CHAPTER 3

MATERIAL AND METHODS

(3.1) Materials:

(3.1.1) SOI map: The Survey of India (SOI), topographical maps at 1:50,000 scale were used for generating thematic maps of the study area.

(3.1.2) Ancillary data: Population data for various years were obtained from the census for the year 1991 and 2001. Information regarding the location of gardens was obtained from the map published by Ananda Sahitya Prakashan of Ahmedabad. Datasets for land use for various years were obtained from the VUDA report.

(3.1.3) Field Survey: A reconnaissance survey was carried out to collect the ground control points of the Gardens and Greenbelts present in the study area for generation of thematic map. Field survey was also carried out for the post classification verification of the classified output.

(3.1.4) Table 2: Satellite data used in the study

Sr. No.	Data used	Year of data acquisition	Wavelength width in µm/ band	Spatial resolution (m)	Swath (km)
1.	IRS-P6 LISS III	2000	0.52-0.59 (green)	23.5	141
			0.62-0.68 (red)		
			0.77-0.86 (NIR)		
			1.55-1.70 (MIR)		
2.	IRS-P6 LISS-IV	2005 2009	0.52-0.59 (green)	5.8	23.9 (MX) 70 (P)
			0.62-0.68 (red)		
			0.77-0.86 (NIR)		
3.	Landasat ETM+	11 November, 2001	0.45-0.515(blue)	30m (60m thermal, 15m pan)	183 km
			0.525-0.605(green)		
			0.63-0.690 (red)		
			0.75-0.90(NIR)		
			1.55-1.75(SWIR)		
			10.40-12.5 (thermal IR)		
			2.09-2.35 (SWIR)		
			0.52-0.90 (pan)		

(3.2) Software used:

Software utilized for digital data processing and preparing the maps were Erdas imagine 9.1, Arcinfo 7.2, ArcGIS 9.2 and Geomedia 5.2. Erdas Imagine is used primarily for geospatial raster data processing and for preparing, displaying and enhancing digital images. ESRI's ArcGIS is a geographic information system (GIS) and it is used for creating maps; compiling geographic data; analyzing mapped information and sharing and discovering geographic information.

(3.3) Methods:

Methodology followed for generating thematic maps, land use change detection, suitability analysis and Eco-city plan generation are discussed separately.

(3.3.1) Methodology for thematic map generation:

The development of Eco-city plan requires the generation of different thematic layers for Vadodara city. Generation of six different thematic maps is given as shown in the flow chart **(Figure 1)**. Thematic maps for **Water body and Transport network** were generated from **Survey of India (SOI), Greenbelts and Gardens location maps** from ancillary data and **ward map of population density** from census information. **Contour** and **slope** were extracted from the satellite data.

Contour map was generated using spatial analyst tool of the ArcGIS software. Ground Control Points (GCP) collected from different locations **(Table 3)** were integrated in the spline module of the spatial analyst tool. The output was obtained in the form of contour map. Contour lines evenly spaced and close together indicated a uniform, steep slope.

The slope map was generated from contour map. Slope inclination is a measure of the relationship between change in horizontal and vertical distances between at least two points usually expressed in percentage. The output slope raster is calculated as percent slope or degree of slope using following formula:

$$\textbf{Percent slope} = \frac{\textbf{change in elevation (Rise)}}{\textbf{Distance (Run)}}$$

Table 3: GCPs of Vadodara city

GCP_ref_Nu	Location_N	Lat	Long	Northing	Easting	Z_value_M
BRD-209	Corner of compound wall (outer) Novlakhi Maidan	22°17'47.12" N	73°11'09.06 "E	2466760.20	313111.17	32.3680
BRD-202	Jaibhavani sainik mahavidayalaya right back side corner terrace, Ghanshayam park	22°18'57.24" N	73°13'24.88 "E	2468870.86	317024.28	41.6890
RBRD-206	On Culvert	22°18'16.00" N	73°07'39.43 "E	2467721.97	307122.15	37.4560
BRD-216	Prathan upwan compound wall	22°16'43.32" N	73°08'32.56" E	2464852.23	308607.66	29.3600
BRD-220	Anshuya Nagar,shri dwarkesh showmills plot no. e-3, baroda-Timber Industrial estate,dabhoi road inner compond wall sw coner	22°16'43.70" N	73°13'33.93" E	2464760.27	317234.93	32.2480
BRD-233	Tarsali Bypass Bharat petrolium,building nt in front of petrolpump back side corner	22°14'27.29" N	73°12'44.03" E	2460581.51	315756.84	27.4310
BRD-237	Mahashivhari Guest House terace back side right corner behind hotel Baba Ramdev no- 1 NH-8	22°13'31.85" N	73°11'20.12" E	2458904.86	313333.78	39.3970
BRD-236	Maretha villag	22°13'27.97" N	73°10'13.98" E	2458808.33	311438.19	26.1560
BRD-225	Kalali village	22°15'34.19" N	73°10'02.16" E	2462694.61	311146.70	39.9880

Table 3: GCPs of Vadodara city (Cont.)						
GCP_ref_Nu	**Location_N**	**Lat**	**Long**	**Northing**	**Easting**	**Z_value_M**
BRD-190	Standard Radiator pvt. Ltd. H-12/13 Industrial Estate Gorwa Baroda-16,ompound wall corner(sw)	22°19'50.27" N	73°09'46.96" E	2470576.64	310807.46	39.1490
BRD-192	Ajita Nagar, A & B provision stors corner of compound wall gate se corner	22°20'04.83" N	73°12'17.11" E	2470972.68	315109.41	37.6410
BRD-181	Pramukh preet residency Ananad deep society canal road, TP-13 compound wall NE corner channai jakat naka	22°20'54.95" N	73°09'48.41" E	2472565.46	310873.32	42.5200
BRD-169	4. jin compound ,terrace SE corner bajwa Hpgas agency office terrace	22°21'57.34" N	73°08'31.81" E	2474511.45	308705.31	41.3410
BRD-222	Bund of farm near Khhatamba village	22°16'54.61" N	73°15'47.34" E	2465051.43	321057.88	34.7710
BRD-195	agriculture production market corporation near NH-8	22°20'08.34" N	73°15'05.83" E	2471023.96	319938.45	43.6900
BRD-185	Golden tubaco company Ltd.near toll tex vadodara halol express way	22°21'19.68" N	73°14'34.71" E	2473228.51	319073.80	44.6520
BRD-179	Undera village farm house terrace backside corner	22°20'42.57" N	73°07'36.53" E	2472231.31	307094.98	39.0970
BRD-158	ONGC compound wall corner(SE), opp- eefluent channel project Ltd Head works dhanora	22°22'58.83" N	73°06'13.76" E	2476452.176000	304779.404000	37.1630
BRD-150	Village Ranoli Railway line overbridge	22°24'01.04" N	73°07'22.44" E	2478340.958000	306768.154000	43.3840
RBRD-171	On Building corner Near NH-8	22°22'05.69" N	73°10'58.30" E	2474717.302000	312899.167000	38.5660

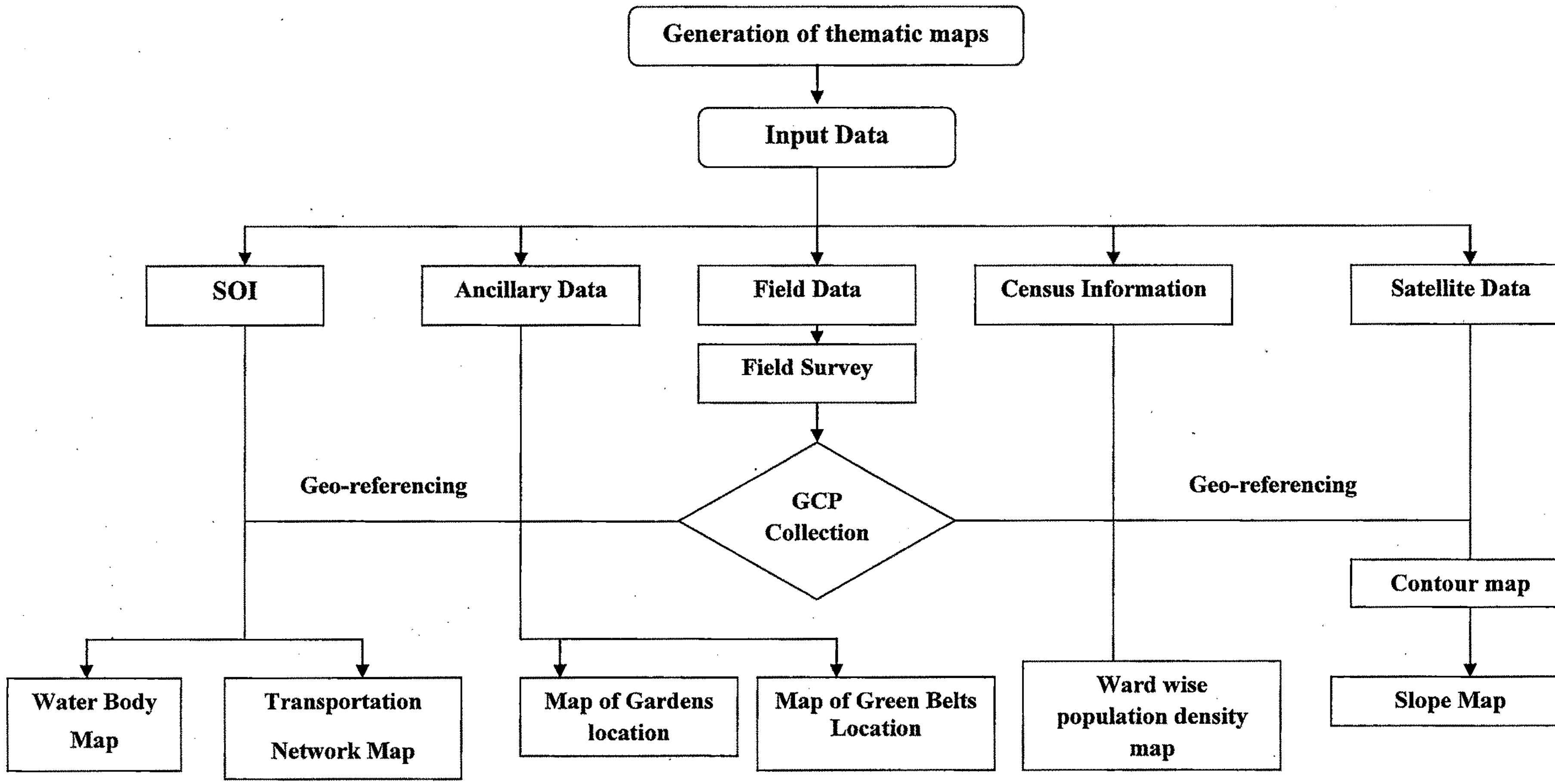

Figure 1: Methodology for thematic map generation

(3.3.2) Methodology followed for Land use change analysis:

The methodology followed for the entire study is brought out distinctly in the flow chart **(Figure 2)**. The land use change at VUDA level was attempted using six different datasets procured from different sources covering a span of 126 years, i.e. from the year 1880 to 2006. Land use change at VMSS level was carried out using seven datasets covering a span of 129 years, i.e. from the year 1880 to 2009. Data for the years 1880 and 1960 were procured from **Barodawala *et al.* (1992)** whereas for the years i.e. 1980, 1996 and 2006 were procured from the VUDA report. All these datasets were geo-referenced using ERDAS Imagine 9.1 software and were brought to one scale. Digitization was performed for these data sets and area under different land use classes was computed using the ArcGIS software. LISS III and LISS IV satellite data were used for the years 2000 and 2009, respectively. The classification scheme adapted is given in **Table 4 (ISRO, 2005)**. Land use training sets each having its own signature files were generated for both LISS III and LISS IV images. These were then subjected to supervised classification which was performed using the algorithm maximum likelihood as it provided better accuracy. Percent change in land use and the related statistics were computed for all the datasets for VUDA as well as VMSS area. L.C.R., U.S.I. ad L.A.C. were calculated only for VUDA level. Estimation of entropy using Shannon's entropy method was carried out for all the data sets at VMSS level.

TABLE 4: URBAN LAND USE/ LANDCOVER CLASSIFICATION AT DIFFERENT LEVELS AND THEIR CODES ACCORDING TO NNRMS STANDARDS

SR. NO.	LUC-CODE	LEVEL - I	LEVEL - II	LEVEL - III
		Built Up		
1.	01-01-00-00		Built Up (Urban)	Residential
2.	01-02-00-00		Built Up (Rural)	
3.	01-01-03-07		Habitation with Plantation	
	01-03-00-00		Transportation	
4.	01-03-01-01			Road
5.	01-03-02-01			Rail
		Agricultural Land		
6.	02-01-00-00		Crop Land	
7.	02-02-00-00		Fallow	
8.	02-03-00-00		Plantation	
		Forest		
9.	03-01-01-00		Dense/Closed	
10.	03-01-02-00		Open	
11.	03-03-00-00		Forest Plantation	
12.	03-05-00-00		Forest Blank	
13.	04-00-00-00	Natural/Semi natural grassland & Grazing land		
		Wastelands		
14.	05-01-00-00		Salt affected land	
15.	05-02-00-00		Gullied/Ravenous land	
			Land with or without scrub	
16.	05-03-01-00			Land with scrub
17.	05-03-02-00			Land without scrub
18.	05-04-00-00		Sandy area	
19.	05-06-00-00		Barren Rocky/Stony waste	
	06-00-00-00	Wetlands		
	06-01-00-00		Inland natural	
20.	06-01-04-00			Waterlogged (Seasonal)
	06-02-00-00			
	06-03-00-00		Coastal Natural	
21.	06-03-05-00			Marshy/Swampy
22.	06-04-00-00		Coastal Manmade	
	07-00-00-00	Water bodies		
23.	07-01-00-00		River/Stream	
24.	07-02-00-00		Canal/Drain	
25.	07-03-00-00		Lakes/ponds	
26.	07-04-00-00		Reservoir/Tanks	

Methodology for estimation of different parameters is explained separately as shown below:

Shannon's entropy (S.E.): S.E. is the measure of the degree of dispersion or concentration of a random geographical variable, i.e. the built-up and is related with urban sprawl. It is calculated according to **Araya (2009)** where entropy is denoted as

$$H_n = \sum_{i}^{n} p_i \log(\tfrac{1}{p_i})$$

where, pi is the probability or proportion of occurrence of a phenomenon in the ith spatial unit out of n units, and thus, is given by:

$$p_i = x_i / \sum^{n} x_i$$

where, *xi* is the density of land development, which equals the amount of built-up land divided by the total amount of land in the *i*th zone in the total zone of *n* zones. The number of zones means the number of buffer zones around the city center or around selected roads.

For estimation of entropy five concentric buffers of 3 km each were laid around the city centre, i.e., Mandvi. The seven land use maps of the years 1880, 1960, 1980, 1996, 2000, 2006 and 2009 were simplified into two major classes, viz. built and non-built areas. Using the above mentioned formulas the entropy for each year was calculated which varied from 0 to 1. If the distribution is maximally concentrated in one region, the lowest value of entropy 0 is obtained while an evenly disperse distribution across space results into the maximum value of 1.

Since entropy measures the distribution of a geographical phenomenon, the difference in entropy between two different periods of time was used to indicate the change in the degree of dispersal of land development or urban sprawl using the formula:

$\Delta En = En(t+1) - En(t)$ where, ΔEn is the difference of the entropy values between two time periods; En (t+1) is the entropy value at time period (t+1); En (t) is the relative entropy value at time period t.

Urban Sprawl Index (U.S.I.): It is a measure of the built environment in a city.

U.S.I. = Urban expansion / Population increase

Land consumption rate (L.C.R.): It estimates the rate at which the land is consumed by the developing area.

L.C.R = A / P (A = areal extent of the city and P = population)

Land Absorption Coefficient (L.A.C.): It estimates the rate at which the developing city absorbs the new urban land **(Yeates and Garner, 1976)**.

$$L.A.C. = A_2 - A_1 / P_2 - P_1$$

A1 and A2 are the areal extents for the early and later years, and P1 and P2 are population for the early and later years respectively.

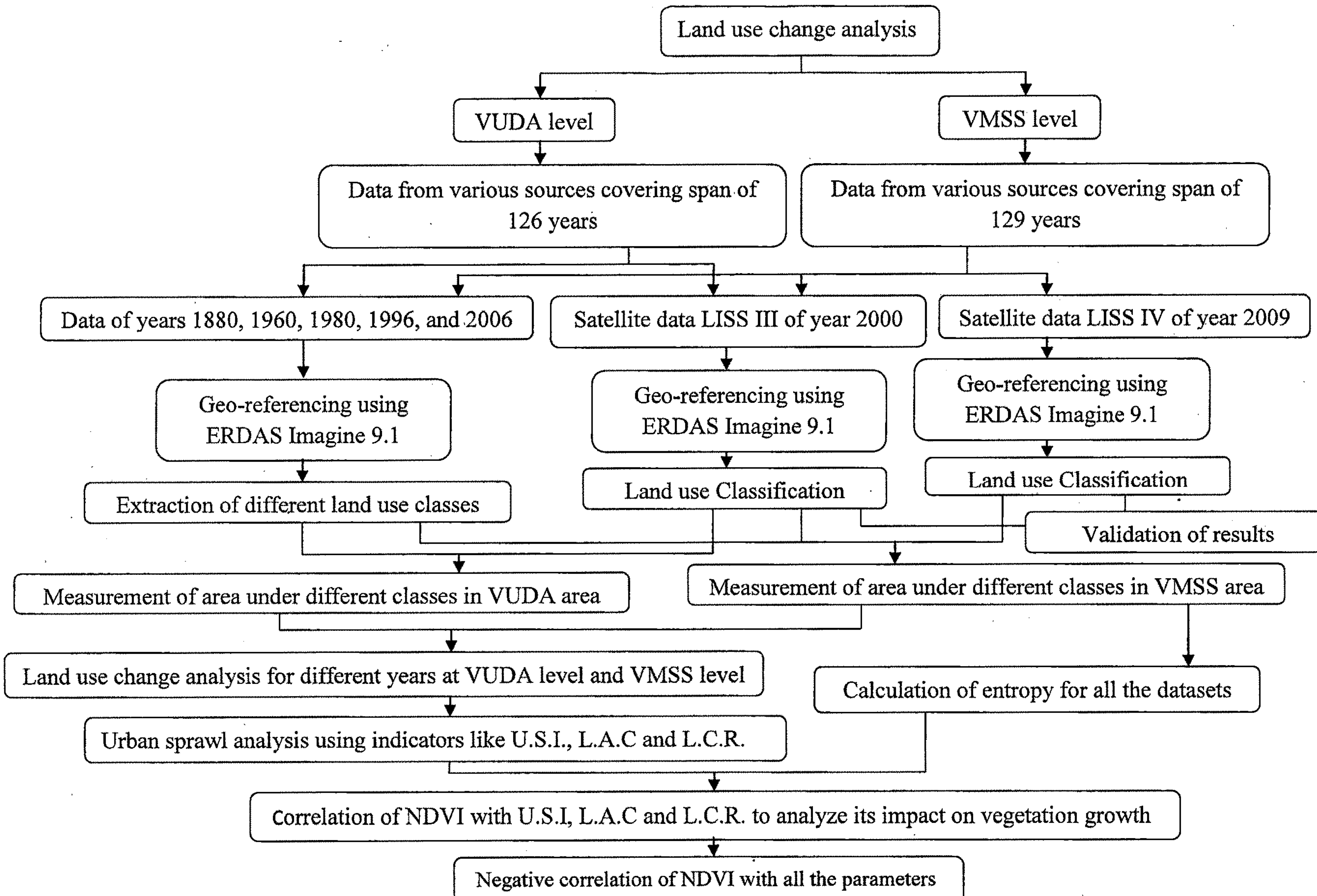

Figure 2: Flowchart showing the methodology adopted for land use change detection

(3.3.3) Methodology followed for Urban green space analysis:

Methodology followed for suitability analysis of UGS, economic valuation of UGS and assessment of the impact of various biophysical and socioeconomic parameters on property value has been segregated in three different parts, i.e. **Part 1, Part 2** and **Part 3,** respectively. All these studies were carried out at VMSS level.

(3.3.3.1) Part 1: Suitability Analysis: Vadodara city is comprised of 13 different wards out of which 10 wards were selected for the UGS suitability analysis depending upon the availability of data for different themes. Various themes considered for identifying suitable sites for UGS development were Slope, Land use, transportation, water body and ground water status **(Figure 3)**. These themes were integrated in GIS to obtain the suitable sites for UGS. Buffers were created around the water bodies and transportation network. Sites which were near the water body and transport network were preferred. Sites with the slope of 0-1% and good ground water status were preferred. More importance was given to open spaces while identifying the suitable sites. Various other themes like temperature, vegetation and related parameters, Population Density (P.D.), Greenbelts and gardens provided additional information in analyzing their influence on the suitable sites. Areas with low P.D., per capita vegetation, slope, and LST were preferred for designating suitable sites. Priority was given to the wards in which total vegetation decreased, which have less gardens and greenbelts.

Methodology for all the parameters viz. Slope, Land use, Population density, Transport, water body, green belt and gardens have already been described in the earlier section while methodology for Vegetation and Temperature are described in this section.

Vegetation: The status of vegetation was analyzed from the biophysical parameter NDVI derived from satellite data LISS III of the year 2000 and LISS IV of the years 2007 and 2009 using the formula:

NDVI = (NIR- Red) / (NIR + Red) (Lillesand *et al.*, 2007)

Temperature: Estimation of changes in temperature was carried out using Landsat ETM+ data (Xu, 2009). The DN values of band 6 were converted into spectral radiance L [W/ (m^2 sr μm)] using the following formula,

$$L = \frac{L_{max} - L_{min}}{Q_{cal\,max} - Q_{cal\,min}} \times (Q_{cal} - Q_{calmin}) + L_{min}$$

Calibration of thermal band was then performed in two steps:

Conversion of the spectral radiance L to sensor Brightness Temperature (BT) into the Kelvin. The conversion formula is given by:

$$BT = \frac{K_2}{\left[\ln\left(\frac{K_1}{L} + 1\right)\right]}$$

where, BT is the at-sensor brightness temperature (K),K_2 is a calibration constant (1,282.71 K), K1 is another calibration constant (666.09 W m^{-2} sr^{-1} lm^{-1}) and L is the spectral radiance at-sensor (W m^{-2} sr^{-1} lm^{-1}).

$$TS = \frac{K2}{\left[1 + \ln\left(\frac{\lambda \cdot BT}{\rho} \cdot \ln\varepsilon\right)\right]}$$

where, TS is the land surface temperature (K), λ is the wavelength of emitted radiance (11.5 lm); ρ is h×c/r=1.438×10^{-2} mK and ε is the spectral surface emissivity.

(3.3.3.2) <u>Part 2: Economic valuation of Urban Green Space (UGS):</u>

For the economic valuation of the UGS, real estate property values were collected from the information available on the internet and from the local information and newspapers. These values were then classified in three main classes, i.e., low, medium and high prices **(Figure 4)**. NDVI values were retrieved from IRS LISS IV 2009 satellite data to understand the vegetation status around these properties. These NDVI values were classified into four classes, viz. High, moderate, less and no vegetation classes. These values were integrated with property prices using the ArcGIS software for economic evaluation of UGS.

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

Assessment of impact of various parameters on property value was determined at VMSS level. Methodology adopted for the study is shown in **Figure 5**. Different biophysical and socioeconomic parameters selected for assessing the impact were NDVI, LST, NDBI, B.D. and P.D. The methodology for P.D., NDVI and LST has been described earlier in this chapter where as methodology for NDBI and BD is described in the following section. NDBI is the measure of built-up area of the city and is measured as follows:

$$\text{NDBI} = (\rho(\text{band5}) - \rho(\text{band4}))/(\rho(\text{band4}) + \rho(\text{band5}))$$

B.D. is the ratio of built-up area to the total area which was calculated ward-wise.

The values for all the above parameters were extracted and integrated with property values using the ArcGIS software. The impact of individual parameters was analyzed using correlation analysis while impact of integrated parameters was analyzed using Principal component analysis (PCA). PCA is a data compression technique which was carried out using SPSS 10.00 in this study.

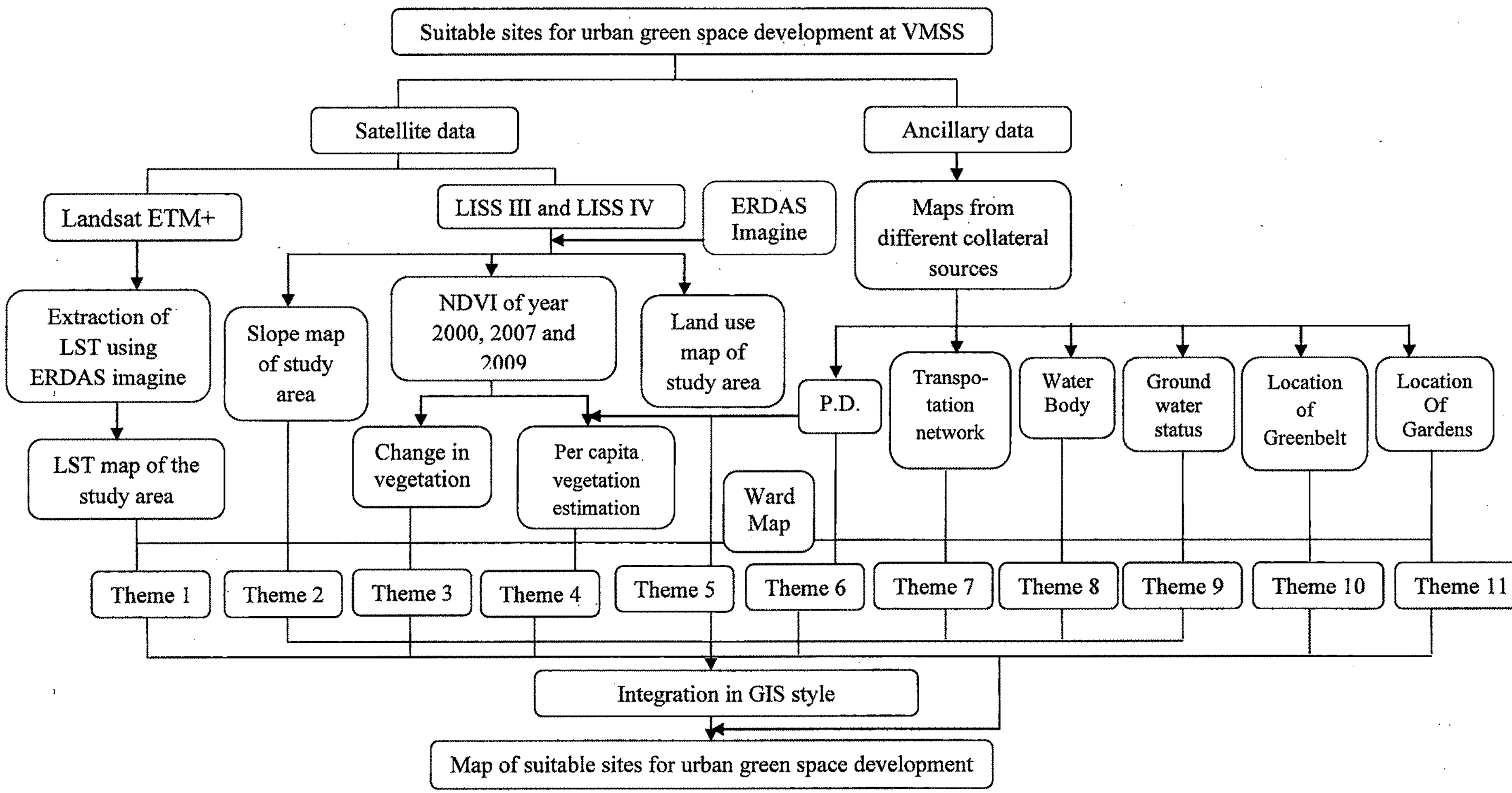

Figure 3: Methodology for identifying potential sites for Urban Green Space development

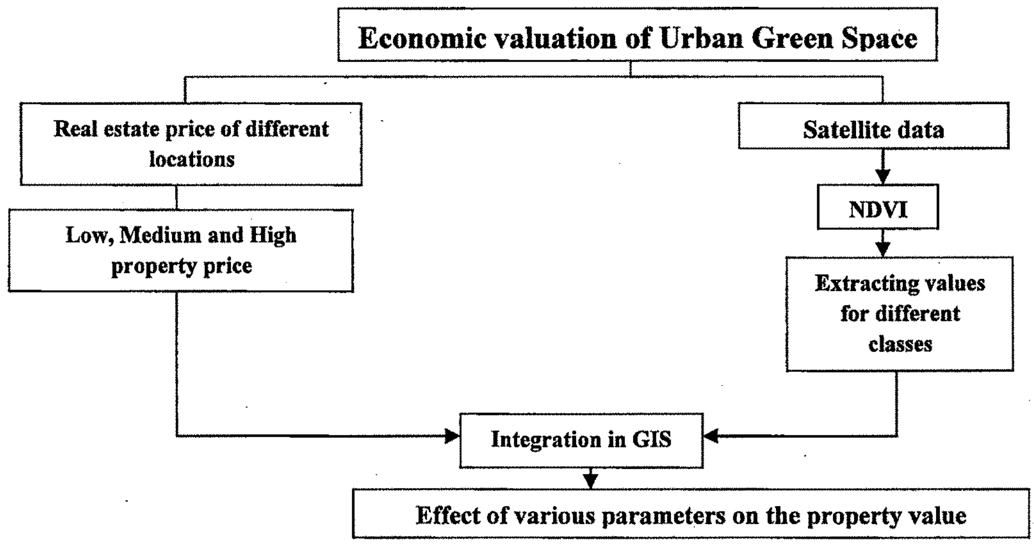

Figure 4: Flowchart showing methodology adopted for Economic valuation of Urban Green Space (UGS)

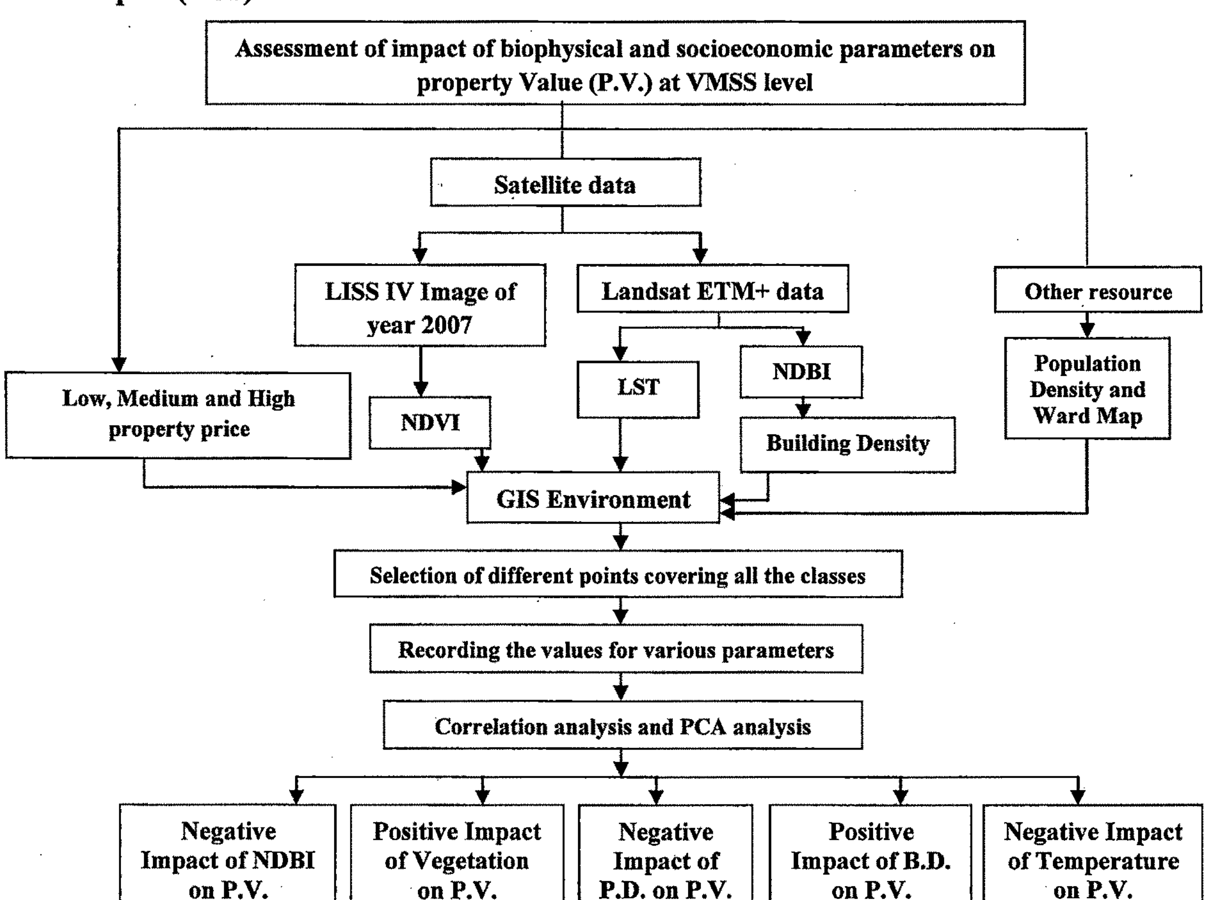

Figure 5: Flowchart showing the methodology adopted for assessment of impact of biophysical and socioeconomic parameters on UGS value

(3.3.4) Methodology followed for Eco-city plan generation:

Three wards comprising the core of the Vadodara city i.e., City Ward, Shiyabaug Ward and Panigate Ward were selected for the Eco-city plan generation. **Figure 6** shows the Flowchart followed for Eco-city plan generation for selected wards. Land suitability analysis was carried out for selected wards using the information utilized for urban green space suitability analysis. This information was integrated in Arcinfo 7.2 based Urban Suitability Analysis Package (USAP) module to get the precise output. This module was having four models depending on preference given to different parameters **(Table 5)**. Ranks were given to different parameters to determine the suitability (**Table 6**). Model No. 4 was considered for the Eco-city plan generation. Output of questionnaire survey carried out for participation of local people was also considered while generating the plan. List of questions are given in Annexure I.

Table 5: Various Suitability models with their preferred parameters

Model	Preferred Parameters	Suitable locations
1	Network and water body	• Area in buffer zone of 50 m around water body and road network is considered not suitable • Area in the buffer zone of 50-100 m is considered as less suitable for the urban development • Area out of this buffer zone is considered as moderately suitable to highly suitable depending upon the distance
2	Slope, Road network and soil depth	• Slope of 0-1% is preferred • Area beyond the buffer zone of 100 m of Road network is preferred more
3	Road network	• Areas along the roadsides are considered as highly suitable
4	Land use	• Land use types like barren land, open space etc. are considered suitable • Land use types like agriculture, vegetation etc. are considered not suitable

Table 6: Ranks given to different categories

Name of the parameter	Categories	Rank
Slope type	**0 – 2 %**	4
	2 – 4 %	3
	4 – 6 %	2
	Above 6 %	1
Water body buffer	**500 and above 500 m**	4
	200 m	3
	100 m	2
	50 m	1
Road buffer	**100 m**	4
	200 m	3
	500 m	2
	Above 500 m	1
Rail Buffer	**2000 m**	2
	5000 m	1
Land use type	**Land with scrub**	4
	Open space	3
	Vegetation, Water body ,Crop land, Vegetation	1
Ground water type	**Built-up**	4
	Moderate	3
	Good to moderate	2
	Good	1

(3.3.5) Methodology for estimation of Air Pollution Tolerance Index (APTI):

The plants which were commonly available in all the wards were selected for the APTI estimation. Ten replicates of fully matured leaves of different plants were collected in the morning (9:00 a.m. to 11:30 a.m.) and immediately taken to the laboratory for the analysis. The Air Pollution Tolerance Index (APTI) was determined by estimating biochemical and biophysical parameters, viz. ascorbic acid, chlorophyll, pH and relative water contents of leaf samples. Ascorbic acid content was estimated using **Roe method (1954)**, Chlorophyll was estimated using **Arnon (1949)** and pH was determined by digital pH meter. Relative water content of leaf material was estimated according to **Ekanayake (1993)** taking the initial weight, turgid weight and dry weight of leaf material. The APTI was calculated using the following formula:

$$APTI = [A (T+P) + R] / 10$$

Where, A= Ascorbic acid (mg/g dry wt.)

T= Total Chlorophyll (mg/g dry wt.)

P= pH of leaf extract.

R= Relative water content of leaf tissue (%).

Gradation of APTI:

The spectrum of APTI was divided as four grades of air pollution tolerance: tolerant (T or grade I), moderately tolerant (MT or grade II), intermediate (I or grade III), and sensitive (S).

The tolerance grades were defined as follows:

(1) Tolerant: APTI > mean APTI+SD;

(2) Moderately tolerant: mean APTI<APTI<mean APTI+SD;

(3) Intermediate: mean APTI-SD<APTI<mean APTI;

(4) Sensitive: APTI < mean APTI-SD.

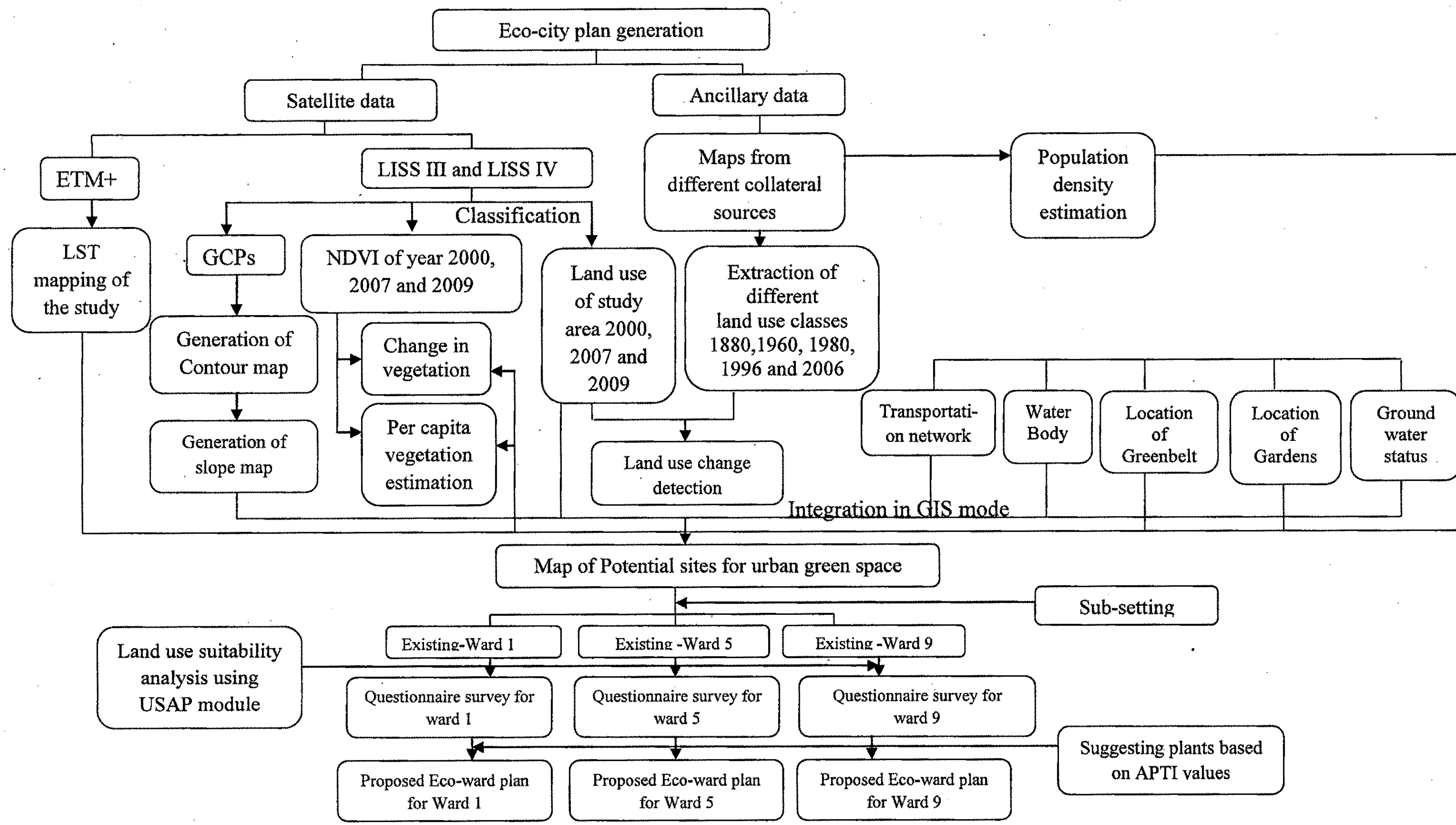

Figure 6: **Flowchart showing methodology adopted for Eco-city plan generation.**