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Structure design of the flood hazard assessment and mapping technology for adaptation of Ukrainian water sector to climate change

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SUMMARY

In the last 20 years, Ukraine has experienced significant floods that have led to emergencies. Recent research suggests that under the influence of climate change, the recurrence of high floods in Ukraine and their magnitude will increase by the end of this century.

One of the modern technologies of adaptation to extreme manifestations of climate change in the water sector is technology of flood hazard assessment and mapping. Its use can help prevent and reduce losses in the Ukrainian economy. The technology flood's hazard assessment and mapping are used to identify areas at the risk of flooding, and consequently to improve flood's risk management and disaster preparedness. Flood hazard assessments and maps typically look at the expected extent and depth of flooding in a given location, on the basis of various scenarios.

This paper presents the structure and content of this technology designed by us and adapted to modern remote methods of environmental research and geographic information technologies.

Introduction

In the last 20 years, in Ukraine, significant floods that have led to emergencies have been observed in 1995, 1998, 2001, 2008, 2010,2017, 2020.

Only from 2000 year more than 280 emergency flood events were in Ukraine: loss from flood – 6 203 750 ₴ or 228 079 €; expenses for liquidation flood events with adverse consequences – 65 419 925 ₴ or 2 405 144 € (Danko et al., 2019). The losses from the 2020 flood are the largest and amount to 5 billions (Naibilsh masshtabni pavodky v istorii Ukrainy, 2020). Our research (Didovets et al., 2019) shows that the recurrence of high floods in this area and their magnitude will increase by the end of this century. One of the modern technologies of adaptation to extreme manifestations of climate change in the water sector is technology of flood hazard assessment and mapping. Its use can help prevent and reduce losses in the Ukrainian economy. The General description of technology flood's hazard assessment and mapping are used to identify areas at the risk of flooding, and consequently to improve flood's risk management and disaster preparedness. Flood hazard assessments and maps typically look at the expected extent and depth of flooding in a given location, on the basis of various scenarios.

Categories and definitions of droughts

There are several definitions of term "flood" in the world literature (Díez-Herrero et al., 2009):

1. According to Webster's unabridged dictionary, flood signifies "a rising and spreading of water over land not usually submerged". It is synonymous with inundation, from the Latin verb inundate.

2. The Spanish Basic Directive on Planning Civil Protection Against Flood Risks defines a flood as the temporary submersion of normally dry lands as a result of an unusual and more or less sudden flow of a quantity of water which exceeds to a given zone's usual quantity.

3. The Federal Emergency Management Agency (FEMA) in the United States further quantifies the surface subject to flooding in order to consider it a flood: "A general and temporary condition of partial or complete inundation of two or more acres (0.81 ha) of normally dry land area or of two or more properties", that is, an excess of water (or mud) over land that is normally dry.

4. The European Community Directive 2007/60/EC on the assessment and management of flood risks defines flooding as "the temporary covering by water of land not normally covered by water". Flood risk, therefore, refers to the potential situation of loss or harm to persons, material belongings or services as a result of the covering of normally dry areas with flood, which are assigned a specific severity (intensity and magnitude) and frequency or probability of occurrence.

An integrated analysis (Stock, 1996), covering the cause-effect chain of precipitation-runoff generation – runoff concentration – flood wave propagation – (routing) -inundation – flood damage, would allow for a comparative assessment of the various flood-triggering and damage-causing factors.

The state-of-the art evaluation on flood risk should include all relevant levels of flood risk composition, both the aspects of naturally induced hazard and vulnerability due to the activity of humans (Plate, 2002). The European Flood Directive defines it as the "combination of the probability of a flood's occurrence and the potential negative effects on human health, the environment, cultural heritage and economic activity associated with flood". There are essentially two types of natural floods: surface flooding ("inland" flooding), in which fresh waters inundated areas of the inner parts of continents; and coastal flooding, in which sea waters or lake-marsh waters inundate the areas along the edge of surface regions.

Surface (river) flooding is prevailing type of flooding in Ukraine. Flood-prone regions of Ukraine are located in the catchments of different Carpathian inflows in the Dniester, in the area of some Danube tributaries as well tributaries of the Prypyat (Dnipro) in the northwest of the country.

To implement at the Association Agreement between Ukraine on the one hand and the European Union on the other hand, one of the priorities for the environmental policy of Ukraine is the harmonization of the water legislation of Ukraine with the EU legislation, in particular, with Directive No. 2000/60 / EC

"On the establishment of the Community framework for activities in the field of water policy "(Water Framework Directive, WFD) and Directive 2007/60 / EC" On Flood Assessment and Management "(Flood Directive), the main principles of which are the implementation of an integrated basin water management model and flood management.

Description of the technology structure and implementation process

Flood's hazard assessment and mapping technology consists of 4 stages (Figure 1):
1. The collection of information about areas at risk of flooding;
2. The preparation of information, tools and data preprocessing;
3. Flood modelling and scenario design;
4. Flood Hazard Assessment/Risk Mapping.

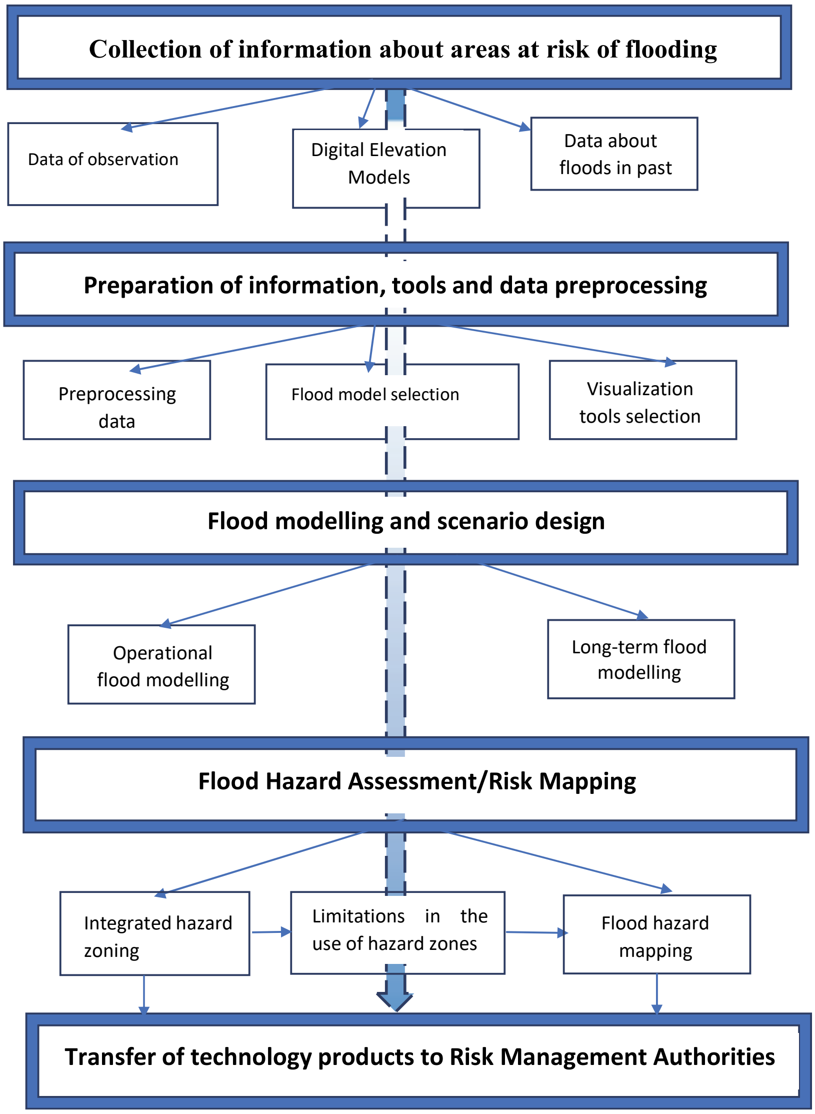

Figure 1 *The structure of flood hazard assessment and mapping technology*

In the first stage of the technology, all kinds of the information required for flood's risk assessment must be collected. Data for flood's risk assessments include both field measurements and remote sensing data. Observational data sources used in flood hazard assessments are either station data (e.g., meteorological stations, discharge gauging stations) or gridded data (e.g., reanalysis data, satellite data). In hydrological flood studies, the most commonly used data are streamflow measurements. Next steps in this technology stage for flood's hazard assessment are: 1) a preparation of detailed topographical and specialized maps and digital elevation models of the river basin district at the appropriate scale including the borders of the river basins, sub-basins and, where existing, coastal areas, showing topography and land use; 2) a description of the floods which have occurred in the past and which had significant adverse impacts on human health, the environment, cultural heritage and economic activity and for which the likelihood of similar future events is still relevant, including their flood extent and conveyance routes and an assessment of the adverse impacts they have entailed; 3) a description of the significant floods which have occurred in the past, where significant adverse consequences of similar future events might be envisaged.

In the second stage of the technology, there must be the preparation of information, chose of hydrological models, mapping tools and data pre-processing. The most common hydrological models are MIKE FLOOD, MIKE 11, MIKE 21, InfoWorks RS, LISFLOOD-FP. MIKE FLOOD is highly efficient and flexible for riverine flood modelling. Flood mapping, risk and hazard analysis of flood incidents from extreme upstream inflows as well as local high intensity rainfall in surrounding catchments are perfectly modelled with MIKE FLOOD. MIKE FLOOD enables flood simulations at multiple scales from river basins to local cells and flood-prone areas along the river. Riverine flood modelling commonly consists of a coupled model of 1D river component, MIKE HYDRO River, and the 2D overland flow component, MIKE 21. The flexibility of the coupled 1D/2D models provides numerous opportunities to analyse complex flooding issues, such as: • Conveyance problems due to improper maintenance of vegetation • Limited upstream flood storage capacity • Crossing infrastructures reducing flow capacity in rivers and floodplains • Flood preventions through optimized structure operation in reservoirs • Flood impacts from dam break or levee breach failures • Land use changes • Climate change flood risk impacts.

Riverine flood modelling with MIKE FLOOD combines river model component, MIKE 11, and our 2D surface modelling component, MIKE 21. Riverine modelling can also conduct with detailed hydrological components and groundwater and surface water interaction using MIKE SHE packages. This includes a surface flood component and a linkage to MIKE 11. The lack of reliable data to calibrate and validate models is often a challenge, especially in ungauged catchments or remote parts of the world. This can often be overcome by using remote sensing information input. Satellite images provide valuable information across time and space, about flood events. Satellites can be used to generate up-to-date maps of flooding. InfoWorks RS is a river modelling software for open channels, floodplains, embankments and hydraulic structures. It combines in a single environment a 1D-2D simulation engine, a geographical analysis and a relative database. InfoWorks RS can be used for accurate and timely flood forecasts and risk assessments. It can accurately simulate rainfall and storm events to evaluate the preparedness and plans of action before flooding occurs.

LISFLOOD-FP is a two-dimensional hydrodynamic model specifically designed to simulate floodplain inundation in a computationally efficient manner in complex topography. It is capable of simulating grids up to 106 cells for dynamic flood events and can take advantage of new sources of terrain information from remote sensing techniques such as airborne laser altimetry and satellite interferometric radar. The model predicts water depths in each grid cell at each time step, and hence can simulate the dynamic propagation of flood waves over fluvial, coastal and estuarine floodplains.

In the third stage, there must be scenario design and flood modelling. DIRECTIVE 2007/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2007 on the assessment and management of flood risks foresees the following scenarios: (a) floods with a low probability, or extreme event scenarios; (b) floods with a medium probability (likely return period ≥ 100 years); (c) floods with a high probability, where appropriate according to the following scenarios: (a) floods with a low probability, or extreme event scenarios; (b) floods with a medium probability (likely return period ≥ 100 years); (c) floods with a high probability, in case it is appropriate.

In the fourth stage an assessment (Flood Hazard Assessment/Risk Mapping), the assessment shall include at least the potential adverse consequences of future flood for human health, the environment, cultural heritage and economic activity, taking into account as far as possible issues such as the topography, the position of watercourses and their general hydrological and geomorphological characteristics, including floodplains as natural retention areas, the effectiveness of defence infrastructures for existing man-made flood, the position of populated areas, areas of economic activity and long-term developments including impacts of climate change on the occurrence of flood. For flood hazard visualization, we must use the creation of flood hazard maps, which shall cover the geographical areas which could be flooded according to the following scenarios, which have been chosen in the third stage of technology (Figure 1). Flood hazard mapping is a basic component in flood risk analysis studies, as it permits the effective evaluation of the spatial distribution of the various elements for severity (such as water surface level, flow velocity, sediment transport, or characteristic times) and frequency (return periods or exceedance probability) of the flood phenomenon. Furthermore, they offer the utility of being able to link the maps and their associated databases to exposure and vulnerability maps in order to analyse and predict risk in an integrated manner by using such tools as geographic information systems (GIS). Hazard can be mapped in three zones (high, medium, and low) for which boundaries and usage restrictions must be established. Likewise, different tools may be used to prepare these maps, both for hazard analysis and integrating risk factors.

Conclusions

Since 2000, more than 280 emergency floods have occurred in Ukraine. Due to climate change, the frequency and severity of floods are increasing. The implementation of the technology for flood risk assessment and mapping is very important for Ukraine. Its implementation can have significant socio-economic benefits, if a number the barriers are to be overcome.
Very important barriers for implementation according to project experts are: lack of state support of hydrometeorological monitoring; measuring equipment, gauges and data transferring; lack of long-term satellite, meteorological and hydrological data sets; lack of awareness about benefits of technology.

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