Natural Hazards. 2016. Vol. 82. № 1. P. 43-61. *(авторская версия)*

INTEGRATED ASSESSMENT OF SOCIO-ECONOMIC RISKS OF HAZARDOUS HYDROLOGICAL PHENOMENA IN SLAVYANSK MUNICIPAL DISTRICT

Stepan P. Zemtsov[1]*, Mariya D. Goryachko[2], Vyacheslav L. Baburin[2], Inna N. Krylenko[3], Natalia M. Yumina[3]

[1] Institute of applied economic research, The Russian Presidential Academy of National Economy and Public Administration. 119571, Russia, Moscow, Prospect Vernadskogo 82.
Phone: +7 495 6294386. E-mail: spzemtsov@gmail.com
[2] Department of economic and social geography of Russia, Faculty of Geography, Lomonosov Moscow State University. 119991, Russia, Moscow, Leninskiye Gory 1. Phone: +7 495 9393812. E-mail: vbaburin@yandex.ru
[3] Department of hydrology, Faculty of Geography, Lomonosov Moscow State University
119991, Russia, Moscow, GSP-1, 1 Leninskiye Gory. Phone: +7 495 9392238. E-mail: krylenko_i@mail.ru
*Corresponding author (e-mail: spzemtsov@gmail.com)

ABSTRACT

In 2012 the damage costs of floods in Russia amounted to about €300m, and these floods have caused nearly 200 fatalities (Kotlyakov et al. 2013). Risk assessment is one of the most pressing scientific topics in Russia, but most of the works are devoted to natural hazards assessment. The purpose of this work is to estimate the influence of hazardous hydrological phenomena on society. The field research was conducted in the Slavyansk municipal district in the Krasnodar region (the south-western part of Russia), which is a highly populated coastal territory with a high frequency of hazardous hydrological events.

Modified methods of the Ministry of the Russian Federation for Affairs for Civil Defence, Emergencies and Elimination of Consequences of Natural Disasters (EMERCOM) were used for potential economic damage calculation. The paper did not only focus on direct, tangible risks, but also included social risk (i.e. risk to life and health). Social vulnerability has been calculated directly as a percentage of vulnerable people, estimated in opinion polls, while in many recent papers the social vulnerability index was calculated as a combination of several statistical indicators. The resulting percentage of vulnerable people was converted to numbers of potential victims. Finally the social risk was expressed by financial indicators in terms of the cost of the value of statistical life lost (Mrozek & Taylor 2002; Viscusi & Aldy 2003).

Social risk can be underestimated in comparison with economic risk because of a low "value of life" in Russia (no life insurance, neglecting of basic safety rules, etc.) (Guriev 2009).

INTRODUCTION

Various natural hazards are quite common on the territory of Russia (Miagkov 1995; Golitsyna & Vasilyeva 2001; Borodko & Kotlyakov 2007; Shoygu et al. 2010), constantly causing destruction and death. Most widespread hazards are in mountain and coastal areas.

Incidents with a regional impact resulting from mountain hazards, including mud- and debris flows, resulted in between 10 and 50 victims each (Fuchs et al. 2013). Minor events are regularly reported; however, details other than qualitative are not available on the national scale. Out of 144 cases of torrent events that caused damage to the population in 1991–2008, 130 occurred in the Northern Caucasus, five in the East Siberia and four in the Far East. In 2001–2008, compared with 1991–2000, the number of torrent events with known damage almost doubled in the Russian mountain regions, which may be a result of urbanisation and changes in the land cover (Shagin 2010; Fuchs et al. 2013; Sokratov et al. 2013).

Hydrological phenomena on plain areas (floods, storm surges, ground water level rise, etc.) are one of the main natural hazards in Russia (Miagkov 1995; Petrova 2006; Shoygu et al. 2010; Koronkevich et al. 2010; Gladkevich et al. 2011). More than 10 million people, or 7.2 per cent of the population, are exposed (Shakhramanjyan 2001; Ministry of Finance 2011), and the area, affected by flooding, covers over 0.5 million km^2, or 2.9 per cent of Russian territory (Shakhramanjyan 2001; Taratunin 2008).

Estimations of EMERCOM and of the Institute of Geography of the Russian Academy of Sciences (RAS) have shown that the 2012 flood losses in Russia amounted to about €300m and caused nearly 200 fatalities; Krymsk citizens in the Krasnodar region in August 2012 experienced particularly destructive consequences (Kotlyakov et al. 2013.).

In Russia, most of the works are related to physical-geographical characteristics and the probability evaluation of hazardous phenomena (Gladkevich et al. 2011). An important scientific area is the development of hazard maps (Merz et al. 2007; de Moel et al. 2009). One of the results of such an evaluation is the zoning map of Russia according to the degree of flood hazard for coastal areas, which is based on information about maximum flood levels during the passage of high water in the rivers, as well as the probability of exceeding these levels (Borodko & Kotlyakov 2007). Maps of flood intensity (Koronkevich et al. 2010), based on the same information about the height and frequency of flooding, were developed by a group of authors in the Institute of Geography in the RAS. Maps of flooding danger (Shoygu et al. 2010), based on data of Hydrometeorological centre of Russia, were created in the Institute of Civil Defence.

There are many classifications of floods, defining the hazard level, taking into account the probability, duration and area of flooding (Dobroumov & Tumanovska 2002), the depth and duration of flooding (Karlin 2008), the repeatability, maximum water levels, duration and area of river flooding (Taratunin 2008). The main characteristics for flood hazard description are: maximum exceedance levels of early flooding, probability levels of early flooding (Golitsyna & Vasilyeva 2001; Borodko & Kotlyakov 2007), total duration of flooding (Semenov & Korshunov 2008) and proportion of flooded area (Koronkevich et al. 2010).

However, most of the works are based on natural factors and did not take into account a number of socio-economic indicators. An assessment of flooding impact on socio-economic development is rarely considered (Petrova 2006; Shagin 2010; Gladkevich et al. 2011). Apart from common river flooding, flood events in coastal regions are the one the main themes in risk management (Baburin et al. 2009; Arkhipkin & Mukhametov 2011; Zemtsov et al. 2012, 2013), but the focus in this works is on the assessment of potential economic damage (Avakyan & Polyushkin 1991; Borsch & Mukhin 2000), while in studies focusing on flood in other European countries social vulnerability is more often reported (Birkmann 2007; Fekete 2010; Fuchs et al. 2011; Field et al. 2012; Fuchs et al. 2012, Aubrecht et al., 2013; Birkmann et al. 2013). The main gap for Russian studies is a lack of works dedicated to the vulnerability of communities.

There are three different hardly integrated approaches for risk assessment related to natural hazards[1] (Fuchs et al. 2011), and scientists from different spheres can use various and unrelated methods for quantification (Fuchs et al. 2012). Geoscientists are tending to explore natural hazards, and how they affect the environment (Keiler et al. 2010; Papathoma-Köhle et al. 2011). Economic consequences of disaster events are the main task for economists and related scientists (Noy 2009). Social loss is the problem of sociology-related disciplines, because a research should take into account social structures and interactions (Cutter & Finch 2008; Cutter et al. 2008).

Any hazardous event has a disaster risk[2], which can be defined as a composition of event occurrence probability and associated potential damages (Ologunorisa & Abawua 2005; Pistrik & Tsakiris 2007; Mikhailov et al 2010). Usually, three main categories of potential damages can be distinguished: environment, infrastructure and people, and consequently, three approaches for disaster risk quantification can be observed: environmental, economic and social risks. Social-economic risk in the work is a product of hazardous event occurrence probability and potential economic (e.g. loss of profit) and social (e.g. injuries or destruction of social network) losses. Every system (ecological, technological or social) has its own level of resistance to disaster risk. The opposite term is vulnerability or “the degree of damage that can be expected depending on the characteristics of an ‘element at risk’ with respect to a certain hazard” (Fuchs et al. 2011)[3]. Vulnerability can be divided into susceptibility, coping and adaptive capacity of the object (Birkmann 2006, 2007; Fekete 2010; Fuchs et al. 2012, Birkmann et al. 2013).

In our study we focus on socio-economic systems of coastal zones and their vulnerability during and after flood events. The main purpose of the work is to estimate the potential

[1] Hazard is “a physical event, phenomenon or human activity with the potential to result in harm. A hazard does not necessarily lead to harm” (Gouldby & Samuels 2005)
[2] Risk is “a probability multiplied by consequence in which the multiplication is to be understood as including the combination across all floods” (Gouldby & Samuels 2005)
[3] Another proper definition is “a characteristic of a system that describes its potential to be harmed. This can be considered as a combination of susceptibility and value” (Gouldby & Samuels 2005)

consequences of flooding on society, using economic damage and social vulnerability assessment techniques. One of the main scientific motivations for the paper was to assess not only economic, "tangible" risk, but also social risk components, and integrate them.

Although Russia has one of the lowest socio-economic risks world-wide, and only 9.4% of Russian population is exposed to natural hazards (World Risk Report 2012), the risk among regions is very unevenly distributed. As such, the risk for coastal areas is considerably higher than the risk for inner land, because of a significantly higher temporal and spatial concentration of hazards, higher density of population[4] and national wealth (infrastructure and fixed assets) in coastal areas (Martinez et al. 2007).

In the work of Gladkevich et al. (2011), related to the complex multifactorial flood risk assessment in Russia, the Russian regions were divided into groups of different flood exposure by using a flood hazard index[5] (Fig. 1); this index was used in our work to identify the most affected and most exposed regions. The Krasnodar region[6] in the south-western part of Russia has a very high flood risk index and one of the highest rates for natural hazards in general (Myagkov 1995; Golitsyna & Vasilyeva 2001). Therefore, the Krasnodar region was chosen for an in-depth analysis of vulnerability and risk. In the work of Zemtsov et al. (2013) social vulnerability of municipal communities in the Krasnodar region was assessed by developing an integrative index. This index was based on the World Risk Index methodology (World risk index 2012; Birkmann, 2006, 2007). The coastal municipal districts in the Kuban river mouth were identified as specifically high-risk territories because of high probability and duration of flooding, high population density on the coast of the rivers and seas (Matishov & Matishov 2013) and a significant portion of the population engaged in agriculture and tourism, which are more vulnerable to flooding than population working in the industrial sector or other spheres.

The Slavyansk municipal district was chosen for detailed analyses of causes and effects of the risk. The area is located in the delta of the Kuban River (Fig. 2) at a height of 1-2 meters above sea level. Hazardous hydrological phenomena are regular (Mikhailov et al 2010), affecting the economy and threatening the health and lives of people. According to Table 1, approximately 3600 people were injured by floods during the last twenty years. In order to assess the vulnerability within this region we used a method that combined both economic and social approaches of vulnerability quantification.

[4] In this case, we are talking about the coastal areas of warm seas (the Black, the Baltic seas and the sea of Japan)

[5] Index of hazard = 0.5*(duration of flooding) + 0.2*(maximum depth of flooding) + 0.1*(probability of flooding) + 0.1*(percentage of flooding area) + 0.1*(curve type of water discharge, which is forming riverbed). Curve of water discharge, forming riverbed, determines the danger of channel and floodplain rearrangement

[6] Krasnodar is the regional capital, which is presented on the map

1. METHODS AND DATA

Risk from flooding can be divided into several different types (ecological, social, economic, etc.) and corresponding categories of damages (loss of vegetation, building destruction, etc.) (Zemtsov et al. 2013) (Table 2). Starting with a scientific or engineering approach, risk is regularly defined as a product of a flooding probability and associated potential damages (Ologunorisa & Abawua 2005; Mikhailov et al. 2010; United Nations 2013).

$$R = \sum_r R_r = \sum_r \left(p \times D_r\right) = \sum_{r,k,i,j} \left(p_j \times D_{rkij}\right) = \sum_{k,i,j} \left(p_j \times D^{Economic}{}_{kij}\right) + \sum_{k,i,j} \left(p_j \times D^{Social}{}_{kij}\right) \qquad (1)$$

where R is an integrated socio-economic risk, or potential annual loss (million € per year), as the sum of two types of risks r: economic and social; p is a flooding probability (in shares), according a category of flood danger j; D is an expected maximum potential damage ($D^{Economic}$; D^{Social}) (million €) of an object i (e.g. a settlement), according its category of damage k[7].

Floods in the Kuban river delta have been classified according to the degree of danger j into three categories (Dobroumov & Tumanovska 2002; EMERCOM 2011)[8]: widespread process of ground water level rise (average probability (p) for most of the settlements is 0.99 per year), floods because of the failure of earth dams with a medium level of danger (0.01)[9] and catastrophic flooding after the breakout of large reservoirs such as the Krasnodar reservoir, and a subsequent destruction of the earth dams (0.001).

The basic model for integral damage calculation (*D)* in discrete form is

$$D = \sum_{i,j} D_{ijk} = \sum_{i,j} \left(d_i \times V_{ij} \times S_{ij}\right) \qquad (2)$$

where d is a maximum potential value of an exposed object i (i varies according to the category of damage k) per unit of area (million € per km^2); V is an vulnerability indicator of an object i (in shares), depending on flood hazard zone j (by categories of danger: 1 – groundwater level rise, 2 – medium flooding, 3 – catastrophic flooding); S is the size of an area, covered by i (km^2).

$$V_{ij} = f(Sus_{ij} - C_{ij}) \qquad (3)$$

where f is a function, Sus is the susceptibility of an object to flooding, C is an ability of an object to resist the impacts of flooding.

To calculate the economic risk, several categories of potential damage were identified:

$$D^{Economic} = D_{Agriculture} + D_{Fixed\_assets} + D_{Infrastructure} + D_{Real\_estate} + D_{Exist\_investment} + D_{Planned\_investment} \qquad (4)$$

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7 All used indicators were entered as separate layers in a geographical information system.

8 Probability of natural and technogenic disasters were estimated according to data of local department of EMERCOM (collected during field trip)

9 Russian authorities over the last 20 years almost did not invest in the construction and maintenance of earthen dams

where $D_{Agriculture}$ is an agricultural damage; D_{Fixed_assets} is a loss of fixed assets; $D_{Infrastructure}$ is an infrastructure damage, D_{Real_estate} is a damage of dwellings in residential section; $D_{Exist\_investment}$ is a loss of existing investment activity, or underinvestment; $D_{Planned\_investment}$ is potential profit loss of planned investment projects.

$$D_{Agriculture} = \sum_{i,j}\left(d^{(1)}{}_i \times V^{(1)}{}_{ij} \times S_{ij}\right) = \sum_{i,j}\left(I_i^{productivity} \times pr^{(1)}{}_i \times V^{(1)}{}_{ij} \times S_{ij}\right) \quad (5)$$

where $d^{(1)}{}_i$ is the cost of potential agriculture production (million €); $I^{productivity}$ – productivity of a crop *i*, which are wheat, soybeans and rice (ton per km^2); $pr^{(1)}$ – price of one ton (€); $V^{(1)}$ is vulnerability (in shares), according to flood hazard intensity *j*, *S* is exposed area of *i* (km^2).

The percentage of average harvest losses during flood events from annual yields was used as coefficient of vulnerability for agriculture. Depending on the category of flooding, different cultures are variable in their vulnerability. The vulnerability coefficient of rice for groundwater level rise is nearly zero due to its moisture resistance (*C*) (a small percentage can still be spoiled with a long standing ground water). We have introduced 0.7 as the coefficient of the vulnerability for winter wheat during flooding according to the hazard category 2 (data of Valuysk pilot reclamation station (Golberg et al. 1988)), 0.9 for soybeans (data of Astrakhan pilot reclamation station (Golberg et al. 1988)) and 0.05 for rice (data of Russian scientific institute of rice (Golberg at al. 1988)). All the yields would be lost, if catastrophic flooding (category 3) would happen.

$$D_{Fixed\_assets} = \sum_{i,j}\left(d^{(2)}{}_i \times V^{(2)}{}_{ij} \times coeff^{(2)}\right) \quad (6)$$

where $d^{(2)}{}_i$ is the cost of fixed assets of an object *i* in industrial and service sectors[10] (€); $V^{(2)}{}_{ij}$ is the vulnerability coefficient as a level of destruction of the object *i* for the categories of flooding *j* (V_1 = 0.1 (replacement of equipment); V_2 = 0.3 (replacement of equipment and repair of building); V_3 = 0.6 (reconstruction)) respectively; $coeff^{(2)}$ is an adjusted amortization coefficient[11] for the municipal district = 0.23 (Baburin & Goryachko, 2009).

The vulnerability assessment was performed using coefficients from recommendations of EMERCOM (Table 3) (e.g. stability of buildings and infrastructure) (EMERCOM 2007).

$$D_{Infrastructure} = \sum_{i,j}\left(d^{(3)}{}_i \times V^{(3)}{}_{ij} \times S_{ij}\right) \quad (7)$$

[10] Economic indicators, such as the cost of fixed assets, were obtained from the Russian Federal State Statistical Service (2012)
[11] Adjusted amortization coefficient is an annual standard level of depreciation (or devaluation) for fixed assets

where $d^{(3)}_i$ is the cost of infrastructure object *i* (e.g. automobile road) per km (€); $V^{(3)}_{ij}$ is the vulnerability coefficient, according the categories of flooding *j* (V_{i1} = 0.1; V_{i2} = 0.3; V_{i3} = 0.6); S_j is the length of an exposed object *i*.

$$D_{\mathrm{Real}\_estate} = \sum_{i,j,c} \left(d^{(4)}{}_i \times V^{(4)}{}_{ijc} \times S_{ijc} \right) \qquad (8)$$

where $d^{(4)}_i$ is the market price of an object *i* per m^2 (€); $V^{(4)}_{ijc}$ is the rate of destruction (in shares) of objects *i* for event *j*, according to three types of construction *c*: wooden houses, brick and stone houses with one floor and brick and block houses with two and more floors; *S* is an exposed area (m^2). The vulnerability coefficients for objects can be determined by table 3. The used methodology is the official guideline for damage calculation in Russia (EMERCOM 2007). A map of residential property prices of Slavyansk-on-Kuban, which was developed for the research, was based on data from free media and local real estate agencies.

$$D_{Exist\_investment} = \frac{\sum_{t=2002}^{2012} \left(\frac{MD^{Investment}{}_t}{MD^{Fixed\_assets}{}_t} - \frac{RF^{Investment}{}_t}{RF^{Fixed\_assets}{}_t} \right) \times MD^{Fixed\_assets}{}_t}{10} \qquad (9)$$

where *t* is a year; $MD^{Investment}_t$ is an amount of investment to fixed assets in the Slavyansk municipal district (€); $MD^{Fixed\_assets}_t$ is the cost of fixed assets in the district (€); $RF^{Investment}_t$ is an amount of investment to fixed assets in the Russian Federation (€); $RF^{Fixed\_assets}_t$ is the cost of fixed assets in the country (€).We have made a strong assumption, that all the underinvestment of the district were related to its unattractiveness because of natural hazards.

$$D_{Planned\_investment} = \sum_{i,j} d^{(5)}{}_i \times \sum_{t=2012}^{T} \frac{CIF_{ti}}{COF_{ti} \times (1 + V^{(5)}{}_{ij})} \qquad (10)$$

where $d^{(5)}_i$ is a total investment of an project *i* (€); *t* is a year, *T* is a number of years of investment project *i* realization; *CIF* is a cash-in-flow and *COF* is a cash-out-flow of a project *i* (€)[12]; $V^{(5)}_{ij}$ is a vulnerability estimation, according to the different hazard zones *j*. Our assumption was that groundwater level rise can generate additional 10% to the total annual cash-out-flow, medium flooding – 50% and catastrophic scenario can double the total annual cash-out-flow. There was a database of planned or expected investment projects with its common financial characteristics.

Component analysis of the data (Fekete 2010), collected in opinion polls, was conducted to identify, in the first step, the most related and valuable questions and, in the second step, to estimate the proportion of weakly, less and most vulnerable people in settlements according to the answers of the questions. This proportion was named vulnerability index. Polls were representative by age and gender, 485 respondents participated in the survey. Based on selected

[12] For more information about cash-in-flow and cash-out-flow calculation see DeFusco et al (2001)

questions (Table 4) we defined three groups of people with different vulnerability: most vulnerable (41.5% of the total population in Slavyansk district), less vulnerable (16%) and weakly vulnerable (42.5%). The first indicator will be used as an index of social vulnerability (V^5) for medium flooding; the sum of the first and the second indicators (57.5%) is a social vulnerability index for catastrophic flooding.

$$D^{Social}{}_L = \sum_{i,j}\left(\rho_i \times S_{ij} \times V^{(6)}{}_{ij} \times V^{Victims}{}_{ij} \times coeff^{\ Victims}{}_L\right) + \sum_{i,j}\left(\rho_i \times S_{ij} \times V^{(6)}{}_{ij} \times V^{Death}{}_{ij} \times coeff^{\ Death}{}_L\right) \quad (11)$$

where L is an approach of estimation (L_1 is proposed by the authors; L_2 is used by Russian government nowadays); ρ is a population density of a settlement i (person per km^2); S is a an exposed (flood prone) area of settlement i (km^2); $V^{(6)}$ is the social vulnerability index (in shares); $V^{Victims}$ is the share of vulnerable people, who are potential victims and potentially will have health problems after a flooding (0.02 is for a medium flooding; 0.05 is for a catastrophic flooding (EMERCOM 2007)[13]); $coeff^{Victims}$ is an indicator of an average health losses per one person: L_1 is a share of an average health insurance coverage in the USA, adjusted for gross domestic product difference between the USA and Russia (€ 5,000 per capita, Guriev 2010), and L_2 is an average free medical insurance coverage for dismemberment in Russia (€ 1,200 per capita); V^{Death} is the death rate or the share of potentially dead persons during a flooding (0.05 is for medium; 0.1 is for catastrophic flooding (EMERCOM 2007)); $coeff^{Death}$ is a financial estimation of a statistical life loss value: L_1 is an average value of life insurances in the USA[14], adjusted for gross domestic product difference between the USA and Russia (€1.5m per life lost (Guriev 2010))[15] and L_2 is the loss of a family with respect to the primary earner (approximately € 50,000 per life lost (EMERCOM 2007)).

Subsequently, some risk simulations for settlements were conducted to show the temporal (people at night are less prepared) and seasonal (tourists are less prepared) dynamics.

2. DISCUSSION OF RESULTS

[13] The methodology was developed in Soviet period. Number of victims and injuries depends on intensity, duration, height and destructive power of flooding. Nowadays, it is more like a practical guide for assessment, consisting of normative values without any explanation of its origin. Our flooding parameters were compared to EMERCOM methodology. For similar information see Kahn (2005), Penning-Rowsell et al. (2005), Jonkman et al. (2008)

[14] Monetization of life loss is debatable issue in literature (Mrozek & Taylor 2002; Viscusi & Aldy 2003), but we apply it in the paper because it is one of the most reasonable approaches for comparing economic and social risks. High value of life can be expressed as life and medical insurance (Guriev 2009), and it is one of the best ways to evaluate social losses, because the best way to assess anyone’s value of life is his own assessment. If the life insurance is high and common in society, it is hard for government or business to ignore safety rules

[15] This method can be called as a “real loss for society”, because it corresponds to all direct (e.g. lost possible future profits, taxes, etc.) and indirect (e.g. previous education and health expenditure, future demographic losses, etc.) losses in financial terms

In the following section, examples of the study results are provided.

Fig. 3 shows the map of flood zones, according the danger categories, and population density in settlements. The blue colour areas show the potential catastrophic flooding areas after a breakout of the Krasnodar reservoir and the destruction of the earth dams. The black hatched areas show flooding areas of a medium danger category because of breaks of the embankment dams. The diagonal stripes indicate a widespread process of groundwater level rise.

2.1. ECONOMIC DAMAGE

The maximum potential agricultural damage can be around €1m for a medium event and almost €32m for the modelled catastrophic event. The agricultural system is quite sustainable for non-catastrophic events due to high level of resilience of rice, which is the main crop.

The fixed assets damage is approximately €20m for the medium scenario and €75.7m for the catastrophic event, which is high because of industrial buildings location in flood-prone areas.

The infrastructure damage for the entire area, following a catastrophic flood event, can amount to €12m, but it is €6m per year for the ground water level rise damages[16]. Most of the infrastructural objects (road network, power network, etc.) are in federal property, and reconstruction of the objects is financed by federal government. Nevertheless, it affects social and economic vulnerability of the local communities, especially of the settlements Achuevo and Zaboyskiy, which are far from the municipal capital Slavyansk-on-Kuban, where the EMERCOM unit is located.

The calculation of the real estate damages was based on the map of residential property prices and the map of different building vulnerability (Table 3), which was developed during the field campaign. The modelled damage after a catastrophic flood could amount to €150m, and every year some buildings are affected by scouring/subsurface erosion. To estimate this impact, we worked out the map of the drainage/sewage system of Slavyansk-on-Kuban, which indicated that only blocks of brick buildings in the city centre are well protected. However, most of the city does not have any drainage system or the drainage system is composed from earthen canals. Even the existing system of drainage is insufficient for discharging the storm hydrograph because of the low elevation differences of the drainage system (less than 1 m) and weakness of the suction pumps. Moreover there is a particular challenge in clearing the drainage system from

[16] It is difficult to separate the damage associated exclusively with raising of groundwater from the damage caused by the change in temperature during the winter season

sediments and vegetation, because local budget is in deficit and local residents are not aware of the system requirements.

The annual investment losses of existing businesses are €38m, according to the data of 2002-2012. The total planned investment losses are about €42m for the projects with a vulnerability index equal to 1 and €0.8m for the projects in the medium flood area.

Total annual losses from groundwater level rise are approximately €8m[17]. It can be sum up with the annual investment losses of existing businesses: €46m is the annual damage from unfavourable geographical location without any disasters. It is more than the total annual budget profit of the municipality (€40m). The total potential medium damages are about to €63m, and the losses from catastrophic events can exceed €314m. Using probability coefficients for different categories of flooding, the damage value is €0.63m and €0.31m per year for medium and catastrophic flooding respectively.

2.2. SOCIAL DAMAGE

The vulnerability of the local communities (settlements) has been calculated on the basis of opinion polls. The percentage of people, who positively answered the additional questions about preparedness for and responses to flooding are shown in Fig. 4. Every answer in the figure is an indicator of vulnerability. The analysis shows that most of the citizens are unaware of and are not prepared to flood events.

There are two indices in Fig. 4. Integral index is the arithmetic mean of the indices, which were calculated for every community as a share of people in it, who gave a positive answer to the questions in the figure (the index is calculated by the equation of linear scaling (min - max) procedure (Fekete, 2010)). The vulnerability index is the percentage of the most vulnerable people (Table 4 and 6)[18]. Comparison between two indices on community level as a form of verification for the social vulnerability index shows that there is no need for applying all questions as an vulnerability indicators (Pearson's correlation coefficient between the indices is 0.9), because the most valuable questions were extracted through the component analysis.

The potential social damage (Table 7) was financially estimated (Tables 8 and 9).

The total potential social damage as a real loss for society is about €11.1m for a medium scenario and about €272m for a catastrophic scenario (€0.52m and €10.9m according to the

[17] The highest value of the damage was calculated for the rise of groundwater, because it is annual and has an impact on virtually all objects of agriculture, infrastructure, fixed assets and real estate, while the probability of flooding is much lower (0.99 to 0.01 and 0.001 in comparison). There are invisible effects during long periods of time

[18] The resulting vulnerability index estimation (0.58) for the Slavyansk municipal district, based on opinion polls, corresponds to the municipal risk index results (0.59) (Zemtsov et al., 2012)

government estimations), meanwhile, the economic damage is about €63m and €314m[19] respectively. There is still a perception in Russia that the main damage from natural disasters is related to buildings and infrastructure losses, which may be true for groundwater level rise[20] and medium flooding; but the potential social losses from death and health problems after catastrophic floods can be equal to the economic damage. Moreover, the number of vulnerable people in summer can be two times greater than it was evaluated, because of the high touristic attraction of the Azov seacoast and fishing marshes.

Social risks can be underestimated in comparison with the economic risk due to a low value of human life resulting from the perception of citizens and governmental agencies (no life or health insurance, neglecting of basic safety rules, etc.) (Guriev 2009).

CONCLUSION

The conducted field research data allowed us to identify the weaknesses in the preparedness for the defined flood hazard scenarios in the Slavyansk municipal district, e.g. improper state of embankment dams and storm sewers, lack of dredging in rivers, planning and implementation of investment projects without risk analysis, etc. The main result of an opinion poll is unwillingness of the population to face hazardous hydrological phenomena, e.g. non-participation in local groups for protection, lack of knowledge of evacuation routes, ignorance of an alarm system, etc. As a result approximately 5.3% of the total district population (6922 citizens) are classified as vulnerable to medium flooding, and 27% (35 134) are vulnerable to catastrophic scenario. Areas and communities with different degrees of risk were identified. The potential damage for a number of settlements (e.g. Achuevo and Derevyankovka) exceeded the costs of protection measures, which raises a question of relocation.

The conducted research has shown the importance of both social and economic components of the risk assessment. Using the previously discussed methods individually does not bring the desired results because of the deficiencies of the Russian statistics. It is essential for the accurate risk assessments to use the complex of methods (statistical, field observations, etc.) on the micro scale level (settlements). The work has a practical importance for the safety of the local communities.

The study showed that despite our understanding of the low damage from groundwater level rise, it is the major economic risk for the municipality because of its widespread occurrence

[19] Krymsk tragedy damage, including government compensations for family member losses, was estimated as nearly €300m (Kotlyakov et al. 2013)
[20] The social damage from groundwater level rise is extremely small, and it is not considered in the work

(almost all the territory), high frequency (almost every year), constant but invisible and not disturbing indirect effects and absence of the reliable drainage system in most of the settlements.

One of the most important results of the work was the accurate estimation of the economic and the social risks in the equivalent measures, which could be achieved only on the settlements level data. Although in Russia the system of protection is directed toward buildings and infrastructure protection as the most expansive components of the socio-economic system; it is worth noting that according to our calculations the social risk can be similar in financial values during extreme natural events. The social damage may be underestimated in comparison with the economic damages due to the low perception of the life value, the low responsibility of the local authorities (most of the incident compensations are federal), which in turn will continue to negatively affect the vulnerability and especially, the coping capacity in Russia.

The high risk of the coastal zones is caused by the combination of the hazardous phenomena, high population density and high economic activity density. In Slavyansk municipal district (as well as in other parts of Russia (Petrova 2004)), the increase of hazardous natural events (possibly caused by the climate change) has coincided with the increasing risk and the recurrence of the technogenic catastrophes because of the errors in the territorial planning, the organization of the warning and the prevention systems and underinvestment of the protection systems. Sustainable development of the Russian regional and local communities is limited by these factors.

The primacy of the economic risk assessments persists in the Russian academic and administrative tradition, partly due to the orientation of the Russian statistics on accounting of the material assets. The nonmaterial parts of the national wealth (people, knowledge, social networks, etc.) are much more difficult to evaluate.

There are approved standards, norms and regulations of EMERCOM for most risk and damage calculations, including the standards of the number of victims' calculations for the varying flooding intensity. This approach can be called technocratic, or economic. The developed standards are often adopted for the entire country and do not take into account the regional specific, do not consider the intangible factors, such as social capital and cognitive specifics of different communities. It is believed that the threat of the natural disasters can be completely eliminated by creating the required protective systems, changing the environment and development of the necessary labour and other resources of EMERCOM.

On the other hand, the role of social capital, including the prevention of the natural disasters and coping with its consequences, is considered as an important component of community resilience in many studies. This approach can be called socially oriented.

The concept of vulnerability in this context is a crucial link between the approaches. Moreover, the concept of vulnerability allows building links between scientists from different directions, EMERCOM, politicians and citizens. Vulnerability is a universal tool for measuring the stability / instability of an exposed object (tree, building or person, etc.) in relation to the disaster; it can be presented as a fraction of the potential losses (percentage of forest or land degradation, percentage of injured people, etc.). Using this description of the term, the article serves the purpose of building a bridge between the economic and the social approaches.

ACKNOWLEDGEMENT

The work was performed in the natural risk assessment laboratory (the geographical faculty of Lomonosov Moscow State University). The authors are grateful to Prof. Klaus P. Koltermann, leading scientists of the laboratory, researcher D. Magritsky and students of the department of economic and social geography of Russia: S. Bedratiy, A. Zhidrov, V. Litvinov, V. Makeeva, N. Moskvitina, A. Novozhilova, A. Pestich, F. Sleznov, A. Snezhko, I. Timofeev, M. Fadeev. The authors are also grateful to Professor S. Fuchs for his valuable recommendations.

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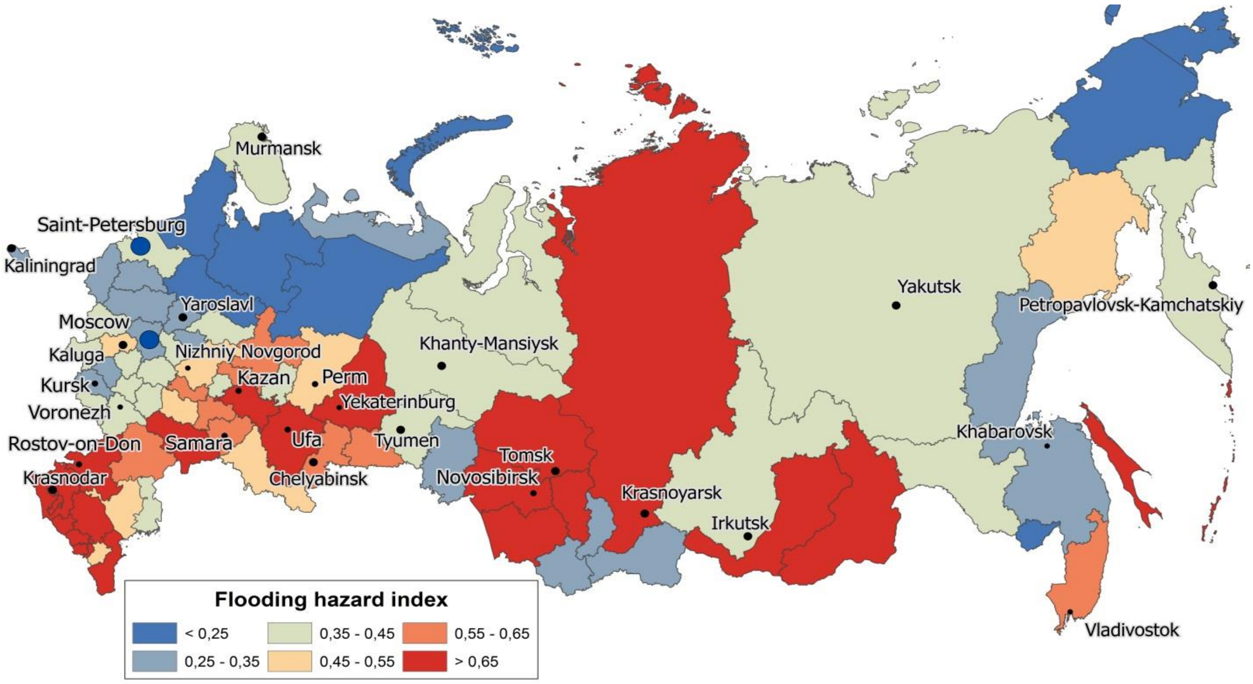

Fig. 1. Flood hazard index for Russian regions in 2010

Source: Gladkevich et al. 2011

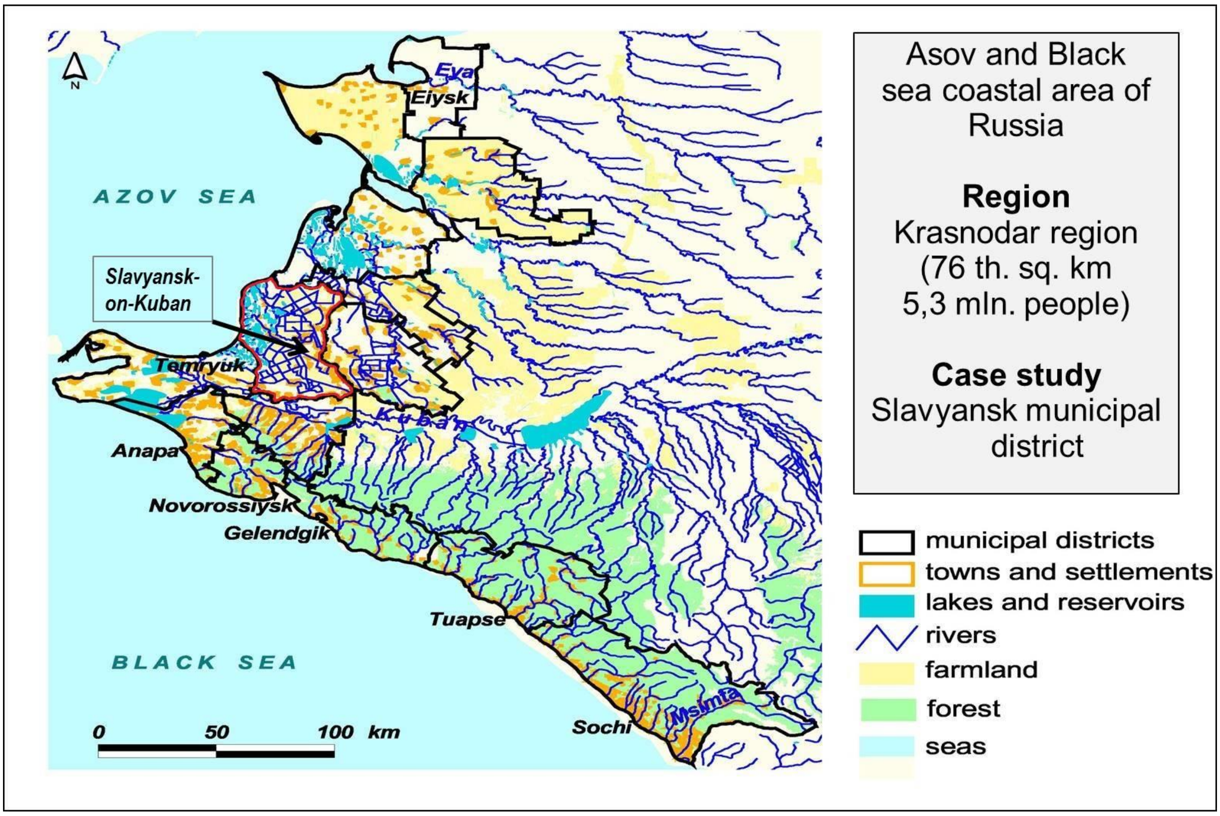

Fig. 2. Coastal municipal districts of the Krasnodar region. Slavyansk municipal district is highlighted by red border

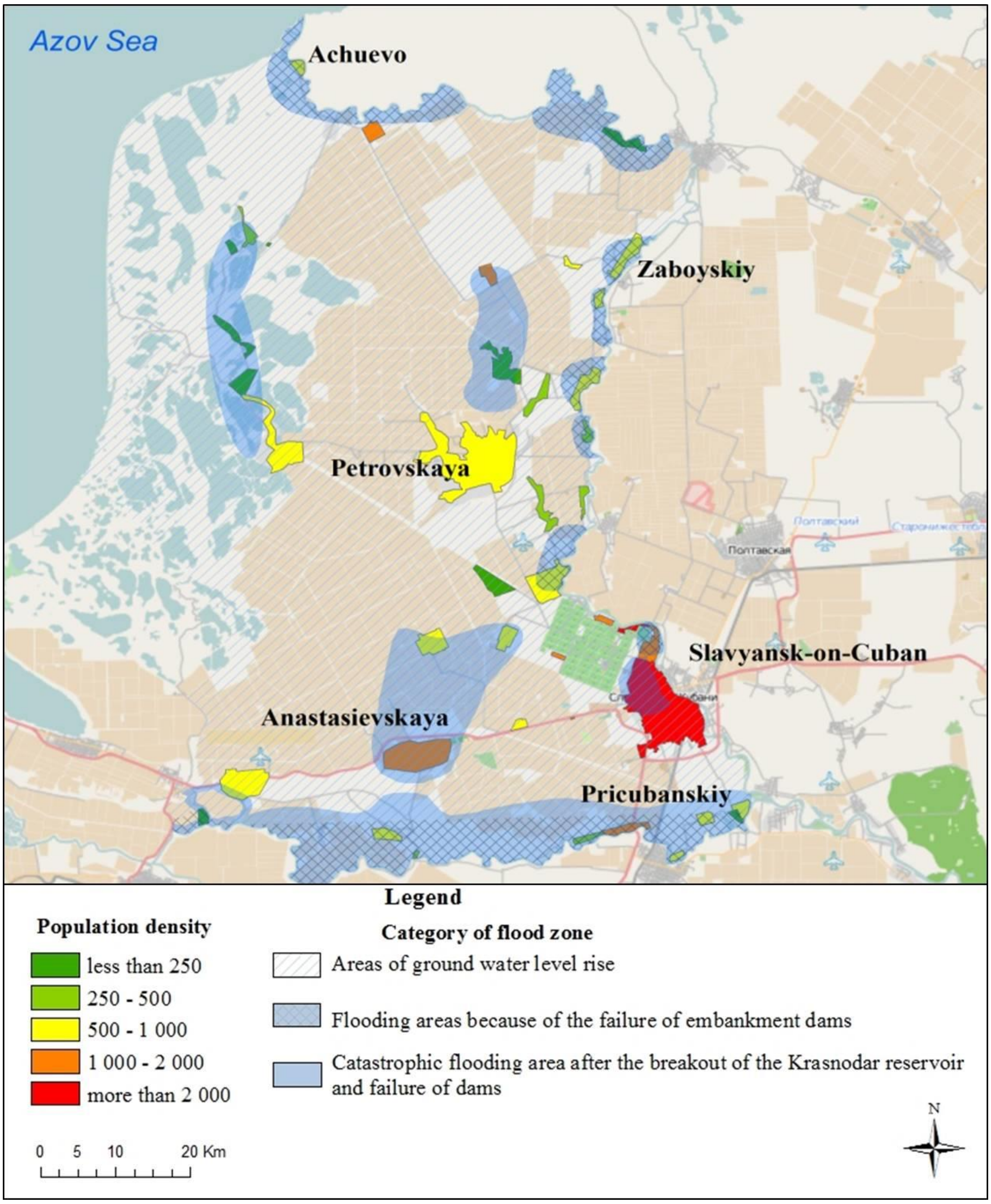

Fig. 3. Population density of the Slavyansk district settlements with respect to hazard zones

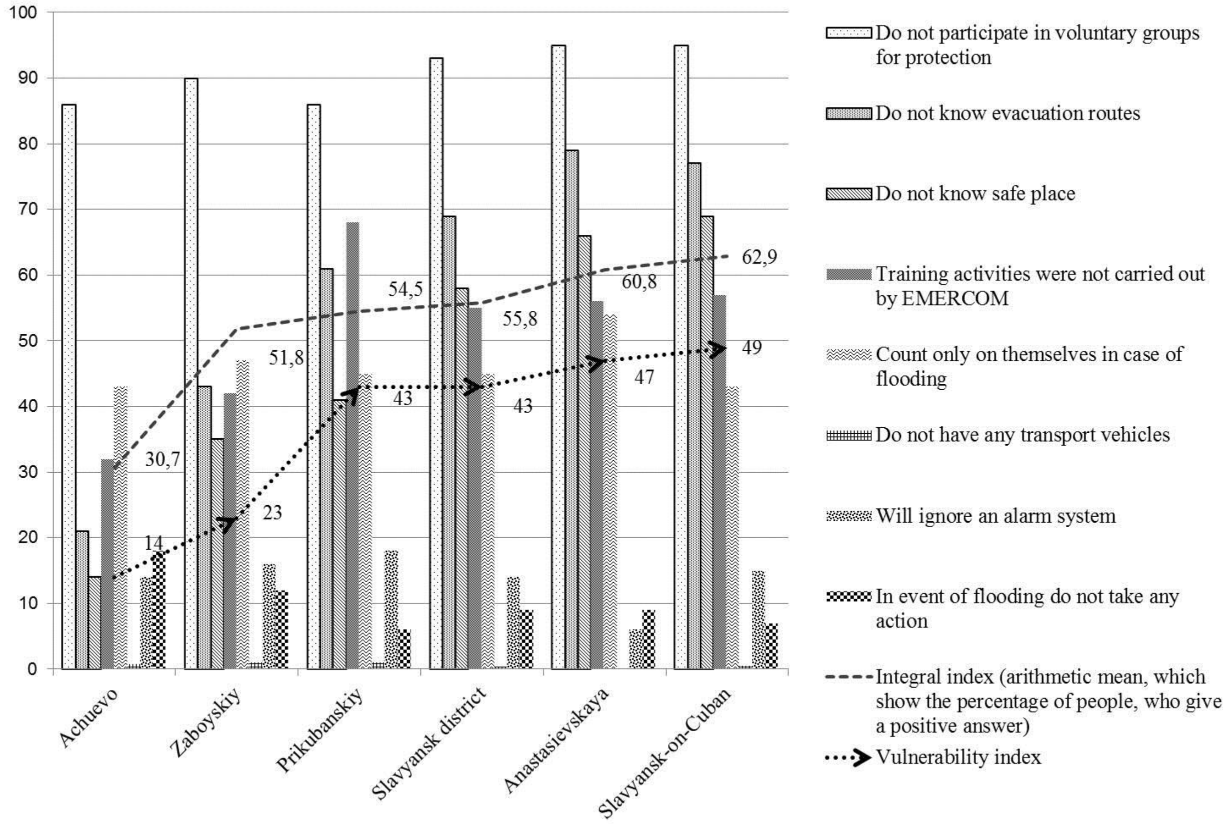

Fig. 4. Percentage of respondents by their answers in settlements, %

Table 1. *The most destructive hazardous hydrological phenomena in the Kuban river delta in the last 20 years*

Date	Flood reason	Damage
1998, March	Heavy rains and groundwater level rise	Around 5000 km^2, 132 settlements, more than 22 thousand houses were flooded, 113 economic objects were damaged. Huge flood activated landslide processes in Temryuk city. Around 107 private houses were damaged and 300 people were injured in Temryuk municipal district.
2001, December — 2002, January	Ice jams, heavy rains and reservoir releases	Huge area along the river and part of Temryuk city were flooded (around 0.74 km^2). 3283 people were injured
2002, July	Snow melting and heavy rains	One of the river dams was broken. 1.5 km^2 of rice fields and pump station were flooded
2011, February	Surge	Water level rose on 1.5 m

Source: Mikhailov et al 2010

Table 2. *Types of socio-economic risks and corresponding damage categories*

Types of risks *(r)*	**Categories of damages** *(j)*			
Environmental	Soil erosion and salinization	Water pollution and fish death	Contamination of drinking water	Forest degradation
Technological	Destruction of infrastructure (roads, bridges, pipelines,	Destruction of assets of industrial enterprises	Destruction of housing	

	power lines, sewer)		
Economic	Loss of profits	Reduction of budget revenues	Reduction of investment attractiveness
Social	Death / Loss of health	Destruction of social ties	Impoverishment
Political	Incompetence of the authorities	Social "explosion" (e.g. strikes)	Looting
Psychological	Loss of mental health		
Informational	Negative press coverage		Loss of territorial brand name

Table 3. *Vulnerability of different types of constructions*

Types of construction	**Medium flooding**	**Catastrophic flooding**
Wooden houses	0.56	1
Brick and stone houses with one floor	0.3	0.6
Brick and block houses with two and more floors	0.1	0.5
Asphalted automobile road	0.1	0.7
Unpaved automobile road	0.5	1

Source: EMERCOM 2007

Table 4. *Combination of answers for groups of people with different value of vulnerability*

	Most vulnerable	**Less vulnerable**	**Weakly vulnerable**
Can you provide the safety of your life?	No	In part. Do not know	Yes
What is your age?	0-16, > 66	56-65	> 16, < 56
How many years do you live in the area?	< 1, 1-5	5-20	> 20
Did you experience flooding?	No	Once	More than once

Table 5. *Distribution of the vulnerability groups for the Slavyansk municipal district*

Index of vulnerability (per cent of most and less vulnerable people)					
		Frequency, persons	Per cent	Valid per cent	Cumulative per cent
Valid	Most vulnerable	192	40.5	41.5	**41.5**
	Less vulnerable	74	15.6	16.0	**57.5**
	Weakly vulnerable	197	41.6	42.5	100
	Total	463	97.7	100	
Missing	System	11	2.3		
Total		474	474	100	

Table 6. *Economic damage for several categories in the Slavyansk municipal district*

	Medium flooding					
Categories of damage	**Agricul ture**	**Fixed assets**	**Infrastructure**	**Real estate**	**Invest ments**	**Total**
Potential damage (€ million)	1.1	20	12.2	29.1	0.8	63.2
Annual potential damage (according to probability of event = 0.01) (€ million)	0.011	0.2	0.122	0.29	0.01	0.63
	Catastrophic flooding					
Categories of damage	**Agricul**	**Fixed**	**Infrastructure**	**Real**	**Invest**	**Total**

	ture	assets		estate	ments	
Potential damage (€ million)	32.3	75.7	13.9	150.1	42.1	314.1
Annual potential damage (according to probability of event = 0.001) (€ million)	0.032	0.076	0.014	0.15	0.04	0.31

Table 7. *Calculation of potential victims and killed*

	Medium flooding				
Communities	**Exposed population**	**Vulnerability index**	**Vulnerable people**	**Victims**	**Deaths**
Achuevo	403	0.14	57	2	0
Zaboyskiy	2306	0.23	530	11	5
Prikubanskiy	297	0.43	128	3	0
Slavyansk-on-Kuban	0	0.49	0	0	0
Total	16 481	0.42	6922	**138**	**7**
	Catastrophic flooding				
Communities	**Exposed population**	**Vulnerability index**	**Vulnerable people**	**Victims**	**Deaths**
Achuevo	403	0.21	85	4	0
Zaboyskiy	2306	0.38	876	44	4
Prikubanskiy	297	0.51	151	8	0
Slavyansk-on-Kuban	38 305	0.6	22 983	1149	115
Total	60 575	0.58	35 134	**1757**	**176**

Table 8. *Social damage calculation according two approaches*

	Medium flooding				**Catastrophic flooding**			
Communities	Real loss for society (1000 €)		Government estimation (1000 €)		Real loss for society (1000 €)		Government estimation (1000 €)	
	Victims	Deaths	Victims	Deaths	Victims	Deaths	Victims	Deaths
Achuevo	10	0	2.4	0	20	0	4.8	0
Zaboyskiy	55	7500	13.2	250	220	6,000	52.8	200
Prikubanskiy	15	0	3.6	0	40	0	9.6	0
Slavyansk-on-Kuban	0	0	0	0	5745	172 500	1378.8	5750
Total district	***690***	***10 500***	***165.6***	***350***	***8785***	***264 000***	***2108.4***	***8800***

Table 9. *Social damage calculation (per year)*

Communities	**Medium flooding with p = 0.01**				**Catastrophic flooding with p = 0.001**			
	Real loss for society (1000 €)		Government estimation (1000 €)		Real loss for society (1000 €)		Government estimation (1000 €)	
	Total potential damage	Annual risk	Total potential damage	Annual risk	Total potential damage	Annual risk	Total potential damage	Annual risk
Achuevo	10	0.1	2.4	0.024	20	0.02	4.8	0.005
Zaboyskiy	7,555	7.555	263.2	2.632	6220	6.22	252.8	0.25

Prikubanskiy	15	0.15	3.6	0.036	40	0.04	9.6	0.01
Slavyansk-on-Kuban	0	0	0	0	178 245	178.25	7128.8	7.13
Total district	***11 190***	***111.9***	***515.6***	***5156***	***272 785***	***272.8***	***10 908.4***	***10.91***