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Localised multi-hazard risk assessment in Kyrgyz Republic

Ocena tveganja večkratnih nevarnosti v Kirgiški republiki

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Abstract

One of the key tasks in ensuring national security is the ability of the state and society to recognise and effectively assess the conditions for disasters, and to prevent them from threatening the sustainable development of the country. The Kyrgyz Republic is highly vulnerable to the influence of climate change, which in turn affects the frequency and intensity of disasters. The Kyrgyz Republic is exposed to almost all types of geological and man-made hazards, including earthquakes, landslides, debris flows, flash floods, outbursts of mountain lakes, dam failures, avalanches, droughts, extreme temperature, epidemics and releases of hazardous substances. Analysis of information on existing risks and their control systems used to reduce their negative impact makes it possible to assess the degree of probability, the expected consequences of threats, determine the degree of risk, the adaptive potential of communities and select appropriate protective measures. Therefore, this study is conducted to assess the hazard, vulnerability and exposure of Suzak district (Jalal-Abad oblast) in order to quantify the risk of the study area using multi-parameter holistic assessment with field collecting of primary data and utilizing Index-based Risk Assessment approach based on applying INFORM Risk model. Collected data was used to downscale subnational INFORM Risk model for municipal and district level using a multi-layered structure. A risk score is calculated by combining 72 indicators that measure three main dimensions: hazard & exposure, vulnerability, and lack of coping capacity. These findings provide an opportunity to develop a more effective disaster risk management at the local and national levels, by prioritizing relevant actions and investments for municipalities – districts which are demonstrated relatively highest risk scores. Also, the possibility of applying localized risk assessment procedures provides an opportunity to obtain more accurate sub-national (district/oblast based) and national levels with effective assessing dynamics of risk.

Izvleček

Ena izmed ključnih nalog pri zagotavljanju nacionalne varnosti je sposobnost države in družbe, da prepoznata in učinkovito ocenita pogoje za nesreče ter preprečita, da bi te ogrozile trajnostni razvoj države. Kirgizistan je zelo ranljiv za vplive podnebnih sprememb, ki vplivajo na pogostost in intenzivnost nesreč. Izpostavljen je skoraj vsem vrstam geoloških nevarnosti in tudi nevarnostim, ki jih povzroči človek, vključno s potresi, zemeljskimi plazovi, blatnimi tokovi, hudourniki, izbruhi gorskih jezer, porušenji jezov, snežnimi plazovi, sušami, ekstremnimi temperaturami, epidemijami in sproščanjem nevarnih snovi. Analiza informacij o obstoječih tveganjih in njihovih nadzornih sistemih, ki se uporabljajo za zmanjšanje njihovega negativnega vpliva, omogoča oceno stopnje verjetnosti, pričakovanih posledic, določitev stopnje tveganja, prilagoditvenega potenciala skupnosti in izbiro ustreznih zaščitnih ukrepov. V tem članku prikazujemo oceno nevarnosti, ranljivosti in izpostavljenosti okrožja Suzak (v regiji Džalal-Abad) z namenom kvantificiranja tveganja z uporabo večparametrske celostne ocene z zbiranjem primarnih podatkov na terenu in uporabo pristopa ocenjevanja tveganja na podlagi indeksa INFORM. Zbrani podatki so bili uporabljeni za prilagoditev regionalnega modela tveganja INFORM za občinsko in okrožno raven z uporabo večplastne strukture. Ocena tveganja je izračunana s kombinacijo 72 kazalnikov, ki merijo tri glavne dimenzije: nevarnost in izpostavljenost, ranljivost in pomanjkanje sposobnosti obvladovanja. Ti rezultati omogočajo razvoj učinkovitejšega upravljanja tveganj nesreč na lokalni in nacionalni ravni, s prednostnim določanjem ustreznih ukrepov in naložb za občine – okrožja, ki imajo relativno najvišje ocene tveganja. Možnost uporabe lokaliziranih postopkov ocenjevanja tveganja omogoča pridobitev natančnejših ocen tveganja na regionalni (okrožni/območni) in nacionalni ravni z učinkovitim ocenjevanjem dinamike tveganja.

Introduction

In recent years, many countries have experienced significant negative impacts from disasters related to the effects of climate change, particularly in the high mountain regions of Asia (Liu et al., 2021; Khanal et al., 2023; Havenith et al., 2017). The Kyrgyz Republic is affected by landslides, especially in the southern regions (Golovko et al., 2017). Catastrophic debris and mud flows affect communities in mountains and valleys, especially in the northern Tien-Shan (Erokhin et al., 2018; Zaginaev et al., 2019). The entire territory of the Kyrgyz Republic is located in a high seismic zone (Kalmetieva et al., 2009). The last major landslide (estimated volume was 10^6 m^3) event in Aysai village (29.04.2017), Uzgen district (Osh oblast) damaged 7 houses and killed 24 people. Recent flash floods in the south of the Kyrgyz Republic (Jalal-Abad oblast) in May 2022 and 2024 damaged facilities and eroded agricultural fields worth tens of thousands of USD. The occurrence of rockfalls and rockslides represents a significant risk to the stability of critical infrastructure, including road and railway networks. On all strategic roads within the Kyrgyz Republic, which connect the various regions, geological hazards present a considerable threat. The potential for rockslides in Boom Gorge on the Bishkek-Karakol road represents a particular concern, given its role as the only direct route connecting the Issyk Kul and Chui oblast, and the potential impact on food security.

To minimize potential losses from disasters, it is necessary to develop effective strategies for disaster risk reduction (DRR) and resilient systems based on risk assessment (Peduzzi et al., 2009). It is important to note that a large majority of worldwide disasters occur in developing countries, where the effect of disasters tends to cancel out real growth in the countries (Long, 1978).

The importance of implementing effective risk reduction practices is confirmed by modern global concepts of sustainable development and the Sendai Framework for Disaster Risk Reduction 2015-2030 in the climate change context (Kelman, 2015). By applying effective DRR practices, even countries with low levels of economic capacity can achieve tangible results in building resilience, ensuring the stability of effective growth even when disasters strike. At the same time, the resources, preserved from possible destruction are directed towards ensuring the most important sectors of development - healthcare, education, social protection, etc., thereby protecting the development gains from the risk of disaster.

To monitor the development of hazardous natural processes in the Kyrgyz Republic, specialized work is regularly carried out by various scientific institutions and agencies within the system of integrated disaster monitoring as part of the disaster risk management policy implemented by the Ministry of Emergency Situations of the Kyrgyz Republic (MES). However, a major challenge is the lack of sufficient information for comprehensive risk assessments at the local level, which hampers the implementation of preventive measures. In order to better understand and assess the risk, a comprehensive approach was taken to collect all locally available information for a pre-selected pilot site. The Suzak district of Jalal-Abad oblast was selected as the pilot site because it is the most exposed to natural hazards, both in terms of the number of disasters registered over the last 30 years and the frequency of occurrence. Considering the population growth rate in the Fergana Valley (Rahmonov, 2022) and the lack of arable land, there is a risk that urban agglomerations will expand into the development zones of hazardous exogenous geological processes.

Study site

The Kyrgyz Republic (KR) is a mountainous, land-locked, lower-middle-income country in Central Asia that has abundant natural resources and potential for the expansion of its hydroelectricity production, agriculture sector, and tourism industry (UN WFP, 2020). The territory is located between two major mountain systems, the Tien Shan and the Pamir. The total area of Kyrgyz Republic is about 199 900 km^2. The Kyrgyz Republic is bordered by Kazakhstan to the north, Uzbekistan to the west, Tajikistan to the southwest, and China to the east. Approximately 94 % of the country is above 1,000 m elevation, and 40 % is above 3,000 m. Over 80 % of the country is within the Tian Shan Mountain chain and 4 % is permanently under ice and snow. The Kyrgyz Republic had a population of 7.3 million in 2023. Most of population lives in the foothills of the mountains and is centered around two urban conurbations, the capital Bishkek and Chuy Valley in the north, and in the south of the country between Osh and Jalal-Abad cities and the eastern edge of the Ferghana Valley. A widespread use of small-scale family-based farms coupled with land degradation makes the agricultural sector rather inefficient (UN ESCAP, 2018). As a result, the country faces moderate to severe food insecurity touching nearly 24 % of the total population and a high dependence on imports of basic food items (UN WFP, 2020).

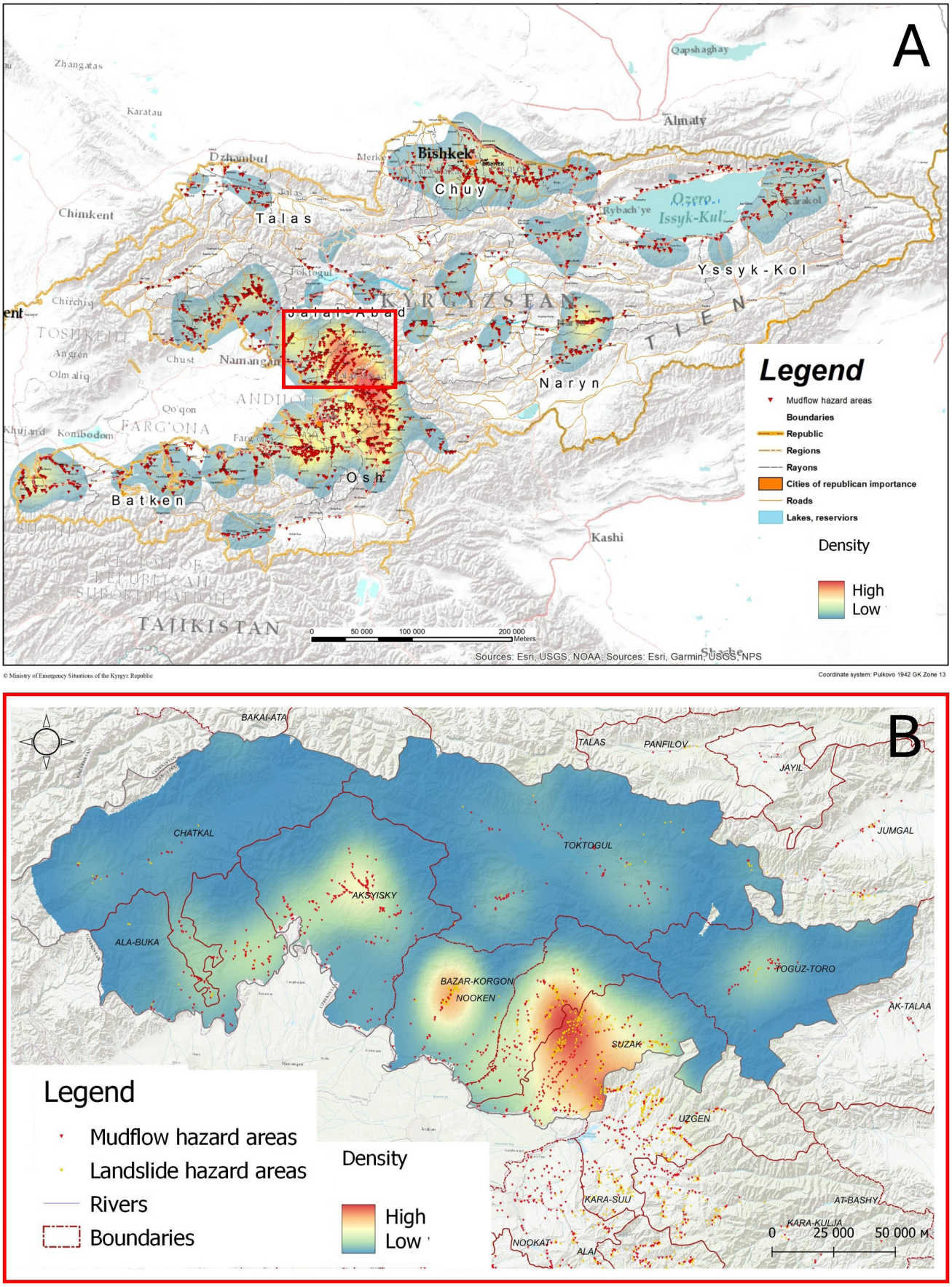

Fig. 1. Susceptibility map by debris and mud floods and landslides of A. Kyrgyzstan, B. Jalal-Abad oblast (data from MES KR).

The Kyrgyz Republic is highly susceptible to natural hazards such as debris and mud floods, landslides, avalanches and earthquakes. According to different estimates, the total absolute multi-hazard Average Annual Loss (AAS) for the Kyrgyz Republic is between USD 92.68 million (UN ESCAP, 2018) and USD 146 million (World Bank, 2011). Of this total multi-hazard AAS, earthquakes contribute 67.54 % and riverine floods 32.46 %. The multi-hazard AAL is heavily concentrated in the southern part of the country - in Osh and Jalal-Abad oblasts (provinces) that together account for almost 50 % of the total multi-hazard AAL (28.86 % and 20.49 % respectively), followed by the Chuy oblast (13.91 %) and Bishkek (10.27 %). Kyrgyz Republic's aggregate loss as a percentage of gross national income is the highest among all Central Asian countries (World Bank, 2011).

Figure 1 A shows a map of Kyrgyzstan with zones based on the occurrence of emergency situations (the most common hazard processes: mudflows and landslides) for the period from 1991 to 2023. The zones with the highest density of debris and mud flows and landslides are located in the southern part of the country: Jalal-Abad and Osh oblasts (Fig. 1 A).

Figure 1B shows the events analysed for the Jalal-Abad oblast. The most affected district in Jalal-Abad oblast is Suzak district, total area of Suzak district is about 3 019 km².

To analyze the existing hazard and risk assessment mechanisms at the local and national levels, a study was conducted to analyze the range of environmental conditions in one of the most hazard-prone regions of the Kyrgyz Republic - Suzak district (Jalal-Abad oblast) on Figure 2, located in the foothills surrounding the Fergana Valley on

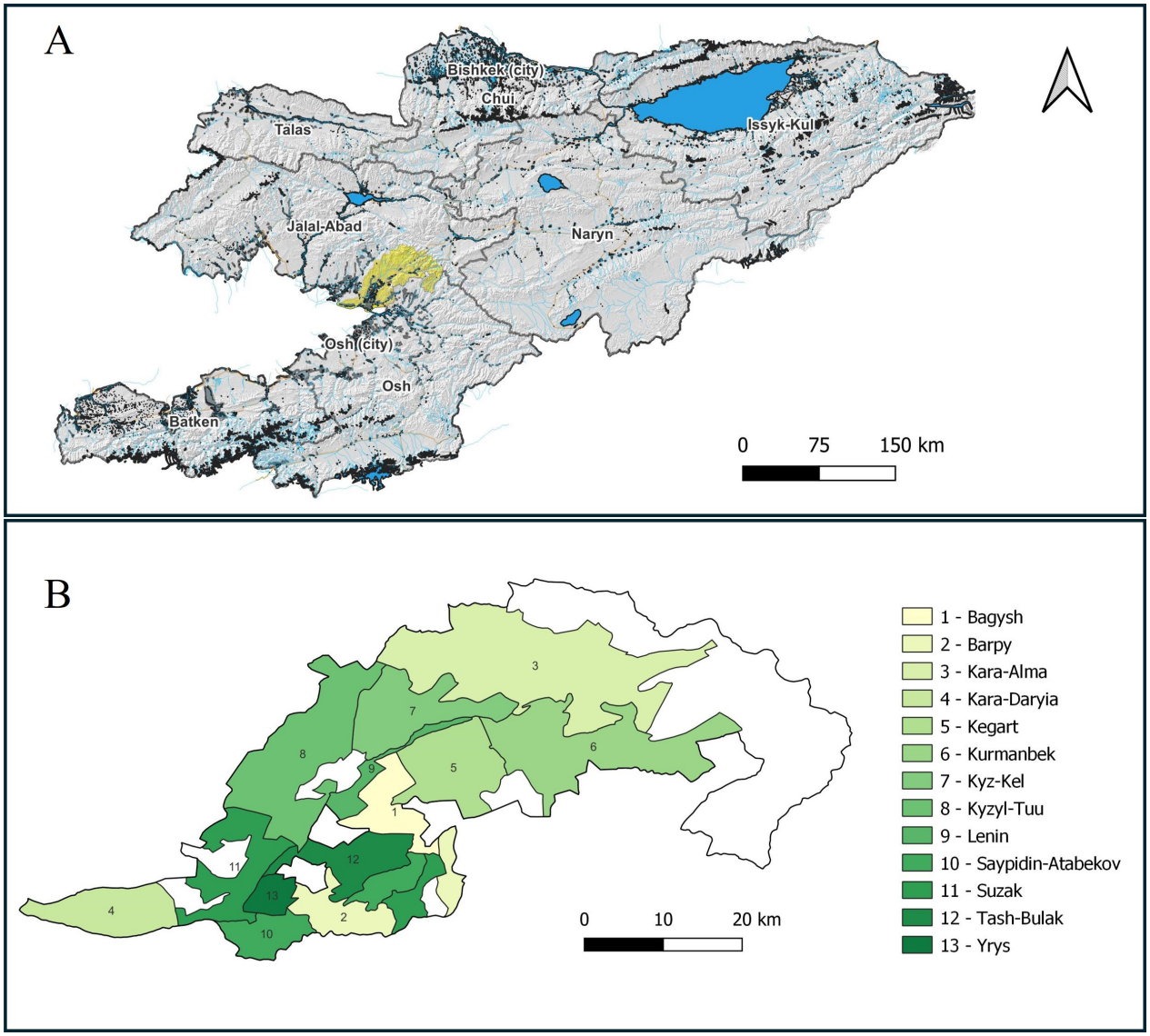

Fig. 2. A. Location of Suzak district; B. Municipalities of Suzak district.

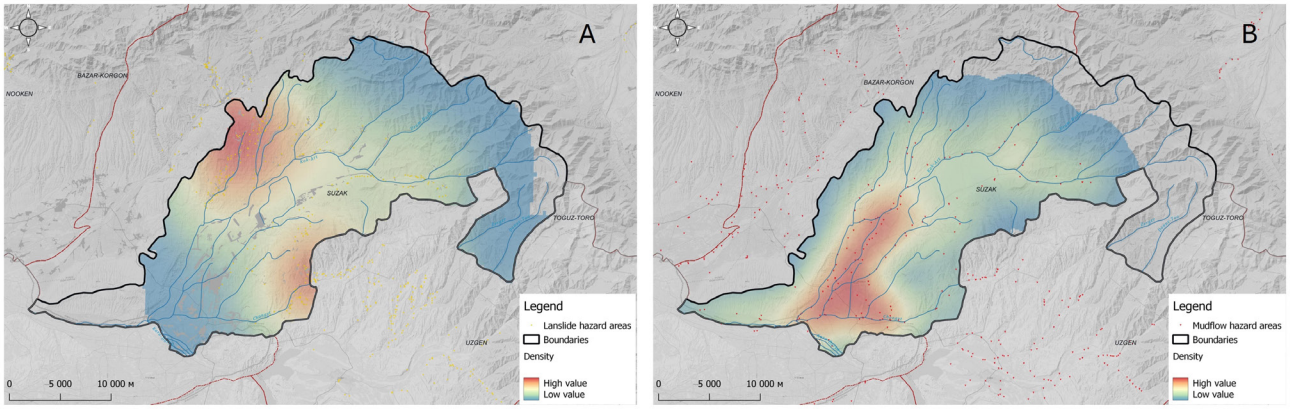

Fig. 3. A. landslide hazard B. Debris and mudflow hazard (Suzak district, Jalal-Abad oblast).

the northeast. In the spectrum of hazards, the territory of the district is most exposed to mudflows and landslides, these are the most developed types of hazards and disasters for the Kyrgyz Republic (in terms of the cases, damage, and losses).

In Figure 3, can be observed that all the settlements (grey blocks) are located in the most hazardous landslide and debris and mudflow areas.

The study area is also characterized by the highest underlying vulnerability indicators - large population, high density, and poverty levels - that increase the level of risk.

Material and methods

This work was carried out in three stages, with the initial field collection and preliminary quantitative analyses of several indicators characterizing hazard, exposure and vulnerability (based on the current methodological experience of the MES), and the subsequent selection of the most relevant indicators that can integrally represent each risk factor (based on the INFORM Risk model (Marin-Ferrer, 2017) developed by the European Union Joint Research Centre (EU JRC)). The INFORM Risk model was chosen for adaptation in this study - as one of the most informative and visually effective methods of presenting data, based on the classical principles of risk assessment and having a well-developed principle of demonstrating and visualizing the risk assessment mechanism. However, the study collected baseline data and compiled a database of 73 different risk components on municipal level within one district. Data were collected in various ways (ground observations, measurements and mapping using UAVs, instrumental measurements, various modelling techniques, statistical data analysis). Based on these data, an initial quantitative assessment of hazard, exposure, and vulnerability have been conducted. As part of these actions, the existing level of understanding and practice of risk assessment and its main factors in the state system (Ministry of Emergency Situations (MES) and local self-government bodies), the technical capabilities of the state system to ensure rapid and centralized collection of the necessary data to produce centralized analysis of multi-risk data were also assessed.

Over the past decade, several quantitative and index-based approaches to risk assessment have been developed. All these approaches are based on the conceptual disaster risk equations developed by Blaikie (Blaikie, 2014), Alexander (Alexander, 2000), Dilley (Dilley, 2005), Van Westen (Van Westen. 2009), Umaraliev (Umaraliev, 2020) and the risk assessment principles of the European Commission (EU strategy, 2009) and the United Nations (UNISDR, 2015). The applied conceptual equation of disaster risk was considered as a function of hazard, vulnerability and exposure:

$$Risk = Hazard\ (H)\ x\ Vulnerability\ (V)\ x\ Exposure\ (Ex) \quad (1)$$

Alternatively, considering the contribution of resilience (UNISDR, 2015), this equation less common than (1):

$$Risk = \frac{Hazard\ (H)\ x\ Vulnerability\ (V)\ x\ Exposures\ (Ex)}{Resilience\ (Rs)} \quad (2)$$

The INFORM Risk model also has three dimensions: Hazard & Exposure, Vulnerability and Lack of Coping Capacity. Each dimension includes different categories, which are user-driven concepts related to the needs of humanitarian and resilience actors. The INFORM Risk Model is based on the risk concepts described above and includes three dimensions of risk: Hazards & Exposure, Vulnerability and Lack of Coping Capacity. They are conceptualized in a reciprocal relationship: the risk of what (natural and human hazards) and the risk to what (population).

The INFORM Risk model balances two major forces: the hazard & exposure dimension on one side, and the vulnerability and the lack of coping capacity dimensions on the other side. Hazard dependent factors are treated in the hazard & exposure dimension, while hazard independent factors are divided into two dimensions: the vulnerability dimension that considers the strength of the individuals and households relative to a crisis situation, and the lack of coping capacity dimension that considers factors of institutional strength. The INFORM Risk model adopts the three aspects of vulnerability reflected in the UNDRR definition. The aspects of physical exposure and physical vulnerability are integrated in the hazard & exposure dimension, the aspect of fragility of the socio-economic system becomes INFORM Risk's vulnerability dimension while lack of resilience to

Table 1. Overview of localised (municipality level) Risk for Suzak district components and indicators under the Hazard and Exposure dimension.

Category	Component	Indicators	Source
Natural	Earthquakes	Number of significant earthquakes in the last 10 years	MES, Field-works, UAV assessment
	Floods	Coastal erosion in the last 10 years, quantity	
		Coastal erosion in the last ten years, km	
		Debris and mud flows	
	Landslides	Landslide (area)	
		Landslide (number)	
		Activity of mudflow-prone rivers	WFP/MES Study on "Conducting a set of research works on vulnerability and hazard assessment in order to integrate effective principles of disaster risk assessment into the national disaster monitoring system of Suzak district of Jalal-Abad oblast"
		Presence of forest plantations on landslide-prone slopes	
		Presence of floodplain forests	
		Rockfalls and rockslides, in the last 10 years, number	MES statistic, Field-works, UAV assessment
		Avalanches, in the last 10 years, number	
	Climate change	Climatic water deficit	FAO Eath Map
		Aridity Index	
	Wildfires	Incidence of wildfires (including forest fires)	MES statistic
		Total number of people dead due to forest fires	
	Population	Presence of dangerous infections (plague, cholera, anthrax, malaria)	WFP/MES Study on "Conducting a set of research works on vulnerability and hazard assessment in order to integrate effective principles of disaster risk assessment into the national disaster monitoring system of Suzak district of Jalal-Abad oblast"
		Population density (people per sq. km of land area)	National Statistical Committee of Kyrgyzstan
		Average household size	
		Children under 5 (% of total population)	
		Availability of educational institutions in the municipality in case of emergency	WFP/MES Study on "Conducting a set of research works on vulnerability and hazard assessment in order to integrate effective principles of disaster risk assessment into the national disaster monitoring system of Suzak district of Jalal-Abad oblast"
Human	Transport accidents	Transport accidents in the last 10 years	MES statistic
		People dead due to transport accidents in the last 10 years	
	Technological hazards	Number of dumpsites	Zoï Environmental Network
		Approximate air distance from pesticides dumpsite	
		Potential Hazardous Lakes	MES statistic
		Presence of industries that may pose risks of climate change	WFP/MES Study on "Conducting a set of research works on vulnerability and hazard assessment in order to integrate effective principles of disaster risk assessment into the national disaster monitoring system of Suzak district of Jalal-Abad oblast"

cope and recover is treated under the lack of coping capacity dimension. The split of vulnerability in three components is particularly useful for tracking the results of disaster reduction strategies over time. Disaster risk reduction activities are often localized and address particular community-level vulnerabilities and capacities.

To accommodate the INFORM Risk methodology, where the vulnerability variable is split among three dimensions, the equation is updated to:

$$Risk = Hazard\&Exposure^{1/3} \times Vulnerability^{1/3} \times Lack\ of\ coping\ capacity^{1/3} \quad (3)$$

This is a multiplicative equation where the risk equals zero if any of the three dimensions is zero. Theoretically, in case of debris and mudflows there is no risk if there is no likelihood of a debris flows to occur or/and the hazard zone is not populated or/and if the population is not vulnerable (e.g., all people have high level of education and live in high level of health and livelihood condition as well as they can afford protective houses/livelihoods) or/and if the resilience of the country to cope and recover is ideal.

Hazard & Exposure

The hazard & exposure dimension reflects the probability of physical exposure associated with specific hazards. There is no risk if there is no physical exposure, no matter how severe the hazard event is. Therefore, the hazard and exposure dimensions are merged into hazard & exposure dimension. As such it represents the load that the community has to deal with when exposed to a hazard event. The disaster risk analysis based on a large number of studies, data and sources, including such key indicators as exposure - the location of people, infrastructure, housing, production facilities and other tangible human assets in areas prone to threats, vulnerability - conditions that increase the susceptibility of a person, community, property or systems to the impact of threats, long-term statistics of emergencies that resulted in loss of life, harm to human health or the environment, significant economic damage and disruption of human life conditions, indicate that the prevailing risk disasters for the population. The dimension comprises two categories: natural hazards and human-induced hazards, aggregated with the geometric mean, where both indexes carry equal weight within the dimension. The Natural Hazard category encompasses physical exposures to primary disasters like earthquakes, floods, landslides, climate change, and wildfires. Conversely, the Human Hazard category quantifies risks using normalized values from transport and industrial accidents. The table below provides an overview of the components and indicators used to populate the localised Risk Index for Suzak district, specifically for the hazard and exposure dimension, as well as the calculation of INFORM categories and dimensions (Table 1).

Vulnerability

Humanitarian organizations primarily focus on people, who constitute the ‘at-risk’ element in the Risk composite index. The impact of disasters on people in terms of number of people killed, injured, and made homeless is predominantly felt in developing countries while the economic costs of disasters are concentrated in the industrialized world. The Vulnerability dimension addresses the intrinsic predispositions of an exposed population to be affected, or to be susceptible to the damaging effects of a hazard, even though the assessment is made through hazard independent indicators. So, the vulnerability dimension represents economic, political and social characteristics of the community that can be destabilized in case of a hazard event. Physical vulnerability, which is a hazard dependent characteristic, is dealt with separately in the hazard & exposure dimension. There are two categories aggregated through the geometric average, socio-economic vulnerability and vulnerable groups. Socio-economic component incorporates components of Development & Deprivation, Gender Inequality, Agriculture and Economy to calculate the normalized index. The indicators used in each category are different in time variability and the social groups considered in each category are the target of different humanitarian organizations. The second category of the applied Vulnerability assessment includes Children under five, Disaster preparedness, Uprooted people, Other vulnerable groups, and Food Security. If the first category refers more to the demography of a country in general, the vulnerable group category captures social groups with limited access to social and health care systems. The following table present an overview of components and indicators used for filling the Risk Index for Suzak district indexes (vulnerability dimension adopted from INFORM Risk model), and calculation of risk categories and dimensions (Table 2).

Table 2. Overview of localized (municipality level) Risk components and indicators under the Vulnerability dimension piloted in target district.

Category	Component	Indicators	Source
Socio-Economic Vulnerability	Development & Deprivation	Share of population that has income below the poverty line	Ministry of Labour, Social Security and Migration of the Kyrgyz Republic (MLSSM)
	Gender equality	Share of women (as % of total population)	National Statistical Committee of Kyrgyzstan (NSC)
		Women educational attainment	
	Agriculture	Energy and energy efficiency Index	WFP/MES Study on "Conducting a set of research works on vulnerability and hazard assessment in order to integrate effective principles of disaster risk assessment into the national disaster monitoring system of Suzak district of Jalal-Abad oblast"
		Number of households dependent on the condition of pastures as a percentage	
		Number of households dependent on soil conditions (farming)	
		Adequacy of sown areas	
		Water sufficiency for irrigation	
	Economy	Availability of tourist places and destinations to accommodate tourists in the municipality	WFP/MES Study on "Conducting a set of research works on vulnerability and hazard assessment in order to integrate effective principles of disaster risk assessment into the national disaster monitoring system of Suzak district of Jalal-Abad oblast"
		Rainfall in summer destroys pasture infrastructure	
		Heavy snowfalls block passes and roads, limiting life support and access to medical care	
		Unemployment rate (people unemployed in total population)	Ministry of Labour, Social Security and Migration of the Kyrgyz Republic (MLSSM)
		Dependency of population from remittances	WFP/MES Study on "Conducting a set of research works on vulnerability and hazard assessment in order to integrate effective principles of disaster risk assessment into the national disaster monitoring system of Suzak district of Jalal-Abad oblast"
Vulnerable Groups	Children U5	Child Mortality	National Statistical Committee of Kyrgyzstan (NSC)
	Disaster preparedness	Victims or deaths in the municipality as a result of disasters	WFP/MES Study on "Conducting a set of research works on vulnerability and hazard assessment in order to integrate effective principles of disaster risk assessment into the national disaster monitoring system of Suzak district of Jalal-Abad oblast"
		Number of large-scale emergency situations in the last 10 years	MES
	Uprooted people	Number of migrants (internal and external)	National Statistical Committee of Kyrgyzstan (NSC)
	Other vulnerable groups	Number of families with disabled people	Ministry of Labour, Social Security and Migration of the Kyrgyz Republic (MLSSM)
	Food Security	Food availability score	WFP
		Food access score	
		Food utilization score	
		Food stability score	

Lack of Coping Capacity

For the coping capacity dimension, the question is which issues the government has addressed to increase the resilience of the society and how successful their implementation is. The coping capacity dimension measures the ability of a country to cope with disasters in terms of formal, organized activities and the effort of the country's government as well as the existing infrastructure which contribute to the reduction of disaster risk. It is aggregated by a geometric mean of two categories: institutional and infrastructural. The difference between the categories is in the stages of the disaster management cycle that they are focusing on. The 'Institutional' category focuses on DRR programs targeting mitigation and the preparedness/early warning phases, while the 'Infrastructural' category assesses capacities for emergency response and recovery. Institutional category incorporates components of Governance, Disaster risk reduction and humanitarian, while Infrastructure category is consistent of: Communication, Physical

Table 3. Overview of localised (municipality level) Risk components and indicators under the Lack of Coping Capacity dimension piloted in target district.

Category	Component	Indicators	Source
Institutional	Governance	Self-organization and potential of the local community	WFP/MES Study on "Conducting a set of research works on vulnerability and hazard assessment in order to integrate effective principles of disaster risk assessment into the national disaster monitoring system of Suzak district of Jalal-Abad oblast"
		Share of population covered by emergency training	
		Availability of qualified emergency personnel and training centers	
	DRR	Availability of recommendations from the MES and whether work is being done to improve safety	
		Emergency response exercises	
	Humanitarian	Availability of local volunteer teams	
Infrastructure	Communication	Individuals using the Internet (% of population)	
		Mobile cellular subscriptions (per 100 people)	
	Physical Connectivity	Road density coefficient	
		Roads' density (field and muddy roads)	
		Roads density (automobile roads)	
	Water and Sanitation	Frequency of power outages	
		Availability of a central water supply system	
		Quality of drinking water	
		Sufficiency of water supply sources	
		Interruptions in drinking water	
	Access to health care	Availability of healthcare services (availability of primary care facilities)	
		Staffing with medical workers	
		Mortality of the population	
	Ecology	Greening of the locality	
		Presence of forest shelterbelts along roads and highways	
		Air quality in the municipality (winter)	
		Air quality in the municipality (summer)	
		Street lighting	

Connectivity, Water and Sanitation, Access to health care and Ecology. The table below presents an overview of the components and indicators used to populate the localised Risk Index for Suzak district, specifically focusing on the lack of coping capacity dimension, along with the calculation of risk categories and dimensions adopted from INFORM Risk model (Table 3).

Results

Hazard and Exposure of the municipalities of Suzak district

The territory of Suzak district is primarily associated with earthquakes, floods, mudflows, droughts, landslides, industrial and transport accidents, large fires, epidemics, mass infectious diseases of people. The greatest number of victims, as well as significant material losses, are caused by droughts, floods and earthquakes, as well as massive infectious diseases of people (for example, the COVID-19 pandemic, limiting the coping capacities of the healthcare systems throughout the district), however the epidemics effect is measured indirectly by measuring mortality and health capacity across municipalities (included in Population component). The results of assessment represented in Table 4.

Based on the assessment results - Kyz-Kel face the highest risk due to very high risk in the natural and human category of the hazard and exposure dimension. When broken down by components, Kyz-Kel exhibits very high risk across the board, except in the areas of transport accidents, wildfires, and population-related factors. Barpy experiences high risk primarily from the natural hazard category, notably from high earthquake exposure. Conversely, Kegart's high risk stems from the human hazard category, due to numerous dumpsites, proximity to the country's largest pesticide dumpsite, and nearby potentially hazardous lakes. Kara-Daryia and Kurmanbek face medium

Table 4. Localized (municipality level) indexes of Hazard and Exposure.

	Earthquakes	Floods	Landslides	Climate change	Wildfires	Population	**Natural**	Transport accidents	Technological hazards	**Human**	**HAZARD & EXPOSURE**
Municipalities	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**
Bagysh	1.7	6.1	3.1	8.7	4.5	3.8	**4.7**	3.9	3.1	**3.5**	**4.1**
Barpy	10.0	6.7	2.7	7.2	4.5	5.0	**6.3**	3.9	2.8	**3.4**	**5.0**
Kara-Alma	0.0	0.0	1.1	1.7	4.5	5.0	**1.4**	3.9	7.4	**5.9**	**4.0**
Kara-Daryia	0.0	3.4	3.0	5.0	4.5	6.3	**2.9**	3.9	7.2	**5.8**	**4.5**
Kegart	0.8	0.8	3.5	8.6	4.5	3.8	**3.8**	3.9	8.1	**6.5**	**5.3**
Kurmanbek	0.0	2.8	4.0	7.6	4.5	5.0	**3.7**	3.9	6.2	**5.2**	**4.5**
Kyz-Kel	10.0	5.8	6.3	6.5	4.5	3.8	**6.5**	3.9	6.2	**5.2**	**5.9**
Kyzyl-Tuu	0.8	1.2	3.8	5.9	4.5	3.8	**3.0**	3.9	6.2	**5.2**	**4.2**
Lenin	0.0	0.5	2.7	5.8	4.5	3.8	**2.6**	3.9	2.7	**3.3**	**3.0**
Saipidin-Atabek	0.0	2.2	3.9	0.0	4.5	6.3	**2.0**	3.9	3.2	**3.6**	**2.8**
Suzak	0.0	0.0	2.5	5.7	4.5	7.5	**2.4**	3.9	2.4	**3.2**	**2.8**
Tash-Bulak	1.7	2.2	3.2	6.1	4.5	3.8	**3.2**	3.9	4.5	**4.2**	**3.7**
Yrys	0.0	3.3	1.9	3.6	4.5	6.3	**2.4**	3.9	2.3	**3.1**	**2.8**

levels of hazard and exposure risk. Kara-Daryia's risk is elevated due to technological accidents, while Kurmanbek experiences the highest climate change risk among the municipalities, driven by high exposure to climatic water deficits. Other municipalities experience varying levels of risk, ranging from low to very low, in both human and natural hazard categories.

Table 5. Localized (municipality level) indexes of Vulnerability.

	Development & Deprivation	Gender equality	Agriculture	Economy	**Socio-Economic Vulnerability**	Children U5	Disaster preparedness	Uprooted people	Other vulnerable groups	Food Security	**Vulnerable Groups**	**VULNERABILITY**
Municipalities	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**
Bagysh	0.0	6.7	4.2	6.0	**4.2**	5.6	1.5	7.8	5.7	3.8	**5.2**	**4.7**
Barpy	0.0	7.2	7.4	7.2	**5.5**	5.6	5.0	3.1	3.3	5.0	**4.5**	**5.0**
Kara-Alma	10.0	6.7	4.8	5.3	**6.7**	5.6	5.0	5.2	10.0	5.0	**6.9**	**6.8**
Kara-Daryia	9.8	2.2	4.8	7.1	**6.0**	5.6	5.0	8.6	2.0	6.3	**5.9**	**6.0**
Kegart	2.1	7.2	5.3	4.8	**4.9**	5.6	3.8	8.0	5.3	3.8	**5.5**	**5.2**
Kurmanbek	4.6	6.7	5.2	4.5	**5.3**	5.6	5.0	8.1	5.0	5.0	**5.9**	**5.6**
Kyz-Kel	7.5	5.0	6.6	5.4	**6.1**	5.6	8.3	0.0	0.0	3.8	**4.4**	**5.3**
Kyzyl-Tuu	1.5	6.7	5.3	3.7	**4.3**	5.6	10.0	1.4	0.0	3.8	**5.7**	**5.0**
Lenin	1.4	6.7	6.4	4.8	**4.8**	5.6	1.3	0.0	8.8	3.8	**4.8**	**4.8**
Saipidin-Atabek	5.4	2.2	3.0	2.8	**3.4**	5.6	0.0	10.0	5.7	6.3	**6.6**	**5.2**
Suzak	10.0	5.0	2.0	7.2	**6.1**	5.6	3.8	6.0	8.3	7.5	**6.5**	**6.3**
Tash-Bulak	1.5	5.5	5.7	3.4	**4.0**	5.6	5.0	10.0	10.0	3.8	**8.0**	**6.4**
Yrys	3.2	7.2	2.7	8.0	**5.3**	5.6	3.8	8.4	6.1	6.3	**6.3**	**5.8**

Table 6. Localized (municipality level) indexes of Coping capacity.

	Governance	DRR	Humanitarian	Institutional	Communication	Physical Connectivity	Water and Sanitation	Access to health care	Ecology	**Infrastructure**	**LACK OF COPING CAPACITY**
Municipalities	(0-10)	(0-10)	(0-10)	(0-10)	(0-10)	(0-10)	(0-10)	(0-10)	(0-10)	(0-10)	(0-10)
Bagysh	4.0	7.8	0.0	**3.9**	0.0	10.0	2.0	4.4	2.7	**5.6**	**4.8**
Barpy	7.0	0.3	0.0	**2.4**	0.0	7.2	4.3	2.9	2.3	**3.4**	**2.9**
Kara-Alma	3.3	0.0	8.3	**3.9**	0.0	10.0	2.8	8.3	3.9	**6.7**	**5.5**
Kara-Daryia	3.3	0.0	0.0	**1.1**	0.0	6.2	4.8	1.5	0.0	**1.6**	**1.4**
Kegart	0.0	0.0	10.0	**3.3**	0.0	6.7	0.0	5.0	0.8	**4.4**	**3.9**
Kurmanbek	0.0	0.0	10.0	**3.3**	0.0	1.1	4.8	1.5	6.0	**1.7**	**2.5**
Kyz-Kel	3.3	0.0	0.0	**1.1**	0.0	2.3	8.0	3.2	5.1	**2.0**	**1.6**
Kyzyl-Tuu	4.6	8.8	3.3	**5.6**	0.0	3.3	0.0	6.7	4.3	**5.5**	**5.6**
Lenin	1.1	0.5	0.0	**0.5**	0.0	3.3	1.2	0.0	1.6	**0.9**	**0.7**
Saipidin-Atabek	5.2	0.5	5.3	**3.7**	0.0	2.6	0.0	8.9	0.8	**5.6**	**4.7**
Suzak	1.9	7.3	0.0	**3.1**	0.0	7.6	2.0	6.1	2.4	**5.7**	**4.5**
Tash-Bulak	8.7	5.5	10.0	**8.1**	0.0	2.4	5.3	6.5	5.4	**3.9**	**6.5**
Yrys	9.5	0.0	0.0	**3.2**	0.0	6.0	2.0	5.6	3.3	**4.1**	**3.7**

Vulnerability of the municipalities of Suzak district

Based on assessment results - Kara-Alma face the highest vulnerability risk due to both, socio-economic and vulnerable groups categories high risk. High proportion of people below poverty line in the socio-economic category and high proportion of families living with disability were among the main contributors to elevated risk. At the same time, Kara-Daryia, Kurmanbek, Suzak and Tash-Bulak municipalities face high risk due to individual factors. While all vulnerability components contributed to the high risk in Kurmanbek, the high risk in Kara-Daryia is a result of elevated risk in the poverty and uprooted people components. High risk in Tash-Bulak and Suzak municipalities, from other side is a result of increased risk of uprooted people and disability, coupled with economic risk (low number of tourist places and rainfall damages) in Suzak municipality. The rest of the municipalities face medium to low risk, although notably higher than in the rest of the dimensions (hazard and exposure and coping capacity). A higher proportion of people facing poverty, unemployment, or disability, in addition to higher risk of child mortality has contributed to the higher risk in the vulnerability dimension (Table 5).

Coping capacity of the municipalities of Suzak district

Based on assessment results, the risk in the coping capacity dimension is the lowest in comparison to the other dimensions, due to low risk in the communications, water and sanitation and DRR components. However, Tash-Bulak faces very high coping capacity risk due to increased institutional risk (lack of emergency response exercises, training and low self-organizational capacity), while the risk in the infrastructure category mitigated the further increase of overall coping capacity risk. Kara-Alma and Kyzyl-Tuu face somewhat high risk among the municipalities due to poor access to health care (staffing of medical facilities and availability of healthcare facilities), coupled with poor road connectivity in Kara-Alma and lack of sufficient emergency response exercises in Kyzyl-Tuu (Table 6).

Risk of the municipalities of Suzak district

Risk Index for municipalities of Suzak district provide a risk overview by ranking the municipalities in the district from very low to very high risk, based on cluster analysis.

Based on the analysis, most of the municipalities face medium risk (5 municipalities: Barpy, Kurmanbek, Saipidin-Atabek, Yrys and Suzak),

2 of the municipalities face low (Kyz-Kel and Kara-Daryia) while one municipality (Lenin) very low risk. Very low to medium overall risk is a result of very low risk in the coping capacity dimension, even though Kyz-Kel and Barpy face high hazard risk. Vulnerability risk is elevated in almost all municipalities, contributing to increase of overall risk across all municipalities. Three of the municipalities face high risk: Kegart (due to high risk in the hazard and exposure and vulnerabilities dimensions), Kyzyl-Tuu (due to high coping capacity and vulnerability risk), while in Bagysh the high risk is a result of elevated risk in all of the dimensions of INFORM. At the same time, Kara-Alma and Tash-Bulak face the highest risk due to very high risk in the lack of coping capacity and vulnerability dimensions (Table 7).

Based on the results of the calculated indexes, thematic maps were prepared at the district level (Figure 4) for the risk and three main calculated indicators (hazard and exposure, vulnerability and lack of coping capacity) based on the collected field material and available generalised data.

Table 7. Localized (municipality level) indexes of Risk.

	HAZARD & EXPOSURE	VULNERABILITY	LACK OF COPING CAPACITY	RISK	RISK CLASS
Municipalities	**(0-10)**	**(0-10)**	**(0-10)**	**(0-10)**	**(V.Low-V. High)**
Bagysh	4.1	4.7	4.8	4.5	High
Barpy	5.0	5.0	2.9	4.2	Medium
Kara-Alma	4.0	6.8	5.5	5.3	Very High
Kara-Daryia	4.5	6.0	1.4	3.4	Low
Kegart	5.3	5.2	3.9	4.8	High
Kurmanbek	4.5	5.6	2.5	4.0	Medium
Kyz-Kel	5.9	5.3	1.6	3.7	Low
Kyzyl-Tuu	4.2	5.0	5.6	4.9	High
Lenin	3.0	4.8	0.7	2.2	Very Low
Saipidin-Atabek	2.8	5.2	4.7	4.1	Medium
Suzak	2.8	6.3	4.5	4.3	Medium
Tash-Bulak	3.7	6.4	6.5	5.4	Very High
Yrys	2.8	5.8	3.7	3.9	Medium

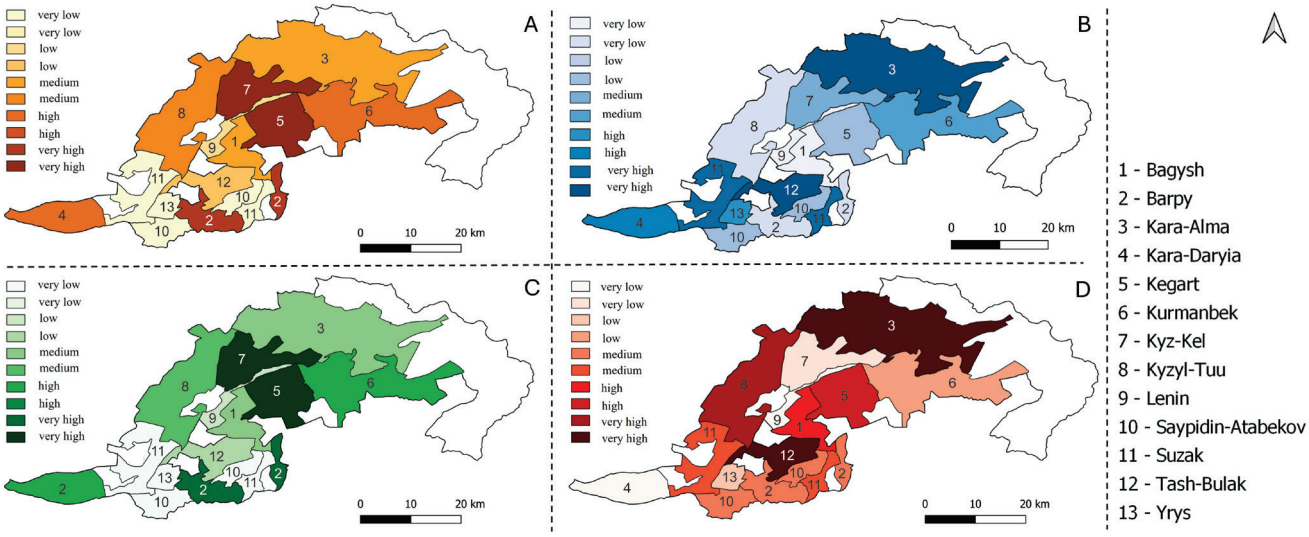

Fig. 4. A. Hazard and exposure B. Vulnerability, C. Lack of coping capacity D. Integrated risk assessment.

Discussion

A deeper understanding of the risk mechanism allows us to establish and develop effective models for its management, which will generally ensure risk reduction, community resilience, and more effective rates of development. Despite the importance of modern knowledge about disaster risk, and the definition of disaster risk, unfortunately current concepts for considering and studying disasters in the Kyrgyz Republic are still predominantly based on the old paradigm of risk where the "risk" is considered equal to "hazard". Furthermore, descriptive and qualitative assessment methods dominate over mathematical and quantitative models, making them less evidence-based and less compelling for the interdisciplinary community of disaster management specialists. Another important disadvantage of the existing approaches to risk and hazard assessment applied in national practices in the Kyrgyz Republic is the absence or separate consideration of vulnerability processes (in which the components of hazard are centrally analyzed by the MES, and the components of vulnerability by the MLSSM). This situation complicates the process of adequate perception and understanding of risk - as potential disaster losses, in lives, health status, livelihoods, assets, and services, which could occur to a particular community or a society over some specified future time and complicates identify effective disaster risk reduction mechanisms.

The risk indexes calculated for the smallest administrative units can significantly enhance governance. They support land use planning, disaster insurance, anticipatory actions, disaster preparedness, and DRM-DRR and civil protection policies. In addition, data from localized risk assessment (municipality based) will provide valid and accurate assessment results at the subnational (district, oblast) and national levels. Using our target area as an example, the risk level of Suzak district can be taken as the average risk of all municipalities, which will be 4.2. However, the risk value of an oblast will make sense if the assessment fully covers all municipalities and districts of one administrative oblast. The same procedure can be applied to oblasts, when many risk values of oblasts will form a reasonable risk index of the entire country for comparisons of its risk level with other countries in the region and the world - in system of unified principles.

This set of works is planned to be implemented during next stage of research. It is envisaged that the authors of this paper will present the assessment results to the Kyrgyz government as a model for potential integration into the national 'Concept for the Development of a Unified Integrated Disaster Monitoring and Forecasting System in the Kyrgyz Republic until 2030'. The model will be developed considering possible replication and scaling at the national level.

The introduction of this mechanism into the national DRM system should also be accompanied by the development of initiatives aimed on improvement of digital data exchange mechanisms. It is also important to note that the identified risk parameters are not constant, they could be changed in the future due to various reasons, including environmental, social, or technical factors (disasters, climate change, industrial activities, the change in DRR education, reconstruction, wear and tear of the facilities, mitigation measures etc.). Therefore, to assess the real status of risk, it would be important to implement risk assessment periodicity. The quantitative multi-risk assessment approach also clearly illustrates the interaction between physical, environmental, and social factors of disaster risk and how they contribute to the risk values (Umaraliev, 2020). Thus, outcomes of research also contributed to raising awareness that the disasters could, in fact, be reduced, if not even prevented (Birkmann & Pelling, 2006) and created a suitable basis for formulating effective strategies for mitigation of their impact on people, communities, and economies.

The quantitative multi-risk assessment procedures can also be effectively integrated into disaster risk financing systems and particularly into disaster insurance programs. Thus, disaster insurance programs occupy an increasingly important place in the structure of DRR because they are strengthening financial resilience (ensure that national financial system and population are financially protected in the disaster events) and because they reduce dependence on post-disaster external aid (or improve the effectiveness of governance). Unfortunately, the disaster insurance sector is one of the least developed DRR mechanisms in Central Asia (CA). In modern times (after the Collapse of the Soviet Union in 1991), in the Kyrgyz Republic the national disaster insurance program was only initiated in 2015 (Law of KR, 2016). Development of an index-based insurance policy is very important in developing countries with limited resources, weak governance, systemic corruption, and high poverty, where big differences in incomes between different socio-economic groups and geographical areas exist and the Kyrgyz Republic is one of those regions, where these environmental and socio-economic issues are particularly acute (UNISDR, 2010).

Conclusion

The study results highlighted practitioners' understanding of 'risk' and 'disaster' concepts, specifically their ability to differentiate the critical risk dimensions: hazard, exposure, and vulnerability.

The localized Risk model for Suzak district uses subnational level indicators of INFORM Risk model applied for 13 municipalities. The national and UN data sources used to construct the model meet four basic criteria: (1) the data is free, publicly available and transparent, (2) the data provides sufficient municipality coverage, (3) the data is reliable (4) and the data allows comparison between municipalities.

The study revealed that the MES's standard monitoring procedures lack a methodological basis for comprehensive risk identification. They focus solely on hazard and exposure without considering their interrelationships or including vulnerability analysis. In this context, current research practice mainly provides a statement of the situation but cannot provide information on the use of which will reduce risk and build resilience.

The localised Risk index for Suzak district represents a final stage of piloting the institutionalization of local risk assessment procedures in Kyrgyz Republic. The Index gathered data from 13 municipalities of Suzak district, Jalal-Abad oblast. A total of 72 indicators have been collected and indexed by following the INFORM Risk model (26 indicators – hazard and exposure, 22 – vulnerability, 24 – lack of coping capacity). The process of development in collaboration between central and local governments, international and research institutions. The risk score combines 72 indicators across three dimensions–hazard and exposure, vulnerability, and lack of coping capacity–to calculate each municipality's risk level. Every municipality has a rating between 0 and 10 for risk and all of its dimensions, categories, and components. The low values of the index represent a better condition (e.g. lower risk / strong or good resilience), and the high values of the index represent a worse condition (e.g. higher risk / weak or bad resilience). The indexes allow a relative comparison of the risk and components between municipalities and of different components within a municipality. Of the 13 municipalities, 2 demonstrated very high risk indexes (Kara-Alma, Tash-Bulak) and 3 are high risk indexes (Bagysh, Kegart, Kyzyl-Tuu) and only one municipality is demonstrated very low risk index (Lenin).

At the next stage of our study, we plan to apply INFORM Risk model with its adaptation to the local context at the level of other rural (Aiyl Aimak) or urban (town administration) municipalities of the Kyrgyz Republic. Adaptation of this method will be developed through the following stages:

- Determination of the optimal set of risk criteria (based on INFORM Risk model standards and the capabilities of the national data and statistics system). Clarifying the existing risk criteria (the form of their mathematical-numerical representation).
- Normalization of risk criteria (categories and components) in a unified system and index standard.
- Calculation of risk components with subsequent assessment of the Risk index.
- Risk mapping and providing information for end-users.

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