IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Dynamism Of Deep Learning For Drought And Flood Prediction In The Narmada River Basin

[1] Prof. Chetankumar B Parmar, [2] Prof. Bhaveshbhai R Maheshwari, [3] Prof. Ramniklal L Gilatar

[1]Assistant Professor (BCA), [2]Assistant Professor (CS), [3]Assistant Professor (BCA)

[1] BCA Department,

[1] Narmada College of Science & Commerce, Bharuch- Gujarat, India

[2] Department of Computer Science,

[2] Narmada College of Science & Commerce, Bharuch- Gujarat, India

[3] BCA Department,

[3] Narmada College of Science & Commerce, Bharuch- Gujarat, India

Abstract: Droughts and floods pose significant challenges to the Narmada River Basin, impacting the socio-economic well-being and environmental sustainability of the region. Accurate prediction of these hydrological events is essential for effective water resource management, agricultural planning, and disaster preparedness. Deep learning techniques, with their ability to extract complex patterns from diverse datasets, offer a dynamic approach to enhance drought and flood prediction. This research paper explores the dynamism of deep learning in case of natural calamities like flood & drought, challenges of environmental conditions, and supporting proactive decision-making for drought and flood management in the Narmada River Basin.

Index Terms **– Narmada, Deep Learning, Machine Learning, Flood, Drought, Natural Calamity, Disaster Management.**

I. Introduction

The Narmada River Basin, located in central India & rises from the Amarkantak plateau in Anuppur district Madhya Pradesh. It forms the traditional boundary between North India and South India and flows westwards over a length of 1,312 km (815.2 mi) before draining through the Gulf of Khambhat into the Arabian Sea, 30 km (18.6 mi) west of Bharuch city of Gujarat.[1] is a critical lifeline for millions of people residing in the surrounding regions. However, the basin is susceptible to the adverse effects of both droughts and floods, which pose significant challenges to the socio-economic development and environmental sustainability of the area.[2] Timely and accurate prediction of these hydrological events is essential for effective water resource management, agricultural planning, and disaster preparedness. Traditional methods of drought and flood prediction in the Narmada River Basin rely on statistical models and remote sensing data, which have limitations in capturing the complex spatiotemporal dynamics of these events.[3] With the rapid advancements in computational power and the availability of vast amounts of data, deep learning techniques have emerged as a promising approach to improve prediction accuracy and enhance early warning systems. Deep learning, a subset of artificial intelligence, enables computers to learn complex patterns and extract meaningful information from large and diverse datasets. By utilizing deep neural networks, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), it is possible to analyze various data sources, including satellite imagery, meteorological data, hydrological data, and historical records of drought and flood occurrences.

The deep learning in drought and flood prediction offers several advantages. Firstly, deep learning models can automatically learn and extract relevant features from complex datasets, enabling a more comprehensive understanding of the underlying patterns and relationships. Secondly, these models can handle multi-dimensional data, allowing for the integration of different variables and sources of information. Lastly, deep learning techniques have the potential to improve prediction accuracy, thereby facilitating better decision-making and resource allocation in the face of impending droughts and floods.[4] The objective of this research paper is to investigate potentials of deep learning for drought and flood prediction in the Narmada River Basin. This study has the potential to support proactive measures, optimize resource allocation, and minimize the impacts of droughts and floods on the communities and ecosystems in the Narmada River Basin. In the subsequent sections of this paper, we will address the challenges, limitations, and future directions of deep learning applications in this context. By leveraging the power of deep learning algorithms, Government & Authorities can pave the way for accurate and reliable prediction models, ultimately contributing to improved water resource management, disaster preparedness, and sustainable development in the Narmada River Basin.

II. Challenges posed by floods and droughts on societies and ecosystems

Floods and droughts are natural phenomena that have profound impacts on both human societies and ecosystems. These hydrological extremes can disrupt the delicate balance of ecosystems, damage infrastructure, and have long-lasting social, economic, and environmental consequences. Understanding the significance of these impacts is crucial for effective management and mitigation strategies.[5]

1.1 Impacts on Human Societies

2.1.1 *Loss of lives and injuries*: Floods and droughts can result in casualties and injuries, especially when they occur suddenly or without warning.

2.1.2 *Displacement and migration*: People living in flood-prone or drought-affected areas may be forced to leave their homes, leading to temporary or permanent displacement and subsequent social and economic challenges. [6]

2.1.3 *Infrastructure damage*: Floods can cause damage to buildings, roads, bridges, and other critical infrastructure, leading to disruptions in transportation, communication, and access to essential services.[7]

2.1.4 *Agricultural losses*: Droughts can severely impact agricultural productivity, leading to crop failures, livestock losses, and decreased food production. Floods can also destroy crops and agricultural infrastructure. [8]

2.1.5 *Economic losses*: Floods and droughts can result in significant economic losses due to damage to infrastructure, disruption of businesses, reduced agricultural productivity, and increased costs of recovery and rehabilitation. [9]

2.2 Environmental Impacts

2.2.1 *Ecosystem disruption*: Floods and droughts can disrupt the balance of ecosystems by altering water availability, water

quality, and habitat conditions. This can lead to loss of biodiversity and ecological disturbances.

2.2.2 *Water resource management*: Floods and droughts pose challenges for water resource management. Floods can cause water pollution, sedimentation, and erosion, while droughts can lead to water scarcity and reduced availability of freshwater resources.[10]

2.2.3 *Impact on aquatic ecosystems*: Floods and droughts can affect aquatic ecosystems, including rivers, lakes, wetlands, and estuaries, by altering water flow, nutrient dynamics, and habitat conditions for aquatic species.[11]

2.2.4 *Water quality issues*: Floods can result in the contamination of water sources with pollutants, such as chemicals, debris, and sewage. Droughts can exacerbate water quality problems by concentrating pollutants in limited water supplies.[12]

III. Challenges in Flood and Drought Management

3.1 *Prediction and early warning systems*: Accurate and timely prediction of floods and droughts remains a challenge due to the complex and dynamic nature of these events. Developing effective early warning systems that can provide sufficient lead time for preparedness and response is crucial.[13]

3.2 *Infrastructure planning and resilience:* The design and planning of infrastructure need to consider the risks associated with floods and droughts, including appropriate drainage systems, floodplain zoning, and water storage and conservation measures.

3.3 *Resource allocation and management:* Managing water resources effectively during both flood and drought conditions requires careful planning and coordination to ensure equitable distribution and minimize negative impacts on ecosystems and human populations.

3.4 *Community awareness and participation*: Enhancing public awareness and participation for floods and droughts is vital to reduce vulnerability and improve response capabilities. This includes education, community engagement, and the development of response plans.[14]

Addressing the significant impacts and challenges posed by floods and droughts requires a comprehensive and integrated approach involving scientific research, technological advancements, policy frameworks, and community engagement. By understanding the impacts and developing effective strategies, societies can better adapt to these hydrological extremes and build resilience in the face of future events.

IV. Importance of accurate prediction in mitigating the adverse effects and minimizing damages caused by floods & droughts

Accurate prediction of floods and droughts plays a crucial role in mitigating their adverse effects and minimizing damages caused by these events. The importance of accurate prediction lies in the following aspects.

4.1 *Early Warning and Evacuation*: Accurate prediction provides early warning of an impending flood or drought event, enabling authorities to issue timely alerts to at-risk communities. This allows people to evacuate to safer areas, reducing the risk of injuries, casualties, and property damage. By providing sufficient lead time, accurate predictions enhance preparedness and evacuation efforts, saving lives and mitigating human suffering.[15]

4.2 *Resource Planning and Management*: Accurate prediction of floods and droughts enables better planning and management of resources, particularly water resources. During floods, authorities can manage reservoirs, dams, and river channels to mitigate the impact of excessive water, reduce downstream flooding, and protect critical infrastructure. In the case of droughts, accurate predictions allow for the allocation and conservation of water resources, implementation of water-saving measures, and efficient agricultural planning to minimize crop losses.

4.3 *Infrastructure Protection*: Accurate flood predictions help protect infrastructure such as roads, bridges, buildings, and utilities. Authorities can take proactive measures to reinforce vulnerable infrastructure, implement flood control measures, and divert water flow to minimize damage. Similarly, accurate drought predictions enable appropriate planning and management of water supply systems, ensuring the availability of water during periods of water scarcity and preventing infrastructure failures.[16]

4.4 *Agricultural Management*: Accurate predictions of droughts and floods are essential for agricultural planning and management. Farmers can adjust their planting schedules, irrigation strategies, and crop choices based on the anticipated water availability. Timely information about upcoming droughts allows farmers to take measures such as soil moisture conservation, water-efficient irrigation techniques, and crop diversification to minimize yield losses. In the case of floods, accurate predictions enable farmers to take preventive measures to protect crops and livestock, minimizing agricultural losses.[17]

4.5 *Emergency Response and Disaster Management*: Accurate predictions facilitate more effective emergency response and disaster management. Emergency services, including search and rescue teams, medical facilities, and relief organizations, can be better prepared and mobilized based on accurate forecasts. Timely information about flood levels, inundation areas, and drought severity helps emergency responders allocate resources and coordinate rescue and relief operations efficiently, reducing response time and maximizing the effectiveness of aid efforts.[18]

4.6 *Cost Savings:* Accurate prediction of floods and droughts results in significant cost savings. By providing early warning and enabling proactive measures, accurate predictions reduce damages to infrastructure, properties, and agricultural crops. This minimizes the economic losses associated with recovery, rehabilitation, and reconstruction efforts. Moreover, accurate predictions also help insurance companies and government agencies in assessing risks and developing appropriate risk management strategies, leading to potential cost savings in the long run.

V. Role & Advantages of deep learning in improving the prediction of floods and droughts

The role of deep learning in improving the prediction of floods and droughts is significant and holds great potential. Deep learning techniques, with their ability to learn and extract complex patterns from large and diverse datasets, offer several advantages for enhancing prediction accuracy and reliability in hydrological forecasting. Here are some key roles of deep learning in improving flood and drought prediction.

5.1 *Capturing Nonlinear Relationships*: Deep learning models excel at capturing nonlinear relationships present in hydrological systems. Traditional statistical models often struggle to capture complex interactions between various meteorological, hydrological, and geographical factors. Deep learning algorithms, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), can automatically learn and represent intricate relationships, enabling more accurate and robust predictions.[19]

5.2 *Feature Extraction and Representation Learning*: Deep learning models are capable of automatically extracting relevant features from raw data, eliminating the need for manual feature engineering. In the context of flood and drought prediction, deep learning algorithms can extract informative features from various data sources, including satellite imagery, meteorological data, hydrological measurements, and historical records. This feature extraction process enhances the model's ability to capture the spatiotemporal patterns associated with floods and droughts.[20]

5.3 *Handling Multidimensional Data*: Flood and drought prediction involve multiple variables and sources of data, including precipitation, temperature, soil moisture, river discharge, and more. Deep learning models can effectively handle multidimensional data, allowing for the integration of diverse datasets into a unified framework. By considering multiple variables simultaneously, deep learning algorithms can capture the complex interactions and dependencies among different factors, leading to improved prediction accuracy.

5.4 *Temporal and Spatial Context Modeling*: Deep learning models, particularly RNNs, are well-suited for modeling the temporal dynamics of hydrological processes. RNNs can capture the sequential dependencies in time series data, such as rainfall patterns or river flow measurements, allowing for better understanding and prediction of future flood and drought events. Additionally, deep learning models can also consider the spatial context by analyzing spatial patterns in satellite imagery or geographical data, providing valuable insights into the spatial distribution of floods and droughts.[21]

5.5 *Handling Big Data and Uncertainty:* Deep learning techniques can effectively handle large and diverse datasets, which are increasingly available in the field of hydrology. With access to extensive historical data, deep learning models can learn from past events and make predictions based on a rich knowledge base. Furthermore, deep learning algorithms can also account for uncertainties by incorporating probabilistic frameworks, allowing for uncertainty quantification in flood and drought predictions.[22]

5.6 *Adaptability and Transferability:* Deep learning models have the ability to adapt and learn from new data, making them suitable for dynamic and changing hydrological systems. As new data becomes available, deep learning algorithms can update their predictions and adapt to evolving conditions. Additionally, the knowledge learned from one region or basin can be transferred and applied to similar regions, facilitating the development of transferable models for flood and drought prediction.

VI. Potential applications of Deep Learning in Flood and Drought Prediction

The application of deep learning in flood and drought prediction in the Narmada River basin offers several benefits and opportunities to enhance the accuracy and reliability of predictions. Here are some specific applications of deep learning in flood and drought prediction for the Narmada River:

6.1 *Rainfall Prediction:* Deep learning models can be used to improve rainfall prediction, which is a crucial factor in flood and drought occurrences. By analyzing historical rainfall data from the Narmada River basin and incorporating other relevant meteorological factors, deep learning algorithms can learn the complex relationships between different variables and provide more accurate and localized rainfall predictions. This information can help in assessing flood risks and water availability during drought periods.[23]

6.2 *Flood Inundation Mapping*: Deep learning models, particularly convolutional neural networks (CNNs), can be utilized for flood inundation mapping in the Narmada River basin. By analyzing satellite imagery, topographic data, and historical flood records, CNNs can learn to identify flood-prone areas and predict the extent of inundation during flood events. This information can assist in developing flood hazard maps, aiding in evacuation planning and emergency response.[24]

6.3 *River Flow Prediction*: Deep learning models can be employed to predict river flow in the Narmada River. By integrating historical flow data, rainfall data, and other relevant hydrological parameters, recurrent neural networks (RNNs) can capture the temporal dynamics and dependencies in river flow patterns. Accurate river flow predictions can help in water resource management, reservoir operations, and flood control measures.[25]

6.4 *Drought Severity Assessment*: Deep learning techniques can be applied to assess the severity and duration of drought events in the Narmada River basin. By analyzing historical drought records, satellite-based vegetation indices, soil moisture data, and other relevant climatic variables, deep learning models can learn to identify patterns and indicators of drought conditions. This information can assist in drought monitoring, agricultural planning, and water allocation strategies.[26]

6.5 *Integrated Forecasting Systems*: Deep learning can be integrated into comprehensive forecasting systems that combine various data sources and models for flood and drought prediction. By integrating meteorological data, hydrological models, and remote sensing data into a unified framework, deep learning algorithms can provide real-time and accurate predictions of flood and drought events in the Narmada River basin. These integrated forecasting systems can support decision-making processes, emergency response planning, and long-term water resource management.[27]

It is important to note that the successful application of deep learning in flood and drought prediction in the Narmada River basin requires a robust data infrastructure, including high-quality data on rainfall, river flow, soil moisture, and other relevant variables. Additionally, continuous model training and validation using updated data are essential to ensure the accuracy and reliability of predictions. Collaborative efforts among researchers, hydrologists, and stakeholders in the Narmada River basin are crucial for the development and implementation of deep learning-based prediction systems for effective flood and drought management.

VII. Challenges and Future Directions

While deep learning has shown promise in flood and drought prediction, there are still several challenges to overcome and future directions to explore, particularly in the context of the Narmada River Basin. Some of the key challenges and potential future directions for deep learning in flood and drought prediction in the Narmada River Basin are:

7.1 *Data Availability and Quality*: Deep learning models heavily rely on large and high-quality datasets for training. In the Narmada River Basin, ensuring the availability and accessibility of comprehensive and reliable datasets, including historical flood and drought records, meteorological data, and hydrological measurements, is crucial. Efforts should be made to improve data collection, sharing, and quality assurance processes.[28]

7.2 *Localized and Context-Specific Models*: The Narmada River Basin is a unique and complex hydrological system influenced by regional climatic patterns, topography, and anthropogenic factors. Developing localized deep learning models that consider the specific characteristics and dynamics of the basin is essential for accurate predictions. Future research should focus on tailoring deep learning models to the Narmada River Basin's specific context to enhance their performance and applicability.[29]

7.3 *Data Integration and Fusion*: Integrating diverse data sources, such as satellite imagery, weather forecasts, soil moisture measurements, and river flow data, can provide a more comprehensive understanding of flood and drought dynamics in the Narmada River Basin. Exploring techniques to effectively integrate and fuse these heterogeneous datasets, while considering their spatial and temporal resolutions, can enhance the predictive capabilities of deep learning models.[30]

7.4 *Explanation and Interpretability*: Deep learning models often operate as black boxes, making it challenging to interpret the reasoning behind their predictions. In the context of flood and drought prediction, understanding the factors and features that contribute to the model's decisions is crucial for building trust and making informed decisions. Developing explainable and interpretable deep learning models for the Narmada River Basin can enhance their utility and acceptance among stakeholders.

7.5 *Transfer Learning and Model Generalization*: The Narmada River Basin shares similarities with other river basins in terms of hydrological processes and environmental conditions. Leveraging transfer learning techniques, where knowledge learned from one basin is applied to another, can expedite model development and improve prediction accuracy in data-scarce areas. Exploring the transferability and generalization capabilities of deep learning models for the Narmada River Basin can facilitate their widespread application. [31]

7.6 *Uncertainty Quantification and Risk Assessment*: Accurately quantifying uncertainty in deep learning-based predictions is crucial for effective decision-making and risk assessment. Developing techniques to incorporate uncertainty estimation within deep learning models can enhance the reliability of flood and drought predictions in the Narmada River Basin. This can aid in risk management strategies, insurance planning, and resource allocation during extreme hydrological events.

7.7 *Operational Implementation and Scalability*: Moving from research prototypes to operational implementation is a crucial step for the practical application of deep learning in flood and drought prediction. Addressing challenges related to model scalability, computational efficiency, and real-time processing capabilities is essential. Developing efficient algorithms, leveraging cloud computing, and considering the computational infrastructure available in the region can support the operational deployment of deep learning models.

Addressing these challenges and exploring the suggested future directions can contribute to the advancement of deep learning in flood and drought prediction specifically tailored to the Narmada River Basin. By overcoming these challenges and embracing the opportunities presented by deep learning, stakeholders and decision-makers can benefit from improved prediction accuracy, enhanced preparedness, and effective management of flood and drought events in the basin.

VIII. Conclusion

In conclusion, deep learning offers several advantages for flood and drought prediction in the Narmada River basin, including handling complex relationships, integrating diverse data sources, capturing spatial and temporal context, extracting meaningful features, adaptability to changing conditions, and incorporating uncertainty analysis. By harnessing the power of deep learning algorithms, it is possible to enhance the accuracy and reliability of flood and drought predictions in the Narmada River basin, facilitating better water resource management, disaster preparedness, and mitigation strategies.

IX. References

[1] Narmada Valley Development Authority, NVDA, Government of Madhya Pradesh, Narmada Basin, Narmada Water Dispute". Nvda.nic.in.

[2] Mujumdar, M. et al. (2020). Droughts and Floods. In: Krishnan, R., Sanjay, J., Gnanaseelan, C., Mujumdar, M., Kulkarni, A., Chakraborty, S. (eds) Assessment of Climate Change over the Indian Region. Springer, Singapore. https://doi.org/10.1007/978-981-15-4327-2_6

[3] Lopez, T., Al Bitar, A., Biancamaria, S. et al. On the Use of Satellite Remote Sensing to Detect Floods and Droughts at Large Scales. Surv Geophys 41, 1461–1487 (2020). https://doi.org/10.1007/s10712-020-09618-0

[4] Ludovic Arnold, Sébastien Rebecchi, Sylvain Chevallier, Hélène Paugam-Moisy. An Introduction to Deep Learning. European Symposium on Artificial Neural Networks (ESANN), Apr 2011, Bruges, Belgium. ⟨hal-01352061⟩

[5] Falkenmark, M., Folke, C., Falkenmark, Malin, Freshwater as shared between society and ecosystems: from divided approaches to integrated challenges.2003. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 2037-2049, doi:10.1098/rstb.2003.1386

[6] Gianna Claudia Giannelli,Eugenia Canessa, After the Flood: Migration and Remittances as Coping Strategies of Rural Bangladeshi Households, 2022, Economic Development and Cultural Change, 1159-1195, doi: 10.1086/713939

[7] Philip J. Vardon, Environmental Geotechnics, E-ISSN 2051-803X, Volume 2 Issue 3, June 2015, pp. 166-174

[8] Qiang Zhang, Xihui Gu, Vijay P. Singh, Dongdong Kong, Xiaohong Chen, Spatiotemporal behavior of floods and droughts and their impacts on agriculture in China, Global and Planetary Change, Volume 131, 2015, Pages 63-72, ISSN 0921-8181, https://doi.org/10.1016/j.gloplacha.2015.05.007

[9] Garbero, Alessandra, and Raya Muttarak. "Impacts of the 2010 Droughts and Floods on Community Welfare in Rural Thailand: Differential Effects of Village Educational Attainment." Ecology and Society, vol. 18, no. 4, 2013. JSTOR, http://www.jstor.org/stable/26269405
[10] Loucks, D.P., van Beek, E. (2017). Water Resources Planning and Management: An Overview. In: Water Resource Systems Planning and Management. Springer, Cham. https://doi.org/10.1007/978-3-319-44234-1_1
[11] Alho, C.J.R.; Silva, J.S.V. Effects of Severe Floods and Droughts on Wildlife of the Pantanal Wetland (Brazil)—A Review. Animals 2012, 2, 591-610. https://doi.org/10.3390/ani204059
[12] Luke M. Mosley, Drought impacts on the water quality of freshwater systems; review and integration, Earth-Science Reviews, Volume 140, 2015, Pages 203-214, ISSN 0012-8252, https://doi.org/10.1016/j.earscirev.2014.11.010
[13] Jonathan Raikes, Timothy F. Smith, Christine Jacobson, Claudia Baldwin, Pre-disaster planning and preparedness for floods and droughts: A systematic review, International Journal of Disaster Risk Reduction, Volume 38, 2019, 101207, ISSN 2212-4209,, https://doi.org/10.1016/j.ijdrr.2019.101207
[14] Wirawan Zakariah Hendra, Kismartini, Community Participation in Flood Disaster Management in Sumbawa Regency (case study in Songkar Village), E3S Web Conf. 73 08004 (2018), DOI: 10.1051/e3sconf/20187308004
[15] Hallegatte, S. (2012). A cost effective solution to reduce disaster losses in developing countries: hydro-meteorological services, early warning, and evacuation. World Bank policy research working paper, (6058).
[16] Nicola Ulibarri, Tyler A. Scott, Environmental hazards, rigid institutions, and transformative change: How drought affects the consideration of water and climate impacts in infrastructure management, Global Environmental Change, Volume 59, 2019, 102005, ISSN 0959-3780, https://doi.org/10.1016/j.gloenvcha.2019.102005
[17] Xinjian Guan, Yawen Zang, Yu Meng, Yuan Liu, Hong Lv, Denghua Yan, Study on spatiotemporal distribution characteristics of flood and drought disaster impacts on agriculture in China, International Journal of Disaster Risk Reduction, Volume 64, 2021, 102504, ISSN 2212-4209, https://doi.org/10.1016/j.ijdrr.2021.102504
[18] Taslima Aktar Rani, Integrating ICT on Adaptation Knowledge About Early Warning System for Disaster Managing in Emergency Response Among Different Class, UIJRT | United International Journal for Research & Technology | Volume 01, Issue 03, 2020 | ISSN: 2582-6832
[19] Jooyeong Yun and Seokwoo Kim and Sunae So and Minkyung Kim and Junsuk Rho, Deep learning for topological photonics, Advances in Physics, volume - 7, 2022, Taylor & Francis, 10.1080/23746149.2022.2046156
[20] S. Dara and P. Tumma, "Feature Extraction By Using Deep Learning: A Survey," 2018 Second International Conference on Electronics, Communication and Aerospace Technology (ICECA), Coimbatore, India, 2018, pp. 1795-1801, doi: 10.1109/ICECA.2018.8474912
[21] Lange, H., Sippel, S. (2020). Machine Learning Applications in Hydrology. In: Levia, D.F., Carlyle-Moses, D.E., Iida, S., Michalzik, B., Nanko, K., Tischer, A. (eds) Forest-Water Interactions. Ecological Studies, vol 240. Springer, Cham. https://doi.org/10.1007/978-3-030-26086-6_10
[22] Alexander Y Sun and Bridget R Scanlon, How can Big Data and machine learning benefit environment and water management: a survey of methods, applications, and future directions, July 2019, IOP Publishing Ltd, Environmental Research Letters, Volume 14, Number 7, DOI 10.1088/1748-9326/ab1b7d
[23] Hernández, Emilcy, et al. "Rainfall prediction: A deep learning approach." Hybrid Artificial Intelligent Systems: 11th International Conference, HAIS 2016, Seville, Spain, April 18-20, 2016, Proceedings 11. Springer International Publishing, 2016.
[24] Konapala, Goutam, Sujay V. Kumar, and Shahryar Khalique Ahmad. "Exploring Sentinel-1 and Sentinel-2 diversity for flood inundation mapping using deep learning." ISPRS Journal of Photogrammetry and Remote Sensing 180 (2021): 163-173.
[25] Alizadeh, Zahra, et al. "Assessment of machine learning techniques for monthly flow prediction." Water 10.11 (2018): 1676.
[26] Kaur, Amandeep, and Sandeep K. Sood. "Deep learning-based drought assessment and prediction framework." Ecological Informatics 57 (2020): 101067
[27] Puttinaovarat, Supattra, and Paramate Horkaew. "Flood forecasting system based on integrated big and crowdsource data by using machine learning techniques." IEEE Access 8 (2020): 5885-5905.
[28] Renée M. Filius, Renske A.M. De Kleijn, Sabine G. Uijl, Frans J. Prins, Harold V.M. Van Rijen, and Diederick E. Grobbee, Challenges concerning deep learning in SPOCs International Journal of Technology Enhanced Learning 2018 10:1-2, 111-127

[**29]** Sankaranarayanan, S., Prabhakar, M., Satish, S., Jain, P., Ramprasad, A., & Krishnan, A. (2020). Flood prediction based on weather parameters using deep learning. Journal of Water and Climate Change, 11(4), 1766-1783.
[30] Peng, Yi, et al. "An incident information management framework based on data integration, data mining, and multi-criteria decision making." Decision Support Systems 51.2 (2011): 316-327
[31] Katiyar, Vaibhav, Nopphawan Tamkuan, and Masahiko Nagai. "Near-real-time flood mapping using off-the-shelf models with SAR imagery and deep learning." Remote Sensing 13.12 (2021): 2334**.**