6th Intercontinental Geoinformation Days

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Investigating the flooded area of Bangladesh by Sentinel_1 and CHIRPS images in the GEE system

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Keywords
Sentinel_1
Flood
NDBI
Climate change
CHIRPS

Abstract

Climate change has been linked to the occurrence of severe weather events such as storms, droughts, and floods. The utilization of remote sensing technology has shown promise in predicting these events and supporting crisis management planning efforts. A noteworthy example is the catastrophic flooding that occurred in Bangladesh in May 2022, resulting in a significant loss of life and displacement of hundreds of thousands of individuals. In response, remote sensing techniques, including CHIRPS satellite imagery and Synthetic Aperture Radar (SAR) data, were employed to monitor and assess the extent and impact of the flooding. The Normalized Difference Built-Up Index (NDBI) was utilized to demonstrate a decrease in urban development by 10% in areas affected by floods. Moreover, the public's preference for urban development was found to be clustered around the northwestern border with India, indicating potential areas of focus for future urban development planning. These findings highlight the utility of remote sensing technology in the realm of crisis management and urban development planning.

1. Introduction

The 2020 average global surface temperature statistically matched 2016 as the warmest year on record, continuing a long-term warming trend due to human activities (climate.nasa.gov). Disaster risk from rainfall is now universally discussed due to its possible connection with global warming. Catastrophic rainfall has been decreasing until the mid-2010s, after which it is likely to increase due to increased rainfall intensity (Towhata, 2022). Of course, natural disasters such as floods happen all over the world. Due to their negative impact on various social, economic and environmental aspects, the need to monitor and map these phenomena has increased. In fact, we use open-source remote sensing (RS) images obtained by optical and radar sensors to access flood-affected areas. In addition, by using Sentinel-1 images, we suggest using ground range detected images (GRD) (Benzougagh et al., 2021). Geospatial resources, including satellite-based Synthetic Aperture Radar (SAR) and optical data, have been very useful in providing time-sensitive information on the extent and impact of natural hazard events such as floods to support emergency response and crisis management efforts (Hertel et al., 2023).

For example, 41.98 percent of the disaster events that occurred in 2021 in Indonesia were flood disasters. A rainfall of 2.08 billion cubic meters occurred in the second week of January 2021 in South Kalimantan, Indonesia, where the volume of rainwater was not proportional to the capacity of the Barito watershed, causing flooding in 11 cities/districts (Adiba and Bioresita, 2022). Konawa Utara District is one of the southeast Sulawesi districts that experienced flash floods in 2019. As a result, this flood caused significant environmental and economic damage and damaged several public infrastructures. Mangidi et al used Sentinel 1 SAR images and the Sigma-Naught Index (NDSI) to investigate this incident. This method can identify the backscatter value comparison from the image before and during the flood. Then the extraction of flood information, the results of this study show that floods occurred in some important areas of North Kunawe region and six (6) regions namely Wiwirano region, Oheo region, Molawe region, Langgikima region, Asera region, Andowia region are under the water is a slave. Among these regions, the Ohio region suffered the most flooding with 1,836.88 hectares (4.1% of the total area of the Ohio region).

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Cite this study

Kamran, K. V., Makky, N., & Charandabi, N. K. (2023). Investigating the flooded area of Bangladesh by Sentinel_1 and CHIRPS images in the GEE system. Intercontinental Geoinformation Days (IGD), 6, 83-88, Baku, Azerbaijan

Dataset was used to test the effectiveness of the proposed model. The findings showed that ES-LSTM and RNN achieved 17.3 and 42.6 in terms of mean absolute percentage error (MAPE), respectively. Meanwhile, the ANN and DT models achieved the prediction accuracy of 96.65% and 84.0%, respectively. Finally, the results showed that ES-LSTM and ANN obtained the best results compared to other models (Hayder et al., 2023). Previous work was done on building flood forecasting models with the aim of reducing risks, proposing policies, reducing mortality and limiting property damage caused by floods. The massive amount of data generated by social media platforms such as Twitter opens the door to flood analysis. Due to the in-situ nature of Twitter data, some government agencies and authorities have used it to track natural disaster events in order to develop a faster rescue strategy. However, due to the shorter duration of tweets, it is difficult to build a complete forecasting model for flood determination. Machine learning (ML) and deep learning (DL) methods can be used to statistically develop flood forecasting models. At the same time, the large volume of tweets makes it necessary to use big data analysis (BDA) tools for flood forecasting. In this regard, this work presents an optimal flood forecasting model based on deep learning with big data analysis (ODLFF-BDA) based on Twitter data. The proposed ODLFF-BDA technique aims to predict the presence of floods using tweets in a big data environment. The ODLFF-BDA technique involves data preprocessing to convert incoming tweets into a usable format. In addition, a bidirectional coder representation of transformers (BERT) model is used to generate emotional textual embeddings of tweets. In addition, a gated regression unit (GRU) with a multi-layer convolutional neural network (MLCNN) is used for local data mining and flood forecasting. Finally, an equilibrium optimizer (EO) is used to fine-tune the meta-parameters of the GRU and MLCNN models in order to enhance the prediction performance. If compared with other algorithm techniques, the memory usage is less than 3.5 MB. The performance of the ODLFF-BDA technique was verified using the Kaggle benchmark dataset, and the findings showed that it significantly outperformed other recent approaches (Indra and Duraipandian et al., 2023). The operating conditions of large cascade hydropower plants are complex. Improving the accuracy of water level prediction of large cascade hydropower plants is significant for flood control, transportation, irrigation, etc. To create input data in the form of a feature map so that the model can weight features of each of the influencing factors when the water level changes, speed, flow and output data of the hydropower plant were also created. In this process, the LSTM parameters are optimized using the Archimedes optimization algorithm, and the output results of the LSTM and GRU networks are weighted to obtain a more accurate water level forecast. The proposed model achieves good accuracy and efficiency in forecasting the water level downstream of Xiangjiaba Hydropower Station, outperforms existing artificial intelligence and hydrodynamic methods, and has strong scalability in flood forecasting and urban rainwater forecasting (Ma et al, 2023). Understanding the different characteristics of rainfall is essential for water resources management. However, the highly variable nature of rainfall is important in accurately estimating rainfall in a particular region. Such variability in rainfall leads to floods or droughts, both of which are potentially catastrophic (Anandh et al., 2022). Knowing the precipitation trends using time series observations is the key to reliably determining the behavior of future observations. In fact, precipitation is an important part of the hydrological cycle, and its gradual change over time, due to ongoing climate change, is of interest to water resource managers and hydrologists. Indeed, global climate change affects the distribution of rainfall, altering water availability by increasing the length of dry periods and increasing the frequency of floods (Kessabi et al., 2023). CHIRPS combines satellite images with a resolution of 0.05° with insitu station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring (chc.ucsb.edu). Many studies have been conducted to investigate the error characteristics of precipitation products in different temporal and spatial scales. In the Adige basin, CHIRPS was shown to be the best product, and all products show larger errors in terms of overall statistical measures in the winter months (Duan et al., 2016). Based on this research, we used Chirps satellite to check it. Mardab al-Hawiza is one of the important marshes in the south of Iraq and near the Iranian border. They are rich in distinctive nature and in the past centuries, large rural communities have been formed around them and their water is taken from the Euphrates and Tigris. In 2018, a destructive flood in the Tigris River basin affected many areas. Ahmed et al. by comparing the land use before and after the flood season for Al-Hawiza swamps and also determined water reflection values using remote sensing and geographic information systems for the years 2018 and 2019, water reflection values using Landsat-8 images between the years It was calculated on 3/4/2018 and 3/7/2019 and before and after the flood wave that covered the southern swamps. The results showed that remote sensing can accurately determine the water and the extent of the flooded area caused by flooding in swamps and extracted from Landsat 8 using the NDBI, NDWI index (Ahmed et al., 2022).

2. Method

By using VH polarizations for vertical transmission and horizontal reception, VV for vertical transmission and vertical reception, and (IW) in the Google earth engine system, a radar image of flooded areas were created. The interferometric wide band (IW) mode is the primary ground acquisition mode and meets most service requirements, acquiring data over a 250 km band with a spatial resolution of 5 meter and 20 meters. Sentinel_1 image on the surface of our study identified with the ground range (GRD) were uploaded in the engine environment, the data of the said polarizations were processed for flood mapping for its accuracy in flood detection, also from decibel images due to the high quality in determining the flood was used. CHIRPS is a 35-year quasi-global rainfall dataset covering 50°S to 50°N from 1981 that integrates indoor climatology, CHPclim, satellite imagery, and rain gauge data (Funk et al., 2016). The best spatial resolution of CHIRPS is 0.05 degrees.

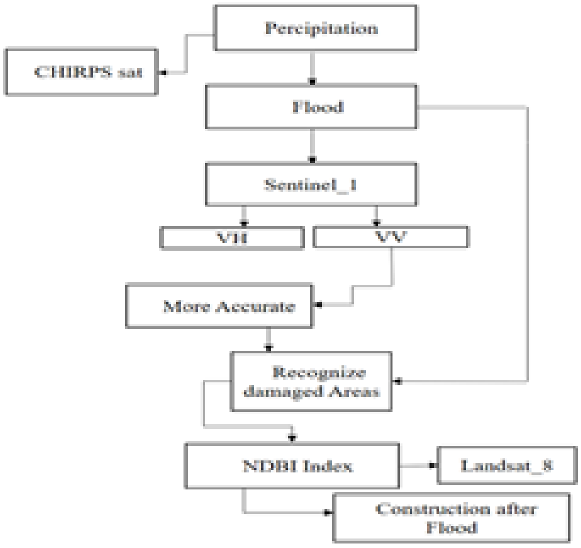

Figure 1. Flowchart

Our study area is located in Bangladesh, which is one of the most flood-prone areas in the world. Bangladesh is a country located in South Asia. The total area of this country is 143,998 square kilometers with a population of 149.7 million people. The population density is 1039 per square kilometer, which is one of the highest in the world. Geographically, it extends from 20°34' to 26°38'N latitude and from 88°01' to 92°41'E longitude. Except for the hilly areas of the southeast, most of the country is a low-lying plain land. In terms of climate, this country belongs to subtropical regions where Dushanbe weather prevails throughout the year. The average temperature of the country in winter is between 7.20 and 12.80 degrees Celsius and 23.90 and 31.10 degrees Celsius (Shahıd et al., 2006). The choice of this country as a study area was due to the fact that in 2022, a flood occurred on the 11th of MAY, which caused the death of hundreds of people and the displacement of several thousand people. Examining and presenting flood prevention methods can be effective.

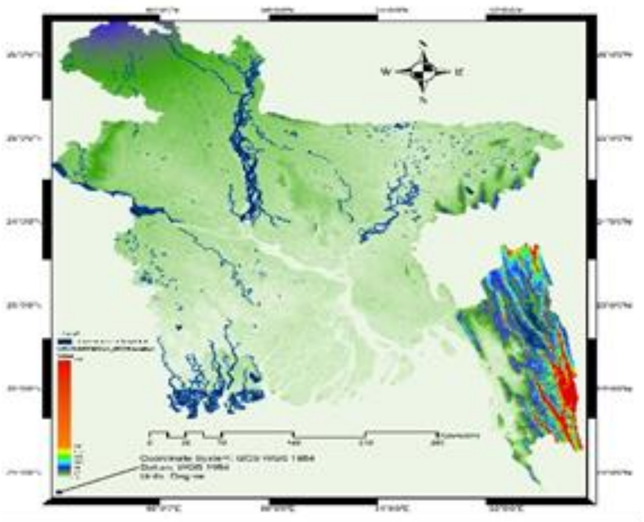

Figure 2. Case study

3. Results

The radar image after the flood was created by two polarizations VV and VH in the GEE system. MAX and MIN numbers indicate greater accuracy in detailing flood effects in VV polarization.

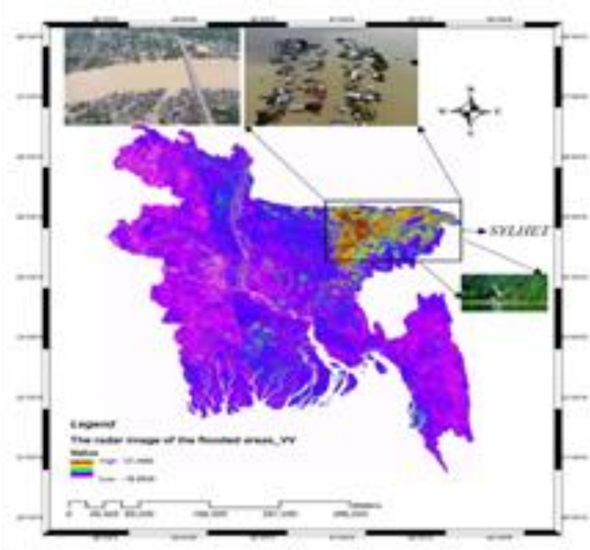

Figure 3. Radar image of the flooded area with VV polarization

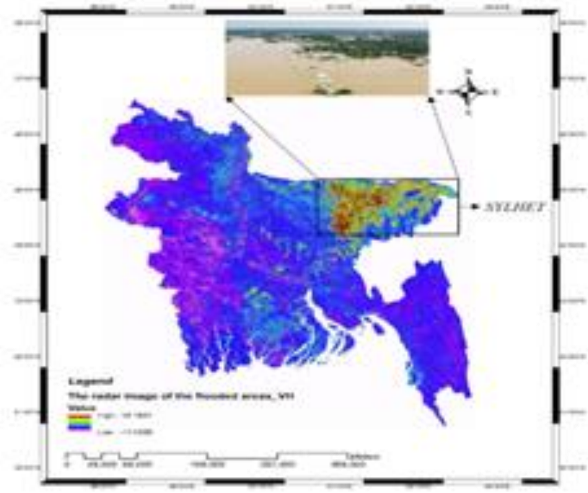

Figure 4. Radar image of the flooded area with VH polarization

Table 1. Table of coverage details by two polarizations

Polarization	VV	VH
MAX effect	23.2464	18.1641
MIN effect	-18.2949	-17.0599

Due to the fact that a severe flood occurred on 11/05/2022 in Bangladesh and had a destructive effect on large parts of this country, we used the GEE system to analyze the rainfall images obtained from the CHIRPS satellite for 14 months. The start date was selected from 05/2021 to 07/2022. The amount of precipitation two months after the flood was extracted for further investigation. The results showed that in the months close to the date of the flood, this country has seen a lot of rain. In the months of MAY, JUNE, 2021, and 2022, the amount of precipitation has increased sharply. The area marked with a dark color is the area of SYLHET state, which has heavy rainfall and there was a destructive flood in that area. Also, the graph of the time series of one year's rainfall with the mentioned satellite in the GEE system was created for further investigation.

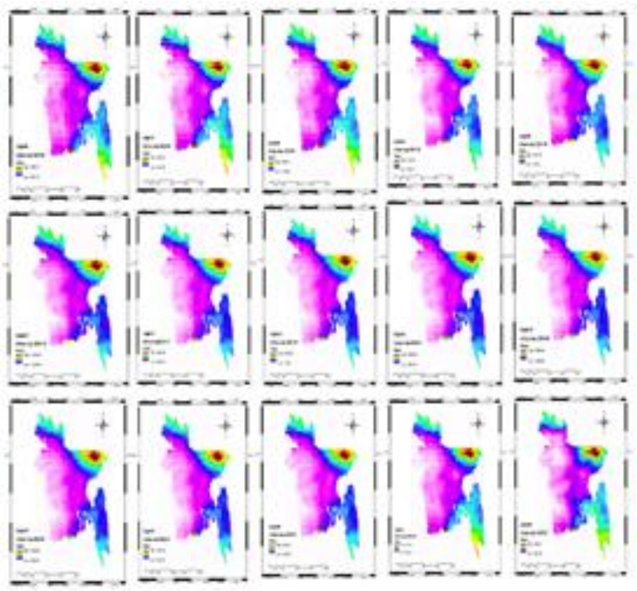

Figure 5. Rainfall images from CHIRPS satellite

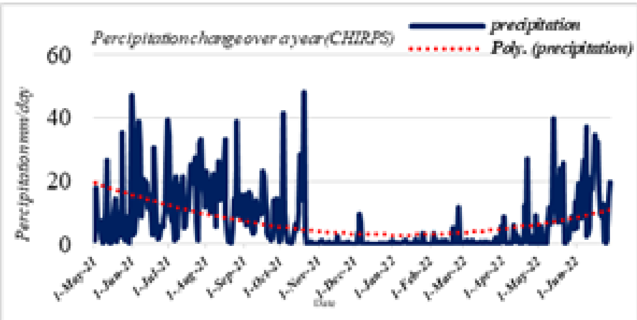

Figure 6. Time series diagram of rainfall in Bangladesh during one year

In addition, the resulting time series graph shows abundant rainfall in the months of MAY and June. One of the important reasons for this flood is heavy and continuous rain. These rainfalls are increasing due to global warming and the necessary forecasts must be made in all countries due to the increase of these rainfalls. Global warming increases the probability of heavy precipitation (from 40 to 60 mm/h) by about 1.3 to 1.8 times, but at the same time reduces the probability of light precipitation (from 1 to 10 mm/h) by about 20%. Gives. Urban development increases the probability of urban rainfall in all intensity ranges. It is worth noting that the effects of rapid urban development could be as important as global warming in the near future in intensifying heavy hourly rainfall in coastal megacities (Chenix et al., 2023). In addition to high rainfall, land subsidence may be another effective factor in flooding (Jiang et al, 2023). Land subsidence (LS) is one of the most challenging natural disasters that has potential consequences such as damage to infrastructure and buildings, creating sinkholes and leading to soil degradation (Eghrari et al., 2023).

The NDBI index, which was extracted with the Landsat_8 sensor, shows the developed areas and is calculated from the following formula.

$$NDBI = (SWIR - NIR) / (SWIR + NIR) \quad (1)$$

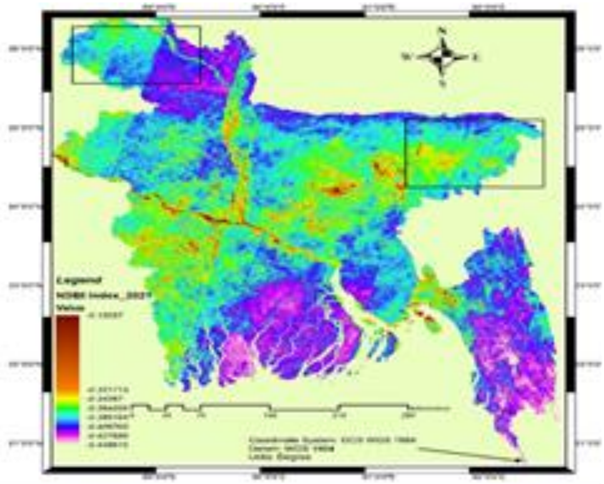

Figure 7. NDBI_2021 index

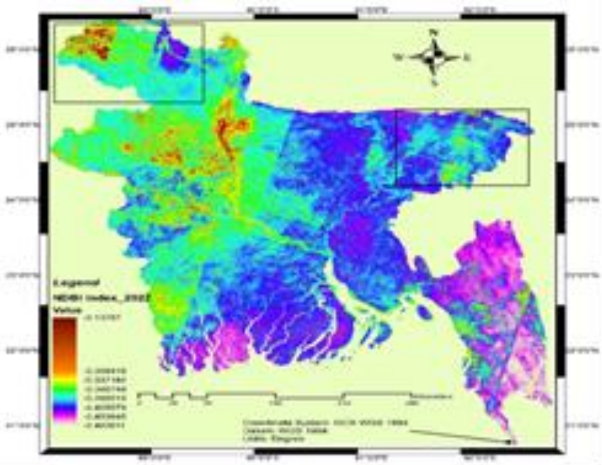

Figure 8. NDBI_2022 index

4. Discussion

Flood mapping using Synthetic Aperture Radar (SAR) and precipitation data from satellites such as Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) is crucial in managing flood risks globally. SAR uses microwaves to detect changes in water coverage and is useful in monitoring flood extent and level conditions day or night. CHIRPS produces high-quality precipitation estimates and combines satellite measurements and ground-based rainfall data to calculate rainfall patterns, aiding in flood risk management and climate change adaptation. The integration of SAR and CHIRPS data provides a comprehensive image of water inundation helping determine volume, speed, direction, and flooded regions, supporting flood risk assessment, prevention, and monitoring. Given the significant impact of flooding worldwide, the use of SAR and CHIRPS technologies is essential to aid decision-making for flood management programs.

5. Conclusion

Floods are known to have severe negative impacts on human life, finances, and urban development. In 2022, Sentinel-1 radar data was utilized to identify areas affected by floods in Bangladesh. The observed CHIRPS satellite images validated heavy precipitation surrounding the estimated flood-affected locations. During May, the northeastern region of Bangladesh experienced torrential rains that culminated in severe flooding. Due to its low-lying environment and numerous rivers, Bangladesh is particularly vulnerable to flooding, mandating a minimum distance between the waterways during periods of heavy rainfall. Analysis utilizing the NDBI index revealed a 10% decrease in urban growth and development rates in the flooded area, indicating that the costly damage caused by the floods had discouraged construction activities in the region. Currently, there is ongoing developmental work in the northwest region of Bangladesh, which shares its borders with India. With global warming, major cities may experience increased rainfall, underscoring the requirement for proactive measures such as precise predictions and necessary preparations to alleviate the risks associated with flooding.

Acknowledgement

Acknowledgements of support for the project/paper/author are welcome.

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