SITE SUITABILITY ANALYSIS FOR INDUSTRIES USING GIS AND MULTI CRITERIA DECISION MAKING

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ABSTRACT:

Developing countries have to be very cautious in utilizing the land as they affect the food security, cause damage to environment and an ecological imbalance might be created in the process of establishing industries to raise the standard of living of the people from poverty. India, as a developing nation with sufficient amount of arable land at present is producing surplus food which is sufficient for all the population, in the recent decades loosing productive agricultural land without proper scientific solution for industries. This is a major concern because it causes not only food scarcity but dependency on the other nations even though we have lot of industries. We need to maintain a balance between Agriculture and manufacturing sectors to have smooth run of the country's economy. The purpose of the study is to assess the land use changes in the areas for recent years which have potential for industrial establishment through land suitability analysis (LSA) to emphasize both agriculture and industries with sustainable development. Geographic information Systems (GIS) and Multi Criteria Decision Making (MCDM) are combined to distinctly identify the suitable zones for industries. Six criteria in Analytical hierarchy Process (AHP) and nine criteria in Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) are evaluated by spatial analysis using ArcGIS software. Considerable amount of productive agricultural land is diverted to non agricultural purposes during last 12 years i.e., from 2004 – 2016, which is at first taken for industrial establishment. Results obtained by the methodology we followed have given considerable accuracy by cross checking the previously established industries with suitability regions. Thus GIS and MCDM can assist the policy makers and planning officials to get a better overview with the resources they possess to carry forward with less damage to environment and agricultural land...

1. INTRODUCTION

Global trepidation for food security and quality of living for succeeding generations and increasing cognizance of environmental degradation pose serious questions to the accomplishments of science and technology. Similar to many other resource management plans, land resource planning includes resource allocation difficulties and the challenge is to devise complex, spatially and temporally interdependent patterns of uses to achieve frequently conflicting goals. Solving issues and making decisions about land resources, demand integration of data and knowledge from various disciplines.

1.1 Need for site suitability

Establishment of industries is in the very interest of the societal development but not for the individual or political gains. Some of the industries established in the state during past decade made this study inevitable. It is completely necessary to setup industries as it generates employment which in turn increases the income source of the people which makes not only the individuals economically stable but also the economy of the state at large. It is not exaggerating to say that it is of national importance as it is directly related to stability of the national economy. The rate of population growth of late has increased drastically and people with unemployment has grown at a proportionate scale which is a very critical thing to be thought off otherwise it may lead to crisis in the country causing a irreparable damage. With this kind of challenge ahead there is complete necessity to setup industries and India being an agriculture dependant nation and with lot of population has to take care of agriculture lands while establishing the industries. Ray (1998) stated that the agriculture sway for a huge chunk of nationwide production in third world nations, it is essential for this sector to prosper so as to contribute workforce to the other sectors. Growth of the industrial sector will able to only flourish if agricultural production is higher than its manufacturer's necessity.

1.2. GIS & Multi Criteria Decision Making (MCDM)

Successful formulation of policies for land usage requires analysis of land usage details to make sure that site selected for certain purpose is appropriate . Land use planning consists of identification, suitability analysis, conflicting judgments in comparative analysis. Many problems associated with real world have spatial factor involved in them. MCDM and GIS can be able to solve them efficiently with their computational capabilities, which implicitly became a platform to the majority of the problems that are required for better planning. Multi criteria Decision Making can be classified into Multi Attribute Decision Making (MADM) and Multi Objective Decision Making (MODM). MCDM is used as a general term including both attribute and objective. The objective of Multi Attribute Decision Making (MADM) analysis is to select the most preferable alternative. There are lots of decision making

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methods that can be used to solve the MADM problems. Additive decision methods are widely accepted to solve the MADM problems along with ideal point methods. Analytical Hierarchy process (AHP) is one of the additive decision methods which is used in lot of real world problems as well as non spatial problems. Breaking complex problems to simple form by hierarchy or levels and then integrate mathematical computation for pair wise comparison and normalization which results in priority vectors also known to be criteria weights.

1.3. Role of Remote Sensing and GIS

Availability of data is vital to perform any type of analysis. Remote Sensing has made that vital component accessible at an incredible level and GIS has played its part in analyzing the data obtained through the former and combination of both has made the primary task of analyzing very easy compared to the earlier days, which used to take many number of days to manually perform a field visit and then prepare a strategy to start the work. Remote sensing has reduced the effort of man power by the help of technology at an astounding manner.

Remote sensing can provide data of land use, topography, drainage pattern, type of soil, etc.. GIS has the capability to store, retrieve, manage and perform analysis using both spatial and non spatial data. Integration of spatial and non-spatial data and handling capacity made GIS a superior tool in the field of geo-spatial world.

A set of criteria are considered to evaluate using MCDM techniques. Data has to be prepared to process and analyze. Cartosat-1 PAN & LISS IV Multi spectral (MSS) are used to prepare some data. High spatial resolution and multi spectral will make distinction in different features more precise.

2. STUDY AREA

The study is conducted in three districts of North coastal Andhra Pradesh i.e., Visakhapatnam, Vizianagaram, Srikakulam.

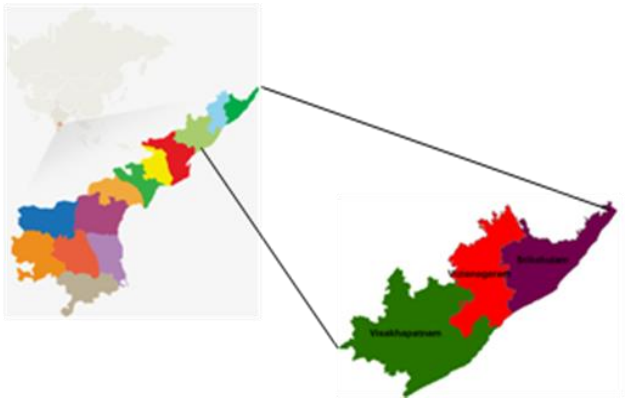

Fig 1: Study area

Visakhapatnam District is one of the North coastal districts of Andhra Pradesh and it lies between 17°15' & 18°32' N and 18°54' & 83°30' E. It has two distinct geographic regions. The district has rich deposits of Bauxite Apatite (Rock Phosphate) Calcite, Crystalline limestone confined to tribal tracts. Bauxite deposits at Sapparla, Jerrila and Gudem of G.K.Veedhi mandal are known to be the largest in the country.

Vizianagaram district is a part of north coastal plains of Andhra Pradesh and lies between $17^0$15’ & $19^0$15’N and $83^0$0’ & $83^0$45 E. The plain portion is a well cultivated tract while the hilly region is dense forest and uneven. Nagavali, Gosthani, Champavati, Vegavathi, Gomukhi rivers, which pass through plains as well as hilly regions. The forests found in the district are: Southern tropical moist mixed deciduous, north tropical dry deciduous-Sal type, Southern tropical dry–mixed deciduous forests, Dry deciduous forests, and Dry evergreen forests.

Srikakulam district is the extreme Northeastern district of Andhra Pradesh situated between the geographic coordinates 18°20’ & 19°10’ N and 83°50’ & 84°50’ E. Around 60% of land is under cultivation and 34% of the population is still dependent on agriculture. The Nagavali, Vamsadhara, Suvarnamukhi, Vegavathi, Mahendratanaya, Gomukhi, Champavathi, Bahuda and Kumbikota Gedda are the important rivers of the district. Vamsadhara, Nagavali and Suvarnamukhi rivers rises in the Eastern Ghats and finally falls into the Bay of Bengal. The major activities of the industries in Srikakulam district are Pharma, Cashew, Jute, coir, Pesticide, Pistons, Ammonium Nitrate, Rice mills, Granite, Stone crushers, Beach Sand minerals, Power & Sugar. Palasa - Kasibugga is a famous center of cashew industries in the district.

3. DATA USED

Land use and Land cover map is prepared using Linear Imaging Self Scanner (LISS) IV multi spectral and Cartosat PAN. The study area is clipped accordingly with the shape file of the area and geo rectification is done using satellite image. It is prepared at a scale of 1:10000 to have more detail of the area taken. Unsupervised classification is performed as there will be lots of classes are present in it**.**

Thematic layers	**Scale**
District administrative boundary	1:50000
District Major road network	1:10000
Water bodies	1:50000
Land use land cover map	1:10000
Flood map	1:50000
Digital elevation model SRTM DEM	30m

Table 1: Thematic layers – Scale

Geology map is obtained from Andhra Pradesh Space Applications Centre from the concerned department. North Coastal Andhra Pradesh has rock types like Granite, Khondalites, Charnockites, Quartz, Laterite, Shale stone, Gneiss complex. Selection should be done carefully by watching out the fault lines and avoid areas nearer to them to ensure stable rock to build a structure.

Elevation of the area where potential locations for industries is sited is to be known for better decision to be taken. Shuttle Radar Topographic Mission (SRTM) DEM was downloaded from a website www.dwtkns.com according to the study area and classified to classes based on elevation present at that

location. Sea level of an area is a very important factor during identification of potential sites. Sites far above the sea level increase the transportation cost are considered inappropriate and sites below the sea level are prone to floods.

Slope map is generated using SRTM DEM. Areas with gentle slope are considered more suitable for construction of large structures. Moreover, stability issues during the construction phase. Steeper slope areas are generally avoided to reduce the risk of instability during construction.

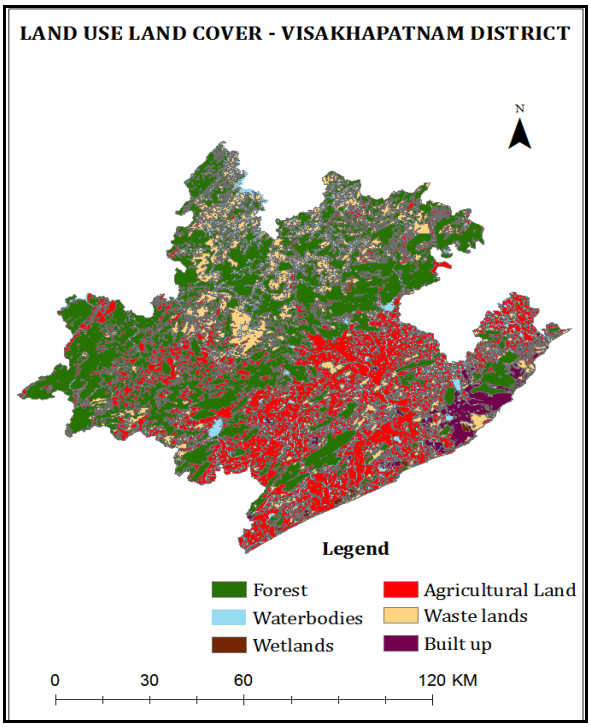

Fig 2: Land use Land cover map

Land use and Land cover maps of 2004-05 and 2015-16 are generated at level III i.e., to the level of type of crop lands and waste lands using LISS IV and Cartosat I PAN merge images. It was prepared and ground points were collected to validate the prepared maps. These maps are to assess the situation before and after the construction of industries during these years. The land use and land cover maps will also help us to locate the available locations of the established factories and land that was transformed for non-agricultural practices.

River maps of the study area are prepared using the toposheets and satellite images. Important rivers are Gosthani, Champavathi, Nagavali, Sarada, Thandava, Varaha, Vamshadhara. Flood prone areas are delineated using these river maps and flood zone maps acquired from APSPDS, Vijayawada.

Previously established industries GPS locations are collected to assess the agricultural land diversion during the time frame which I have considered. As shown in the map industries are agglomerated in the urban areas of Visakhapatnam, in and around Vizianagaram.

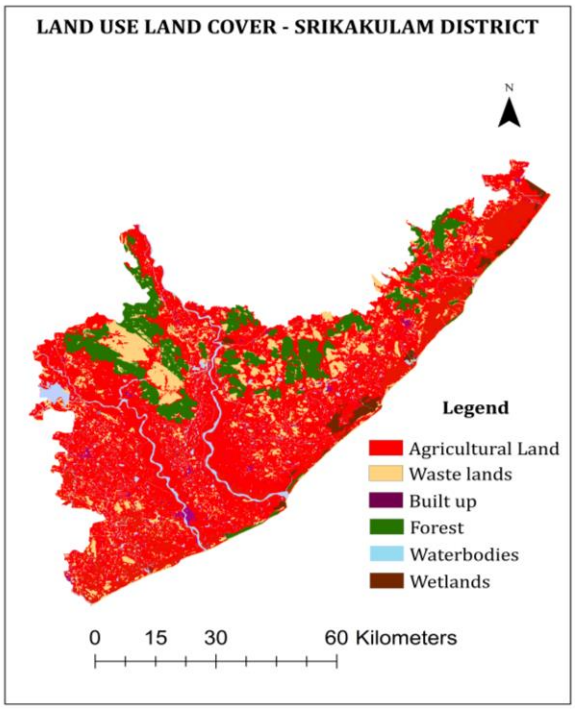

Fig 3: Land use Land cover map

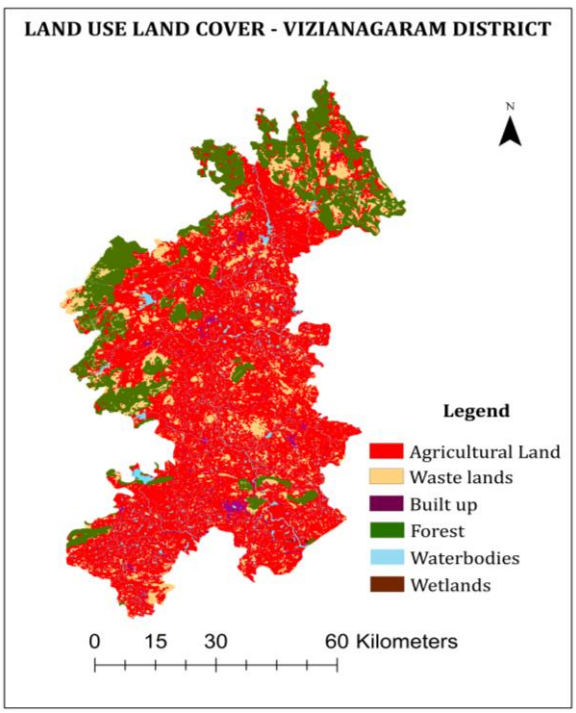

Fig 4: Land use Land cover map

Availability of labour (marginal and non-workers) at the village level is obtained as an attribute data from Department of Economics and Statistics, Govt. of Andhra Pradesh and a map is prepared using interpolation technique.

Cost of the land for the study area is prepared as it is required to integrate in the list of criteria. Data is procured as attributes and map is prepared by interpolation technique.

Ground water level is vital aspect to assess the situation of water availability to initiate any kind of construction. Piezometer readings are collected and a map was prepared using interpolation as we don't have Piezometers located all over the study area considered.

The problem of finding suitable land for establishing industries is analyzed by the following method that utilizes advanced tools to tackle the problems associated in best possible way to get the most accurate outcome for sustainable land utilization. Any sort of imbalance in land utilization can have very grave impact on the land use system. It is known fact that land is exploited in many ways and utilizing it judiciously is an achievement of a decision maker.

The first phase deals with assessing agricultural land use by Land use and Land cover map (LULC) of the time period taken for the study and the locations of already established factories in the region. Both data are analyzed along with land use before the establishment of factories and can assess the effect of improper setup of industries at improper locations without scientific solution.

Data used is prepared using different inputs.
Firstly, Study area is delineated using the satellite image of LISS (Linear Imaging Self Scanner) IV – MSS (Multi Spectral Scanner) and Cartosat I PAN (Panchromatic).
Road network of minor, major, state and national highways within the study area are drawn and a shape file is created. According to the available sources of information, to establish an industry different thresholds are to maintained. A new industrial which comes under major pollution contributor should be constructed at a suitable location which is greater than 500 meters from national highways. Industries which produce medium and low pollution can be setup at a distance of 100-500 meters from the national highways. A new industrial which comes under major pollution contributor should be constructed at a suitable location which is greater than 100 meters from state highways and other major roads. Industries which produce medium and low pollution can be setup at a distance of 50-100 meters from the state highways and other major roads

Geology was considered as it plays an important in the suitability decision of sites for industries. Strength of the rock and absence of fault zones will make the site suitable at the first place. Without this consideration, we cannot go forward in the process of site selection at any cost. The following types are present in our study area: Khondalites, Charnockites, Granite, Gneiss complex, Shale stone, Alluvium, Laterite, Quartz. The strength of the rocks is in this order.
Gneiss complex > Charnockites > Granite > Khondalites > Laterite > Quartz > Shale stone > Alluvium

Flood maps of the region are considered as it is also one of the important factors to select a site for establishing any firm. As industries are meant to be generally with medium to high investment, care should be taken in such a manner that investment is not at stake with hasty decisions. So flood zones are identified and categorized according to their scale of inundation during floods. The data collected was from past 100 years to get a better output. With the available data, areas nearer to rivers are classified into flood zones and non flood zones along the river banks. Any site which is closer to river bank may be at some time being a threat to industry; they are avoided at all times.

Elevation is also considered as one of the criteria to identify the area which is at an elevation suitable to locate a site as the elevation goes on increasing, the cost of raw materials reaching the site, cost of fuel, constructing difficulties etc., come into picture. So using Shuttle Radar Topographic Mission (SRTM) DEM- 30 meters, study area is segregated to classes. Area which is under 100 meters is considered to be highly suitable, 100 and 200 meters as moderately suitable, 200 to 300 as less suitable, more than 300 meters as not suitable.

Slope map provides us the information such as the slope of the area which is also very crucial for ease for construction and stability at later stages. Based on the steepness area is divided into classes. Slope is calculated in percentage
0 – 2 as level or nearly level, 2 – 6 as Very gently sloppy, 6 – 12 strongly sloppy, 12 – 20 moderately steep sloppy, above 25 as steep sloppy.

3.1 Analytical Hierarchical Process (AHP)

Spatial AHP is termed by Siddique et al., 1996 for the purpose of multi criteria decision analysis that integrates GIS and AHP. In this project Spatial AHP is used to spot suitable sites for industries and to quantify the levels through categorization and usage of knowledge, facts based user preference and data contained in GIS maps. The most difficult assignment in carrying out land suitability analysis approach for an exacting land use type is to assign the relative weights of the entity criteria that are to be considered. Thus, the study limited the criteria to the nine most important aspects.

Saaty's Nine point scale

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over the other	Experience and judgment slightly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance is demonstrated in practice
9	Extreme importance	Evidence that favor one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between two adjacent judgments	When compromise is needed
Reciprocals	If activity i is assigned to one of the above numbers compared to activity j, then j has the reciprocal value compared to i	
Rational	Ratios that arise from the scale	if consistency were to be forced by obtaining n numerical values to span the matrix

Fig 5: Saaty's nine point scale

AHP is divided into three stages:
I) Decomposition - Identify and structure the criteria
II) Comparative judgment - through pair wise comparison
III) Aggregating the priorities - Calculate suitability index
This fig depicts whole procedure of AHP for establishing industries. Structuring the ladder is comparatively subjective activity and depends on decision maker's skill and experience. Criteria are to be considered based on the importance of user's requirement.

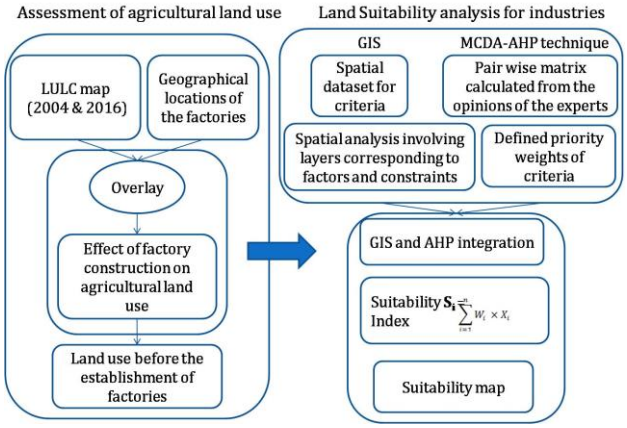

Fig 6: Methodology for AHP

First step in finding out suitability is

i) weigh the attributes associated with each criterion (attributes of thematic layers)
ii) weigh the criteria layers (thematic layers)

The first stage is to determine the significance of attribute values associated with decision factors and the second stage of weighting derives the relative importance of criteria.

Pair wise comparison is to derive relative importance and it involves these steps:

i) Development of comparison matrix
ii) Compute relative importance in criteria and attributes of criteria separately
iii) Calculate consistency measure and consistency index

Comparison matrix is derived based on 1 – 9 scale measures of preference developed by Saaty. Once the comparison matrix is obtained, weight assigned to each criterion is determined by normalizing the eigenvectors of the comparison matrix. Normalization of eigenvectors is done by dividing individual element by sum of the column elements.

CRITERIA	LULC	FLOOD	GEOLOGY	ELEVATION	ROAD NETWORK	SLOPE
LULC	**1.0000**	0.2000	0.2000	5.0000	5.0000	1.0000
FLOOD	5.0000	**1.0000**	1.0000	3.0000	5.0000	3.0000
GEOLOGY	5.0000	1.0000	**1.0000**	5.0000	7.0000	3.0000
ELEVATION	0.2000	0.3333	0.2000	**1.0000**	3.0000	0.2000
ROAD NETWORK	0.2000	0.2000	0.1429	0.3333	**1.0000**	0.2000
SLOPE	1.0000	0.3333	0.3333	5.0000	5.0000	**1.0000**

Table 2: Pair wise comparison matrix- expert opinions

Once consistency measure is calculated, we will now determine consistency index by using following formula. It is based on study of λ either greater or equal to number of criteria for positive, equal matrices or λ = n for consistent matrix.

$$CI = (\lambda - n)/(n - 1) \quad \text{..... Equ 1}$$
$$= (6.6433\text{-}6)/(6 - 1) = 0.1286$$

CI provides the deviation from consistency and then we calculate consistency ratio (CR)

$$CR = CI / RI \quad \text{..... Equ 2}$$
$$= 0.10$$

Where RI is randomly generated pair wise matrix. A value of CR < 0.1 gives reasonable consistency.

The last step of AHP is to aggregate the following equation od suitability index (Si)

$$\sum_{i=1}^{n} W_i \times X_i \quad \text{..... Equ 3}$$

S_i suitability index, W_i is the weighted vector of the criteria, Xi is relative weight of the criteria map.

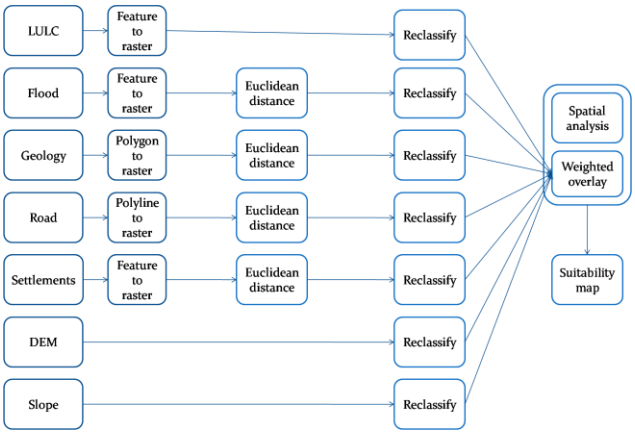

Fig 7: GIS model to implement AHP technique

3.2. Sensitivity analysis:

Sensitivity analysis is a method used for evaluating how sensitive the spatial multicriteria model output is to small changes in the input values. This approach aims at analyzing the effects of introduced perturbations in the input values on the output (criterion outcomes).

The two most important essentials to consider in sensitivity analysis are criterion weights and attribute values. Out of these, sensitivity to attribute weights is perhaps more important. If the ranking of alternatives proves to be sensitive to one or more weights, the accuracy in estimating weights should be inspected carefully.

In the present context of site suitability analysis for industries, suitability map is generated. The weights of criteria we have are changed at a certain percentage to find out the changing pattern of the suitability map within the classes of suitability from original weights of criteria.

Criteria	Weights
LU/LC	0.130896
Flood	0.296936
Geology	0.326998
Road Network	0.035088
Elevation	0.064213
Slope	0.145868

Table 3: Priority vectors from weighted decision matrix

In here we have performed the sensitivity analysis in such a way that one criterion is increased by 1 percent & rest of the criteria are decreased by same and the process continues with each and

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criteria to visualize the changes in the suitability map produced. The same process is done by changing the weights by 2, 3, 5 percent.
This table shows the change in the suitability levels according to the change in priority vectors.

	Original weights	1 percent change	2 percent change	3 percent change	5 percent change
Land use & Land cover	0.1308	0.1322	0.1335	0.1348	0.1374
Flood	0.2969	0.2939	0.2909	0.2880	0.2820
Geology	0.3269	0.3237	0.3204	0.3171	0.3106
Elevation	0.0642	0.0635	0.0629	0.0622	0.0610
Road network	0.0350	0.0347	0.0343	0.0340	0.0333
Slope	0.1458	0.1444	0.1429	0.1414	0.1385

Table 4: Percentage of suitability areas from sensitivity analysis

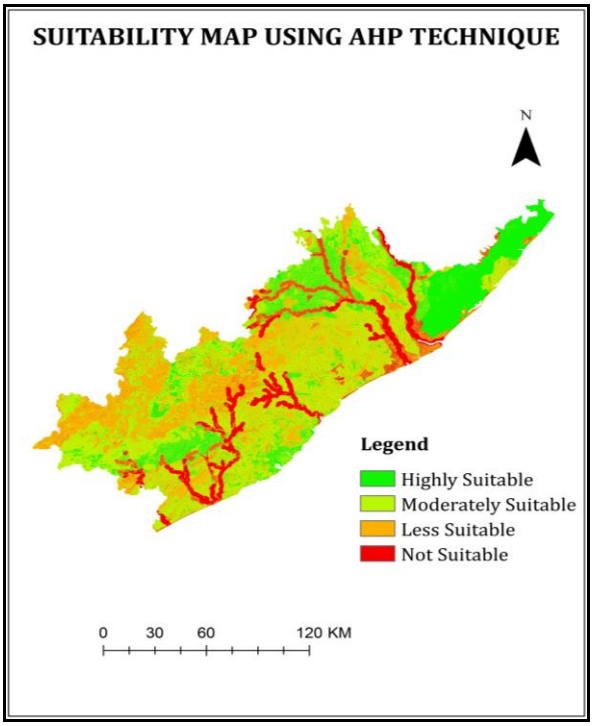

Fig 8: Suitability map to establish industries using AHP

4. RESULTS AND DISCUSSIONS

4.1. Suitability map using GIS and MCDM

The following result is from aggregate of all the criteria considered i.e., individual thematic layers are multiplied to the respective priority vectors obtained from pair wise comparison matrix of Analytical Hierarchy Process. Suitability map of the region is classified to classes from not suitable to highly suitable based on the cumulative evaluation of the criteria and weightages given to them at criterion level as well as attribute level. In this analysis to obtain a suitability map, geology and flood were given more weightages as they can’t be ignored while considering any area for any industrial establishment. Some of the area in Visakhapatnam and Srikakulam districts is found suitable according to the criteria selected and evaluation done but due to constitutional authority possessed by the land which comes under agency area of this district cannot be selected for any large scale industrial establishment as this area is a place for indigenous tribes.

4.2. Sensitivity Analysis

This is generally performed to check the uncertainties and variations of the criteria. Naturally uncertainty prevails when we deal real world problems. To analyze the situation in a better possible way we take this sensitivity analysis as an option to address the issue. This analysis is generally done because most of the times the criterion values are provided by human beings and they possess inherent bias towards some criteria selected in any of the problem considered for MCDM. To understand the change by which we can be able to get a better idea in decision making. Here, we have done slight changes in the values of priority vectors such that Land use and land cover’s priority vector’s value is raised by 1 percent and values of remaining priority vectors are reduced by 1 percent. Thus, a very slight change in the suitability is noticed. Suitability area with 1 percent change in land use and land cover has increased by 1 percent. and rest of the classes remain almost same

Suitability levels	Suitability map	1 percent change suitability map
Not suitable	3.9610	3.9147
Less suitable	12.258	12.1664
Moderately suitable	33.204	33.2439
Suitable	34.546	34.7575
Highly suitable	16.030	15.9172

Table 5: Percentage of suitability areas from sensitivity analysis (1 percent change in land use land cover)

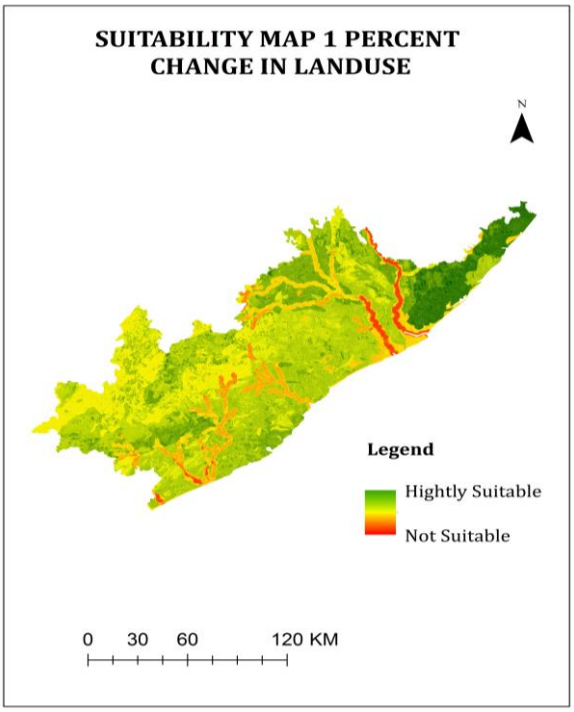

Fig 9: Suitability map with 1 percent change

The same operation is performed at a change of 5 percent to detect the change with considerable detection in the change of suitability classes. LULC’s priority vector’s weight was reduced by 5 percent and the remaining criteria are increased by 5 percent to observe the change occurring.

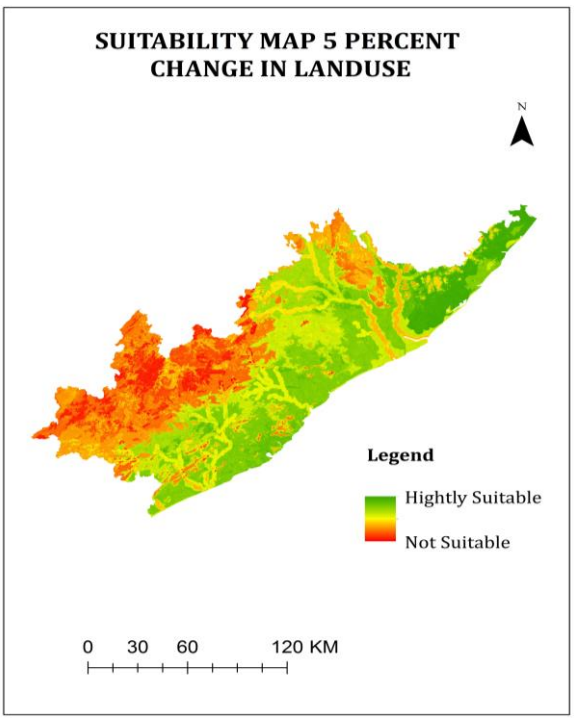

Fig 10: Suitability map with 5 percent change

Suitability levels	Suitability map	5 percent change suitability map
Not suitable	3.9610	15.9823
Less suitable	12.258	24.0520
Moderately suitable	33.204	24.2007
Suitable	34.546	25.7958
Highly suitable	16.030	9.9690

Table 6: Percentage of suitability areas from sensitivity analysis (5 percent change in land use land cover)

Here, regions which came under suitable are at some places changed to unsuitable or moderately suitable, making the task meaningful which proves that this kind of analysis is required when we address these kinds of problems.

4.3. Conclusions

The spatial way of identifying the potential industrial sites and the necessity to include decision maker’s preferences in the analysis require a combination of GIS and MCDA methods. Their synergy resulted in the MC-SDSS, which is an efficient tool for integrating DM’s preferences regarding industrial sites analysis for feasible areas with the help of multi criteria methods. A real world case study in the three districts of north coastal Andhra Pradesh i.e., Visakhapatnam, Vizianagaram, Srikakulam was conducted, enabling the performance of various environmental and economic criteria in the screening of industrial sites location problem. This region is selected particularly as there is dire need to save the available land which is productive and at the same time, remaining region of the state which is productive is losing the land at a very rapid rate. As the time is ripe to maintain both agriculture as well as industries for smooth running of the region without any chaos with unemployment and food scarcity, this area has gained my attention to work. With the problem at hand and short listing the important factors necessary for the solution are considered. Main factors being land use and land cover detail, geology of the area, elevation and slope of the region, viable road network to make the work easier at least in the initial stages. Evaluation process was conducted with the help of some expert opinions and individual perspective who provided the necessary judgment to fill the comparison matrix. Finally suitability maps were generated by AHP. Finding the potential industrial sites using different techniques gives us a better picture to assess the problems associated in it. Uncertainty is an inherited feature while we deal with real world problems. So, we performed sensitivity analysis by changing the criterion weights to certain percentage to estimate the area changes within the classes of suitability and to decide the suitability area. The conducted analysis is not measure to the method’s superiority in that problem solving. Various methods work better way for different inputs we have provided to them and the decision maker’s necessity. A GIS based land suitability analysis extends the utilization of overlay operators to the decision maker’s preferences. Some of the multi criteria methods have to be investigated later to get a better results. Development of new computational methods in GIS environment makes it interesting for improving the efficiency in evaluating the industrial establishment process.

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