SITE SELECTION FOR NUCLEAR POWER PLANTS USING GEOGRAPHIC INFORMATION SYSTEM AND ANALYTICAL HIERARCHY PROCESS
A Case Study on Khulna Division, Bangladesh

by

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This study aims to find a suitable site for a nuclear power plant using the geographic information system and analytical hierarchy process in the Khulna division, Bangladesh. Selection of a suitable site for a nuclear power plant is vital for the safety of the installation, workers, the public, and the environment. This study was conducted considering four stages, namely conceptual and planning, area survey, site characterization, and site confirmation stage. In the area survey stage, six criteria were divided into twelve sub-criteria, namely population density, earthquake, river, riverbank erosion, airport, road and railway, protected area, forest, groundwater table, rainfall, wind speed, and thunderstorm. A suitability map of each sub-criterion was made using geographic information system software. The weighting of each criterion was determined using an analytical hierarchy process and finally, a geographic information system-based overlay analysis was performed to prepare the final suitability map of the Khulna division which indicates 315.30 km^2 and 2991.27 km^2 of its total area as the most suitable and suitable, respectively for nuclear power plant establishment. Twenty-six potential areas were selected from the most suitable areas for further study. This study follows a comprehensive methodology and thus may help policymakers for the establishment of nuclear power plants in Bangladesh and abroad.

Key words: Bangladesh, nuclear power plant, geographic information system, analytical hierarchy process, suitability map

INTRODUCTION

Electricity is generated from various sources following different technologies throughout the world. Hydropower, nuclear, coal, gas, biomass, geothermal, wind, tidal, and solar energies are the main sources of power generation and most of the sources generate power by rotating a steam turbine. Nuclear technology of power generation is the most advanced and reliable form of clean energy among these technologies. A nuclear power plant (NPP) is a thermal power plant, where nuclear fission produces thermal energy followed by electrical energy. The world is facing a threat due to increasing global warming, so the generation of clean and sustainable energy is in demand. Power generation from nuclear energy is a sustainable and safe source of energy that reduces greenhouse gas emissions, unlike fossil fuels. The use of nuclear energy to generate electricity comes with several advantages over traditional electricity generation sources, *i. e*., low carbon emissions, low operations and fuel costs, balanced distribution of fuel sources across the globe, and long operational periods [1]. Therefore, there is a growing interest in harnessing energy from an NPP in developing countries. As of May 2023, the World Nuclear Association reported that there were 436 nuclear power reactors in operation, and 59 nuclear power reactors under construction [2].

Bangladesh is known as an agro-based economic country with a large population. However, it has undergone a significant change in the economy through industrialization in the last twenty years. Industrialization has become the major socio-economic development factor in Bangladesh which is drifting the national power genera-

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tion. At present, the growth of electricity demand is around 9-10 %, which is expected to increase further in the coming years [3]. Thus, the government has a vision to achieve a total generation capacity of 40000 MW by 2030 and 60000 MW by 2041 against the cure generation of 22512 MW [3]. In this perspective, the Bangladesh government is introducing two units of NPP in Rooppur, Pabna, which are expected to be commissioned in 2024 and 2025 with a combined capacity of 2400 MW [3]. Besides, the site selection process for the 2nd NPP is going on in the southern part of Bangladesh [4].

According to the safety regulations of the IAEA, it is important to select an appropriate site before installing an NPP [1]. The characteristics of the selected site directly affect the NPP design, construction costs, and construction time, thus site selection and the evaluation process are essential for the safe installation and operation of nuclear facilities [5]. Therefore, the present study aims to find a suitable site for the establishment of NPP in Khulna division which is situated in the South-Western part of Bangladesh.

A site selection process consists of four stages; namely conceptual and planning stage, area survey stage, site characterization stage, and site confirmation stage [6, 7]. The geographic information system (GIS) and the analytical hierarchy process (AHP) were used in this study as a part of the conceptual and planning stage and area survey stage. The main six criteria (climatological criterion, geological criterion, sociological criterion, pedological criterion, hydrological criterion, and ecological criterion) were divided into twelve sub-criteria in the area survey process. The final suitability map helped to find out the most suitable, suitable, moderately suitable, unsuitable, and completely unsuitable area in the Khulna division for the establishment of NPP.

MATERIALS AND METHODS

Study area

There are eight divisions in Bangladesh. The Khulna division is the third largest division of Bangladesh with an area of 22285 km^2. The location of Khulna division on the world map is situated at 21°40' north latitude to 24°12' north latitude and 88°34' east longitude at 89°57' east longitude [8]. Figure 1 shows the map of the area under study (Khulna division) for this study.

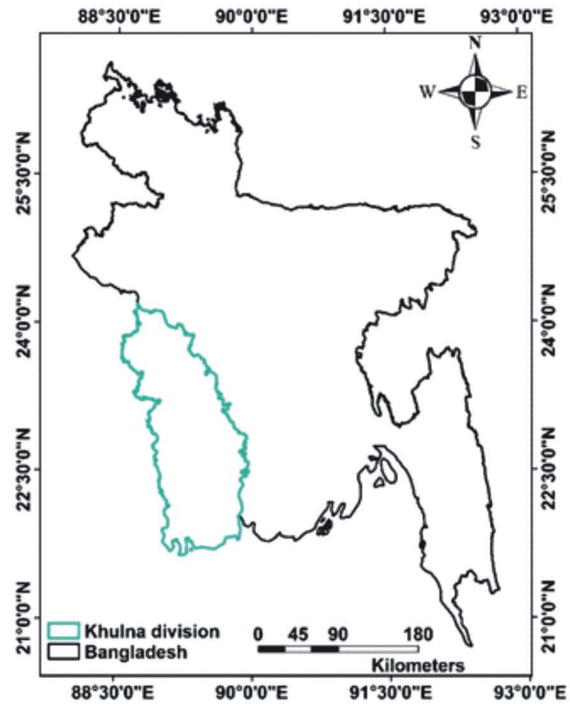

Figure 1. Map of the study area

Input data

As mentioned earlier, in the current study six criteria (climatological criterion, geological criterion, sociological criterion, pedological criterion, hydrological criterion, and ecological criterion) were divided into twelve sub-criteria (population density, earthquake, river, riverbank erosion, airport, road and railway, protected area, forest, groundwater table, rainfall, wind speed and lightning). The vector point data of some sub-criteria (population density, earthquake, airport, protected area, groundwater table, rainfall, wind speed, and thunderstorm) and 1:1000000 scale data of others sub-criteria (river, riverbank erosion, road, and railway, and forest) were collected from different national organizations for this study. The final suitability map was prepared using these data in a GIS environment.

Methodology

The siting methodology for this study has been developed in four stages, namely the conceptual and planning stage, area survey stage, site characterization stage, and site confirmation stage. In the conceptual and planning stage, the methodology to establish an NPP has been prepared. During the area survey stage, relevant vector data have been assembled on a regional scale. Data used for sub-criteria, namely population density, earthquake, groundwater table, rainfall, wind speed, thunderstorm, airport, and protected area are the vector point data, and river, river bank erosion, road, railway, and forest are the vector polyline or polygon data. At this stage, the suitability map of each sub-criterion was made based on the grading scale of each sub-criterion, tab. 1. The suitability map of each sub-criterion was converted to a raster map using GIS for overlay analysis. Finally, the overlay anal-

Table 1. Criteria classification and grading of the sub-criteria applied in this study

Criteria	Sub-criteria	Classification guideline (Classification was done according to international practices and experts' judgment based on the environmental setting of the region under study)	Classification considering study area	Grading (x_{ij}) 0 – Excluded area 1 – Completely unsuitable 2 – Unsuitable 3 – Moderately suitable 4 – Suitable 5 – Most suitable
Geology	Earthquake (Magnitude on Richter's scale)	Different magnitudes represent different amounts of shock, such as 2.5-slight, 4-strong, 5-very strong, 7-disastrous, 8.5-catastrophe, and, >8.5-great catastrophe [7]. A lower-magnitude earthquake zone is suitable for an NPP according to IAEA [9]	>8.5 7-8.5 5.5-7 4-5.5 2.5-4	1 2 3 4 5
Climatology	Rainfall [mm]	The area that has a low rainfall rate is preferred over that which has a high rainfall rate [10]. Grading for this sub-criterion was made considering the highest and lowest value of annual rainfall in the Khulna division [7]	1850-1950 1750-1850 1650-1750 1550-1650 1450-1550	1 2 3 4 5
	Wind speed [Knots]*	Dominant wind areas should not be considered in NPP site selection [11]. The wind speed sub-criterion was classified based on the maximum and minimum values under the study area [7]	5.5-6.5 4.5-5.5 3.5-4.5 2.5-3.5 1.5-2.5	1 2 3 4 5
	Thunderstorms (Days per year)	Lightning is an atmospheric electrostatic discharge (spark) accompanied by thunder, which typically occurs during thunderstorms [12]. The lightning flashes striking directly a structure can cause: immediate mechanical damage; fire and/or explosion; injuries to people; and failure or malfunction of electrical and electronic systems [13]. Thus the area with low probable thunderstorms is preferable. The thunderstorm sub-criterion was classified based on the maximum and minimum values under the study area [7]	87-95 79-87 71-79 63-71 55-63	1 2 3 4 5
Social/ economical	Population density (per km^2)	The [14] was used to classify the population density sub-criterion. low population density area is more suitable for an NPP establishment	>20000 1000-2000 500-1000 100-500 0-100	1 2 3 4 5
	Road and railway [km]	Power plants should be constructed close enough to roads and railways to lessen the construction costs, but very close to the roads and railways may be harmful to pedestrians in case of an accidental incident. Thus, a distance of 1 km from major and 500 m from minor roads has been avoided in different studies [15]	0-0.5 >7 5-7 3-5 1-3 0.5-1	0 1 2 3 4 5
	Airport [km]	According to the Bangladesh Atomic Energy Regulatory Authority safety guide, a nuclear power plant should be 5 km and 8 km away from small and major airports, respectively [7]	0-5 5-7 7-9 9-11 11-13 >13	0 1 2 3 4 5
Hydrology	Groundwater table [m]	The [16] states that a groundwater table under 30 m is most suitable for NPP siting. The [16, 17] was used to grade the groundwater table sub-criterion	<5 5-15 15-25 25-30 >30	1 2 3 4 5
	River [km]	Distance of water resources within 3 km of an NPP is most suitable [5]. The [7] indicates that the distance of the river within 1 km is excluded	0-1 >9 7-9 5-7 3-5 1-3	0 1 2 3 4 5
	Riverbank erosion [km]	Riverbank erosion should not occur with such frequency that can affect any kind of nuclear installation. The [7] was used to grade this sub-criterion	0-2 2-4 4-6 6-8 8-10 >10	0 1 2 3 4 5
Pedology	Forest [km]	An NPP site should not be built in forested area [18]. Forest 500 meters around it, was considered as an exclusion area in this study	0-0.5 0.5-1 1-2 2-3 3-4 >4	0 1 2 3 4 5
Ecology	Protected area (Wildlife life, eco-park, safari park) [km]	The [15] claims that an NPP site shouldn't be placed in a protected area, hence, around 1 km area of protected zone was considered as excluded	0-1 1-3 3-5 5-7 7-9 >9	0 1 2 3 4 5

*1 Knots = 0.514 ms^{-1}

ysis using GIS software and the multi-criteria analysis (MCA) method, AHP was done to prepare the final suitability map of the Khulna division. After completing the screening process the most suitable, suitable, moderately suitable, unsuitable, completely unsuitable, and excluded areas in the Khulna division were identified. The excluded area should be left out during the site selection process to avoid the undue event to the NPP. For the final site selection field visit, site characterization and site confirmation need to be performed.

RESULTS AND DISCUSSION

The GIS software, grading of the different sub-criteria, and the AHP method were utilized to prepare the suitability map of the Khulna division as described in the following sections.

Evaluation criteria

The methodology was evaluated in the conceptual and planning stage of site selection. The proposed candidate locations should be assessed in terms of the severity of external events and phenomena, including both natural and man-made occurrences that might compromise the plant's safety. This site selection analysis of the selected area was performed using six criteria divided into twelve sub-criteria (which may hamper the plant's safety). The selection of criteria and sub-criteria were done according to international practice and the environmental settings of the area under study. The selection of criteria and sub-criteria, suitability map of each sub-criterion, and final suitability map of the selected area were performed under the area survey stage. Table 1 shows the classification guideline and grading of the sub-criteria applied in this study.

Geological criterion

Geology has a long-term effect on NPP including safety, technical feasibility, and operational durability. Bangladesh has three main earthquake zones. The Khulna division is situated in the low-risk zone [19]. Earthquakes can cause great damage to any construction as a result of movements within the earth's crust or volcanic eruption. Earthquake data on the Richter scale for the previous 1918 to 2019 years were collected from the Bangladesh Meteorological Department (BMD). Figure 2 shows a suitability map of the earthquake sub-criterion where most of the areas of the Khulna division are in the most suitable and suitable zone.

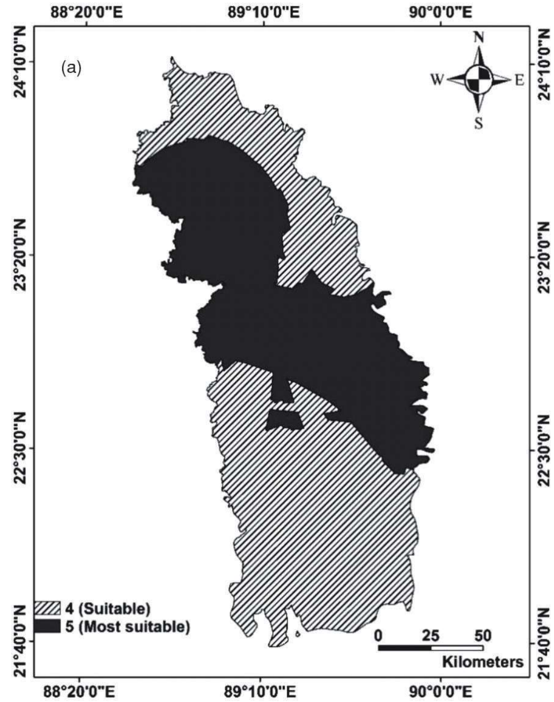

Figure 2. Suitability map for earthquake sub-criterion

Climatological criterion

This criterion contains wind speed, thunderstorm, and rainfall sub-criteria. Thirty-two years (1988-2017) of vector point data for thunderstorms, rainfall, and wind speed were collected from BMD but a few weather stations had less than thirty-two years of data. Areas with a low probability of extreme weather are acceptable to construct an NPP. Lightning, which typically occurs during thunderstorms, could damage a structure, transmission line, and towers [20]. Thus thunderstorm risk areas should be avoided during site selection. Figure 3(a) shows the suitability map for thunderstorms where most of the areas are moderately suitable and most suitable to set up an NPP in the Khulna division. When radioactive materials are released from an NPP during an uncontrolled accident, meteorological information is essential for estimating the pathway of a plume of radioactive material to ensure safe evacuation and control [21]. Atmospheric discharges of radionuclides from NPP greatly depend on wind speed and direction and can have a detrimental effect on human beings [22]. Most often, powerful tornadoes caused due to high wind speed are observed in Bangladesh which can create destructive effects on the NPP [23]. Excessive rainfall can cause a serious flood. Therefore, the low rainfall region is more suitable than the high rainfall region for NPP siting. Figures 3(b) and 3(c) are the spatial presentations of wind speed and rainfall sub-criterion. These maps indicate that most of the areas are suitable regarding wind speed sub-criterion and the southern part of the Khulna division is unsuitable for an NPP due to excessive rainfall.

Hydrological criterion

Hydrological criterion comprises three sub-criteria, namely river, riverbank erosion, and groundwater table. Bangladesh is a riverine country. There are many big and small rivers in Bangladesh, thus flood and riverbank ero-

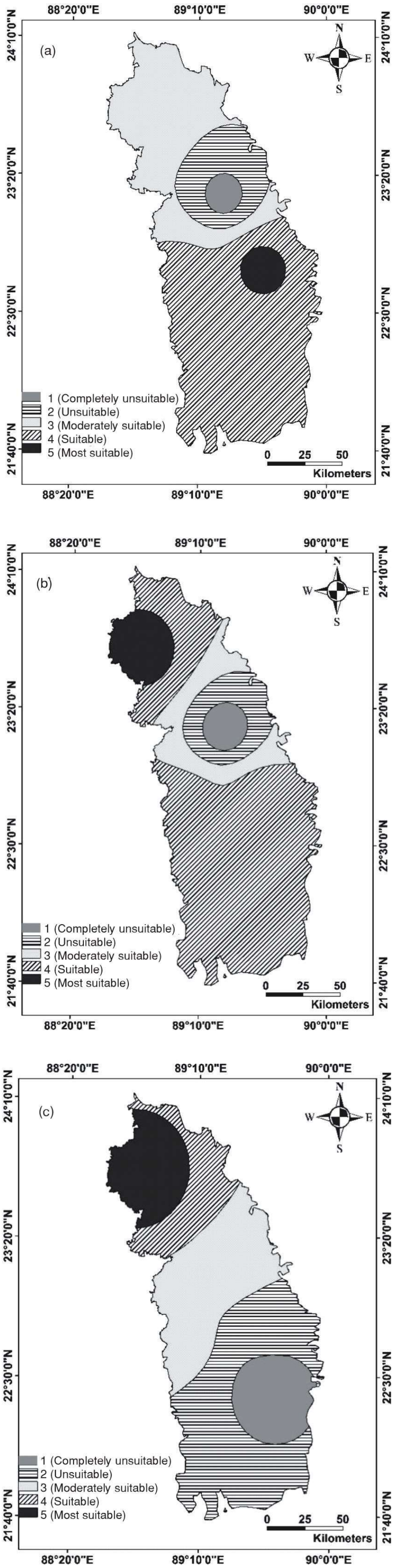

Figure 3. Suitability map of (a) thunderstorm, (b) wind speed, and (c) rainfall sub-criteria

sion are very common phenomena and can damage any construction. Therefore, the distance from rivers and areas with riverbank erosion are very important factors in the site selection process. In another aspect, cooling water sources is very important for a nuclear power plant. During power plant operation, adequate water resources should be available for cooling systems. No source of cooling water in direct contact within 8 km should be considered as an excluded area [5]. Therefore, NPP should be constructed near a surface water source but not too close, because flood and erosion can damage the construction. The 1:1000000 scale data for river and riverbank erosion were collected from the survey of Bangladesh (SOB) and Water Resources Planning Organization, respectively. The groundwater table is the distance from the surface to underground water. During an explosion, the nuclear core melt can contaminate the groundwater table [16]. Thus high value of water table is preferable for NPP siting. Nine years (2010-2018) of groundwater table data were collected from the Bangladesh Water Development Board. Figures 4(a-c), groundwater table, river and riverbank erosion sub-criteria, respectively. In the case of the groundwater table and river sub-criterion, large areas of the Khulna division are completely unsuitable whereas large areas are most suitable for riverbank erosion sub-criterion.

Socio-economic criterion

This criterion comprises population density, road and railway, and airport sub-criterion. Bangladesh is a highly populated country thus the population sub-criterion has a great importance during NPP siting. The general principle in the siting of nuclear power plants is to have the facilities in a low population area and far away from large population centers [1]. Data for this sub-criterion were collected from the Bangladesh Bureau of Statistics. Figure 5(a) represents the suitability map for the population density sub-criterion and indicates less area is suitable for NPP siting. During the construction and operation of an NPP, a large number of goods need to be transported thus a feasible transportation system helps reduce the costs. The accidental situation may create an undue effect on the pedestrian, thus NPP should not be very close to the roads and railways. An NPP should not be built close to an airport because of unelectable chances of airplane crashes during take-off and landing phases of flight which may cause serious damage to the NPP [18]. The vector data for airport, road, and railway sub-criteria were collected from SOB. Figures 5(b) and 5(c) are the suitability maps of these two sub-criteria.

Pedological criterion

Forest provides different beneficial things to humans and the environment and is the living place of different animal species. Therefore, an NPP should not

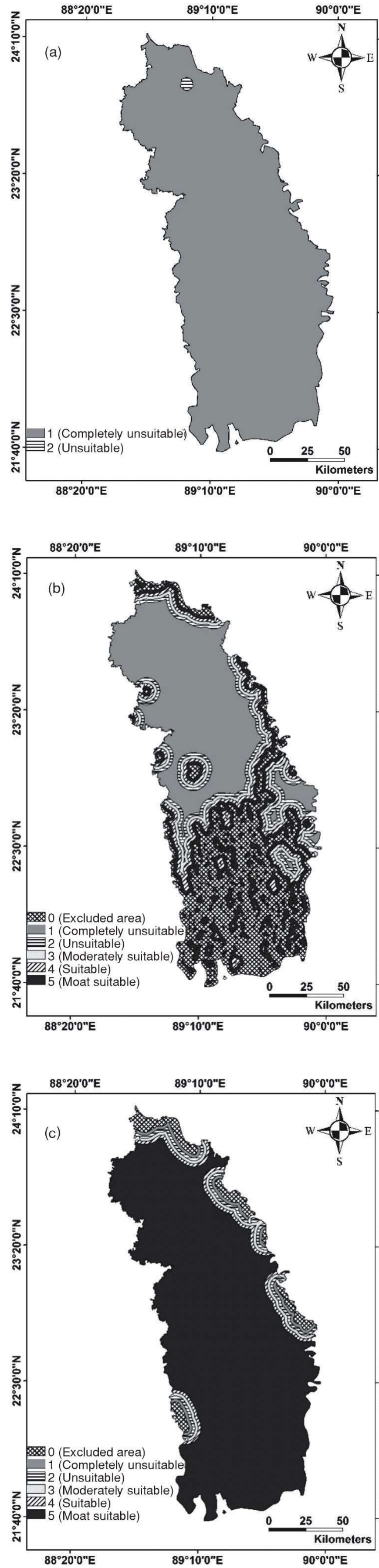

Figure 4. Suitability map for; (a) groundwater table (b) river, and (c) riverbank erosion

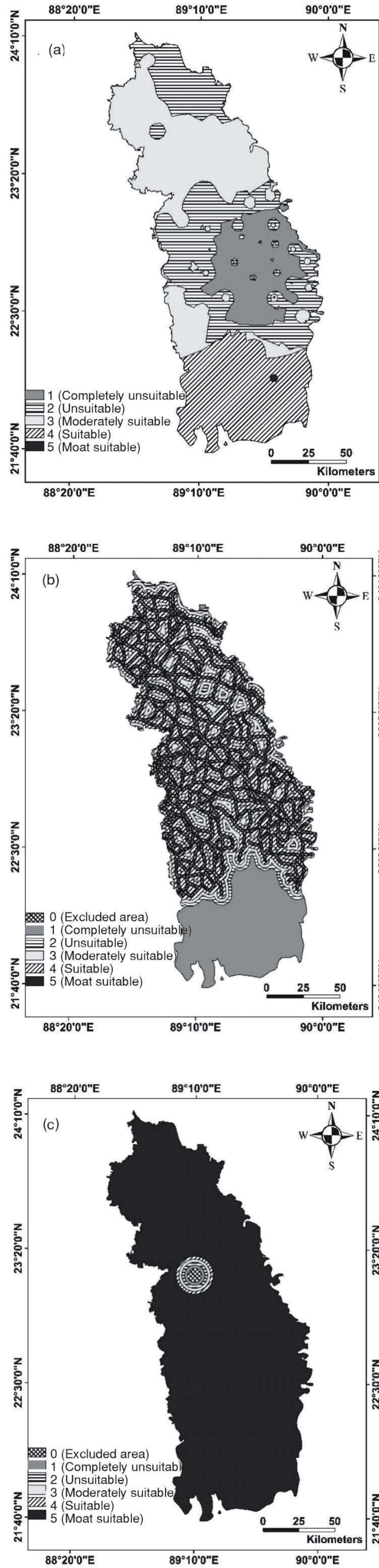

Figure 5. Suitability map of; (a) population, (b) road and railway, and (c) airport sub-criterion

be constructed in the forest area. The NPP just beside the forested area may generate adverse effects in case of an accidental case. Thus, a 500 m area around the forest is considered an excluded area. The data for this sub-criterion was collected from SOB. Figure 6 shows the suitability map for the forest where almost all the areas for this sub-criterion are most suitable.

Ecological criterion

The ecological criterion contains a protected area sub-criterion where wildlife areas, eco-parks, safari parks, and national parks have been taken under consideration. An NPP should not be constructed in these protected areas [18, 24]. The data for this sub-criterion was collected from SOB. Figure 7 is the suitability map for this sub-criterion and indicates that the Khulna division is most suitable for the ecological criterion.

Geographic information system

The GIS software has a high ability to manage large volumes of spatial data and consider many factors from a variety of sources [25]. Spatial data/vector data refers to the data that has a specific coordinate to define a specific location on the earth's surface. The GIS can take vector data (point, polyline, and polygon) as input and convert it to a user-defined output. The GIS is used to edit, visualize, and analyze spatial data. It edits the geographical data depending on the user's choice and by overlaying the maps it creates the suitability map.

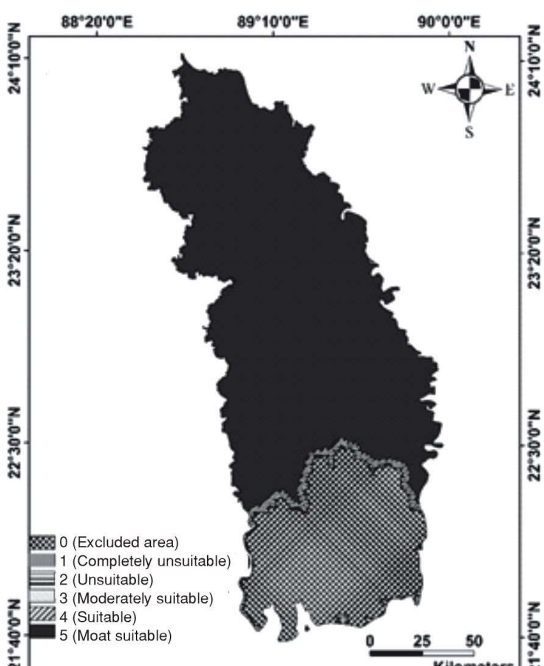

Figure 6. Suitability map of forest

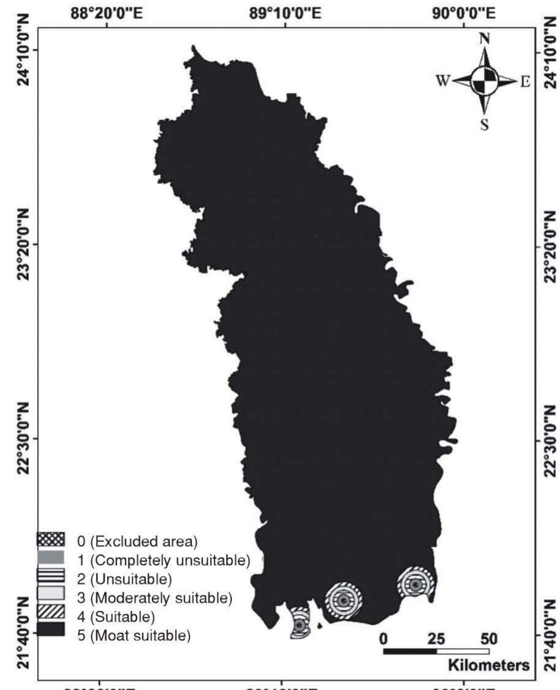

Figure 7. Suitability map of protected area

Multi-criteria analysis

The MCA is a decision-making technique providing weights to the sub-criteria according to their importance in the site selection process. It is required to rank or short-list possible alternatives and to choose the best one among several alternatives. There are several MCA techniques; among those AHP is the common and popular one that has been used in this study. The AHP is a measuring theory that aims to calculate a priority weight from paired comparisons of items based on a given criterion or feature to create a priority in the decision-making process [26]. The combination of AHP and GIS techniques helps to identify suitable lands according to necessity [7-14]. The AHP method provides a pairwise comparison matrix (PCM) that gives the relative weight of each sub-criterion. The pairwise comparison of each sub-criterion concerning other sub-criterion on a scale of 1 to 9, tab. 2, was done to build a PCM. The pairwise comparison was done using experts' judgment and published research articles [5, 27]. Table 3 shows the importance of values utilized in the PCM, moreover, fractional values used in the PCM indicate importance between 1-2, 2-3, 3-4, *etc.*

The consistency ratio (CR) indicates the inconsistency of the PCM and is defined as [7]

$$\mathrm{CR} = \mathrm{CI}/\mathrm{RI} \tag{1}$$

The consistency index (CI) is calculated as,

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n-1} \tag{2}$$

The sum of the products between the column total of the PCM and the corresponding value of the

Table 2. Importance values utilized in the AHP method [28]

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Demonstrated importance	Activity is strongly favored and its dominance is demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals of the above nonzero	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	

Table 3. The PCM and relative importance weights of the sub-criteria

Sub-criteria	Population	River	Earthquake	Riverbank erosion	Airport	Road and railway	Protected area	Forest	Groundwater table	Rainfall	Wind speed	Thunderstorm	Weights (w_j)
Population	1.00	1.20	1.50	1.50	2.00	2.50	3.00	3.50	4.00	4.30	4.50	5.00	0.179
River	0.83	1.00	1.20	1.30	1.30	2.00	2.50	3.00	3.50	4.00	4.30	5.00	0.147
Earthquake	0.67	0.83	1.00	1.20	1.20	1.30	2.00	2.50	3.00	3.50	4.00	4.50	0.123
Riverbank erosion	0.66	0.77	0.83	1.00	1.00	1.20	1.30	2.00	2.50	3.00	3.50	4.30	0.107
Airport	0.50	0.76	0.83	1.00	1.00	1.20	1.30	1.50	2.00	2.50	3.00	3.50	0.097
Road and railway	0.40	0.50	0.76	0.83	0.83	1.00	1.00	1.30	1.50	2.00	2.50	3.00	0.078
Protected area	0.33	0.40	0.50	0.76	0.77	1.00	1.00	1.20	1.30	1.50	2.00	3.00	0.066
Forest	0.28	0.33	0.40	0.50	0.66	0.77	0.83	1.00	1.30	1.50	1.50	2.00	0.053
Groundwater table	0.25	0.29	0.33	0.40	0.50	0.67	0.76	0.77	1.00	1.30	1.30	2.00	0.045
Rainfall	0.23	0.25	0.29	0.33	0.40	0.50	0.67	0.67	0.77	1.00	1.00	1.50	0.038
Wind speed	0.22	0.23	0.25	0.29	0.33	0.40	0.50	0.67	0.77	1.00	1.00	1.20	0.034
Thunderstorm	0.20	0.20	0.22	0.23	0.29	0.33	0.33	0.50	0.50	0.67	0.83	1.00	0.028

λ_{max} = 12.06292, CI = 0.00572, RI_{12} = 1.48, and CR = 0.003714 << 0.1

weight is known as the principle eigenvalue, λ_{max}. The number of sub-criteria is indicated by n. The random consistency index (RI) is a constant parameter, and RI_{12} indicates the value of RI for twelve sub-criteria, which is 1.48 [29]. The value of CR less than 10 % is acceptable and indicates the consistency of the PCM [27]. In this study, the value of CR is 0.37 % which indicates the appropriateness of the judgment.

After determining the relative importance weights and suitability maps of each sub-criterion, the overlay analysis was performed among suitability maps using the GIS and the simple additive weighting method. The following formula was used in this method [14]

$$R_i = \sum_{i=1}^{i=n} x_{ij} w_j \tag{3}$$

where R_i is the suitability index of area i and w_j – the weighting of sub-criteria j, and x_{ij} – the grading value of area i under sub-criteria j. The final suitability map, fig. 9, was calculated using x_{ij}, from tab. 1 and w_j, from tab. 3. Figure 8 shows the excluded area and residual area map, where the excluded area comprises excluded areas of all the sub-criteria, and the residual area indicates areas, that could be surveyed for site selection. The equal interval classification of the suitability index was used to classify the residual area. The maximum and minimum values of the suitability index were 4.4 and 2.3, respectively, for the residual area. For the excluded area the suitability index was 0. The combination of the classified residual area and the excluded area produces a final suitability map of the study area, fig. 9.

The final suitability map comprises six areas, namely most suitable, suitable, moderately suitable, unsuitable, completely unsuitable, and excluded area. This map shows that a small area is in the most suitable category, which indicates the small area has the potential for NPP establishment in the Khulna division. Table 4 shows the amount of area under different grading.

This study shows that about 1.41 % (315.30 km^2) area of Khulna division which is most suitable, about 0.45 % (100.83 km^2) area is completely unsuitable,

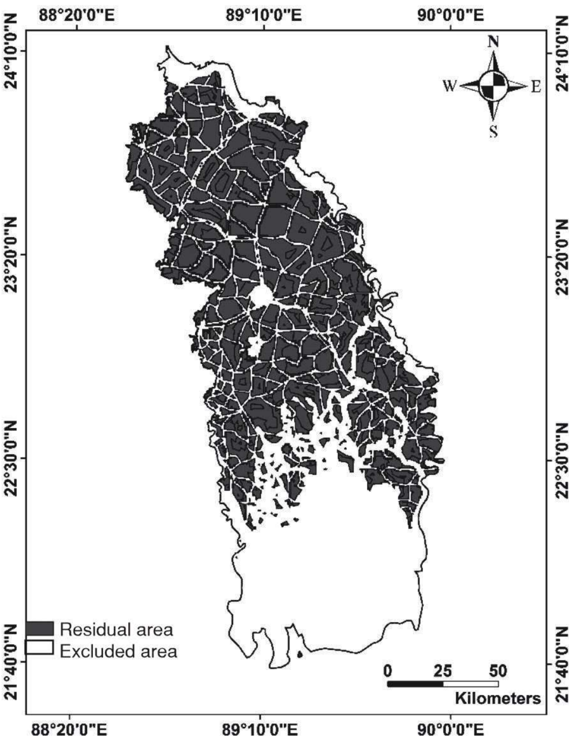

Figure 8. Excluded area and residual area map

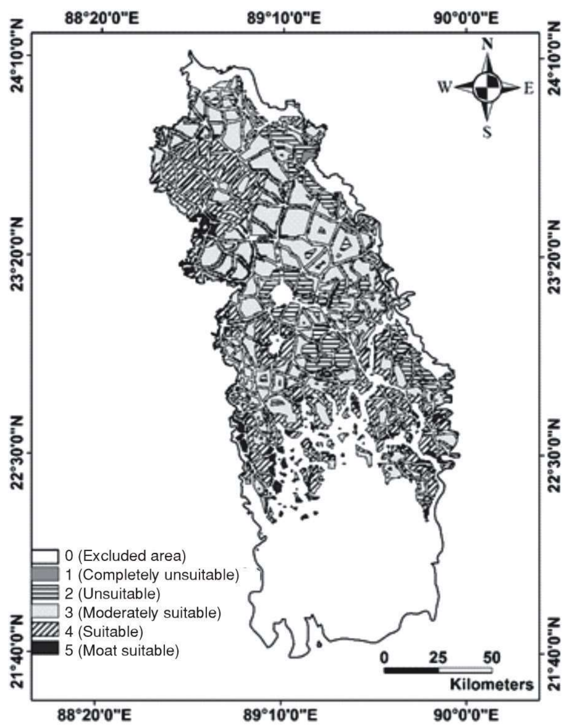

Figure 9. Final suitability map of the Khulna division

about 6.89 % (1536.78 km^2) area is unsuitable, about 23.01 % (5128.83 km^2) area is moderately suitable, about 13.42 % (2991.27 km^2) area is suitable and about 54.82 % (12211.99 km^2) area is excluded regarding siting of an NPP. Twenty-six potential areas were selected from the most suitable area with the highest suitability in-

Table 4. The area under different grading

Grading	Area [km^2]
Completely unsuitable	100.83
Unsuitable	1536.78
Moderately suitable	5128.83
Suitable	2991.27
Most suitable	315.30

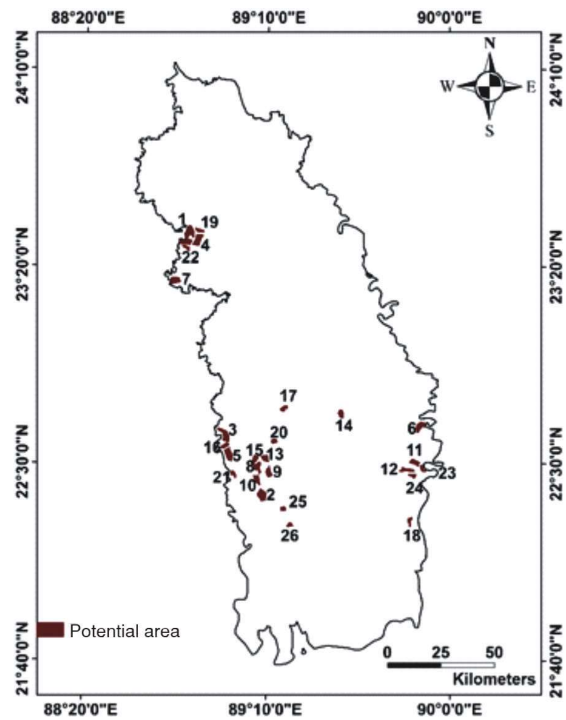

Figure 10. Map of potential areas in Khulna division for NPP

dex fit for NPP establishment. A typical 1000 MW nuclear facility in the USA needs a little more than 1 square mile (2.58 km^2) area to operate [30]. Whereas, according to [31], a nuclear energy facility requires 1.3 square miles (3.36 km^2) for a 1000 MW Plant. Thus, areas greater than three square kilometers were considered potential areas for further study. Figure 10 and tab. 5 show the potential area map and details of the potential areas, respectively.

The reconnaissance field survey, site characterization, and site confirmation need to be performed on these potential areas to identify the final site for the establishment of NPP in the Khulna division.

CONCLUSION

The GIS software and the AHP method were used for preliminary analysis to identify potential areas for the construction of a NPP in the Khulna division of Bangladesh. The analysis was conducted on the whole territory of the division based on six main criteria; namely geology, climatology, hydrology, pedology, socio-economy, and ecology; sub-divided into twelve sub-criteria. The priority weight and suitability map of each sub-criterion

Table 5. Twenty-six potential areas selected from the most suitable category

Area number	Area [km^2]	Longitude (decimal degrees)	Latitude (decimal degrees)
1	26.035	88.8023	23.4608
2	14.558	89.1473	22.367
3	14.062	88.9754	22.6213
4	13.390	88.8473	23.4448
5	12.790	88.9945	22.5389
6	11.133	89.8656	22.6598
7	10.196	88.7445	23.273
8	9.051	89.1266	22.4851
9	7.790	89.1769	22.463
10	7.594	89.1233	22.4334
11	7.217	89.8408	22.5077
12	7.035	89.8045	22.475
13	6.776	89.1607	22.5231
14	6.391	89.5047	22.7118
15	6.083	89.1137	22.5193
16	5.066	88.9774	22.5758
17	4.909	89.245	22.7345
18	4.102	89.8189	22.258
19	3.939	88.8543	23.4849
20	3.905	89.201	22.5962
21	3.877	89.0157	22.4565
22	3.769	88.7947	23.4122
23	3.696	89.8757	22.4819
24	3.528	89.8318	22.4511
25	3.177	89.2437	22.3099
26	3.030	89.2739	22.242

was prepared using the AHP method and GIS software. The siting process of radioactive waste disposal facilities in Bangladesh [14] as well as in Serbia [24] was conducted using the GIS, which helped this study identify probably suitable areas. Areas containing unfavorable conditions or constraints may jeopardize the safety of nuclear installations and, therefore, are not appropriate for the construction of NPP. Hence, grading analysis was utilized to impose these constraints in the area under study. The final suitability map indicated twenty-six potential zones with maximum and minimum areas of 26.035 km^2 and 3.030 km^2, respectively, as the most suitable for the construction of NPP in consideration of the safety of the facility, public, and the environment as well for the planning purpose of the government. Therefore, this research work will pave the way for the policymakers to find a site suitable for establishing NPP in the area under study in Bangladesh. Lastly, essential and prerequisite activities of the reconnaissance field survey stage, the site characterization stage, and the site confirmation stage need to be completed for deciding the final site for establishing NPP in the proposed region.

AUTHORS' CONTRIBUTIONS

The idea of this research was from Md. I. Ali and K. N. Sakib. The data collection and the scanning were done by A. S. Lova, A. Mahmud, R. Amin, and T. Islam. Md. Moniruzzaman and Md. M. Tasnim helped to write this article. The data analysis and manuscript preparation were done by all the authors.

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ИЗБОР ЛОКАЦИЈА ЗА НУКЛЕАРНЕ ЕЛЕКТРАНЕ КОРИШЋЕЊЕМ ГЕОГРАФСКОГ ИНФОРМАЦИОНОГ СИСТЕМА И ПРОЦЕСА АНАЛИТИЧКЕ ХИЈЕРАРХИЈЕ
Студија случаја области Кулна у Бангладешу

Циљ рада је да се одреди погодна локација за нуклеарну електрану у области Кулна у Бангладешу, користећи географски информациони систем и процес аналитичке хијерархије. Избор одговарајуће локације за нуклеарну електрану од виталног је значаја за безбедност постројења, раднике, јавност и животну средину. Студија је спроведена у четири фазе: осмишљавање и планирање, истраживање подручја, карактеризација локације и потврда локације. У фази истраживања подручја, шест критеријума подељено је на дванаест поткритеријума: густину насељености, земљотрес, реку, ерозију обала реке, аеродром, пут и железницу, заштићено подручје, шуму, ниво подземних вода, падавине, брзину ветра и грмљавине. Мапа подобности сваког поткритеријума направљена је коришћењем софтвера географског информационог система. Пондерисање сваког критеријума обављено је коришћењем процеса аналитичке хијерархије. На крају, извршена је анализа преклапања заснована на географском информационом систему да би се припремила коначна мапа прикладности области Кулна за изградњу нуклеарне електране – која указује на 315.30 km^2 и 2991.27 km^2 њене укупне површине као најпогодније и погодније, респективно. Двадесет шест потенцијалних подручја одабрано је од најпогодније области за даље проучавање. Овај рад следи потпуну методологију, тако да може помоћи креаторима политике за успостављање нуклеарних електрана у Бангладешу и иностранству.

Кључне речи: Бангладеш, нуклеарна електрана, географски информациони систем, аналитички хијерархијски процес, мапа подобности