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Landslide hazard assessment in the south of Ukraine

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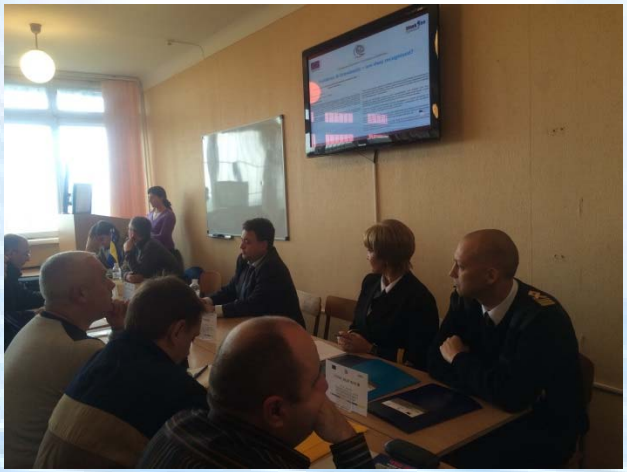

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Mora & Vahrson methodology for regional landslide hazard assessment of the southern Ukraine .

Selecting a method is due to the availability of input data for the calculations. Calculations and construction of maps was carried out using the software QGIS 2.10, SAGA GIS2.1, with partial use of ArcGIS 10.2.

Landslide hazard assessment carried out within the south of Ukraine. The western border of the territory - the border line with the state of Moldova, the southern border - the Black Sea coast, the eastern - Nikolaev, the width of the area - 100 km from the coast of the Black Sea.

The spatial resolution of the digitized maps, and the resulting maps of 90 m (based on the accuracy of the data available on the factor of the slope).

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Mora & Vahrson methodology

Landslide hazard in a particular area is formed by two components - the intrinsic landslide susceptibility (**SUSC**) and the value of the trigger factor (**TRIG**).

The value of the landslide hazard in the south of Ukraine is calculated using the formula:

HI = SUSC * TRIG= (Sr * Sl * Sh) * (Ts + Tp)

where:

Sr : “Slope” factor

Sl : Geology factor

Sh: Humidity factor

Ts: (Earthquake) Seismic triggering factor

Tp: Precipitation triggering factor

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Slope factor (Sr)

For construction of maps topography slopes used SRTM data.

The Slope Factor is defined by the maximum difference in elevation per unit area **Rr** = Relative Relief per grid unit (square km), **Rr = (Hmax-Hmin)/km²**
Data on slopes topography are expressed in points in accordance with Table:

Relative Relief Rr (m/km2)	Classification	Slope Factor Sr
0-75	Very Low	0
76-175	Low	1
176-300	Moderate	2
301-500	Medium	3
501-800	High	4
>800	Very High	5

Table 1. Slope factor classification

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Slope factor (Sr)

Relief within the of southern Ukraine is characterized by a small relative, mostly moderate, low and medium, Rr < 500 m/km^2.

The highest slopes relief (up to 500 m / km^2) are observed in the northern areas of the south of Ukraine, in the river valleys.

Most of the area is characterized by slopes up to 175 m / km^2.

The map of slope factor of southern Ukraine

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Geology (lithology) factor (SI)

Map of geologic factors (lithology factor) is made by an expert evaluation. The main parameter of the geological factor is the shear strength. To compile this map have been used and digitized geological and tectonic maps of regional geological enterprises and maps of the National Atlas of Ukraine (2010).

In compiling maps took into account the age of the rocks, the degree of lithification, genetic type, lithological composition, thickness non-lithified sediments.

Geology factor is expressed in points in accordance with Table 2.

Age and type of geological formations	Classification	Geology (lithology) Factor SI
All rocks	moderate	2
Non-lithified alluvial and limanical Neogene-Quaternary deposits (sandy and silt formation)	medium	3
Neogene-Quaternary loess and clay loam deposits, thickness <20 m	high	4
Neogene-Quaternary loess and clay loam deposits, thickness <20 m and intensely abrasive rocks and deposits of the coastal zone	very high	5

Geology (lithology) factor classification

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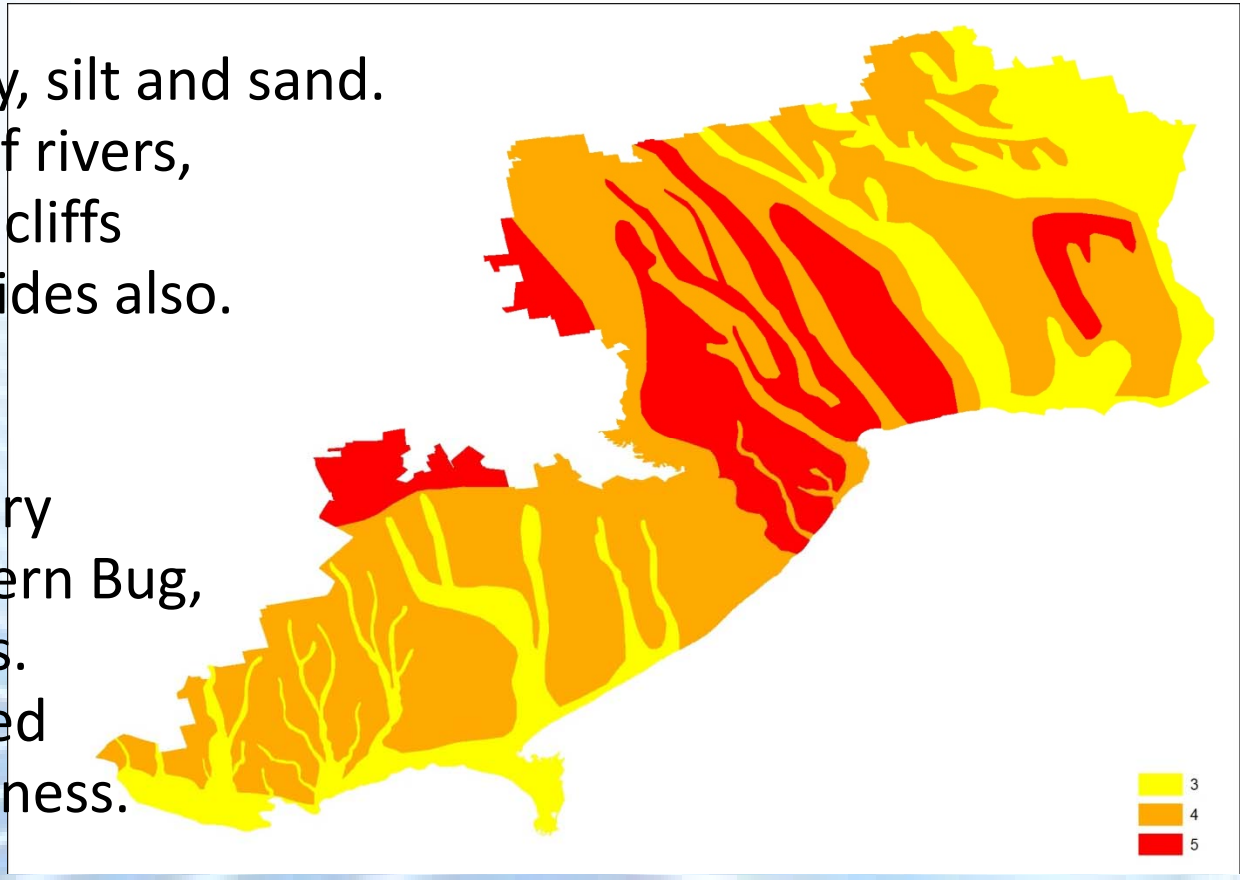
Geology (lithology) factor (SI)

In the south of Ukraine are mainly distributed Neogene and Quaternary slightly lithified deposits of sand and silt and clay formations with low shear strength.

The most susceptible landslides are loess rocks that consist of clay, silt and sand. Rock that destroyed the waters of rivers, limans and the sea in the coastal cliffs are intensively susceptible landslides also.

The most susceptible landslides on geology factors are the territory between the Dniester and Southern Bug, especially in watershed highlands. These areas prevalent non-lithified silty-clay deposits with high thickness.



The map of geology factor of southern Ukraine

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Humidity factor (Sh)

Humidity factor was calculated based on the number of precipitation in every month of the year. We used maps of precipitation in summer (April-October) and winter (November-March) seasons (National Atlas of Ukraine, 2010).

It was assigned the index of precipitation at each map and every month of the year in accordance with Table 3.
The sum of index of 12 months of the year was moved to humidity factor points according to Table 4.

Average Monthly Precipitation AMP (mm/month)	Assigned Value
<125	0
126-250	1
>250	2

Average monthly rainfall values classification

Accumulated value of Precipitation Indices	Qualification	Factor Sh
0-4	Very Low	1
5-9	Low	2
10-14	Medium	3
15-19	High	4
20-24	Very High	5

Moisture factor (Sh) from accumulated AMP values

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Humidity factor (Sh)

Number of precipitation is not more than 550 mm / year in the south of Ukraine, including in the warm season - 325 mm, and in the cold season - 225 mm.

Number of precipitation in the south of Ukraine is <125 mm / month in most of the year, 4 months of the year - 126-250 mm / month.

Thus, Humidity factor in the south of Ukraine is equal to 1. This constant was used in the formula for calculating the landslide hazard.

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Seismic (Earthquake) triggering factor (Ts)

It performed general seismic zoning (GSZ-2004) to the south of Ukraine on the basis of the intensity of earthquakes with a recurrence period of earthquakes - 500 years.

According to the GSZ-2004 intensity of possible earthquakes in the south of Ukraine is from 6 points to the east,
up to 8 points in the west,
in the area of the Danube Delta
(12-point scale).

Digitized maps of probable seismic intensity to determine the seismic factor (Ts).
Seismic factor (Ts) was determined by Table

Intensities (MM) Tr=100yr	Qualification	Factor Ts
III	Slight	1
IV	Very Low	2
V	Low	3
VI	Moderate	4
VII	Medium	5
VIII	Considerable	6
IX	Important	7
X	Strong	8
XI	Very Strong	9
XII	Extremely Strong	10
Seismic Intensity factor		

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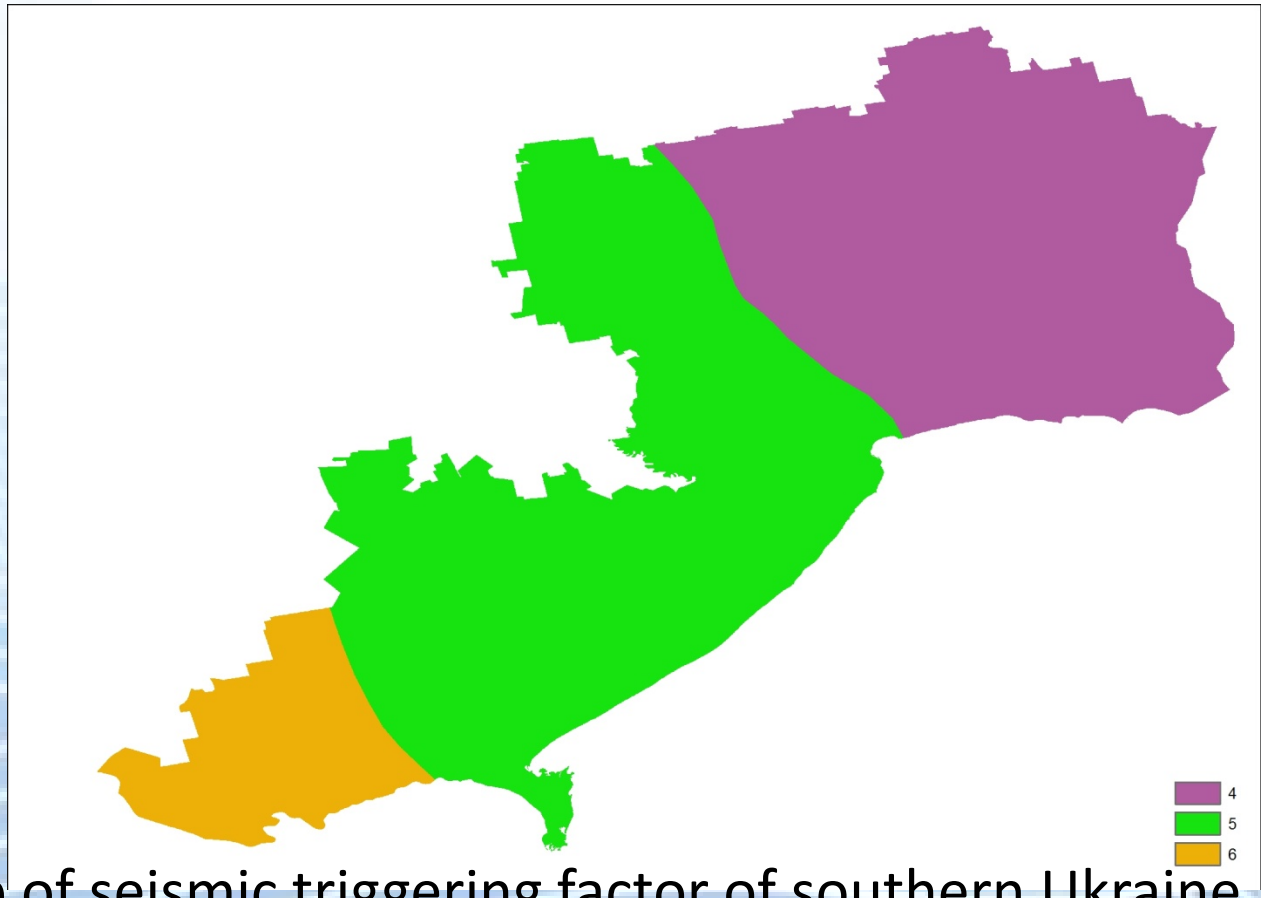
Seismic (Earthquake) triggering factor (Ts)

Meaning seismic factor (Ts) is in the range of from 4 to 6 in the south of Ukraine.

The highest values are typical for the south-western region – the Danube Delta.
This is due to the proximity of the Vrancea zone in Romania.



The map of seismic triggering factor of southern Ukraine

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Precipitation triggering factor (Tp)

Were processed observations of hydrometeorological stations and maps of daily maximum precipitation (National Atlas of Ukraine) for determining precipitation triggering factor.
The values of this factor is expressed in points from Table.

Maximum Rainfall n>10yrs, Tr = 100yrs	Rainfall n<10yrs; Average	Qualification	Tp Factor
<100mm	<50mm	Very Low	1
101-200mm	51-90mm	Low	2
201-300mm	91-130mm	Medium	3
301-400mm	131-175mm	High	4
>400mm	>175mm	Very High	5

Precipitation factor (Tp) originating from the classification of maximum daily precipitations over a return period if 100yrs. An auxillary classification based on the average yearly maximum values per day is given in column 2.

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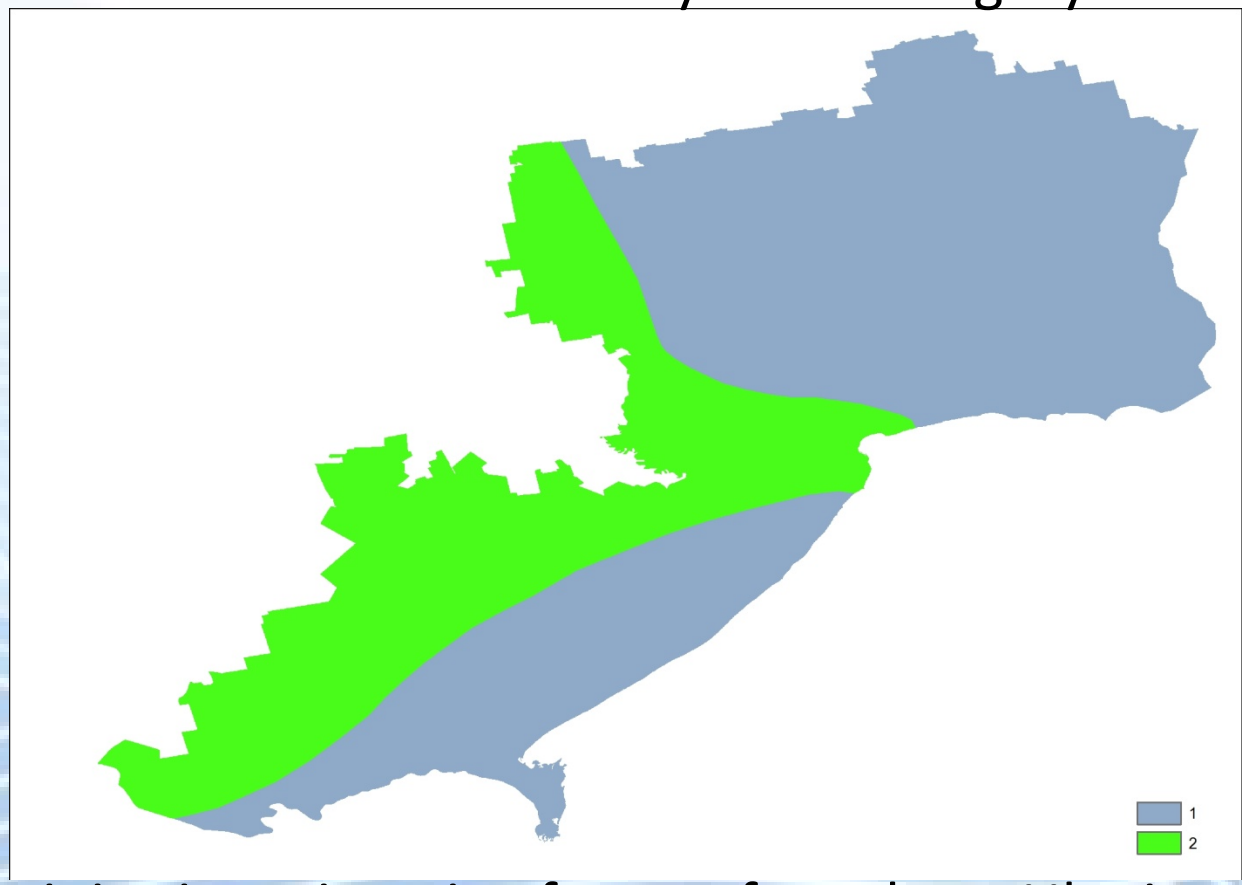
Precipitation triggering factor (Tp)

The southern Ukraine areas present average maximum daily precipitations in the range up to 90mm, so they fall into the “Low” and “Very Low” category (Tp=1-2).



The map of precipitation triggering factor of southern Ukraine

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Results

Thus, the results of calculations landslide hazard were calculated for the southern of Ukraine. The results are shown in points in accordance with Table 7.

Value of HI	Class	Classification of Hazard of Landslide Potential
<6	I	Negligible
7-32	II	Low
33-162	III	Moderate
163-512	IV	Medium
513-1250	V	High
>1250	VI	Very High

Classification of the Landslide Hazard HI parametric values.

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Results

The obtained values of the potential landslides hazard is in range from <6 to 105 points.

Landslide hazard of southern Ukraine is characterized mainly as "Negligible", "Low" and "Moderate".

The most dangerous sites are located in the basin of the Dniester River, along the shores of the Black Sea estuaries and the coast of the Black Sea near the city of Odessa.

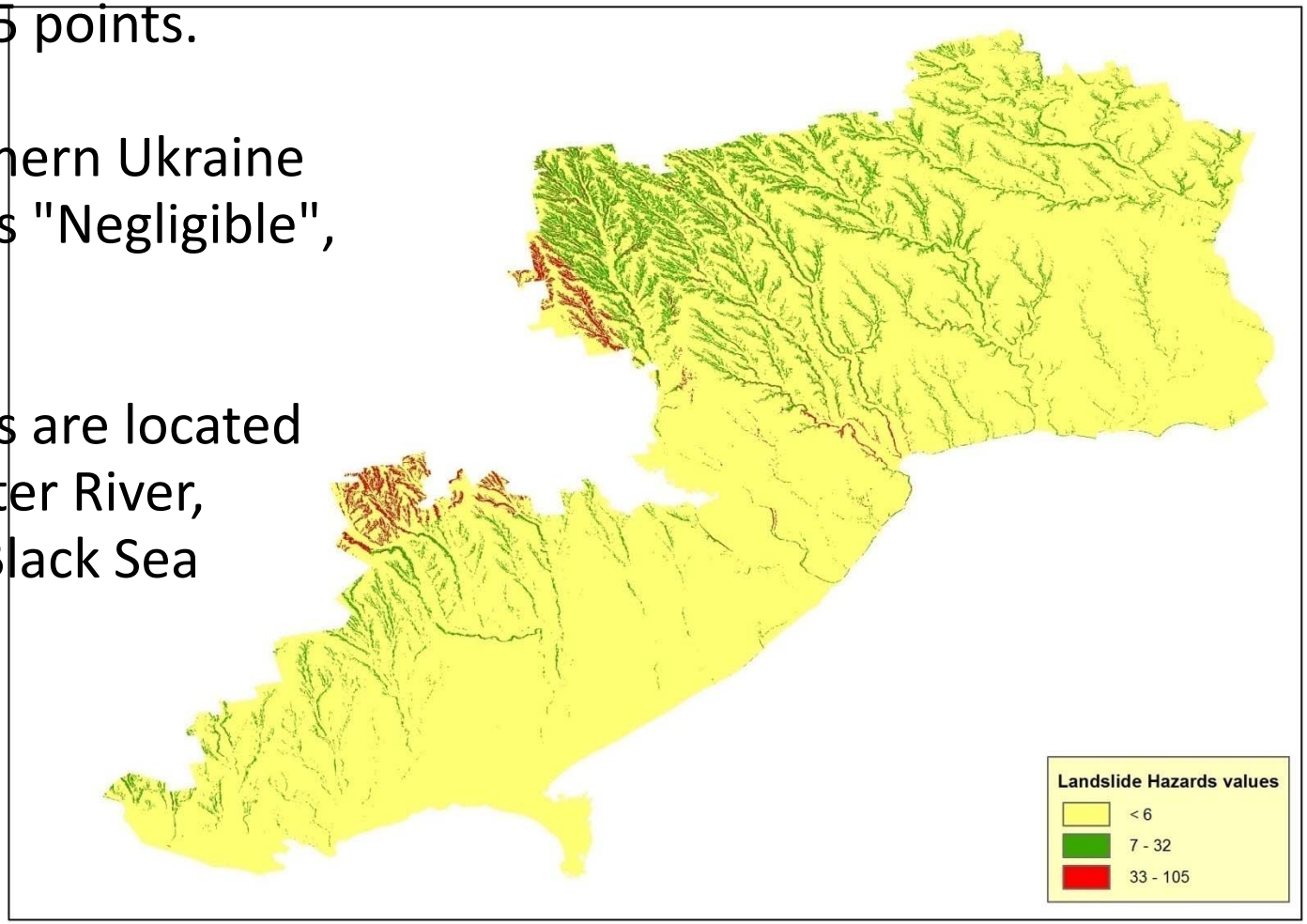

Fig.5. The resultant map of landslide hazard of southern Ukraine

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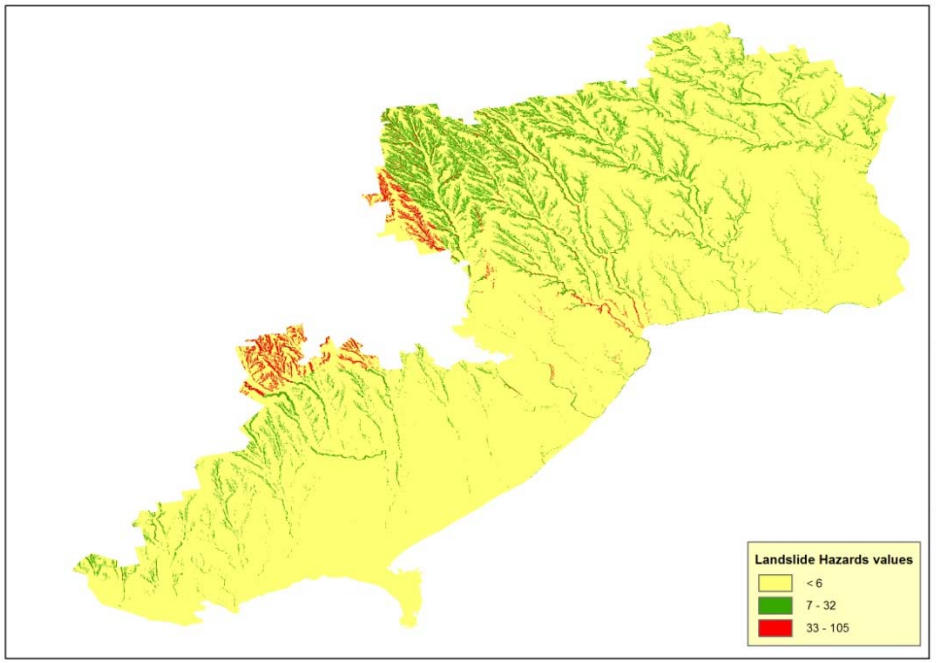
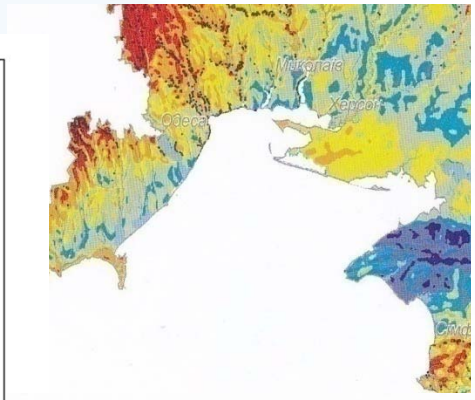
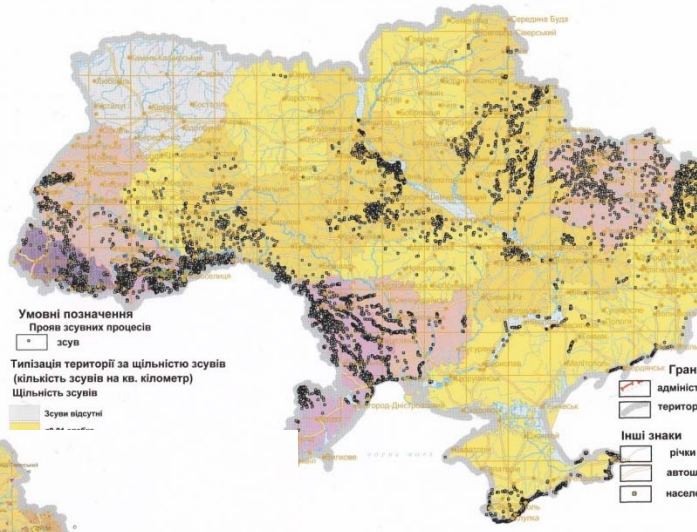
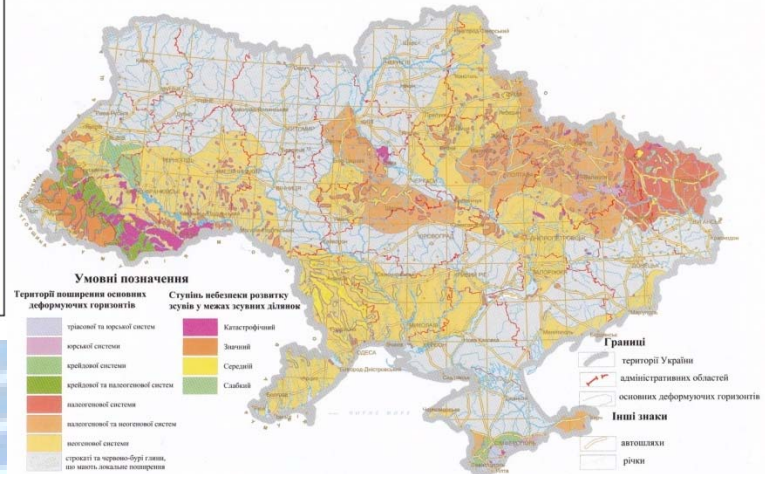
Results

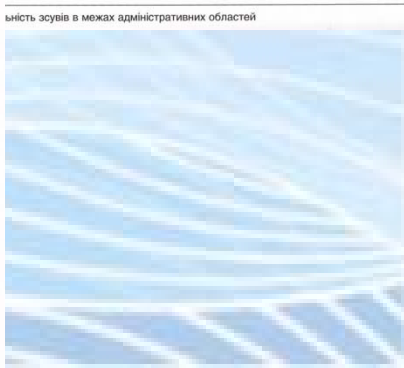
The results are in good agreement with Ukraine made in the national estimates of the potential danger of landslides and real data on manifestations of landslide processes on the territory of Ukraine.











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Thank you for attention!

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