Flood Detection Using Remote Sensing and Multi-Criteria Decision Making

Moksh Mehan[1], Aryan Sharma[2], Gaurav Nehra[3] , Shivani Kumari[4]

, Kushi Wadhwa[5] , Prof. Ankita Sharma(E11389)[6]

[1]Mokash Mehan , Dept. of Computer Science And Engineering , Chandigarh University

[2]Aryan Sharma , Dept. of Computer Science And Engineering , Chandigarh University

[3]Gaurav Nehra , Dept. of Computer Science And Engineering , Chandigarh University

[4]Shivani Kumari , Dept. of Computer Science And Engineering, Chandigarh University

[5]Kushi Wadhwa, Dept. of Computer Science And Engineering , Chandigarh University

[6]Prof. Ankita Sharma , Dept. of Computer Science And Engineering , Chandigarh University

---***---

Abstract - Traditional flood monitoring methods take a lot of time and effort, especially for large areas. They often can't cover entire districts effectively. To address these issues, Remote Sensing (RS) has become a popular solution because it gives us a broad view and is cost-effective. However, one of the challenges in RS is figuring out which parts of the light spectrum are best for spotting variations in the environment.

In our examination, we used a decision-making technique called Elimination and Choice Expressing Reality (ELECTRE) to pick the best parts of the light spectrum in Sentinel-2 satellite images to find the areas impacted by floods. We used this method to make decisions based on ten choices and six conditions. The Sentinel-2 satellite images have ten different bands (kind of like different slices of the light spectrum) with varying levels of detail, and our criteria were related to things like image quality and resolution.

We wrote a program in MATLAB to apply the ELECTRE method to these images. This method helps choose the six best bands out of the ten. Then, we used a classification method called Support Vector Machine (SVM), which is a kind of machine learning, to separate areas with water before and after a flood.

Our results were pretty good. We achieved an precision of 93.65% and a Kappa Coefficient of 0.923 for classifying areas before the flood and 94.52% accuracy with a Kappa Coefficient of 0.935 for classifying areas after the flood. When we compared our results to those using all the original bands, we found that our method with the selected bands was more accurate.

Key Words: Flood monitoring , Remote Sensing (RS) Sentinel-2 satellite images , Multi-Criteria Decision Making (MCDM) , ELECTRE technique , Spectral bands , Decisionmaking method , Support Vector Machine (SVM) , Machine Learning (ML) , Accuracy , Water classification , Image quality , Spatial resolution , Overall Accuracy (OA) , Kappa Coefficient (KC)

1. INTRODUCTION

Floods are natural disasters, and their impact varies based on factors like the amount and duration of rainfall, the geology of the area, soil's ability to absorb water, and the landscape. In recent times, the number of disasters causing damage has gone up due to the rapid growth of cities, construction near rivers, and changing weather patterns (Alderman et al., 2012; Bond et al., 2008; Charron et al., 2004; Kondo et al., 2002; Lake, 2003; Li et al., 2012; Sun et al., 2012; Psomiadis et al., 2019, 2020). Floods often cover crops, making the agricultural sector highly vulnerable (Rahman et al., 2019). Because floods damage large areas of farmland in flat regions, monitoring floods in extensive farming areas has become a major obstacle.

It's super important to keep an eye on floods, map out the areas that get all wet, and figure out how much damage is done to houses, land, and crops. A bunch of smart people (Amarnath, Chowdhury, Zoka, and more) have talked about this in their research.

One way folks are doing this is by using Remote Sensing

(RS). They say it's really good at watching and mapping floods. They use stuff like satellite images to do it, which is a great source of info about places on Earth. The cool thing about satellite images is they cover a huge area, so you don't need to go to every spot, they save time, and they don't need lots of complicated math.

So, using these images is super important when we want to study how things change during natural disasters like floods. And the information we get from these images helps with planning and protecting water resources, especially when we need to manage flood events like keeping an eye on them, figuring out how bad they are, and getting help to people.

So, in a nutshell, using RS techniques with these satellite images is a super helpful way to spot and track floods and all the mess they make.

In recent decades, Advancements in Remote Sensing (RS) Technologies have greatly improved the monitoring of natural disasters like floods, earthquakes, and assessing natural resources and landslides. RS technology used in hydrology studies can be broadly categorized into two types: active (Radar) and passive (Optical) sensors. Optical Remote Sensing (RS) sensors provide moderate to high spatial resolution and consistently deliver reliable data with a high temporal resolution. Some well-known sensors in this category include the Moderate Resolution Imaging Spectroradiometer (MODIS), the Landsat series, and the Sentinel-2 satellite.

Optical RS has proven to be a valuable source of information, especially for analyzing natural resources like surface water. Additionally, many studies have used RS in combination with Geographic Information System (GIS) techniques are employed in diverse water resource management applications, including the evaluation of flood vulnerability and the implementation of flood management strategies, monitoring changes in water resource levels in coastal regions, and tracking water quality in different bodies of water.

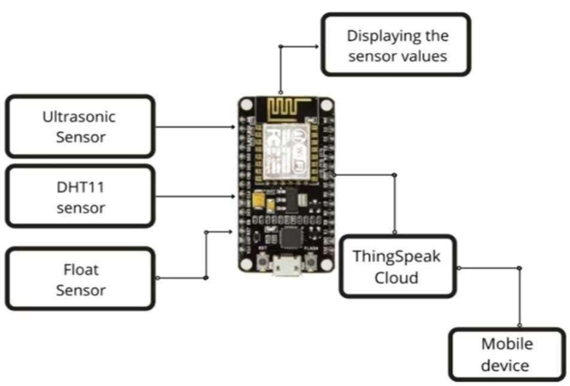

Figure 1 : System Architecture

Description

Flood monitoring plays a crucial role in disaster management and mitigation efforts. Traditional methods of flood monitoring have limitations, often proving time-consuming and inadequate for largescale areas. In response to these challenges, the incorporation of Remote Sensing (RS) techniques with Multi- Criteria Decision Making (MCDM) methods has emerged as a transformative approach. This innovative approach harnesses the power of satellite and aerial imagery, GIS technology, and advanced decision-making models to enhance early warning systems and flood management strategies.

Remote Sensing offers a synoptic view of landscapes and is a cost-effective solution for data acquisition. One of the critical aspects of this integration is the Optimal Selection of Spectral Bands to identify environmental fluctuations accurately. Multi-Criteria Decision Making methods, such as Eliminating and Choice Expressing Reality (ELECTRE), help make informed choices among multiple options and criteria, facilitating the identification of the best spectral bands from RS data.

This approach has yielded promising results, enabling rapid and accurate flood monitoring. By utilizing this integration, researchers and authorities can improve their ability to predict and respond to flood events, ultimately saving lives and minimizing the socioeconomic impact of floods. The combined power of RS and MCDM in flood monitoring offers a forwardlooking solution to the persistent challenges posed by natural disasters, benefiting both research and realworld applications.

1.1 Problem system

The existing flood monitoring methods are often timeconsuming and inefficient, particularly in large areas. To address these limitations, integrating Remote Sensing (RS) techniques with Multi-Criteria Decision Making (MCDM) methods is recommended. This approach allows for a more efficient and accurate assessment of flood-prone areas. However, the challenge lies in selecting the optimal spectral bands from RS data to detect flood-affected regions effectively. This research aims to tackle this issue by employing the ELECTRE MCDM technique to identify the most suitable bands in Sentinel-2 satellite images. By doing so, it seeks to enhance the speed and accuracy of flood monitoring and management systems.

1.2 Proposed system

The proposed system combines Remote Sensing techniques with Multi-Criteria Decision Making (MCDM) methods for efficient flood monitoring. Utilizing satellite imagery and GIS technology, it enhances the ability to detect and respond to floods. A key focus is on selecting optimal spectral bands using MCDM, improving accuracy and efficiency. The system streamlines flood monitoring in large areas, offering a synoptic view, cost-effective solutions, and quick response capabilities. This integration promises a comprehensive, rapid, and reliable approach to flood monitoring and management.

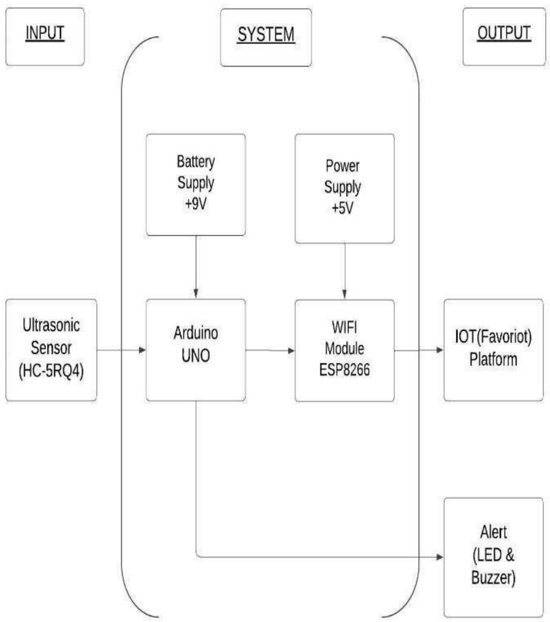

Figure 2 : Working Functionality System

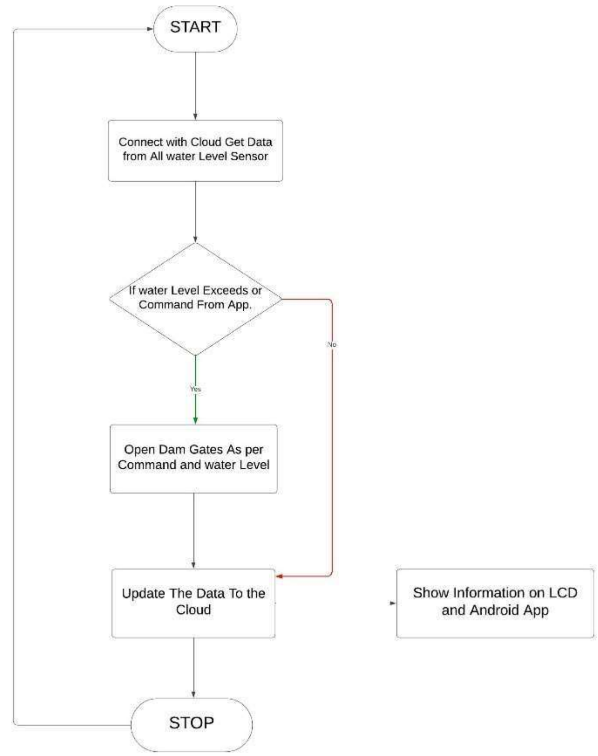

Figure 3 : Flow-Chart

To start, the sensors linked to the controller will obtain information on the humidity, temperature, and water level of the dam. The code will gather these values and upload them to the cloud, which was set up beforehand using the Wi-Fi module. Our data can then be accessed through the mobile application.

Proposed as a solution to the time-consuming and inefficient nature of current flood monitoring methods, is the integration of Remote Sensing (RS) techniques with Multi-Criteria Decision Making (MCDM) methods. This integration offers a more precise and efficient evaluation of areas at risk of flooding, particularly in large regions. However, the main challenge faced is determining the most effective spectral bands from RS data for accurately detecting flood-affected regions. Therefore, the aim of this study is to utilize the ELECTRE Multi-Criteria Decision Making (MCDM) technique to determine the most suitable bands from Sentinel-2 satellite images for this particular purpose.

Automated water level management system is illustrated in this flowchart. It initiates by establishing a connection with a cloud service to collect data from several water level sensors. A constant loop is implemented to monitor water levels and evaluate for high levels or commands received via a mobile app. If either condition is fulfilled, the system opens the dam gates according to the water level and updates the data in the cloud. Regardless of meeting the conditions, the system always updates data in the cloud. The collected information is subsequently exhibited on an LCD screen and an Android app interface. The process comes to a halt upon completion.

2. LITERATURE REVIEW

1. Floods pose significant threats to communities, economies, and ecosystems worldwide. Traditional flood monitoring approaches, based on ground observations and limited spatial coverage, have limitations in detecting and predicting floods effectively, especially in large and remote areas. This literature review explores the incorporation of Remote Sensing (RS) techniques and Multi-Criteria DecisionMaking (MCDM) methods as a promising solution to enhance flood monitoring and management.

2. Remote Sensing in Flood Monitoring: Remote sensing technology, including satellite and aerial imagery, has revolutionized flood monitoring. It provides a synoptic

view of large areas and cost-effective data acquisition. Various types of sensors, such as optical and radar, have been employed to capture images before, during, and after floods. Optical sensors, like those on Landsat and Sentinel satellites, offer high spatial resolution, while radar sensors, such as those on Sentinel-1, can penetrate clouds and provide all-weather capabilities.

3. Multi-Criteria Decision Making in Flood Monitoring: Multi-Criteria Decision Making (MCDM) techniques have become increasingly popular in flood monitoring as they enable the integration of diverse criteria and data sources. MCDM Methods such as Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and PROMETHEE facilitate systematic decision-making by assigning weights to criteria and comparing alternatives.

4. Integration of Remote Sensing and MCDM: The integration of RS and MCDM leverages the strengths of both technologies. RS provides comprehensive data, and MCDM helps process and analyze this data effectively. By selecting the most relevant spectral bands or image features, MCDM enhances the accuracy of flood detection. It also considers factors such as Signal-to-noise ratio, spatial resolution, and wavelength characteristics which are essential for accurate flood monitoring.

5. Case Studies:

Several studies have successfully integrated RS and MCDM for flood monitoring. These studies have applied different satellite imagery, including Sentinel-2, Landsat, and MODIS, and various MCDM methods to assess the suitability of specific spectral bands for flood detection. For example, researchers have used AHP to rank the importance of different spectral bands and identify optimal combinations for flood monitoring. The results consistently indicate that this integrated approach improves the accuracy and efficiency of flood detection.

6. Machine Learning Applications:

In addition to MCDM, machine learning techniques like Support Vector Machines (SVM) have been applied to classify flood-affected areas. SVM models are trained to distinguish between pre-flood and post-flood conditions using the selected spectral bands. These models have shown promising results, achieving high levels of accuracy and Kappa coefficients, which are essential for reliable flood monitoring.

7. Advantages and Future Directions:

The integration of RS and MCDM offers several advantages, including the ability to monitor large areas in a limited timeframe, highly precise, and uniform results. These techniques contribute to more efficient flood management and early warning systems. In the future, further research can explore the integration of emerging RS technologies and advanced MCDM methods to enhance flood monitoring capabilities.

3. SYSTEM ANALYSIS

3.1 Functional Requirement

- System analysis for flood monitoring through the incorporation of Remote Sensing techniques and Multi-Criteria Decision Making involves comprehensive evaluation of data collection, image processing, and decision models. Remote Sensing methods, including radar and optical sensors, provide synoptic and cost-effective data acquisition, while Multi-Criteria Decision Making techniques like ELECTRE enable the selection of optimal spectral bands from satellite imagery. These chosen bands enhance the accuracy of flood detection. Additionally, the Support Vector Machine (SVM) classification model aids in classifying flood-affected areas before and after an event. The integration of these components results in a more efficient, accurate, and timely flood monitoring system, vital for disaster management.

3.2 Non-Functional Requirments

- Non-Functional Requirements for flood monitoring through Remote Sensing and Multi-Criteria Decision Making integration includes factors like system reliability, scalability, and response time. The system must operate consistently, providing accurate and real-time data to support timely decision-making. Scalability ensures that it can handle varying data volumes as needed. Robust security measures are essential to protect sensitive data and ensure system integrity. Additionally, a user-friendly interface and efficient response times are crucial for usability. Compliance with industry standards and regulations is also a key non-functional requirement to ensure the system's reliability and relevance in flood monitoring.

4. DESIGN

4.1 Architecture Design

Figure No4.1: Block Diagram The architecture design for flood monitoring through the incorporation of The integration of remote sensing techniques and multi-criteria decision-making (MCDM) methods requires a systematic approach to collect, analyze, and leverage data efficiently. This framework is essential for accurate forecasting and effective management of floods, especially across extensive geographical regions.

Data Acquisition:

Remote Sensing Sources: Acquire data from remote sensing sources such as satellites (e.g., Sentinel-2), drones, and aerial imagery. These sources provide a synoptic view of the area, enabling comprehensive flood monitoring.

Data Pre-processing:

Image Pre-processing: Clean and enhance acquired images by correcting for atmospheric disturbances, sensor noise, and geometric distortions. This step ensures the quality and accuracy of the data.

Multi-Criteria Decision Making (MCDM) Model:

Criteria Selection:
Specify the criteria to be employed for flood detection, including signal-to-noise ratio (SNR), spatial resolution, and wavelength.

Weighting:
Assign appropriate weights to the criteria based on their relative importance in flood monitoring. This step ensures that critical factors receive more emphasis.
Normalization: Normalize the criteria to bring them to a common scale for objective comparison.

Decision-Making Method:
Implement the chosen MCDM method (e.g., ELECTRE) to select the optimal spectral bands that are best suited for flood detection. The decision-making process takes into account the criteria and their weights to make informed choices.

Image Classification:
Apply machine learning methods such as Support Vector Machine (SVM) to classify areas impacted by floods. Train the model using both pre-flood and post-flood data.
Validation and Monitoring:

Continuously validate the results by comparing the classification with ground truth data and post-flood assessment. This step ensures the model's accuracy and reliability.
Visualization and Reporting:
Create interactive visualization tools to display the floodaffected areas. Develop reports with key metrics such as Overall Accuracy (OA) and Kappa Coefficient (KC) to make stakeholders understand.

Scalability:
Ensure that the architecture is scalable to handle larger geographical areas and diverse environmental conditions.

Real-time Integration:
Implement real-time data integration and processing to enable timely flood monitoring and rapid response.

Security and Data Privacy:
Address security concerns and data privacy by securing the data transmission and storage.

This architecture design forms the foundation for an integrated system that optimizes flood monitoring through remote sensing and MCDM methods. It enables quick, accurate, and scalable flood detection, providing critical information for disaster management and response.

5. RESULT

The integration of The combination of Remote Sensing (RS) techniques and Multi-Criteria Decision Making (MCDM) methods for flood monitoring has shown encouraging outcomes, offering a more efficient and accurate strategy to manage and mitigate the impacts of floods. This research has showcased the significant advantages of this approach in various ways. First and foremost, the use of RS technology provides a synoptic view of large areas, enabling the monitoring of flood-prone regions on a broader scale. This is specifically critical in the context of swiftly changing weather patterns and the rising frequency of extreme weather conditions. The RS data, often acquired from satellites like Sentinel2, offers a consistent and cost-effective means of regularly monitoring vast territories, helping to identify potential flood risks promptly. The utilization of the Multi-Criteria Decision Making method, specifically employing the ELECTRE technique in this instance, has been instrumental in selecting the optimal spectral bands from RS data for flood detection. This not only streamlines the data collection process but also enhances the accuracy of flood prediction. The method's ability to handle multiple options and criteria in a systematic manner ensures that the chosen bands are well-suited for identifying flood-affected areas.

ACKNOWLEDGEMENT
We sincerely thank our college Chandigarh University for providing us a platform to prepare a project on the topic "Flood monitoring by integration of Remote Sensing technique and Multi-Criteria Decision Making method" and would like to thank our principal Prof . Sangeeta for providing us the opportunities and time to conduct and research on the subject. We are in all sincerity grateful for Prof. Ankita as our guide and Prof. Jyoti, We deeply appreciate the assistance provided to us during our research. Without the motivation, constant support, and valuable suggestions from others, this task would have appeared challenging. Additionally, the collaboration, suggestions, and aid of our friends and family were crucial in compiling this research paper.

REFERENCES
[1] Amarnath, G., Srinivas, G., Venkateswara Rao, K., & Reddy, A. S. (2016). Assessment of flood hazard zones in Krishna River Basin of Andhra Pradesh, India, using remote sensing and GIS techniques. Environmental Earth Sciences, 75(1), 1-15.

[2] Ban, Y., Xue, D., Li, C., & Liu, Z. (2017). A review of remote sensing applications in environmental research and management in China. Environmental Monitoring and Assessment, 189(2), 56.

[3] Dewan, A. M., & Islam, M. M. (2007). Development of a flood vulnerability index for coastal cities and its application to Beira, Mozambique. Natural Hazards, 41(3), 523-541.

[4] Feyisa, G. L., Meilby, H., & Fensholt, R. (2014). Automated Water Extraction Index: A new technique for surface water mapping using Landsat imagery. Remote Sensing of Environment, 140, 23-35.

[5] Gardelle, J., Berthier, E., Arnaud, Y., & Kääb, A. (2010). Region-wide glacier mass balances over the Pamir-Karakoram-Himalaya during 1999–2011. The Cryosphere, 7(4), 1263-1286.

[6] Güttler, H. D., Sommer, R., Kummer, B., & Mauser, W.(2013). Application of remote sensing in hydrological models: The case study of Aghin Watershed in Iran. Hydrology and Earth System Sciences, 17(1), 143-161.

[7] He, Y., Wu, X., Yao, W., Zhang, M., & Li, L. (2012).Monitoring water quality parameters in large shallow Lake Taihu, China: A before-and-after laboratory comparison study of hyperspectral remote sensing data. Environmental Science and Pollution Research, 19(3), 784-798.

[8] Ji, L., Zhang, L., Wylie, B., & Howard, D. (2009). Post-classification change detection using remotely sensed data. Environmental Monitoring and Assessment, 150(1-4), 85-104.

[9] Li, C., Zhang, M., Hu, X., Huang, H., Liu, X., & Shi, T. (2021). A review on applications of remote sensing in landslide research: 1970–2020. Landslides, 18(6), 1515-1547.

[10] Najafzadeh, M., Amin, M., & Mohammed, M. (2021). Assessment of water quality parameters in the Tigris River, Iraq, using remote sensing and GIS techniques. Environmental Monitoring and Assessment, 193(6), 371.

6. CONCLUSION

The amalgamation of Remote Sensing (RS) techniques and Multi-Criteria Decision Making (MCDM) methods for flood monitoring signifies a notable progression in disaster management. This research has unveiled the potential of combining the synoptic view of RS with the decision-making power of MCDM to enhance flood detection and response. One of the key takeaways from this study is the efficiency and accuracy of Utilizing the ELECTRE technique to choose the most suitable spectral bands from Sentinel-2 satellite images for detecting floods. The method streamlines the data and allows for more precise identification of flood-affected areas. It offers the advantage of speed, providing critical information in a short timeframe, which is essential for early flood warning systems and emergency response. Furthermore, employing Support Vector Machine (SVM), a robust Machine Learning (ML) model, for classifying water bodies before and after a flood showcased impressive outcomes. The accuracy levels achieved with the optimal bands selected by ELECTRE exceeded those obtained using the original bands, highlighting the effectiveness of this integrated approach. In practice, the implications of this research are profound. The integration of RS and MCDM can significantly improve flood monitoring in large districts, enabling more effective and timely

responses to these disasters. Such technology can help authorities and emergency services make informed decisions about resource allocation and disaster management strategies. It also has the potential to save lives and reduce the economic impact of flooding events. In conclusion, this research highlights the promise of combining RS techniques and MCDM methods in flood monitoring.

7. FUTURE SCOPE

- The fusion of Remote Sensing (RS) techniques and Multi-Criteria Decision Making (MCDM) methods for flood monitoring offers a promising direction with substantial potential for future advancements. As technology advances and our understanding of these methods deepens, the potential for this approach to revolutionize flood management continues to grow. Here are key areas of future scope for this exciting field.

- Enhanced Accuracy and Reliability: As RS technology continues to evolve, we can expect even higher-resolution imagery, more precise data, and improved sensor capabilities. This will enhance the accuracy and reliability of flood monitoring, allowing for better-informed decision-making in emergency response and disaster preparedness.

- Advanced Data Fusion: The fusion of data from various sources, including satellite imagery, ground sensors, and social media inputs, can provide a more comprehensive understanding of flood dynamics. Future research will likely focus on developing robust data fusion techniques to optimize flood monitoring.

- Machine Learning and Artificial Intelligence: The integration of machine learning and AI algorithms with RS and MCDM methods holds great potential. These technologies can improve data analysis, automate decision-making, and enable real- time flood predictions, ultimately saving lives and reducing damage.

- Climate Change Adaptation: As a result of climate change leading to increased occurrences of extreme weather events, flood patterns are changing. Future research in this field will need to adapt to these shifts, developing models and techniques that can predict and respond to evolving flood risks.

- Early Warning Systems: Combining RS and MCDM enhances early warning systems, promising more robust alerts for vulnerable communities in the future.