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Influence evaluation of the regional hydrometeorological conditions on the development of landslides on the territory of Ukraine

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SUMMARY

The aim of the study is to analyze the spatial distribution of hydrometeorological conditions to reveal the relationship with dynamic and development of landslides on the territory of Ukraine. The increasing dependence of the number of recorded landslides on annual precipitation and number of spontaneous hydrometeorological phenomena is established. The administrative regional coefficients of the hydrometeorological conditions influence have been calculated, which should be taken into account in the process of forecasting the landslide hazard. The results of the calculations are presented as thematic map based on influence level of the regional hydrometeorological conditions on the development of landslides on the territory of Ukraine.

Introduction

Landslides are widespread in almost all administrative regions of Ukraine. The total number of landslides is about 23 thousand units and is constantly changing due to the liquidation, formation of new or merging of already existing close displaced sliding processes (Information yearbook 2019). Catastrophic development of landslide processes often leads to emergencies that cause considerable material damage. Therefore, forecasting landslide processes with taking into account the influence of all initiating factors at local and regional levels, is an urgent task.

According to numerous landslide studies the cause of the sliding process is a set of huge variety of natural and man-made factors (Rudko and Osiuk, 2012; Kuzmenko et al., 2016; Kasiyanchuk et al. 2015). A set of permanent factors determine the genetic features of exogenous geological processes. The dynamics of landslide development are mostly determined by time-varying factors, one of which is regional meteorological conditions (Heruk et al., 2017; Kovrov O. et al., 2018; Kuzmenko et al., 2012). The development of landslide processes depends not only on the deviation of precipitation from the norm, but also on the time during which these deviations are observed (Emelianova 1978). Given the climate diversity of the Ukraine, it would be appropriate to study the features of the hydrometeorological conditions in administrative regions of Ukraine.

The analysis of the administrative regions hydrometeorological features was carried out on the basis of a statistical analysis of the territory's tendency to the occurrence the spontaneous hydrometeorological phenomena, the annual precipitation and the distribution of landslides throughout the administrative regions of Ukraine. The main task is to identify and substantiate the spatial distribution of hydrometeorological conditions and landslide hazard on a regional scale using GIS technologies.

Geoinformation analysis landslides and spontaneous hydrometeorological phenomena distribution throughout the administrative regions of Ukraine

The landslide dynamics and development depend on factors of both natural and man-made origin. Moreover, the set of factors changes in the spatial ratio. The decisive factor in the activation of landslides is the saturation of rocks with water. Mostly the water source which supplies the landslide body rock is precipitation, in some cases groundwater and runoff. In general, landslide occurs after critical water saturation of rocks. Therefore, landslides in most cases cause heavy and prolonged atmospheric precipitation. The main quantitative indicator of precipitation is its annual amount. Figure 1 presents a graph of the spatial distribution of landslides per square kilometer and annual precipitation throughout the administrative regions of Ukraine. The spatial distribution of these factors have strong connection in Zakarpattia and Chernivtsi region. Therefore, in order to properly use rainfall dynamics as a factor of landslide development, it is important to take into account both the amount of precipitation and its intensity which together determine the hydrometeorological conditions of the territory.

The precipitation intensity is the variable in time and space, so characteristic of the territory's tendency to the occurrence of spontaneous hydrometeorological phenomena will be used instead of the precipitation intensity. To determine the quantitative characteristics of the territory's tendency to the occurrence the spontaneous hydrometeorological phenomena, it is proposed to use the average annual value of the total number of such phenomena as heavy rains, very heavy rains, heavy rains and storm rains, prolonged rains, heavy storm rains. For further analysis average values of annual precipitation and annual number of spontaneous hydrometeorological phenomena for the period 1992-2006 have been calculated (Lipinskyi et al., 2006). The largest number of spontaneous hydrometeorological phenomena was registered in Zakarpattia, Ivano-Frankivsk, Lviv regions and AR Crimea, which is related to the orographic features of these territories. The smallest number in the territories of Rivne, Zhytomyr, Volyn, Chernihiv and Sumy regions. Spatial analysis of the landslide distribution shows that the largest number of landslides were recorded in Zakarpattia, Ivano-Frankivsk, Lviv, Kyiv, Odesa, Kharkiv, Chernivtsi regions and AR Crimea. At the same time, the least landslide hazard territories are the Volyn, Rivne, Zhytomyr and Chernihiv regions. In general, a comparative analysis of the registered landslide and spontaneous hydrometeorological phenomena numbers shows that the general trend of extreme values coincides.

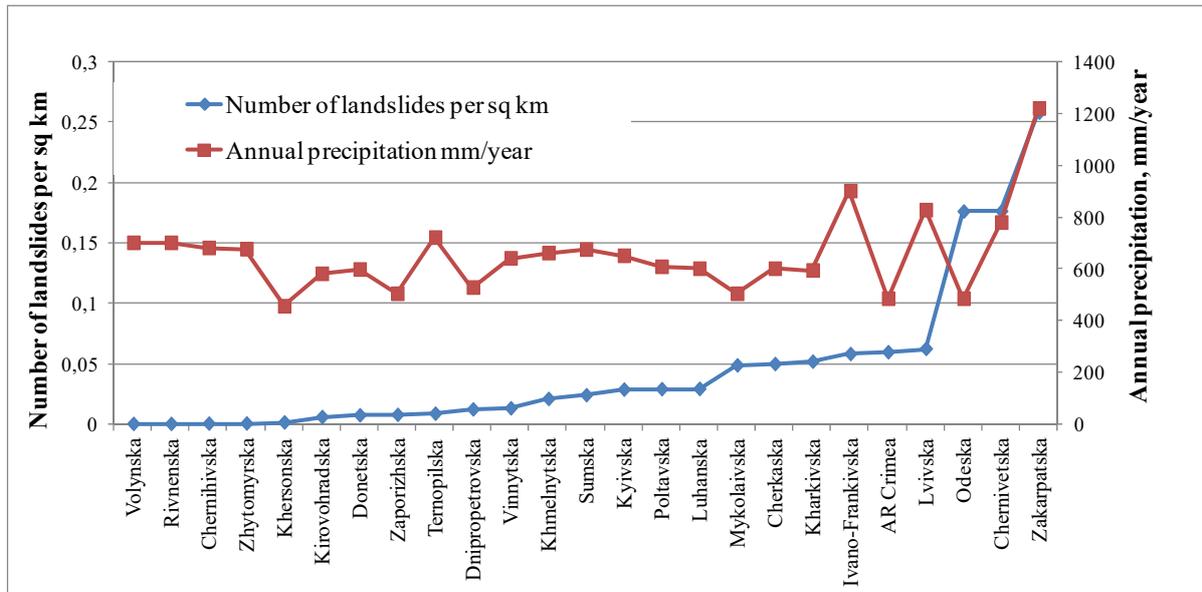


Figure 1 –The landslide number and annual precipitation spatial distribution graph

To determine the regional influence level of hydrometeorological conditions on the landslide hazard we propose to calculate the regional coefficients of the hydrometeorological conditions using next formula:

$$K_{hc} = R \cdot P / P_{avg} \quad (1)$$

where R - annual value of the total number of spontaneous hydrometeorological phenomena, P – annual precipitation, mm/year, Pavg - average value of annual precipitation for the territory of Ukraine.

Figure 2 presents the graph of the spatial distribution of landslides per square kilometer and the coefficients of the hydrometeorological conditions throughout the administrative regions of Ukraine.

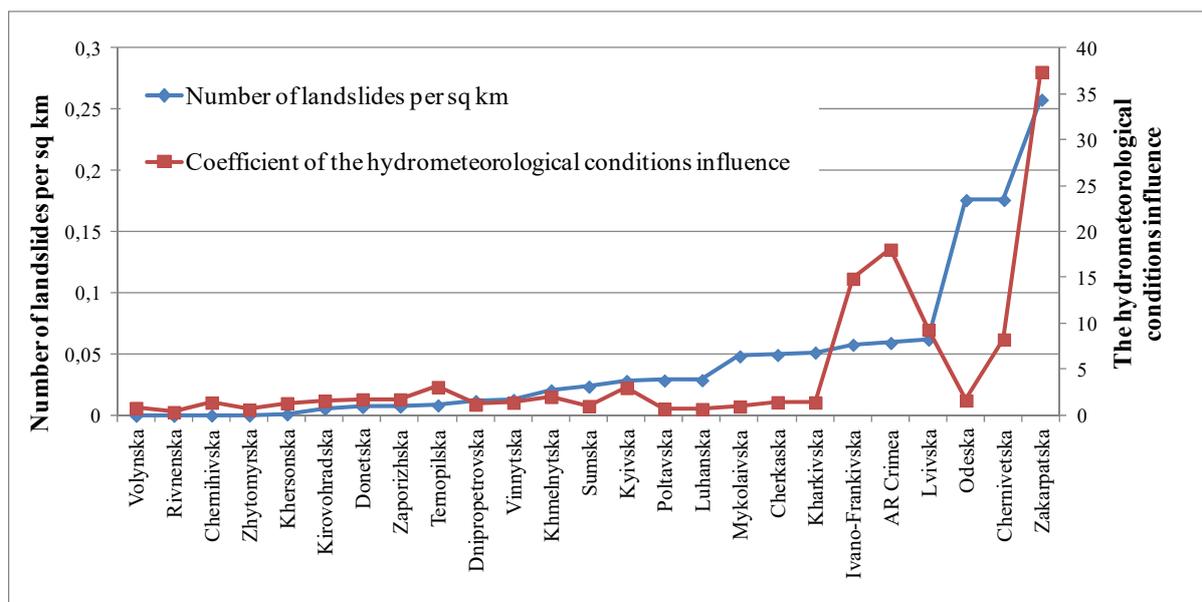


Figure 2 –The the regional coefficient of hydrometeorological conditions and landslide number per sq km spatial distribution graph

Statistical correlation data analysis of landslide hazard and hydrometeorological conditions of the territory of Ukraine was conducted for next values:

- 0,54 landslide number per sq km and the annual precipitation;
- 0,54 landslide number per sq km and annual value of the total number the spontaneous hydrometeorological phenomena;
- 0,70 with regional coefficients of the hydrometeorological conditions.

Thus, the increase of the correlation coefficient while taking into account both the annual precipitation and annual number of spontaneous meteorological phenomena, the assumption regarding the dependence of the regional features of the hydrometeorological conditions on landslide dynamics is confirmed. Figure 3 represents the thematic map, which was built using regional coefficients of the hydrometeorological conditions.



Figure 3 The thematic map based on of the regional coefficient of the hydrometeorological conditions on the development of landslides on the territory of Ukraine

The values of regional coefficients of the hydrometeorological conditions determine the changing influence level of the regional hydrometeorological conditions on landslide development. Mostly this level responds to landslide hazard level. But there are also some diversities. In particular, in Odessa region we have huge amount of landslides 0,18 per sq km and at the same time a moderate influence level of the hydrometeorological conditions (<2). The fact is that factors which determinate the landslide hazard in this region are abrasion, shore processing, erosion and man-made flooding. By removing the Odessa region data from the sample allows to obtain a correlation between regional coefficient of the hydrometeorological conditions and the affected landslides of 0,80. An increase in the correlation coefficient when removing the extreme value confirms the dependence under study. The influence is very significant so it is necessary to take into account both the amount of precipitation and number of spontaneous meteorological phenomena, but it should be considered with taking into account other factors that initiate landslides.

Conclusions

1. Hydrometeorological conditions are one of the determining factors of the landslide development.
2. The quantitative characteristics of the territory's tendency to the occurrence of the spontaneous hydrometeorological phenomena is proposed. The regional coefficients of the hydrometeorological conditions influence on landslide development have been calculated.
3. The correlation analysis of the regional coefficients of the hydrometeorological conditions and the number of landslides was carried out, in particular the correlation coefficient is 0,80. Therefore, the territory's tendency to the occurrence the spontaneous hydrometeorological phenomena should be taken into account in the process of forecasting the landslide hazard.
4. In further studies, the spatial analysis of the relationship of landslide development and spontaneous hydrometeorological phenomena can be carried out for other territorial and natural taxa, such as administrative districts, engineering-geological regions, various lithofacies zones, etc.

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