SUITABLE SITES ASSESSMENT FOR SOLAR POWER PLANT IN COX'S BAZAR DISTRICT: AN AHP-GIS COMBINED APPROACH

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ABSTRACT

Bangladesh is facing increasing challenges in meeting its rising electricity demand, driven by rapid population growth, urbanization, and economic development. This growing demand poses a major challenge, as continued dependence on fossil fuels contributes to environmental degradation and energy insecurity. Solar power presents significant potential to address this issue in a sustainable manner. This study aims to identify and prioritize suitable sites for solar power plant development in Cox's Bazar district by integrating Geographic Information Systems (GIS) and Analytical Hierarchy Process (AHP), and Multi-Criteria Decision Analysis (MCDA). Eight key factors (i.e., Global Horizontal Irradiation (GHI), Direct Normal Irradiation (DNI), Land Use and Land Cover (LULC), slope, aspect, elevation (DEM), distance to roads, and distance to power substations)were selected, reclassified, and weighted according to their relative influence on site suitability through AHP. A weighted overlay analysis in GIS was then applied to generate a spatial suitability map highlighting optimal locations. The results indicate that Cox's Bazar district contains highly suitable sites, particularly in Teknaf, Ukhia, and Ramu. The total moderately suitable area was estimated at 1167.0885 km², while areas such as Chakaria and Pekua were identified as less suitable due to land use and infrastructure constraints. These findings underscore the potential of geospatial and multi-criteria approaches for renewable energy planning and provide a decision-support tool for guiding future solar energy infrastructure development in Bangladesh.

Keywords: *AHP, GIS, Suitability, Solar Power Plant, Cox's Bazar*

1. INTRODUCTION

The need for energy is growing daily globally due to scientific and technological advancements and the fast expanding human population (International Energy Agency, 2022). By 2040, the world's energy consumption is expected to increase by 25% (Rios & Duarte, 2021). Furthermore, due to the effects of fossil fuels on the environment, there is an increasing awareness of the concerns associated with climate change and for that numerous nations are urged to suggest plans for switching to renewable energy sources from fossil fuels (Habib et al., 2020). They are searching for more economical, sustainable, and ecologically friendly energy sources (Shorabeh et al., 2019). As a result, there has been a boost in interest in alternative renewable energy sources like hydropower, solar, geothermal, and wind (Günen, 2021). Solar energy is easily accessible, affordable, safe, and pollution-free which transforms direct sunlight into energy that may be used for a number of applications (Günen, 2021; Nandal et al., 2019). It is the fastest-growing renewable energy source in the world which has seen an 80% cost decrease and is expected to continue declining in the future years (Ünsal et al., 2024). It has a lower impact on the environment than other energy sources (Gökler, 2025). Bangladesh offers an ideal geographic circumstances, with an average annual sunshine duration of 1,900 kWh/m2 and daily solar radiation ranging from 4 to 6.54–6.5 kWh/m2 (Babu, 2024). One of the things to be noticed that Bangladesh's coastal areas, such as Teknaf, Saint Martin's Island, Cox's Bazar, etc., have the highest Direct Normal Irradiance (Hossain et al., 2021). In coastal regions, the average yearly solar radiation is comparable such as Cox's Bazar is a seaside region with an average annual solar radiation of 4.77 KWh/m2/day which makes it a promising place for solar power plant establishment) (Kabir et al., 2016). There are several studies (Aghaloo et al., 2023; Anam et al., 2025; Aziz et al., 2025; Md. R. Islam et al., 2024b; Rana & Moniruzzaman, 2024b) that have showed suitable sites for solar power plant via the apllication of Analytical Hierarchy Process (AHP), Fuzzy AHP approach and Georaphic Information System (GIS) based data. But having said that Cox's Bazar is one of those promising sites (Kabir et al., 2016) for the establishment of solar power plants, there has been no studies for this place on this matter. Some studies (Hossain et al., 2023; A. Islam et al., 2013; Liza et al., 2020) have talked about the potentiality of this district but there is no site selection analysis for Cox's Bazar district. To address this gap, this study does the suitability analysis for Cox's Bazar district via the AHP approach in GIS. Two objectives were selected: 1) to identify key factors affecting solar power site suitability and 2) To create a suitability map using GIS and AHP approach. The results will help local governments locate solar power plants in more desirable areas.

2. MATERIALS AND METHOD

2.1 Study area

The Cox's Bazar District (Chittagong Division) spans 2382.38 square kilometres and is situated between latitudes 20°43' and 21°56' north and longitudes 91°50' and 92°23' east. It is bordered to the north by Chittagong District, to the south by the Bay of Bengal, to the east by Arakan (Myanmar) and the Naf River, and to the west by the Bay of Bengal (Banglapedia, 2023). Due to its large amount of non-agricultural fallow land and high solar irradiation, Cox's Bazar is thought to be a better location for utility-scale commercial solar plant development. In order to reach the nation's overarching aim of producing 10% of its energy from renewable sources, Cox's Bazar can be developed to draw in the private sector and mobilise investment in clean energy (Inspira Advisory and Consulting Limited, 2024).

2.2 Data source

To conduct this study, different data were collected from different source which is showed on the below (**Error! Reference source not found.**). Global Horizontal Irradiation (GHI) and Direct Normal Irradiation DNI were collected from the Global Solar Atlas developed by the World Bank Group. Land Use and Land Cover (LULC) data was obtained from ESRI Sentinel-2 imagery. The Digital Elevation Model (DEM) data were acquired from NASA Earth Data, providing topographic information such as elevation and slope. Open Street Map was the source for the road network data. And the power sub-station data were obtained Power Grid Company of Bangladesh for assessing connectivity to the national power grid, as sites located nearer to substations reduce transmission losses and infrastructure costs (Jung & Schindler, 2021)

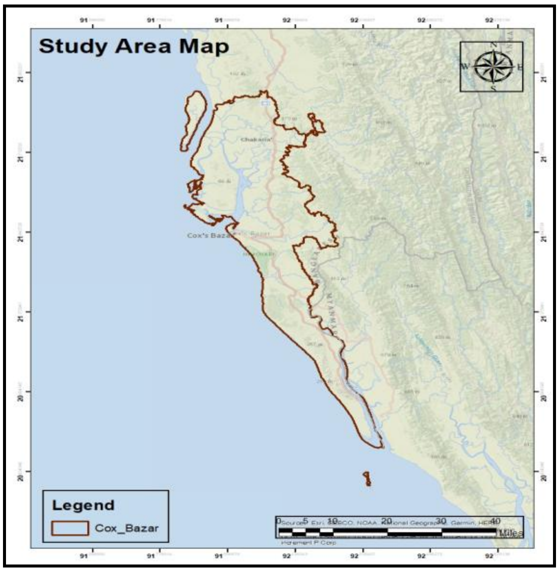

Figure 1: Map of Cox's Bazar district

Table 1: Data sources

Data	Source	Format	Time
GHI	Global Solar Atlas (World Bank Group, 2020)	Raster	2020
DNI	Global Solar Atlas (World Bank Group, 2020)	Raster	2020
LULC	ESRI sentinel-2	Raster	2025
DEM	NASA Earth Data	Raster	2025
Road	Open Street Map	Shape File	2025
Sub-station	Power Grid Bangladesh	Shape File	2020-2025

2.3 Methodology

The methodology (Figure 2) shows the steps towards the site suitability assessment for solar power plant establishment in cox's Bazar district. It starts with the literature review which leads to recognize problems and formulate objectives for this current study. All the criteria (i.e, GHI, DNI, LULC, distance from power sub-station, slope, aspect, elevation and distance from road) were collected from respective source according to (Table 1). Next, Analytical Hierarchy Process (AHP) is used to assign weights to each criterion based on their relative importance in determining solar suitability. Each thematic layers is then reclassified according to its suitability ranking (Table 3). After that, final suitability map is generated by combining the weighted layers using weighted overlay method in ArcGIS. The outcome identifies the most suitable areas for solar power plant installation in Cox's Bazar district.

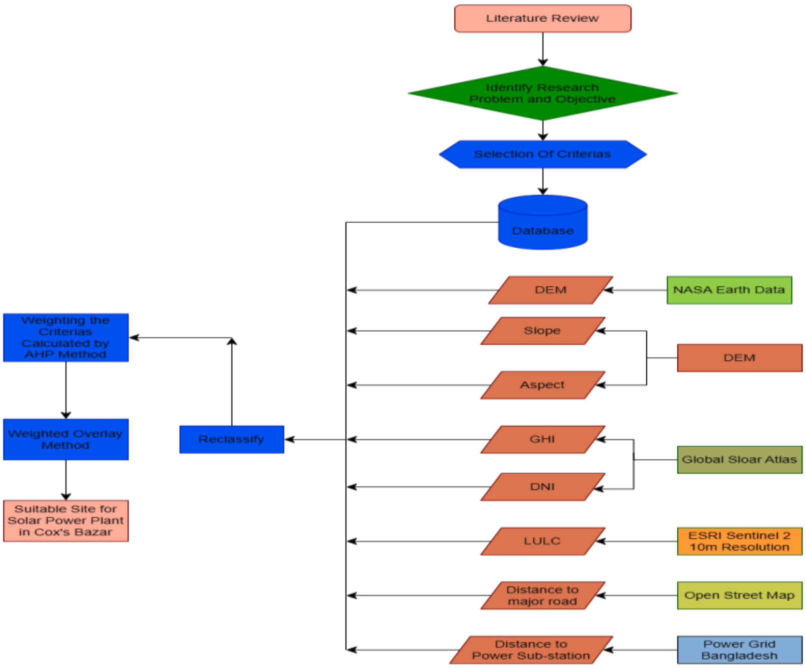

Figure 2: Methodological workflow

2.4 Analytical Hierarchy Process (AHP)

AHP is a Multiple-Criteria Decision Making (MCDM) technique that deals with challenging decision-making circumstances, such as several conflicting criteria.(Saaty, 1987) It can help planners organise the choice problem and balance the importance of numerous variables in the field of solar site appropriateness (Guntupalli et al., 2025). The AHP approach use pairwise comparison matrices to assess various criteria and establish their relative importance or weights by calculating geometric means and normalised values (Arunbose et al., 2021). For this study, expert opinion and field experiences were involved into the weights of each specific layer (**Error! Reference source not found.**). The factor that got high weightage, has a strong affect on the site selection where the low weightage gives the sign of a minimum weighatge of a factor. To verify the truthfulness of pairwise comparisons, consistency checks are done (Hosen et al., 2025). The Consistency Ratio (CR), introduced by Saaty, is used to check how consistent the decisions are in the AHP process. If the CR value is less than 0.1, the matrix is considered consistent. The CR is calculated using the Consistency Index (CI), the maximum eigenvalue (λmax) of the comparison matrix, and the Random Index (RI), which depends on the size of the matrix (n) (Bera & Maiti, 2021).

$$CR = CI/RI \qquad ....(1)$$

Where,

$$CI = (\lambda max - n)/(n-1) \qquad ....(2)$$

Table 2: Evaluation scale of AHP (Saaty, 1987)

Degree of Importance	Explanation
1	Equally important
3	Slightly more important
5	Moderately more important

Degree of Importance	**Explanation**
7	Very strongly important
9	Extremely important
2, 4, 6, 8	Intermediate values between the above levels
Reciprocal values	If activity I is more important than activity j in terms of relative significance of a_{ij}, then activity j is more important than i in terms of relative importance $\frac{1}{a_{ij}}$.

2.5 Description of Pairwise Comparison and Weight Determination

To assess the relative significance of various thematic levels, a pairwise comparison matrix was constructed, where each thematic layer was compared with every other layer based on its influence on solar energy potential. Included thematic layers were GHI, DNI, LULC, distance from power sub-station, slope, aspect, elevation and distance from road. So after the construction of the matrix, the relative weights of each criterion were derived through AHP computation. (Table 3) shows the weights of the all thematic layers. The results showed that with 0.254 weight GHI stood at the top followed by DNI (0.164), LULC (0.152) and distance from power sub-station (0.140). The rest of the layers slope, aspect, elevation and distance from road had weights respectively 0.084, 0.065, 0.075 and 0.066. The Consistency Ratio (CR) value of 0.002889 confirmed that the pairwise comparison was logically consistent and acceptable.

Table 3: Allocate weight to all thematic layer and rank the sub-features of each thematic layer.

Thematic layers	**Classes**	**Weights**	**Rank**
GHI (KWh/m²)	1714.118042 - 1782.785034	0.254	1
	1782.785034 - 1792.281982		2
	1792.281982 - 1800.682007		3
	1800.682007 - 1809.083008		4
	1809.083008 - 1822.597046		5
DNI (KWh/m²)	1200.577026 - 1330.605957	0.164	1
	1330.605957 - 1349.963989		2
	1349.963989 - 1372.974976		3
	1372.974976 - 1404.020996		4
	1404.020996 - 1437.259033		5
LULC	Water body	0.152	1
	Trees		3
	Crops		4
	Built Area		2
	Flooded Vegetation		4
	Bare ground		5
	Rangeland		5
Distance from Power Sub-station (m)	0 - 1000	0.140	5
	1000 - 3000		4
	3000 - 5000		3

	5000 - 10000		2
	10000 - 44711.445313		1
Slope (degree)	0 - 3	0.084	5
	3 - 5		4
	5 - 10		3
	10 - 18		2
	18 - 65		1
Elevation (m)	0 - 3	0.075	1
	4 - 10		2
	11 - 30		3
	31 - 75		4
	76 - 300		5
Distance from Major Road (m)	0 - 100	0.066	1
	100 - 1000		5
	1000 - 3000		4
	3000 - 5000		3
	5000 - 10000		2
	10000 - 19801.113281		1
Aspect (degree)	North (-1 - 22.5)	0.065	1
	Northeast (22.5 - 67.5)		1
	East (67.5 - 112.5)		2
	Southeast (112.5 - 157.5)		3
	South (157.5 - 202.5)		5
	Southwest (202.5 - 247.5)		3
	West (247.5 - 292.5)		2
	Northwest (292.5 - 337.5)		1
	North (337.5 – 360)		1

3. RESULT

3.1 Development of thematic layers

3.1.1 Elevation

Elevation is one of the significant factors for determining a suitable location for a solar power plant. Higher elevations get more solar radiation as higher elevations experience cooler temperatures because of thinner and lower atmospheric pressure (Kırcalı & Selim, 2021; Rana & Moniruzzaman, 2024a). Therefore, higher elevations were ranked higher and lower elevations were ranked lower. The SRTM 30-meter resolution data were employed to prepare the elevation in this study. The value of the elevation map (Figure 3(a)) ranges from 0 m to 300 m. These values were categorized into five classes in particular (0-3) m, (4-10) m, (11-30) m, (31-75) m, and (76- 300) m.

3.1.2 Slope

Slope is one of the most important terrain features(Rana & Moniruzzaman, 2024a). The slope of the land is an important feature in deciding whether a location is suitable for a solar power plant. Slope affects how the land is used. Extremely steep slopes are vulnerable to landslides or erosion. (Rana & Moniruzzaman, 2024a). The irregular, steep slopes experience additional costs in the construction and maintenance of the solar power plant. (Khan et al., 2023). A slope of less than 5⁰ is recommended for the suitable location of a solar power plant (Khan et al., 2023). DEM was utilized to produce the slope map using the slope tool in ArcGIS software. The slope map (Figure 3(b)) of Cox Bazar differs from 0⁰ to 64.5633⁰. It was divided into five classes based on the degree of suitability. (0-3) degree slope areas are highly suitable for a solar power plant. (3-5) degree slope areas are suitable areas for constructing a solar power plant. Areas greater than a slope with 10⁰ are not suitable for a photovoltaic solar power plant location.

3.1.3 Aspect

The aspect map is important to determine the slope orientations (Colak et al., 2020). Placing the solar energy plant on the proper land will maximize the solar irradiance it receives. The southerly slope of the northern hemisphere is prioritized for using the land aspect criteria (Md. R. Islam et al., 2024a). Cox Bazar is located in the northern hemisphere. In this region southerly slope receives more direct solar radiation throughout the year. Therefore, the southerly slope was weighted more heavily. The SRTM 30-meter resolution data was utilized to produce the aspect map using the aspect tool in ArcGIS software. Northerly, northeasterly, and northwesterly slopes were ranked lowest as this area is less favorable for solar energy generation. (Figure 3(c)) shows the land aspect map of Cox's Bazar District.

3.1.4 LULC

Land use is one of the most important criteria in the site selection of photovoltaic solar power plants. To choose a site with the fewest hazards and the most sun exposure, it is essential to evaluate the land use and land cover of Cox's Bazar District. Bare land and non-agricultural empty lands are suitable for a solar power plant. Agricultural lands, built-up areas or settlements, water bodies, large trees, forests, and protected areas are not suitable (Kırcalı & Selim, 2021). ESRI Sentinel-2 10 m resolution data were used to analyze the land use of the Cox's Bazar District. Bare ground and Rangeland were ranked highest, and water bodies, built-up areas, and trees were less prioritized, as these are not suitable for a solar power plant. (Figure 3(d)) shows the Land Use and Land Cover map of Cox's Bazar District.

3.1.5 Distance from the Major road

The distance from the major roads is an important factor for the site selection of solar power plants. Access to the site is necessary to transport heavy machinery, components, and maintenance trucks. If the site is closer to the main road, it will save cost and time. Solar power plants should be at least 100 m away from the roads, as they can create visual pollution (Khan et al., 2023). 100 m to 1000 m is most suitable for a solar power plant, considering the maintenance and construction costs. A distance of more than 10000 m or 10 km is not suitable for a solar power plant. Therefore, a distance of 100 m to 1000 m is ranked highest, and a distance of more than 10000 m is ranked lowest. Proximity to a major road is shown in the map (Figure 3(e))

3.1.6 Distance from the power sub-station

Power sub-stations distribute electricity to consumers. The site should be closer to a power sub-station to easily distribute the electricity to consumers. Constructing a new solar power plant near a power substation can reduce the power loss. Power plants should be near substations, ensuring that it is not necessary to construct new substations (Rediske et al., 2019). A distance of 0 m to 1000 m is ranked highest, and a distance of more than 10000 m is ranked lowest. Proximity to power stations is shown in the map (Figure 3(f))

3.1.7 GHI

GHI or Global Horizontal Irradiance is a unit of measurement for the total solar radiation that an earth location gets on a horizontal surface(Rana & Moniruzzaman, 2024a). GHI measures the total solar radiation that is converted into power by solar panels (Rana & Moniruzzaman, 2024a). The higher the GHI value, the more energy will be produced by a solar power plant. The GHI value of Cox Bazar differs from 1714.118042 kwh/m^2 to 1822.597046 kwh/m^2 . The final GHI map (Figure 3(g)) has been classified into five categories. Higher value was assigned to higher value, and lower value was assigned to lower value.

3.1.8 DNI

DNI or Direct Normal Irradiance is a crucial element referred to as direct beam radiation (Rana & Moniruzzaman, 2024a). DNI measures the amount of solar irradiance that reaches the ground without being scattered by the atmosphere (Rana & Moniruzzaman, 2024a). Higher DNI values offer better opportunities to install solar power plants. The higher the DNI value, the more direct sunshine the place will get. The DNI value of Cox Bazar differs from 1200.577026 kwh/m^2 to 1437.259033 kwh/m^2. The final DNI map (Figure 3(h)) has been classified into five categories, namely (1200.577026 - 1330.605957) kwh/m^2, (1330.605957 - 1349.963989) kwh/m^2, (1349.963989 - 1372.974976) kwh/m^2, (1372.974976 - 1404.020996) kwh/m^2, and (1404.020996 - 1437.259033) kwh/m^2. High rank has been assigned to a high DNI value.

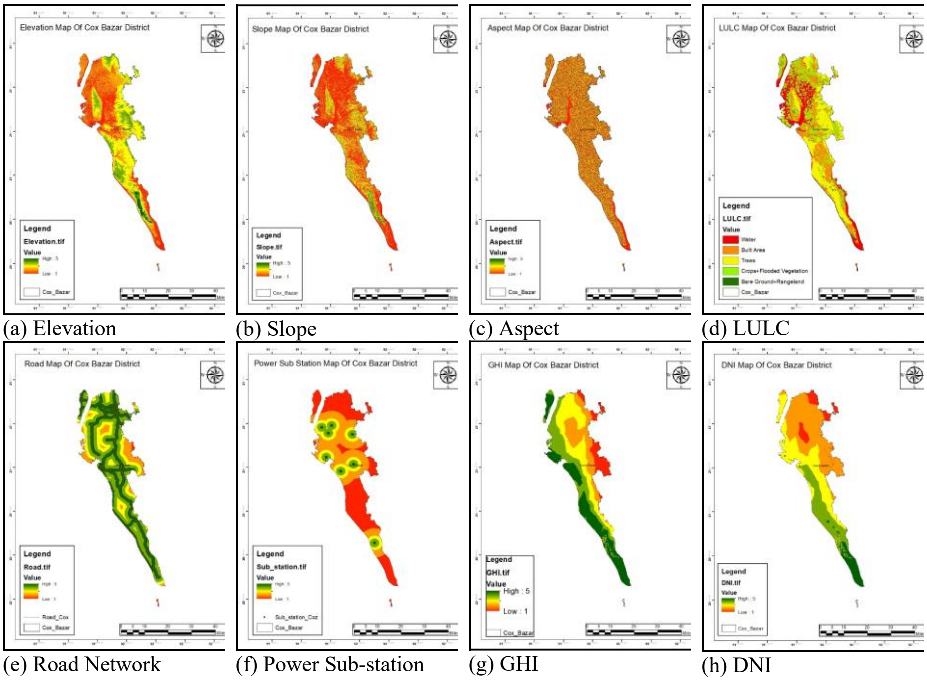

Figure 3: Combined thematic layers used for suitability analysis: (a) Elevation, (b) Slope, (c) Aspect, (d) LULC, (e) Road Network, (f) Power Sub-station, (g) GHI, (h) DNI

3.2 Identification of suitable zone for solar power plants

Bangladesh, as a country, mostly relies on fossil fuels, particularly natural gas, which constitutes about 65% of the total power generation(Sarker et al., 2024). Due to population growth, urbanization, and industrialization, Bangladesh's energy demand has been increasing rapidly. Traditional energy sources are not sufficient to meet the rapidly increasing energy demand. Moreover, these sources have an adverse effect on the environment. Solar energy systems can be an important source of energy to solve our energy gap. The selection of a suitable site for a solar photovoltaic power plant is a crucial step, as it is a high-cost investment. For this reason, this research has been conducted to delineate the potential site for a solar photovoltaic power plant in Cox's Bazar District. All eight thematic layers, namely elevation, slope, aspect, LULC, GHI, DNI, distance from major roads, and distance from power sub-stations, have been assimilated through the weighted sum tool in ArcGIS to delineate the final map. The suitability analysis map for solar power plant (Figure 3) is divided into five categories, such as very low suitable area, low suitable area, moderately suitable area, high suitable area, and very high suitable area. These categories are covered by 0.12%, 38.76%, 52.75%, 8.35%, and 0.02% land of the total area in Cox's Bazar District, respectively. The total area of very low and low suitable areas is, respectively, 271.89 hectares and 85740.75 hectares. Most of the area of Pekua and Chakaria Upazila is not suitable for installing solar power plants.116708.85 hectares of Cox's Bazar District are moderately suitable for installing solar power plants. Most of the area of Kutubdia and Moheshkhali Upazila is moderately suitable. Some areas of Teknaf, Ukhia, and Ramu are suitable for installing solar power plants.

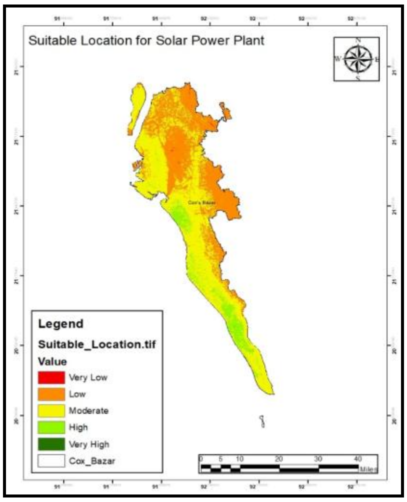

Figure 4: Suitable Location for Solar Power Plant of Cox's Bazar District

4. DISCUSSION

This study finds out that 52.75% area of Cox's Bazar district belongs to moderate suitable site which is highest in percentage. The second most is 38.75% which is representative of low suitable areas. For high suitable areas, 8.35% area is found. Lastly, 0.12% and 0.02% of Cox's Bazar district area belong respectively to very low suitable and very high suitable locations. Teknaf, Ramu, Cox's Bazar Sadar and Maheshkhali are the upazilas which have got more moderate, high and very high suitable areas. From the opposite scenario, Chakaria and Pekua are the two upazilas where low suitable areas are mostly found. This study was conducted via GIS based AHP approach. Eight factors were assigned into the process where GHI stands with most weight among those eight factors. The second most influnced factor turns out to be DNI and LULC comes very next. The next sequence respectively comes as distance from power sub-station, slope, aspect, DEM, distance from road. In the global context, there have been a number of studies (Amrani et al., 2024; Flora, 2025; Isabelle Flora, 2025; Riek & Eremed, 2025) where suitable site analysis was done with MCDM or AHP, incorporated in GIS. (Md. R. Islam et al., 2024b) has done the site suitability assessment for solar power plant in Bangladesh. There are also some other studies (Aziz et al., 2025; Rana & Moniruzzaman, 2024b) who have also done the same assessment through AHP and geospatial techniques respectively. The current study finds out the suitable locations for solar power plant in Cox's Bazar district via AHP-GIS based approach which has not been done before. A few studies (Hossain, 2020; Kabir et al., 2016) are there which have talked about the simulation of power plants on different basis in Cox's Bazar. So suitability assessment for solar power plant for Cox's Bazar district was never done before untill this study. From an economic perspective, advance steps need to be ensured which will prioritize high suitable areas for solar power plant establishment. Additionally, authorities must look up to the moderate areas to make them more suitable for solar power plant. As this study marks the low and very low areas, authorities need to eleminate those areas in terms of installing solar power plant.

Lastly, the limitations of the study reveal areas that could be modified. Factors such as distance from major roads was incorporated in GIS by georeferencing where minor positional errors might be available. GHI and DNI were not found after 2020 which indicates towards limited wdition of spatial data. Additionally, more factors can be included in this type of analysis except those eight factors from this study.

5. CONCLUSION

This research paper shows the GIS based AHP approach towards the suitable areas for solar power plant location. By mapping in GIS, visualization of suitable areas are much understandable. This will provide to the authority to find the suitable areas for solar power plant location in short tiime and more accurately. Those institutions, companies who want to work on this part, this study will have positive impact for them.

As this study helps to find out the high suitable area for solar power plant location, government and authority should prioritized those areas. Moderate areas also can be improved to estabish solar power plant. Relevant infrastructure and access road towards the site needs to be installed or upgraded.

In future, researchers can conduct this study with the upgraded and accurate data which can create more satified output. Even more factors can also be included such as average temperature, duration of sunlight, relative humidity, intensity of occurrence of natural disasters, population density etc. Also with the current methodology, researchers can apply to other study areas to indentify the suitable location for solar power plant.

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