retain existing embodied energy and amenities which reduces costs.

First step to convert the city into an eco-city development is to carry out the questionnaire survey of the residents of the city. This will help the planners to receive ideas for the proper input and strategy for development thereby providing various amenities in vicinity their home. In addition, the city planners should aim at energy efficiency in transport and buildings, optimal planning solutions in terms of locations, distances and spaces. Energy sources should be solar cells on grass rooftops, wind turbines, biomass plant using waste from agriculture production to generate steam/electrical power, and methane gas from digested sewerage and waste materials. This will reduce air and noise pollution. Eco-house which includes very good insulation all round, large windows facing southwards to provide passive solar heating (possibly with double glass wall-greenhouse area to trap sun with vents to cool in summer) and a heat pump. Other features such as reimbursed power return to grid, solar water heating, biomass wood or waste heating should be included. Citizens should be encouraged to implement the concept of 'walk-to-work and walk-to-school'. High density and mixed use are characteristic for pedestrian-oriented settlement patterns. This requires a radically different approach to city planning, with integrated business, industrial, and residential zones. In addition, there is a need to reduce land demand and sealed-up area. This can be achieved by designing compact urban patterns (avoiding urban sprawl) which allows the preservation of natural green areas and agricultural lands. This will provide land for both human use and also as habitats for other living organisms and for natural processes (such as the water cycle and carbon-fixing in green plants). City should also aim to increase urban green space as it provides many benefits to citizens. Waste should be recycled for fertilizers. Eco-city should include improved public transport to reduce vehicular emissions. Cities should also try to develop the key performance indicators that provide guidance to city administrators.