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Geospatial analysis to assess the potential site for coal based thermal power station in Gujarat, India

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ABSTRACT

The advanced space technology known as Remote sensing and GIS is a perfect tool for Geo Spatial applications in science and engineering. In the present study, identification of suitable site for Thermal Power Plant along the mining area in Rajpardi district of Gujarat, India is one of the evidence of Geospatial technology for mankind development. Multi-spectral satellite data and collateral data of geology, geomorphology, topography, settlement and transport, forest cover, hydrology and climate were used to generate the integrated thematic database in GIS platform for selecting the suitable site for Thermal Power Station (TPS) construction. Selection of site for TPS was based on four primary criteria, such as land, water, coal mine and environment, and two secondary criteria, namely settlement and accessibility to the site. A Site-Suitability Index (SSI) is processed the multi spatial parameters according to the regulatory guidelines of MoEF (Ministry of Environment and Forest) and CEA (central Electricity Authority). Each class in spatial layers is assigned with weighed value 1 to 10 based on the relative importance to suitability. The sum of Weightage of spatial layers using weighted overlay analysis, the result have been classified as high, medium, low and not suitable

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Key Words: GIS, Remote sensing, Site-Suitability Index, Weighted overlay, Thermal power station, India.

INTRODUCTION

At present 54.09 percent (93918.38 MW) of total electricity production in India is from Coal Based Thermal Power Station. This coal source is from the coal mines either surface or sub surface mining from the various part of Indian sub continent. A coal based thermal power plant converts the chemical energy of the coal into electrical energy. This is achieved by raising the steam in the boilers, expanding it through the turbine and coupling the turbines to the generators which converts mechanical energy into electrical energy [1]. Selection of suitable sites for waste disposal in the surrounding of urban area can be done by analysis of several environmental factors using GIS. (i.e.) it is one of the spatial analyses such as weighted overlay analysis help to select the possible suitable solid waste disposal sites and is categorized in to three categories. Remote Sensing data provides ground information with micro scale and GIS can integrate the various spatial and non spatial parameters based on the assigned Weightage and processed to find the suitable site for waste disposal with enhanced accuracy [2].

Degree of accuracy in site suitability analysis is based on the analysis of multi layers integrated in complex relationship of one another based on the suitability analytical method. The differential weighting of input parameters attributes and the proposed method of standardization is adopted in the process [3]. The spatial variation of attributes within each factor is not uncommon because most datasets come with inherent natural variability. Standardization is therefore necessary to make it commensurable for a site suitability analysis [4]. The assigned Weightage of classes is also an important aspect of a site suitability analysis. Assigning the weight to particular parameter is depending upon the degree of suitability to the site selection [5], [6].

The classification and the weighting schemes determine the cell values of raster layer have an effect to determine the weight of individual cell in site suitability analysis. In some approach, it is a process of deriving a composite map through the linear combination of input factors [7]. Soil parameter is one of the important factors in site selection studies. The productivity characteristic of soil is determine the environment and ecosystem of the local area and considering the important soil properties such as depth, base saturation, texture and structure, organic matter content, mineral reserve and soil moisture are essential factors in agricultural land and forest development, while selection of site for infrastructure and construction these factors required to take for analysis throughout the area [8]. Remote sensing imagery is used to detect the changes of land use and land cover in spatially and temporally. In the land use land cover changes studies between 1991, 1999 and 2009 from the satellite image data, it is predicted that the positive and negative changes among the all types of land covers, but however, the land use of infrastructure increased up normally along the urban periphery and agriculture and other natural vegetation cover is decreased rapidly [9]. In a discrete classification system, the attributes of an input factor may be classified using various classification schemes. Most modern GIS have built-in classification schemes such as equal area, equal interval, natural break, and quantile and standard deviation functions [10].

The main objective of this study is to assess the problems raised in extraction of the coal from the mine to ecosystem of the local area and their influences on cyclic environmental processes. The potential site for coal based thermal power plant is must required to survey and assess the impact of the plant on environment for long time. The integrated Remote sensing and GIS technology have capability to process multiple spatial datasets of an area for selecting the suitable site for thermal power plant construction.

Introduction to the Study

The study on Evaluation of Suitable Site for Coal Based Thermal Power Station in Rajpardi Mining Area in Gujarat is carried out to prove Geospatial technology is effective and economical in research and development. Analyzing Spectral Signatures of Lignite composition in multispectral Remote Sensing data LANDSAT 7 ETM+ (30 mts) covered Lignite Mining of Rajpardi area of Bharuch District in Gujarat to target the distribution of Lignite coal reserve bed. Indian subcontinent proved with coal reserves was about 92,445 million tons in which Bituminous and Anthracite coal reserves are about 90,085 million tons and lignite is about 2,360 million tons. India is at fourth place in coal reserves in the world and the production of coal in India every year is nearly 447.3 million tons. However all production is used for indigenous purpose only. Indian Government is planning to supplement 100,000 MW of electricity for increasing its installed capacity to 300,000 MW by year 2017. Out of which, 59,000 MW will be generated from coal-based Thermal Power Stations.

Location of Study area

The lignite mining area of Rajpardi in Bharuch Dist, Gujarat is one of the well known places in India for geological and mineralogical aspects. The selected study area is located 5km away from Rajpardi Township towards south. This is bounded by latitude extension in about $21^0\ 00'\ 00''$N to $21^0\ 14'\ 15''$ N and longitude extension is from $73^0\ 21'\ 00''$ E to $73^0\ 38'\ 13''$ E. The river Narmada is flowing in west 32km away from the study area and Deccan hilly terrain lies in the South and South-East to the study area. Plain area of Rajpardi Township located in north and other settlements namely Hingoria, Vasna and Dholakuva are located in North East, South and South-West direction respectively.

Relief and Drainage

Relief covers different elevation due to accumulation of dissected hilly area. In the east part the elevation is about 300m and it gradually decreases up to 200m in the central alluvial plain, then increase towards west up to 340m elevation from MSL. Two major tributaries of R. Narmada flow from South East towards North-West through middle portion and join with Narmada River in North West. Number of streams with parallel drainage pattern flowing from various direction and join with major tributaries of River.

Geological settings over the Lignite reserved

The sub surface lignite reserve bed vector layer overlaid on the geological features to find out the interpretation among them. From this overlaying analyze the maximum lignite reserve bed distributed over the ferruginous sand stones with mixture of clay pebbly sand stone and conglomerate which found in lower Miocene age. However lignite also associated with the clay mixed

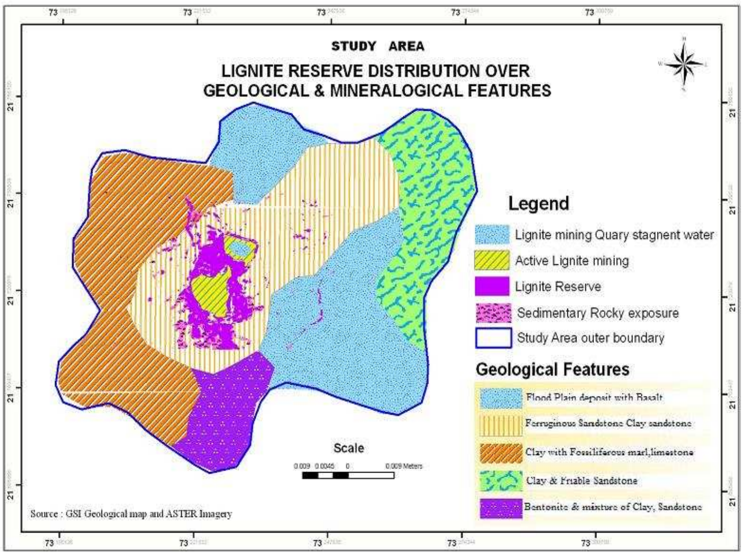

Fig.2. Geological features in the study area

fossil ferrous marl, limestone, sandstone and siltstone conglomerate in the North West part and small portion of lignite also distributed over flood plain deposited of Basalt and alkali basalt in south middle portion of study area.

Geomorphology

Four types of geomorphic units such as hilly area in east and south east which covered with Pediplain sedimentary distributed along central, north, north east and south part. The central alluvial plain distributed in northwest and south portion in covered the area extent is about 3.72 Sq.km. From the central position towards west Dissected carbonadoes sedimentary is distributed and which

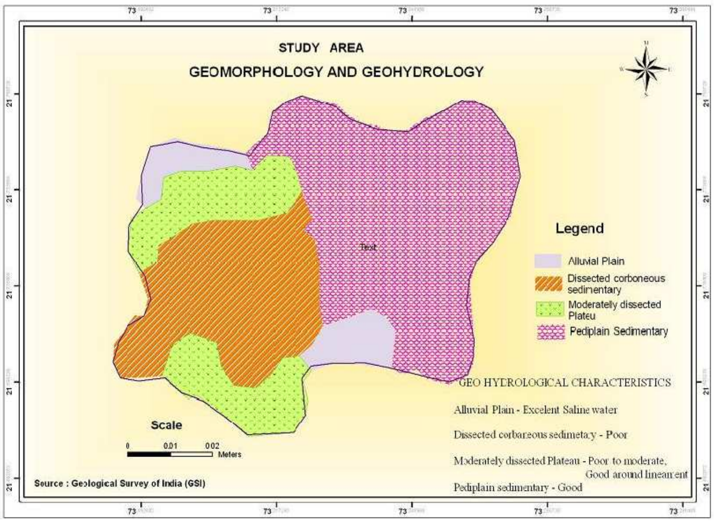

Fig 3.Geomorphology of the Study area

- associated with Pediplain sedimentary moderately dissected plateau and moderately dissected plateau covered adjacent to Carbonaceous sedimentary in both north west and south part of study area is about 8.54 Sq.km. The excellent saline water is occurred at low level bed in Alluvial plain. Poor and poor to moderate ground water condition in Dissected carbonaceous rocky and Moderately dissected plateau respectively. Ground water level is good in and around the lineaments which passing through these regions.

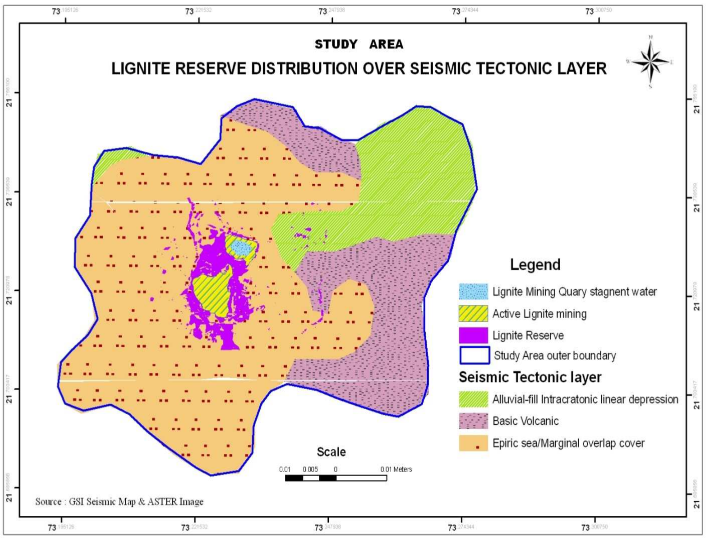

Fig.4. Seismic Tectonic Plates in the study area

In the Pediplain sedimentary, water condition is good to moderate which is also depending on surface water sources.

Seismic tectonics and Lignite reserve bed interrelationship

The Bougher gravity anomaly of -30 M.Gal gravity contour line is passing through north portion of lignite reserve bed, which indicates the area lines is moderate risk zone of seismicity, the whole part lignite reserve bed distributed on the Epiric sea/marginal overlap cover of seismic tectonic layer. Besides this in the east part of study area lignite reserve bed flow over Basaltic Volcanic Plates.

Slope and lignite reserve bed Interrelationship

The steep slope flow 366 mts height and gentle slope from 354mts in north-east towards middle. The lignite reserve bed distributed at the elevation is about 220mts to 200mts MSL towards North to south. However the over burden material covered over the lignite reserve bed is about 65 to 75 feet only, hence it is subsurface reserve bed.

Land use/ land cover

Generally, surrounding of mining area under agricultural land. In the West part of study area accumulated with upland vegetation (open scrub which occupied the area extent is about 7.72 Sq.km) and rocky and along the upland scrub forest cover distributed from South towards North is about 3.10 Sq.km. East side covered with one time crop land which includes Fallow land and currently cultivable land, it is distributed around 8.14 Sq.km. In the mid part exist mine is about 2.7 Sq.km around the mining area and the overburden materials were dumped here and there. Lignite reserve bed occupied under sub

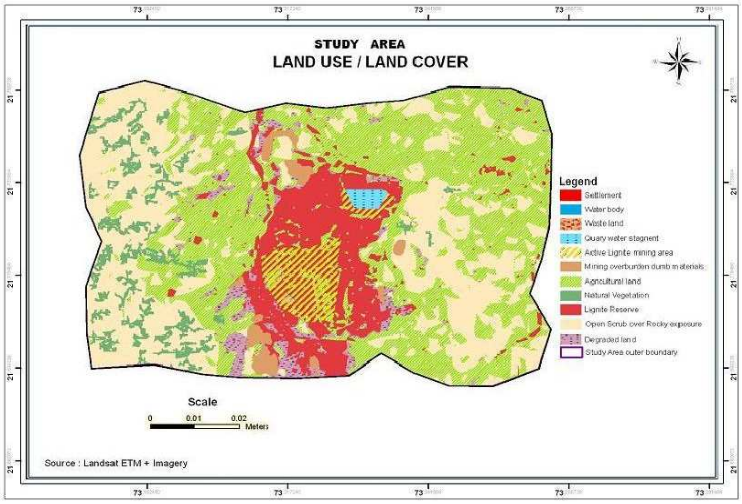

Fig.6. Land use / Land cover along the Lignite reserve bed

- surface from North to South is about 6.97 Sq.km along them current mining is going on. Settlements and built-ups are isolated which located in North- East part and West to mining region, which covered 4.02 Sq.km.

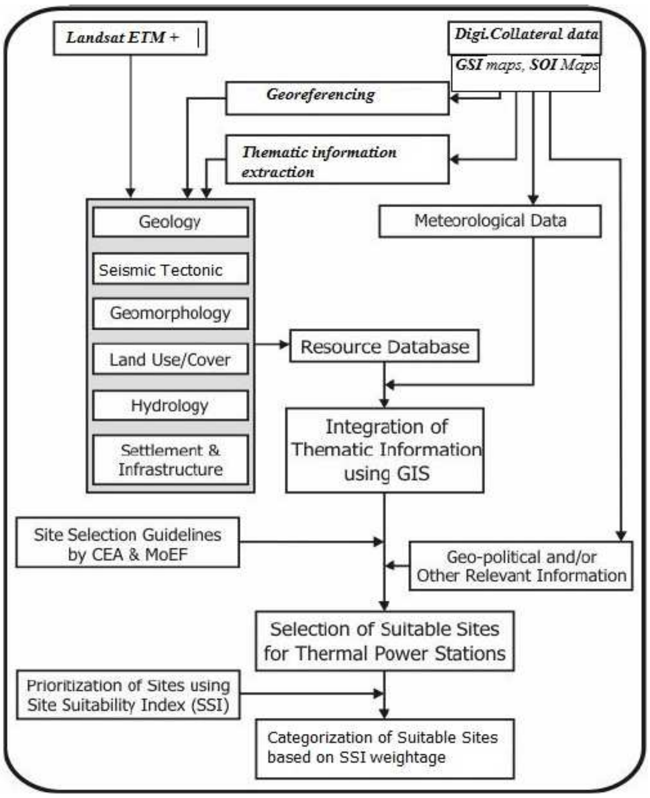

Fig.7. A flow diagram showing methodology for site selection for TPS

Geospatial Data Analysis for Suitable Site Selection

The following types of data were collected for this study such as, Landsat ETM+ imagery (30mts Spatial Resolution), SOI Toposheets, Geological and Geomorphological maps.

Methodology

Digital satellite data were processed using Digital Image Processing System. Pre-processing of data was carried out to correct for geometric and radiometric distortions to eliminate noise and to enhance the spectral and spatial frequency domain. Landsat ETM + imagery was used to explore the lignite reserve bed by processing of spectral signature of lignite gathered from USGS spectral library using spectral target detection tool in ERDAS Imagine 9.2 and land use and land cover were extracted by using Supervised Classification through Maximum likelihood classifier technique. Other thematic information like geology,

geomorphology, and Boundaries of the coal basin and the communication network such as roads, railway lines, administrative boundaries, canals and major settlements/infrastructures were digitized from GSI maps and SOI topo sheets respectively. All thematic vector layers were integrated and introduced in to overlaying and weightage analysis to carry out Site Suitability Index (SSI) using spatial analyst tool in Arc GIS 9.3 to target potential sites for TPS.

Site Suitability Index

Potential site for TPS have been evaluated from the analysis of geospatial data using computerized GIS soft ware by following analysis; Selection of sites for TPS was based on four primary criteria, such as land, water, coal and environment, and two secondary criteria, rehabitation and accessibility to the site. Ranking (order of priority) was done based on the above mentioned criteria to select the best site for TPS surrounding each coal basin.

Guidelines of CEA & MoEF for Site Selection for Thermal Power Plant in India :

Guidelines of Ministry of Environment & Forest [MoEF], Government of India, for site selection of coal-based thermal power stations:

(i) Locations of thermal power stations are avoided within 25 km of the outer periphery of the following:
   (a) metropolitan cities;
   (b) National park and wildlife sanctuaries;
   (c) Ecologically sensitive areas like tropical forest, biosphere reserve, important lake and coastal areas rich in coral formation;
(ii) The sites should be chosen in such a way that chimneys of the power plants does not fall within the approach funnel of the runway of the nearest airport;
(iii) Those sites should be chosen which are at least 500 m away from the flood plain of river system;
(iv) Location of the sites are avoided in the vicinity (say 10 km) of places of archaeological, historical, cultural/religious/tourist importance and defense installations;
(v) Forest or prime agriculture lands are avoided for setting up of thermal power houses or ash disposal.

Guidelines of Central Electricity Authority [CEA], Government of India, for site selection of coal-based thermal power stations:

(a) The choice of location is based on the following:
   (i) Nearness to coal source;
   (ii) Accessibility by road and rail;
   (iii) Availability of land, water and coal for the final installation capacity;
   (iv) Coal transportation logistics;
   (v) Power evacuation facilities;
   (vi) Availability of construction material, power and water;
   (vii) Preliminary environmental feasibility including rehabilitation and resettlement requirements, if any;
(b) Land requirement for large capacity power plant is about 0.2 km^2 per 100 MW for the main power house only excluding land for water reservoir (required if any).
(c) The land for housing is taken as 0.4 km^2 per project.
(d) Land requirement for ash pond is about 0.2 km^2 per 100 MW considering 50% of ash utilization. Land for ash pond is considered near the main plant area (say 5 to 10 km away). In case of non-availability of low lying ash pond area at one place, the possibility of having two areas in close proximity is considered.
(e) Water requirement is about 40 cusecs per 1000 MW.
(f) First priority is given to the sites those are free from forest, habitation and irrigated/agricultural land. Second priority is given to those sites that are barren, i.e. wasteland, intermixed with any other land type, which amounts to 20% of the total land identified for the purpose.
(g) Location of thermal power station is avoided in the coal-bearing area.
(h) Coal transportation is preferred by dedicated marry-go-round (MGR) rail system. The availability of corridor for the MGR need to be addressed while selecting the sites.

Fig.8. MoEF and CEA Guidelines for TPS

For each of the primary and secondary criteria allocated 10 weightage points, respectively, were given which sums up to a total of 100 weightage points. Each criterion was further divided into a number of sub-criteria with equal weightage points. Available standards and guidelines of Government of India were taken into account while fixing the sub-criteria. A procedure for calculating site-suitability index (SSI) based on the above criteria was designed in order to quantify subjectivity of the regulatory guidelines and other related parameters used in the selection process.

The parameters considered for the ranking of spatial features and normalized calculations according to guide lines of CEA and MoEF are given as follows

1. Environment [Round(0.250xE)
2. Land [Round(0.250xL), where L=(L1+L2)]
3. Requirement of rehabilitation & resettlement (R&R) [R=R1]
4. Water [Round(0.250xW), where W=(W1+W2+W3)]
5. Coal [Round(0.667xC), where C=(C1+C2+C3)]
6. Total Points [Environment + Land + R&R + Water + Coal + Accessibility]
7. Fig 9. Weightage allocation and Algorithm of Site Suitability Index

(1) Environment [Round(0.250xE), where $E=(E_1+E_2+E_3+E_4+E_5+E_6+E_7+E_8)$]	?
(a) The proposed TPS site is at a distance beyond 25 km from the outer peripheries of metropolitan cities.	$[E_1=10xP_1]$
(i) True	$[P_1=1]$
(ii) False	$[P_1=0]$
(b) The proposed TPS site is at a distance beyond 25 km from the outer peripheries of national parks, wildlife sanctuaries, and ecologically sensitive areas like tropical forests, biosphere reserves, national parks & sanctuaries, important lakes and coastal areas rich in coral formations.	$[E_2=10xP_2]$
(i) True	$[P_2=1]$
(ii) False	$[P_2=0]$
(c) The proposed TPS site is at a distance beyond 10 km from the outer peripheries of places of archaeological, historical, cultural/religious/tourist importance and defense installations.	$[E_3=10xP_3]$
(i) True	$[P_3=1]$
(ii) False	$[P_3=0]$
(d) The proposed TPS site does not fall in the approach funnel of the runway of the nearest airport.	$[E_4=10xP_4]$
(i) True	$[P_4=1]$
(ii) False	$[P_4=0]$
(e) The proposed TPS site does not utilize forest or prime agriculture land.	$[E_5=10xP_5]$
(i) True	$[P_5=1]$
(ii) False	$[P_5=0]$
(f) The proposed TPS site is at a distance beyond 5 km from the high tide line (HTL) (for coastal areas only).	$[E_6=10xP_6]$
(i) True	$[P_6=1]$
(ii) False	$[P_6=0]$
(g) The proposed TPS site is at least 500 m away from highway(s).	$[E_7=10xP_7]$
(i) True	$[P_7=1]$
(ii) False	$[P_7=0]$
(h) The proposed TPS site is at least 500 m away from the flood plain of the Riverine System.	$[E_8=10xP_8]$
(i) True	$[P_8=1]$
(ii) False	$[P_8=0]$
(2) Land [Round(0.250xL), where $L=(L_1+L_2)$]	?
(a) Land use/cover	$[L_1=10xP_9]$
(i) Wasteland	$[P_9=4]$
(ii) Wasteland with scrubs	$[P_9=3]$
(iii) Wasteland with scrubs mixed with 20% single-cropped agriculture land	$[P_9=2]$
(iv) Wasteland with scrubs mixed with more than 20% single-cropped agriculture land	$[P_9=1]$
(b) Terrain	$[L_2=10xP_{10}]$
(i) Flat	$[P_{10}=4]$
(ii) Flat to gently undulating	$[P_{10}=3]$
(iii) Gently undulating	$[P_{10}=2]$
(iv) Undulating	$[P_{10}=1]$
(3) Requirement of rehabilitation & resettlement (R&R) [$R=R_1$]	?
(a) R&R activities	$[R_1=10xP_{11}]$
(i) Required	$[P_{11}=0]$
(ii) Not required	$[P_{11}=1]$
(4) Water [Round(0.250xW), where $W=(W_1+W_2+W_3)$]	?
(a) Quantity of water available in the vicinity of the proposed site	$[W_1=10xP_{12}]$
(i) $[AW_R/A_Y]$% is less than 20%	$[P_{12}=4]$
(ii) $[AW_R/A_Y]$% is between 20% to 40%	$[P_{12}=3]$
(iii) $[AW_R/A_Y]$% is between 40% to 60%	$[P_{12}=2]$
(iv) $[AW_R/A_Y]$% is between 60% to 80%	$[P_{12}=1]$
(v) $[AW_R/A_Y]$% is more than 80%	$[P_{12}=0]$
* (b) Requirement of reservoir/dam/barrage for water intake of the proposed plant	$[W_2=10xP_{13}]$
(i) Not required	$[P_{13}=3]$
(ii) Increase in capacity of old structure(s) required	$[P_{13}=2]$
(iii) New structure(s) required	$[P_{13}=1]$
* (c) Aerial distance of the proposed site from the water source $[W_3]$	$[W_3=10xP_{14}]$
(i) Distance in km (use normalized points^)	$[P_{14}=?]$
(5) Coal [Round(0.667xC), where $C=(C_1+C_2+C_3)$]	?
(a) Availability of required amount of coal for the proposed plant	$[C_1=10xP_{15}]$
(i) Available	$[P_{15}=1]$
(ii) Not Available	$[P_{15}=0]$
# (b) Aerial distance of the proposed site from coal source	$[C_2=10xP_{16}]$
(i) Distance in km (use normalized points^)	$[P_{16}=?]$
# (c) Presence of railway network and/or MGR for coal transport	$[C_3=10xP_{17}]$
(i) Present	$[P_{17}=1]$
(ii) Absent	$[P_{17}=0]$
(6) Accessibility [Round(0.125xA), where $A=(A_1+A_2+A_3)$]	?
(a) Road (in 10 km radius)	$[A_1=10xP_{18}]$
(i) National highway	$[P_{18}=3]$
(ii) State highway	$[P_{18}=2]$
(iii) Any other road	$[P_{18}=1]$
(iv) No road	$[P_{18}=0]$
(b) Railway network (in 10 km radius)	$[A_2=10xP_{19}]$
(i) Main line	$[P_{19}=3]$
(ii) Branch line	$[P_{19}=2]$
(iii) Any other line	$[P_{19}=1]$
(iv) No railway line	$[P_{19}=0]$
(c) Airport	$[A_3=10xP_{20}]$
(i) Within 200 km of the proposed site	$[P_{20}=2]$
(ii) More than 200 km of the proposed site	$[P_{20}=1]$
Total Points [Environment + Land + R&R + Water + Coal + Accessibility]	?

* Proceed only if W_1 is not zero
\# Proceed only if C_1 is not zero
^ Normalized points (for P_{14} & P_{16}) = $(D_1-D_2)/D_1$,
where D_1 = Most far-away site among the selected sites,
D_2 = Aerial distance of the proposed site
Annual water requirement $[AW_R]$ = 892999.233xW_R in cubic meter,
where W_R = water requirement for the power plant in cusec (cubic foot per second)
Annual yield $[A_Y] = (A_R \times C_A)$ in cubic meter
where A_Y = annual yield of the catchment in cubic meter,
C_A = area of the catchment in square meter, and
R_A = annual runoff in meter.

RESULTS AND DISCUSSION

The Lignite reserve distribution over the study area has been derived from Remote sensing data by analyzing spectral signature using Digital Image Processing technique. The lignite reserve and other parameters which described above have been selected according to the guide lines of MoEF [11] and CEA [1]. Each data converted in to vector layer registered in UTM WGS 84 geocentric coordinate system (why means Shapes are preserved) with appropriate attribute information. For example, in the layer of Land use/ Land cover, waste land with water and distance from the lignite reserve bed, transport facility and distance from the settlement area, it weighted with 10, 8, and 6 per 2 Km distance respectively. One time crop land had weighted by higher than multi crop cultivable land. The sub surface features like Geological, Seismic anomaly and hydro geomorphological suitability also considered with specific weightages. Then all layers were transferred in to ESRI Grid format based on weightages in terms of their suitability level. Multi Criteria Analysis (MCA) was carried out by inputting this layer to calculate the overall weightages using GIS software through Site Suitability Index algorithm (SSI). (Table.1).The raster product of the result of MCA using SSI reclassified into three categories based on total Weightage. They classified raster applied with ranking as per suitability. That is maximum weighted area(rank I) showed in dark shade which has highly suitability, medium weighted area (rank II) has moderately suitability and weightage is less area (rank III) has least suitability for TPS respectively. The positional coordinates of derived suitable sites overlaid on the SOI toposheets with 1: 25000 scales in order to check the accuracy of suitability and for further study.

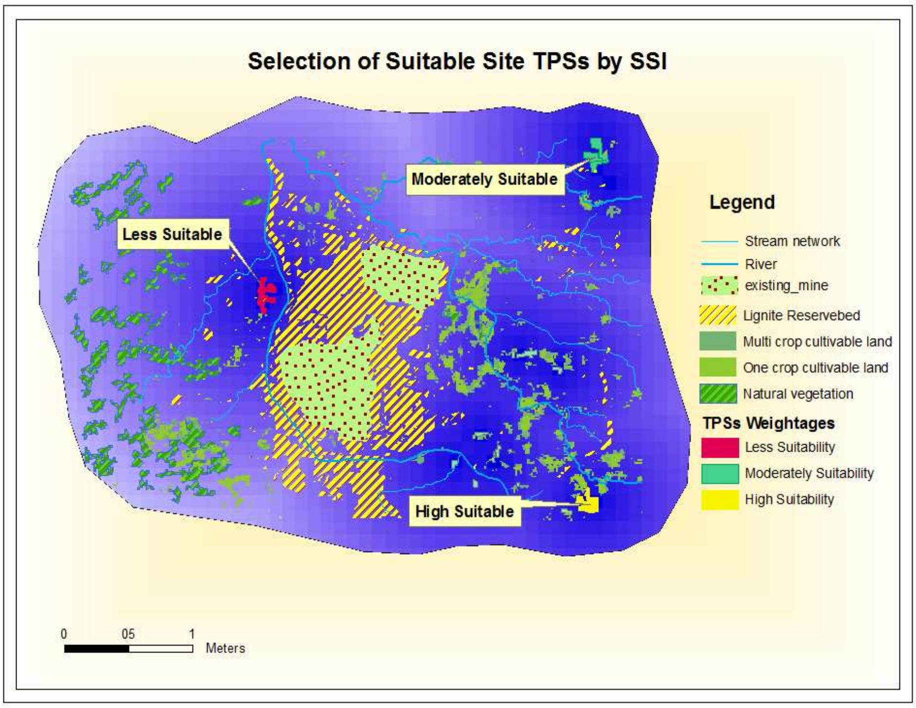

Fig.10. Suitable site for Thermal Power Station construction in the study area

CONCLUSION

The present study has proved significance and necessity of Geospatial technology for resource analysis and utilization. In the study, there are two concepts of research were carried out to select the Potential site for thermal power station around the Coal mines in Gujarat, such as Satellite imagery and its spectral signature used to detect the distribution of Lignite coal reserve bed. Second one is selection of potential sites for TPS by considering many geological and environmental features as per MoEF and CEA, Govt of India guidelines. This is provided the significant accuracy as primary level survey and it is ultimate in terms of economical and time saving. The analysis of MCA – SSI has been effectively produce results to target suitable sites. Such as, in the South-East part of the lignite mine have evolved as highly suitable sites then West to the existing mining region near the rural settlement has less suitability. The moderately suitable area have identified in North – West of the Coal reserve bed, by improving some facilities like transport and water and they have enhanced the potential of the area as suitable for thermal power plant construction.

REFERENCES

[1] Central Electricity Authority of India (CEA), **2011**, http://www.cea.nic.in/reports/yearly/annual_rep/2009-10/ar_09_10.pdf

[2] Tamilenthi S, Chandramohan K, Vijayalakshmi P, Suja Rose RS, *Journal of Advances in Applied Science Research*, **2011**, 2(6), 379 - 392.

[3] Basnet BB, *Geographic information system based manure application planning (Ph.D. dissertation)* University of Southern Queensland, Australia, **2002**, pp 87.

[4] Burrough PA, *Geographic objects with intermediate boundaries, Chapter 1: Natural objects with indeterminate boundaries*, Talylor and Francis, UK, **1996**, pp 23-28.
[5] Burrough PA, MacMillan RA, Van Deursen W, *Journal of Soil Science*, **1992**, 43, 2, 193 - 210.
[6] Hong Jiang, Eastman R, *Int. Geographical Information Sciences*, **2000**, 14, 2, 173 - 184.
[7] Chrisman NR, *Exploring geographic information systems*, John Wiley & Sons, Canada, **1997**, 91-103.
[8] Punithavathi J, Tamilenthi S, Baskaran R, *Journal of Advances in Applied Science Research*, **2011**, 2(3), 525 - 235.
[9] Punithavathi J, Tamilenthi S, Baskaran R, Mahesh R, *Journal of Advances in Applied Science Research*, **2012**, 3(2), 986 - 993.
[10] Mitchell A, *The ESRI guide to GIS analysis*, ESRI Press, Redlands, California, **1999**, pp
[11] Ministry of Environment and Forest (MoEF), *Guide lines for Industries and Impact Assessment*, **2011**, http://moef.gov.in/citizen/specinfo/enguin.html.