

Evaluation of potential pit-head sites for coal-based thermal power stations based on site-suitability index (SSI) using geospatial information

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Evaluation of potential pit-head sites for coal-based thermal power stations based on site-suitability index (SSI) using geospatial information

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Abstract

Multi-spectral satellite data along with other relevant collateral data on geology, geomorphology, topography, infrastructure, forest cover, hydrology and meteorology were used to generate integrated thematic information on GIS platform for selecting sites for pit-head, coal-based Thermal Power Stations (TPSs). Selection of sites for TPSs was based on four primary criteria, namely land, water, fuel (coal) and environment, and two secondary criteria, namely resettlement & rehabilitation (R&R) and accessibility to the site. 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. Ranking or 'order of priority' was done based on the SSI to select the best site for TPSs surrounding each coal basin.

For each of the primary and secondary criteria 20 and 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 were taken into account while fixing the sub-criteria. The site-suitability index (SSI) for each selected site was arrived at based on weightage points scored for all the six criteria. Potential sites were ranked according to the SSI. The SSI has been effectively used in prioritizing selected sites for pit-head coal-based TPSs.

Introduction

India 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 pit-head, coal-based Thermal Power Stations (TPSs). About 26,380 million tonnes of geological coal reserve has been identified in 15 coal basins of India for installation of the above to generate the required amount of power.

Satellite remote sensing data together with collateral data on geology, topography, hydrology, meteorology, etc., were used to identify the potential sites in a radius of 50 km from the coal source already identified for the purpose. In some coal basins, 100 km radius was considered where suitable sites were not available in 50 km radius. The proposed installation capacities of the TPSs range from 1000 MW to 10,000 MW based on the availability of coal.

The present work demonstrates the use of geospatial information in selecting potential sites for TPSs and in evolving a site-suitability index (SSI) in order to rank these sites.

Geospatial Data Analysis for Site Selection

Data Source

IRS-ID/LISS-III satellite data of the year 2003 was used in the present study along with other relevant collateral data. The collateral data included: (i) geological maps of coal basins from Geological Survey of India [GSI] (ii) maps from Coal India Ltd. [CIL] and its subsidiaries showing coal source blocks (iii) topographical sheets of Survey of India [SoI] (iv) forest cover map of the area from Forest Survey of India [FSI] (v) power grid map of India from Power Grid Corporation of India [PGCI] (vi) meteorological data from nearest monitoring stations of Indian Meteorological Department [IMD] (vii) specific guidelines of CEA for power projects (viii) specific guidelines of MoEF for power projects (ix) hydrological information from Central Water Commission [CWC] and State Irrigation Departments.

Methodology

Digital satellite data were processed using *Geomatica v.8.x* digital image processing system. Pre-processing of data was carried out to correct for geometric distortions, eliminate noise and calibrate the data radiometrically. As number of scenes covers the study area of each coal basin, master image of each basin including its surrounding areas was produced by merging adjacent scene data with the help of ground control points (GCPs). Polyconic projection along with modified Everest Ellipsoidal model was applied in order to make these images compatible with

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 km² 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 km² per project.
- (d) Land requirement for ash pond is about 0.2 km² 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.

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.

the SoI topographical sheets. Contrast stretching was applied to the image data to accentuate the contrast between features in the image.

The enhanced satellite images were analyzed using interpretation keys evolved from image and geo-technical elements. The images were segmented using these keys to extract layered thematic information on geology, geomorphology, land use/cover, etc. Boundaries of the coal basin and coal source blocks were digitized from the maps obtained from GSI and CIL. Communication network such as roads, railway lines/ existing marry-go-round rails,

administrative boundaries, canals and major settlements/infrastructures were digitized from the satellite data with the help of SoI topographical sheets into different layers of the image database. Existing TPSs along with power distribution network were digitized from PGCI maps into separate layer. Areas of influence for the vector/point data were generated. All thematic information were integrated using *MapInfo v.6.x* GIS.

Meteorological data on rainfall, humidity, temperature, wind flow pattern, etc. were integrated with the resource database. The site selection guidelines of CEA and MoEF were considered while selecting the potential sites. Catchments surrounding the potential sites were identified and preliminary estimation was carried out on water availability near the sites based on

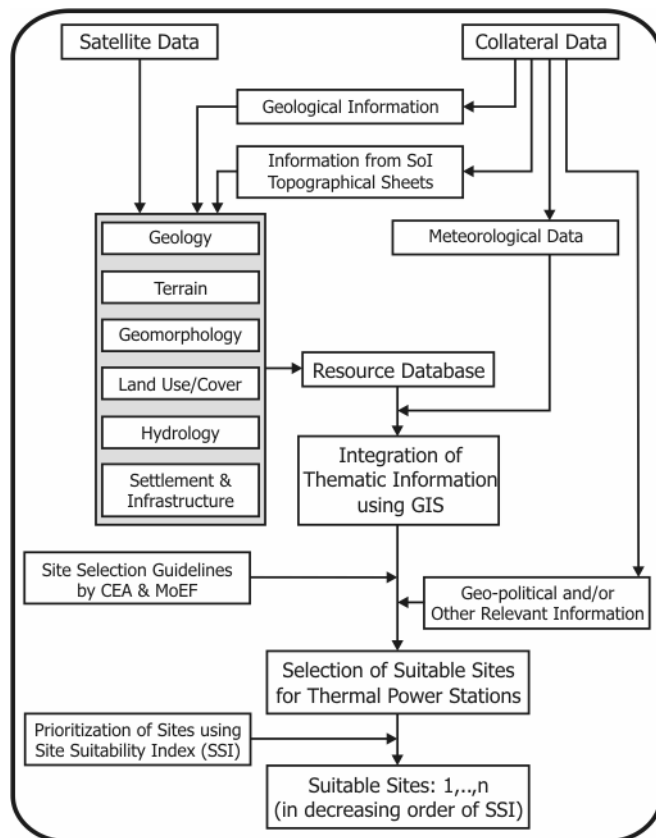


Figure-1: Flow diagram showing methodology for site selection based on geospatial information.

annual yield of the catchments and surface runoff. A flow diagram showing methodology for site selection based on geospatial information is given in **Figure-1**.

Land use/cover maps of each of the TPS sites were generated. Selective ground truthing was carried out in order to collect ground information and to verify the land use classes present in these sites. Site-suitability analysis was carried out in order to find out various alternative site scenarios.

Site Suitability Index

Infrastructural development projects follow certain standard procedures of survey and investigation before implementation. The stages are: (i) Preliminary Report (ii) Pre-feasibility Report (iii) Feasibility Report (iv) Detail Project Report. The present work was carried out during the preliminary stage.

Selection of sites for TPSs was based on four primary criteria, namely land, water, fuel (coal) and environment, and two secondary criteria, namely R&R and accessibility to the site. Ranking or 'order of priority' was done based on the above-mentioned criteria to select the best site for TPSs surrounding each coal basin; the purpose of this selection was to provide sites with least socio-economic, environmental and infrastructural development costs and best return in power generation.

For each of the primary and secondary criteria 20 and 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 study and normalized calculations are given in **Table-1**. The site-suitability index (SSI) for each selected site was arrived at based on weight-points scored for all the six criteria. Potential sites were ranked according to the SSI.

Conclusion

The present study has demonstrated the use of geospatial information in selecting potential sites for thermal power stations. Site suitability index (SSI) was designed to quantify subjectivity of the regulatory guidelines and other related parameters used in the selection process. The SSI has been effectively used in prioritizing the selected sites for setting up pit-head, coal-based thermal power stations with a cumulative capacity of 36,200 MW in the vicinity of Talcher, Ib-River, Korba, Mand-Raigarh, Singrauli, Tatapani-Ramkola, North Karanpura and Rajmahal coal basins of India.

Table-1: Site suitability analysis matrix for the proposed pit-head, coal-based TPS

(1) Environment [Round(0.250x E), 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(0.250x L), 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		$[P_{11}=1]$

Table-1: Site suitability analysis matrix for the proposed pit-head, coal-based TPS (Contd...)

(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]		?
<p>§ Proceed only if W_1 is not zero</p> <p>@ Proceed only if C_1 is not zero</p> <p>& 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</p> <p>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)</p> <p>Annual yield $[A_Y] = (A_R x C_A)$ 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.</p>		

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