ACTION PLAN MAP DEVELOPMENT USING GIS & AHP: - A CASE STUDY ON SURENDRANAGAR, GUJARAT

Project Report submitted as a requirement for the partial fulfillment of the Degree of Master of Science in Environmental Science

By

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Certificate

This is to certify that the Dissertation Report entitled "**Action Plan Map Development Using GIS & AHP :- A Case Study On Surendranagar, Gujarat"** is an authentic record of the work carried out from 24/01/2020 to 02/04/2020 by **Arjun P R (18PEVS7880),** student of M.Sc. Environmental Science, Centre for Environmental Studies, Dept. of Zoology, Sacred Heart College (Autonomous), Thevara, Kerala under the guidance of **Mr. T.Shanker Prasad** Scientist/Engineer-SF National Remote Sensing Centre, ISRO, Hyderabad, in partial fulfillment of the requirements for the **Master of Scicnce in Environmental Science.**

Hyderabad
03/04/2020

T.Shanker Prasad
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भारतीय अन्तरिक्ष अनुसंधान संगठन **Indian Space Research Organisation**

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CERTIFICATE

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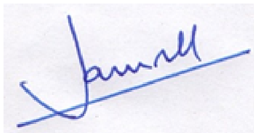

Place: Thevara,
Date: 15/05/20

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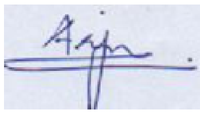
DECLARATION

I, ARJUN P R, hereby declare that the Project work entitled as "**Action Plan Map Development Using GIS & AHP: - A Case Study of Surendranagar, Gujarat** ", submitted to Centre for Environmental Studies, Sacred Heart College (Autonomous), Thevara, in partial fulfillment of the requirements for the award of Master of Science in Environmental Science, is an authentic record of the work done by me to the best of my ability on the basis of available literature under the guidance of **Mr. T.Shanker Prasad Scientist/Engineer-SF** Outreach Facility National Remote Sensing Centre, ISRO Hyderabad and no part of this work has formed the basis for the award of any other degree in any university or published anywhere.



ARJUN P R

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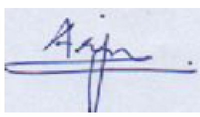
Above all, this piece of work is accomplished with the blessings and powers that work within me and also the people in my life. I bow before GOD for all with a sense of humility and gratitude...........



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ABSTRACT

Land suitability evaluation for plantation, horticulture, and Highrise building construction is carried out in Surendranagar District of Gujarat, India. There are many factors which affect the land suitability assessment like soil, slope, land use, geomorphology, groundwater, and boundaries. All these factors have been assigned weightage obtained from Saaty's method. The land evaluation results of the present study area were classified into four categories of Land suitability (highly suitable, moderately suitable, marginally suitable, and unsuitable) as per Food and Agriculture Organization (FAO). These categories were arrived at by integrating the various layers with corresponding weights in Geographical Information System (GIS) environment. The aim of this study was to determine the present lands in Surendranagar District that will be suitable for plantation, horticulture, and Highrise building constriction using AHP, and GIS-model building methods. At the end of the assessment, it was estimated that part of merely 22% of the study area is suitable. According to Highrise land suitability map, 11.7% are highly suitable for horticulture and for plantation 31% is highly suitable for the study area. Finally, based on the land suitability assessment, action plan map was developed for plantation, horticulture and Highrise building construction for Surendranagar District.

Keywords; land evaluation, land suitability, AHP; analytic hierarchy process, Saaty's methods, GIS model builder

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ABBREVIATIONS AND ACRONYMS

AHP	Analytical Hierarchy Process
CI	Consistency Index
CR	Consistent Ratio
DEM	Digital Elevation Model
EME	Electro-Magnetic Energy
FAO	Food and Agricultural Organization
GDMP	Group Decision Making Process
GIS	Geographical Information System
LSI	Land Suitability Index
LULC	Land Use and Land Cover
MCDA	Multi-Criteria Decision Analysis
MCDM	Multi-Criteria Decision-Making Method
MCE	Multi Criteria Evaluation
MSW	Municipal Solid Waste
NRSC	National Remote Sensing Centre
PGIS	Participatory Geographical Information System
RS	Remote Sensing
TOPSIS	Technique for Order Preference by Similarity to The Ideal Solution
WLC	Weighted Linear Combination

Chapter 1

INTRODUCTION

1.1 Introduction

Geographical information system (GIS) is a set of software tools that is used to input, store, manipulate, analyze and display geographical information. Strategically, GIS may be a philosophy, a way of making decisions within an organization where all information is held centrally and is related by its location. Technological development in computer science has introduced geographic information system (GIS) as an innovative tool in landfill process. GIS combines spatial data (maps, aerial photographs, satellite images) with the other quantitative, qualitative and descriptive information databases. GIS also has georeferencing tool for rectification of inputted data with reference to real world coordinates. It accepts both raster and vector data and also has conversion tools for converting raster to vector and vector to raster formats. It also has some statistical analysis tools, network analysis tools, tracking analysis tools, editing tools, geocoding tools etc. It also has 3D tools for preparation of 3D maps.

Remote sensing (RS) is one of the excellent tools for inventory and analysis of environment and its resources, owing to its unique ability of providing the synoptic view of a large area of the earth's surfaces and its capacity of repetitive coverage. Its multispectral capability provides appropriate contrast between various natural features where as its repetitive coverage provides information on the dynamic changes taking place over the earth surface and the natural environment. The main objective of remote sensing is to measure the Electro-Magnetic Energy (EME) coming from the sun and which is reflected, scattered or emitted by the surface features. Remote sensing (RS) data techniques and Geographical information system (GIS) provide efficient methods for analysis of land suitability study.

Food and Agricultural organization (FAO, 1976) defined a well-known method for land suitability analysis by considering various parameters. The various parameters like land use/land cover, soil texture, slope, soil pH, soil salinity, soil depth, drainage, groundwater quality and soil nutrients[nitrogen(N),phosphorus(P),and potassium(K)] Geographical Information System (GIS) is a useful tool for effective the mapping of land suitability and evaluation (Collins et al., 2001). Using GIS tools, it is possible produce one thematic map (crop land suitability map) by overlaying thematic map of various parameters taken into consideration (Rossiter, 1996). In this study, Multi-Criteria Decision-Making Method (MCDM) is incorporated due to inclusion of various suitability parameters. As various parameters are involved in present study and each parameter should be weighted based on their relative importance. The weightage analysis has been integrated in the GIS technology producing an accurate and reliable crop land suitability map. The integration of GIS, remote sensing and Multi Criteria Evaluation (MCE) can be termed as Spatial MCDM.

Land use suitability analysis is the process of determining the suitability of a given land area for a certain type of use (agriculture, forest, recreation, etc.) and the level of suitability. An important part of this process is the determination of the criteria that affect the suitability of the land (Al-Shalabi et al., 2006). The presence of various and multiple criteria makes land use suitability analysis increasingly complex because, to support the long-term use of a piece of land without deterioration, criteria such as the socio-economic and environmental costs and consequences must be taken into consideration in addition to the inherent properties of that unit of land (Duc, 2006; Bandyopadhyay et al., 2009).

Surendranagar is an administrative district in Saurashtra region of Gujarat state. It is a peninsular region of Gujarat, India, located on the Arabian Sea coast. It covers about a third of Gujarat state, notably 11 districts of Gujarat. According to the census of India, for the year 2011, Surendranagar had a population of 1,756,268. Rapid urbanization and industrialization are lead towards population growth. From the beginning of civilization man has used the land resources to satisfy his needs. The land resources regeneration is very slow while the population growth is very fast, leading to unbalance. Hence in this study I attempted to generate an Action Plan Map by the evaluating Suitable site for Highrise-building, Horticulture and Plantation purpose.

In this study, the site selection for Highrise-building, Horticulture and plantation in Surendranagar District used geographical information system (GIS) and multi-criteria decision analysis (MCDA).The thematic layers of soil, land use, geomorphology, ground water and slope were considered as primary criteria and weights for criteria, and sub-criteria were assigned by MCDA analysis. The multi criteria decision analysis (MCDA) is an analytical hierarchy process (AHP) which is developed by SAATY. This technique provides a mention of decomposing the criteria into sub-criteria that can be hierarchically ranked on a numerical scale (1-9). The MCDA technique integrated with GIS provides qualitative and quantitative results compared to that of the simple weighted average techniques.

1.2 Guideline of FAO

The land suitability evaluation carried out by various workers according to the guidelines of Food and Agricultural organization (FAO, 1976). This guideline has procedures to evaluate the suitability of land for intended land use. In these guidelines, the quality of land is defined in the form of order or class in terms of their suitability. Mostly, land suitability classes are characterized as suitable (S) to not suitable (N). If three Classes are recognized within the Order Suitable, (Class S1, S2, S3)

Class S1 Highly Suitable; Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

Class S2 Moderately Suitable: Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.

Class S3 Marginally Suitable: Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.

Within the Order Not Suitable, there are normally two Classes:

Class N1 Currently Not Suitable; Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner

Class N2 Permanently Not Suitable; Land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner

1.3 Aim & Objective

The study aims to identify the Suitable site for Highrise-building, Horticulture and plantation in the Surendranagar District. The study area consisting 10talus and 654 villages in the surrounding. A major portion of the district is drought prone. This district is essentially an underdeveloped district having diverse terrain conditions and varied but limited endowments of nature.

1.3.1 Objective of the project

- To develop the suitable site for Highrise-building
- To develop the suitable site for Horticulture
- To develop the suitable site for plantation

Chapter 2

REVIEW OF LITERATURE

Z Hassan et al., (2017) carried out a research on the site selection for Solar PV power Plant in Saudi Arabia using Geographic information System (GIS) and Analytical Hierarch Process (AHP)- Multi Criteria Decision Analysis (MCDA).The criteria for site selection are Solar irradiation, Air temperature, Slope, Land aspect, proximity to urban, proximity to highways, proximity to power and weights for criteria and Sub criteria were assigned MCDA analysis. The model considers different aspects, such as economic and technical factors, with the goal of assuring maximum power achievement while minimizing project cost. An analytical hierarchy process (AHP) is applied to weigh the criteria and compute a land suitability index (LSI) to evaluate potential sites. The LSI model groups sites into five categories: "least suitable," "marginally suitable," "moderately suitable," "highly suitable" and "most suitable."

Bagheri et al., (2013) identified suitable land site for building hotels in the coastal areas of Terengganu in Malaysia. The aim of this study is to demonstrate how GIS tools and AHP model can be used for integrated coastal resource planning and management. The thematic layer of Build-up, land cover, river, slope, and road were considered as primary criteria and weights for criteria, and sub-criteria were assigned by MCDA analysis. The methods used to combine attribute scores with weights or preferences that should be used in the process of weight value calculations, so it avoided some subjective ideas affecting the results and combine the quantitative and qualitative methods. As a result, it can be concluded that the land-use suitability assessment for setting up hotels in coastal areas. These efforts will help the government to find a suitable area for future urban development by effectually using limited land resources

Dadhich et al., (2017) carried out a suitable study on the Agriculture land suitability evaluation for wheat cultivation using Geomatic and Geographical Information System (GIS) in the Patan

District of North Gujarat, India. The major factors considered for studies are land use, land cover, soil texture, slope, soil pH, soil salinity, soil sodicity, soil depth, soil drainage, groundwater quality and soil nutrients [nitrogen (N), phosphorous (P), potassium (K)]. These factors were ranked based on FAO land evaluation system using (FAO, 1976) guidelines. Weight for each and every parameter is derived from AHP process. In this study relative importance of each and every parameter is considered by determining weightage factor using Saaty's method and based on weight derived from Saaty's method, final suitability map is derived in GIS environment. The results of the present study area were classified into four categories are highly suitable, moderately suitable, marginally suitable, and unsuitable as per Food and Agriculture Organization (FAO). These Study to help the decision makers, farmers as well as agricultural development planners. The Study aimed to achieving best utilization of the available and limited land resources.

Chaudhary et al., (2016) Study has been carried out by using a combination of geographic information system (GIS) and Analytical hierarch process (AHP). It was used to determine the suitable fire site selection in Kathmandu Metropolitan City, Nepal. In present study documented the fire station suitability zonation mapping in Kathmandu Metropolitan City using Group Decision Making Process (GDMP) in the GIS interface. The selection parameters are distance from roads, land cover, distance from rivers and population density were considered for the analysis. Each parameter was evaluated by rating methods. In the next step the relative importance of parameters to each other was determined by AHP. The results Shows only 13.46% of the study area is highly suitable for fire station location. fire station suitability zonation map can be used for the construction of new fire stations in Kathmandu Metropolitan City.

Turgut et al., (2013) investigated most suitable site was to determine the lands for agricultural use in the Yusufeli district of Artvin city, Turkey. The parameters of great soil group, land use capability class, land use capability sub-class, soil depth, slope, aspect, elevation, erosion degree and other soil properties were used by Analytic Hierarchy Process (AHP). The weight of each parameter assigned by expert opinion. The aim of this study was to determine the present agricultural lands in Yusufeli district that will be left under the reservoirs of the Artvin, Yusufeli and Deriner Dams and to find alternative areas suitable for agriculture using GIS and AHP methods. At the end of the assessment, it was estimated that part of merely 8% of the study area is suitable According to Agriculture land suitability map, the study area classified to five categories; highly suitable, moderate suitable, marginally suitable, less suitable and unsuitable areas.

Pramanik (2016) a potential agricultural site for Darjeeling district in the state of West Bengal was determined by using Geographic Information System (GIS) and Multi-criteria Decision Analysis (MCDA). The Weights of criteria are Slope, Elevation, LULC, Soil moisture, Distance from river, Soil Characteristics, Geology, Aspect, Distance from road were considered for Analytical Hierarch Process (AHP). Land suitability analysis can help to establish the strategies for the development of agricultural productivity. AHP with the integration of GIS-based multi-criterion decision making an approach using DEM and Landsat 8 satellite data was utilized to evaluate land suitability for agriculture production in hilly areas. According to Agriculture land suitability map, the study area classified to four categories; highly suitable, moderate suitable, marginally suitable and unsuitable areas.

An attempt was made by Yigiter et al., (2010) suggest the Suitable site for the most earthquake prone provinces of Adana Turkey, were determined by the use of an analytical hierarchical process (AHP) and GSI. In the Study contained six land use categories of Adana are high rise blocks, multi storey buildings, low storey buildings, industrial sites, waste disposal sites and green land based upon geo environmental criteria. In this study, the judgment related to the influence of each geo-environmental criterion on each land use category was made by consulting experts. Weight for each and every parameter is derived from AHP process. In this study relative importance of each and every parameter is considered by determining weightage factor using Saaty's method and based on weight derived from Saaty's method, final suitability map is derived in GIS environment

Uyan (2013) identified suitable selection for solar farm using analytic hierarchy process (AHP) and GIS in Karapinar region, Konya, Turkey. Multi criteria evaluation methods are often used for different site selection studies. Site selection for solar farms is a critical issue for large investments because of quality of terrain, local weathering factors, proximity to high transmission capacity lines, agricultural facilities and environmental conservation issues. Environmental and economic factors were all together considered in the computation process including five criteria categorized in two factors. Final suitability map was created for combined all criteria. This study can offer a methodology and decision support to the decision maker for solving the solar farms site selection.

Sarkar et al., (2006) used GIS and RS application to study Soil resource appraisal towards land use planning in *Patloinala* micro-watershed of Puruliya district, West Bengal, India. The Visual interpretation of IRS ID LISS-III fused with PAN data (1:12,500 scale) was carried out for delineating the physiographic units based on the variations in image characteristics. The major physiographic units identified were upland *(Tanr)*, medium land *(Baid)*, and low land *(Bahal* and *Kanali)*. On the basis of physiographic variation and soil or soil site characteristics such as texture, depth, slope, erosion etc. the problem areas were identified and land use plan has been suggested for the overall development of the micro-watershed. The study concentrates on the cadastral level of Puruliya district. With the help of visual interpretation of False color composite (FCC) images generated from spectral bands2, 3, and 4(blue, green, and red band) in conjunction with detailed ground truth data, eight physiographic units were delineated and mapped. The study to describe physiographic boundaries within the micro-watershed, the results demonstrated that major problem occur in the physiographic region (upland, medium land, and low land).

A Set of GIS map layers used by Julie Sweitzer et al., (1996) to delineate the information on the current landscape characteristics and population distribution patterns in the drainage basin of the Baltic Sea. There are seven map layers included in the database: Land Cover, Drainage Basin, Administrative Units, Population Distribution, Arable Lands, Pasture Lands, and Wetlands. The results relating the distribution of land cover and population as a function of distance from the coast. A Few years ago, an environmental action plan was launched by using this database, the purpose to "assure the ecological restoration of the Baltic Sea" emphasizing the reduction of Nutrient pollution.

Mahamid, Thawaba et al., (2010), A potential site for an appropriate landfill area for Ramallah (Ramallah is a Palestinian city) was determined by using Geographic Information System (GIS) and Multi Criteria Decision Analysis (MCDA). A potential site was allocated taking into consideration of the sensitive areas and found the best location for the regional landfill site. The site was selected with an area of 0.0102 sq.km which is located near Dir-Dibwan village with low to very low vulnerability which gives a high ability to prevent leachate comes from waste to reach ground water, also the site is located in clayey area that has less permeability, with a slope less than 5% that will prevent any pollutant to be mixed with drainage water

Floods are a regular feature in Greater Dhaka, the capital of Bangladesh during the monsoon season. Ashraf M et al., (2007) to Evaluating Flood Hazard for Land-Use Planning in Greater Dhaka of Bangladesh Using Remote Sensing and GIS Techniques. The objective is to asses flood hazard in Greater Dhaka for the historical flood event of 1998 using Synthetic Aperture Radar (SAR) data with GIS data. Flood-affected frequency and flood depth calculated from the multi-date SAR imageries were used as hydrologic parameters. Elevation heights, land cover classification, geomorphic division and drainage network data generated from optical remote sensing and analogue maps were used through GIS approach. Flood hazard maps by considering the interactive effect of land cover, elevation, and geomorphic units for flood affected frequency and floodwater depth were constructed. The hazard maps showed that a major portion of Dhaka were within moderate to very high hazard zone, especially fringe areas. It observed increasing population pressure is forcing many people to enter the vacant land of the City by filling up of natural channels and floodplains. Consequently, flood risk is increasing. In order to ameliorate flood induced damage, the developed flood hazard map would be invaluable. Government can use hazard maps for ensuring the proper development planning of the very high and high hazard zones which is supposed to be urbanized by the year 2010. The study will provide information about flood protection measure such as construction and development of infrastructure and preparedness of aid and relief operation for high hazard areas for future flood event.

Sumathi et al., (2007) carried out a suitability study on the potential landfill in the Pondicherry region using a Multi-criteria Decision Analysis (MCDA) and overlay analysis using a Geographic Information System (GIS).Water supply resources, sensitive sites, land use, air quality, groundwater quality and geology are the several factors considered in the siting process. Depending upon their relative importance, the weightings were assigned to each criterion. A set of 17 potential sites was identified in the first level of analysis while subsequent screening and refinement on the basis of existing microscopic factors led to the optimized selection of the 3 most suitable sites for landfill construction. The sites were ranked on the basis of area availability. Sites1,5, and 13 covering area of 0.36 km2, 0.11km2 and 0.06 km2 respectively, were chosen as the suitable landfill construction

An attempt was made by Anika k *et al., (*2007) to suggest the alternative sustainable land use options in a watershed using GIS. This study to consider the present land use/ land cover, soils, slope and geomorphology. It deals with different perspective of watershed management such as alternative sustainable land uses based on soil and water conservation measures, groundwater prospects, land capability, and present land use/land cover in the area. The approach is ensuring stoppage of further degradation of the resources through appropriate soil conservation measures and land uses. The land use planning study area in Andhra Pradesh represents the status of the entire Deccan trap of the semiarid India. In the present study, one such micro watershed near Hyderabad was used for proposing alternate land use options. Soil and water conservation Map, Ground water Map, Land use/Land cover Map and Land capability Maps are integrated for generating alternate sustainable land use options map.

Ajay et al., (2014), a potential landfill site for Aurangabad city in State of Maharashtra was determined by using Geographic Information System (GIS) and Multi-criteria Decision Analysis (MCDA). It is found that resident of city area protesting against dumping of garbage. They are facing serious health issues because water pollution and foul smell. Another believed that, identifying a new site very critical using traditional way for dumping of solid waste. A rule -based identification of new site is done using a RS-GIS which saved time and increase accuracy. For suitability study required data was collected from the survey of India and NRSC Hyderabad. A spatial feature extraction was done using for reserved forest area, water bodies, canals, drainage network and road and railway network. Rasterization process were applied on top sheet to extract settlement area. For every spatial feature a buffer zone was created as per guideline given by the ministry of environment, India. After this process a one by one overlay analysis was performed. Seven sites which follow the guidelines and having more than 100 Acres area were selected for field visit.

By combining RS and GIS information with adequate field data Rokande et al., (2004) carried out a study along the Chandrapur district, Maharashtra, India. The water resources development action plan sasti watershed been interpreted by RS data to identify and outline various ground features such as geological structures, geomorphic features and their hydraulic characters. It provide unbiased information on geology, geomorphology, structural pattern and recharging conditions, which logically define the groundwater regime and help to generate water resources development action plan. The Study area is divided into four groundwater potential zones (Very High, High, Moderate and Low). In the watershed zones of different exploitation structures have been delineated by generating GIS model for borewell, normal dug well, large diameter dug well and dug-cure-bore well. Recharge structures like percolation tanks, check dams and roof top rainwater harvesting and runoff rainwater harvesting are also suggested in area to improve the groundwater conditions.

Narsimha Rao et al., (2018), carried out the study on selecting a potential landfill site for Guntur Municipal Corporation, Andhra Pradesh using Geographic Information System (GIS) and Multi-criteria Decision Analysis (MCDA). Geographically designed and based thematic layers such as land use land cover, geology, geomorphology, soil type, slope characteristics were considered in the suitability process. For site selection and mapping of solid waste disposal site eight criteria were taken and analyzed, and analysis is carried based on Multi-Criterion Decision Analysis. The map is reclassified into three classifications as Suitable (115552 m^2) and moderately suitable (11521600 m^2) and not suitable (10296734.61 m^2)

Shailendra Raj and Avadhesh kumar koshal (2012) to demonstrated the usefulness of GIS technology in conjunction with Remote Sensing for site-specific farming area. Satellite Data-IRS P6-LISS III and LISS IV, Resource Sat, Carto Sat and other latest data used for site-specific area mapping. Image Processing Software's are ERDAS Imagine, Geomantic & MGE workstation and GIS software's are ARC GIS, Map info, Arc View & ILWIS used for analysis of remote sensing data. Collateral Data used for GIS analysis-topographic map, cadastral map geology map, soil map, rainfall map. Visual and digital interpretation methods were used to prepare pre-field interpreted map. The satellite data is interpreted based on photo elements like tone, texture, size, shape, pattern, aspect, association etc. These pre-field interpreted maps and digitally enhanced satellite data are used on the ground to identify different elements of various themes. The action plan report can be created using the Geodatabase and total decision support system can be developed to depict location and type of action / control measures recommended for management and developmental plan of site specific area

Aksoy et al., (2019) identifies suitable land sites for a 35-year period using a Geographical Information System (GIS) with Multi-Criteria Decision Analysis (MCDA). To assess the proposed approach, the city of Antalya was chosen for study, being the city with the highest population growth in Turkey. Twelve available parameters i.e. digital elevation model, aspect, slope, temperature, precipitation, earthquake zone, distance to fault lines, prepared through a series of GIS analysis, were used to carry out a landfill site selection. The weights of the parameters were obtained from a constructed Analytical Hierarch process (AHP) matrix, and the consistency index and the consistency ratio recorded as 0.091 and 0.062, respectively.

Protection Zones were considered and omitted for potential landfill. The analysis revealed a number of potential landfill sites. Furthermore, the volume of solid waste for the next 35-year period was calculated using dynamic population data and possible candidate sites for landfill were generated.

NadaliAlavi & Goudarzi et al., (2013), Study has been carried out by using a combination of geographic information system (GIS) and Analytical hierarch process (AHP). It was used to determine the best site for disposal of municipal solid waste (MSW) in Mahshahr County, Iran. In order to decision making for landfill siting a structural hierarch formed and the most important criteria: surface water, sensitive ecosystems, land cover, urban and rural areas, land uses, distance to road, slope, and land type where chosen according to standards and regulations of Iran. Each criterion was evaluated by rating methods. In the next step the relative importance of criteria to each other was determined by AHP. Land suitability for landfill was evaluated by simple additive weighting method. According to landfill suitability map, the study area classified to four categories; high, moderate, low and very low suitability areas

Mcconchie and Mckinnon (2002) estimated Community-Based Maps to promote collaborative natural Resource Management. The study was carried out Luchun County, Yunnan in southwest China. It explores the use of MIGIS for community-Based planning which integrates the technique of Participatory Learning Action or PLA and Mobile Interactive GIS. The techniques used in China to empower a negotiated, bottom up approach to developing an understanding and mitigation strategy that limits the continued clearance of native and regenerating forest for firewood there by further diminishing biodiversity. The results integrated georeferenced digital data allowed the testing of various future management scenarios. For example, the establishment and protection of riparian forest zones along streams is critical to sustainable environmental management and ecosystem security. Slope erosion processes are supplying large amounts of debris to the stream channels that are rapidly aggrading and covering the most productive paddy with coarse gravel.

Suman et al., (2012) investigated most suitable site, as a waste disposal sites for Nabadwip Municipality which is located in the extreme west of Nadia district, West Bengal. A suitable disposal site must follow environmental safety criteria and attributes that will enable the wastes to be isolated so that there is no unacceptable risk to people or the environment. Criteria for site selection included natural physical characteristics as social, land-use, ecological and economic factors. Geographical Information System (GIS) has provided an opportunity to integrate field parameters with population and other relevant data. Multi-criteria decision analysis was used in the selection of suitable disposal sites for dumping of solid waste.

Kapilan et al., (2018), carried out the research on the site selection for urban solid waste disposal in the Coimbatore district using Geographic information System (GIS) and Analytical Hierarch Process (AHP)- Multi Criteria Decision Analysis (MCDA). Thematic layers of lineament density, Land Use and Land Cover, population density, groundwater depth, drainage density, Slope, Soil texture, geology and geomorphology were considered as primary criteria and weights for criteria, and sub-criteria were assigned by MCDA analysis. The weight score was validated by consistency so that the efficiency of the selected criteria was justified. The overlay analysis in GIS environment provides 17 potential zone in Coimbatore district, among which, four suitable sites were screened and refined with the help of field investigation and visual interpretation of satellite image.

The forest land forms and boundary changes of Nepal was studied by Shrestha (2006) with the aid of GPS and GIS using in a participatory mapping of community forest in Nepal. This study is a combination of two sets of works carried-out in collaboration with Forest Action in Two FUGs i.e. Baisakheswori Community FUG (Dolakha) and Sundari Community FUG (Nawalparasi). The work supports ongoing research efforts on “Developing Methodologies for Sustainable Harvesting of Medicinal Plants in Nepal”. The work were carried-out five kid of Mapping techniques ,such as Sketch mapping, application of Orthophoto, GPS mapping, Cadastral survey and Chain and Compass survey. The use of Participatory GIS (PGIS) in the field of community forest management combines the collection of both quantitative (more objective) and qualitative (more subjective) information. These include mapping boundaries of the forest, block division of the forest area, preparing the resource map, locating social as well as peripheral components in mapping the context of community and forest development. The application of Participatory GIS is a fundamental tool in visualizing the spatial contexts of community forests in NEPAL.

Jaiswal et al., (2018) carried out the study to find the problem of urban municipal solid waste disposal is challenging task faced by civic bodies and planning authorities in almost all the cities of rapidly developing countries like India. Researcher made an attempt to find out the suitable sites for waste disposal in the area around Dehradun city using Geospatial Multi-criteria Decision Analysis (MCDA) techniques from remote sensing data. Two different decision rules of MCDA are used, namely, Analytical Hierarchical process based Weighted Linear Combination (AHP-WLC) and Technique for order preference by Similarity to the Ideal Solution (TOPSIS). Raster based suitability analysis has been done and the result obtained by the two methods are compared. Identical results with minor differences identifying best suitable sites outside the eastern boundary of the city where existing dumping site is located are obtained.

Hanbali et al., (2011) carried out a study on urban expansion and selected optimum solid waste disposal sites within Mafraq City using GIS based weighted linear combination.1989,1999 and 2009 Landsat data were used to support the selection process of disposal sites. A GIS combines the spatial data namely maps, aerial photographs, and satellite images with qualitative, quantitative and descriptive information databases. Weighted Linear Combination (WLC) is one of the widely used MCDA methods for land suitability analysis. Final resulted area classified into most suitable, moderately suitable, poorly suitable and unsuitable classes for landfill sites sitting

Pandey et al., (2010) developed a soil and water conservation structure map of a small agricultural watershed of Karso, Hazaribagh, India using remote sensing and GIS techniques. The existing maps and field observation data have been utilized for generating a land use/land cover map, distinctive topical layers. The thematic parameter was further useful decision-making process for watershed development and management and also for watershed prioritization. Morphological parameters of sub watersheds were derived to understand its usefulness for surface water development. The remote sensing and GIS tools provide the appropriate platform for convergent analysis of large volume of multidisciplinary data and decision making for development of watershed development plan. The limitations of detailed field survey can be reduced with the help of high spatial resolution satellite data and finer scale of mapping for different thematic layers. The methodology developed can be applied to similar terrain conditions, with some local considerations and modifications.

Mangrule et al., (2013) used recent technologies like remote sensing and GIS to develop an action plan for watershed management in Khultabad Taluka of Aurangabad District. The aim of management plan is the process of is the process of creating and implementing plans, programs, and projects to sustain and increase watershed functions that affect the plants, animal and human communities inside watershed boundary. In the study generate optimum utilization of existing natural resources like land, vegetation and water in watershed. The main objective of the present study is to generate information/databases on 1:25,000 scale pertaining to hydro geomorphology, Drainage, surface water bodies, watershed, transport network etc. using multi-temporal satellite data. The study recommended that water harvesting should be given importance to avoid the wastage of rainwater from the watershed. This will also increase the groundwater recharge and vegetative cover to control soil erosion, various action plans like construction of recharge structures, afforestation etc. have been proposed

Chapter 3

MATERIALS AND METHODOLOGY

3.1 Study Area

Surendranagar District is located in the north western part of Saurashtra Peninsula of Gujarat State. The Rann of Kachchh towards north, the vast low-lying alluvial tract plains of North Gujarat towards east and uplands of the central Saurashtra towards and south and west encircle the district. The district covers an area of 10,489 Sq.km and falls in the Survey of India Degree sheets 41N and 41M, between North latitudes 22° 8‘and 23° 3‘and East longitudes 70° 58‘and 72° 12‘shown in Fig 3.1.The district has 651 villages and 11 towns (populations greater than 1, 00,000) spread over 10 talukas, namely Wadhwan, Limbdi, Dasada, Dhranghadhra, Chotila, Chuli, Halvad Muli, Sayla and Lakhtar.

The district has common boundaries with five other district of Gujarat States. The District is surrounded by Katch’s Desert & Mehsana District in North, Ahmedabad and Bhavnagar District in South & West respectively Rajkot District. The people of this district are mainly dependent on rain water for cultivation as the irrigation potential developed so far is very limited. The district has subtropical climates. It is hot during summer and cold in winter. It receives rains 760mm to 967mm during the year. Since the agriculture which depends on rains water gets drought in alternate year. The district has significant minerals wealth. The important minerals are Fire clay, Silica sand, Black stone, Sand stone etc. and the district has covers forest area of 531.08 sq. km.

The normal climate of the district is temperate with moderate proportion of heat and cold. There are three main seasons. Wadhwan, Muli, Chotila,Thangadh & Sayla Talukas fall in Agro Climatic Zone-7, Dhrangadhra and Dasada Talukas fall in Agro Climatic Zone-8 and the Bhal and coastal areas fall under Agro climatic Zone-6, it is characterized as semiarid climate. The whole district was drought prone area. Hence the present work is done for the suitable site analysis for planation, horticulture and highrise-building purpose. GIS play a vital role for Land suitability analysis. Using this tool to analyze the thematic layer of soil, slope, groundwater, geomorphology and landuse and it generate an action plan map for the suitable location.

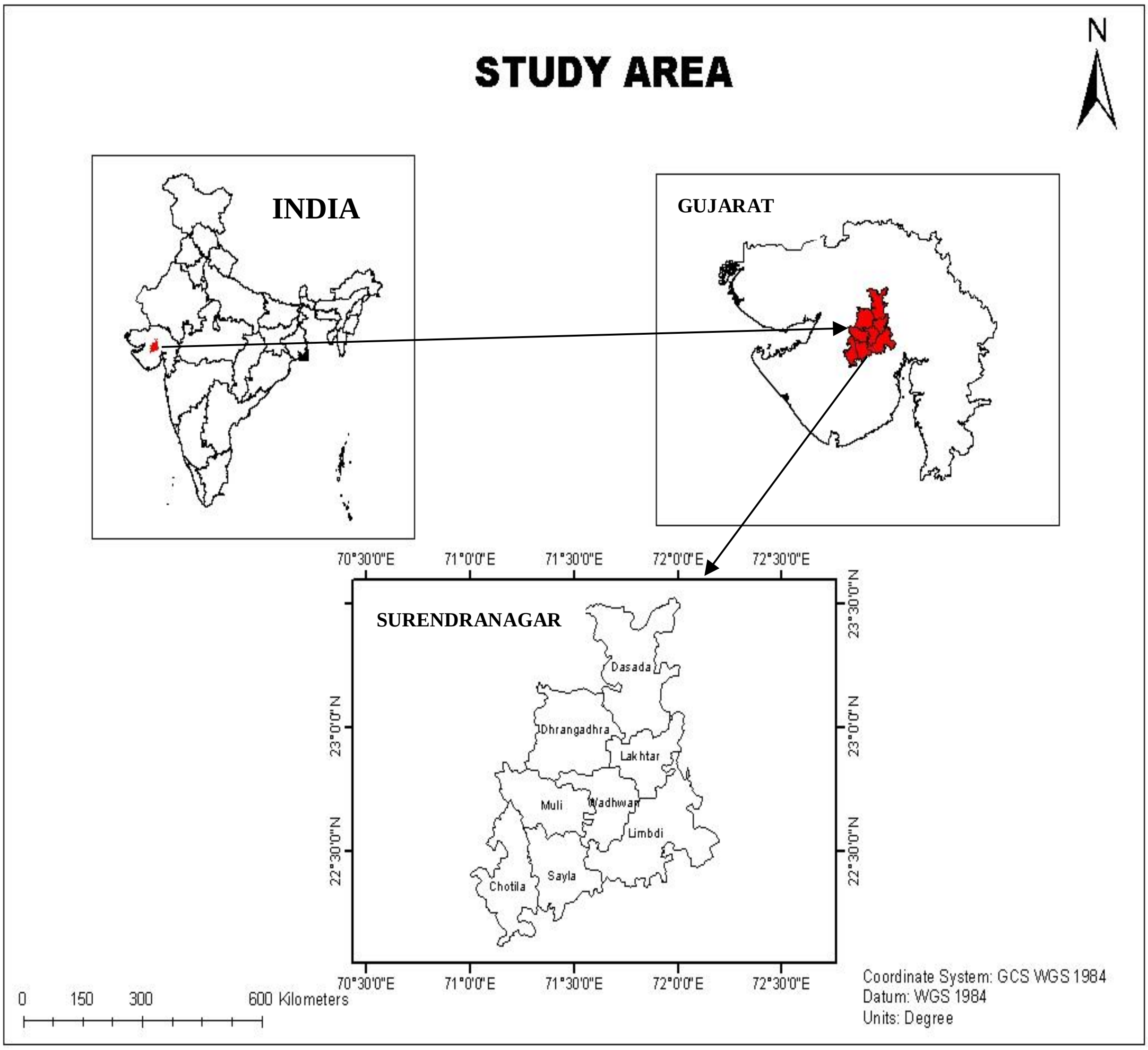

Fig 3.1: Location Map of Study area

3.2 Data source

Data includes slope, geomorphology, soil, groundwater, land use and boundary maps sourced from concern department of National Remote Sensing Centre (NRSC). The ArcGIS 10.6.1 software was used for the generation of thematic maps, weighted overly analysis and preparation of final sites suitability maps. The interpretations and calculations for multi-criteria evaluation rules totally depend on the selected parameters. There is no well-defined technique or rule for selection of parameters affecting suitable site selection analysis. The selection of parameters varies from place to place for different area. In this study, criteria variables are selected based on literature review, expert opinion and internet source

3.3 Tool Used

- ArcGIS 10.6.1
- Microsoft Excel

3.4 Methodology

Methodology in this strategy includes thematic map generation, assigning weight factor, weighted overlay analysis by analytical hierarch process (AHP)-Multi-Criteria Decision Analysis (MCDA), site identification and model building ArcGIS software. The schematic description of methodological framework is presented in Fig 3.2. In present study, six thematic layers namely, geomorphology, soil, slope, groundwater, land use and boundary used AHP-MCDA.

All the base maps were reclassified according to the rank of the parameter in all layers. The suitable site for plantation, horticulture and Highrise-building were obtained by overlaying all the thematic maps in weighted overlay analysis method using spatial analyst tool in ArcGIS. During Weighted overlay analysis, the percentage weights were given to all individual parameters of each thematic map, and weights were assigned according to paired wise consistent AHP matrix. Weighted overlay analysis along with restricted layers gives output as an action plan of suitable site for plantation, horticulture and Highrise-building area which further evaluating with threshold criteria on the basis of score and area. The output map is generated using union tool according to the suitable, moderately suitable, highly suitable and not suitable criteria method

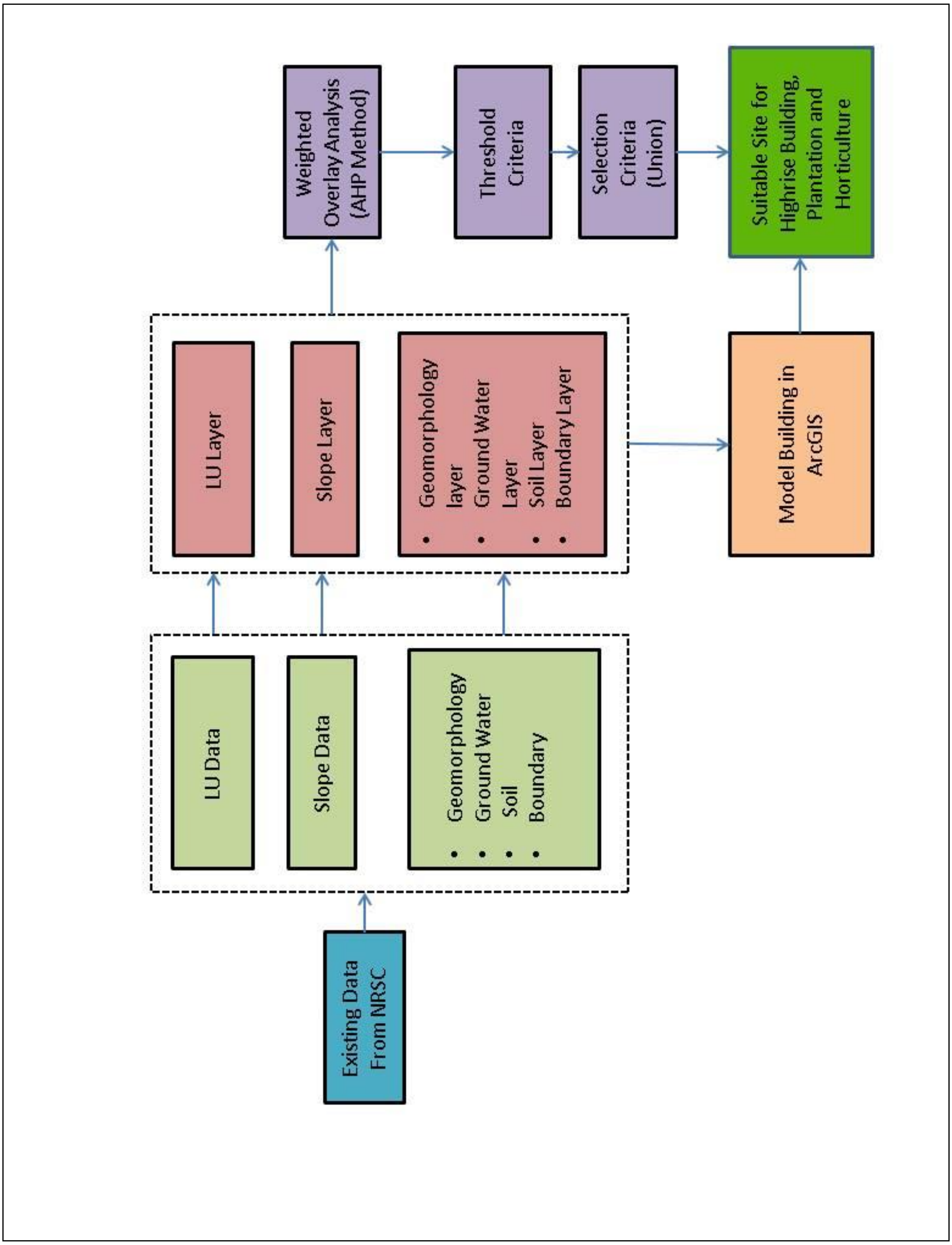

Fig. 3.2 : Schematic Flow Chart for Methodology

3.5 GIS based MCDA for Suitability score

In this study, weighted overlay technique has been used for suitable site selection for plantation, horticulture, and Highrise-building area. Weight for each and every parameter is derived from Analytical Hierarchy Process (AHP). The AHP is a multi-criteria decision-making method introduced by Saaty (1977). The AHP method allows users to find out the weightage of the factors in the solution of a multi-criteria problem. Weightages are derived based on the input by the user in terms of relative importance of criteria. Pairwise comparison for different criteria is carried out e.g. how important is criteria 'A' with respect to criteria 'B', 'C', 'D' etc. (Baniya, 2008). The comparisons are measured on a ratio scale. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measurements of the alternatives in terms of each individual decision criterion.

The GIS–multi criteria decision analysis is a decision making process that transforms the geographical data into the hierarchical network based on the importance of criteria and its sub-criteria. The methodology of the GIS–MCDA contains the following processes. At first, the most important parameters (criteria) are assigned for the problem. The evaluation factors used to address the suitability of the land evaluation in the study area were soil, slope, geomorphology; ground water and land use factors were ranked based on SAATY Scale. The parameters are converted into thematic layers for decision-making using analytic hierarchy process (AHP).The score for each criterion and its sub-criteria is fixed based on relative importance to each other as well as guidelines of existing research publications (Table 3.1) .The rating of the scale is assigned on a 9 point continuous scale (9, 8, 7, 6, 5, 4, 3, 2, 1, 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9). If the factor value is on the left side of 1, comparison matrix constituted with actual value otherwise constituted with reciprocal value. The score 9 for the most important and 1 for equal importance whereas 1/9 represents the least important. The normalization matrix method is used to calculate priority vector (weight) of each criterion and its sub-criteria. The value of each cell in the matrix is constituted by score value of the comparison matrix divided by the column total.

Table 3.1: SAATY's Scale of importance intensities

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two parameters contribute equally to the objective
3	Moderate Importance	Experience and judgment slightly favor one parameter over another.
5	Strong Importance	Experience and judgment slightly favor one parameter over another.
7	Very strong Importance	A parameter is Strongly favored and its dominance is demonstrated in practice
9	Extreme Importance	The evidence Favoring one parameter over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two	When compromise is needed

Table 3.2: Suitability scores for Highrise-building:

Sr.No	Name of Thematic Criteria	Criteria Guideline (Ref)	Class with respect to present Study Area	Suitability Score (1-less preferred, 9-extremely preferred)
1	Landuse	15,26	Build up Grass Wet Waste land	1 3 7 9
2	Soil	14,9	Coarse Loamy Fine Loamy Skeletal Sandy Fine loamy	1 2 5 7 9
3	Groundwater	27,28	Good Good but saline Poor Moderate to poor Moderate	1 2 3 4 7
4	Geomorphology	30,32	Eolian Flood plain Pedi plain Plateau	1 4 6 9
5	Slope	33,34	10-15% 5-10% 3-5% 1-3% 0-1%	1 1 5 6 9

Table 3.3: Suitability scores for Plantation:

Sr.No	Name of Thematic Criteria	Criteria Guideline (Ref)	Class with respect to present Study Area	Suitability Score (1-less preferred, 9- extremely preferred)
1	Landuse	26,27	Agriculture Forest Grass land Waste land	1 2 4 9
2	Soil	28.29	Loamy skeletal Coarse Loamy Fine Loamy Fine	1 3 7 9
3	Groundwater	14,15	Moderate Good but saline Good to moderate Good	1 2 4 9
4	Geomorphology	9,22	Coastal plain Plateau Flood plain Pedi plain Alluvial plain	1 1 4 7 9
5	Slope	15,18	15-35% 10-35% 3-5% 1-3% 0-1%	1 1 3 7 9

Table 3.4: Suitability scores for horticulture:

Sr.No	Name of Thematic Criteria	Criteria Guideline (Ref)	Class with respect to present Study Area	Suitability Score (1-less preferred, 9- extremely preferred)
1	Land use	26,27	Agriculture Build up Forest Wasteland Grass land	1 1 2 7 9
2	Soil	34,35	Sandy Loamy skeletal Coarse loamy Fine loamy Fine	1 1 4 6 9
3	Groundwater	18,23	Moderate Good but saline Good to moderate good	1 2 4 9
4	Geomorphology	30,31	Costal Plateau Flood plain Pedi plain Alluvial plain	1 1 4 7 9
5	Slope	28,29	5- 10% 3-5% 1-3% 0-1%	1 2 4 9

3.6 Analytical Hierarchy Process (AHP):

Analytic Hierarchy Process (AHP) is one of Multi Criteria decision making method that was originally developed by Prof. Thomas L. Saaty. In short, it is a method to derive ratio scales from paired comparisons. The input can be obtained from actual measurement such as price, weight etc., or from subjective opinion such as satisfaction feelings and preference. AHP allow some small inconsistency in judgment because human is not always consistent. The ratio scales are derived from the principal Eigen vectors and the consistency index is derived from the principal Eigen value.

AHP is an effective tool for dealing with complex decision making, and aid the decision maker to set priorities and make the best decision. By reducing complex decisions to a series of pairwise comparisons, and then synthesizing the results, the AHP help to capture both subjective and objective aspects of a decision. In addition, the AHP incorporates a useful technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision making project process. The AHP considers a set of evaluation criteria, and a set of alternative options among which the best decision is to be made. The AHP generates a weight for each evaluation criterion according to the decision maker's pairwise comparisons higher the weight gives the more importance to the corresponding criterion.

This study makes use of the AHP, as one of the most popular Multi-Criteria Decision Analysis (MCDA) methods, to determine the weights so the parameters in GIS. SAATY (1980), developed a method that makes a pairwise comparison of the number of items of input data. Following the pairwise comparison, the overall weights are compute for each layer (Table), with each parameter both columns and rows. Each parameter is then compared with every other parameters, with each comparison being given a number between 1-9. The comparisons scores were added into the matrix, and then the weight of parameter was computed.

In order to check whether the constructed AHP matrix and the computed weights are consistent or not, the consistency index (CI) and consistency ratio (CR) were computed.

The CR value for constructed matrix can be calculated as follows

$$\mathbf{CI} = (\boldsymbol{\lambda}\ \mathbf{max} - \mathbf{n}) \div (\mathbf{n} - \mathbf{1})\ \ \textbf{........ (I)}$$

$$\boldsymbol{CR} = \boldsymbol{CI} \div \boldsymbol{RI}\textbf{....... (II)}$$

Where λ max- is the product between each element of the weight and the column total of the comparison matrix (The average of consistency vector)

n- number of parameter

RI is the Random consistency Index (RI), taken from Table 3.5

RI is a constant parameter which is assigned on the basis of criteria we considered

Table 3.5: Random consistency scale

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	**0**	**0**	**0.58**	**0.9**	**0.12**	**0.24**	**0.32**	**0.41**	**1.45**	**1.49**

The CR value is lower than 0.1, meaning that the AHP matrix is consistent.

Table 3.6: AHP pair wise comparison matrix for Highrise-building

High-rise building	Land use	Soil	Ground water	Geomorphology	Slope	Weight
Land use	1	0.5	0.25	0.2	0.125	0.042933
Soil	2	1	0.33333	0.25	0.142857	0.064809
Groundwater	4	3	1	0.333333	0.166667	0.128923
Geomorphology	5	4	3	1	0.25	0.22257
Slope	8	7	6	4	1	0.540765
Consistent Ratio (CR): 0.095038						

Table 3.6.1: Land use site suitability for Highrise-building

Land use (HR)	Built-Up	Grass	Wet	Wasteland	Weight
Built-Up	1	3	7	9	0.573947
Grass	0.333333	1	5	7	0.291316
Wet	0.142857	0.2	1	3	0.090263
Wasteland	0.111111	0.142857	0.333333	1	0.044474
Consistent Ratio (CR): 0.099686					

Table 3.6.2: Soil site suitability for Highrise-building

Soil(HR)	Coarse Loamy	Fine	Loamy Skeletal	Sandy	Fine Loamy	Weight
Coarse Loamy	1	0.333333	0.2	0.142857	0.111111	0.035028
Fine	2	1	0.25	0.2	0.166667	0.061161
Loamy Skeletal	5	4	1	0.333333	0.2	0.148153
Sandy	7	5	3	1	0.333333	0.26263
Fine Loamy	9	6	5	3	1	0.493029
Consistent Ratio (CR): 0.080517						

Table 3.6.3: Groundwater site Suitability for Highrise-buildings

Ground water (HR)	Good	Good But Saline	Poor	Moderate to Poor	Moderate	Weight
Good	1	0.5	0.333333	0.25	0.142857	0.052354
Good But Saline	2	1	1	0.333333333	0.25	0.104766
Poor	3	1	1	1	0.2	0.126381
Moderate to Poor	4	3	1	1	0.166667	0.176462
Moderate	7	4	5	6	1	0.540036
Consistent Ratio (CR):0.0900262						

Table 3.6.4: Geomorphology site Suitability for Highrise-building

Geomorphology (HR)	Eolian	Flood Plain	Pedi plain	Plateau	Weight
Eolian	1	0.25	0.166667	0.111111	0.044472
Flood Plain	4	1	0.25	0.166667	0.113201
Pedi plain	6	3	1	0.25	0.235234
Plateau	9	6	4	1	0.607093
Consistent Ratio (CR):0.093124					

Table 3.6.5: Slope site Suitability for Highrise-building

Slope (HR)	10-15%	5-10%	3-5%	1-3%	0-1%	Weight
10-15%	1	1	0.2	0.166667	0.111111	0.044355
5-10%	1	1	0.333333	0.25	0.125	0.052028
3-5%	5	3	1	0.25	0.2	0.133056
1-3%	6	4	4	1	0.333333	0.258087
0-1%	9	8	5	3	1	0.512474
Consistent Ratio (CR):0.08326						

Table 3.7: AHP pair wise comparison matrix for Plantation

plantation	Ground water	Slope	Land use	Geomorphology	Soil	Weight
Ground water	1	1	0.3333333	0.166666667	0.111111	0.047431
Slope	1	1	0.25	0.2	0.166667	0.053292
Land use	3	4	1	0.333333333	0.2	0.132775
Geomorphology	6	5	3	1	0.25	0.245459
Soil	9	6	5	4	1	0.521043
Consistent Ratio (CR):0.095174						

Table 3.7.1: Ground water site Suitability for Plantation

Ground water	Moderate	Good but Saline	Good to moderate	Good	Weight
Moderate	1	0.5	0.25	0.111111111	0.053669
Good but Saline	2	1	0.333333333	0.125	0.084516
Good to moderate	4	3	1	0.166666667	0.18517
Good	9	8	6	1	0.676645
Consistent Ratio (CR):0.099459724					

Table 3.7.2: Slope site Suitability for plantation

Slope	15-35%	10-15%	3-5%	1-3%	0-1%	Weight
15-35%	1	1	0.33333	0.142857	0.111111	0.046878
10-15%	1	1	0.5	0.2	0.142857	0.056008
3-5%	3	2	1	0.33333	0.2	0.10913
1-3%	7	5	3	1	0.25	0.254762
0-1%	9	7	5	4	1	0.533222
Consistent Ratio (CR):0.068829						

Table 3.7.3: Land use site suitability for Plantation

Land use	Agriculture	Forest	Grassland	Wasteland	Weight
Agriculture	1	0.5	0.25	0.111111	0.056687
Forest	2	1	0.25	0.2	0.098452
Grassland	4	4	1	0.25	0.243228
Wasteland	9	5	4	1	0.601633
Consistent Ratio (CR):0.08063165					

Table 3.7.4: Geomorphology site suitability for Plantation

Geomorphology	Costal Plain	Plateau	Flood Plain	Pedi plain	Alluvial Plain	Weight
Costal Plain	1	1	0.25	0.1428571	0.11111	0.043119
Plateau	1	1	0.5	0.2	0.11111	0.049482
Flood Plain	4	2	1	0.3333333	0.166666667	0.108155
Pedi plain	7	5	3	1	0.2	0.230138
Alluvial Plain	9	9	6	5	1	0.569106
Consistent Ratio (CR):0.09880493						

Table 3.7.5: Soil site suitability for Plantation

Soil	Loamy Skeletal	Coarse Loamy	Fine Loamy	Fine	Weight
Loamy Skeletal	1	0.333333333	0.14285714	0.111111	0.044474
Coarse Loamy	3	1	0.2	0.142857	0.090263
Fine Loamy	7	5	1	0.333333	0.291316
Fine	9	7	3	1	0.573947
Consistent Ratio (CR):0.099686253					

Table 3.8: AHP pair wise comparison matrix for Horticulture

Horticulture	Land use	Geomorphology	Slope	Ground water	Soil	Weight
Land use	1	1	0.3333	0.2	0.1111	0.048495
Geomorphology	1	1	0.5	0.25	0.125	0.054538
Slope	3	2	1	0.25	0.1666	0.10174
Groundwater	5	4	4	1	0.2	0.225045
Soil	9	8	6	5	1	0.570182
Consistent Ratio (CR):0.093663						

Table 3.8.1: Land use site suitability for horticulture

Land use	Agriculture	Build Up	Forest	wasteland	Grassland	Weight
Agriculture	1	1	0.5	0.142857	0.111111	0.049108
Build Up	1	1	0.333333	0.25	0.125	0.05095
Forest	2	3	1	0.333333	0.166667	0.104464
wasteland	7	4	3	1	0.2	0.227135
Grassland	9	8	6	5	1	0.568343
Consistent Ratio (CR):0.093457						

Table 3.8.2: Geomorphology site suitability for Horticulture

Geomorphology	Costal Plain	Plateau	Flood Plain	Pedi plain	Alluvial Plain	Weight
Costal Plain	1	1	0.25	0.1428571	0.111111111	0.043119
Plateau	1	1	0.5	0.2	0.111111111	0.049482
Flood Plain	4	2	1	0.3333333	0.166666667	0.108155
Pedi plain	7	5	3	1	0.2	0.230138
Alluvial Plain	9	9	6	5	1	0.569106
Consistent Ratio (CR):0.0988049						

Table 3.8.3: Slope site suitability for Horticulture

Slope	5-10%	3-5%	1-3%	0-1%	Weight
5-10%	1	0.5	0.25	0.111111	0.053842
3-5%	2	1	0.25	0.125	0.081144
1-3%	4	4	1	0.2	0.209852
0-1%	9	8	5	1	0.655162
Consistent Ratio (CR):0.096978					

Table 3.8.4: Groundwater site suitability for Horticulture

Groundwater	Moderate	Good but Saline	Good to moderate	Good	Weight
Moderate	1	0.5	0.25	0.111111	0.053669
Good but Saline	2	1	0.333333333	0.125	0.084516
Good to moderate	4	3	1	0.166667	0.18517
Good	9	8	6	1	0.676645
Consistent Ratio (CR):0.099459724					

Table 3.8.5: Soil site suitability for Horticulture

Soil	Sandy	Loamy Skeletal	Coarse Loamy	Fine Loamy	Fine	Weight
Sandy	1	1	0.25	0.2	0.111111	0.046035
Loamy Skeletal	1	1	0.5	0.2	0.125	0.052049
Coarse Loamy	4	2	1	0.3333333	0.142857	0.108547
Fine Loamy	6	5	3	1	0.2	0.214923
Fine	9	8	7	5	1	0.578446
Consistent Ratio (CR):0.098537188						

In the case of high-rise building suitable, plantation, and horticulture site identification, the CR value is 0.095038, 0.095174, and 0.093663 respectively; the value is less than 10 %. So, the calculated AHP matrix is consistent. And weight of each parameter multiplied with sub criteria weight of each parameter, and then the output value is added to a new attribute table using field calculator. Later by using union tool all the attribute tables are joined together .Based on the new attribute table the existing thematic layer is updated then create a new column in the attribute table which holds the sum of all output values. Finally, according to SAATY's Scale guidelines, the total score is categorized as in their suitability. Mostly land suitability classes are characterized as suitable(s) to not suitable (n).

3.7 Model Building in Arc GIS

3.7.1 Generation of thematic Maps using Model Building

Model Builder is a visual programming language for building geoprocessing workflows which is used to create, edit, and manage models; Models are workflows that string together sequences of geoprocessing tools, feeding the output of one tool into another tool as input. Model Builder can also be thought as a visual programming language for building workflows

- Model Builder is easy-to-use application for creating and running workflows containing a sequence of tools.
- Creation of tools with Model Builder. Tools created with Model Builder can be used in Python scripting and other models.
- Model Builder, along with scripting, is a way to integrate ArcGIS with other applications.

. Using model building tool in ArcGIS generated the suitability analysis and further preprocessed the model.

3.7.2 Model for Location of site for Plantation

Aim: Select suitable site(s) for plantation using modelling techniques in ARC GIS

Data/Feature classes

- Land use
- Soil
- Geomorphology
- Groundwater
- Slope

Decision Rules:

- The soil category should be Loamy Skeletal, Coarse Loamy, Fine Loamy or Fine
- The Land use should be Grassland or Wasteland
- The Geomorphology should be Costal Plain, Plateau, Flood plain, Pedi plain or Alluvial Plain
- The Groundwater should be good or moderate

- The Slope category should be 0-1%, 1-3% ,3-5%,5-10% or10-15%

Procedure:

1. Open ARC MAP/CATALOG and if necessary, invoke the ARC TOOL BOX. Right click on the Toolbox, choose New Tool Box and give it a name (say, 'plantation'). Create a new tool set and create/add a model.
2. Save the tool box in a location
3. Right click on the new tool box created and say **New > Model**.
4. Add data, Drag the required tools from ARC TOOL BOX, connect them etc.

Once the model is constructed,

(a) Validate the entire model
(b) Save the model.
(c) Run the complete model

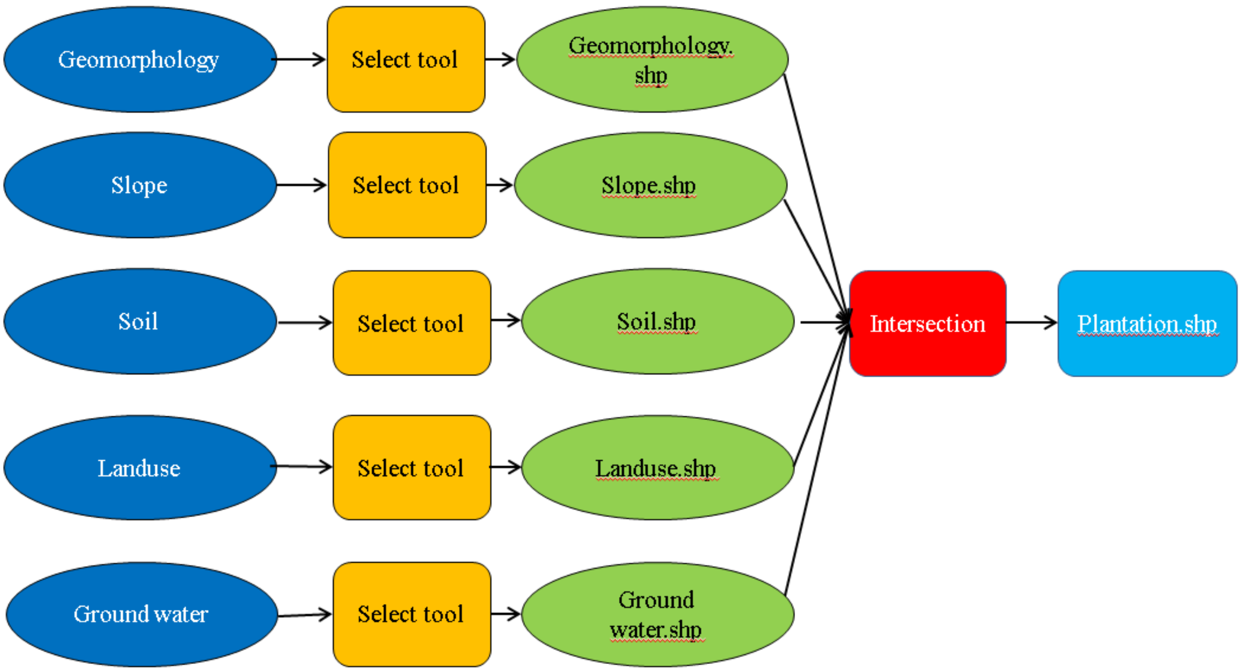

Fig 3.7.1: Plantation flow-chart

3.7.3 Model for Location of site for Horticulture

Aim: Select suitable site(s) for Horticulture using modelling techniques in ARC GIS

Data/Feature classes:

- Land use
- Soil
- Geomorphology
- Groundwater
- Slope

Decision Rules:

- The soil category should be sandy, Loamy Skeletal, Coarse Loamy, Fine Loamy or Fine
- The Land use should be Agriculture, Build Up, Forest, Wasteland or Grassland
- The Geomorphology should be Costal Plain, Plateau, Flood plain, Pedi plain or Alluvial Plain
- The Groundwater should be good, Good to moderate, or Moderate
- The Slope category should be 0-1%, 1-3%, 3-5% or 5-10%

Procedure:

1. Open ARC MAP/CATALOG and if necessary, invoke the ARC TOOL BOX. Right click on the Toolbox, choose New Tool Box and give it a name (say, 'Horticulture'). Create a new tool set and create/add a model.
2. Save the tool box in a location
3. Right click on the new tool box created and say **New > Model**.
4. Add data, Drag the required tools from ARC TOOL BOX, connect them etc.

Once the model is constructed,

(d) Validate the entire model

(e) Save the model.

(f) Run the complete model

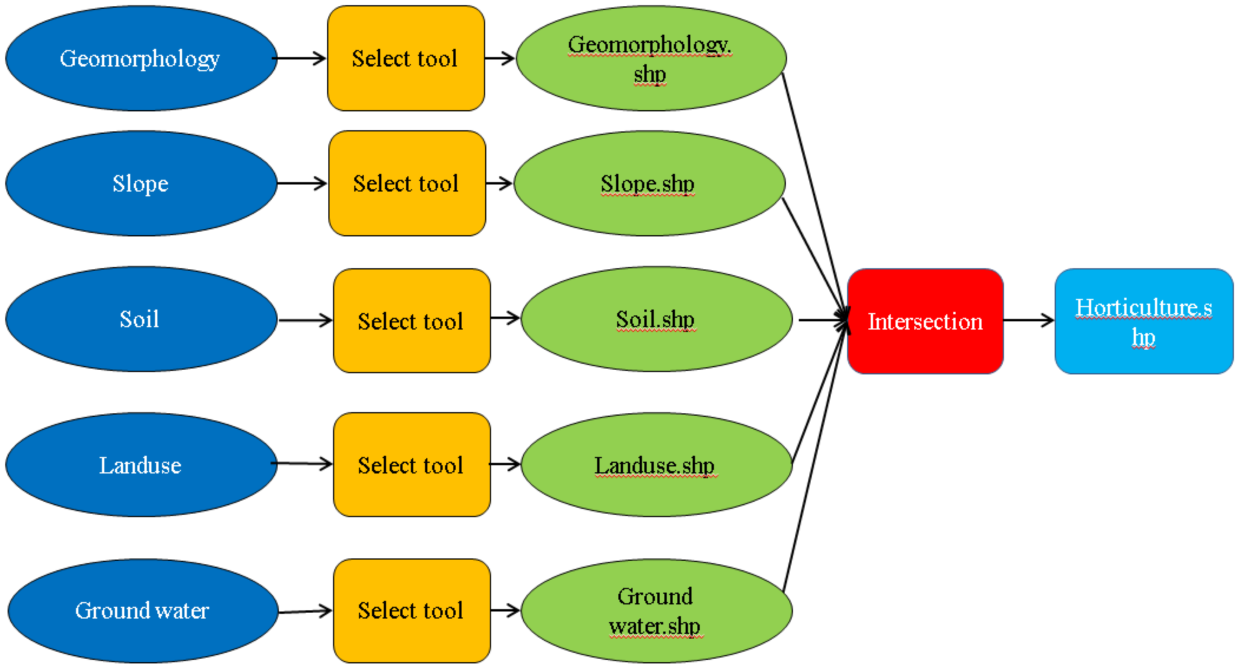

Fig 3.7.2: Horticulture Flow-chart

3.7.4 Model for Location of site for High Rise buildings

Aim: Select suitable site(s) for constructing high rise building using modelling techniques in ARC GIS

Data/Feature classes:

- Land use
- Soil
- Geomorphology
- Groundwater
- Slope

Decision Rules:

- The soil category should be Loamy Skeletal, Sandy, And Fine Loamy
- The Land use should be Wet or Wasteland
- The Geomorphology should be Eolian, Flood Plain, Pedi Plain or Plateau

- The Groundwater should be moderate to poor or moderate
- The Slope category should be 0-1%, 1-3% or 3-5%

Procedure:

5. Open ARC MAP/CATALOG and if necessary, invoke the ARC TOOL BOX. Right click on the Toolbox, choose New Tool Box and give it a name (say, ‘High rise building’). Create a new tool set and create/add a model.
6. Save the tool box in a location
7. Right click on the new tool box created and say **New** > **Model**.
8. Add data, Drag the required tools from ARC TOOL BOX, connect them etc.

Once the model is constructed,

(g) Validate the entire model

(h) Save the model.

(i) Run the complete model

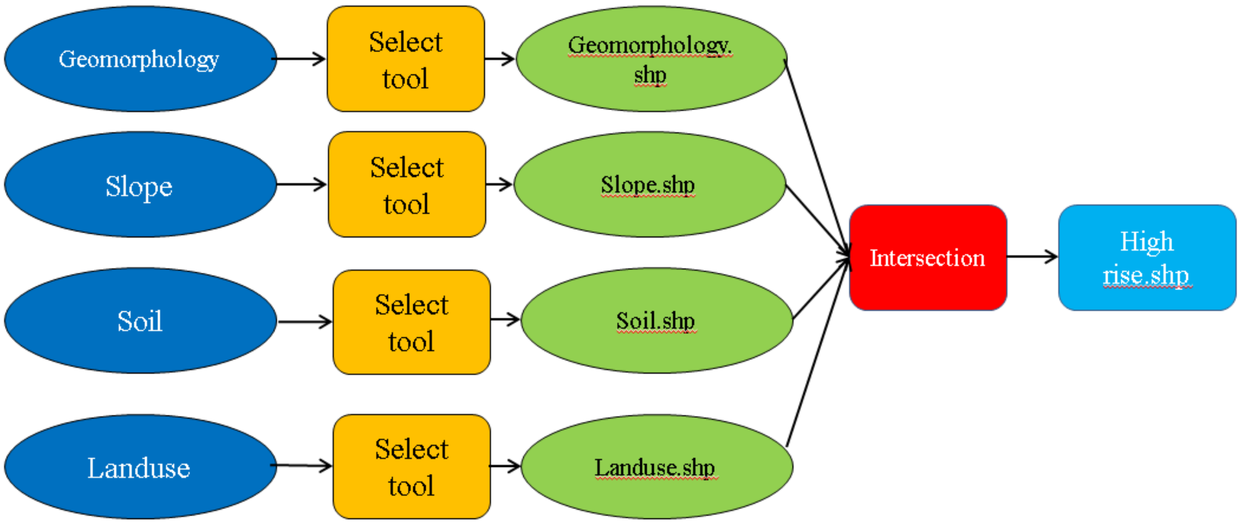

Fig 3.7.3: Highrise building-Flow-chart

Chapter 4

RESULTS AND DISCUSSIONS

4.1 Various Thematic Maps

The Thematic Map viz., Soil Map, Slope Map, Land use Map, Groundwater Map, Boundary Map and Geomorphology Map were considered as the thematic parameter for suitable site selection analysis in the study area of Surendranagar District, Gujarat. These thematic parameters criteria were used to develop an action plan map in this area.

4.2 Area of Interest- Surendranagar District, Gujarat, India

4.3 Criterion for paired wise comparison matrix

4.3.1 Soil

The soils of Surendranagar district may be classified into three main categories:

a. Medium black soils

b. Red Sandy soils

c. Silty soils

Medium black soils generally occur at shallow depths (less than 5m) where basalts/shale forms the main rock unit and is exposed on the surface in the south, southwest and central part of the area. These soils are good in fertility but not suitable for heavy irrigation. The red sandy soils occur in north east, east and south east part of the area. The silty soils are found along a narrow strip close to the little Rann of Kachchh in the north east and along shallow alluvial tracts and hard rock areas in central uplands has appreciable content of sand. The soil is shallow, medium black in Wadhwan, Muli, Chotila and Sayla talukas. Sandy and alluvial in Halvad, Dhrangdhra, and Dasada talukas and medium black poorly drained and saline in Lakhtar, Chuda and Limbadi talukas. The thematic map is shown in Fig 4.1.

4.3.2 Slope

Another parameter to be taken into account in suitable site selection for Highrise-building, plantation, and horticulture is derived from slope data. The data referring to the change in elevation in the direction of the steepest descent. The Slope tool in ArcGIS identifies the steepness at each cell of raster surface. Lower the Slope value indicates flatter the terrain while higher the slope value shows steeper the terrain. The suitability of land surface is measured by slope value present in the region. In the present study area, Slope parameters play a vital role to identify suitable sites with respect to the Highrise-building, plantation, and horticulture area. The Slope map is prepared with eleven categories (0-1%, 1-3%, 10-15%, 15-35%, 3-5%, 35-50% 5-10%, village, river, Town, Water bodies) is shown in Fig 4.2.The most part of the study area cover 0-1% of Slope surface.it contain 88% of total area which is highly suitable site for Highrise-building, plantation, and horticulture.

4.3.3 Land Use

Land Use Pattern Land utilization is influenced by a number of physical, social and economic factors. Initially it is influenced by the physical factors i.e. environmental and geological, later on socio-economic factors such as growing pressure of population on land, advancement of technological know how, market, demand and price response become more pronounced

In present study the land use was prepared with eight major classes namely agriculture, Build up, Forest, Grass land/ Grazing Land, Waste Land. Water bodies, Wetlands and others. Basically Surendranagar is primarily an agricultural district with cotton and cumin as the predominant crops. The other major crops cultivated are bajra, wheat, sesamam, groundnut, etc. and almost all agricultural land is un-irrigated as shown in Fig 4.3. Among the total area agriculture covered 80.76% followed by Buildup (1.24%), Forest (0.002%), Waste Land (10%), Water Bodies (3%), Wet Land (0.004%), and Others (3.8%) table 4.1

The district is not having much major forest area and not mineral forest products. There is limited scope for establishing forest based industries. The State Government through Forest Department and District Rural development Agency has been undertaking various works relating to forestry and waste land development.

The Grasslands have been classified into two categories, viz., (I) Reserved and (ii) Non-Reserved. The grass species that naturally came up were harvested. Secondly after harvesting the left over grass (in the Vidis, locally known as "Taliyata") was thrown open for grazing. This resulted in the hardening of the soil and the uprooting of good quality sods. Thus owing to ceaseless harvest and grazing, there was a sharp reduction (both in quality and quantity) in the varieties of grasses. Consequently many of these grasses have made their way in the shade of the trees and bushes (Sinha, Pinto and Patel R.I.).

Table 4.1: Percentage of Land use Class

Sr.No	Land use Classes	Area_Sq.km	Area_%
1	Agriculture	7310.58	80.76
2	Buildup	113.077	1.24
3	Forest	0.185	0.002
4	Grass	30.48	0.3
5	Wasteland	968.69	10
6	Water bodies	278.15	3
7	Wet land	0.397	0.004
8	Others	349.786	3.8

4.3.4 Geomorphology

The physiography aspect of the district varies in different talukas. The Wadhvan, Limbdi, Sayla, Lakhtar, Dasada talukas are mostly plain country, Dharangadhra and Halvad are gently undulating, while chotila and Muli are hilly. As shown in Fig4.4, the district can be divided into following three main geomorphic units shown below.

(I) Almost the entire eastern half is a plain alluvial area with elevations varying from 5 m above mean sea level (amsl) to 40 m amsl.

(ii) The north western part forms the gently undulating terrain comprising mainly the semi consolidated sedimentary rocks with elevations varying from 30 m to 144m amsl, except in the extreme north where there is sudden fall in elevation to 8 m amsl near Little Rann of Kachchh.

(ii) The south western pat forms rugged topography with many isolated hill ranges and hillocks of Deccan traps rising to heights ranging from 100 m to 3m amsl (Chotila hill). The geomorphology is made up with 11 parameters namely Alluvial Plain, Coastal Plain, Deltaic Plain, Denudational Hills, Eolian Plain, Flood plain, Pedi Plain, Plateau, River, Town and Village and water bodies. The suitability score for geomorphological parameters in (table 3.3)

4.3.5 Ground water

The groundwater in the area occurs phreatic, semi-confined and confined conditions. The ground water occurrence is controlled by topography, drainage, lithology and disposition of fractures and joints. The medium to coarse grained sandstone act as good repository of ground water. The thematic map of ground water is shown in Fig 4.5. The main water bearing formations identified with in the area as follows:

(a)Ground Water in alluvium:

Most of the northern and eastern parts of the district, covering an area of about 5375 Sq. Km, comprise semi and unconsolidated formations. The ground water occurs under unconfined to confined conditions. The depth of the wells in this formation ranges between 2.00 and 30.00 m bgl. The depth of water levels range from 0.20 to 20.0 m bgl. The yield of shallow dugwells varies from 40 to 60 m3/day. The depth of the tube wells ranges from 60 to 300 m. The free flow discharge of these well ranges from 5 to 60 m3/day.

(b) Ground Water in Dhragadhra & Wadhwan Sandstone:

The Dhragadhra and Wadhwan sandstone are the most important water bearing formations in the district. They occupy about 2700 Sq.Km. area and situated in the central and northwestern parts of the district. The shallow dugwells in the depth range between 5 and 28m, tapping Upper Dhragadhra sandstone have water yielding capacity of 20 to 60 m3/day. The general range of water level in this aquifers is around 4 to 22 m. A number of tubewells sited, in Middle Dhrangadhra formations, down to depths ranging between 90 and 157 m are in operation. The yield of tubewells vary from 25 to 80 m3/day. The piezometric head in this aquifers vary from 10 to 30 mbgl. The Wadhwan sandstone exposed in certain areas near streams and river channels or in the vicinity of surface water reservoirs are yielding fresh water in the order of 15 to 30 m3/day.

(c) Ground Water in Deccan Traps:

The Deccan basalts, unconfirmbly overlying the Dhrangadhra and Wadhwan formations form aquifers in southern part of the district, covering an area of 2100 Sq.Km. The movement of ground water is controlled by weathered zone, joints and fissures. The groundwater occurs under both water table and semi-confined conditions. The depth of the dug wells in the traps range from 6.0 to 28.0 m and depth to water level rests between 1.0 and 20 m bgl. The yield of shallow dugwells ranges from 20.0 to 50.0 m3/day. The depth of the boreholes tapping interflow zones range from 80 to 110 m, where in the piezometric head rests between 18 and 25 m bgl. As such the yield of the shallow/deep boreholes in the traps are ranging from 35 to 70 m3/day.

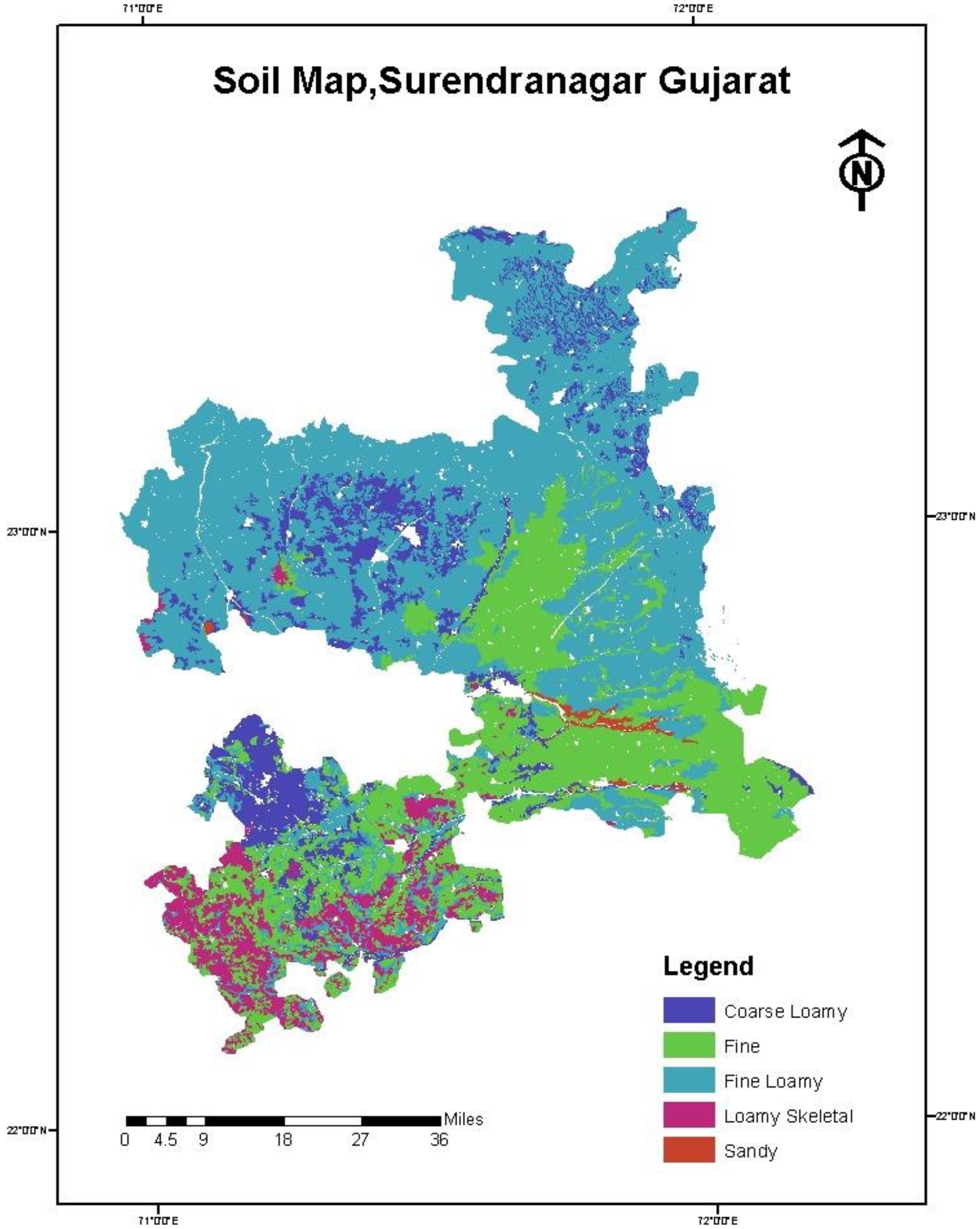

Fig 4.1: Thematic map of Soil

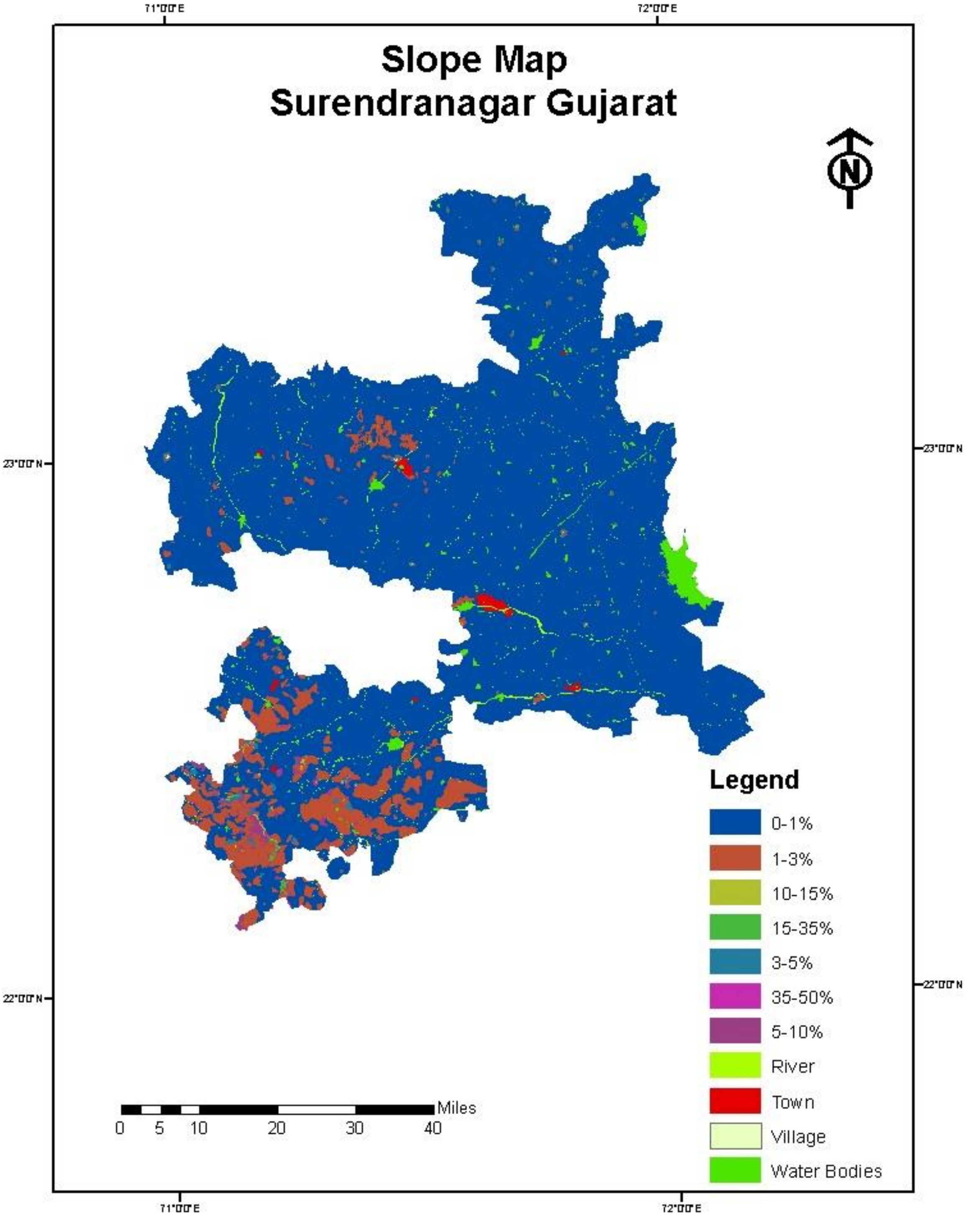

Fig 4.2: Thematic map of Slope

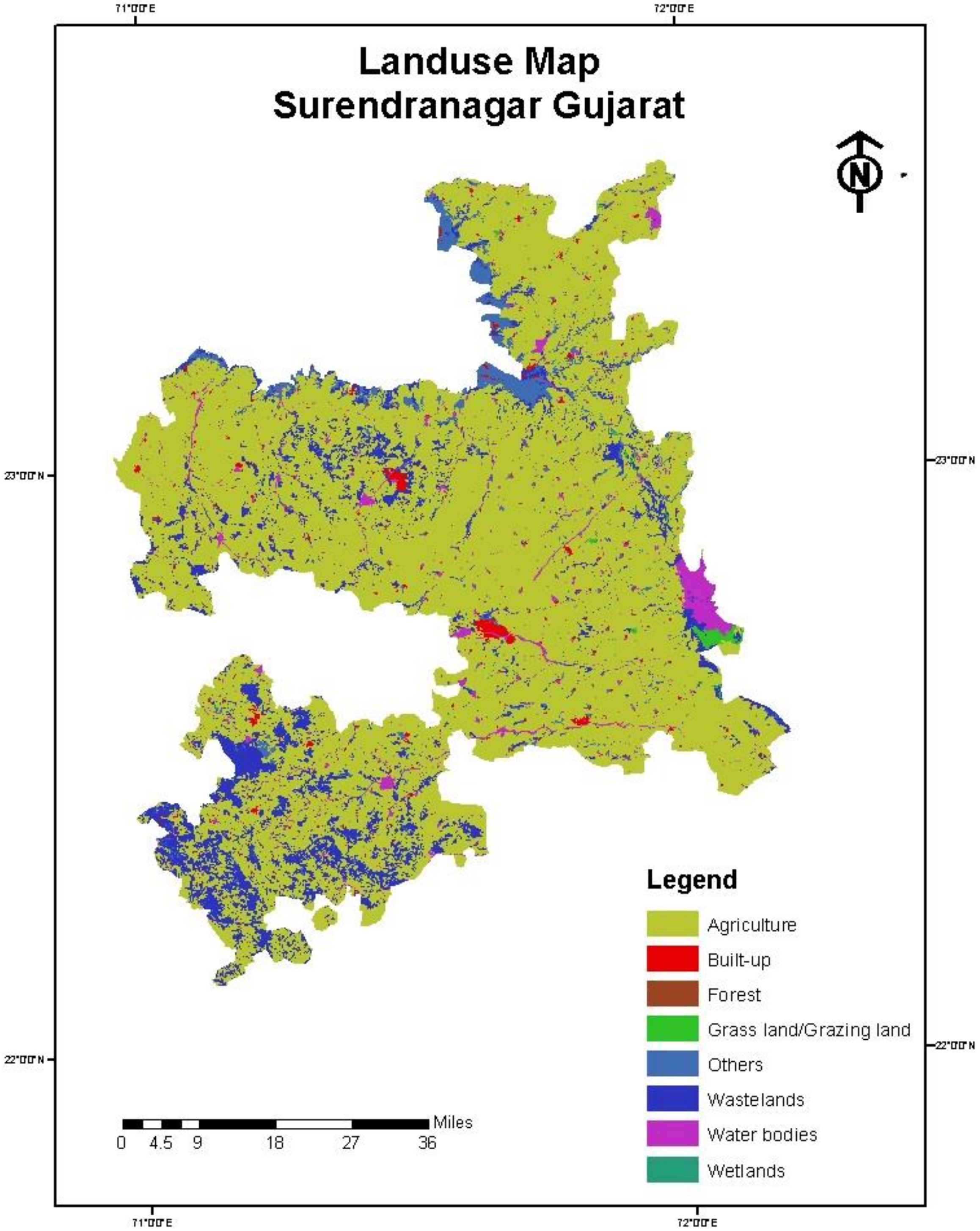

Fig 4.3: Thematic map of Land use

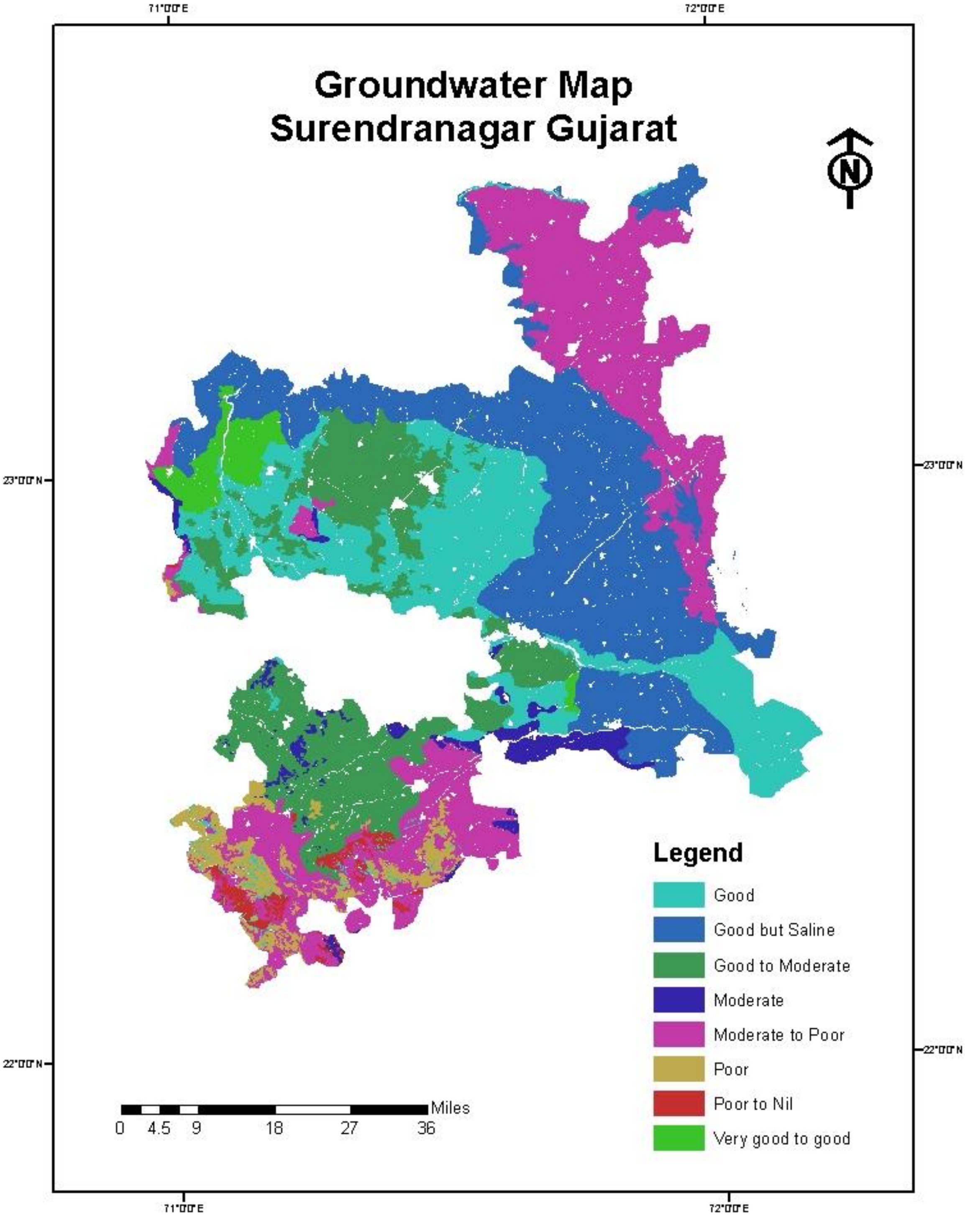

Fig 4.4: Thematic map of Groundwater

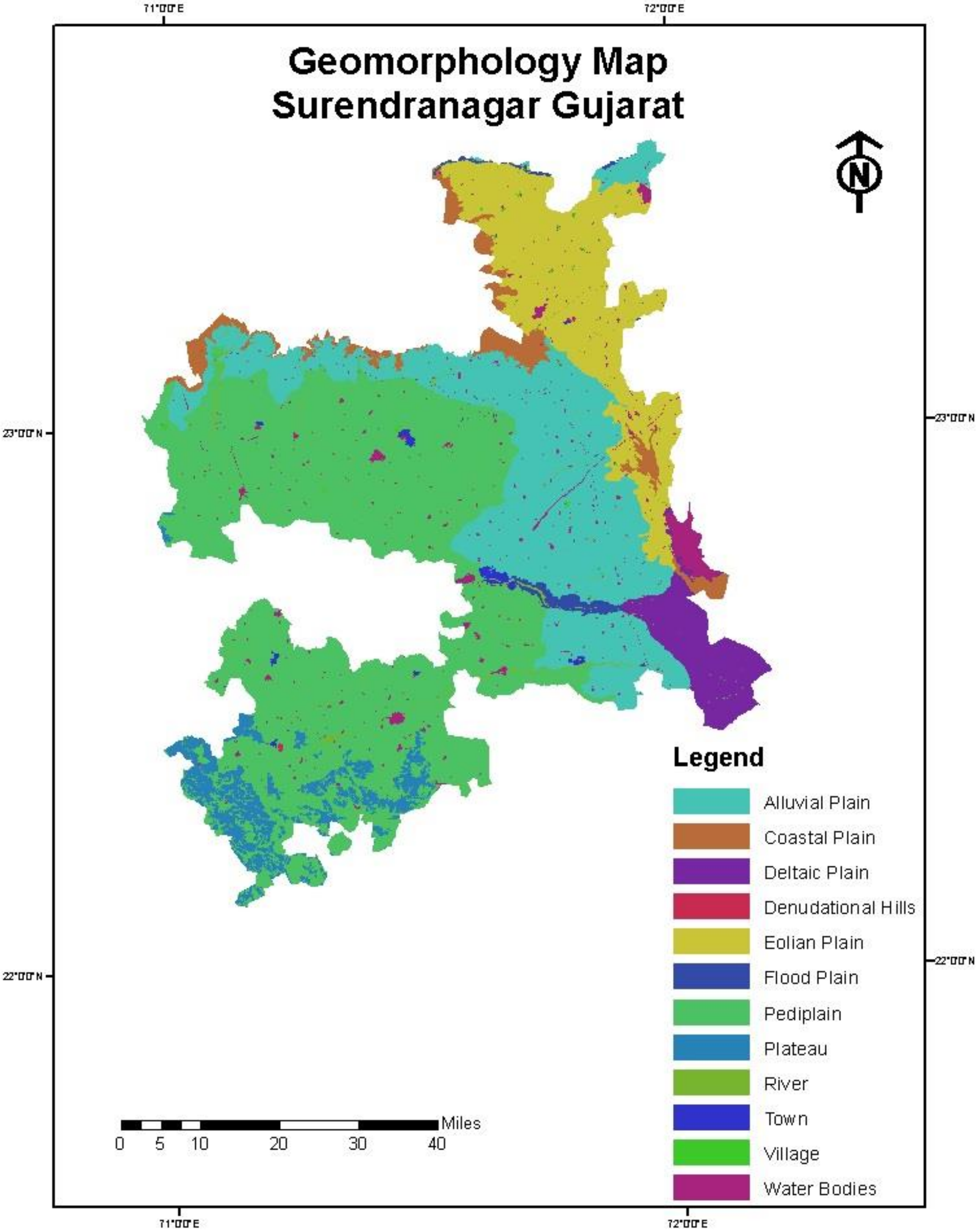

Fig 4.5: Thematic map of Geomorphology

4.4 Discussion

The suitable site analysis for high rise building, plantation and horticulture has been conducted in Surendranagar District, Gujarat. The various factors used to analyze the site suitability in study area. The study analyses five parameters in the selection of land suitability. The parameters are soil, slope, geomorphology, ground water and land use. The suitable site was delineated by integrating the thematic layer with suitable weight s using GIS –MCDA techniques. The comparison matrix was developed for five criteria and the weights were evaluated for the factors by AHP analysis technique. The relative importance of each and every parameter is considered by determining weightage factor using Saaty's method and based on the weight derived from the Saaty's method, final suitability map is derived in GIS environment.

The acceptable consistency ratio (0.0950,0.0951 &0.093) is obtained from the pair wise matrix. The calculated weight of each factor is presented in (table 3.6 to table 3.8.5)

The weights for criteria and sub-criteria are integrated to the schematic layer and suitability maps were prepared by weighted overlay analysis GIS environment. The resultant map has been categorized into highly suitable, less suitable and not suitable (Fig 4.6 to Fig 4.11).

The result of the study indicate that most of the area of Surendranagar District, i.e. 22% are highly suitable and 56% are moderately suitable for high rise building construction, where most of the highly suitable area is covered around north western and south western part of Surendranagar District and moderately suitable area is covered around north and north eastern part of Surendranagar districts of Gujarat which is almost nearly south of little Rann of kutchh., where the Fine loamy and sandy soils which are the primary factors responsible for the suitability estimation . For Horticulture cultivation 11.7% is highly suitable situated around south eastern and partially covered around south western part of Surendranagar District and 27.9% is moderately suitable which spreads almost central and covers half of the southern part of Surendranagar district, here the slope plays a major role for the suitability estimation where the slope ranges from 0-1 and hence the area is highly suitable for horticulture, the location site for plantation is 31% which is highly suitable where most of the suitable area is covered around the central and partial southern parts of Surendranagar district and 40% is moderately suitable in the area which is covered around south and south eastern part which is of in a partial coverage, the fine, fine loamy soil and the availability of groundwater makes it a better suitability for the plantation around the Surendranagar district.

Based on the model building suitability analysis for plantation most of the highly suitability area are outspread around the south western part of Surendranagar district, where as the moderately suitable area are found around south eastern and central part of the district. For Highrise building construction the southern part of the Surendranagar is highly suitable and northern part is moderately suitable. The highly generated horticulture is mainly found at the central part of Surendranagar, and the moderately covered is around central east of Surendranagar district.

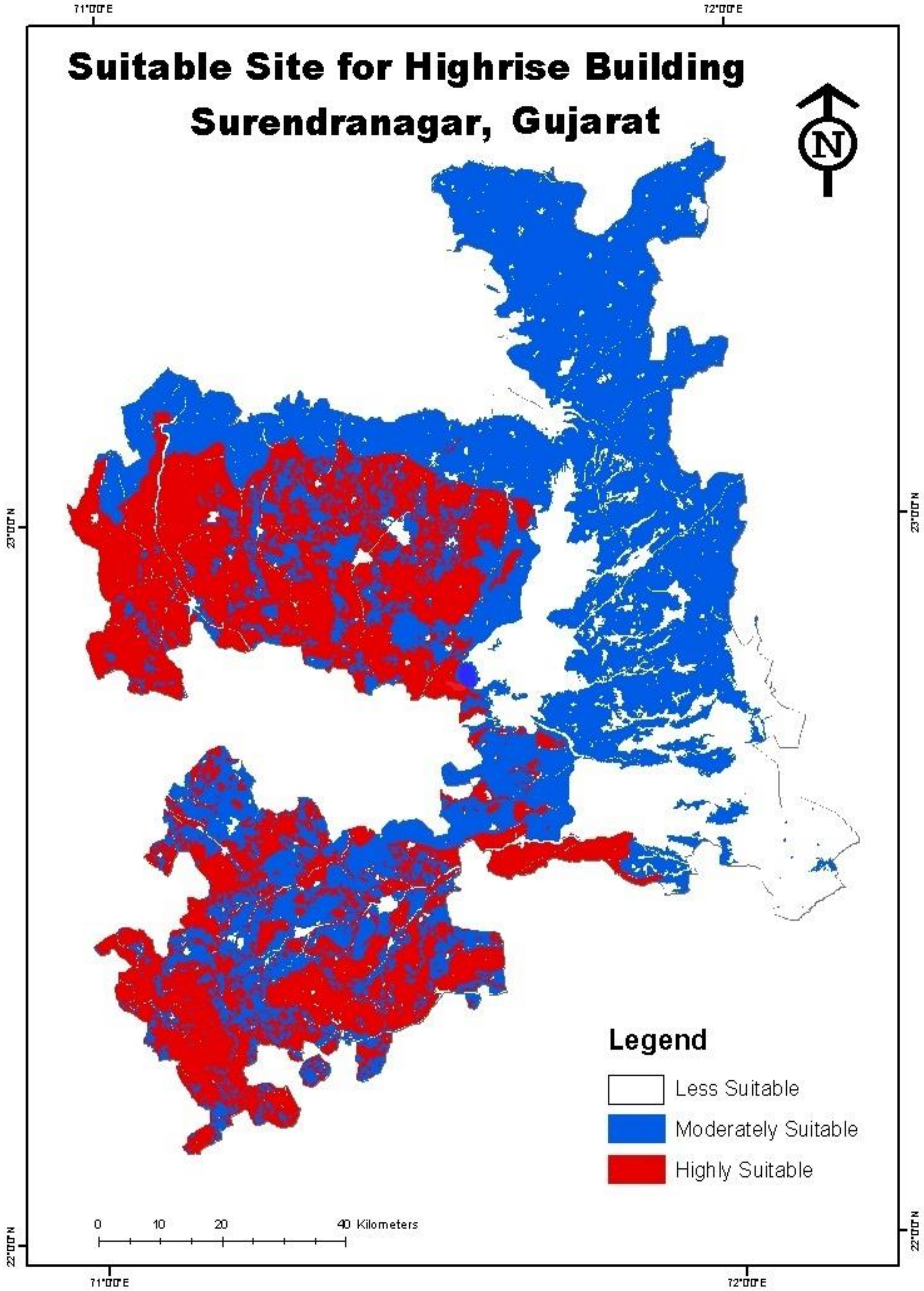

Fig 4.6: Suitability Map for Highrise building using AHP

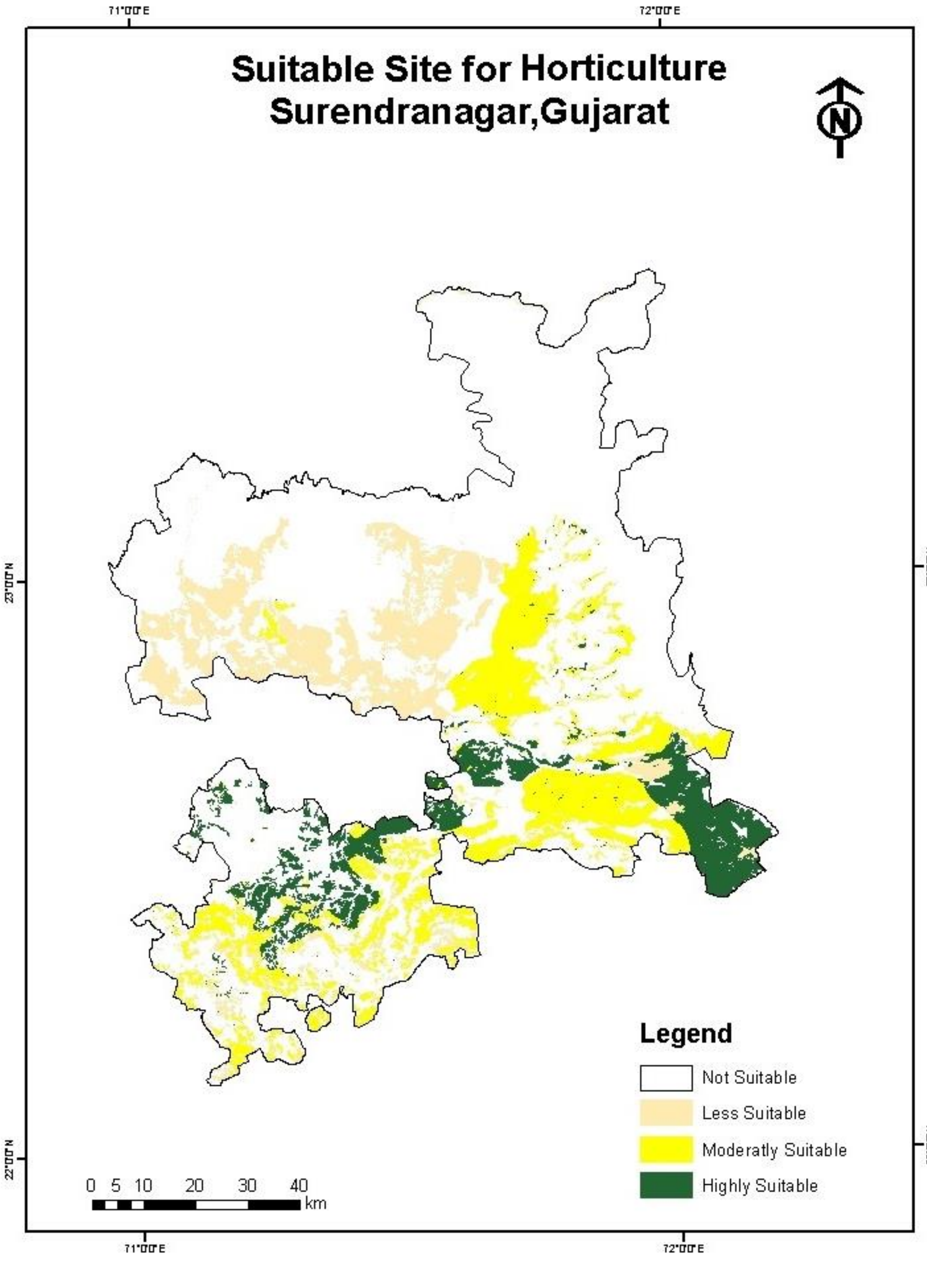

Fig 4.7: Suitability Map for Horticulture using AHP

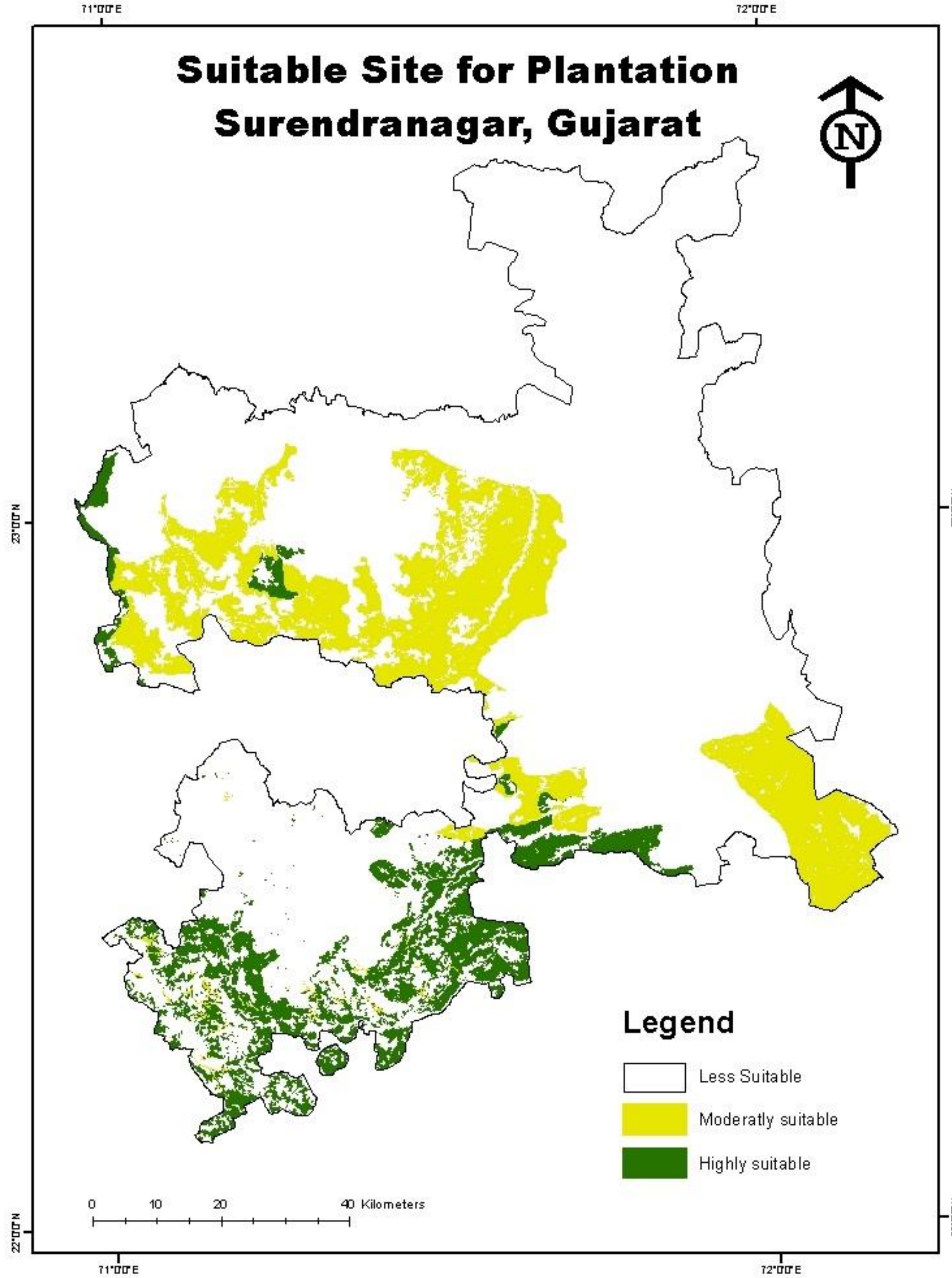

Fig 4.8: Suitability Map for plantation using AHP

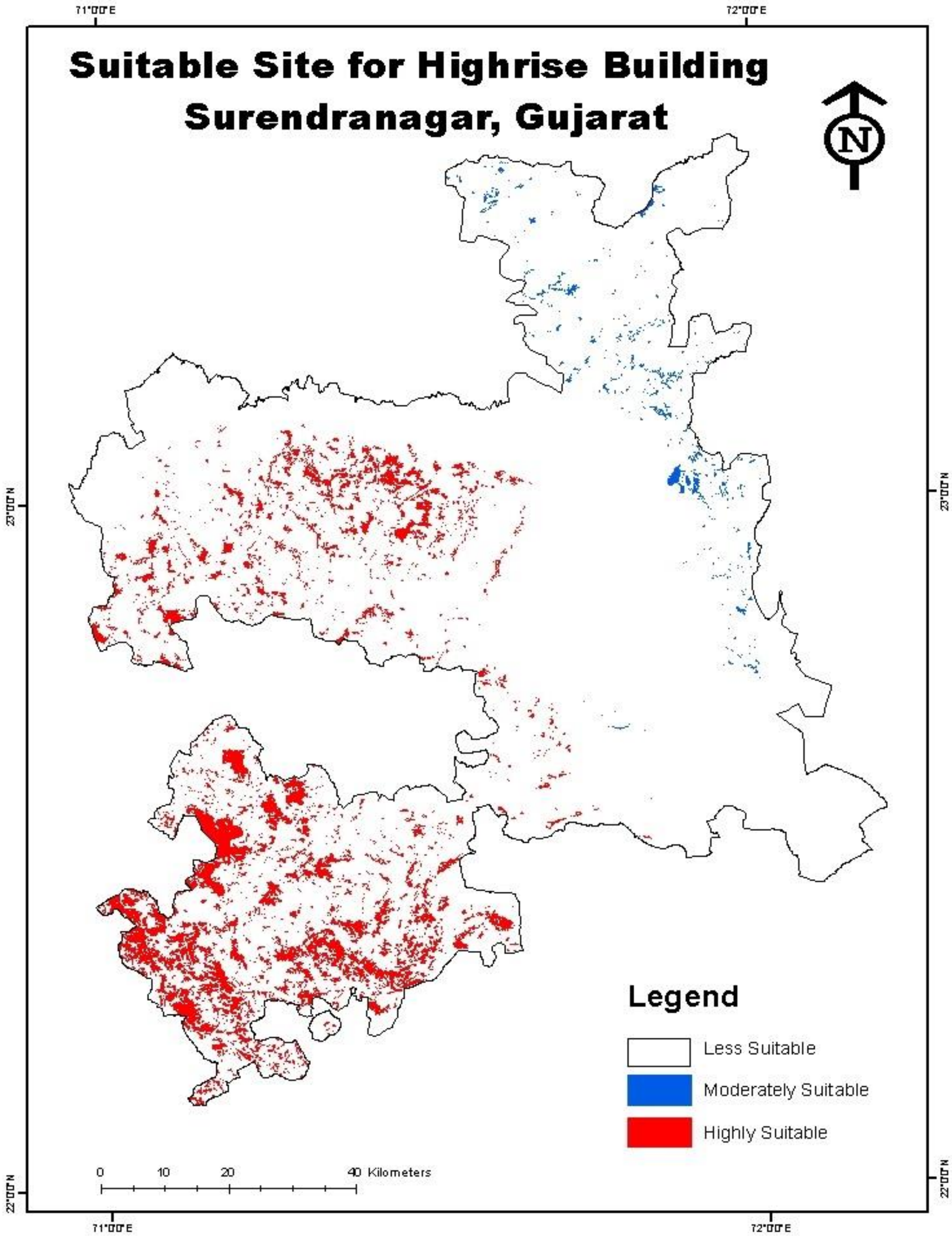

Fig 4.9: Suitability Map for Highrise building using Model building

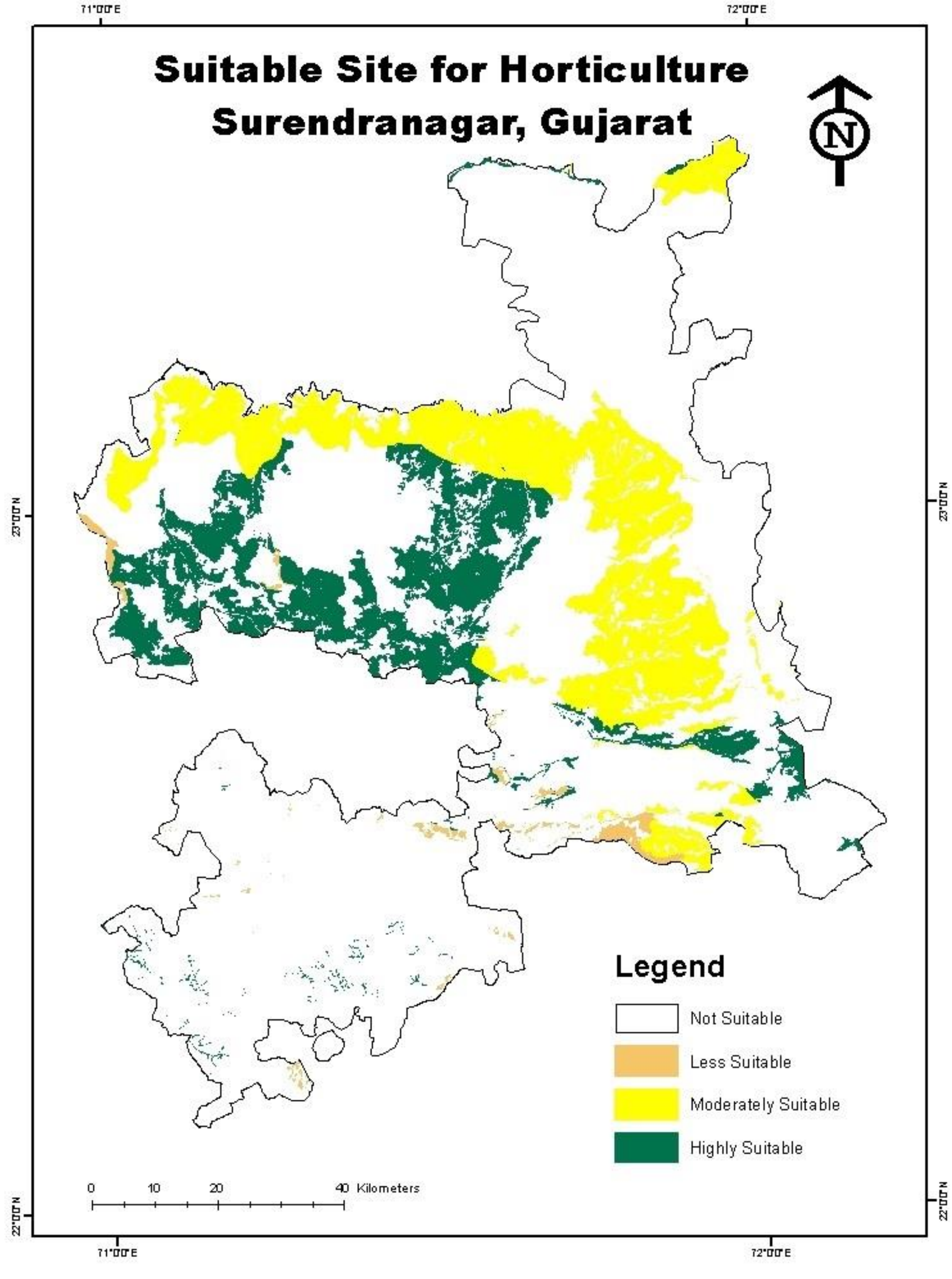

Fig 4.10: Suitability Map for Horticulture using Model building

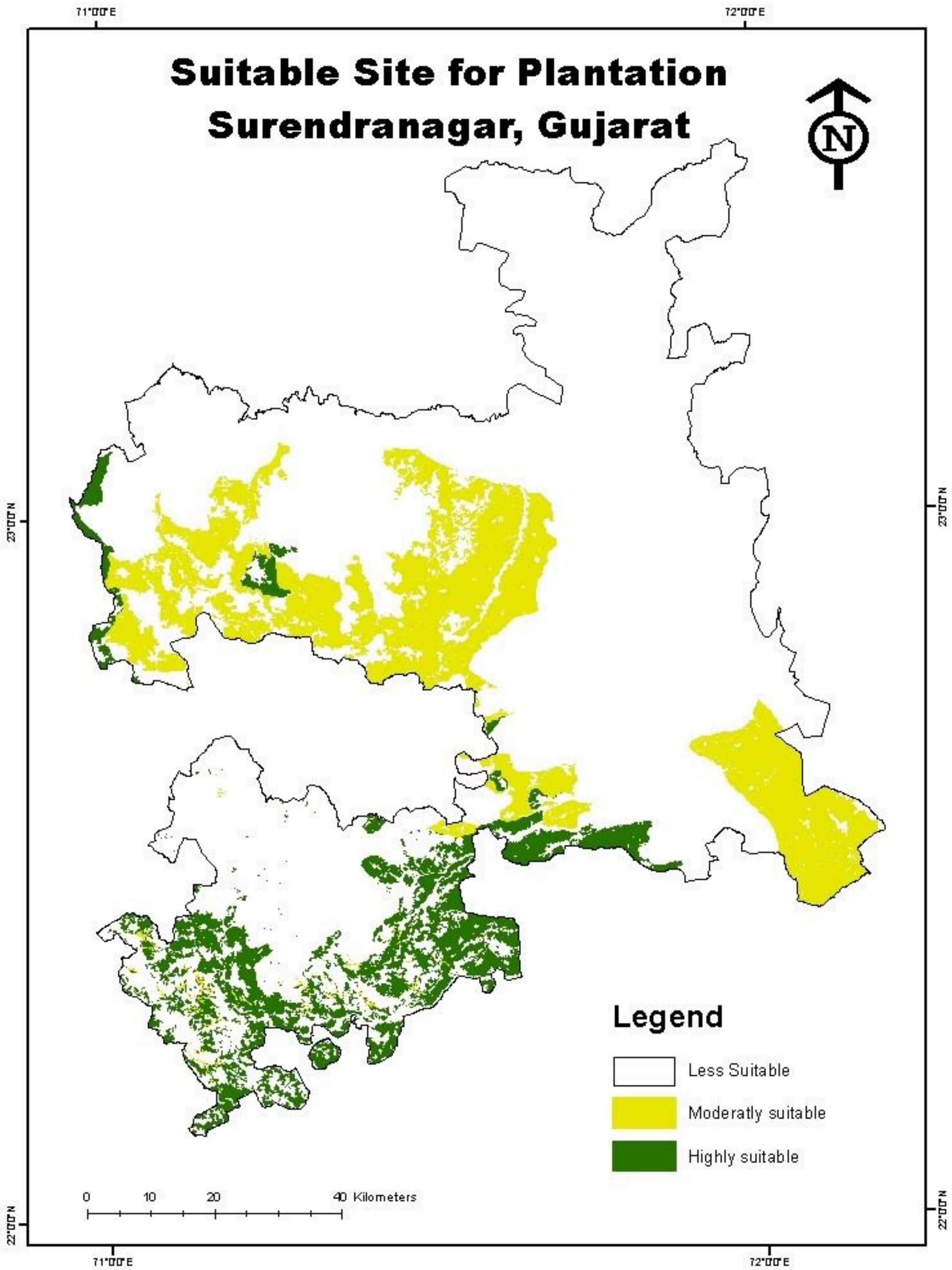

Fig 4.11: Suitability Map for Plantation using Model building

Chapter 5

CONCLUSION

The study has demonstrated the use of AHP and Model Building which is integrated to determine the suitability of the land in the district of Surendranagar, Gujarat which is mainly for various uses based on geo-environmental criteria. The selected thematic layers are geomorphology, soil, slope, land use and groundwater were considered as primary criteria and weights for criteria, and sub-criteria were assigned by MCDA analysis. Weight for each and every parameter is derived from AHP process. The pair-wise comparison matrix is performed for decision making and assign optimal weights to the criteria and the consistency ratio of 0.095038, 0.095174, and 0.093663 was obtained which is less than 10 % that had endorsed the accuracy of comparison matrix, although previous literature contains many examples of Model Building and AHP using GIS for the suitable site selection, to the best of our knowledge none have used restriction datasets, threshold criteria and selection criteria together, where it gives more accurate results. Generally noticeable is that the South, South–West, Central and partial part of Northern part of Surendranagar have larger percentage area for ‘highly suitable’ and ‘moderately suitable’ land for the selected parameters which includes High rise building construction, Plantation and Horticulture. In this study relative importance of each and every parameter is considered by determining weightage factor using Saaty’s method and based on weight derived from Saaty’s method, final suitability map is derived in GIS environment. Nevertheless, the study has demonstrated the advantages of using AHP in the analysis and solution of such complicated decisions and can provide helpful guidance for land use planning, decision makers and famers for agriculture.

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