ISSN 2664-4150 (Print) & ISSN 2664-794X (Online)
South Asian Research Journal of Engineering and Technology
Abbreviated Key Title: South Asian Res J Eng Tech

| Volume-4 | Issue-6 | Nov-Dec- 2022 | **DOI: 10.36346/sarjet.2022.v04i06.004**

Original Research Article

Flash-Flood Potential Mapping in Agricultural Land Using Rule-Based Classification Approach on Multi-Temporal Synthetic-Aperture Radar (SAR) Data over Jhajjar and Rohtak Districts of Haryana State

Om Pal[1], Hemraj[1*], Sultan Singh[1]

[1]Haryana Space Applications Centre (HARSAC), Hisar, CCS, Campus, Haryana Agricultural University, Hisar, Haryana 125004, India

***Corresponding Author:** Hemraj
Haryana Space Applications Centre (HARSAC), Hisar, CCS, Campus, Haryana Agricultural University, Hisar, Haryana 125004, India

Article History
Received: 24.11.2022
Accepted: 27.12.2022
Published: 31.12.2022

Abstract: Flash floods are known to be most dangerous flood. In recent decades there is change in the climate and urban development causing increase in the risk of flash flood for human population. Remote sensing and geographical information system playing a very important and feasible role in assessment of the flash flood over a decade. This paper describes the synergetic use of Synthetic-aperture radar (SAR) data to delineate and mapping of the flooded area at its peak. The methodology was tested on the flash flood event that occurs in Jhajjar and Rohtak districts of Haryana in July, 2022. Four Sentinel-1 Synthetic-aperture radar data were acquired and pre-processed, two images are acquired before the occurrence of the event and two SAR images were acquired after the event. For the identification and demarcation of the flooded area, the rule-based classification approach was used. The results of the study suggests the scope of using multi-temporal Sentinel-1 VV polarized C-band SAR data to develop an operational flash-flood area identification and framework.

Keywords: Flash-flood, Synthetic-aperture radar, Rule based classification.

INTRODUCTION

In recent decades, the natural disaster and its related phenomenon like flash-flood have the significant impacts on the environment and human population. Flash-flood is a natural disaster that occurs rapidly after the heavy precipitation (Elkhrachy, 2015). In recent decade, there is an increase in the flash floods events due to the change in the weather and climate. The flash-flood is a kind of natural disaster which causes the damage to the ecosystem, agricultural area, build up area and the loss of human life. The floods may pollute the potable water by the transfer of industrial and biological waste which will results in the environmental pollution (Messner Frank & Meyer, 2006). Therefore, to delineate the spatial extent of the flooded area becomes very crucial and obligatory procedure to be used in disaster risk management strategy (Costache & Tien Bui, 2020). In order to plan for the relief management by the local administration during the emergency phase and even after the event, the exact mapping of the extent of water spread becomes very crucial to avoid the severe damage to the agricultural fields, road-rail network, human settlement and life. The traditional methods based on ground surveys used for flood mapping are time consuming and may not be feasible due to the bad weather conditions during the emergency phase. So, alternative methods for the assessment of flooded areas involves the use of remote sensing and geographical information system techniques which is playing a very crucial and feasible role in the recent era (Brivio *et al.*, 2002).

The importance of remotely sensed data in flash-flood monitoring and mapping is well recognized. It is observed from previous few decades that various studies in different countries such as Saudi Arabia (Elkhrachy, 2015), India (Jain *et al.*, 2005), Egypt (El-Saadawy *et al.*, 2020), Romania (Costache *et al.*, 2021), Iran (Shahabi *et al.*, 2020) and United States of America (Klemas, 2015) were carried out using the integration of remote sensing and GIS for the

Copyright © 2022 The Author(s): This is an open-access article distributed under the terms of the Creative Commons Attribution **4.0 International License (CC BY-NC 4.0)** which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited.

flood mapping. In the recent years optical data which acquired by the passive sensors onboard satellite has been widely used for the delineation and mapping of flooded area. This approach involves the visual and digital interpretation of the satellite imagery. Optical data operates in the visible, near infrared and mid infrared region of electromagnetic spectrum. The electromagnetic radiations operating in optical region being of shorter wavelength are not able to penetrate through the clouds in rainy season. This inability to penetrate through the clouds poses constraints for flood mapping. Synthetic-aperture Radar (SAR) being an active remote sensing system operating in the longer wavelength region of electromagnetic spectrum can provide all weather data for the monitoring and mapping of flooded area. This is because longer wavelength region electromagnetic radiations can easily penetrate through the clouds and rain. Also SAR is capable of operating day or night. In radar image, backscattering is recorded from various land cover surfaces. The backscattering coefficient being the function of smoothness, roughness, dielectric properties etc. may vary from surface to surface. It is observed in various studies that horizontal smooth surfaces such as water surfaces, roads, runways etc. reflect the maximum energy away from the sensor causing specular reflection. This causes dark tonality of the smooth surfaces in SAR imagery. The specular reflection can be decreased by bad climatic conditions or the presence of roughening in the surface and vegetation which makes the detection of flooded area more difficult (Laugier *et al*., 1997). Moreover in the SAR imageries due to the random constructive and destructive interference between the coherent returns issued from various scatterers present on earth surface causes a undesirable noise called as speckles. These grainy salt-and -pepper pattern structure present in radar imagery reduces the quality of the image and hence put constraints in the image classifications. This results in the difficulties in the interpretation of SAR images. The speckle filtering is an efficient tool for reducing the speckles and hence improving the quality of the image for better image interpretation.

Sentinel-1 satellite is a Synthetic-aperture Radar mission of Copernicus program which provide a high-resolution data. Due to the sensitivity of the backscattered signals to open water, SAR becomes the most appropriate data for the flood assessment and mapping (Zoka *et al*., 2018).

The objective of this study is to monitor and mapping of flash-flooded area by using the available SAR data with the help of hierarchal rule-based classification approach. Therefore, the main focus of the study is to identify the major areas affected by the flash-flood hazard. In the present case the flash flooded event occurred on the last week of July, 2022 following by an extreme and heavy precipitation in the central part of the Haryana in which Rohtak and Jhajjar Districts got highly affected. For the flood mapping the Sentinel-1 Synthetic-aperture radar data operating in the C-band data was downloaded and pre-processed. For better demarcation and flood mapping, two satellite imageries before the event and two after the event were used. For the demarcation of flooded area, the hierarchal rule-based classification technique is used. This study suggests the scope and potential of multi-temporal SAR data operating in C-band to develop an operational flash-flood area identification and framework.

Study Area and Data

Study Area

The study area includes the Jhajjar and Rohtak districts of Haryana State. The study area lies between 28° 30' to 28° 54' North latitudes and 76° 27' to 76° 54' East longitudes covering an area of 3579 Km2. The study area has a sub-tropical climate and with an average rainfall of 592mm. The area is occupied by the Indo-Gangetic alluvium with a sandy loam to clay loam soil type. Wheat and paddy are the major agricultural crops of this area.

Data Used

Multi-temporal Sentinel-1A SAR data were used for the estimation of flash-flood area in the Rohtak and Jhajjar Districts of Haryana. This data was downloaded from the Copernicus website (https://scihub.copernicus.eu/dhus/#/home) from July to August 2022. Sentinel-1A having C band SAR provides all weather day and night data at temporal resolution of 12 days. In this study, the C-band high resolution GRD data of IW mode with a spatial resolution of 10m of VV polarized descending order data has been used for the assessment of flash-flood area.

METHODOLOGY

The multi-date Sentinel-1(SAR) datasets were acquired from the Sentinel data website (https://scihub.copernicus.eu/). The multi-date SAR data of Sentinel-1 was pre-processed by using SNAP software by following the standard procedure of pre-processing. The acquired data was filtered to remove speckles and calibrated to get radar backscattering coefficient in dB. The radar backscattering coefficient (in dB) then was converted in digital number DN (amplitude of the backscattered signal). The detailed methodology is shown in flowchart in fig.2.The multi-date geo-referenced and co-registered data was used for the identification and mapping of flooded area.

Based on the temporal behavior of various land cover features and noting the backscattered values on the multi-date data, a knowledge was formed. Using the knowledge base, hierarchical decision rules were formed which were used to segregate the flooded and non flooded area based on the temporal backscatter response.

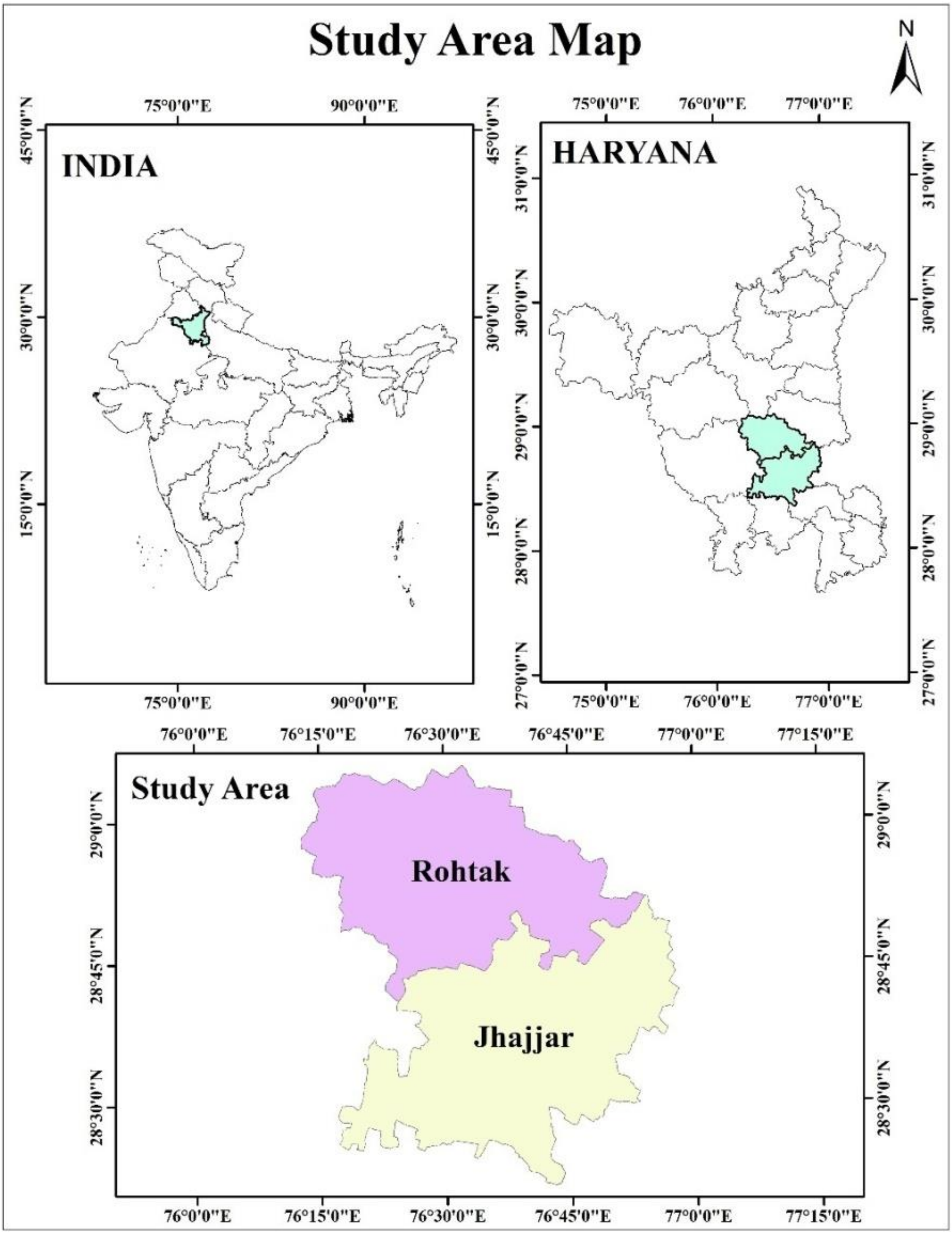

Figure 1: Location map of Study Area

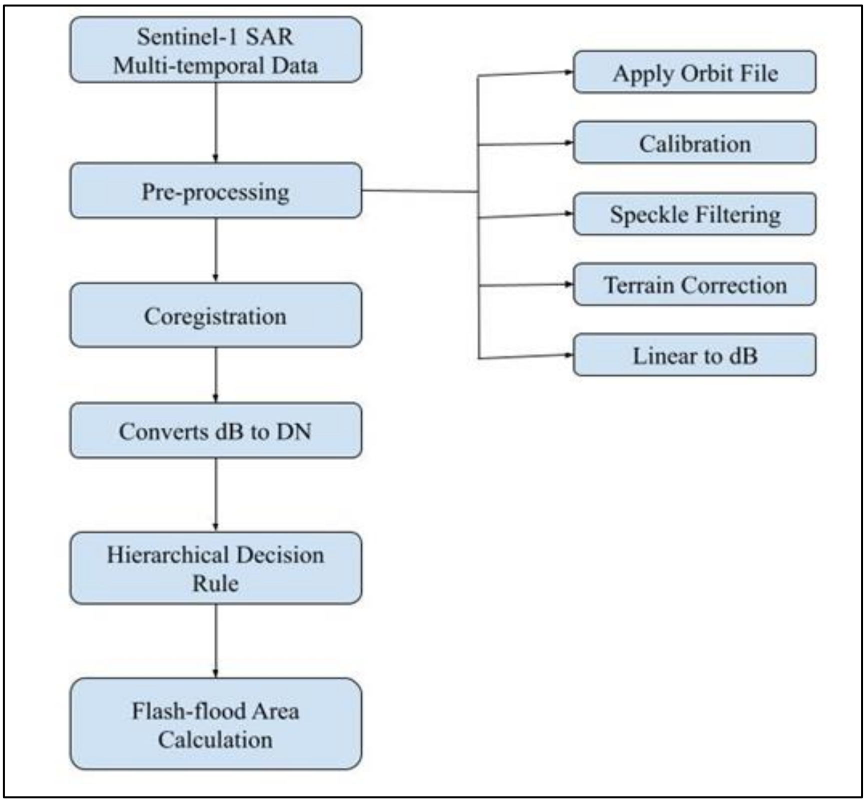

Figure 2: Methodology Chart

The total area in hectare was computed by multiplying the number of pixels under the flood to the area of each pixel.

RESULTS AND DISCUSSION

Any natural calamities like flash flood causes damage to the agriculture, settlements, rail road network etc. During flood the management authorities requires detailed and accurate spread of the water for the mitigation measures to rescue the people and property. With the integration of remote sensing and GIS the detailed and accurate information of flood affected areas can be find out with less time period. In this present study spatial and temporal dynamics of flash-flood were assessed and analyzed by using Sentinel-1 SAR data.

SAR Backscattering study and Analysis

In many studies it is observed that SAR plays a very crucial role to map backscattering properties of different land cover features. In the present study the backscattered values recorded in multi-temporal SAR imageries were analyzed for various land cover features viz., settlement, water body, agriculture and flash-flooded areas. As depicted in the figure 3 settlement areas shows the highest and constant backscattering in all the dataset having very small change. This may be due to the effect of corner reflection from the settlement areas causing maximum return to the SAR antenna. The water bodies show the lowest and constant backscattering in all the datasets which may be due to the effect of specular reflection from the smooth water surfaces causing maximum return of the radiations away from the antenna. Based on the temporal backscatter the cultivated area was segregated in main growing paddy and other associated kharif season crops. The paddy crop depicts high backscattering in the month of June and rapid decrease in backscattering in the month of July which may be due to the transplanting of paddy crop in the fields. As the crop grows the backscattering increases in the month of august .For the other associated kharif season crops low backscattering is observed in July and after that other crops depict increasing trend in the backscattering due to the vegetative growth of the crop.

In the flash-flooded areas, there is high backscattering in the imageries acquired before the event and low backscattering in the imageries acquired after the event. The water has low backscatter value as compared to other spatial land features which are to high backscatter value (Schlaffer *et al*., 2017; Zhao *et al*., 2019). After studying the temporal backscatter profile of all main land cover classes in the study area, range of backscattered values for flooded areas in multi-date imageries is selected and hierarchical decision rules were framed that clearly separates the flooded areas from the other land cover classes. So, after studying the temporal backscatter profile, a clear difference between the flash-flooded and non-flooded areas is made and based on this the flooded areas can be clearly mapped. The affected area by the flood was calculated by multiplying the number of pixels to the area of each pixel.

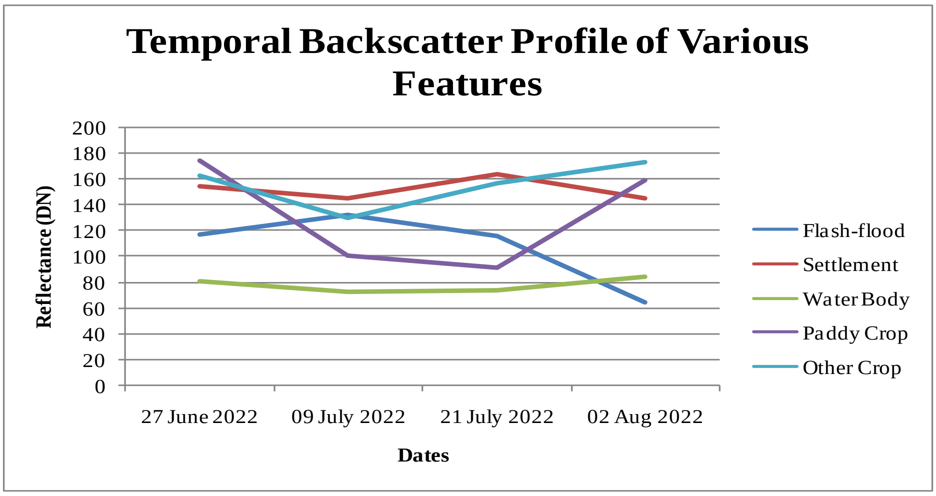

Figure 3: Backscatter profile of SAR data over various spatial features

Image classification and area estimation

The flash-flood identification, discrimination and mapping was done by using the multi-date Sentinel-1 SAR data .The temporal backscatter profile from 27 June 2022 to 02 August 202 was analyzed to develop a knowledge base. Using the knowledge base, hierarchal rule-based classification approach was used to delineate the flash-flood area from other land cover features.

Figure 4 shows the classified flash-flood mask overlaid on multi-temporal SAR data. So, by studying the temporal backscatter profile the flash-flooded area can be clearly delineated from other land cover features like settlement, water bodies, and agricultural land etc.

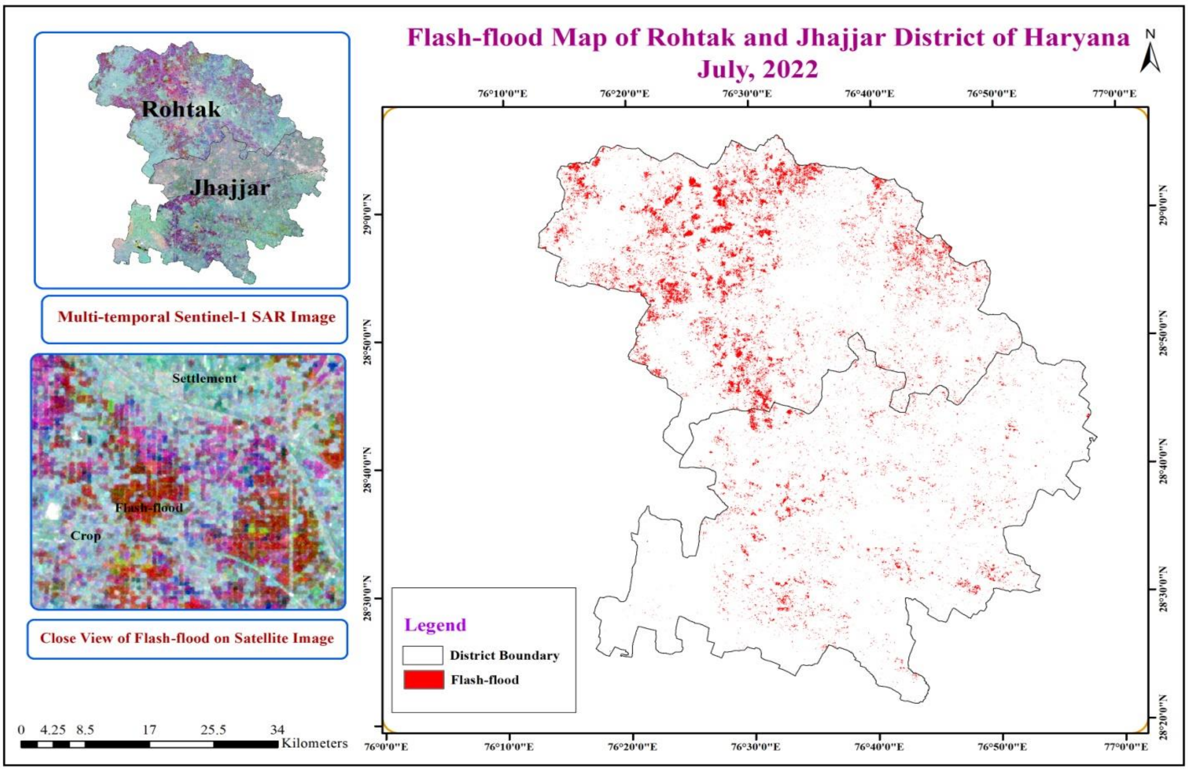

Figure 4: Classified Flash-flood mask overlaid on Rohtak and Jhajjar district boundary

As per the classification of SAR data the total area of flash-flood of Rohtak and Jhajjar is 45953.3 Acers. The total area was calculated by multiplying the number of pixels under the flash-flood mask to the area of each pixel and the total was multiplied with 2.4711 for area in acres. The total flash-flood area of Rohtak and Jhajjar district was 35014.2 and 10939.1 acres respectively. As per the satellite data Rohtak faces 31.24% more flash-flood than Jhajjar district.

CONCLUSION

The exact mapping of flooded area is essential to assess the actual damage caused by flood. Various satellite data interpretation techniques based on visual observation/interpretation of satellite imagery and algorithm applied to single date imagery has limitations to delineate the inundated areas during the flood. Optical data operates in the visible, near infrared and mid infrared region of electromagnetic spectrum. The electromagnetic radiations operating in optical region being of shorter wavelength are not able to penetrate through the clouds in rainy season. This inability to penetrate through the clouds poses constraints for flood mapping. Synthetic-aperture Radar (SAR) being an active remote sensing system operating in the longer wavelength region of electromagnetic spectrum can provide all weather data for the monitoring and mapping of flooded area. In the present study, to discriminate the flooded area from non-flooded areas two SAR images before the event and two after the event were acquired. The use of multi-temporal images is very important for the areas where the natural calamities like flash flood have occurred. The present study emphasis the potential of multi-temporal SAR data to map out the flooded area using the ruled based classification approach.

ACKNOWLEDGEMENTS

Authors are grateful to Director HARSAC, Hissar for providing necessary support to carry out this study. The authors sincerely thank Copernicus Open Access Hub for free downloading of Sentinel-1Amulti-temporal SAR data.

REFERENCES

- Brivio, P. A., Colombo, R., Maggi, M., & Tomasoni, R. (2002). Integration of remote sensing data and GIS for accurate mapping of flooded areas. *International Journal of Remote Sensing*, 23(3), 429–441. https://doi.org/10.1080/01431160010014729
- Costache, R., Arabameri, A., Blaschke, T., Pham, Q. B., Pham, B. T., Pandey, M., Arora, A., Linh, N. T. T., & Costache, I. (2021). Flash-flood potential mapping using deep learning, alternating decision trees and data provided by remote sensing sensors. *Sensors (Switzerland)*, 21(1), 1–21. https://doi.org/10.3390/s21010280
- Costache, R., & Tien Bui, D. (2020). Identification of areas prone to flash-flood phenomena using multiple-criteria decision-making, bivariate statistics, machine learning and their ensembles. *Science of the Total Environment*, 712, 136492. https://doi.org/10.1016/j.scitotenv.2019.136492
- El-Saadawy, O., Gaber, A., Othman, A., Abotalib, A. Z., Bastawesy, M. El, & Attwa, M. (2020). Modeling flash floods and induced recharge into alluvial aquifers using multi-temporal remote sensing and electrical resistivity imaging. Sustainability (Switzerland), 12(23), 1–20. https://doi.org/10.3390/su122310204
- Elkhrachy, I. (2015). Flash Flood Hazard Mapping Using Satellite Images and GIS Tools: A case study of Najran City, Kingdom of Saudi Arabia (KSA). *Egyptian Journal of Remote Sensing and Space Science*, 18(2), 261–278. https://doi.org/10.1016/j.ejrs.2015.06.007
- Jain, S. K., Singh, R. D., Jain, M. K., & Lohani, A. K. (2005). Delineation of flood-prone areas using remote sensing techniques. *Water Resources Management*, 19(4), 333–347. https://doi.org/10.1007/s11269-005-3281-5
- Klemas, V. (2015). Remote sensing of floods and flood-prone areas: An overview. *Journal of Coastal Research*, 31(4), 1005–1013. https://doi.org/10.2112/JCOASTRES-D-14-00160.1
- Laugier, O., Fellah, K., Tholey, N., Meyer, C., & De Fraipont, P. (1997). High temporal detection and monitoring of flood zone dynamic using ERS data around catastrophic natural events: The 1993 and 1994 Camargue flood events. European Space Agency, (Special Publication) ESA SP, 997(414 PART 1), 559–564.
- Messner F., & Meyer, V. (2006). "Flood Damage, Vulnerability and Risk Perception – Challenges for Flood Damage." *Environmental Research*, 149–167.
- Schlaffer, S., Chini, M., Giustarini, L., & Matgen, P. (2017). Probabilistic mapping of flood-induced backscatter changes in SAR time series. *International Journal of Applied Earth Observation and Geoinformation*, 56, 77–87. https://doi.org/10.1016/j.jag.2016.12.003
- Shahabi, H., Shirzadi, A., Ghaderi, K., Omidvar, E., Al-Ansari, N., Clague, J. J., Geertsema, M., Khosravi, K., Amini, A., Bahrami, S., Rahmati, O., Habibi, K., Mohammadi, A., Nguyen, H., Melesse, A. M., Ahmad, B. Bin, & Ahmad, A. (2020). Flood detection and susceptibility mapping using Sentinel-1 remote sensing data and a machine learning approach: Hybrid intelligence of bagging ensemble based on K-Nearest Neighbor classifier. *Remote Sensing*, 12(2). https://doi.org/10.3390/rs12020266
- Zhao, J., Chini, M., Matgen, P., Hostache, R., Pelich, R., & Wagner, W. (2019). An automatic SAR-based change detection method for generating large-scale flood data records: The UK as a test case. *International Geoscience and Remote Sensing Symposium (IGARSS)*, 2019-July, 6138–6141. https://doi.org/10.1109/IGARSS.2019.8900534
- Zoka, M., Psomiadis, E., & Dercas, N. (2018). The Complementary Use of Optical and SAR Data in Monitoring Flood Events and Their Effects. 2, 644. https://doi.org/10.3390/proceedings2110644