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# A Comprehensive Review for Evaluating Impacts of Urbanization on Flood Risk Assessment Techniques

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**Abstract:** Urbanization has amplified the vulnerability of cities to natural disasters, particularly urban flooding. The trends of past centuries reveal that unplanned urban growth, particularly in floodplain areas, amplifies vulnerability, leading to higher peak runoff and shorter lag times between rainfall and discharge. In under-developing countries, where rapid urbanization coincides with climate risks, face significant flood hazards due to inadequate planning, infrastructure strain, and changing land-use patterns. This study employs a comprehensive review of the impact of urbanization on flood risk tools. Through spatial analysis and hydrological modeling, the study identifies areas most at risk of flooding and simulates flood scenarios based on varying rainfall and urbanization patterns. It also highlights the tools and techniques vital for the identification of floods. The findings highlight the urgent need for smarter urban planning, with an emphasis on using data to guide decisions that can protect lives and property. Additionally, it recommends integrating real-time monitoring technologies to refine flood preparedness and response strategies.

*Keywords: Urbanization, IoT-Based Flood Monitoring, GIS, Remote Sensing, Smart Cities, Hydrological Modeling.*

## I. INTRODUCTION

Urbanization is a defining feature of modern life, shaping the way we live, work, and interact. Around 70% of the world's population by 2050, is expected to settle in built-up areas[1]. Urban migration is not something new that is gaining attention just now[1]. It has been around from many centuries due to the growth in population, infrastructural facilities and living standards available in urban areas. In a developing country like Pakistan, the rate of urbanization is very fast. In this situation, land-use changes and land-cover are investigated as vital components in monitoring the current policies, managing environmental changes and natural resources[2]. While it brings opportunities for growth and development, it also introduces challenges that demand urgent attention. One of the most pressing issues linked to rapid urbanization is the growing vulnerability of cities to natural disasters, particularly urban flooding. As cities expand, often without adequate planning, the strain on drainage systems, land-use changes, and increasing population density exacerbate the risks of flooding. These events disrupt lives, damage infrastructure, and place immense financial burdens on communities and governments.

Flooding is a common, wide-ranging, and destructive natural disasters worldwide[3]. In Pakistan, the challenges posed by urban flooding are particularly severe. Ranked among the most climate-vulnerable nation[5], Pakistan has experienced recurring flood events that have claimed lives, displaced millions, and caused significant economic setbacks. Islamabad and Rawalpindi, two rapidly growing urban centers, are no exception to these risks[5]. The convergence of urban sprawl, inadequate infrastructure, and the impacts of climate change creates a perfect storm for disaster, emphasizing the need for innovative solutions.

This study explores the intersection of urbanization and flood risk, focusing on how GIS and remote sensing can be harnessed to address these challenges. While research around the world has advanced our understanding of flood risk assessment, much of it remains region-specific or lacks the integration needed for comprehensive urban flood management. Our work seeks to fill this gap by developing a framework tailored to the unique needs of Pakistani cities. By analyzing historical rainfall patterns, land-use changes, and topographic factors, the study aims to identify high-risk areas and simulate potential flood scenarios. These insights will not only support disaster preparedness but also guide policymakers and urban planners in building flood-resilient cities.

The urgency of this research lies in the tangible impact it can have on lives and communities. With cities growing at an unprecedented rate, it’s clear that traditional approaches to urban planning are no longer sufficient. By bridging the gap between technology and policy, this study aims to contribute practical, data-driven solutions to one of the most pressing challenges of our time: safeguarding urban spaces against the increasing threat of floods.

## II. TECHNIQUES FOR DATA RETRIEVAL

### 2.1. Precipitation

Several studies have estimated rainfall distribution[6]. Spatial interpolation algorithms can estimate rainfall over a specific region from rain gauge records [7][8]. Although rain-gauge records are accurate and trustworthy at the station where they are installed, the network density is typically insufficient to capture the regional distribution of rainfall.

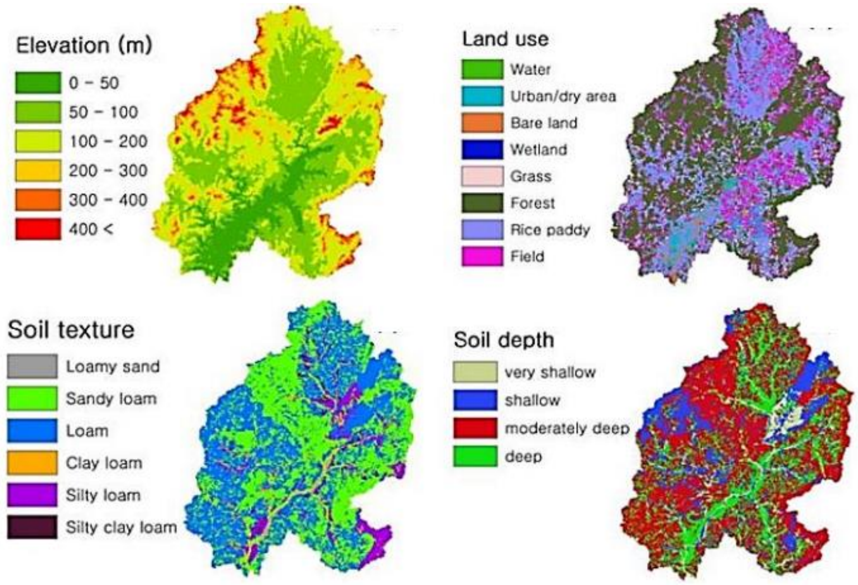


Fig.1 Digital Elevation Models with Geographical Features by Kim and Kim[9]

Elevation influences rainfall patterns, with higher areas often receiving more precipitation. Land use affects how rainfall interacts with the landscape, such as higher retention in forests or increased runoff in urban areas. Soil texture and depth determine infiltration and water storage, impacting runoff and absorption.

Table 1. Available DEM and their resolutions

| Sr. No. | Source | Spatial Resolution | Provider |
|---|---|---|---|
| 1 | Global Multi-resolution Terrain Elevation Data | 30 arc-second (1 km) 7.5 arc-second (225 m) 15 arc-second (450 m) | USGS Earth Explorer |
| 2 | ASTER Global Elevation Data | 1 arc-second (30 m) | USGS Earth Explorer |
| 3 | Shuttle Radar Topography Mission | 3 arc-second (90 m) 1 arc-second for U.S. 1 arc second global | USGS Earth Explorer Earth Explorer Reverb / Echo |
| 4 | National Elevation Dataset | 1/9 arc-second (3 m) 1/3 arc-second (10 m) 1 arc-second (30 m) 2- arc-second (60 m) only Alaska | The National Map Viewer |

These datasets can be integrated with rain-gauge data and satellite observations to improve spatial interpolation and capture rainfall distribution more accurately, especially in regions with sparse rain-gauge networks Digital Elevation Models Digital Elevation Models (DEMs) with a resolution of 1cm to greater than 200m, sourced from platforms like USGS Earth Explorer, are used for terrain mapping and flood extent analysis.

### 2.2. Land-Use and Land Cover-Data

Land-Use and Land-Cover (LULC) data is essential for understanding impact of urbanization on floods. Urbanization increases impervious surfaces such as roads and buildings, which reduce water infiltration and amplify surface runoff, making urban areas particularly prone to flooding. Agricultural regions, depending on the type and intensity of farming practices, influence soil permeability and erosion, while forests with dense vegetation reduce runoff and aid in groundwater recharge. LULC data also shows how natural water bodies reduce flooding peaks by serving as retention areas. Satellite imagery from the Landsat series (2000–2024) will help assess urban sprawl, vegetation changes, and land-use variations.

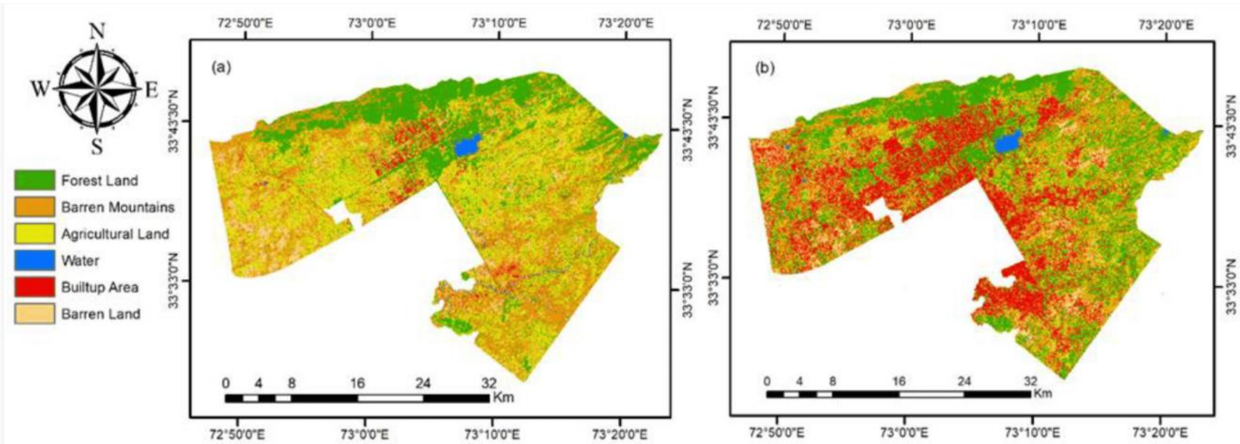


**Fig.2** Urban Sprawl in Islamabad by Adeel, M., & Hassan, S. [6]

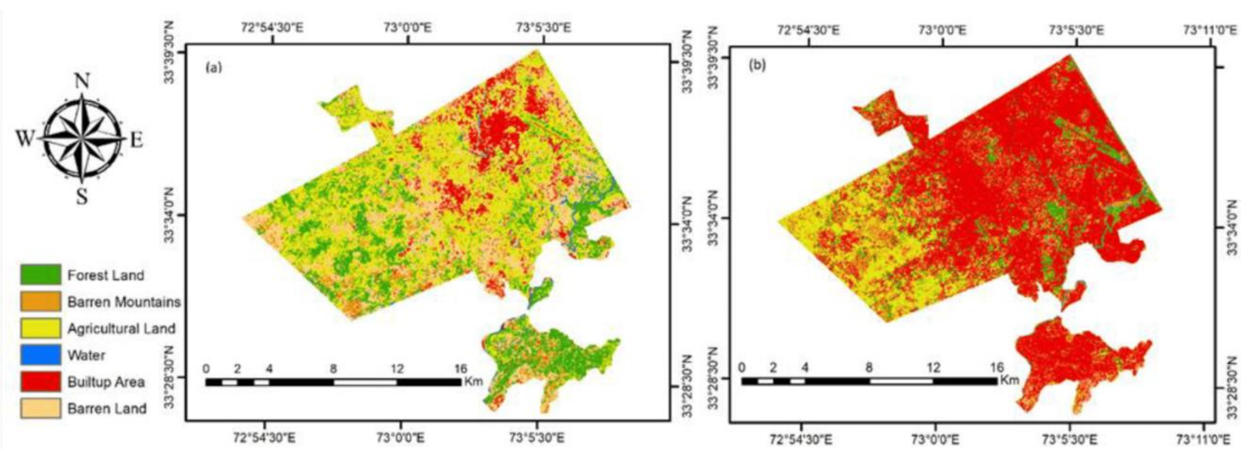


Fig. 3 Urban Sprawl in Rawalpindi by Adeel, M., & Hassan, S. [6]

Rawalpindi's built area rose from 9.8% in 1990 to 58.80% in 2020. The study found an annual urban expansion of about 0.88% for Islamabad and 1.63% for Rawalpindi.

A significant demographic shift is underway as rural populations migrate to cities for better jobs, education, and healthcare. This rural-to-urban migration is a key driver of Pakistan's rapid urbanization, with cities like Karachi, Lahore, and Islamabad expanding at an unprecedented rate. While this urban growth fuels economic development, it also poses significant environmental and infrastructural challenges, particularly in terms of flooding.

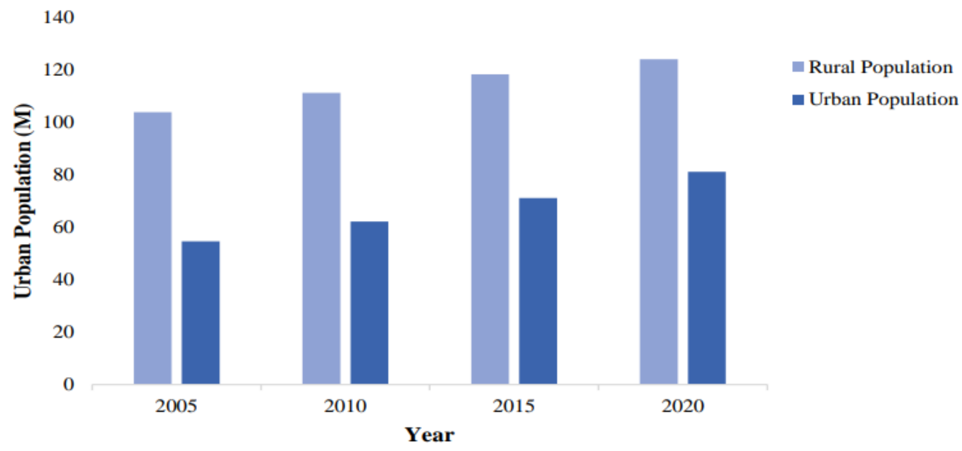


Fig. 4 Urbanization Trends in Pakistan[5]

## 2.3. Satellite Data for Urbanization and Flood Risk Assessment

Satellite imagery providing high-resolution, continuous, and up-to-date data over wide area is essential for urbanization and flood risk monitoring. Urban growth and flood risks are often spatially and temporally dynamic, making satellite data an essential tool for tracking changes over time, understanding land use patterns, and assessing flood vulnerability. Satellites can to map flood affected areas and monitor water levels. By analyzing surface water and hydrological changes over time, satellites help in flood modeling, risk mapping, and the identification of flood control measures.

Table 2. Comparison of Satellite Sensor Specifications

| Satellite Sensor | Spatial Resolution (m) | Temporal Resolution (days) | Spectral Resolution | Number of Bands | Wavelength Range (µm) | Spectral Accuracy | Applications | Additional Features |
|---|---|---|---|---|---|---|---|---|
| **Landsat-8 OLI/TIRS** | 15 | 16 | Multispectral | 11 | 0.43–12.51 | High | Detailed land cover mapping, environmental monitoring | Improved cloud removal |
| **Sentinel-2 A/B MSI** | 10–60 | 5 | Multispectral | 12 | 0.44–2.19 | High | Vegetation and land cover monitoring, frequent revisit | High spatial resolution, large-scale data coverage |
| **Landsat-7 ETM+** | 15–60 | 16 | Multispectral | 8 | 0.45–9.0 | High | Water quality monitoring, vegetation analysis | Enhanced spatial resolution, SLC-off issue |
| **EO-1 Hyperion** | 30 | 16 | Hyperspectral | 242 | 0.35–2.57 | Very High | Vegetation and soil quality monitoring | High spectral resolution |
| **Sentinel-1** | 10 | 6 | Radar (C-band) | 1 | - | Moderate | Land deformation, all-weather capability | Long-term atmospheric monitoring |
| **AVHRR** | 1 km | 1 | Multispectral | 6 | 0.58–1.23 | Moderate | Climate monitoring, vegetation health | Long-term satellite record |
| **Terra ASTER** | 15–90 | 16 | Multispectral | 14 | 0.52–11.65 | High | Geological mapping, surface temperature analysis | Precise radiometry |

Remote sensing resolutions play a crucial role in determining the quality and applicability of data collected by sensors. Spatial resolution defines the smallest detail that can be captured, indicating the level of detail visible in an image. Temporal resolution is how often a sensor access to the same area, which is essential for monitoring dynamic changes over time. Spectral resolution is the ability to distinguish fine differences in wavelengths, enabling the identification of specific materials or features. Additionally, spectral accuracy and application accuracy reflect the precision of measurements and their reliability for specific applications, ensuring that the data is both scientifically valid and practical for intended uses. Together, these resolutions and accuracies determine the effectiveness of remote sensing technologies in diverse fields.

Table 3. Latest Satellite Sensors - Comparative Table

| **Satellite Sensor** | **Spatial Resolution (m)** | **Temporal Resolution (days)** | **Spectral Resolution** | **Number of Bands** | **Wavelength Range (µm)** | **Spectral Accuracy** | **Applications** | **Additional Features** |
|---|---|---|---|---|---|---|---|---|
| Pleiades Neo | 0.3 | 1 | Multispectral | 6 | 0.4–1.0 | High | Urban planning, agriculture, disaster response | Enhanced agility, daily revisit |
| WorldView Legion | 0.3 | <1 | Multispectral | 8 | 0.4–1.04 | High | Infrastructure monitoring, environmental studies | Constellation for rapid revisit |
| Beijing-3 | 0.3 | 2 | Multispectral | 4 | 0.45–0.89 | Moderate | Land use mapping, resource management | High agility, rapid targeting |
| SuperView-Neo | 0.3 | 2 | Multispectral | 4 | 0.45–0.89 | Moderate | Urban development, forestry | Stereo imaging capability |
| Landsat 9 | 15–100 | 16 | Multispectral | 11 | 0.43–12.5 | High | Environmental monitoring, land use change | Improved radiometric resolution |
| Sentinel-2A/2B | 10–60 | 5 | Multispectral | 13 | 0.443–2.19 | High | Agriculture, forestry, disaster monitoring | Wide swath width, frequent revisit |

Several modern satellite sensors provide high-resolution multispectral imagery for various applications. Pleiades Neo and WorldView Legion offer ultra-high resolutions (0.3 m) with daily or near-daily revisit capabilities, ideal for urban planning, disaster response, and environmental studies. Beijing-3 and SuperView-Neo also deliver 0.3 m resolution with moderate spectral accuracy, suited for land use and resource management, with features like rapid targeting and stereo imaging. Landsat 9 and Sentinel-2A/2B provide medium to high resolutions (10–100 m) with broader spectral ranges, useful for large-scale environmental monitoring and agriculture, with frequent revisits and improved radiometric capabilities.

Table 4. Various Applications of Satellite Series

| Applications | Satellite System | Resolution and Band Used | References |
|---|---|---|---|
| **Depth of River** | Lidar | 10 cm, NIR | Dewan, Ashraf M., Monirul M. Islam, T. Kumamoto, and M. Nishigaki. 2007. |
| **Drainage system** | SRTM, ASTER | 90 m, 30 m, C-band, X-band, VNIR, SWIR | Meijerink, A. M. J. 1996. |
| **Agriculture runoff** | IRS, Landsat | 35 m, 72 m, 30 m, VNIR, SWIR | Ogania, J. L., Puno, G. R., Alivio, M. B. T., and Taylaran, J. M. G. 2019. |
| **Land surface temperature** | AVHRR, ASTER/ERS2, LANDSAT, MODIS, Sentinel-3, GOES | 1 km, 90 m, 30 m (multispectral), -100 m (thermal), 1 km/6 km, VIS, NIR, TIR, VNIR, SWIR, IRS | Kim, Changhwan, and Dae-Hong Kim. 2020. |
| **Vegetation cover** | NOAA-16, MODIS, LANDSAT, Sentinel-2, SPOT, PROVA-V, AVHRR/GIMMS, VIIRS | 1.1 km, 250 m, 1 km, 30 m, 10–60 m, 1 km, 375 m, 500 m, Microwave, VIS, NIR, VNIR, SWIR, Red | Tehrany, Mahyat Shafapour, Pradhan, Biswajeet, and Jebur, Mustafa Neamah. 2013. |
| **Land use pattern** | AVHRR, LANDSAT, MODIS, SPOT, ASTER/ERS2, IRS | 1 km, 30 m, 500 m, 250 m, 20 m, 30 m, 35 m, 72 m, VIS, NIR, G, R, NIR, IIR, VNIR, SWIR | Dirks, K. N., Hay, J. E., Stow, C. D., and Harris, D. 1998. |
| **Flood risk assessment** | Sentinel-1, TerraSAR-X, RADARSAT, Landsat, MODIS | 1 m, 3 m, 30 m, 90 m, C-band, X-band, SAR, VIS, NIR | Tabios III, Guillermo Q., and Jose D. Salas. 1985. |
| **Erosion monitoring** | Landsat, Sentinel-2, TerraSAR-X | 30 m, 10 m, 1 m, VIS, NIR, SWIR | Klein, T., Nilsson, M., Persson, A., and Håkansson, B. 2017. |
| **Aquatic habitat mapping** | Landsat, Sentinel-2, SPOT | 30 m, 10 m, 20 m, VIS, NIR, SWIR | Turner, W., Rondinini, C., Pettorelli, N., Mora, B., Leidner, A. K., Szantoi, Z., Buchanan, G., Dech, S., Dwyer, J., Herold, M., et al. 2015. |
| **Infrastructure monitoring** | WorldView, TerraSAR-X, RADARSAT | 0.5 m, 1 m, 10 m, VIS, SAR | Wulder, M. A., Masek, J. G., Cohen, W. B., Loveland, T. R., and Woodcock, C. E. 2012. |

## III. DISCUSSION

The findings of this study underscore the significant influence of urbanization on flood risk, particularly in the rapidly urbanizing regions. The GIS-based spatial analyses and hydrological modeling reveal that urban sprawl has drastically increased impermeable surfaces, exacerbating peak runoff and reducing lag times during rainfall events. These observations align with prior research highlighting the role of urbanization in intensifying flood risks globally, yet they provide a region-specific understanding crucial for local policymakers.

A notable outcome of this study is the identification of critical high-risk zones, where urbanization, inadequate drainage infrastructure, and topographic vulnerabilities converge. The flood simulations for varying return periods (10-year, 50-year, and 100-year) further highlight its escalating impact of climate change, predicting an additional 15-20% increase in flood exposure by 2050. This finding not only corroborates global studies on climate-induced flood risks but also emphasizes the urgent need for localized adaptive strategies in Pakistan's urban centers.

The integration of IoT-based real-time monitoring systems demonstrates the potential to transform flood risk management by enhancing early warning capabilities and dynamic decision-making. This technological approach, when combined with GIS-based flood risk maps, provides a robust framework for mitigating urban flood risks. However, the socioeconomic implications of flooding, particularly for vulnerable communities in informal settlements, indicate the necessity for inclusive urban planning that prioritizes resilience and equity.

The results of this study have broad implications for urban flood risk management. They highlight the critical need for sustainable urban planning practices that account for floodplain preservation, green infrastructure development, and the enhancement of drainage systems. Furthermore, the adoption of real-time data integration into urban planning can significantly improve disaster preparedness and resource allocation.

Future research directions could expand on this work by incorporating higher-resolution datasets and broader climatic variables such as wind and temperature, which may influence flood dynamics. Additionally, exploring the socioeconomic impacts of flooding in greater depth could inform policies that balance technical solutions with community needs. Finally, the application of machine learning techniques in flood prediction models offers a promising avenue for refining and automating risk assessments.

## IV. CONCLUSIONS

In conclusion, this study sheds light on the relationship between urbanization, climate change, and flood vulnerability in rapidly developing cities. The study has demonstrated the immense potential of GIS and remote sensing technologies in providing actionable insights for flood risk management. However, the findings also underscore the urgent need for a multi-faceted approach that combines technological innovation, sustainable urban planning, and proactive community involvement. By leveraging this study uses GIS and remote sensing to identify high-risk locations and simulating potential flood scenarios. The integration of hydrological modeling with urban planning offers actionable insights that are crucial for enhancing flood resilience in urban areas.

The findings highlight the significant impact of unchecked urbanization on flood vulnerability, emphasizing the importance of sustainable urban planning and adaptive infrastructure development. The proposed GIS-based approach not only facilitates effective disaster preparedness but also supports policymakers in making data-driven decisions to protect lives and property.

- Rapid urbanization increases impermeable surfaces, leading to higher peak runoff and shorter lag times, exacerbating flood risks.
- Real-time monitoring technologies are proposed to enhance early warning systems and improve dynamic flood risk management.
- Emphasizes the need for urban planning that incorporates floodplain preservation, green infrastructure, and better drainage systems to mitigate flood risks.

Looking forward, this study can be extended to incorporate additional climatic factors, such as temperature and wind, to further refine flood risk assessments. The implementation of smart city technologies, such as IoT-enabled flood monitoring systems, promises to revolutionize urban flood management, providing real-time data for proactive interventions. Ultimately, the methodologies and insights presented in this study can serve as a model for other climate-vulnerable urban regions, paving the way for smarter, safer, and more resilient cities.

## REFERENCES

[1] U Nations. Revision of world urbanization prospects. United Nations: New York, NY, USA, 2018.
[2] Fan GF, He Y, Gu JQ, et al. 2012. The rainstorm disaster and its risk assessment based on GIS in Zhejiang Province. Chin Agri Sci Bull. 28(32):293–299. (In Chinese with English Abstract)

[3] Wang, Y., Ding, Y., Zhang, J., Shao, H., & Zhang, H. (2024). Urban Flood Resilience Assessment of Zhengzhou Considering Social Equity and Human Awareness. Land, 13(1), 53.

[4] LuPeng , Yifei Wang , Liang Yang , Matthias Garchagen , Xiangzheng Deng (2023). A comparative analysis on flood risk assessment and management performances between Beijing and Munich.

[5] Ahmed, T. (2021). *Urbanization and its impacts on floods using GIS—A case study* (Master's thesis). Central University of Science and Technology, Pakistan.

[6] Adeel, M., & Hassan, S. (2021). Urban expansion and its impact on land use changes in Rawalpindi, Pakistan. *Sustainability, 13*(22), 12842. https://doi.org/10.3390/su132212842

[7] KN Dirks, JE Hay, CD Stow, and D Harris. High-resolution studies of rainfall on norfolk island: Part ii: Interpolation of rainfall data. Journal of Hydrology, 208(3-4):187–193, 1998.

[8] Guillermo Q Tabios III and Jose D Salas. A comparative analysis of techniques for spatial interpolation of precipitation 1. JAWRA Journal of the American Water Resources Association, 21(3):365–380, 1985

[9] Changhwan Kim and Dae-Hong Kim. Effects of rainfall spatial distribution on the relationship between rainfall spatiotemporal resolution and runoff prediction accuracy. Water, 12(3):846, 2020.

[10] Saka, J. K., & Dhanjal, A. (2023). A hybrid deep learning model for multi-source flood susceptibility mapping in the Narmada River basin, India. Remote Sensing, 15(14), 3678.

[11] Zhao, X., Yang, Y., Wu, C., Ma, X., & Chen, Y. (2023). A Deep Learning-Based Method for the Detection of Land Subsidence Using Multi-Source Data: A Case Study of Shanghai, China. Remote Sensing, 15(7), 1872.