Mon23-070

System for continuous 2D modeling of flood zones of the Uzh River

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SUMMARY

Modeling flood zones is a relevant and integral part of contemporary geographical and hydrological research. Due to climate change and irresponsible use of natural resources, the risk of hazardous natural phenomena, including flooding, is increasing. This phenomenon can have various causes, from intense rainfall to the failure of hydraulic structures, and can result in severe consequences for the natural environment, infrastructure, and human life.

Detailed modeling and forecasting of potential flood zones allow us to better understand and manage the risks associated with this phenomenon. Such an approach can serve as the foundation for developing climate change adaptation strategies, planning the placement of new infrastructure projects, and creating early warning systems.

In this article, we explore methods for forecasting flood zones using data from hydrological stations on the Uzh River within the Transcarpathian region, as well as the methodology for presenting such a system as a web resource.

Introduction

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Detailed modeling and forecasting of potential flood zones allow us to better understand and manage the risks associated with this phenomenon. Such an approach can serve as the foundation for developing climate change adaptation strategies, planning the placement of new infrastructure projects, and creating early warning systems (Resolution of the Cabinet of Ministers of Ukraine, 2018).

In this article, we explore methods for forecasting flood zones using data from hydrological stations on the Uzh River within the Transcarpathian region, as well as the methodology for presenting such a system as a web resource.

Method and results

The objective of this project is to develop a flood forecasting and modeling system capable of predicting potential flood risks based on data related to climate change, hydrological conditions, topography, and other factors. The system should assist managers, researchers, and communities in implementing effective flood prevention and protection measures. According to data from Kozytsky et al. (2018), hydrological data are essential for modeling. The average monthly indicators of annual runoff for the Uzh River are presented in Table 1.

Table 1 *Hydrological data for Uzh river*

Stantion Name	Average Monthly Water Discharge ($м^{3/s}$)											
	1	2	3	4	5	6	7	8	9	10	11	12
Uzh-Zhornava	6,9	9	8	9,8	10,8	5,8	6,1	2,5	2	6,6	6,6	5,2
Uzh-Zarichovo	27	31,7	23,5	23,7	33,6	14,8	22,5	7,1	5,4	15,8	21	21,8
Uzh-Uzhhorod	31,6	71,5	59,2	60,2	23,1	14,3	4,3	3,9	7,3	20,9	18,1	26,6
Turya-Simer	1,6	8,7	23	17	12	4,2	5,2	8,6	1	0,8	6,3	13,7

In Table 2, data on the average annual water discharge at the stations of the Uzh River are presented, as well as catchment areas and calculated water discharges for floods of different probabilities.

Table 2 *Input Data for Flood Predictor*

Stantion Name	Average Annual Discharge	Catchment Area	Runoff Rate	1%	5%	10%	25%
Uzh-Zhornava	79,3	286	0,27727	372	260	215	160
Uzh-Zarichovo	247,9	1280	0,19367	1390	1010	855	656
Turya-Simer	102,1	474	0,18907	490	355	300	226
Uzh-Uzhhorod	341	1970	0,17310	1930	1400	1175	870

Taking Uzh-Uzhgorod as the main station (since this is precisely where the modeling segment is), we will calculate the following indicators. We will show the relationship between the average annual discharges at the stations and the catchment areas by creating a scatter plot (Fig.1). In the scatter plot, the X-axis will represent the catchment area, and the Y-axis will represent the average annual discharge. Additionally, the correlation coefficient will be displayed in the upper-right corner of the plot.

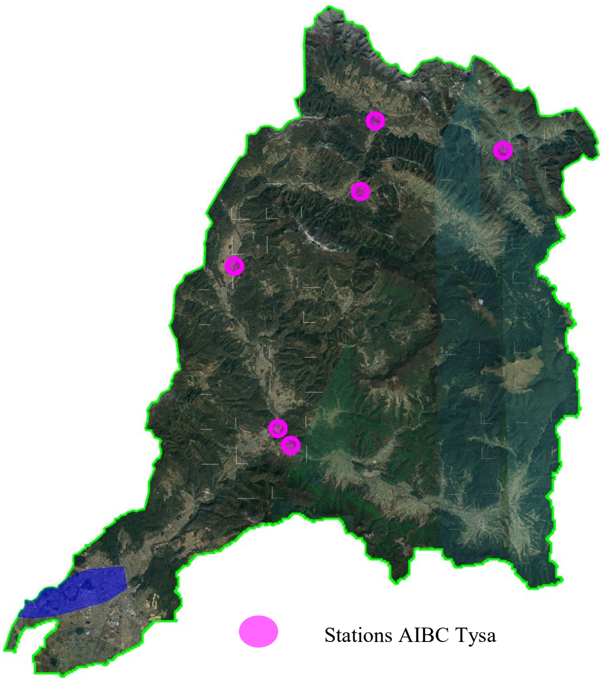

Figure 1 *Catchment Area of the Uzh river*

The equation for predicting flood zones is presented in formula (1).

$$(V_{Zarichevo} + V_{Simer} \mathbf{+\text{-}0{,}05}(V_{Zarichevo} + V_{Simer}))dt = V_{Uzhgorod}, \quad (1)$$

V – water discharge at the station, dt – change in discharge over time (while passing from Symer/Zarichevo to Uzhgorod).

he flood prediction and modeling system has been developed using modern programming and data analysis technologies (Shrestha et al., 2020). Programming languages such as Python, as well as libraries for machine learning and geospatial analysis, are used for development. Web applications may be used to ensure a user-friendly interface. The developed system serves as an integrated solution for monitoring and forecasting flood zones based on data from hydrological posts. Every two hours, the system automatically receives water level data from hydrological stations located in various parts of the river basin. This data is processed, analyzed, and used for modeling potential flood zones.

The system employs advanced algorithms and mathematical models to determine areas that could be affected by flooding, taking into account current data and the topography of the territory. This approach allows for prompt responses to changes in the hydrological situation and timely alerts to relevant services about potential risks.

As a specific implementation example of this model: Status as of 04 – 06.08.2023.

Table 3 *Input data for modeling*

Date Time	water level	the amount of precipitation	air temperature	volume water
04.08.2023 18:00	-183	0.8	32.1	7
04.08.2023 20:00	-181	0.8	28.6	9
04.08.2023 22:00	-181	0.9	25.4	9
05.08.2023 02:00	-143	10.4	21.6	77
05.08.2023 16:00	-133	13.7	34.6	97
05.08.2023 18:00	-113	13.7	33.7	131
05.08.2023 20:00	-84	13.7	29.2	185
05.08.2023 22:00	-77	13.7	25.9	199
06.08.2023 12:00	-140	0.1	20	83
06.08.2023 14:00	-142	0.1	21.6	80

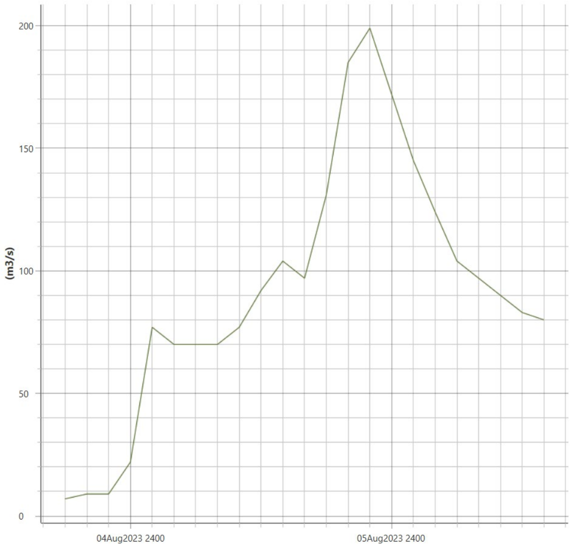

Figure 2 *Hydrograps 04-06 August 2023 y.*

Figure 3 *Result for 06.08.2023 y. 07:00 a.m.*

Figure 4 *Result* for 06.08.2023 y. 11:30 a.m.

Conclusions

Rapid access to up-to-date data allows for prompt responses to hydrological changes, ensuring effective monitoring of flood risks. The integration of data from various river basin stations enhances the accuracy and reliability of modeling potential flood zones. The system minimizes the need for manual data entry or processing, optimizing resources and staff time. The obtained information can be used for strategic planning of flood prevention and mitigation efforts (Rangari et al., 2019). The system underscores the need for regular and systematic data updates to ensure the timeliness of information. In conclusion, this system is a modern and effective tool for monitoring and responding to potential flood risks, which can significantly improve the safety of populated areas and infrastructure located along river basins.

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