***Systematic Review***

**Exploring the applications of GIS based multi-criteria decision analysis techniques in Bangladesh: A systematic review**

## Abstract

This systematic review aims to explore the application of geographic information system (GIS)-based multi-criteria decision analysis (MCDA) techniques in addressing diverse environmental and socio-economic challenges in Bangladesh. The study fills the gap in consolidated evidence regarding the effectiveness and sectoral orientation, as well as the methodological variety of GIS-MCDA applications, especially in the context of developing countries. A ten-year time frame has been chosen for collecting literature using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework from various scholarly databases. Findings reveal that GIS-MCDA techniques have gained widespread acceptance across various sectors, including disaster management, water resource management, energy, waste management, urban planning, tourism, agriculture, healthcare, and industry. Analytical hierarchy process (AHP) has been found as most popular MCDA technique to utilize in various sectors efficiently. However, the findings also note some essential knowledge gaps in existing literature such as the excessive focus on some particular disaster (e.g., floods), minimal implementation in less-researched areas and industries, and insufficient field validation or stakeholder engagement in most studies. The review highlights the operational significance of GIS-MCDA and its ability to aid spatially informed and evidence-based decision-making. It also recommends the necessity of wider thematic coverage, a hybrid approach of methods and participatory structure to develop the practical application value of such tools. Combining the sector-specific knowledge with the spatiotemporal trends, the paper provides an original contribution by conducting the first comprehensive evaluation of GIS-MCDA implementation in Bangladesh, which thus forms the basis of more participatory, sustainable, and resilient planning.

**Keywords:** Geographic information system (GIS), Multi-criteria decision analysis (MCDA), Analytical hierarchy process (AHP), GIS-MCDA, PRISMA, Bangladesh.

#### Introduction

Finding an appropriate solution becomes more problematic in complex decisions making situation that involve numerous factors and where each factor has different type and level of importance. In order to deal with such complexity, multi-criteria decision analysis (MCDA) methods are implemented as valuable instruments in the decision-making process (Basílio et al., 2022; Sahoo & Goswami, 2023). MCDA also stands for multiple-criteria decision-making (MCDM), is a formal approach to solving multi-criteria decision-making problems that arise when making decisions based on the multiple factors that are often in conflict with each other. It allows decision-makers and researchers to carry a preference evaluation by evaluating a number of alternatives and differ between them if no unified best solution is available (Wątróbski et al., 2019). MCDA techniques have been applied in almost all the classical sectors such as; supply chain management and logistics, engineering and manufacturing systems, healthcare, environmental management and sustainable development and are proven effective in solving selection, ranking, evaluation and sorting problems (Cegan et al., 2017; Frazão et al., 2018; Chowdhury & Paul, 2020; Goyal et al., 2020; Basílio et al., 2022). There are different types of MCDA techniques that are popularly used by researchers, for example AHP (Analytical hierarchy process), TOPSIS (Technique for order preference by similarity to the ideal solution), ANN (Artificial neural network), ELECTRE (Elimination and choice translating reality), MAUT (Multi-attribute utility theory), Fuzzy logic, PROMETHEE (Preference Ranking Organization Method for Enrichment of Evaluations) etc. (Wątróbski et al., 2019; Mu, 2022; Sahoo & Goswami, 2023; Benabbou, 2024).

On the other hand, geographic information systems (GIS) are sophisticated software which are used to collect, store, manage analyze and display spatial or geographical information. GIS allows the user to view and interpret data for better understanding the relationships and trends in dataset through maps and diagrams (Liu & Cheng, 2020). Its three core activities of data integration, spatial analysis, and visualization are critical in the study of complicated spatial processes. Integration of GIS-MCDA enables better solving at spatial decision-making related issues where GIS is used to analyze spatial data alongside MCDA techniques (Greene et al., 2011; Malczewski & Rinner, 2015). This integration enables the decision-makers to achieve some level of balance by systematically comparing trade-offs between the conflicting criteria in order to get more substantive and less arbitrary outcomes (Greene et al., 2011). In context of decision making, GIS offers a more powerful tool for spatial analysis and MCDA is designed to assess decision-making criteria according to the preferences of users. Together, they transform geographical data and make value judgments to enable decision-making on different uses, such as pre-screening suitable land and deciding where to allocate or how to manage resources (Malczewski, 2006; Girard et al., 2012; Merino-Benítez et al., 2023; S. S. Rana et al., 2024).

In the realm of Bangladesh, GIS-MCDA has been used effectively in a wide variety of research to solve some of the most important problems such as urban planning, disaster management, resource allocation and environmental assessment (M. M. Rahman & Szabó, 2022; Siam et al., 2022; Amin et al., 2023; Monir et al., 2023; Murshed et al., 2023). They prove its applicability of integrating spatial data in multi-criteria evaluations that enhances the decision-making process. Despite the demonstrated effectiveness of such integration, there is still a notable lack of a review paper that present the comprehensive summary of works related to GIS-MCDA integration particularly in Bangladesh. As several works have been illustrated the applicability of GIS-MCDA in different fields, there should be a review paper on existing literatures that aggregate all these researches concerning to Bangladesh. Thus, the current research intends to address the existing gap by developing a systematic literature review on the integration of GIS-MCDA in context of Bangladesh.

Through utilizing the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) framework, the primary objective of the paper is revealing the different sectors where MCDA has been applied with the help of geospatial technologies in Bangladesh till now. Besides, the study will highlight the utilization of different methods of MCDA. It will also allow researchers and practitioners to know of which research themes have previously been explored, how various methodologies have been applied in various geographical settings, and what strategies can be successfully implemented or developed in the future. Therefore, by synthesizing information related to GIS-MCDA research, this study will identify critical gaps in existing research and provide future research directions for scientists and professionals who need to apply these technologies while working on multifaceted, spatial problems in context of developing countries. Such organized knowledge will help researchers specially to identify explored and unexplored themes in a region and minimize the repetition of using ineffective methods. Thus, this review can contribute to sustainable development and more effective management of resources as well as disasters. In the long run, it intends to support better decisions enhancing Bangladesh’s preparedness for the existing and future issues.

#### Methodology

This systematic literature review intended to present a detailed overview of the integration of GIS and MCDA in Bangladesh, with an emphasis on different sectors in context of decision-making process. PRISMA guidelines were used to adapt the methodology and due to restricted access to some databases like Scopus and Web of science, manual process of collecting literatures were also tailored.

***1.2.1 Search strategy and data collection process***

The first search approach was made aiming to select research articles related to geospatial technologies and MCDA in Bangladesh for the 2015-2024 period. The search was limited to Google Scholar and indexed journals; preferring any publication that was in high impact journals, proceeding and credible source online.

The words and phrases for the search were chosen in terms of the major ideas connected with geospatial technologies, MCDA, and decision-making in the context of Bangladesh. These keywords were, “*GIS-MCDA*”, “*geospatial technologies and multi criteria decision*”, “*Geographic Information Systems and MCDA*” in context of Bangladesh. To enhance the retrieval’s precision, Boolean operators were used to link the word with connectors such as ‘AND’, ‘OR’, ‘NOT’ in order to enhance the collection of the relevant studies. Therefore, an initial search yielded 500 articles from peer-reviewed scholarly research. This method may reduce the number of articles compared to paid databases, to some extent, but by using a filtering approach and inclusion/exclusion criteria, only articles of good quality were considered.

***1.2.2 Eligibility Criteria***

The eligibility criteria have been developed in a way to stay relevant to the research objectives and correspond to the guidelines of the PRISMA framework. Research that has been conducted in Bangladesh and published in 2015-2024 were considered for the review. As for the article type, preference was given to the only peer-reviewed journals, conference proceedings and technical reports as the source is more likely to meet the academic standards. Exclusion criteria omitted the articles that were not written in English and solely focused on GIS or MCDA technique. Following PRISMA guidelines, duplicate articles were also removed and 210 articles were selected for screening. Articles which were irrelevant and without clear methodological description were excluded and 150 full-text articles were selected to assess eligibility. The last data pool included 118 full-text articles which seem to be more appropriate to do further analysis, and gave good ground to identify the current status of GIS-MCDA study in Bangladesh.

To depict the whole process, a PRISMA flow diagram was adapted, modified to include the various stages in the selection and screening processes, as well as providing an overall view of the final synthesized dataset (Figure 1).

***1.2.3 Data extraction for synthesis***

To synthesize the findings of 118 full-text articles, each article was reviewed carefully to extract the key information. To organize the key information focusing title, published year, explored themes, sectoral application, specific geographical settings, applied techniques, major findings and limitations, a data extraction table was created. The table used for data extraction helped in sorting out the literature for analysis. It made possible thematic coding that enabled the grouping of acquired articles according to their specific utilization of GIS-MCDA. From this coding process, current trends as well as the major themes of different research came out.

Even though this review was conducted adhering to the PRISMA guidelines, limitation associated with the manual identification and collection of articles were evident. This lack of direct access to databanks such as Scopus and Web of Science may have caused a limitation on the search. Use of free access platforms and manual selection may bring about bias in study identification and data quality. However, to minimize possible bias, the eligibility criteria were applied, the quality assessment was carried out, and only the studies that met high methodological standards and valuable insights were included.

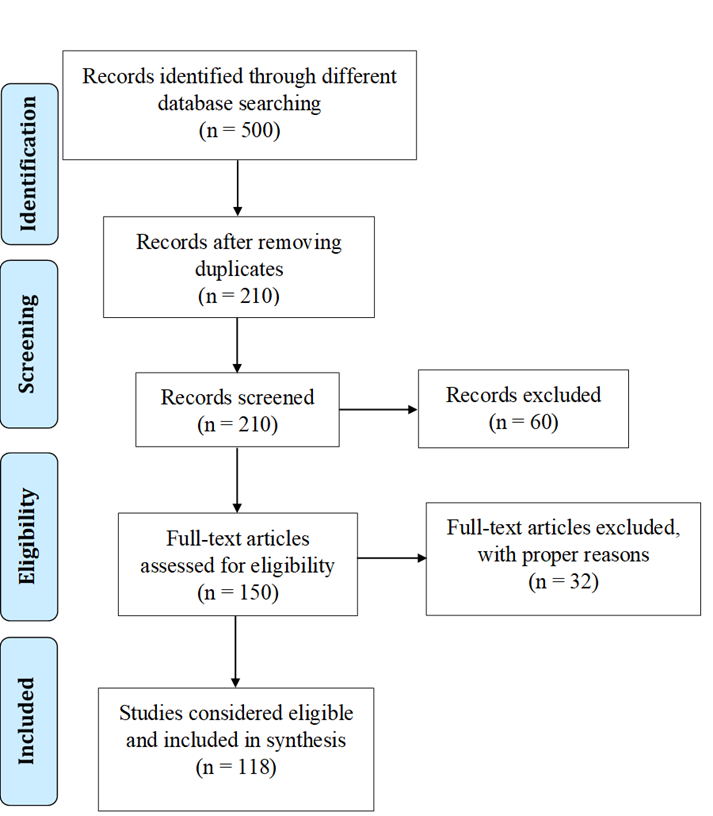


Figure 1: Adapted PRISMA framework (Moher et al., 2009)

#### Findings

***1.3.1 Year wise of published articles***

The following graph (Figure 2) depicts the number of published articles per year on the integration of geospatial technologies with MCDA in Bangladesh for the period of 2015-2024. An increasing trend is seen in the number of researches in this field. It first evolved from five articles observed in 2015, a slight decline in 2016 and then a steady rise throughout 2017 and 2018. However, the number of publications increased sharply to 13 in 2019, which indicates that the enhanced importance of using geospatial technologies along with decision making techniques. This upward trend was maintained with consistent publication rates of fifteen and sixteen articles between 2020 to 2022. In fact, there was a rise in the number of articles in 2023 and 2024, where 21 and 24 articles were published, respectively, a significant rise in use of GIS-MCDA among scholars.

The total number of 118 articles published over the ten-year period has established GIS-MCDA as an increasingly valuable tool for solving multifaceted spatial and decision-making issues, including those involved in environmental and disaster risk management. The line graph also portrays the increased importance of GIS-MCDA and its prospect for future research and utilization in practice (Figure 2).

Figure 2: Number of published articles per year (2015-2024)

***1.3.2 Sector wise published articles***

Research on GIS-MCDA integration across different sector in context to Bangladesh has been illustrated by the pie chart (Figure 3). It reveals that “disaster management” is the most explored sector, contributing to 46% of all the studies. Research in “water resource management” sector is about 21% highlight the efficient use of GIS-MCDA in sustainable resource allocation and planning. Use of GIS-MCDA in “agricultural sector” contributes 7% and in “waste management” 7%, proving to be important for maintaining food security and sustainable land use planning and management. The “urban planning” is total 6% of the studies, while “energy” covers 5%. Industry, health and vulnerability, and tourism sector remain the least of them with proportions of approximately 3%, 3% and 2% respectively. Such sectoral distribution of the GIS-MCDA applications demonstrates its broad applicability in addressing different problems, with a focus on disaster response and resource optimization.

Figure 3: Sector wise published articles (2015-2024)

***1.3.3 Literature classification***

**Spatial distribution of GIS-MCDA research**

The research dissemination of GIS-based Multi-Criteria Decision Analysis (MCDA) throughout Bangladesh displays uneven distribution across regions since specific locations applied it to a greater extent. The following map figure 4(a) depicts how GIS-based MCDA research divides itself among the eight administrative divisions found within Bangladesh. GIS-MCDA research exhibits the highest level of activity in Chittagong where 33 studies have been recorded. Khulna, with 28 research cases, trails behind, demonstrating a significant focus on this division. The research field has focused on Rajshahi and Rangpur similarly because 22 studies appeared in each division. The research activity in Barisal shows lower engagement when compared to other administrative divisions due to its 14 research studies. The capital division Dhaka seems to attract 12 GIS MCDA research studies while Sylhet has slightly fewer at 11. Mymensingh stands as the division with the minimum research studies as records show only 8 studies. The research activity concentrates on the southern and southeastern parts of Bangladesh including Chittagong and Khulna divisions yet Mymensingh and Sylhet represent areas with fewer GIS-based MCDA investigations.

**Disaster management**

The application of GIS-based MCDA in disaster management related research has become a common feature in Bangladesh over the past decades. It has been utilized in assessing and mapping hazard susceptibility, risk, and vulnerability in various geographical environments. Significant focus has been on flood-related disasters following the chronic inclination to seasonal floods and flash floods in the Jamuna-Brahmaputra, Atrai and Meghna river basins (Jamal et al., 2020; Sarker et al., 2024; Akter & Ataullah, 2025; Md. Z. Rahman & Akter, 2024). Nonetheless, other disasters have also been studied through GIS-MCDA such as cyclones (Hasan et al., 2024), landslides (Rabby & Li, 2020), erosion (Roy et al., 2021), waterlogging (Azad et al., 2024), earthquakes (M. S. Alam & Haque, 2022), fire (M. S. Alam et al., 2019), and drought (Sarkar et al., 2024).

Table 1 highlights the explored themes from the existing researches using GIS-MCDA in disaster management sector. Themes are categorized in terms of disaster type. Figs. 4(b), and 4(c) are the visual representation of the geographic distribution of GIS-MCDA-based disaster-related researches in Bangladesh. Most flood-related research has focused on districts and river basins that face high risks of seasonal floods and flash floods, as shown in Figure 4(b). It provides a perspective on the geographic coverage of Disaster-related GIS-MCDA research in general, and Figure 4(c) illustrates the regions where several hazards have been evaluated using this method. For example, some areas of the Chittagong Division face the risk of flooding, landslides, coastal erosion, and cyclones simultaneously. Cities such as Dhaka, Mymensingh, and Khulna are becoming increasingly prone to waterlogging, earthquakes, and fires. Erosion and cyclonic storms are a threat to coastal districts like Barguna and Co-x-s Bazar. The spatial patterns depicted in these maps highlight the increasing use of GIS-MCDA in hazard-prone and ecologically sensitive areas across the nation.

Recent research has surpassed traditional AHP-based models by incorporating hybrid decision-making models, which enhance the accuracy and utility of models in the decision-making process. These are AHP-ANN (M. Rahman et al., 2019), AHP-ANP (Riaz & Mohiuddin, 2025), AHP-DNN (Siam et al., 2022), and AHP-Fuzzy logic (K. F. Alam & Ahamed, 2023; Azad et al., 2024). Just as well, ANFIS-GIS (Mourin et al., 2017), TOPSIS (M. S. Alam et al., 2019), and AHP-TOPSIS (M. S. Alam & Haque, 2018) have been applied to evaluate a wide variety of hazards. These methodological developments are indicators of a growing complexity in spatial analysis related to disaster risk reduction. The thematic and geographic scope of the accompanying maps shows the dynamic role of GIS-MCDA in assisting data-centered and site-specific planning within the context of disaster management in Bangladesh.

Table 1: Overview of themes from the existing researches in disaster management sector

|  |  |
| --- | --- |
| Disaster type | Explored themes |
| Flood | Mapping flood risk and assessment; Flood susceptibility mapping; Flood susceptibility model development; Flood hazard zonation and flood shelter suitability mapping; Flood prone area identification; Flood vulnerability assessment |
| Waterlogging | Waterlogging risk assessment and zone identification |
| Cyclone | Suitability assessment for cyclone shelter; Cyclone surge susceptibility assessment; Cyclone risk assessment; Cyclone exposure mapping |
| Landslide | Landslide susceptibility mapping, assessment; Landslide risk assessment; Landslide susceptibility modeling |
| Drought | Delineating drought vulnerability |
| Fire | Fire hazard risk assessment |
| Earthquake | Earthquake vulnerability assessment and mapping; Seismic vulnerability assessment; Seismic micro-zonation |
| Erosion | Soil erosion susceptibility mapping; Soil erodibility mapping; Coastal erosion vulnerability assessment |

|  |  |  |
| --- | --- | --- |
| *4(a)* | *4(b)* | *4 (c)* |

Figure : Here, 4(a) represents the spatial distribution of GIS-MCDA research in Bangladesh; 4(b depicts spatial distribution of GIS-MCDA research in flood prone regions and 4 (c) depicts spatial distribution of GIS-MCDA research in multi-hazard prone regions

**Urban planning**

Limited studies are found in urban planning sector that utilized the integration of GIS-MCDA, especially AHP to solve several urban planning and site suitability issues in some important cities of Bangladesh like Rajshahi, Pabna, Chittagong, Khulna etc. Table 2 highlights the context, geographical distribution and summarized findings of existing literature. Specifically, these studies explored several themes such as the selection of suitable areas for CBDs, choice of accommodation sites, and aid in land utilization and support of industrialization that is in line with SDGs. The study findings serve the interests of actual policy formation and problem solving whereby policies have to deal with, for instance, traffic jams, city growth and energy and raw materials. However, the interpretation of the results has affected by the limited set of evaluation criteria and the use of specific datasets.

Table 2: Existing studies using GIS-MCDA related to urban planning sector

|  |  |  |  |
| --- | --- | --- | --- |
| Article Reference | Context | Location | Findings |
| (M. M. Rahman & Szabó, 2022) | Urban land-Use Optimization | Rajshahi city | Identified optimal locations for residential development.  Limited focus in urban sustainability. |
| (Parvez & Islam, 2020) | Site suitability of urban growth | Pabna municipality | Identified potential CBD areas for future development.  Aided in controlling urban development. |
| (Parvez, 2020) | Site suitability for taxi parking | Pabna municipality | Aided policymakers to solve parking and traffic congestion related issues.  Reliance on expert opinions and specific data sources. |
| (Sadat, 2020) | Suitability analysis of a future CBD area | Pabna municipality | Identified potential CBD area.  Used limited criteria. |
| (Paul & Roy, 2020) | Assessment of road landscape | Khulna city | Assessed road landscape condition.  Based on qualitative perceptions. |
| (J. Alam, 2018) | Accommodation suitability | Chittagong city | Identified optimum locations for accommodation.  Only four criteria were used to test. |
| (Absar et al., 2016) | Site suitability | Chittagong | Selected best locations. |

**Waste management**

Eight studies were selected under this sector for full-text review. Most of the research in waste management sector were conducted in city area and utilized GIS-MCDA, especially AHP to select optimum locations for landfilling. Apart from these, Akther et al., (2019) tried to identify suitable sites for biogas plant installation and Reza & Akter (2018) evaluated the existing practices of waste separation and disposal through applying GIS-MCDA. Table 3 represents the explored theme, location and key findings of existing literature.

Table 3: Summary of the researches related to waste management sector

|  |  |  |  |
| --- | --- | --- | --- |
| Article reference | Location | Context | Key findings |
| (Tazin et al., 2024) | Mymensingh | Site selection of waste conversion facilities | Remained uncollected waste about 10-12 tons; 8 sites were identified based on social, economic and environmental factors. |
| (Arefin et al., 2024) | Dhaka | Waste disposal suitability mapping | Northern sites were identified as unsuitable for shallow groundwater level and thinner clay layers. 12 sites were identified as optimal areas. |
| (Guha et al., 2023) | Rangpur | Suitability analysis of landfill | Illustrated suitable sites and most critical factors were family size and education in terms of waste generation. |
| (M. Islam et al., 2020) | Savar | Site suitability for landfilling | Identified 21 suitable locations while 12 locations were recommended for future landfilling. Highlights the importance of improved waste management governance. |
| (M. Islam et al., 2020) | Rajshahi | Site suitability for landfilling | Addressed unorganized management, critical factors for site selection and found 6% areas are highly suitable. |
| (A. Dey et al., 2019) | Chittagong | Site suitability for landfilling | Poor and unsuitable landfill conditions and capacity is insufficient for city’s population. Need urgent improvement. |
| (Akther et al., 2019) | Dhaka | Site suitability of biogas plant | Only one site is identified as most suitable based on social, economic and environmental factors. |
| (Reza & Akter, 2018) | Natore | Finding optimum technology | Evaluated the existing practices of waste separation and disposal. |

**Industry**

Only a few studies have been found (Table 4) under this sector. Among them, three studies utilized the integration of geospatial technology and AHP to figure out suitable sites for industrial development, while Sharmin & Solaiman (2019) integrated AHP and TOPSIS along with GIS to optimize the sites of bank branch expansion.

Table 4: Summary of the existing works related to industrial sector

|  |  |  |  |
| --- | --- | --- | --- |
| Article reference | Location | Application Area | Key findings |
| (Haque et al., 2021) | Khulna | Industrial site suitability | Current sites are ineffective for sustainable industrialization.  10% area is suitable, most suitable land is located in Eastern side. |
| (Sharmin & Solaiman, 2019) | Bangladesh | Bank branch location optimization | Influenced by geographic and demographic factors.  Can be adapted for other financial institutions. |
| (Muhsin et al., 2018) | Savar | Site suitability for industries | More than 10% agricultural lands decreased in two decades and converted into industries.  Only 4% land is highly suitable and site selection were influenced by proximity to major roads. |
| (Ahesan & Masron, 2015) | Joypurhat | Site suitability for rice mills | Ten sites were identified.  Distance from roads and settlements were significant criteria. |

**Agriculture**

Using GIS-MCDA in agricultural sector has been identified as an emerging sector and only eight studies (Table 5) are considered for full-text review. Most of the researchers utilized AHP in different geographical regions to find out suitable sites for agricultural production, development and vulnerability assessment. Apart from these, Mostafiz et al., (2021) applied fuzzy logic to develop seasonal multicrop land suitability analysis model for Dinajpur, Rangpur, Kurigram and Gaibandha. Overall, this sector offers ample scope for further research.

Table 5: Summary of the existing researches related to agricultural sector

|  |  |  |  |
| --- | --- | --- | --- |
| Article reference | Location | Context | Key findings |
| (M. S. P. Rana & Moniruzzaman, 2023) | Northwestern part | Site suitability for livestock production | Thakurgaon, Panchagar, Dinajpur, Naogaon, Joypurhat and Bogra are low suitabile area while Kurigram, Nilphamari, Pabna, Lalmonirhat, Gaibandha, Rangpur and Sirajganj are highly suitable. |
| (M. A. Hoque & Ahmed, 2023) | Chittagong | Land suitability for rubber cultivation | Optimal temperature, suitable elevations, moderate slopes, and fitting soil properties are favorable for rubber cultivation. |
| (Binte Mostafiz et al., 2021) | Dinajpur, Rangpur, Kurigram and Gaibandha | Model development for land suitability of crops | Land suitable for vegetables in Kharif-1, Kharif-2, Rabi seasons were 42%, 55% and 19% respectively.  Developed seasonal multicrop land suitability analysis model. |
| (Hossen et al., 2021) | Southern part | Land Suitability Assessment | Critical factors were drainage and soil salinity.  Southeastern is highly suitable. |
| (Ahamed et al., 2021) | Rajshahi | Environmental  protection and entrepreneurship for sustainable agricultural development | Women of Bangladesh relied on chemical fertilizers and showed interest in processed food and handicraft industries. |
| (Das et al., 2020) | Sylhet | Land Suitability for Sustainable Tea Production | Only 3.37% area is highly suitable and 31 tea estates are located in highly suitable area. |
| (M. Z. Hoque et al., 2019) | Coastal | Assessing Agricultural Livelihood Vulnerability | Bhola, Patuakhali, and Lakshmipur are the hotspot of vulnerability distribution. |
| (M. M. Islam et al., 2018) | Rangpur, Lalmonirhat, and Kurigram | Sustainable rice production | Proposed crop insurance model for low quality land owners.  Identified suitable land percentages. |

**Energy**

Six studies (Table 6) were found relating to energy sector that utilized GIS-MCDA. All were conducted between 2022 and 2024 and considered the entire country as study area. Five of the researches applied AHP to identify suitable sites for renewable energy related plant or farm installation while Aghaloo et al., (2023) used BWM-fuzzy logic method to select site for solar-wind hybrid renewable energy systems.

Table 6: Summary of the researches related to energy sector

|  |  |  |
| --- | --- | --- |
| Article reference | Context | Key findings |
| (M. S. P. Rana & Moniruzzaman, 2024) | Site suitability for solar power plant installation | Highly suitable areas are western and northwestern part (Rajshahi, Pabna, Sirajganj, Natore, Naogaon, Chapainawabganj, Bogura, Faridpur, Jessore, Jehenaidha, Magura, Kushtia, Choudanga, Meherpur) |
| (M. R. Islam et al., 2024) | Site suitability assessment for solar power plants | Highly suitable is 44.59%, located in south and southwest of the country.  31.18 % area is prohibited for solar power plant installation. |
| (Aghaloo et al., 2023) | Site selection for the solar-wind | Chittagong is identified as most suitable area.  Totals of 11% and 25% of the area were suitable and moderately suitable.  Solar irradiation, elevation, distance to rivers and waterbodies are most critical factors. |
| (Amin et al., 2023) | Renewable sites selection | Identified optimal sites and constraints in existing renewable energy research. Economic analysis supports feasibility of renewable projects over non-renewable options. |
| (T. Ahmed, 2025) | Site selection for solar power plant | Most suitable sites are in Southeastern Bangladesh. |
| (M. R. Islam et al., 2022) | Wind farm site suitability assessment | Wind speed, land slope, and elevation are critical factor. |

**Health, tourism and vulnerability**

Overall, six studies (Table 7) were selected to discuss under these sectors. Among them, one research applied GIS-MCDA in health sector for mapping Covid-19 susceptibility (Sarkar, 2020). From the research, it is found that being the most populous city of Bangladesh and having international connection with other countries, Dhaka was the most susceptible place and Naogaon was the least susceptible place. Despite this, the paper overemphasizes some elements such as the healthcare system and transportation that may play a huge role in determining vulnerability. On the other hand, through utilizing AHP, two research was conducted in Sundarbans (Sheikh et al., 2025) and Saint Martin's Island (Habib et al., 2024) to assess ecotourism suitability. Sheikh et al. (2023) considered Sundarbans most suitable for ecotourism due to its rich biological and historical values. Likewise, Habib et al. (2024) reported 30 percent of the Saint Martin’s Island are suitable for tourism. Remained three studies were found related to vulnerability and sensitivity assessment.

Table 7: Summary of the researches related to vulnerability assessment

|  |  |  |  |
| --- | --- | --- | --- |
| Article reference | Location | Theme | Key findings |
| (Tasnuva & Bari, 2024) | South coast | Livelihood vulnerability assessment | High livelihood vulnerability is found at the periphery of the study area, especially near the riverbanks. |
| (Murshed et al., 2023) | Coastal (19 districts) | Climate change sensitivity assessment | Developed a composite sensitivity index. Coxsbazar, Pirojpur, Bagerhat, Shariatpur, Patuakhali and Chandpur (0.33) were the most sensitive districts. |
| (Ha-Mim & Hossain, 2022) | Southwestern Coastal | Vulnerability mapping | Eastern, central, and southern regions exhibited a higher vulnerability than the northwest part of the study area. |

**Water resource management**

Among all MCDA techniques, AHP-GIS is the most popular in Bangladesh to address the problems related to water resource management (Table 8), such as groundwater potential mapping, vulnerability assessment, or the selection of rainwater harvesting sites (M. S. P. Rana & Moniruzzaman, 2023a; Howlader et al., 2024; Sheikh Sayed et al., 2025). Hybrid methods, such as fuzzy logic and machine learning (e.g., AHP-ANN), have led to improvements in the accuracy of groundwater assessment (Sresto et al., 2021; Sheikh Sayed et al., 2025). Furthermore, more sophisticated decision-making instruments, such as ELECTRE, have been employed in the selection of drinking water sources in saline coastal areas due to the unique nature of geo-hydrological issues (Peters et al., 2019).

Research using GIS-MCDA methods encompasses various hydrogeological conditions, including drought-prone northwestern regions, saline southwestern coastal areas, and rapidly developing regions, such as Dhaka city, where groundwater over-abstraction is particularly acute (Roman et al., 2021; Priya et al., 2022; B. Dey et al., 2023). Hydrogeological variability is observed in research cases from northeastern areas, whereas countrywide research offers complete groundwater zoning schemes (M. M. S. P. Rana et al., 2022; Sarkar et al., 2022). Taken together, these studies prove the flexibility of the GIS-MCDA to the local and regional contexts, providing practical tools to sustainable water resources planning.

Table 8: Overview of existing works related to water resource management

|  |  |  |
| --- | --- | --- |
| Thematic Focus | Locations / Regions | Representative References |
| Groundwater Potential Mapping & Zoning | Northwestern Bangladesh (Rangpur, Dinajpur, Rajshahi, Naogaon, Atrai–Sib River Basin) | (Jahan et al., 2019; Arefin, 2020a; N. Ahmed et al., 2021; Sarkar et al., 2022; Monir et al., 2023; M. S. P. Rana & Moniruzzaman, 2023a) |
| Northeastern Districts (Moulavibazar, Habiganj, Sylhet, Sunamganj) | (Priya et al., 2022; B. Dey et al., 2023) |
| Urban and Peri-Urban Areas (Dhaka, Gazipur, Kushtia, Jashore) | (Arefin, 2020b; Shahinuzzaman et al., 2021; M. M. Rahman et al., 2022; Dipto et al., 2023; Fatema et al., 2023; Sheikh Sayed et al., 2025) |
| Nationwide / Other Regions (Chittagong, Bangladesh-wide) | (Akter et al., 2020; M. M. S. P. Rana et al., 2022) |
| Groundwater Vulnerability & Management | Khulna, Southwestern Coastal Region | (Peters et al., 2019; Roman et al., 2021; Sresto et al., 2021; Howlader et al., 2024) |
| Rainwater Harvesting & Reservoir Site Selection | Northwestern and Urban Areas (Naogaon, Rajshahi, Dinajpur, Dhaka) | (Akter & Ahmed, 2015; M. A. Hoque et al., 2022; M. S. P. Rana & Moniruzzaman, 2023a) |
| Groundwater Recharge & Aquifer Evaluation | Chittagong, Kushtia | (Akter et al., 2020; Shahinuzzaman et al., 2021; Khan & Haque, 2023) |

#### Discussion and future research direction

The use of GIS-MCDA applications has increased significantly in the last 10 years in Bangladesh, particularly, in areas involving disaster management and water resources management. There are however major limitations. Most of disaster studies focus on flood prone coastal regions, whereas hazards such as drought, fires, and earthquakes have not been extensively studied. In the methodological context, hybrid methods like AHP-ANN, AHP-DNN, and ANFIS-GIS are already on the rise, but some methodologies remain invalidated in the field, with little stakeholder involvement, thus not being practical. Most models are single-hazard-oriented and ignore social-political influences, whereas multi hazard reality exists in regions such as Chattogram.

Methodological dominance of AHP in water resource studies is also frequently not backed by much empirical validation (Sheikh Sayed et al., 2025; Sresto et al., 2021). On a spatial scale, studies focus on saline and drought-stricken areas and do not pay adequate attention to peri-urban groundwater depletion. The quantity and quality of groundwater are often discussed separately and socio-environmental aspects are hardly incorporated within wider resilience approaches.

Due to the use of limited datasets, expert judgment, and narrow goals (CBD or accommodation site selection), studies in urban planning are limited to specific objectives. This limits relevance within the fast-changing urban setting. The research on waste management focuses on landfill siting, with little attention to the aspect of treatment, recycling, and behavior. There is still a lack of systemic integration. In case of industrial research, use of GIS-MCDA are scare and mostly stationary, with minimal environmental and social sustainability considerations. The agricultural research is on the rise, but it is fragmented to suit either land or crop type without the connection to livelihoods and climate. The studies of energy, especially those examining the suitability of solar and wind sites, rely more on physical criteria rather than infrastructure, economics, or policy feasibility (Aghaloo et al., 2023; M. S. P. Rana & Moniruzzaman, 2024). There are limited but promising studies on the intersection of health, tourism, and vulnerability. Long-time sustainability or community viewpoints are overlooked in COVID-19 and ecotourism reviews (Sarkar, 2020; Habib et al., 2024; Sheikh et al., 2025).

Future studies should focus on more thematic and spatially balanced coverage to advance the field, particularly in areas that have been underrepresented in the literature and hazard research. The systematic use and testing of hybrid GIS-MCDA methodologies could be urgently achieved through the wider adoption and validation of empirical data, coupled with participatory methodologies, to increase contextual accuracy and legitimacy. Complex, multi-hazard, and multi-sectoral realities need to be captured using integrative frameworks that incorporate socio-economic, environmental, governance, and climatic dimensions. Larger and more specialized sets of criteria that reflect the dynamic changes in the urban and natural environments where resilience and sustainability are applied and integrate sector studies into holistic resilience and sustainability can enhance policy relevance and practical application. Additionally, the active involvement of different stakeholders in the research process will facilitate the broader application of research findings across the sector. By resolving the issues described above, GIS-MCDA can be utilized more effectively to facilitate evidence-based decision-making and sustainable development within the context of a highly dynamic and complex socio-environmental landscape in Bangladesh.

#### Conclusion

The present systematic review reveals significant insights related to diversified use of integrated geospatial technologies and MCDA techniques in different sectors of Bangladesh. The review results show that GIS-MCDA has been utilized by various sectors such as disaster management, water resource management, urban planning, waste management, energy, health, tourism and industrial sectors to address enormous critical issues. AHP is revealed as the most widely used technique and its versatility in numerous applications has been established, however, Fuzzy AHP, ANP, TOPSIS and AHP-ANN are also used in complex and predictive research. Geographic distribution also highlights the hotspot of specific disasters that can aid in country’s sustainable and efficient management of resources as well as disaster risk reduction. Also, increase of emerging themes in energy, industry and tourism sectors pinpoints to the shifting research focus towards environmental conservation and sustainable development. However, lack of high-resolution data, technical expertise and computational requirements are restricting the optimal use of GIS-MCDA in Bangladesh. The future research may use enhance access to data, invest in technical instruments, and apply the complex models in a simplified way to get optimum benefit. Overall, this review emphasizes the importance of GIS-MCDA in decision making contexts for sustainable development of the nation and establishes a direction for further research and policy acceptance when challenged by environmental and socio-economic issues.

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