

## ESTIMATION OF FLOOD DAMAGE IN URBAN AREAS OF UKRAINE

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### Abstract

The estimation of flood spreading in urban areas of Ukraine is carried out. Total increase of flood in urban areas of administrative regions of Ukraine is investigated. It is shown that flooding in Ukraine has already become a major factor in ecological and geological complexity of life safety in industrial and urban areas. The most important regions of the country in which flooding has become a significant factor that directly affects the dangerous change of geological environment are determined. In general this creates an additional threat to the security of the population in these areas and can be a determining factor of environmental degradation in cities and town in most regions of the country. It is concluded that during 1998-2014 the impact of global climate change on activation of urban flooding in Ukraine has been growing in the conditions of lack of defensive ability of hydraulic structures against increased level of precipitation and expanding of flooding areas. Grade of administrative regions of Ukraine on the level of growth of urban flooding is offered. Expected socio-economic losses out from urban flooding in Ukraine are assessed. Some of the greatest values of expected loss have been observed within the most industrialized and populated regions of Ukraine. It is shown that urban flooding in Ukraine has already become an additional factor in shaping the nature of man-made threats to the security of urban population of these areas. The complex of measures for reduction of the negative impact of and damage from urban flooding in the conditions of Ukraine are offered.

**Keywords:** *urban areas, flood, risk, climate change, extreme weather, natural disasters, damage.*

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### 1. Introduction

According to the numerous researches environmental risks are becoming the top position among global risks of greatest concern [1-3]. Various extreme weather events including floods and droughts lead to devastating negative consequences for population, infrastructure and environment around the world. At the same time climate change has already become the key factor causing an increased frequency of floods. In this regard it is important to consider the combined implications of these environmental risks on key development and security issues including food security, political and social instability [4-5].

Urban flooding is considered as a dangerous geological process in urban areas caused by intense or prolonged rainfall which overcomes the capacity of the drainage system and leads to major economic losses and devastating social and environmental impacts.

Recent data from State Service for Emergencies and State Geological Service of Ukraine showed a continuing negative trend to remain further spreading of flood processes across the country during recent years [6-7].

### 2. Analysis of published data and problem definition

According to the UN data the urban population will have almost doubled to an estimated 6.4 billion by 2050 [2]. The most of the increase in urban populations will occur in countries with limited ability to deal with the new risks associated with urban development. Among such risks the urban flooding has already become the noticeable form of disaster in the world, and the UN forecasts that the number of people in large cities exposed to flooding will more than double in the first half of this century [1].

Research of manifestation of urban flooding around the world demonstrated that risk of its distribution has a tendency to increase in the near future [8-10]. Analysis of UN and the World Bank official papers on the implications of global climate change showed a substantial increase of

losses from natural disasters and urban flooding in recent years [1, 3]. The main approaches for assessment of damage from activation of exogenous geological processes in Ukraine [11, 12] and worldwide [14, 15] are analyzed. Taking into account the negative consequences of urban flooding with regards to global climate change [2, 3], we can conclude the need to clarify results of a comprehensive analysis of the spread of urban flooding, as well as improving methods of risk assessment of its occurrence in Ukraine.

The goal of this research is the estimation of flood damage in urban areas of Ukraine with regard to influence of global climate changes which lead to increasing the risk of economic losses and devastating negative consequences for population, infrastructure and environment.

In order to achieve the goal of this research the following specific tasks have been established:

- estimation of urban flooding manifestation in Ukraine for the period of 1980-2006;
- investigation of total increase of flood zones in urban areas of administrative regions of Ukraine;
- development of grade of administrative regions of Ukraine on the level of growth of urban flooding;
- evaluation of expected socio-economic losses out from urban flooding in Ukraine.

### 3. Materials and Methods

The study area covers the territory of Ukraine geological structure of which is determined by its location in the southwestern part of the East European platform and partially in the mountainous regions of the Carpathians and the Crimea. Significant changes of physical and mechanical properties of soils resulted in the change of groundwater regime and development of flooding across the most regions of the country [16, 17].

The various data on urban flooding distribution across the country including tables, maps from the Ministry of environment and State Service for Emergencies of Ukraine were used for spatial analysis in GIS environment.

The data received from spatial analysis were combined with data tables on urban flooding area at regional level using Microsoft Excel. On this basis grade of administrative regions of Ukraine on the level of growth of urban flooding was realized with the use of statistic methods.

### 4. Experimental procedures

With the use of geoinformation system the most recent data including maps and various layers on urban flooding in Ukraine from State Service for Emergencies and State Geological Service has been integrated into ArcGIS 9. On this basis the map of distribution of urban areas suffered from flooding processed across Ukraine was created (Fig.1).



**Fig. 1.** Distribution of settlements suffered from flood in urban areas of Ukraine

According to the data from Ukrainian Research and Design Institute of municipal buildings the increment of land flooding in urban areas of Ukraine is assessed. Evaluation results indicate extremely high growth of flood in urban areas for the period of 1984 – 2006 which is 11,421.2 hectares.

On this basis the grade of administrative regions of Ukraine in terms of increment of flooding areas for the period of 1984 – 2006 is calculated (Fig. 2).

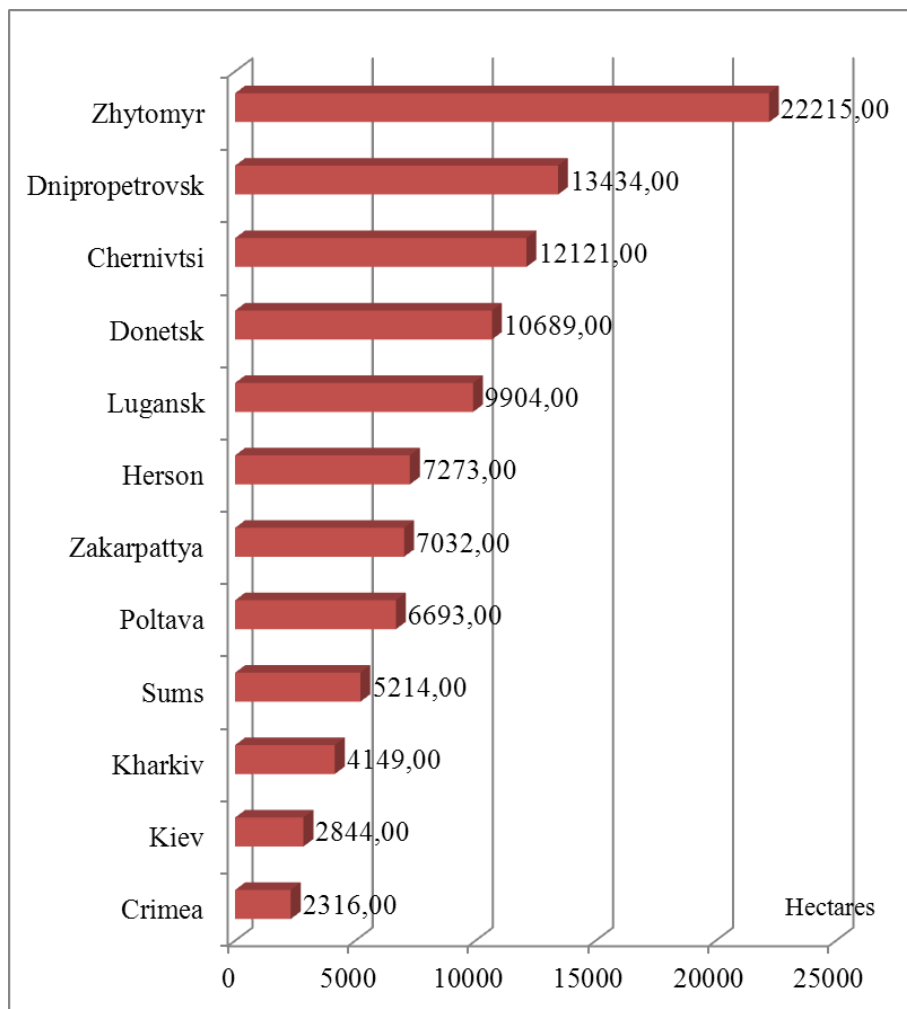


Fig. 2. Grade of administrative regions of Ukraine on level of growth of urban flooding

According to the recent data from State Service for Emergencies of Ukraine, the direct losses from flooding can reach up to 25 million UAH per year [6]. In the meantime during the intensification of this process they can reach 46 million UAH. In addition to direct economic losses up to 16 million persons are suffered from the flooding within the area of 70 thousand km<sup>2</sup> [6]. With regard to expert estimation, the socio-economic losses in rural areas could reach 500 UAH while in urban areas economic losses from flooding can reach 46 thousand UAH per 1 hectare of flooded land.

Based on these parameters and taking into account further spread of flooding with limited introduction of protective measures there is an opportunity to assess the expected socio-economic losses for the administrative regions in Ukraine and rank them in terms of damages. This will ensure not only enhance the validity of management decisions to prevent the negative consequences of flooding, but also will determine the regions where losses may have the greatest value. The results of such assessment based on loss level of 50 thousand UAH per 1 ha of flooded urban areas in Ukraine are provided in Table 1.

**Table 1**

Evaluation of expected socio-economic losses from urban flooding in Ukraine

Region	Urban flooding area, ha	Expected socio-economic losses from urban flooding, million UAH
Crimea	8804	440,20
<b>Dnipropetrovsk</b>	<b>25455</b>	<b>1272,75</b>
<b>Donetsk</b>	<b>18099</b>	<b>904,95</b>
<b>Zhytomyr</b>	<b>22530</b>	<b>1126,50</b>
Zakarpattia	7123	356,15
Zaporizhia	8599	429,95
Lugansk	10695	534,75
<b>Odessa</b>	<b>20101</b>	<b>1005,05</b>
Poltava	11557	577,85
Kharkiv	10054	502,70
<b>Herson</b>	<b>13881</b>	<b>694,05</b>
Chernivtsi	12886	644,30

## 5. Results

### 5. 1. Assessment of urban flooding manifestation in Ukraine during 1984-2006

Recent data from State Service for Emergencies and State Geological Service of Ukraine showed a continuing negative trend to remain further spreading of flood processes in the country during recent years [6]. The worst situation with flooding was established mainly in the central and southern regions of Ukraine. Among the most flooded ones are primarily Dnipropetrovsk, Zhytomyr, Mykolaiv, Odessa, Poltava, Kharkiv and Kherson regions (**Table 2**).

**Table 2**

Urban flooding in Ukraine for 2014

Region	Area, thous. km <sup>2</sup>	Flooding Area, thous. km <sup>2</sup>	Amount of flooded settlements
Volyn	20,2	9,14	59
Dnipropetrovsk	31,9	7,29	925
Zhytomyr	29,9	0,04	47
Kiev	28,9	0,021	82
<b>Mykolaiv</b>	<b>24,6</b>	<b>17,033</b>	<b>761</b>
<b>Odessa</b>	<b>33,3</b>	<b>20,575</b>	<b>983</b>
Poltava	28,8	0,15	48
Rivne	20,1	11,7	157
Kharkiv	31,4	0,122	68
<b>Kherson</b>	<b>28,5</b>	<b>11,3</b>	<b>306</b>

Mykolaiv region has a constant manifestation of flooding on 72 % of its territory including 761 settlements while the flooded area in the city of Mykolaiv exceeded 50 km<sup>2</sup>. Flooding in Odessa region is spreading on more than 20 thousand km<sup>2</sup> of its territory including 983 urban areas. At the same time near 30% of the Odessa city territory is located in the zone of constant flooding.

The flooding in urban areas of Kherson region has continuous character with spreading over the area of 11.3 thousand km<sup>2</sup>. The most affected by these disaster areas are south-western and north-western ones. The determining factor in the development of flooding process here is intense and durable carrying out of reclamation work, accompanied by a large external water supply and construction of man-made water bodies [17, 18]. In total there are 269 settlements affected by urban flooding including the town of Genichesk, Kakhovka, Kherson and others. The flooding is manifested over the 50 % of the regional center city mainly in the form of separate lots, which

will eventually be transformed into large areas.

In the mining regions of Ukraine additional problems associated with urban flooding have arisen in connection with the closure of mines and quarries, especially by the method of "wet" conservation, based on a physical auto-rehabilitation groundwater levels rise to historical marks. The largest areas of flooding in the western regions coincide with the area of mining in Lviv-Volyn basin. Flooding is most manifested in the central part of Chervonograd mining region, where more than 90% population and the majority of industrial facilities and linear engineering services are located. Due to the destruction of sewage systems, selection of mine waters and leaching of groundwater toxic components from rocks mine dumps that used to falling asleep flooded areas, ground water were contaminated and became unsuitable for household drinking water supply.

It should be noted that western regions of Ukraine primarily Carpathian are exposed to extreme weather events which lead to the growing of flood risk. The flooding in the Carpathians Rivers can repeat 4-5 times a year. There are certain patterns of its occurrence that appear in alternating periods of high and low water content. The floods in periods of high water content become threatening and sometimes have a catastrophic scale.

One of the most large-scale flooding event in recent years occurred in July 2008 in the territory of 6 administrative regions of Western Ukraine. According to the MOE of Ukraine as a result of the disaster more than 30 people died, 784 settlements, more than 44,000 houses and 57,000 hectares of farmland were flooded [11]. Overall, according to expert estimates negative consequences of flooding affected up to 16 million people.

Urban flooding in Ukraine is observed in almost all administrative regions except Ivano-Frankivsk. However development of urban flooding can be associated with [18, 20]:

- Annual water loss from water supply, sewage and thermal power networks could reach up to 1.1 bln. m<sup>3</sup>, which lead to 2-3 times increase in the natural infiltration of ground water supply;
- Significant reduction of surface runoff in built up areas;
- Reduction of the natural drainage of groundwater due to planning of ravine network, river beds and slopes.

## **5. 2. Ranking of administrative regions of Ukraine on the level of growth of urban flooding**

The results indicate that the highest level of increment of urban flooding in Ukraine is observed in Zhytomyr, Dnipropetrovsk, Chernivtsi, Donetsk, Luhansk, Transcarpathian, Poltava regions. Attention should be drawn to the fact that the significant increase of flooding areas has been recorded in most cities of industrial and technological regions of Ukraine, namely Donetsk, Luhansk, Dnipropetrovsk etc. where the majority of the population lives in cities and towns. It should also be noted that within their territory the loess are dominating as an engineering-geological basis.

Such situation has already led to the substantial loss of strength in buildings and stability on slopes. In general this creates an additional threat to the security of the population in these areas and can be a determining factor of environmental degradation in cities and town in most regions of the country [11, 21].

## **5. 3. Evaluation of expected socio-economic losses from urban flooding**

It should be noted that in the absence of effective protective measures to eliminate the consequences of urban flooding the estimated damages could also be in the form of hidden losses of society due to accelerated wear of engineering networks, buildings and deterioration of public health.

Obtained data suggest that the greatest level of expected social and economic losses from urban flooding are observed in Dnipropetrovsk, Zhytomyr, Odessa, Donetsk, Kherson, Chernivtsi, Poltava, Luhansk, Kharkiv regions. Of particular concern is the fact that some of the greatest values of expected loss have been witnessed in industrialized and densely populated regions of Ukraine, particularly the Dnipropetrovsk, Donetsk, Lugansk ones. Practically urban flooding has already become an additional factor in shaping the nature of man-made threats to the security of urban population of these areas.

One of the most important factors of strengthening the negative impact of urban flooding is global climate change, accompanied by an increase of precipitation and a reduction in the freezing of rocks, which generally contributes to enhance of ground water supply and increase of flooding

areas. According to various evaluations, the increase of temperature of water and soil horizons within the flooding areas can reach up to 10-20<sup>0</sup> C. This process can lead to speeding up the chemical suffusion by 2-4 times and increasing the aggressiveness of groundwater and rock background. At the same time reduction of engineering and seismic stability of various concrete constructions can also be associated with urban flooding [19, 21].

Summarizing the above we can conclude that urban flooding in Ukraine has already become a major factor in ecological and geological complexity of life safety in industrial and urban areas. As far as its manifestation is influenced by a complex interaction of man-made, natural and technological factors, additional research of patterns of urban flooding development is needed.

## 6. Discussion

Analysis of research results allow to determine the main reasons of urban flooding growing in Ukraine. One of the most important factors in this regard is the consequences of global climate changes including high level of precipitation, erosion of river valleys and distortion of water regime in rivers.

Unsatisfactory state of natural drainage systems caused by creation of artificial reservoirs, siltation of rivers, ravines, lakes and small streams drainage weakens the ability of geological environment to slow down the process of urban flooding.

At the same time high level of anthropogenic impact in urban areas mainly caused by industrial and urban development, construction of reservoirs, ponds, tailings, canals, water supply and irrigation systems leads to the spreading of urban flooding.

The analysis of growth of urban flooding areas in Ukraine showed that during the period 1984-2006 average increase of flooding areas across the country reached 2.5 times. This indicates a very dangerous tendency to growing urban flooding risks and its negative consequences to the population and environment over the country.

According to available assessments, at present regional flooding affects the safety of 30% of the state population and represents a real threat of deformation of various infrastructure objects, residential and industrial buildings and utilities. Acquired data have shown that increased impact of urban flooding within the territories with high population density and numerous potentially dangerous objects has already reached the level of threat to national security. Therefore, it seems appropriate to develop a framework and the adoption of the law on risk reduction, prevention and elimination of harmful effects of urban flooding primarily by optimizing water use and water discharge across the country with regard to co-operation with the EU on this issue.

## 7. Conclusions

Monitoring data from the State Service for Emergencies of Ukraine indicate a continuing dangerous trend in recent years to the further development of urban flooding in most regions of the country. Worst situation with urban flooding was developed mainly in the central and southern regions of Ukraine. The dimension of damage clearly shows that urban flooding has already become a real threat to safety in more than 2000 cities and town in Ukraine. In the meantime, in some regions of the country, particularly in the Kherson region, flooding has become a significant factor that directly affects the dangerous change of geological environment. During the 1998-2014 the impact of global climate change on activation of urban flooding has been growing taking into account the lack of defensive ability of hydraulic structures against increased level of precipitation and expanding of flooding areas.

The highest level of increment of urban flooding in Ukraine was observed in Zhytomyr, Dnipropetrovsk, Chernivtsi, Donetsk, Luhansk, Transcarpathian and Poltava regions. At the same time significant increase of flooding areas has been recorded in various cities of industrial and technological regions of Ukraine, namely Donetsk, Luhansk, Dnipropetrovsk etc. where the majority of the population lives in urban areas.

Reduction of the negative impact of and damage from urban flooding in the conditions of Ukraine requires accomplishment a number of measures the most important of which are:

- Restoration of existing drainage systems and construction of drainage facilities;
- Clearing of river beds, maintaining the necessary level of draining capacity;
- Increase of forest areas and protected areas to optimal size;
- limiting or stopping irrigation within the areas of critical rise of groundwater;
- Ensuring uninterrupted energy supply of reclamation facilities and equipment;

- Reconstruction of emergency water and sewer networks;
- Enhancing of monitoring for groundwater use, regime of water protection zones and coastal strips;
- Social protection of the population living in flooded areas.

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