Natural Hazards in Tajikistan

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Summary

The nature, geology and climate of Tajikistan is the reason for natural hazards such as avalanches, mudflows, and glacial lake outburst and floods. These hazards were studied and mapped in the Soviet period and most hazards assessments rely on outdated maps. A research-for-policy study on natural hazards and climate change in Tajikistan was recently funded by the OSCE Office in Tajikistan (April-November 2016). The study was carried out by different expert groups qualified in the areas of geology, hydrology, meteorology and climatology. The present report present the work done on avalanches, mudflows and glaciers.

The first part (Part I) presents a status review and map of avalanches in Tajikistan. The avalanche assessment used existent mapping, aerial surveys of the past years, satellite images and surveys. About 30,000-40,000 potential avalanche prone spots were identified where major damage may occur to the natural and urban environment. In total, the avalanche prone areas occupy nearly 75% of Tajikistan.

The second part (Part II) present the status and a digital map of mudflows in Tajiistan. The study identified 573 mudflow sites of which 338 were caused by rain, 8 by glacial melt, 148 derived from snowfields and 79 were of mixed type (elements of the above). Among these, 194 are hazardous that could cause imminent damage to infrastructure.

Part III on glaciers presents an inventory on glaciers types in Tajikistan and their related hazards such as glacial lake outbursts and associated mudflows. The mapping used past maps, satellite images and Google Earth® as tools. The new digital map of glaciers show 7,109 glaciers with an area of 6,854.01 km^2. The developed map also outline 542 burst-prone glacial lakes, which are located both on the glacier body and in its marginal parts, often at the retreating glacier front.

The maps produced on avalanches, mudflows and glaciers are the first maps produced since the Soviet period. The maps are in scale of 1:100,000 as follows:

- ‘’Avalanches map of Tajikistan’’
- ’’Mudflows map of Tajikistan’’
- “The map of glaciers dynamics in Tajikistan’’

Part I: Assessment and distribution of avalanches in Tajikistan

1. Introduction

Avalanches occur on steep slopes with significant snowfall. In Tajikistan, mountains reach 7000 m and the snow depth can be upto 4-5m. The avalanche prone areas occupy about 75% of the territory and about 30,000 to 40,000 avalanche spots was observed by Ashurov et al. (1999). The distribution and risk of avalanches is still insufficiently studied in Tajikistan, except in highland areas Anzob area and Shahriston passes where the avalanche risk is quite well known.

Generally, avalanches form on snow covered slopes due to slope failure (slip, slide) or snow accumulation by moving snow ("snowball" effect). The reasons leading to avalanche initiation are several and partly unknown making their prediction to some extent random. Avalanches occur typically at the end of the winter. Sudden avalanches can lead to loss of lives and infrastructural damages. In the past, avalanches have completely destroyed residential areas (Jirgatal, Hoyit, Gharm, Shughnon), damaged bridges and halted transportation for a long period (e.g. the road to the southern portal of the Istiklol tunnel, Anzob, Shahriston and Haburobod).

The aim of this study was to shortly review and present the information on avalanches in Tajikistan. The final outcome of the work is a digital avalanche map for Tajikistan. To large extent the mapping build on past maps based on assessment of terrain steepness, snow accumulation conditions and forested slopes.

2. Materials and methods used in the avalanche mapping

The digital mapping was done using information from past Soviet time maps that were available at a scale 1:3,000,000 reported by Runichev and Sannikov (1968), at a scale of 1:500,00 by Uskov (1983) and regional maps by Saidov et al. (2010 a and b) for the Pamir and Pamir-Alai Mountains areas of Ishkoshim, Shughnon, Murghob and Jirgatal districts and six jamoats (village councils).

Avalances were mapped using information on snow depth and slope. As altitude is important indicator for snow depth this was also used in the mapping. The key theory used in the mapping to delineate avalanches prone areas were:

- The snow depth contours of 30 cm to delineate areas where the formation of avalanches is possible, and contours of 70 cm - areas where avalanches are usually formed and represent a significant danger (using the approach by Losev 1962),
- The mountainous terrain was divided to high (over 3,000 m a.s.l.), medium (1,000-2,000 m a.s.l.) and low mountainous terrain (600-1,000 m a.s.l.) indicating snow depth and risk of avalanches.
- Slopes steeper than 15° and higher than 50-100 m are avalanche prone slopes (Tushinsky, 1970). In the low mountainous terrain, which are common in Southwest Tajikistan (less than 600 m a.s.l.) avalanches do not occur.

To support the mapping and verify the results we used information from I) past maps, II) satellite data, III) ground based monitoring data when available.
Data from weather stations, snow courses and avalanche stations was used for the territory of Hissar and Zarafshon for two stations (Anzob and Shahristan passes), with data since 1960. Information on the avalanches for the past 20 years has been also drawn from the Committee for Emergency Situations and Civil Defense of the Republic of Tajikistan. While the data I valuable, the scope of the areal coverage is relatively small and mainly limited to the area around Anzob and Shahriston meteorological stations.

Data was available from specific studies related to the construction of tunnels, road construction and maintenance, and the investigation of avalanche accidents. Data was available from Hissar and Zarafshon ridges, where field studies in connection with the surveying of Istiklol and Shahriston tunnels and along the Dushanbe-Chanak and Aini Panjakent highways. Also similar field survey data is available from small part of the Pamirs, the Varzob gorge, and the upper Zarafshon.

Satellite image interpretation was done when lack of data on avalanches was apparent. Information on avalanches or their probability was established by satellite images (Google Earth, Landsat-7). The work was conducted by comparing satellite images mainly of summer landscape with images taken from other season periods. For summer periods, the identification looked for geomorphological and geo-botanical signs. Aerial survey data from 1985-2010 was also used.

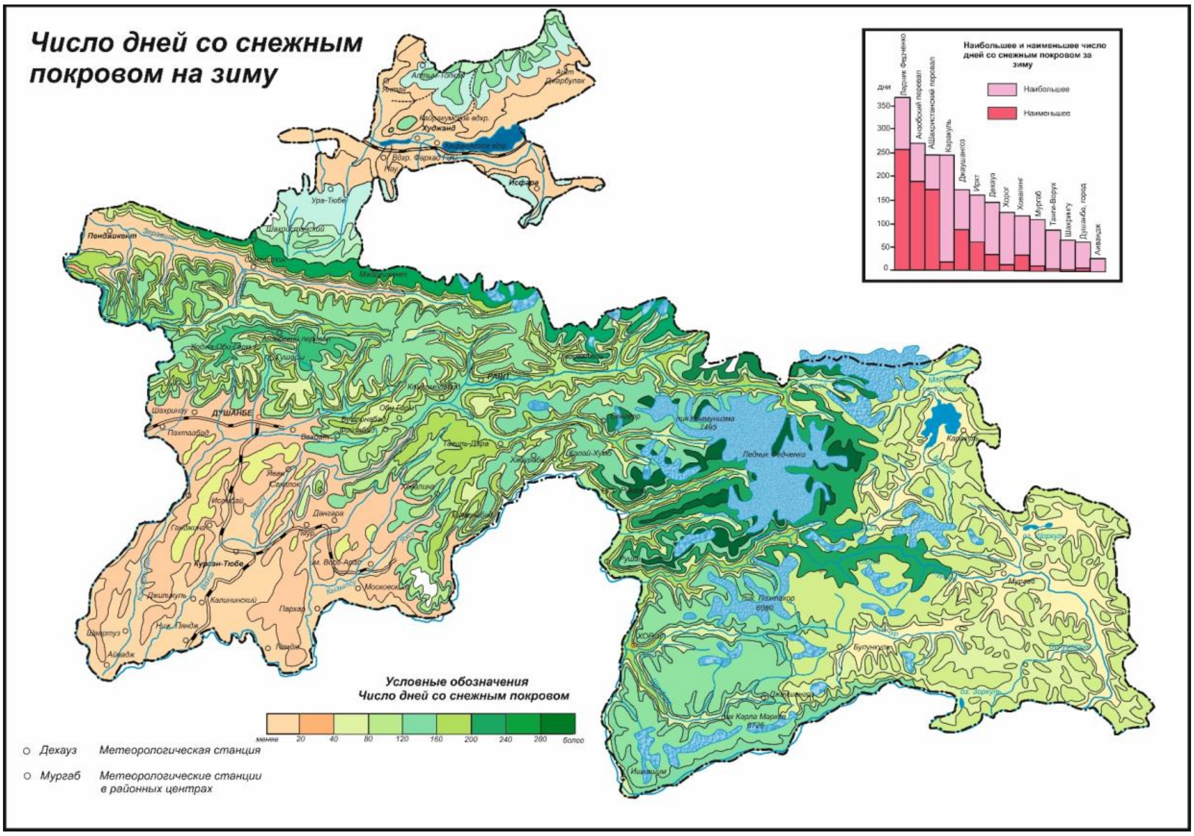

Fig. 1. Number of days with snow cover (scale 1:3000 000 by Zagriznenko G. B.,. Atlas of the Tajik SSR, 1968).

3. Avalanche maps of Tajikistan

The map of avalanche risk in Tajikistan indicate risks in the mountainous regions with high snow fall (e.g. the westerly regions of the Pamir mountains). The avalanche map show 3 main areas for avalanche risk marked as different colors in the appended maps.

- *Slopes with a high degree of avalanche hazard (brown color):* This includes all areas of the alpine highlands of all mountainous regions, the strongly segmented midlands in areas with significant snow depth (about 70 cm or more), and the low mountain areas in conditions of very high snowfall (more than 1.5 m), for example, the Ziddi river valley, snowy regions of the Eastern Pamirs.
- *Slopes with medium avalanche hazard (light/moderate brown):* these occur when a) the network of avalanches is sparse, and/or b) the avalanches occur only in the years of increased snowfall or special meteorological conditions. Most of central Tajikistan is in this group (snow depth less than 50-70 cm)
- *Slopes with a low degree of avalanche hazard (light green/brown):* avalanches are very rare and occur only in certain small areas (the steepest parts of slopes of downwind exposure and only during snowy years). In general, this type includes areas with averagely low snow cover, but significant fluctuations in snowfall conditions. The edge parts of the Western Tien Shan ridges may serve an example, where the area of avalanches is usually limited by elevations of 1,400-1,800 m a.sl., and in snowy years descends to elevations of 1,000 m a.s.l. This type includes midlands with little snow such as the Eastern Pamirs (Murghab district); lowlands with normal medium snowfall; and foothills and low mountains in snowy areas of such as Faizabad; north-western slope of Peter the Great ridge; and the Kurama ridge.

A separate category is presented for areas where avalanches are not currently observed, but may emerge in the future due to global change. This includes densely forested mountain areas with thick of snow cover the formation of avalanches can occur if the region is deforested (e.g., the Obihingou river valley, southern slope of the Vakhsh ridge, etc.).

The accuracy of the avalanche maps depend on the data available. Some mountain areas that have been poorly explored as in the case of Pamir mountains. Also more data would allow for a more detailed description of avalanche activity. In the future, anthropogenic factors, such as deforestation, can increase avalanche probability while the wider climate change impacts can also have a major effect on avalanche frequency and magnitude.

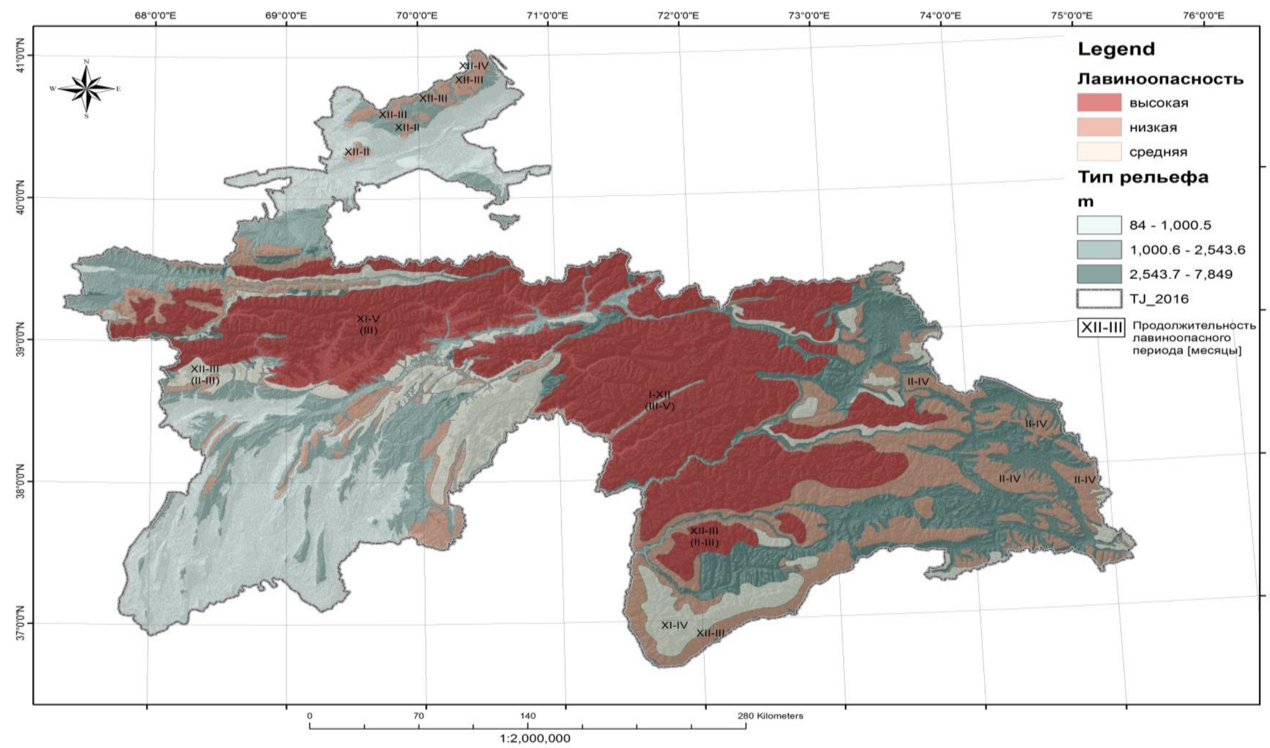

Fig. 2. Avalanche prone slopes (after Mirzo S. Saidov).

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Part II: Assessment and distribution of the mudflows in Tajikistan

1. Introduction

In Tajikistan mudflows are common in lowlands and midlands in the south and north of Tajikistan. Mudflows occur as sudden flows of debris with high content of soil and rock material originating in mountain areas after rainfall (Fig. 3). A mudflow has three zones i) initiation (source of rock and soil), b) the transit zone (where mudflow is transported) and iii) the zone of accumulation (mudflow fans) as shown in Fig. 3.

Fig. 3. The classic structure of mudflow in Obchaka village in the Surkhob river valley showing zone of initiation, transit and accumulation (photo by N.Ischuk).

There are three main driving factors that lead to mudflow formation:

1. Climatic: heavy rainfall, rapid snow melt, glacial lake outburst.
2. Geology and geomorphological features: topography leading to slope failure (source of soils and rocks), lack of vegetative ground cover, earthquakes.
3. Anthropogenic: deforestation, overgrazing, the consequences of mining operations and so forth.

About 95 % of mudslides are caused by heavy rainfall or continuous rain. Typically precipitation above 15-20 mm per day in arid areas cause debris flows (Perov, 2012). Melting snow does not generate significant mudslides, but melting snow add to the rainfall effect and may cause small snowfield (snow patch) mudslides. In Tajikistan, valley parts and foothills mudflows typically occur in the spring. In the mountainous and highland regions, mudflows usually emerge in summer, when the snowmelt begins. Mudflows is serious hazard in Tajiksitan. In 2015 in Tajikistan a simultaneous sharp rise in temperature and precipitation during the spring triggered a series of massive mudflows with catastrophic effects in the country.

The aim of this study was to update maps of mudflows distribution in Tajikistan. The map support the assessment of mudflows floods and their threats to infrastructure, land development design, residential and industrial facilities. In the report, the term “mudflow hazard” is used for the potential harm or damage that mudflows may cause. The ‘’mudflow risk’’ is a combination of frequency or probability of mudflow formation with certain characteristics. In this report, the term “mudflow risk” applies in an attempt to estimate the potential impact of mudflows in human lives and infrastructure.

2.Methodology of mapping mudflows distribution in Tajikistan

A digital map on ‘’Mudflow hazards and distribution in Tajikistan’’ was developed in a scale 1-500,000. For mapping mudflows, literature review and past maps were used. The old maps produced during the Soviet time by Lim et al. (1984) and Tukeev and Uskov (1984) show mudflow channels and alluvial fans in non-scale conventional symbols. The newly developed maps also show mudflow origination areas (source area), mudflow fans (deposition areas) and the assess the risk (hazardous and non-hazardous). The mudflows harmful to infrastructure are marked by a red border as presented in Fig.4.

The existent maps were validated through satellite imagery in Google Earth software by further analyzing the data with Geograhic Information System tools. During the image processing, the interpretive signs used were- shape, color, image pattern as follows:

- **For zones of glacial mud flows initiation**, a V-shaped incision in soft sediments is typical; for rain-caused mudflows – a denudation funnel turning into a pothole, circus-form upper reaches of watercourses that serve as a perfect precipitation concentrator.
- **For the transit and formation zone**, a light tone of the channel strip is typical- it is the main interpretive sign of mudflows: the lighter is the tone, the younger is the age of the last mudflow. Specific elements in the transit area are also: a scalloped pattern of the riverbed edge and mud deposit fans outside the channel in the areas of sharp turns.
- **For the accumulation area,** a mudflow debris cone is typical - in the form of a complete fan or a sector – a fragment of proluvial alluvial fan (debris cone). Sometimes mudflows do not form alluvial fans - mudflow material is discharged directly into the mainstream of a larger watercourse that carries them away. For interpretation of an accumulation zone all types of interpretive signs, including indirect ones are equally informative. The different types of mountain terrain interpretive signs have their own characteristics as presented in Table 1.

Uncertainty exist in the categorization between hazardous and non-hazardous may be arbitrary. There are for instance cases where ‘’non-hazardous’’ mudflows are created through deposits accumulated in the channel extensions, sometimes not reaching the mouth of the watercourse. Due to minor deviations of the watercourse, the speed of these mud floods is relatively low. Therefore, they practically do not cause damage, but only flood obstacles arising in the way by a mud and stones mixture. Also, it should be noted that only the mudflows that have distinct interpretive signs have been shown. In some river valleys, (for example, the Varzob River) the traces of previous mudflows have been faded out and no traces of mudflow activity can be detected in them.

Rain caused mudflows are most common in Tajikistan, except for the Eastern Pamirs area. For this type of mudflows, circus shaped extensions in the upper parts of the valleys are common with numerous erosional incisions on the slopes, as well as the presence of loose sediment on the bottom and on the slopes. Transit and formation paths are often straight, slightly winding, have a significant inclination in the upper parts of the valley. Sometimes the mudflow mass transit paths are absent and mudflow alluvial fan appears right from the mudflow origination area

In the Yakhsu river basin, where conglomerates with grits are prevalent, water and stone flowing without alluvial cones are frequent. At the bottom of the Zarafshon river valley there are many pothole shallow landslides formed due to the linear erosion. There are also mud floods without origination sites and gully formation is very strongly developed by forming suspended streams without alluvial fans. In the Pamirs, in the Vanj and Yazghulom rivers, valleys mudflows almost cause no harm, because all the villages are located high above the watercourses. The danger exists only for roads and bridges.

Table 1. Typical interpretation signs of mudflows on black and white aerial photo images of scale 1:20, 000-1:40, 000

Morpho-dynamic zones of a mudflow basin	Interpretation criteria	
	Direct (image shape, colour, pattern)	**Indirect**
Initiaion (origin)	<u>Shape</u> • Narrow V-shape incisions on slope benches and moraines • Water collecting funnel, (completely or partially) lightened by denudation and erosion processes <u>Colour</u> • Sharp change in colour of the streamway band – grey into light – in mudflow origination site • Change in colour of mudflow incisions on moraine benches marking origination sites of mudflows of various age	Mudflow, landslide, sloughing site, below which traces of mudslide are observed in the streamway
Transit	<u>Shape</u> • Streamway often occupies the whole bottom of the valley with sharp boards of the incision sites. • Ridges of large detrital material or flat bands of mudslide sediments along watercourse. • Alternation of narrowed and widened parts of the waterbed, the latter mark local accomulation areas (fields). • Discharge of detritus on the slopes in the channel sharp winding areas. <u>Colour</u> • Light in the streamway band and from light to gray in the interim accumulation sites and in nearby streamway zone. <u>Pattern</u> • Scalloped, with traces of bank collapses along the edge of channel incisions.	Narrow band or elongated islands of hardwood (poplar, alder, birch) in the zone of mudflow effect among coniferous and mixed forests

Accumulation	Shape • Mudflow debris cone in the form of a fan or a narrow sector with "sleeves" below the main accumulation field. • Deep box-shaped incision in the surface of the ancient cone Colour • Light – sediments of fresh mudflows, light gray - recently past mudflows. Pattern • Ripple, resulting from the alternation of ridges debris and dry riverbeds • Solitary lumps or their chains, oriented along the axis of mudflow motion	Availability of multiple contours occupied by heterogeneous or uneven vegetation, marking mudslides of different ages

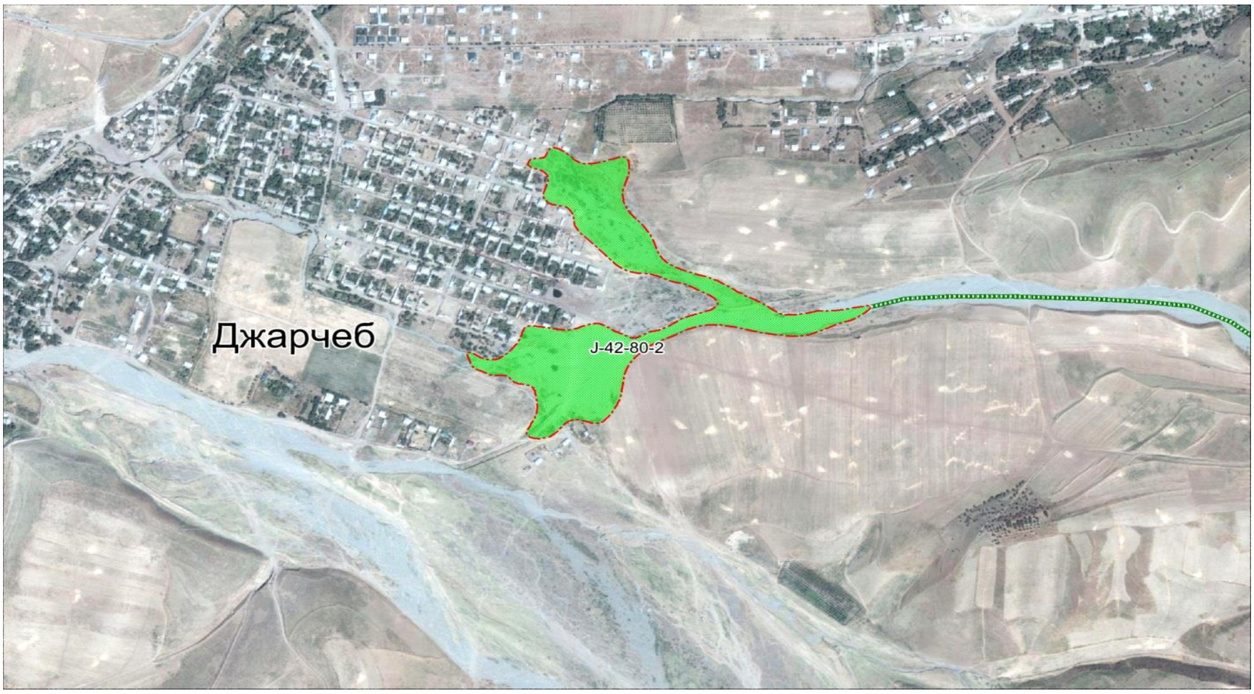

Fig. 4. Mudflow alluvial fan threatening the village Jarcheb (Google Earth image).

Fig. 5. Mudflow in Khuroson in May 2005 (photo provided by the UNDP).

Fig.6. Mudflow exit zone to the Ilyak river valley (Photo by N. Ischuk).

3.Mudflow maps of Tajikistan

The mudflow map (scale 1: 500, 000) present the type of formation, transit path, and the area of accumulation. In total, 573 mudflows of origination sites ranging from 0.017 km^2 to maximum - 7.58 km^2 were mapped. Of these 338 are rain-caused, 79 are of the mixed type, 8 are of the glacial type and 148 are of the snowfield type. Among the 573 mudflows, 194 are hazardous. In addition, 20 areas of mud flood origination are shown, mainly for western and northern parts of Tajikistan.

The analysis of the State Observations Service of the Main Geological Survey under the Government of Tajikistan has identified the following river valleys as the most dangerous and most exposed to floods and mudslides:

1. Mogiyondara, Shing, Forob, Kshtut in Panjakent district;
2. Fondarya and Yagnob in Ayni district;
3. Zarafshon in Panjakent and Ayni district;
4. Pongaz, Oshoba and Shaidon in Asht district;
5. Vanj, Yazghulom, Bartang, Gunt, Shahdara in Gorno-Badakhshan Autonomous Region;
6. Panj, Kofarnihon, Yakhsu, Tairsu and Kyzylsu in the Khatlon region.

Mudflows pose the greatest hazard to the villages in the Bartang, Gunt, Shahdara, Panj river valleys (Fig. 7, 8), where villages are located right on the alluvial fans of lateral tributaries that often carry mudflows or there is a possibility of occurrence along heavy rainfalls. For instance, in the very hot summer of 2015, a heavy precipitation has caused a massive mudflow. Mudflows may be also formed in the places where they have never occurred before, and these streams were before considered non-hazardous (for example, the river near the Barcem village, but should be classified as hazardous.

Rain caused mudflows are most common in Tajikistan, except for the Eastern Pamirs area. Snowfield-caused mudflows are typical for the Eastern Pamirs, mountainous parts of the West Pamir and Hissar-Alai. The lack of vegetation, the presence of a large amount of loose debris, and snow cover contribute to the emergence of mudflows during snowmelt. These are usually non-hazardous since there are no national economic facilities and villages in the area of their influence.

Mixed type mudflows occur mainly in the transition zone between East Pamir and West Pamir, as well as in some parts of the Hissar-Alai and the Panj River Valley where the precipitation is both in the form of snow and rain. Most of them are mudflow hazardous (Fig. 10). In total, 79 mixed type mudflow origination sites are identified in Pamirs, of which 36 are hazardous mudflows.

Glacial mudflows are rare and have been distinguished by clear signs: the potholes in the watercourse bed, the proximity of the glacier, from which water necessary for the formation of the mudflow outsource, and the presence of the typical alluvial fan. In total, 8 glacial mudflows are identified, 3 of which are hazardous (Fig. 11).

Fig.7. Alluvial cone of the Nishgar river in the Panj river valley (Photo by N. Ischuk).

Fig.8. Mudflow debris cone from the Haidar river valley, Obihingou river basin (Photo by N.Ischuk).

Fig.9. Alluvial fan near the Razuch village posing a threat to the population, Bartang river valley (photo by N. Ischuk).

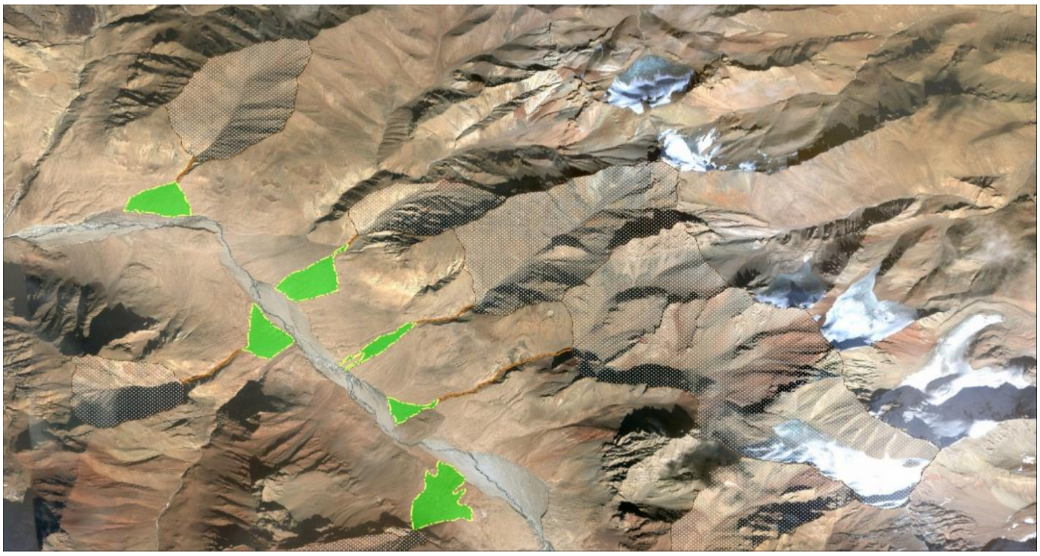

Fig. 10. Snowfield-caused type of mudflows in the Zortashkol river valley (Source: Google Earth image edited by N. Ischuk).

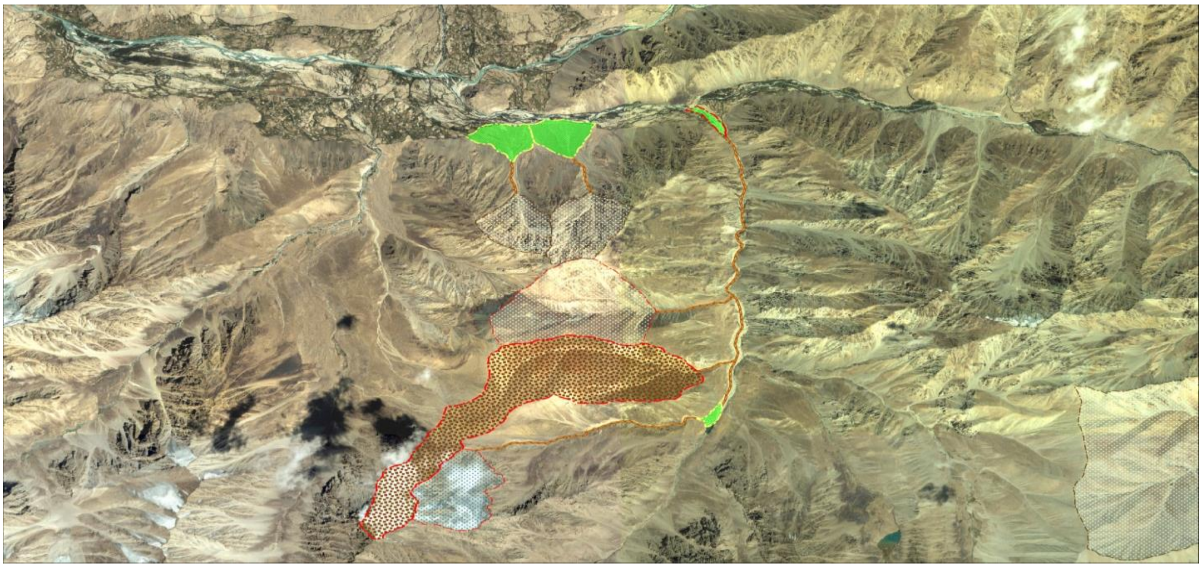

Fig.11. Origination sites of glacial, mixed and snowfield caused type mudflows in the Duzahdara river basin (Source: Google Earth image edited by N. Ischuk).

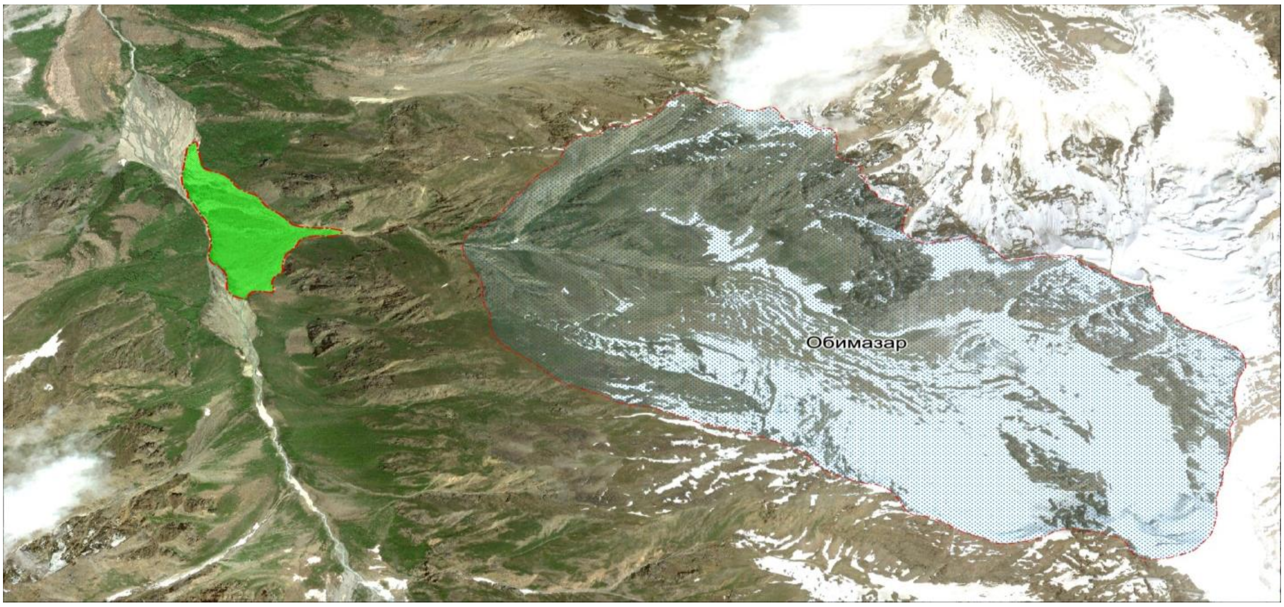

Fig. 12. Glacial type mudflow origination site in the Obimazor river basin. The alluvial fan can cause the channel blockage and a breakthrough type mudflow (Source: Google Earth image edited by N. Ischuk).

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Part III: Assessment and distribution of glaciers in Tajikistan

1. Introduction

Glaciers are common features of Tajik mountains, especially in the Pamir. The glaciers found include rock glaciers, valley and niche glaciers. Some glaciers are large reaching 70 km in length being longer than the Himalaya glaciers. The main hazard of glaciers is linked to moving glaciers that block rivers valleys leading to lakes that may suddenly burst resulting in hazardous flood and mudflows.

Glacier movement depends on its mass balance and inclination of its bed. In order to determine the behavior of the glacier, sufficient long term data on its mass balance is needed for more than 100 years. Remnants (terminal moraines) from the last Holocene deglaciation can be used to assess past glacial processes and degradation rates. Glaciers surge is caused by increase in glacier mass balance that lead to ice melt and movement [Paterson, 1984]. The frequency of surging is not regular, and both surging and not surging glaciers can be located in the same basin.

Most valley rock glaciers are adjacent to the extremities of modern glaciers, or coexist with them. They are formed due to ice buried under the detritus which is so-called dead ice. Niche rock glaciers are formed by the formation of ice in clusters of debris on the slopes (talus deposits) or in moraine deposits remnants (side moraines). Buried ice is more resistant to external air temperatures and therefore more resistant to melt. The mobility of rock and niche glaciers depends on their ice content. The prerequisite for their formation is the presence of detrital material on the slope and a large diurnal temperature difference required for moist condensation. Niche rock glaciers can be also formed at the account of the buried ice contained in the side moraines.

The objective of the present work was to produce a digital map on the ''Glacier distribution in Tajikistan'' at a scale 1:500,000. The last complete and most comprehensive data on the glaciers of Tajikistan are contained in the Database of glaciers created along the Soviet period (ГУГК, 1984). The mapping was carried out from previous topographical maps and by interpretation of satellite images. The Landsat multispectral satellite images (7 ranges) and Google Earth space images (with a resolution of up to 1m per pixel) were used.

2.Glacier mapping methodology

For glaciers mapping, old topographical maps from 1975-1981 were digitizing at scale 1: 100,000. The glaciers were then located using multispectral (7 band) Landsat satellite images, that show the glacier extent at year 2011. These pictures were prepared using ranges 4-3-2 in which pure ice was reflected as bluish color that facilitated the digitization of glaciers on the satellite images. The digitized images were superimposed to produce the final map. A database was compiled using data on location and size of glaciers over the period 1971 to 2011.

Google Earth images were used to locate moraine ridges of past glaciers formed during the last deglaciation about 13.4 thousand years ago. Interpretation of rock glaciers and terminal moraine ridges was performed by continuous inspection of mountain areas on satellite images at the scale of 1: 5,000. Rock glaciers were divided into valley and foothill types based on satellite images. Dangerous rock glaciers are shown on the map by a red contour.

Fig. 13. Terminal moraine formed by the Rivakkul lake (Source: Google Earth image edited by N. Ischuk).

Fig. 14. Terminal moraine – the Rivakkul lake dam (photo by N. Ischuk).

Fig. 15. Valley rock glaciers in the Kokuybel river valley (Source: Google Earth image edited by N. Ischuk).

Fig. 16. The same rock glaciers in the Kokuybel river valley (photo by N. Ischuk).

Fig. 17. Foothill rock glaciers in the Kokuybel river valley (Source: Google Earth image edited by N. Ischuk).

Fig.18. The same rock glaciers in the Kokuybel river valley valley (photo by N. Ischuk).

3.The map of glaciers dynamics in Tajikistan

During the analysis of the topographic maps the 6,094 glaciers were produced with a total area of 9,539.15 km². The digitization of glaciers using satellite photographs gave 7,109 glaciers with an area of 6,854.01 km². According to the database of glaciers of the USSR (ГУГК, 1984), the number of glaciers in Tajikistan was 8,492, with an area of 8,476 km². The inconsistency in number and size area may be attributed to the fact that the approach to define a glacier and its size may differ. On topographic maps, both pure ice and ''dead'' parts of the glaciers (ice buried under the detritus), separated from the main body are drawn up. Most of these areas are covered with detrital material and contain a large amount of debris (moraine). On the other hand, according to the satellite (Landsat) images, only non-moraine glaciers parts, sometimes with patches of snow accumulation in the upper glaciers have been accounted. In our case, the area determined by topographic maps and aerial photos of 1959 and later years, was measured by using master charts. Only those glaciers of which the area was more than 0.1 km² were considered.

In the mapping, 2,055 rock glaciers were observed of which 1287 are the valley rock glaciers and 768 – niche type glaciers. Moreover, 103 hazardous valley rock glaciers and 45 hazardous niche rock glaciers were identified. The largest number of dangerous valley rock glaciers are concentrated on the Rushan ridge (Fig. 22, 23), the North Alichur ridge (Fig. 24), the Beleuli ridge and Shahdara ridge. In some valleys, rock glaciers can cause blockage of river beds, formation of a lake, which can later burst and invoke mudflows.

Dangerous rock glaciers are shown on the map by a red contour. In total, we observed 61 surging glaciers (Table 2). There are mostly concentrated in Fedchenko glacier system in the upper Obihingou river. A small part is situated in Tandykul basin, on the Wakhan range and in the upper valley of the Sauksay river. The developed map also shows 542 burst-prone glacial lakes. These are located both on the glacier body, and in its marginal parts, often at the retreating glacier front. These lakes are the most dangerous. At their filling to a full capacity, there is a threat bursting and formation of mudflow. No assessment of the degree of danger was carried out due to the lack of data on lake water volume.

Terminal moraine complexes are a sign of the last glaciation degradation. Only the Holocene age moraine complexes (for the period of 13.4 thousand years) are marked on the map. Totally, 2,802 terminal moraine complexes are shown on the map. The difficulty of this analysis is that the terminal moraine glacier complexes are not all preserved in the present terrain.

Table 2. Surging glaciers of Tajikistan, edited by the Atlas of natural resources of the Tajik SSR, 1984).

NO	Surging glaciers of Tajikistan		
1	Abdukahor	32	The Bear
2	Akbaital	33	Muzgazy
3	Baralmos	34	Mushketov
4	Batrut	35	Naspar
5	Bivachny (Camping)	36	Peter the First
6	Bogchigir	37	Podkova (Horseshoe)
7	Big Saykdara	38	Ravak

8	Byrs	39	Rakzou
9	Burakurmas	40	RGO
10	Vaizirek (№88)	41	Sagdar
11	Vali	42	Satsu
12	Vanchdara	43	Northern Zulumart
13	Gando	44	Northern Tanymas
14	Garmo	45	Scogach
15	Grum-Grzhimailo	46	Sugran
16	Darwaz	47	Sitargy
17	Dzerzhinsky	48	Tamdikul
18	Didal	49	Tanymas 2
19	Dorofeev	50	Tanymas 3
20	Western October	51	Tokaest
21	Zardibiruso	52	Ulughbek
22	Zugvand	53	Urtabogchigir 1
23	Zuruzamin	54	Urtabogchigir 2
24	Ishtansaldy	55	Fortambek
25	Karl Marx	56	Khabarvivkhats
26	Kasvir	57	Shaugado
27	Kishtijarob	58	Shogazy
28	Comsomol	59	Shokalsky
29	Lipsky	60	Yazghulomdara
30	Mazaar	61	Yazghulom
31	Small Saukdara		

Fig. 19. RGO glacier (photo N. Ischuk, 2009).

Fig. 20. Bear glacier (photo N. Ischuk, 2011).

Fig. 21. Surging Tamdykul glacier (photo N. Ischuk).

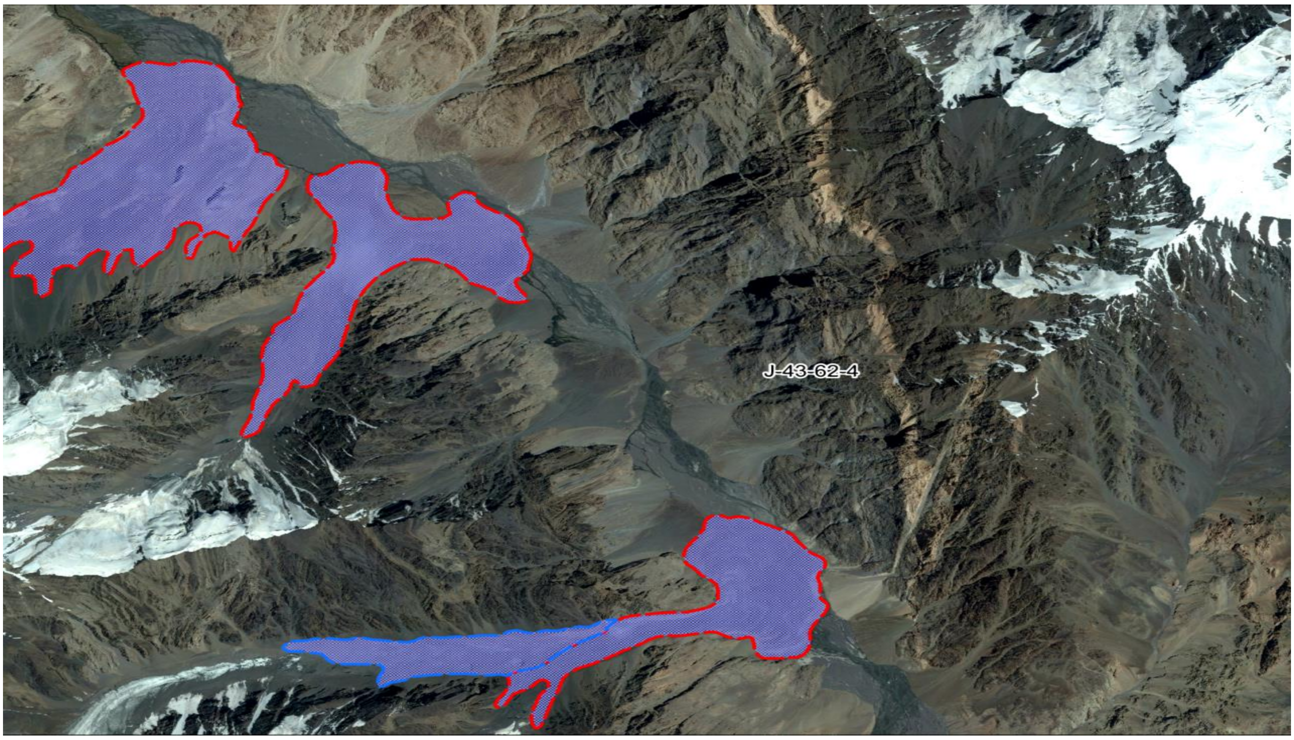


Fig. 22. Hazardous rock glaciers in the Kattamarjanay river valley (Google Earth image edited by N. Ischuk).

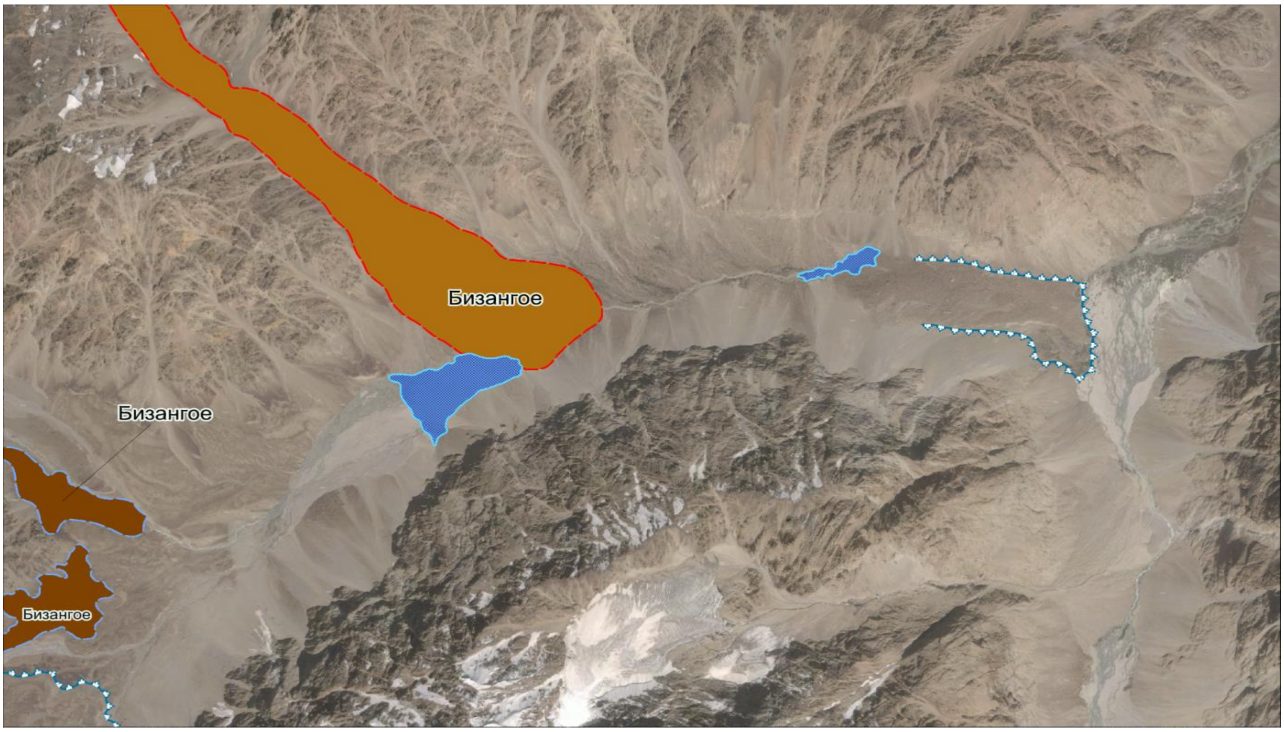


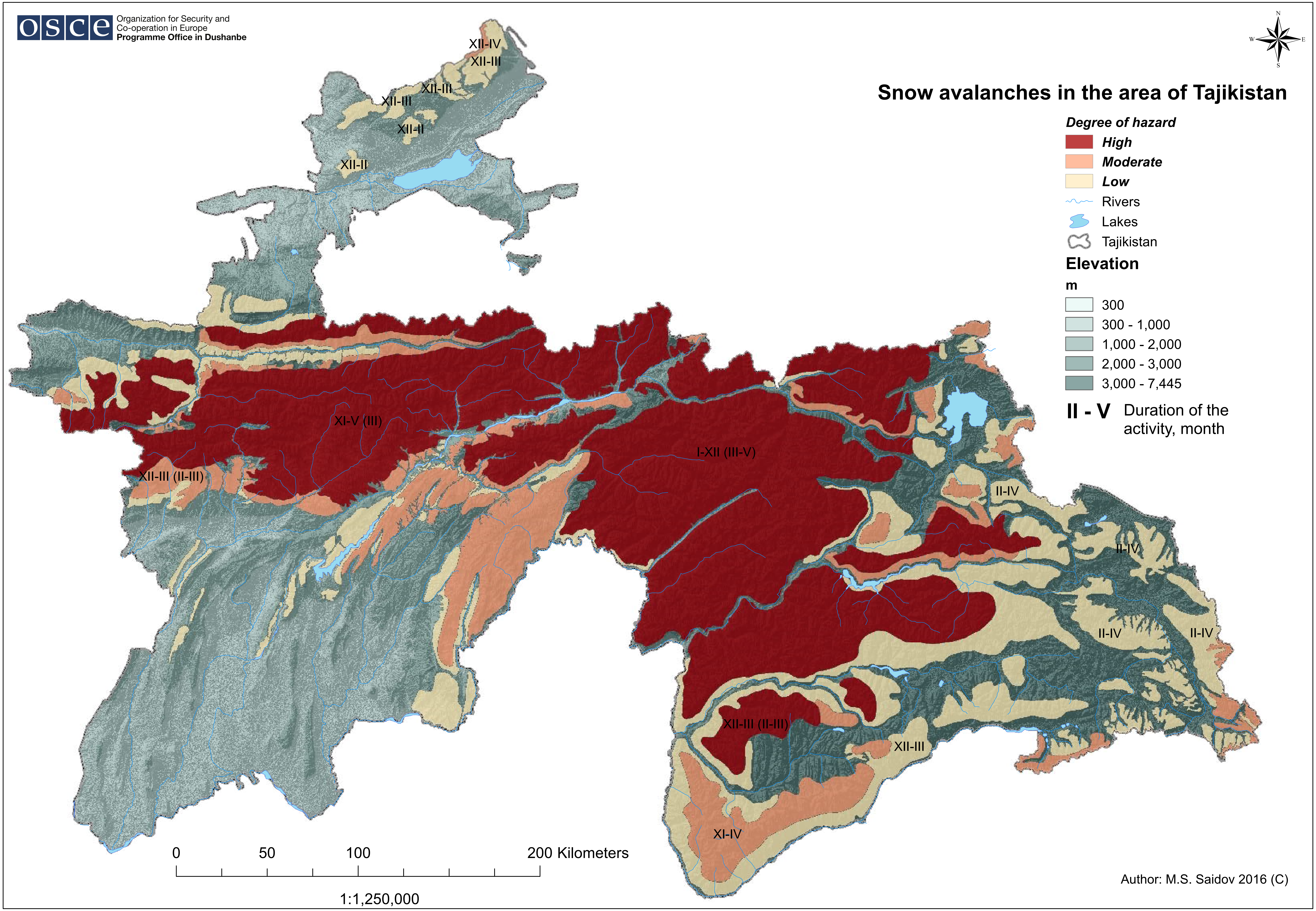
Fig. 23. Stone glacier that blocked the riverbed and formed a lake. The Bizangoe river valley (Source: Google Earth image edited by N. Ischuk).

Fig. 24. Rock glaciers that have blocked the riverbed and formed a lake as a result of merging. the Ak-Djilga river valley (Source: Google Earth image edited by N. Ischuk).

References

Atlas of the natural resources of the Tajik SSR. GUGK under the Soviet of Ministers of the USSR (Main Agency of Geodesy and Mapping under the Soviet of Ministers of the USSR), 1984.

Paterson U.S.B. (1984) Glacier physics. M., "Mir", 1984, pp.471.


OSCE
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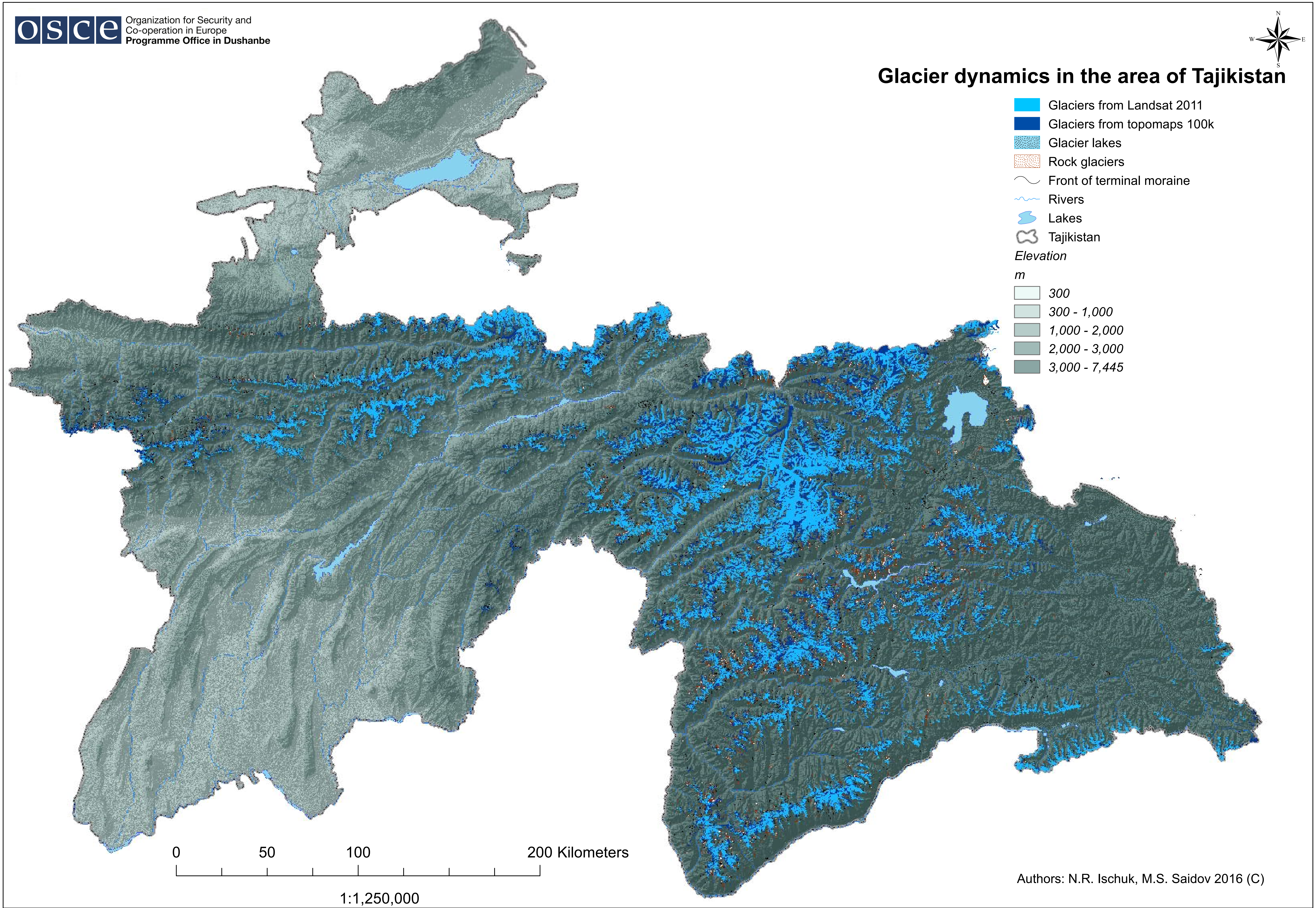
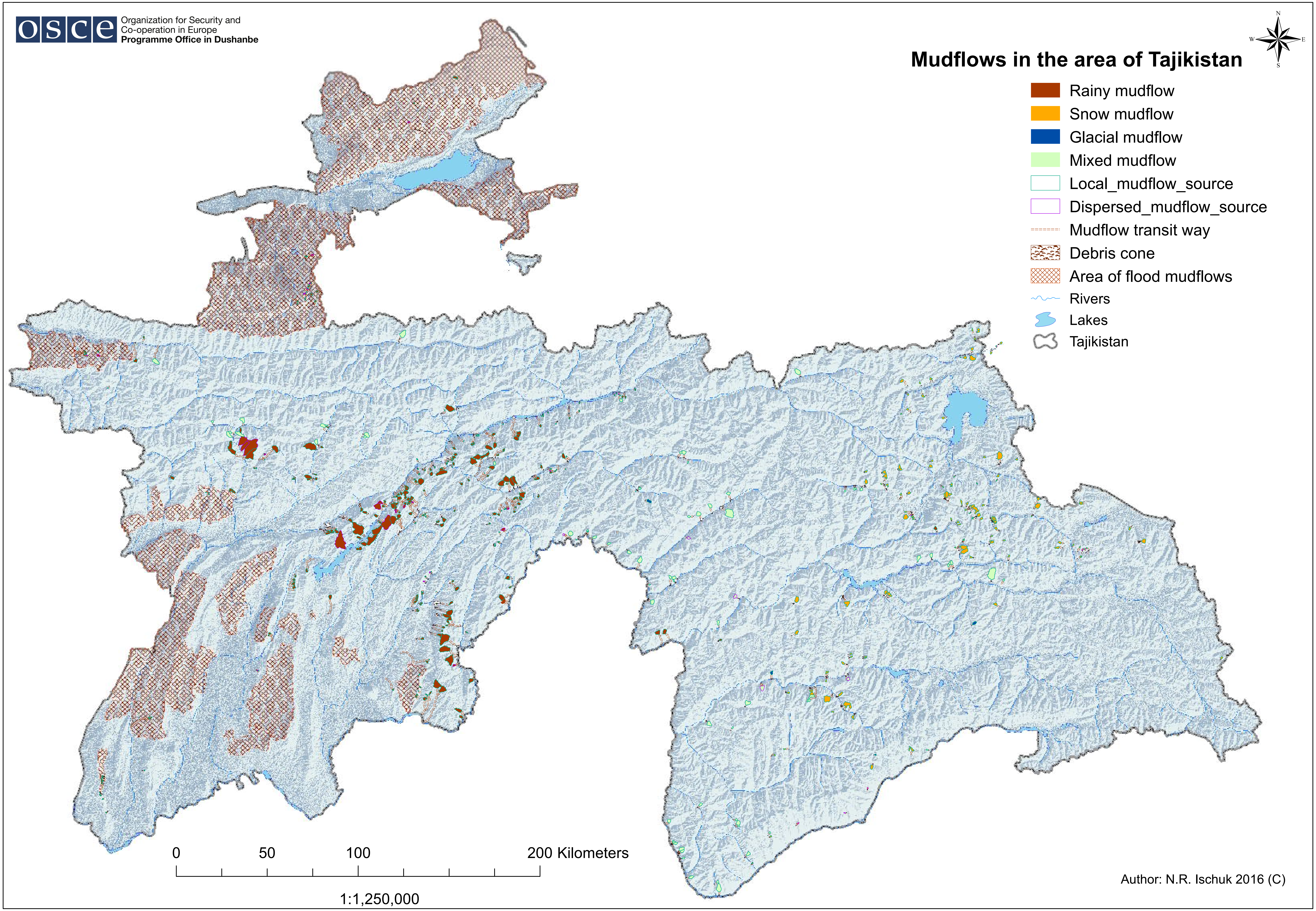
Snow avalanches in the area of Tajikistan
Degree of hazard
High
Moderate
Low
Rivers
Lakes
Tajikistan
Elevation
m
300
300 - 1,000
1,000 - 2,000
2,000 - 3,000
3,000 - 7,445
II - V
Duration of the activity, month
N
S
W
E
XII-IV
XII-III
XII-III
XII-III
XII-II
XII-II
XI-V (III)
XII-III (II-III)
I-XII (III-V)
II-IV
II-IV
II-IV
II-IV
XII-III (II-III)
XII-III
XI-IV
0
50
100
200 Kilometers
1:1,250,000
Author: M.S. Saidov 2016 (C)


Organization for Security and
Co-operation in Europe
Programme Office in Dushanbe
Glacier dynamics in the area of Tajikistan
Glaciers from Landsat 2011
Glaciers from topomaps 100k
Glacier lakes
Rock glaciers
Front of terminal moraine
Rivers
Lakes
Tajikistan
Elevation
m
300
300 - 1,000
1,000 - 2,000
2,000 - 3,000
3,000 - 7,445
0
50
100
200 Kilometers
1:1,250,000
Authors: N.R. Ischuk, M.S. Saidov 2016 (C)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Organization for Security and
Co-operation in Europe
Programme Office in Dushanbe
Mudflows in the area of Tajikistan
Rainy mudflow
Snow mudflow
Glacial mudflow
Mixed mudflow
Local_mudflow_source
Dispersed_mudflow_source
Mudflow transit way
Debris cone
Area of flood mudflows
Rivers
Lakes
Tajikistan
N
W
E
S
0
50
100
200 Kilometers
1:1,250,000
Author: N.R. Ischuk 2016 (C)