

Strengthening Capacities to Assess Climate Change Vulnerability and Impacts to Shape Investments in Adaptation Technology for Azerbaijan's Mountain Regions

Final report, 30.06.2020



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Contents

1	Introduction and background	4
1.1	Objective of this report	4
1.2	Context of the Technical Assistance	4
1.3	Ongoing Climate Change Adaptation Activities in Azerbaijan	5
2	Pilot study area, target sectors and current climate	6
2.1	Pilot study area	6
2.2	Target sectors: Water and agriculture	7
2.2.1	Water sector	7
2.2.2	Agriculture Sector	9
2.3	Current climate	10
3	General methodology	12
3.1	The Impact Chains approach	12
3.2	Quantitative data	13
3.3	Questionnaire	14
4	Calculation and analysis of hazards and impact indices	15
4.1	Climate change, future scenarios and potential effects	15
4.2	Snow cover changes	22
4.3	Erosion modelling	23
4.4	Forest accessibility	23
4.5	Land degradation assessments	24
5	Assessment of major climate risks	24
5.1	Risk of drought	25
5.1.1.	Risk of drought in agriculture in foothill areas	25
5.1.2.	Risk of drought in agriculture in mid elevation areas	26
5.2	Information on climate-related drought hazards	27
5.3	Comprehensive risk assessments	28
5.3.1	Risk of drought in agriculture in foothill areas	28
5.3.2	Risk of drought in agriculture in mid elevation areas	29
5.4	Risk of flood in foothill areas	31
5.4.1	Understanding risks and impact chains	31

5.4.2	Information on climate-related flood hazards	32
5.4.3	Comprehensive Risk assessment.....	32
5.5	Risk of forest damage	34
5.5.1	Understanding risks and impact chains.....	34
5.5.2	Information on the climate-related hazard	35
5.5.3	Comprehensive Risk assessment.....	35
5.6	Risk of erosion (all zones)	38
5.6.1	Understanding risks and impact chains.....	38
5.6.2	Information on the climate-related hazard	39
5.6.3	Comprehensive Risk assessment.....	39
6	Discussion on climate risks in Azerbaijan’s mountains.....	42
7	Conclusions and outlook.....	43
8	Methods transferability to other mountain regions of Azerbaijan	44
Annex	45

1 Introduction and background

1.1 Objective of this report

This report summarizes the findings of a CTCN funded pilot study which aimed to develop an indicator-based climate change assessment for Azerbaijan's mountain regions to support decision making in adaptation planning. Methods and indicators were specifically selected for mountain regions and target sectors in a participatory process. The work was conducted in collaboration with the Ministry of Ecology and Natural Resources of Azerbaijan and relevant stakeholders. The pilot study regions were the districts of Ismayilli and Shamakhi. The developed indicators and results of the climate risk study could provide the scientific basis for adaptation planning, including the support for the development/revision of the National Adaptation Plan (NAP). They can also serve as a basis for further development of follow-up activities using international financial mechanisms such as the Green Climate Fund and Adaptation Fund. In addition, the developed indicators could be replicated in other mountain regions of Azerbaijan and across the Caucasus region.

1.2 Context of the Technical Assistance

While Azerbaijan has been actively engaged in international climate change negotiations since the 1990s, its focus during the first years was mainly on climate change mitigation. Adaptation to climate change has gained increasing prominence only relatively recently. The country conducted a climate technology needs assessment (TNA) in 2012, which identified agriculture, water and disaster risk reduction as priority sectors with regards to technology needs for climate change adaptation.

In order to direct investments towards the most vulnerable sectors using the most appropriate adaptation approaches, a sound assessment of climate impacts and vulnerabilities is a crucial prerequisite. However, Azerbaijan lacked a thorough vulnerability and impact assessment (VIA) as well as the necessary methodological tools and expertise to conduct such a study. For these reasons, the Climate Change and Ozone Center under the Ministry of Ecology and Natural Resources (MENR), functioning as the National Designated Entity (NDE) to the Climate Technology Centre & Network (CTCN), submitted a Small Scale Funding Agreement (SSFA)-Proposal to CTCN in March 2016.

The proposal submission was supported by the UN Environment Vienna Programme Office, which had been actively engaged in climate change adaptation activities in the Caucasus region for many years. The objective of the CTCN technical assistance (TA) is to support Azerbaijan in developing climate change indicators for mountain regions to be used for vulnerability and impact assessments that are comprehensive and scientifically sound. These assessments are of crucial importance to support decision making and investments regarding adaptation planning in Azerbaijan's mountain regions.

Eurac Research in Bolzano, Italy, with its long-standing research tradition on climate change impacts and adaptation was selected as the contractor responsible for the implementation of the TA. Eurac Research has developed a standard climate risk assessment guideline for the German "Gesellschaft für internationale Zusammenarbeit" (GIZ) (see section 3.1) and has conducted similar assessments in a range of countries, including Germany, Burundi, Japan, and Tajikistan. The implementation of the SSFA project started in March 2019.

1.3 Ongoing Climate Change Adaptation Activities in Azerbaijan

The Republic of Azerbaijan has joined international efforts to mitigate the negative effects of global climate change after the ratification of the United Nations Framework Convention on Climate Change (UNFCCC) in 1995. Major climate change-related activities in the country began in 1997 in the framework of the Initial National Communication of Azerbaijan to the UNFCCC. Under the coordination of the former State Hydrometeorology Committee, working groups and subgroups dedicated to the different aspects of climate change were set up.

Research activities and studies on different sectors were carried out and summarized in the First National Communication of Azerbaijan to the UNFCCC, which was submitted to the Convention Secretariat in 2000. Under the coordination of the MENR, also the Second and Third National Communications of Azerbaijan have been submitted to the UNFCCC Secretariat in 2010 and 2015, respectively. Currently, experts are working on the preparation of the Fourth National Communication, which is scheduled to be submitted to the UNFCCC Secretariat in 2020.

Studies on the impacts of climate change and potential adaptation measures are part of these above-mentioned National Communications. For the First National Communication¹, vulnerability assessments have been undertaken for five sectors: water, agriculture, forestry, land resources and coastal zones. In the development of climate scenarios for these assessments, a method based on GISS / GFDL-3 models and temperature statistics of the Institute of Geography of the Azerbaijan National Academy of Sciences were used.

In the framework of the Second National Communication², short VIA studies have been elaborated for four sectors: water resources, agriculture, coastal zones and human health. For this report, climate scenarios based on the "PRECIS 1.4" (Providing Regional Climates for Impact Studies) model were used. For the Third National Communication³, brief sectoral vulnerability analyses were undertaken for the following six sectors: water resources, agriculture, forestry, tourism, coastal zones and human health. The climate scenarios for these assessments were computed using the MAGICC/SCENGEN 2.4 software.

Besides these efforts coordinated and undertaken by the Ministry of Ecology and Natural Resources, also other actors have elaborated studies and implemented projects on climate change adaptation. The World Bank, for instance, has undertaken a major study to assess the vulnerability of Azerbaijan's agriculture sector to the adverse effects of climate change, based on available scientific literature, interviews and questionnaires (World Bank, 2012). A brief assessment of the vulnerability of forests in Azerbaijan has been prepared in the framework of the ENPI-FLEG II programme (ENPI-FLEG, 2015).

An important project on climate change adaptation, the ClimaEast Pilot Project "Ecosystem-based approaches to climate change," funded by the EU and implemented by UNDP, included a range of specific climate change adaptation measures implemented in Azerbaijan's mountain regions. Another UNDP-project called "Integrating climate change risk management by vulnerable communities in the Greater Caucasus region of Azerbaijan", funded by the Special Climate Change Fund (SCCF), aimed to reduce the vulnerability of Azerbaijan's mountain communities in the Greater Caucasus region to climate change-induced water stress and flood hazards by improving water and flood management.

¹ <https://unfccc.int/resource/docs/natc/azenc1.pdf>

² <https://unfccc.int/resource/docs/natc/azenc2.pdf>

³ <https://unfccc.int/resource/docs/natc/azenc3.pdf>

Moreover, an ongoing programme of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and its partners⁴ is considering sustainable land management and slow hazardous conditions, such as erosion, for the provision of ecosystem services and the use of natural resources.

In addition to these projects, there are also various climate change adaptation projects in the pipeline as of autumn 2019. These include a project submitted by UNDP to the Green Climate Fund (GCF) entitled "National Adaptation Plan (NAP) Support Programme for adaptation planning and implementation in Azerbaijan," which is expected to commence in 2020. Another important project proposal submitted to the GCF is called "Scaling-up Multi-Hazard Early Warning Systems and the Use of Climate Information in Azerbaijan" and is expected to start in 2020 too. Both projects, and a number of other proposals currently in review, will play a crucial role in increasing Azerbaijan's resilience against the negative effects of climate change.

2 Pilot study area, target sectors and current climate

2.1 Pilot study area

The Ismayilli and Shamakhi regions have been selected by the MENR as pilot areas for the present study. These two neighbouring districts unite many of the factors that are characteristic for Azerbaijan's mountain regions. Both are situated on the Southern slope of the Greater Caucasus and extend over a variety of agro-ecological zones, ranging from semi-arid foothills via temperate forested areas to alpine conditions prevailing at the higher altitudes of the mountain range (Figure 1).

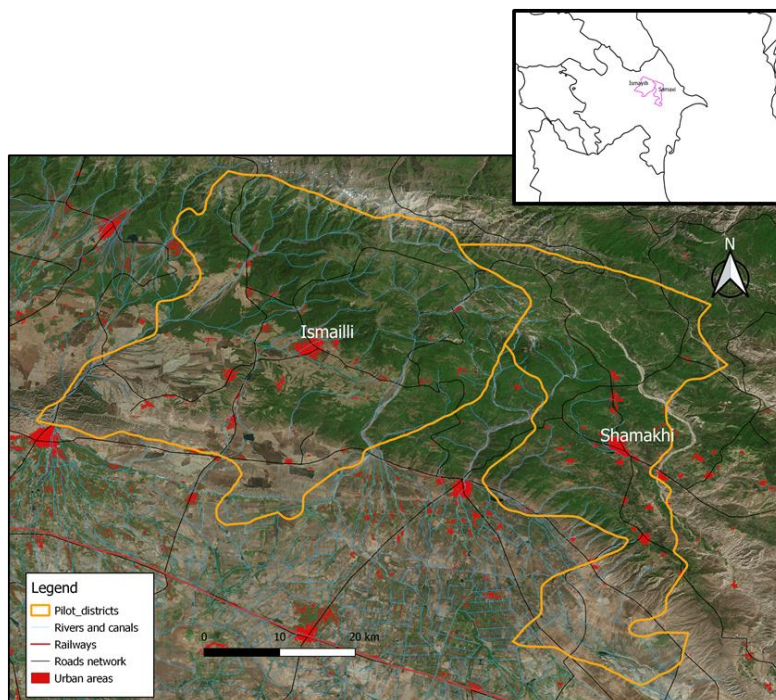


Figure 1 - Ismayilli and Shamakhi pilot regions, with borders, river, road and railway networks and urban areas

⁴ <http://biodivers-southcaucasus.org/about>

Ismayilli region extends over a surface area of 2.070 km² and counted 86.700 inhabitants at the beginning of 2019, which amounts to an average of 42 people per km². 28.100 inhabitants are classified by Azerstat as urban – most of them residing in the town of Ismayilli – and 58.600 as rural, spread around 105 rural settlements (Azerstat, 2019⁵), some of them very remote from the district centre.

Parts of the Ismayilli region are located in the lowlands of Acinohur and in the Alazan Haftaran valley. To the North of these mountain foothills, the Greater Caucasus range rises, with the highest peak in the territory of Ismayilli region being Babadag (3.628m), also an important site of pilgrimage. Most of the population is concentrated in the lower areas, where also most of the agricultural and economic activities take place.

In 2018, the economic output of Ismayilli region amounted to roughly 258.3 million Manat (equivalent to approximately 140 million Euro), i.e. a per capita production of around 2990 Manat. The largest part of this (37.1%) was generated in the agriculture, forestry and fishing sector, followed by construction (33.1%) and trade (24.4%). Industry, transport and information & communication lag behind with 3.8%, 1.3% and 0.4%, respectively (Azerstat, 2019).

The second pilot district, Shamakhi region, is situated to the East of Ismayilli and is also part of the Greater Caucasus range. It is slightly smaller than Ismayilli and covers a surface area of 1.670 km². Shamakhi region had 105.100 registered inhabitants in early 2019, i.e. 63 inhabitants per km². 49.400 people are residing in urban areas, and 55.700 in 57 rural settlements in the district (Azerstat, 2019).

According to the State Statistical Committee, Shamakhi region in 2018 had an economic output of around 261.4 million Manat, which translates into a per capita production of roughly 2500 Manat (i.e. 1346 Euro), thus slightly lower than the per capita output of Ismayilli. The largest portions of Shamakhi's gross domestic product was generated in the construction sector with 34.4%, followed by trade (33.8%), agriculture, forestry and fishing (26.5%), industry (3%), transport (1.9%), and information & communication (0.4%) (Azerstat, 2019⁶).

Both districts also hold considerable touristic potential, as they are relatively close to the city of Baku with its more than two million inhabitants and international air connections. Many tourists, national and international alike, flee the summer heat of the plains towards the cooler alpine valleys and forested areas of Shamakhi and Ismayilli regions. This touristic potential of the regions is likely to rise further when the effects of climate change make summer heat in the city even more difficult to bear. The road linking the capital to these districts is currently being upgraded, reducing the travel time necessary to reach both Shamakhi and Ismayilli.

2.2 Target sectors: Water and agriculture

2.2.1 Water sector

Water flowing from Azerbaijan's mountain ranges and from neighbouring Georgia is of crucial importance for the economy and livelihoods of millions of Azeris residing in the lowlands. The national authorities mainly responsible for water management and policymaking are the Ministry of Ecology and Natural Resources (MENR) as well as the State Agency for Water Resources established in 2011 within the Ministry of Emergency Situations (MES). Furthermore, there are two mainly state-owned joint stock companies

⁵ <https://www.stat.gov.az/source/demography/?lang=en>

⁶ https://www.stat.gov.az/source/system_nat_accounts/?lang=en

that fulfil important tasks in water management, namely the Azerbaijan Amelioration and Water Farm JSC and Azersu JSC.

Rivers play a crucial part in the Azerbaijan's water sector. The extensive river network covering almost all of the country supplies most of the irrigation water and power most of its hydroelectric power plants. In total there are 8.359 rivers, all of them draining into the Caspian Sea basin, where hydrographically Azerbaijan belongs to. The longest river in Azerbaijan is the Kur River, with 906 km of its total length of 1.515km situated within the territory of Azerbaijan. In total, the Kur River covers an area of 188.000 km². The second largest river of the country, and a tributary to the Kur River, is the Araz River, whose watershed extends over a surface area of 102.000 km².

In addition, there are numerous smaller rivers, especially in the mountain areas, including the two pilot areas Ismayilli and Shamakhi. Most of these rivers are fed by snow melt and rain. In other districts, also glacier melt contributes to river flow in summer. The most important of Azerbaijan's glaciers include Bazarduzu (covering an area of 3.62 km²), Shahdag (1.08 km²), Bazaryurd (1 km²), and Tufan (0.51 km²). There are also around 450 natural freshwater and saltwater lakes on Azerbaijan's territory, most of them small lakes in mountainous areas. The largest lake is Sarisu lake, extending over an area of 65.7km² with a volume of 59.1m³ (MENR, 2015⁷).

In total, Azerbaijan's water reserves amount to 30.9 billion m³, 10.3 billion m³ of which are formed on Azerbaijan's own territory and another 20.6 billion m³ entering the country from its neighbours (MENR, 2015). The average annual rainfall within Azerbaijan is 427mm, equivalent to a total of 36.96 km³, out of which less than a third (119mm or the above-mentioned 10.3 km³) constitute the country's water formulation. The remaining 26.6 km³ evaporate (Water Strategy Draft, 2016).

Around 71.7% of the water abstraction from natural resources is consumed, out of which almost three quarters (73%) are used for irrigation and agriculture. 23% are used by industrial needs, and around 3.3% are being consumed as drinkable water for domestic purposes. A very significant amount, namely almost 40%, is being accounted for as "water loss during transportation" (Azerstat, 2019⁸). There is, thus, significant potential to increase the efficiency of Azerbaijan's current water management system (Table 1).

⁷ <https://unfccc.int/resource/docs/natc/azenc3.pdf>

⁸ <https://www.stat.gov.az/source/environment/?lang=en>

Table 1 - Main indicators characterizing the protection of water resources and their rational use (in million m³) over the period 1990-2018 (Source: Azerstat, 2019)

	1990	1995	2000	2005	2010	2015	2018
Water abstraction from natural water resources - total	16176	13971	11110	12050	11566	12285	12847
per capita, m ³	2293	1847	1397	1438	1295	1289	1308
Water consumption - total	12477	10223	6588	8607	7715	8567	9205
of which:							
domestic and drinking purposes	402	327	449	521	405	323	306
industrial needs	3418	2173	2316	2360	1742	2117	2111
of which drinking water	317	111	82	61	54	46	44
irrigation and agriculture supply	8627	7720	3819	5710	5497	6057	6722
Volume of recycled and consequently used water	1628	1696	1875	2224	1787	2441	2345
in percent to total water consumption for industrial needs	32	44	45	49	51	54	53
Water losses during transportation	4206	3747	3053	3443	3851	3718	3643
Discharge of sewage waters	5026	4247	4106	4878	6005	5575	5147
of which untreated waste water	303	134	171	161	164	305	272

The amount of water taken from natural sources as well as water consumption have decreased, however, since the 1990s – by 32.7% and 34.1%, respectively. This is likely due to the combination of the degradation of water management infrastructure and practice after the collapse of the Soviet Union and the actual lack of water sources and its imbalance condition compared to the water demand. Today, the management of water resources for irrigation purposes is to a large extent being undertaken by 479 Water Users Associations (WUAs), with the total irrigated area served by them is 1.329.044 hectares (Water Strategy Draft, 2016).

2.2.2 Agriculture Sector

Despite the economic development and modernization Azerbaijan has experienced over the last years, the agriculture sector still remains of crucial economic importance. Although it only contributed 7.2% to Azerbaijan's GDP in 2017 (compared to 27.3% for the mining sector, including oil and gas), 36.4% percent of its employed population or 1.75 million people were dependent on incomes from agriculture, forestry and fishing (Azerstat, 2019).

Like many Post-Soviet-states, Azerbaijan has seen far-reaching structural transformations in its agriculture sector over the last three decades. While in the early 1990s more than 60% of agricultural production took place in large-scale agricultural enterprises, this share has dropped to less than 10% in 2017 (Azerstat, 2019⁹). This restructuring of agricultural activities towards many private smallholders has been accompanied, in some cases, by drops in productivity and irrigation infrastructure degradation. This has led to calls for “land consolidation” to reverse this trend which are currently gaining more prominence in the debate in Azerbaijan (opinions from workshop participants in Baku on July 11th, 2019).

More than half (54%) of the gross output of the agriculture sector in Azerbaijan is generated via the production of livestock products. Of the almost 4.8 million hectares of land categorized by the State Committee on Property Issues as “utilised agricultural area”, 51% are classified as hayfields and pastures

⁹ <https://www.stat.gov.az/source/agriculture/?lang=en>

and 43% as arable land. In 2017, almost 1.7 million hectares have been characterized as “sown areas”, i.e. agricultural lands under active use. On 35.8% of these sown areas, wheat was cultivated, on 19.1% barley, on 8.2% cotton, on 4.2% vegetables, on 3.5% potatoes and on 2.1% maize, the rest of the land being used for a wide range of other agricultural products. On these lands, almost 3 million tons of cereals and pulses were produced, 1.4 million tons of vegetables, 910.000 tons of potatoes, 438.000 tons of melons, and 208.000 tons of cotton (Azerstat, 2019).

Around 1.4 million hectares of the country’s arable land are irrigated (Azerstat, 2019). Due to the hot and dry climate, especially in the plains and lowlands of Azerbaijan, sufficient irrigation is necessary to achieve good yields. According to information contained in the Draft of the National Water Strategy from 2016, 85-90% of agricultural products are produced on irrigated lands. Irrigation infrastructure, often dating back to the Soviet Union, is of crucial importance to maintain productivity in these areas. Nevertheless, a substantial part of this infrastructure degraded significantly over the last decades – especially secondary and third level irrigation channels. As a result of this, and in combination with improper irrigation management in other areas, more than 600.000 hectares of land experience some form of degradation, including salinization (Water Strategy Draft, 2016).

In the pilot areas of the present study, Ismayilli and Shamakhi, there are various forms of agriculture. Large parts of the foothills and lowlands are formally categorized as irrigated lands, although the actual inefficient irrigation infrastructure and management only allows for low yields (mostly wheat cultivation). Where enough irrigation water is available, many farmers have been switching to other crops like grapes over the past years.

In the middle altitude zones of these districts, situated roughly between 1000 and 2000 meters above sea level, much of the land is covered by forests. The agricultural areas situated in these areas, often steep and hardly accessible hillsides, are mostly used for hay and fodder production to sustain livestock breeding.

The high-altitude mountain areas are mainly used as summer pastures, also by herders arriving from other districts of the country. This influx of livestock often contributes to pastures degradation due to overgrazing and erosion, as the maximum number of heads of cattle or sheep per hectare is often exceeded. Moreover, a recent land category conversion from winter pasture into arable land (approx. 23000 ha in the last decade) have been causing an earlier livestock transhumance and hence increasing pressure to summer pastures. Monitoring and controlling the herds in the often-remote areas proves to be difficult and is only rarely enforced.

2.3 Current climate

On the territory of Azerbaijan eight different climate zones can be found, ranging from semi-desert and steppe climates to alpine tundra in the higher elevations of the Greater and Lesser Caucasus mountain ranges. The predominant climate is subtropical, with high amounts of sunshine (between 1.900 and 2.900 hours annually). Hot and dry summers are prevalent in the lowlands, whereas in the mountain areas summers are cooler and, at least in parts of the territory, more humid. The lowest temperatures recorded on the territory of Azerbaijan are -32 °C and the highest 45 °C. Rainfall ranges from 150-200mm annually on the Absheron peninsula to 1.600-1.700mm annually in the foothills of the Talysh mountains. Two thirds of Azerbaijan’s territory experience less than 400mm of average annual rainfall (MENR, 2015¹⁰).

¹⁰ <https://unfccc.int/resource/docs/natc/azenc3.pdf>

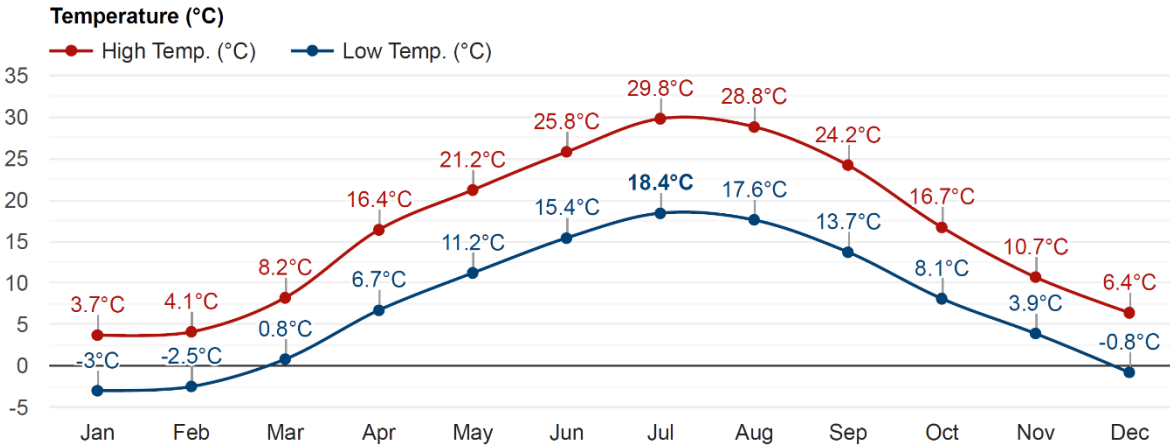


Figure 2: Average temperature in Shamakhi (Source: <https://www.weather-atlas.com/en/azerbaijan/Shamakhi-climate>)

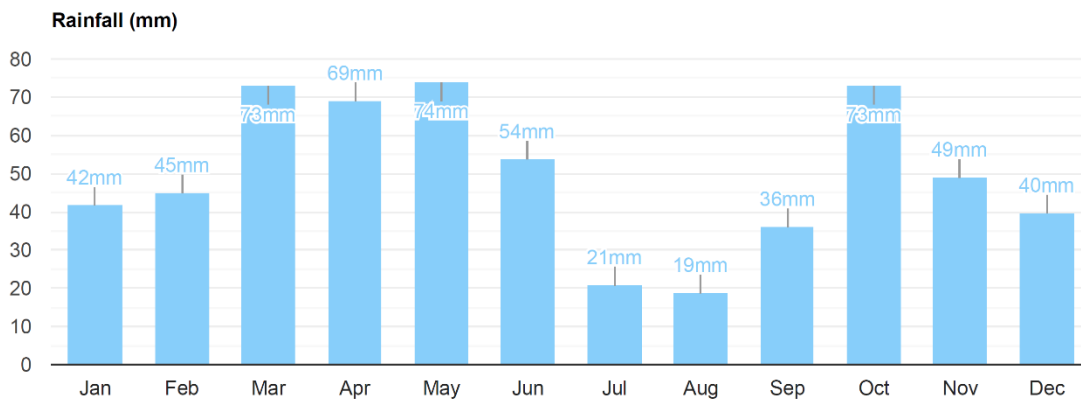


Figure 3: Average rainfall in Shamakhi (Source: <https://www.weather-atlas.com/en/azerbaijan/Shamakhi-climate>)

Over the decade 1991 – 2001, the mean annual temperature in Azerbaijan showed an increase of 0.4 °C compared to the 30-year period 1961 – 1990. Precipitation annual totals experienced a decreasing trend over the recent decades, showing a higher spatial variability over the country than temperature (GRIDA, 2015).

Temperature rise is expected to continue over the future together with further changes in total precipitation and extreme weather events, such as heavy rainfall and droughts, even though with higher uncertainty. These changes could further exacerbate the various risks in mountain regions, especially related to agriculture, ecosystems, human health and community resilience (Gilda, 2015; MoNP 2015; MoENR 2010). In particular, Azerbaijan’s agriculture and water sectors are heavily dependent on freshwater supply from snow and rain for irrigation, hydropower and domestic use (SDC, 2019). 80% of the country agricultural output comes from irrigated lands, making this sector particularly vulnerable to future climate risks with relevant economic losses due to more severe drought occurrences (WB, 2012).

Due to the steep topography, the Greater Caucasus region is also susceptible to floods, mudflows and other natural hazards (GRIDA, 2015; UNDP, 2018). Over recent decades, the frequency and magnitude of floods have increased, also triggered by single rainfall events of high intensity (USAID, 2017; UNDP, 2018). These evidences of the region physical vulnerability highlight the need to develop proper early-warning

systems and infrastructures to monitor and manage natural hazards, which are still missing or unevenly distributed over the country (UNDP, 2018).

3 General methodology

3.1 The Impact Chains approach

This study aims to support a better comprehension of the factors involved in climate vulnerability and impact assessments. The approach here reported follows and builds upon the existing knowledge developed in the Vulnerability Sourcebook and its Risk Supplement¹¹. The so-called Impact Chain methodology provides an established and scientifically sound approach to explore the risk factors according to the IPCC AR5 definition of the risk components (i.e. hazard, exposure and vulnerability) (Figure 4). An impact chain is an analytical tool that helps to better understand, structure and prioritize the factors that drive risks in the system of concern. The approach investigates factors involved in risk processes combining quantitative data analyses (e.g. indices and statistical regressions) with qualitative information coming from local experts and stakeholder’s participation (e.g. climate managers and local farmers). Local knowledge is hence included in the analysis providing information that would not be possible to collect from in-situ data, earth observation products or indices-based analysis only. The final risk assessment results from the combination of the hazard, exposure and vulnerability components into one score on a low-moderate-high-very high ranking scale through a qualitative assessment visually supported associating a green-yellow-orange-red colours scale. Such assessments can be validated and integrated by local expert’s revision and their opinions. By doing so, the impact chains application allows to engage the local experts throughout the whole risk assessment combining their knowledge and improving their comprehension of vulnerability factors and the adaptation strategies to adopt.

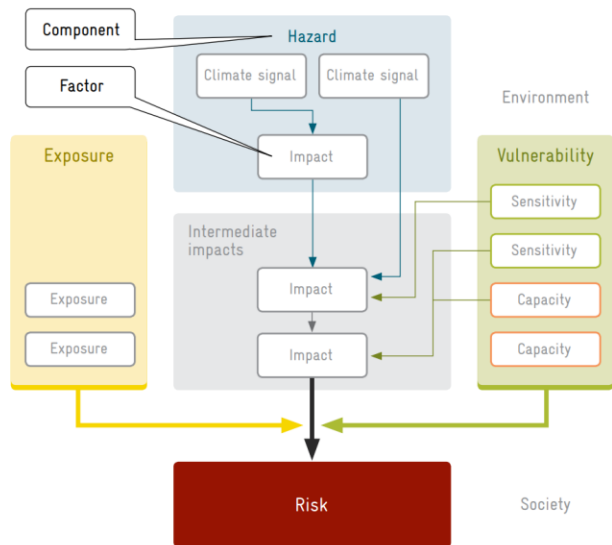


Figure 4 - Structure of an impact chain according to the IPCC AR5 concept.

¹¹<https://www.adaptationcommunity.net/vulnerability-assessment/vulnerability-sourcebook/>;
https://www.adaptationcommunity.net/wp-content/uploads/2017/10/GIZ-2017_Risk-Supplement-to-the-Vulnerability-Sourcebook.pdf

In this project, the Impact Chains were developed in a workshop, which was held on the 11th of July 2019 in Baku, involving experts from the Ministry of the Ecology and Natural Resources (Figure 5). At that stage, hazard, exposure and vulnerability factors and their relations were identified and connected to address specific risks processes (e.g. risk of drought for agricultural areas). This application allowed to quickly collect initial information and get local perceptions on the relevant factors for final risks from drought, flood, forest damage and erosion. The Impact Chains developed during the workshop were used as a base for further steps of investigation on the data needed and their availability to represent the identified risk factor. Climate indices were calculated from climate change projections, data-driven and spatial analyses were carried out based on ancillary data, a questionnaire and this report was provided to key experts for the integration and collection of their local knowledge. In particular, this process was established to overcome the Covid-19 emergency conditions, which did not allow to hold a second workshop with experts and stakeholders in Baku envisaged for March 2020.

Finally, the combination of data driven analyses with more qualitative opinions from local experts' participation both in the workshop, the questionnaire and the revision of this report provided information on hazard, exposure and vulnerability components of risk. Such analyses were then reported in a summary table at the end of each risk assessment together with the level of confidence and a brief description of critical settings of risk conditions for the two pilot areas for current and future situation.



Figure 5 – Workshop in Baku on the 11st July 2019 for the development of the Impact Chains together with local experts from the Ministry of the Ecology and Natural Resources

3.2 Quantitative data

This project was based on the combination of quantitative and qualitative information. Quantitative information was mainly used for climate and climate change information. For a detailed description on climate data and climate data processing and analysis see section 4.1. Furthermore, data on terrain, land use, statistical data as well as earth observation data was employed to develop indices and analyses at territorial level. Results of quantitative data and analyses were visualized through maps using Geographic Information Systems. Some of the local data were provided by the local offices of the Ministry of Ecology

and Natural Resources in Baku. This process was carried out together first with Mr. Bariz Mehdiyev and then Mr. Yashar Karimov, two local consultants from the Ministry of the Ecology and Natural Resources, who supported us in the data collection from the governmental agencies. Many other information was retrieved from established open datasets listed in Table 2. This table represents a base for further analyses and knowledge sharing in future applications and research improvements on the whole Azerbaijan country.

Table 2 - List of available territorial datasets used within the climate vulnerability assessment in two pilot regions of Azerbaijan

Resource	Data type	Resolution	Description / Link
Climate data and climate change information	Regular grid	0.5° x 0.5°	CMIP5 output of four climate models (IPSL-CM5A-LR, GFDLESM2M, HadGEM2-ES and MIROC5) (see section 4.1) https://www.isimip.org/
Digital Elevation Model	Regular grid	90 m	https://cgiaresci.community/data/srtm-90m-digital-elevation-database-v4-1/
Land Cover	Regular grid	300 m	https://sustainable-caucasus.unepgrid.ch/layers/ESA2010_Cauc:geonode:ESA2010_Cauc
Global forest change	Regular grid	30 m	https://earthenginepartners.appspot.com/science-2013-global-forest
Built-up settlements	Regular grid	3 arcs	https://www.worldpop.org/geodata/summary?id=17065
Road networks	Vector data	-	https://geonode.wfp.org/layers/ogcserver.gis.wfp.org:geonode:azetr roads osm
Rivers	Vector data	-	https://sustainable-caucasus.unepgrid.ch/layers/geonode:river_of_azerbaijan_republic_1
National statistics	Aggregated information at rayon levels	-	https://www.stat.gov.az/source/agriculture/?lang=en

Country level information on Azerbaijan and local information on the two selected pilot areas were extracted from global datasets and maps. This information was then used as inputs to model risk processes.

3.3 Questionnaire

Information on local experts' opinions on current condition of vulnerability factors was retrieved during the workshop and by a questionnaire based on the Impact Chains components. The questionnaire was structured in 4 parts, for a total of 34 questions and involving 8 local experts from a different range of

expertise, mainly from hydrology, agriculture and forestry. Part 1 involves drought risk, part 2 focuses on flood risk, part 3 deals with forest damages and part 4 with the management settings on those common factors across different risk processes (e.g. Integrated Water Resource Management, financial and human resources) (more information in the Annex). The questionnaire was composed of multiple choices, open questions and specific questions where experts could vote selecting a low-medium-high-very high ranking system.

By doing so, existing vulnerability factors were evaluated, and the Impact Chains were integrated with other factors perceived as relevant in the overall risks. This step was particularly relevant to both retrieve information on potential misrepresentations associated to the limited data availability and to integrate local knowledge within the analyses.

4 Calculation and analysis of hazards and impact indices

Different desk-based research methodologies were applied to complement the local knowledge from the workshop with more quantitative assessments of potential climate impacts in the two pilot areas. Climate data was used as input to calculate and visualize future projections of climate-hazards indices over the whole country. While such analysis provided information on the climate-related hazards (e.g. drought severity and flood frequency), vulnerability and impact indices were developed to describe exposed elements and their vulnerability factors due to the limited data availability. This process supported a synthetic representation of various information, their interpretation and dissemination.

4.1 Climate change, future scenarios and potential effects

To further assess future climate changes in Azerbaijan and to support future adaptation options, available climate change scenarios until the end of XXI century for the country were collected and analysed. In particular, the climate projections of daily temperature and precipitation over the period 2006 – 2099 under two emission scenarios, i.e. the Representative Concentration Pathways RCP4.5 (medium emission reduction) and RCP8.5 (no emission reduction or also called “business as usual” scenario), were retrieved from the ISIMIP (Inter-Sectoral Impact Model Intercomparison Project) dataset¹² together with the historical simulations over the period 1951 – 2005. The ISIMIP2b simulation protocol provides bias-corrected CMIP5 output of four climate models (IPSL-CM5A-LR, GFDLES2M, HadGEM2-ES and MIROC5) at 0.5° x 0.5° spatial resolution¹³. The bias-correction was performed by considering the reference EWEMBI dataset¹⁴ which covers the entire globe at 0.5 horizontal spacing and daily temporal resolution from 1979 to 2013.

Climate simulations were used to calculate a range of different indices considering both trends of average conditions and extreme values over the simulation period (Table 3). Such analysis provided useful information on chronic shifts of average climatic conditions and acute extreme features in terms of frequency, duration and severity over the whole Azerbaijan.

¹² <https://www.isimip.org/>

¹³ <https://www.geosci-model-dev.net/10/4321/2017/>
<https://www.earth-syst-dynam.net/9/627/2018/>

¹⁴ <http://dataservices.gfz-potsdam.de/pik/showshort.php?id=escidoc:3928916>

Table 3 – List of relevant climate-related hazards indices calculated using CMIP5 outputs of four climate models

Climate-hazard	Index name	Index description
Mean temperature	Mean temperature	Mean temperature over different timescales (monthly, seasonal, annual)
Maximum temperature	Annual daily maximum temperature	Maximum daily temperature over different years
Mean precipitation	Mean precipitation	Mean precipitation over different timescales (monthly, seasonal, annual)
Maximum precipitation	Maximum of 5-day precipitation sum	Maximum cumulative precipitation calculated considering a 5 days window
Drought	Standardized Precipitation Index (SPI-12)	Statistical monthly index comparing cumulated precipitation for 12 months with the long term precipitation distribution for the same location and cumulation period
	Standardized Precipitation Evapotranspiration Index (SPEI-12)	Statistical index comparing cumulated climatic balance for 12 months with the long term distribution for the same location and cumulation period

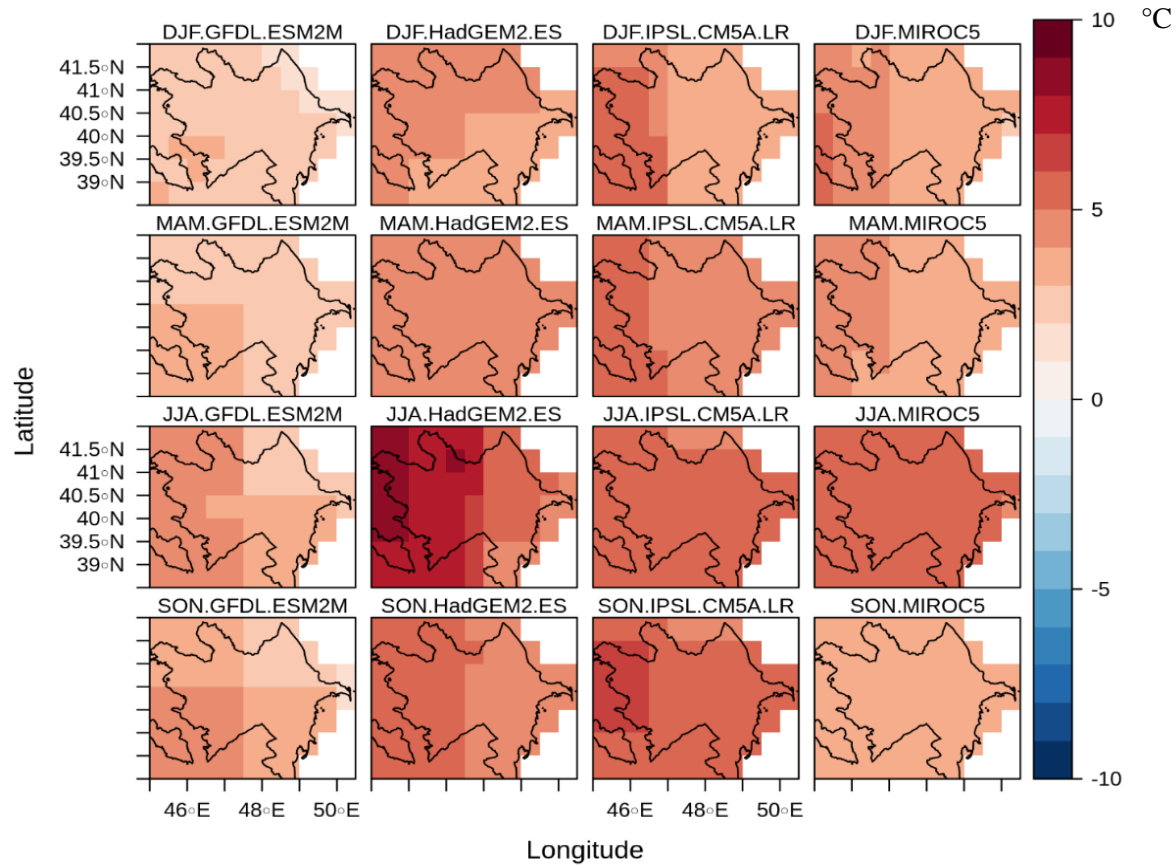


Figure 6 – Temperature increase until 2080. Spatial distribution of mean differences in seasonal maximum temperature between 2051 – 2080 and 1971-2000 for each model simulation under RCP8.5. Climatological seasons are considered (DJF for winter, MAM for spring, JJA for summer and SON for autumn)

The 1951 – 2099 model ensemble series of mean annual temperature averaged over all the grid cells covering Azerbaijan reveals significant increases in temperature at annual and seasonal scales for both RCPs. In particular, the annual mean temperature ensemble series over the entire spanned period (1951 – 2099) shows an increase of around +0.3°C and +0.5°C per decade in RCP4.5 and RCP8.5 scenarios, respectively. Even though the trends for precipitation are less evident, a significant decrease is pointed out in summer of -25 mm and -40 mm by the end of the century for RCP4.5 and 8.5, respectively, together with a significant increase in winter precipitation of around 10 mm for both scenarios.

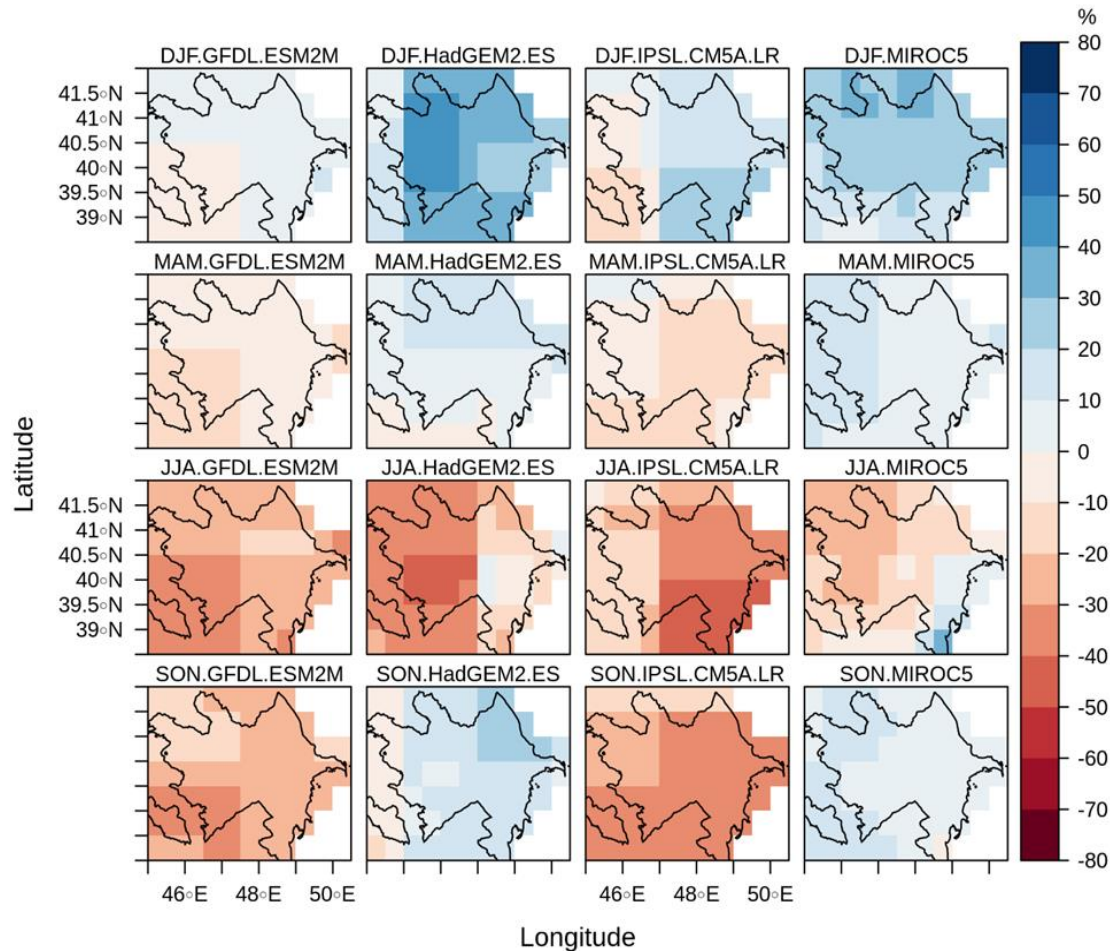


Figure 7 - Spatial distribution of mean relative differences in seasonal total precipitation between 2051 – 2080 and 1971–2000 for each model simulation under RCP8.5. Climatological seasons are considered (DJF for winter, MAM for spring, JJA for summer and SON for autumn)

The spatial distribution of the climate signal was evaluated by computing for each model simulation and both RCPs the changes in the 30-year means of seasonal temperature and precipitation over 2051 – 2080 with respect to the recent past (1971 – 2000) for each grid point (Figure 6 and Figure 7, only maximum temperature and total precipitation from RCP8.5 are reported). The increase in maximum temperature is depicted by all models with the greatest increase in summer (5°C–10°C) and autumn (4°C–7°C), especially in the western part of the country. It is important noting the generalized increase in temperature over the whole country. From a climate impact perspective, similar temperature changes in different areas (e.g. mountain and coastal) also means different types of impact. For example, while a 4°C temperature increase in autumn in a mountain area could lead to no or very limited snow precipitation, which then would affect the hydrological cycle in the upcoming months and downstream, in coastal areas such an increase might lead to no or very different impacts.

A lower model agreement is evident for precipitation, especially in spring and autumn. It is worth noting that the spatial variability of changes is very smoothed due to the coarse spatial resolution of the climate projections (~ 50 km), which does not allow to capture the local variability and to identify specific hotspots. However, even if the temperature change is similar overall the country, the impacts are expected to highly vary over the different areas.

Changes are not involving the mean climate signal only, but also climate extremes. The annual daily maximum temperature extreme is expected to experience an increase of up to 10°C in the western Azerbaijan at the end of the XXI century in RCP8.5 scenario (Figure 8a) together with a relevant increment in the annual occurrence of tropical nights (days with minimum temperature above 20°C), which in 2099 will affect around 60 days more than today (not shown). The same signal is depicted by RCP4.5 but with slower increments. A general increase in rainfall intensity is also pointed out (Figure 8b). The maximum 5-day precipitation sum is found to increase especially in the far future over the eastern and coastal portion of the country up to +40% in 2070 – 2099 (RCP8.5) with respect to reference period (1971 – 2000).

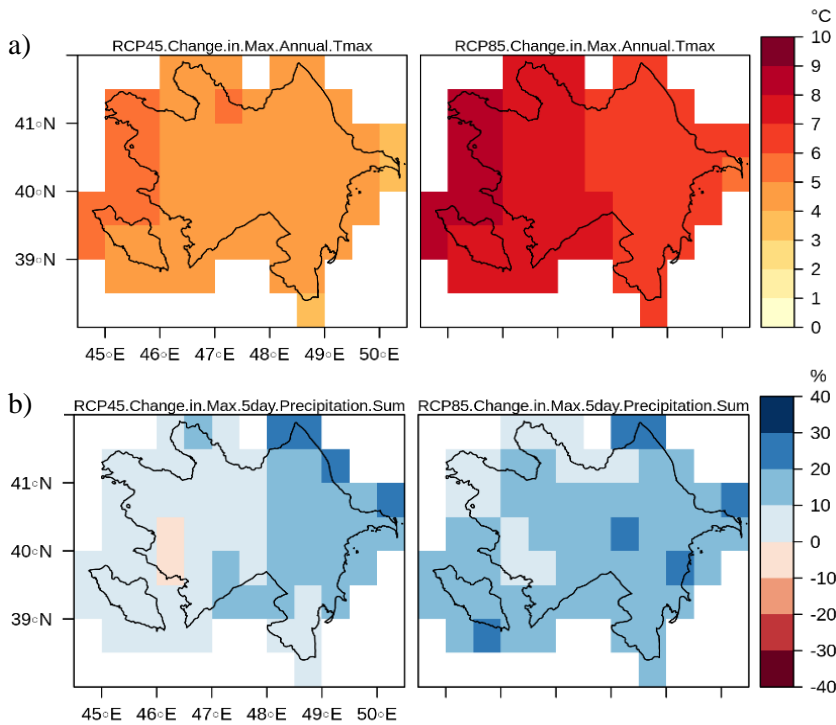


Figure 8 - Spatial distribution of differences between far future (2070 – 2099) and reference (1971 – 2000) in a) annual maximum temperature extreme (absolute differences) and b) annual maximum of 5-day precipitation sum (relative differences) for both RCP scenarios

Changes in drought conditions and characteristics over Azerbaijan were also investigated by combining the information on temperature and precipitation. The Standardized Precipitation Index and the Standardized Precipitation Evapotranspiration Index computed at monthly scale over a 12-month accumulation period, i.e. SPI-12 and SPEI-12¹⁵, highlighted a generalized increase in drought frequency (number of event per 10 years), duration (months per event) and severity (absolute integral of standardized index values during one drought event) over future, especially in the western part of the country for the 2070 – 2099 period. SPEI-12 reports a more intense increase in drought conditions than SPI-12 due to the contribution of rising temperature in triggering greater evapotranspiration rates. In Figure 9 and Figure 10 the projected changes in drought conditions due to precipitation variability (SPI-12) and the water balance (precipitation *minus* evapotranspiration, SPEI-12) for 2070 – 2099 with respect to reference period (1971 – 2000) are reported.

¹⁵<https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/joc.5291>
<https://climate.colostate.edu/pdfs/relationshipofdroughtfrequency.pdf>

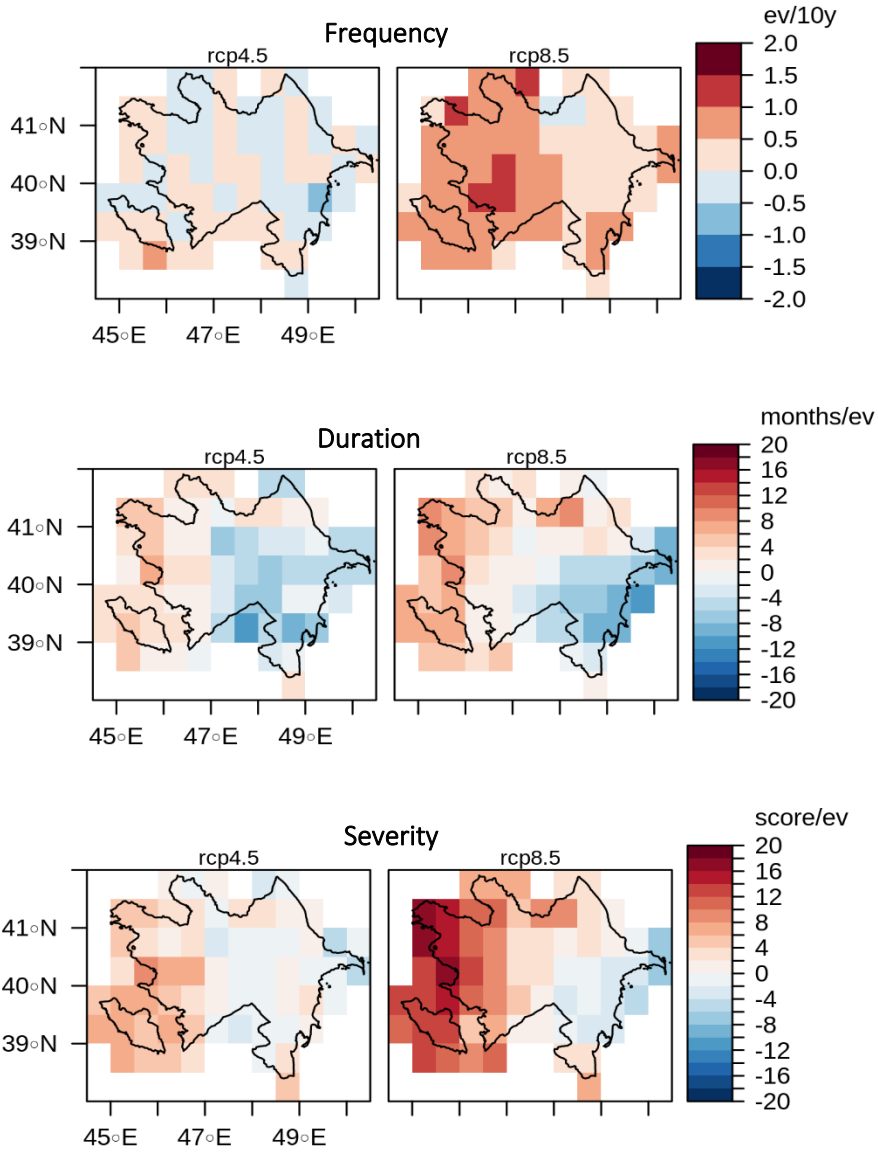


Figure 9 - Changes in drought frequency (number of events per 10 years), duration and severity in far future (2070 – 2099) with respect to the reference period (1971 – 2000) under both RCP scenarios. Drought spells are computed from SPI-12 series and depend on precipitation only

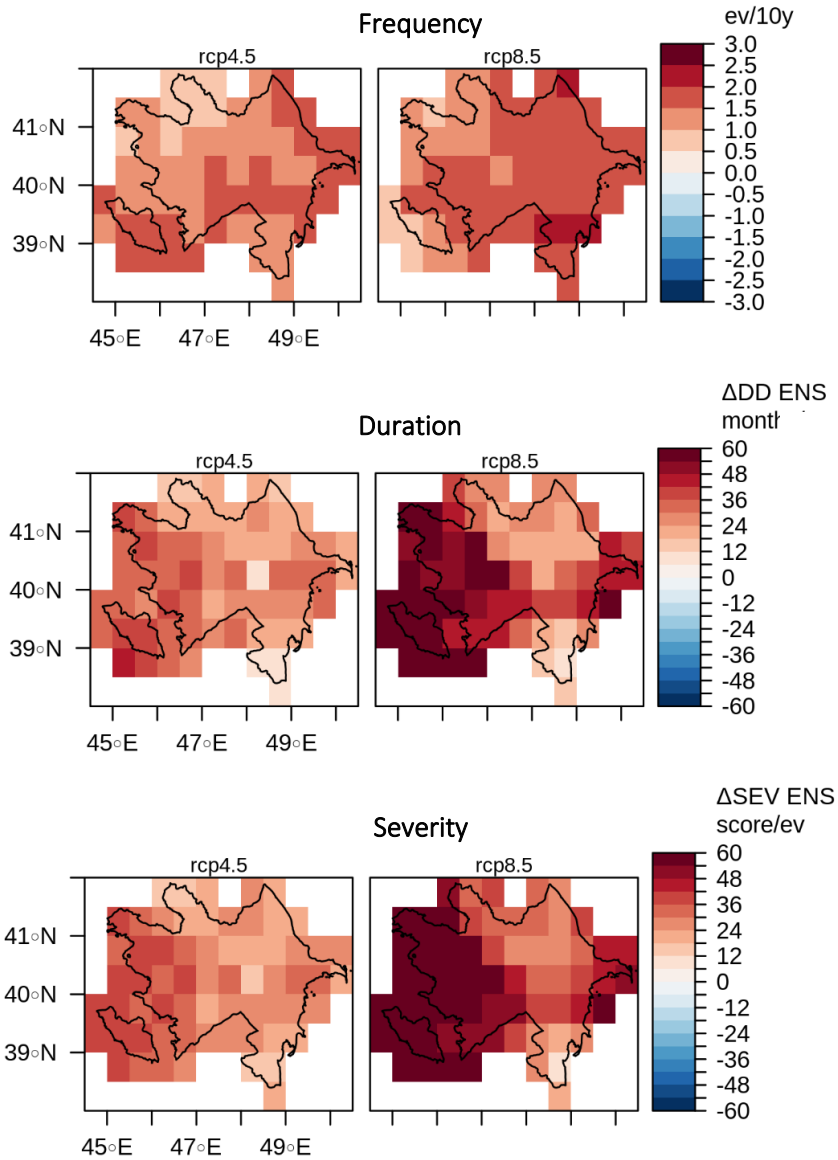


Figure 10 - Changes in drought frequency (number of events per 10 years), duration and severity in far future (2070 – 2099) with respect to the reference period (1971 – 2000) under both RCP scenarios. Drought spells are computed from SPEI-12 series and depend on precipitation and evapotranspiration balance.

4.2 Snow cover changes

Climate change can also be detected looking at the snow changes over the last decades. To better monitor these changes and understand the snow dynamics, observations from surface stations, remotely sensed data, and model simulations have been extensively exploited on several mountain areas in the most recent decades¹⁶. More specifically, remotely sensed images can provide information on snow spatial pattern, thus representing a valuable tool in remote and high elevation areas, where few ground stations are available.

Recently, Notarnicola, 2020⁷ presented a quantification of snow changes in global mountain areas by exploiting the full data set of MODIS imagery from 2000 to 2018. This analysis reveals that around 78% of the global mountain areas are undergoing a snow decline characterized by snow cover duration decrease up to 43 days, and a snow cover area decrease up to 13%. Few areas show positive changes with snow cover duration increase up to 32 days, and snow cover area increase up to 11%, mainly during wintertime in Northern Hemisphere.

Greater Caucasus is among the areas in the Northern Hemisphere that is suffering from snow decrease in the last two decades. In details, the main significant changes are related to the Snow Cover Duration (SCD) (that is the duration of the snow in one season expressed in days) and the Last Day of Snow (LSD) (that indicates the last day an area is covered by snow thus providing indications on the snow melt timing). The main elevation belts affected by these changes are between 2500 m and 4000m, and between 4000 m and 5500 m. In the following, the values related to the changes in the main snow parameters are reported (the values in bracket represent the 95% confidence interval based on Mann-Kendall statistics):

- Changes in SCD over 2000-2018 between 2500-4000 m: -20.9 days (-40.8 days, - 2.4 days)
- Changes in SCD over 2000-2018 between 4000 – 5500 m: -15.0 days (-20.9 days, -8.3 days)
- Changes in the LSD (earlier snow melt) over 2000-2018 between 2500-4000 m: - 16.8 days (-28.8 days, -3.4 days).

The analysis with meteorological parameters indicates that the main driver for the snow changes is related to the increasing near surface temperature which affects the snow decrease especially during winter (from December to February) and in spring period (from March to May).

In Figure 11, as an example the variation of SCD over 2000-2018 is illustrated over the Greater Caucasus, where the dark red and blue areas indicate significant negative and positive changes respectively.

¹⁶ <https://onlinelibrary.wiley.com/doi/pdf/10.1002/wcc.179>
<https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/joc.5674>
<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016EF000514>
<https://www.nature.com/articles/s41612-018-0012-1>
<https://www.sciencedirect.com/science/article/pii/S0034425720301516>

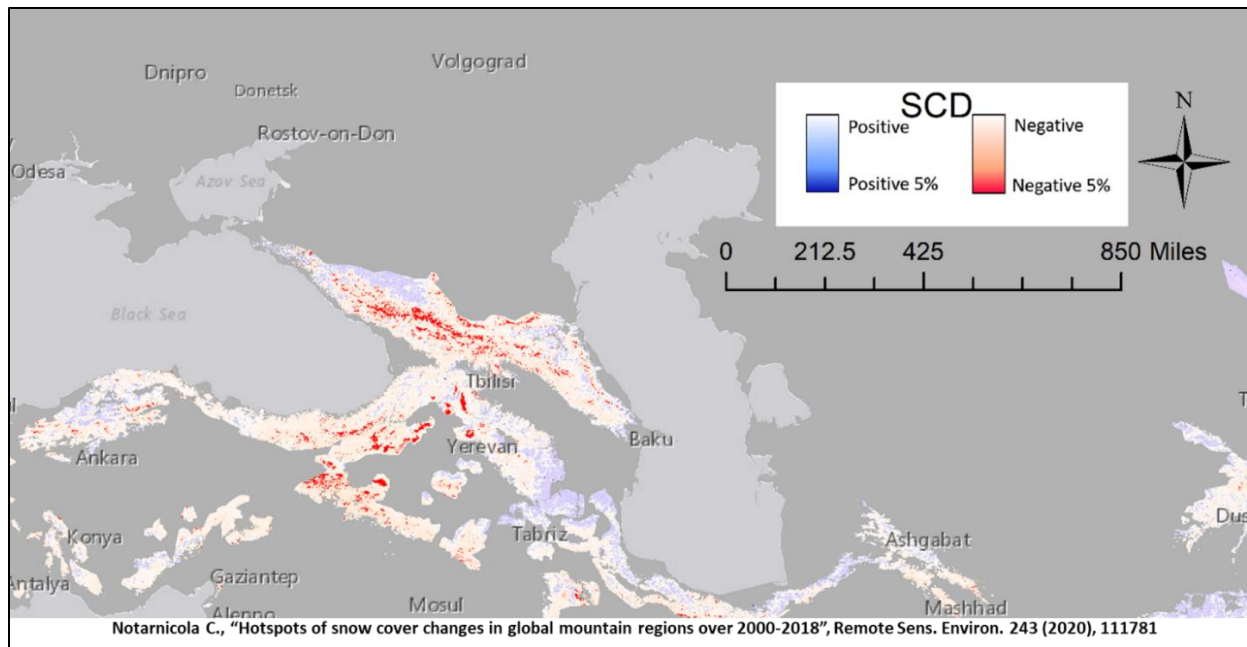


Figure 11 - Snow Cover Duration (SCD) changes over 2000-2018, for the area of Great Caucasus. The dark red and blue areas indicated significant negative and positive changes. (Author C.Notarnicola, Eurac Research).

4.3 Erosion modelling

In case of erosion, the RUSLE index-based approach¹⁷ was here applied according to the data availability in the region. The model was selected to other more accurate, but resource intensive approaches (i.e. physically based models), to cover large scales areas in a data scarce environment with moderate resources. Although this model does not provide information on run-off contributions to erosion processes, it provides a useful outlook on potential hotspot of erodibility mainly connected to morphological characteristics and land cover type. Slope length and slope angle (LS-factor) were combined with the land cover type map to provide a synthetic information on hotspot of erosion process and soil loss. Data of slope length, steepness and land cover type were elaborated through established functions for the RUSLE index in the SAGA software, reported in QGIS software for visualization and resulting in a synthetic index ranked as low-medium-high-very high according to the values and their quantiles distribution.

4.4 Forest accessibility

Indices were developed to evaluate vulnerability factors and their contributions to specific risk processes. In case of risk of forest damage, a forest “accessibility” index was developed combining land cover information with a slope angle map. Results were reported in QGIS for visualization through a synthetic index ranked in a low-medium-high-very high scale according to their quantiles distribution. By doing so, we investigated the effects of land cover and slope angle maps on the final risk of forest damages due to deforestation activities.

¹⁷ <https://access.onlinelibrary.wiley.com/doi/abs/10.2134/jeq1993.00472425002200030009x>

4.5 Land degradation assessments

The assessment of vegetation changes was here implemented to detect potential processes of land degradation. This analysis involved Earth Observation techniques being a unique tool to map land cover change processes across space and time. Although land cover modifications strongly vary among land cover classes, vegetation change is a key indicator to mirror changes in land use intensity (loss of vegetation cover due to increasing animal numbers and subsequent overgrazing) that may result in land degradation. A pixel-based trend analysis, based on EO-derived vegetation cover estimates, is an effective method to consistently map vegetation changes in a spatial and retrospective way which allows to understand the underlying land use change processes¹⁸. The open Google Earth Engine was here employed to map long-term vegetation changes in the two rayons in Azerbaijan and allowing transferability of such approach to other mountain regions. All Landsat surface reflectance images (Landsat 5,7,8) between June and September were selected covering a time period from 1984 to 2019 to derive long term vegetation changes. A 4 months period was selected in order to integrate a large amount of Landsat images (hence increasing the chance to get a cloud-free image for each pixel for each year) representing mid-season vegetation conditions (following an initial visual assessment of recent Sentinel-2 satellite). To rule out annual variations in the vegetation signal and cloud and cloud shadow affected areas, an annual cloud-free composite was derived by calculating the pixel-based median band values for all images within each year. For doing this, the cloud masks provided together with the Landsat products were considered. For each composite the widely used Normalized Vegetation Index (NDVI) was derived as a reliable indicator of the vegetation amount and its condition. Finally, a linear pixel-based trend was calculated using the annual NDVI and the results were compared with regional statistical datasets and expert's opinion to investigate hotspots of land degradation due to livestock presence.

5 Assessment of major climate risks

The pilot areas – and the mountain regions of Azerbaijan more generally – are characterized by a variety of agro-ecological zones. They range from dry and agriculturally exploited plains and foothills at lower altitudes via temperate forest and pasture areas with comparatively less anthropogenic pressure on natural resources up to the high mountain zones with its summer pastures. Within these different zones, also the main climate risks and their root causes differ.

In the zones situated at lower altitudes, a multitude of factors contribute to a high vulnerability to the adverse effects of climate change in the water and agriculture sectors. The forest and pasture areas situated roughly between 1000 and 2000 meters above sea level, on the contrary, are characterized by less pressure on natural resources. As a consequence, they are in better shape and therefore more resilient against current extreme weather events and potential future changes in climate. The vulnerability of the transitional zone between the lower and the middle areas as well as the high mountain pastures can be categorized as intermediate (see Figure 12).

Each of the main risks identified during the workshop in Baku and confirmed on the field trip and during the focus group discussions in the regions will be represented by one impact chain in the following section. As outlined above, these risks differ according to the respective agro-ecological zones. Following the

¹⁸ <https://www.sciencedirect.com/science/article/pii/S0034425711000435>
<https://www.tandfonline.com/doi/abs/10.1080/0143116031000103844>

methodology outlined in section 3, each impact chain includes the underlying root-causes of a climate risk, the climate trigger (hazard), the various vulnerability factors, as well as the relevant exposure factors.

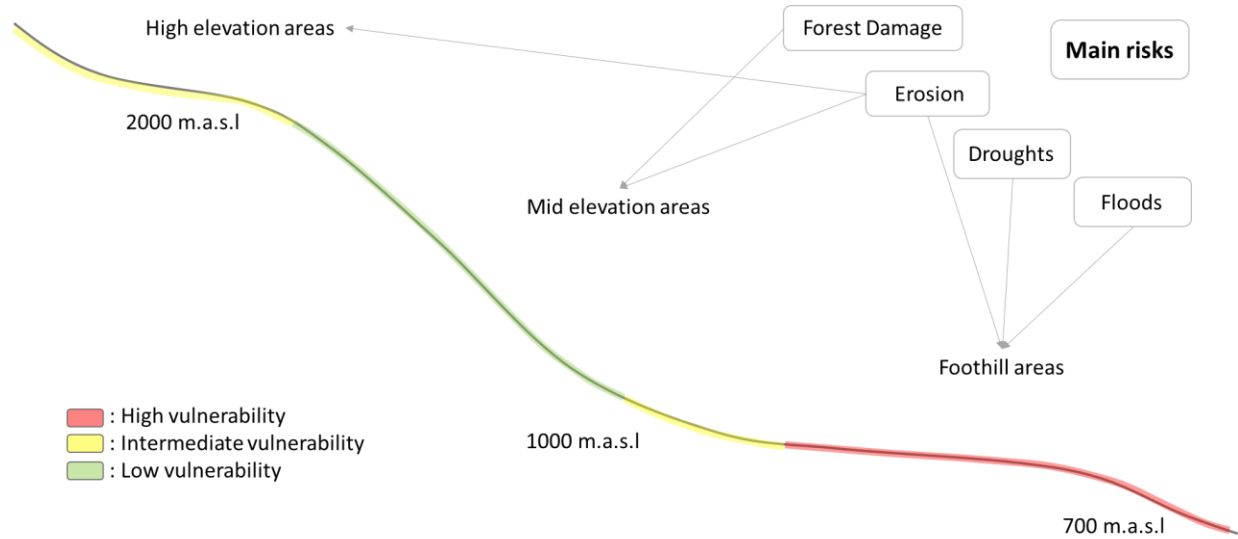


Figure 12 - Overview of agroecological zones in the pilot areas of Ismayilli and Shamakhi

5.1 Risk of drought

Risk from drought events for the two pilot areas considered agriculture in the foothill areas and the potential impacts in agriculture at mid elevation. These cases were considered as two different areas in terms of climate-hazards, but also for the exposure and vulnerability factors. For each of the two cases, an impact chain was developed and here below reported.

5.1.1. Risk of drought in agriculture in foothill areas

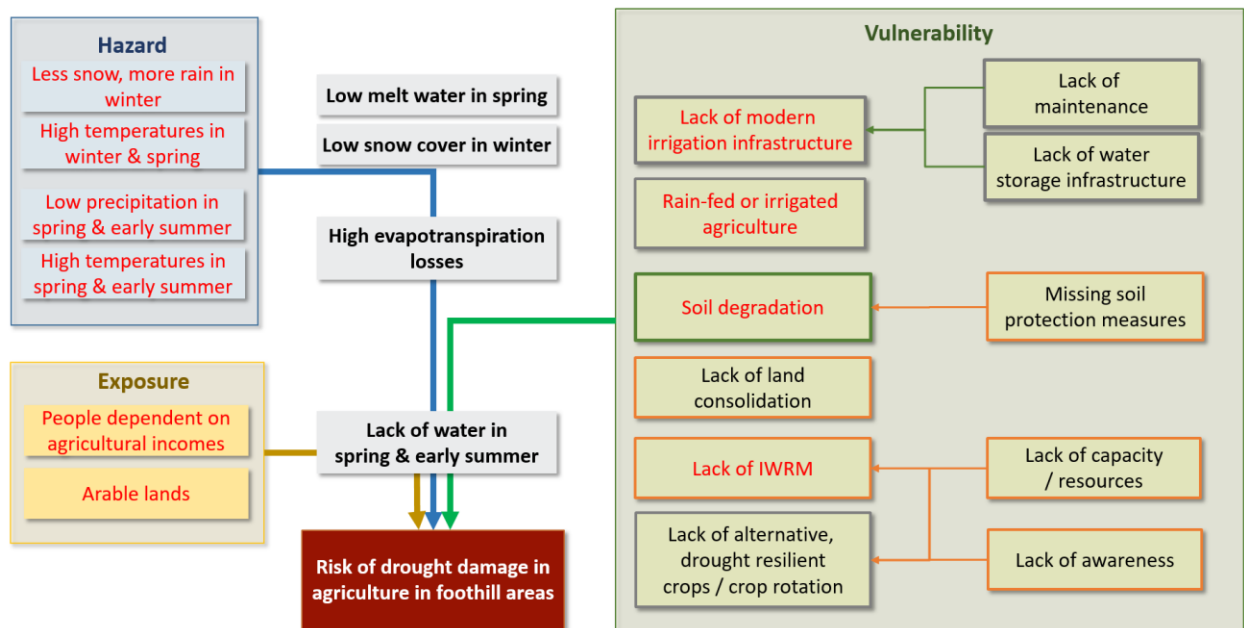


Figure 13 - The Impact Chains on drought damage in agriculture in foothill areas

The foothill areas of both Ismayilli and Shamakhi districts are currently already very dry, with intensive agriculture possible on irrigated fields only. On rain-fed lands most farmers cultivate wheat. This cultivation is mostly undertaken with little resources and basic cultivation techniques – and modest yields as a result. Insufficient crop rotation, which often is part of this low-intensity farming, can lead to soil degradation if one and the same crop is cultivated on the same fields for many years.

Due to the restructuring process after the collapse of the Soviet Union, many farmers only own relatively small land plots, which hampers more efficient agricultural practices. Land consolidation, i.e. the unification and joint cultivation of small separate land plots, is therefore an ongoing process in these areas. In many cases, only farmers cultivating larger areas can afford to install and/or maintain the irrigation systems and use modern cultivation techniques (seeds, fertilizer) necessary to achieve adequate yields.

One possible alternative crop with some tradition in the region are grapes. Vineyards were the most prominent form of agriculture during most of the Soviet period. Today, most farmers lack the necessary resources and knowledge to introduce the advanced cultivation methods and water saving irrigation techniques necessary to grow grapes on their lands. Most of them, therefore, stay with traditional methods and crops that are highly vulnerable to changes in climate and water availability. As some of the farmers remarked: “If it gets even drier and hotter here, we will have to move away.”

The lack of modern irrigation infrastructure, lack of proper water management practices, soil degradation and insufficient knowledge on modern cultivation techniques all contribute to a **high vulnerability** of these farming lands against the weather-related hazards prevailing in these areas. These include the different factors outlined in the impact chain above, which contribute to the lack of water in spring and early summer.

5.1.2. Risk of drought in agriculture in mid elevation areas

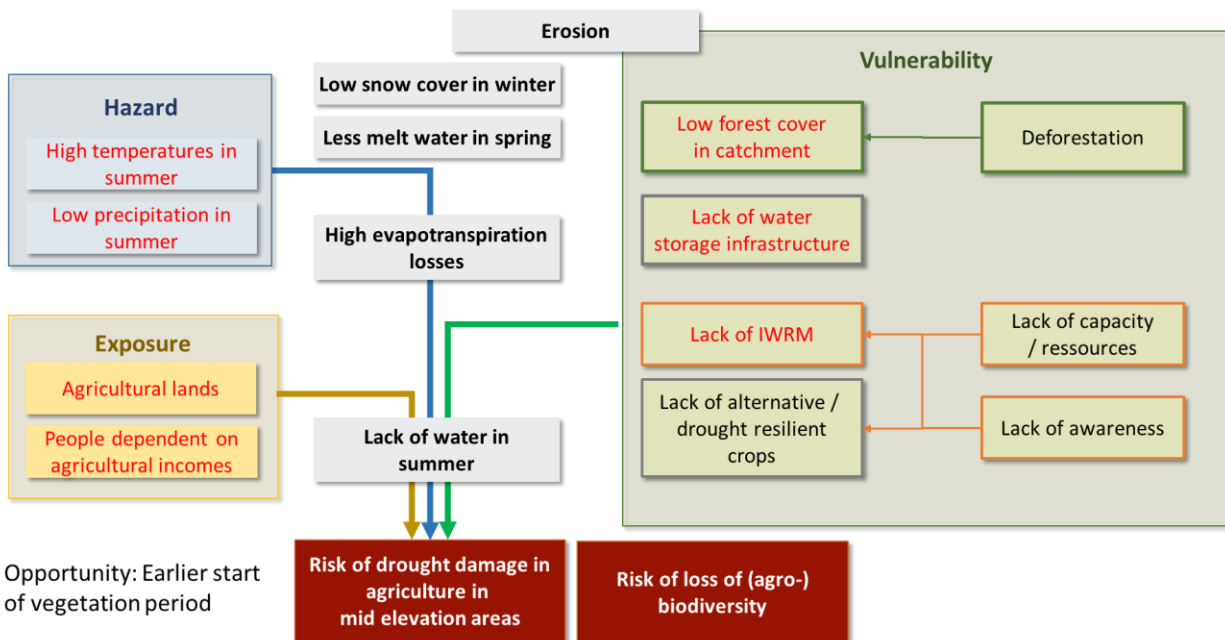


Figure 14 – The Impact Chains on drought damage in agriculture in forest and in pasture areas

Today, the forest and pasture areas of Ismayilli and Shamakhi districts experience enough rainfall to sustain large forested areas, productive pastures and small-scale agriculture (mainly kitchen gardens). According

to the villagers, only few dry years have been observed over the last decades. **Generally, today a low climate vulnerability** can be observed in these areas, with resilient production systems and ecosystems in comparatively good shape. Global warming and its effects in terms of a longer vegetation period could have positive effects on agricultural yields in the region, for instance for fodder (hay) production.

However, deforestation as well as the lack of capacity, resources and awareness and associated harmful land-use patterns (lack of proper water management and/or suitable, more drought-resistant crops) could contribute to a **moderate vulnerability** of these areas **in the future** if prolonged dry periods become more frequent. Higher evapotranspiration losses coupled with less available water in spring and summer as well as unfit water management patterns and infrastructure could become challenging. Additionally, the heat stress could also be a problem to certain tree and plant species in the region and could thus contribute to a risk of biodiversity loss.

Currently, due to the low population density (**low exposure**) coupled with a tendency of out-migration – especially from remote villages to the district centres or to the capital Baku – there is little land-use pressure on the natural resources. The **vulnerability** against the adverse effects of climate change **is higher in lower-lying areas** close to larger settlements, which already today are not only hotter and drier but also experience a higher risk of overuse of land resources due to the proximity of villages and towns. Also, tourism and its associated land-use patterns – the construction of restaurants and hotels along roads, for instance – contribute to deforestation and the higher pressure on natural resources in these areas.

5.2 Information on climate-related drought hazards

The analysis of future drought events in Azerbaijan considered the SPI-12 and SPEI-12 indices and their three main characteristics of frequency (number of events per 10 years), duration (months per event) and severity (absolute integral of standardized index values during one drought event) (section 4.1). These features were computed and visualized at the national level, providing information on potentially affected macro-areas (Figure 9 and Figure 10). Results show a generalized increase over the whole country in terms of frequency, duration and severity. This is particularly clear for the RCP8.5 and long-term scenarios (2070 – 2099) where the projected increase in temperature drives drought events exacerbation especially in the western part of Azerbaijan.

On the eastern and coastal side, results on droughts are more complex and sometimes in contrast with the opinion arisen during the workshop on a generalised increase in temperature and in dry conditions. In particular, climate scenarios represented a moderate increase in drought conditions for eastern and coastal parts in terms of frequency (RCP8.5) and severity (RCP4.5) or even a decrease in frequency (RCP4.5), duration (RCP4.5 and 8.5) and severity (RCP8.5).

Temperature increase is also affecting snow covers on the Greater Caucasus. Results on past trends from 2000 to 2018 showed ongoing conditions of decrease in Snow Cover Duration at different altitudes (-20.9 days between 2500-400 m) and in the Length of Snow Duration (-16.8 days between 2500-4000 m). Reduced snow cover and earlier snow melt during winter in the spring period are already affecting the amount of water available and can lead to further consequences to foothill downstream users.

5.3 Comprehensive risk assessments

5.3.1 Risk of drought in agriculture in foothill areas

While climate-hazards related parameters for drought events were investigated considering CMIP5 climate data, vulnerability factors were assessed through the implementation of a participatory approach. Information on factors such as irrigation infrastructures or the existence of an integrated water resource management was based on experts' opinions and collected through the questionnaire reported in the Annex.

Results highlighted drought risk as an important climate hazard for agriculture in the two pilot areas. Drought as a **hazard** is rated as **high** for both, Ismayilli and Shamakhi. **In future** droughts as a hazard will even get more severe which motivates to rate the future hazard as **very high**. Although there are irrigation infrastructures in both areas, which lowers vulnerability to drought, experts reported a wider irrigation coverage in Ismayilli (estimated coverage 26% \pm 10%) which results in a **moderate vulnerability** while in Shamakhi (estimated coverage 11,3% \pm 9%) **vulnerability is higher**. In Shamakhi with its high share of arable land (see Figure 155.3.2) also **exposure is high**, while it is only **moderate** in Ismayilli

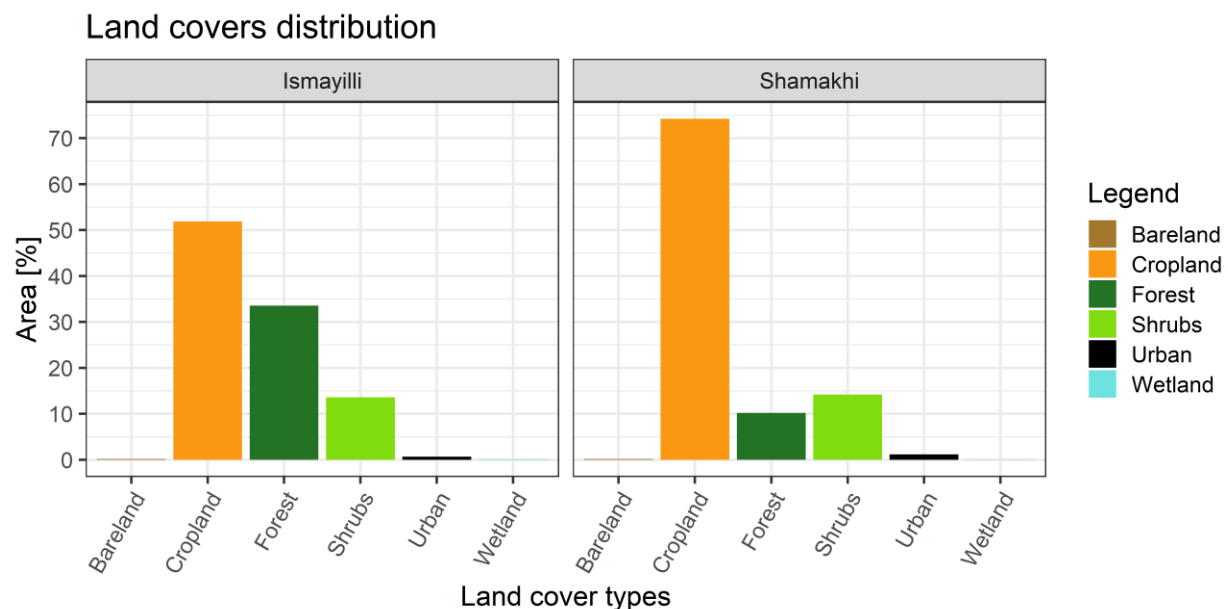


Figure 15 - Percentage distribution of land cover types for the two pilot areas. Calculation based on their own total area (Land cover map from Table 2).

While experts pointed to the high agriculture dependence on water from rain and snow melt, especially for rain-fed agriculture, the ongoing shift from rain-fed to irrigated agriculture is improving its vulnerability to drought conditions. However, such an improvement was also associated with an increase in water demand, which is still relying on few and low efficient irrigation infrastructures.

For these reasons, the overall **risk** assessment from **drought events in agriculture in foothill areas** is rated as **moderate** in Ismayilli and **high** in Shamakhi **under current conditions**. With climate change and the resulting higher temperatures, a higher drought risk and reduced water supply in summer from snow melt the drought **risk** is rated **high** in Ismayilli and as **very high** Shamakhi **in future** (Table 4).

In general, confidence in risk assessment on droughts is moderate given the fact that drought impact is already relevant today and the vulnerability of agriculture in foothill areas is obvious. Future risk will depend on the climate development but to a large extent also on the introduction of an efficient and water saving irrigation system.

Table 4 - Summary of the risk of drought in agriculture in foothill areas in Ismayilli and Shamakhi for the current and future (2050-2080) situations

Risk of drought in agriculture in foothill areas				
	Current Situation		Future (2050-2080)	
	Ismayilli	Shamakhi	Ismayilli	Shamakhi
Hazard (Drought)	High	High	Very High	Very High
Vulnerability	Moderate	High	Moderate	High
Exposure	Moderate	High	Moderate	High
Risk	Moderate	High	High	Very High
Confidence of Assessment	Moderate		Moderate - Low	
Critical settings	Small farm-holders with rain-fed or poorly irrigated fields, inefficient irrigation systems, agriculture on already degraded soils.			

5.3.2 Risk of drought in agriculture in mid elevation areas

Mid elevation areas of Ismayilli and Shamakhi are characterized by a mixture of forests, pastures and agricultural fields mainly around villages and cities. The rural economies of these areas rely on agricultural land products and are hence particularly vulnerable to potential climate change impacts. Climate-related impacts are expected to be stronger in the northern and western part of Azerbaijan, where most of the forested and summer pasture areas are located. While drought impacts on forest ecosystems need longer periods in order to affect deep soil moisture, pasture areas can be affected even in relatively short periods of drought conditions. Impacts on shrubs and low vegetation can then have consequences on grazing, livestock and on those rural economies depending on them.

Drought as a hazard is generally less expressed in the mid elevation areas than in the foothills due to higher precipitation rates around the year. Therefore, drought as a **hazard** is rated as **moderate for the current situation**. However, the climate scenarios indicate that future droughts might become more severe, which would lead to a **high drought** hazard even in mid elevations.

Due to the mix of non-intensively used pasture and forest, agriculture and forest is less vulnerable to droughts than in the floodplains. Therefore, **vulnerability** is rated as **low for the current condition** in both regions. If deforestation, which was reported as a potential trend for the mid elevation zone, will increase, vulnerability would raise from low to **moderate in future**.

Currently the mid-elevation zone is not highly populated due to a trend of out-migration and land-use is not intensive. Due to this fact, **exposure** is rated as **low for the current situation**. Experts reported a potential

reversal of population trend. If population will increase in the mid-elevation zone exposure would raise to moderate in future.

The **risk** of drought impact on agriculture in the mid elevation area is currently rated only as **low**. In future, with raising drought severity and potentially an intensification of land use and population growth the risk related to drought would raise to **moderate in future** (Table 5).

In general, confidence in risk assessment on droughts is moderate. Future risk will depend on the climate development but on the population and land-use development in the region.

Table 5 - Summary of the risk of drought in agriculture in mid elevation areas in Ismayilli and Shamakhi for the current and future (2050-2080) situations

Risk of drought in agriculture in mid elevation areas				
	Current Situation		Future (2050-2080)	
	Ismayilli	Shamakhi	Ismayilli	Shamakhi
Hazard (Drought)	Moderate	Moderate	High	High
Vulnerability	Low	Low	Low/Moderate	Low/Moderate
Exposure	Low	Low	Low/Moderate	Low/Moderate
Risk	Low	Low	Moderate	Moderate
Confidence of Assessment	Moderate		Moderate - Low	
Critical settings	Risk is higher in the lower parts of the hillslopes close to the bigger settlements due to higher temperatures and more intensive land-use. Deforestation to develop new pastures and/or arable land could increase risk.			

5.4 Risk of flood in foothill areas

5.4.1 Understanding risks and impact chains

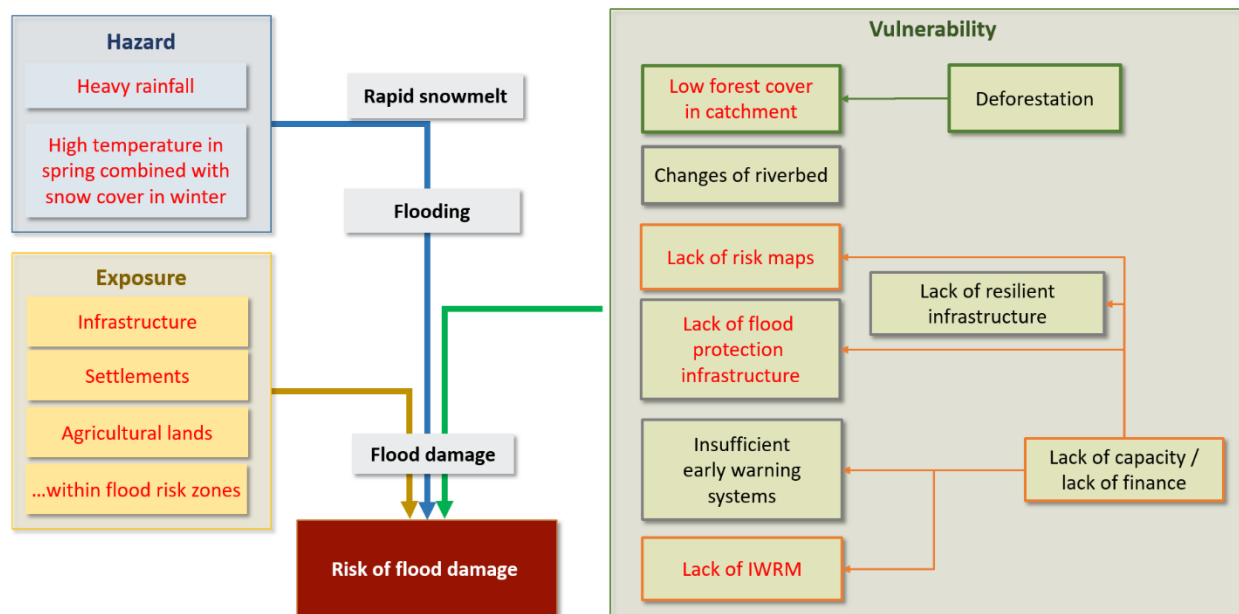


Figure 16 – The Impact Chain on risk of flood damage

The risk of flood damage is already an issue today, especially in the foothill areas. Heavy rainfall events and high temperatures in spring contributing to rapid snowmelt are the main climate hazards affecting flood risk. The way natural resources are used in the areas also play a role for the flood risk of a certain region. Deforestation and the resulting low forest cover in a catchment are important ingredients to a higher risk of flood damage, as deforested areas are less capable of storing water during heavy rainfall events than deforested and degraded ones.

Particularly exposed to these hazards are settlements, infrastructure like roads and irrigation systems, as well as agricultural lands situated within flood risk zones. The fact that these assets are located in these zones in the first place is often due to a lack of awareness. The unavailability of proper flood risk maps is a factor contributing to this issue, but also due to poor governance at the local level, for example an insufficient enforcement of rules. People often find ways around restrictions if they want to construct in certain areas hence exposing themselves to high risks.

The flood risk for these assets is particularly high if there is no adequate flood protection infrastructure or if the infrastructure at risk is not constructed properly, i.e. is not resilient against external shocks like floods. This is often due to a lack of finance and resources, but also capacity. The latter also contributes to the frequent absence of proper integrated water resource management (IWRM). Without such an approach, solutions to flood risk in one place could potentially increase the risk in another one further downstream. Also unchecked changes to the riverbed, for example through the excavation of gravel, can contribute to higher risks for assets situated downstream. Parts of these risks could be mitigated with proper early warning systems. These are, however, mostly absent and thus the risk to lives and livelihoods remains high in many places.

5.4.2 Information on climate-related flood hazards

Heavy precipitation was considered as a climate parameter for flood risk and its future projections. In this case, the maximum consecutive 5-days precipitation (intense precipitation sum over a 5-days period) was computed and visualized. The maximum consecutive 5-days precipitation index characterizes the magnitude of precipitation over different days that could lead, for example, to a river flood in floodplains.

Figure 8b, reported the differences between future and past in terms of maximum consecutive 5-days of precipitation, showing an increase especially in the far future over the eastern and coastal part of the Azerbaijan up to +40% in 2070 – 2099 (RCP8.5) with respect to reference period (1971 – 2000).

Although the spatial resolution of the climate projections does not allow to characterize local conditions in the pilot areas, Ismayilli and Shamakhi are also subject to a generalized increase in the conditions of extreme precipitation. Such information needs to be linked with the current exposure and vulnerability conditions in the two rayons for a final assessment of their flood risk.

5.4.3 Comprehensive Risk assessment

Local experts were involved and their opinions collected to characterize factors of flood exposure and vulnerability during the impact chains development and the questionnaire.

Results from the questionnaire showed a mixed consensus on the importance of flood events in the two pilot areas. This result is in agreement with the information arisen during the initial impact chains development where floods are recognised to be connected with other hazardous processes (such as riverbed changes, flood caused by soil impermeabilization after a drought event, erosion and landslides) calling for a more integrated assessment of their potential consequences.

In both areas the available financial resources to cope with flood events are limited (Figure 17) and this information is also in line with the lack of flood risk maps, highlighted as a relevant factor by the experts to better comprehend flood dynamics, disseminate information and increase awareness in the population.

Risk reduction resources for flood events

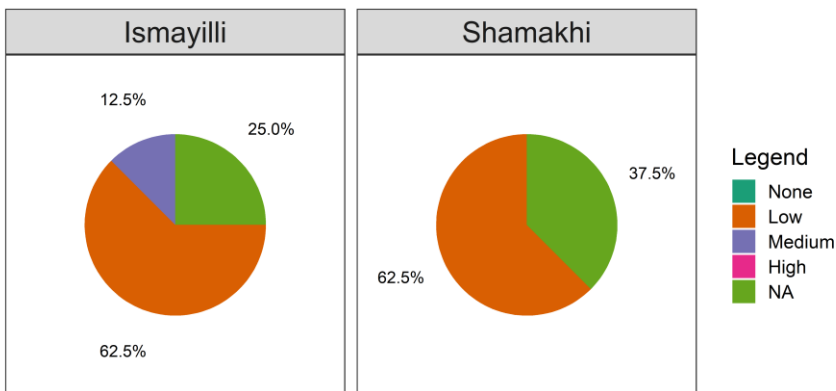


Figure 17 – Distribution of expert's opinions (in percentages) on 4 classes of risk reduction resources (None, low, medium, high) for flood events the two pilot areas of Ismayilli and Shamakhi. NA values corresponds to "No Answer" from the experts.

For these reasons, flood risk is mainly driven by the increase in duration and severity of meteorological events and the little resources available to cope with flood hazards. For these reasons, **risks of flood**

damage in foothill areas of Ismayilli and Shamakhi are rated as **moderate for the current, as well as for the future situation** (Table 6).

In general, confidence in risk assessments on flood is moderate to low for the current situation. Data on floods and flood damages for the current information were not available. Climate scenarios indicate an increase in heavy precipitation events, but with a high uncertainty since precipitation extremes are not so well reflected in coarse scale climate scenarios. Future risk will furthermore depend to which extent effective adaptation measures to reduce vulnerability will be taken and to which extent exposure (e.g. settlements, infrastructure) will increase in the regions.

Table 6 - Summary of the risk of flood in foothill areas in Ismayilli and Shamakhi for the current and future (2050-2080) situations

Risk of flood in foothill areas				
	Current Situation		Future (2050-2080)	
	Ismayilli	Shamakhi	Ismayilli	Shamakhi
Hazard (heavy rain)	Moderate	Moderate	Moderate/High	Moderate/High
Vulnerability	Moderate/High	Moderate/High	High	High
Exposure	Moderate	Moderate	Moderate	Moderate
Risk	Moderate	Moderate	Moderate	Moderate
Confidence of Assessment	Moderate - Low		Low	
Critical settings	Settlements, infrastructure like roads and irrigation systems, as well as agricultural lands situated within flood risk zones. Areas with no adequate flood protection infrastructure or infrastructure at risk that is not constructed properly. Unchecked changes to the riverbed, for example through the excavation of gravel.			

5.5 Risk of forest damage

5.5.1 Understanding risks and impact chains

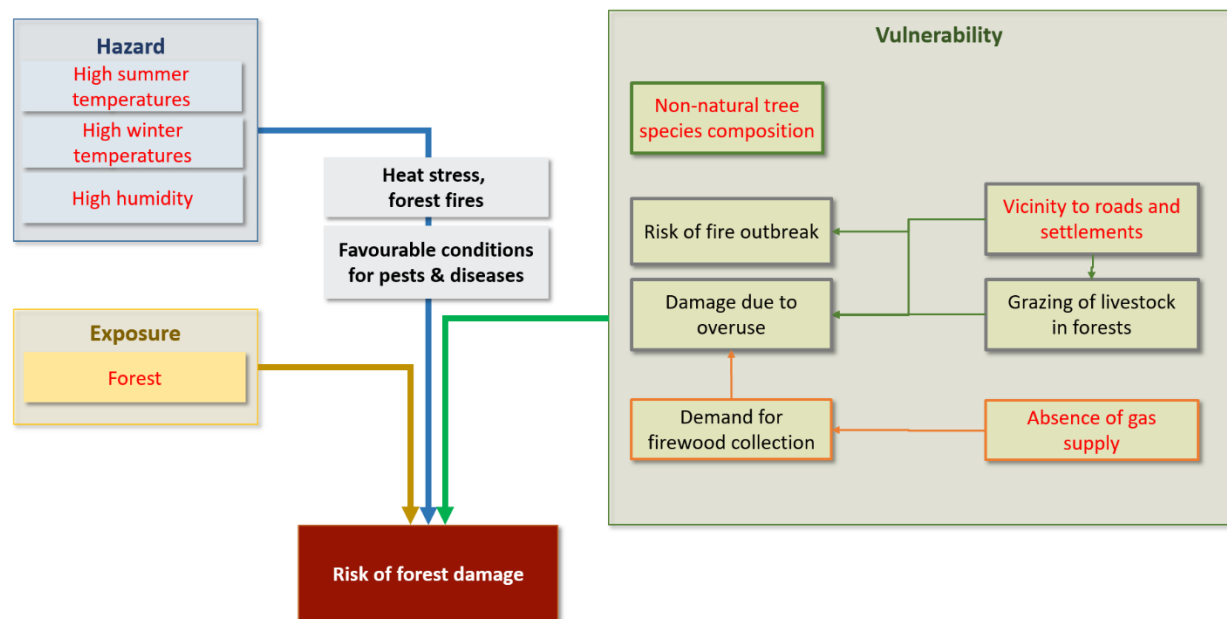


Figure 18 – The Impact Chain of risk of forest damage

In total there are 84.000 hectares of forest in Ismayilli and Shamakhi districts under the management of the regional forestry centre. Many of the experts in charge of forest management have been on the job since Soviet times. They argue that the anthropogenic pressure to the forests was particularly high after the collapse of the Soviet Union, as in those years there was a high demand for firewood and little control.

Today, this has already significantly improved, as most of the villages are now supplied with Azerbaijan's abundant reserves in natural gas. In certain villages, however, the absence of gas supply still results in a high demand for firewood collection and, as a consequence, contributes to forest damage due to overuse. This is also true for forests situated close to villages and roads in the lower parts of the districts, where many people graze their livestock in the forests due to a lack of alternatives.

Another element contributing to the risk of forest damage are forest fires. The risk for fire outbreak again is high close to roads and settlements, as many of the fires are caused by humans. The experts also observed that nowadays forest fires start earlier and can sometimes already be observed in January if there is no snow and there is a prolonged series of dry days – which, according to the experts, can be observed more and more frequently.

In general, according to their observation, the climate in the forest zone is getting warmer and more humid, which creates favourable conditions for pest and diseases. At the same time, increasing heat stress and dry spells are a problem for many tree species. Particularly vulnerable is the walnut tree (decrease in productivity), while oak is among the more drought resistant tree species. As a critical indicator for drought damage the forest management experts identified a series of days above 35°C, as trees are not able to cope anymore if temperatures are higher than this threshold for more than three days.

5.5.2 Information on the climate-related hazard

The analysis of CMIP5 climate projections in section 4.1 provided several information on changes in future climate-hazard conditions. The climate signals of high summer and winter temperatures reported during the participatory impact chains development found evidences from the seasonal differences between the 2051 – 2080 climate projections and the averages over the 1971 – 2000 reference period (Figure 6). All models report an increase of maximum temperature with the highest increase in summer (5°C - 10°C) in agreement with the factors identified as relevant for forest damages.

Climate extremes also play an important role throughout the country. An increase of annual daily maximum temperature extreme up to 10 °C is expected by the end of the XXI century in the RCP8.5 scenario (Figure 8a).

Although the model has a coarse spatial resolution of about 50 km, significant increases in temperature are reported especially in the western part of Azerbaijan for all seasons for the RCP8.5 scenario. This area involves the Ismayilli rayon where most of the forested area are located compared to Shamakhi.

5.5.3 Comprehensive Risk assessment

While climate change scenarios depicted conditions of temperature increase leading to climate-hazards exacerbation, the analysis of exposure and vulnerability factors showed limited relevance of the forest damage compared to other risk processes, such as drought or erosion.

In particular, the analysis of the Global Hansen Forest loss dataset¹⁹ provided information on the changes within the two pilot areas. Hotspots of forest loss were mainly detected in the Ismayilli rayon during the period 2001-2018 and reported in Figure 19.

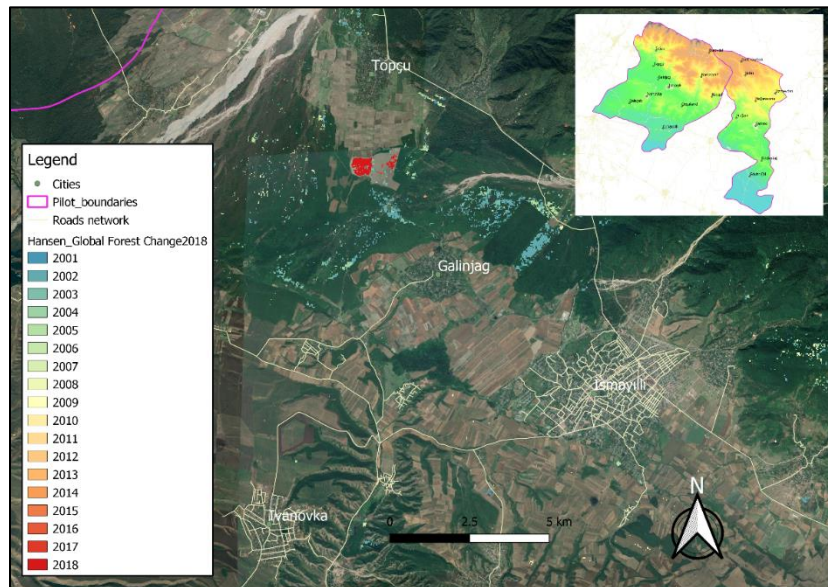


Figure 19 – A hotspot of relevant forest changes extracted from the 2001 - 2018 changes in the Ismayilli rayon

This information was also coupled with the time series of annual losses in forested areas for the two pilot regions (Figure 20). Over the available time series, Ismayilli lost 557 ha of tree cover (equal to a decrease of 0.67% in tree cover), while Shamakhi lost 65 ha (equal to a decrease of 0.31% in tree cover). Such results

¹⁹ <https://earthenginepartners.appspot.com/science-2013-global-forest>

are in agreement with the decreasing trend of deforestation reported during the workshop and the main relevance of the Ismayilli rayon in terms of past losses and forests extensions.

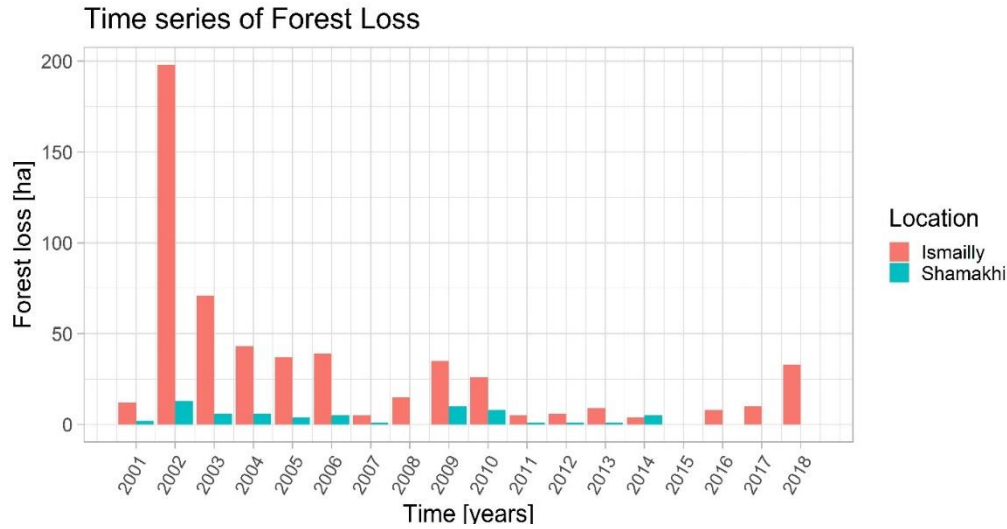


Figure 20 – Time series of forest loss in hectares for the two pilot areas of Ismayilli (red) and Shamakhi (light blue)

Other relevant components from the initial impact chains were here considered according to their data availability. Information on the road networks was available and used here to assess potential relations between forest damages and roads proximity. However, from a quantitative analysis of past forest change data, the very few detected changes close to Ismayilli city mainly related to those areas with lower slope degree and hence with a higher accessibility, as reported in Figure 21.

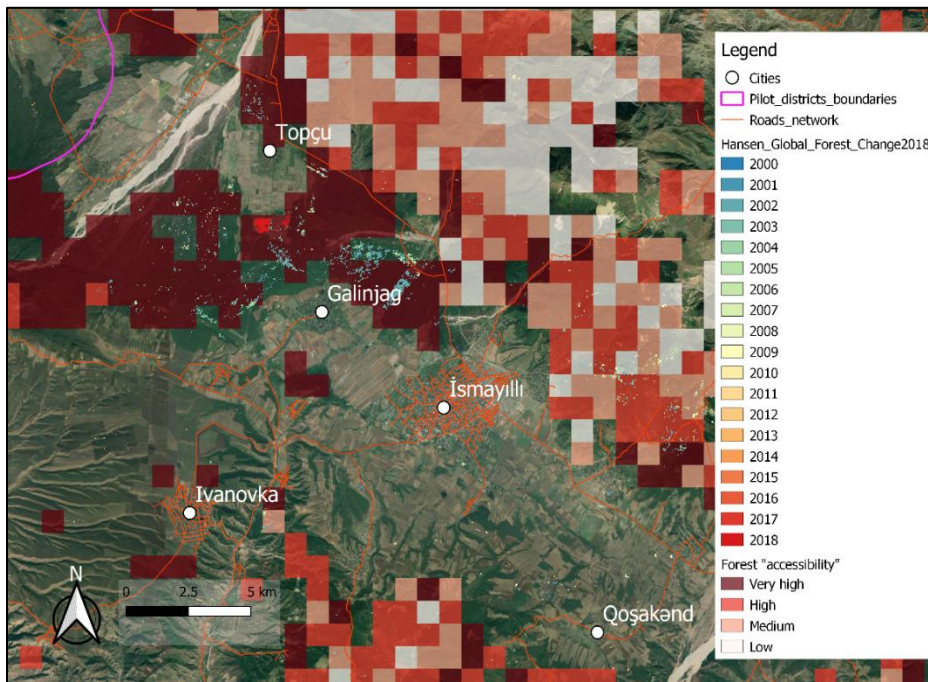


Figure 21 – Forest accessibility from Low (pale rose) to Very High (dark red) as a combination of forest land cover and terrains degree of slope. Focus on the hotspot of forest changes in the Ismayilli rayon

Overall, limited processes of deforestation and a medium natural composition in both pilot areas contributes to a **low risk of forest damage** in Ismayilli and Shamakhi today. Future risk will depend on the combination of projected maximum temperature exacerbation and population development and potential deforestation activities, which could lead even to a **moderate risk** in both regions (Table 7).

Confidence for statements on the current situation is high. A temperature increase and a resulting higher risk in future is relatively certain, while the development of vulnerability is rather uncertain. That is why confidence is only moderate for the future risk assessment.

Table 7 - Summary of the risk of forest damage in Ismayilli and Shamakhi for the current and future (2050-2080) situations

Risk of forest damage				
	Current Situation		Future (2050-2080)	
	Ismayilli	Shamakhi	Ismayilli	Shamakhi
Hazards (high temperatures)	Low	Low	Moderate	Moderate
Vulnerability	Low	Moderate	Moderate / High	Moderate / High
Exposure	Low	Low	Moderate	Moderate
Risk	Low	Low	Moderate	Moderate
Confidence of Assessment	High		Moderate	
Critical settings	Forest in lower mountains (higher temperatures, more heat stress and drought risk) in vicinity to settlements and roads (more disturbance due to grazing, wood collection, potential fire ignition). Particularly vulnerable is the walnut tree.			

5.6 Risk of erosion (all zones)

5.6.1 Understanding risks and impact chains

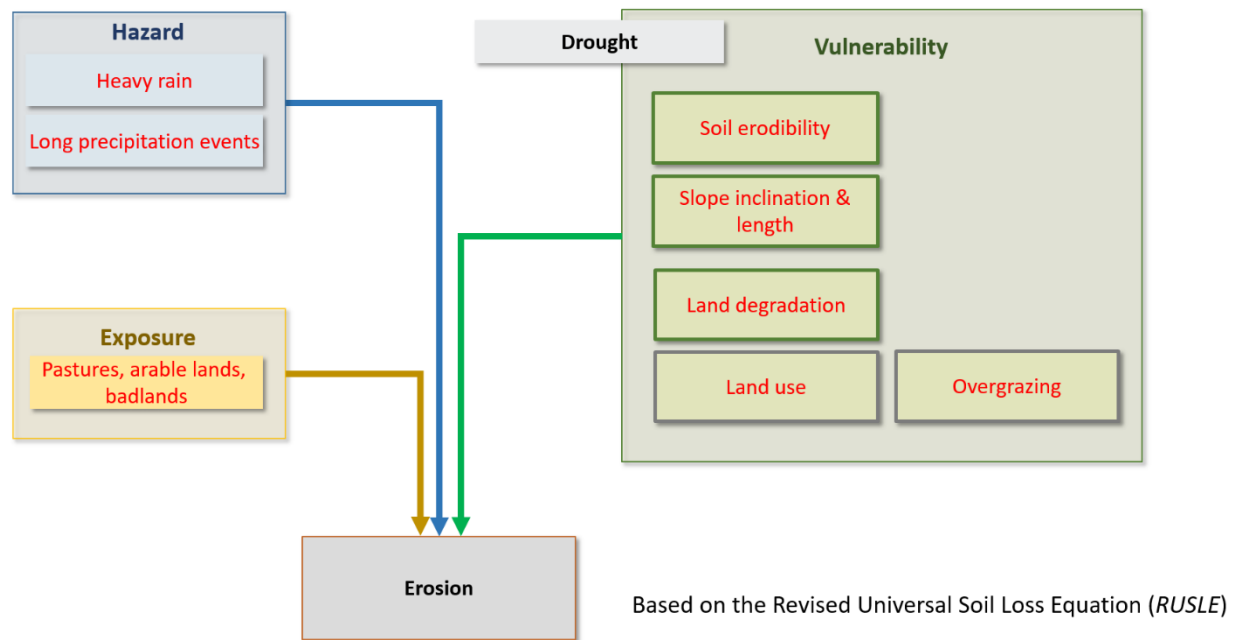


Figure 22 - Impact Chains on risk of erosion

Erosion is a problem in all agro-ecological zones of the two pilot districts Ismayilli and Shamakhi, but most in the lower and higher zones and least in the forested areas situated in the middle. Based on the Revised Universal Soil Loss Equation (RUSLE), there is a number of factors contributing to the risk of erosion: heavy rain and long precipitation events are potential hazards, soil erodibility, slope inclination and length, land degradation as well as land use and overgrazing, together with droughts, contribute to the vulnerability. Exposed are pastures, arable lands, and unused lands alike.

In the foothill areas of the two districts, villagers reported that today's agricultural cultivation – mainly wheat – contributes to erosion as opposed to the vineyards that occupied most of the arable land during Soviet times. Vineyards and forested areas are less prone to erosion, with the areas most at risk being heavily degraded steep areas. Landslides occur frequently there. According to the villagers, also the construction of roads contributes to erosion and landslides.

In the high-mountain pasture areas of the two districts, overgrazing is an important contributor to the increasing erosion being observed there. According to experts from the forest management department and villagers alike, mainly the additional pressure by herders coming from the lowlands up to the summer pastures is to blame. With their increasing influx and the increasing size of their herds, the number of livestock per hectare is beyond sustainable levels. With regards to sheep, for instance, the number per hectare should be around 6-8 sheep, but increasingly in some areas this number is higher than 20. The increasing erosion resulting thereof also contributes to a higher risk of landslides, especially on steep slopes. It also contributes to a higher amount of debris in the rivers and thus to higher flood risk in the villages downstream.

5.6.2 Information on the climate-related hazard

The development of the Impact Chains supported the understanding of the main climatic and anthropogenic factors involved in erosion processes. Heavy precipitation plays a fundamental role affecting erosion, especially in steep slopes with little or no vegetation. On the one side, climate projections provided information on heavy precipitation events at aggregated temporal resolution (i.e. difference over 30-year periods) hence providing a snapshot on future trends of heavy precipitation features (Figure 8b). On the other side, erosion modelling would require information on each rainstorm, the kinetic energy of raindrop's impact and the rate of associated runoff. Although the available temporal resolution of climatic projections does not provide such an information, the generalized increase in maximum consecutive 5-days precipitation is considered as a proxy variable that can lead to an increase in the overall risk if coupled with high vulnerability area .

5.6.3 Comprehensive Risk assessment

Index-based analysis support the integration of different information for a comprehensive representation of risk conditions. In this case, erosion processes were evaluated based on the RUSLE modelling technique²⁰ which was coupled with expert statements from GIZ experts involved in an ongoing project on sustainable land management and erosion processes from pastures²¹. By doing so, the quantitative erosion analysis was validated (and integrated) by the qualitative information from local experts.

The results from the erosion analysis for the two pilot areas provide an insight on potential hotspots of erosion as shown in Figure 23 in orange and red colours (i.e. high and very high erosion conditions). Land cover resulted to play a fundamental role, with forest areas having important effects lowering erosion even in high slope areas, while cropland and low vegetated areas being more vulnerable to erosion processes.

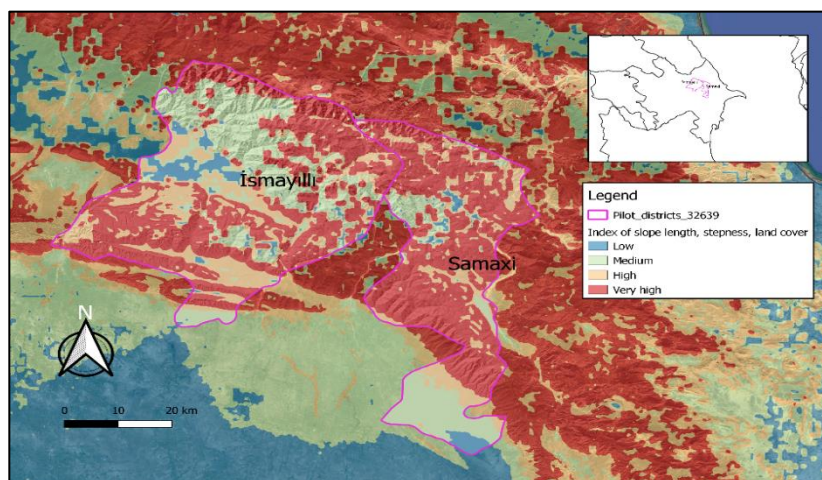


Figure 23 - Results from the quantitative RUSLE-based characterization. Potential low erosion in blue, medium in green, high in orange and very high in red colour.

The result was then compared with the information provided by local GIZ experts on current hotspots of erosion as reported in Figure 24. Areas number 1 and 2 from their opinion were also ranked as very high level of erosion with the RUSLE-based index. Only the hotspot area number 3 in the lower part of Shamakhi from the local experts was ranked as a medium risk of erosion area using the RUSLE-based index. Such a

²⁰ <https://www.sciencedirect.com/science/article/pii/S1462901115300654>

²¹ <http://biodivers-southcaucasus.org/about>

result mismatch is likely due to the erosion type in foothill flat areas mainly driven by run-off, which was here not captured due to the limited data availability on rainfall local events.

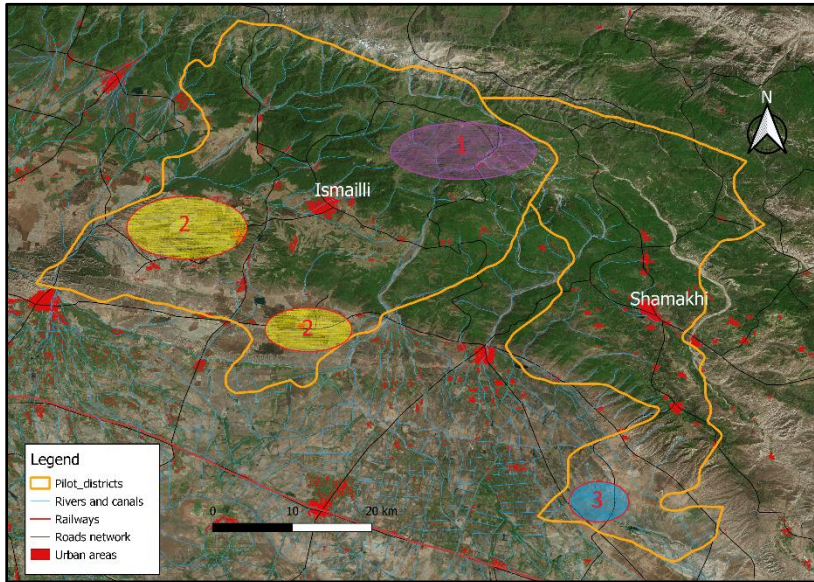


Figure 24 - Results from a GIZ expert opinion on hotspots of erosion. Area number 1 erosion due to overgrazing, number 2 due to conventional agriculture in steep slope, number 3 due to land use change from pasture to arable land

Moreover, the erosion analysis considered grasslands degradation on a long-term period due to the ongoing intense overgrazing that was highlighted by the local experts in the two pilot areas. The Normalized Differential Vegetation Index (NDVI) provides a robust index for vegetation analysis over long time periods. The NDVI trend analysis based on time series of Landsat images (see section 4.5) resulted in heterogeneous pattern with increasing, neutral and decreasing trends. Negative trend coefficients were clearly associated with decreasing annual NDVI values over time (orange and red colours in Figure 25)

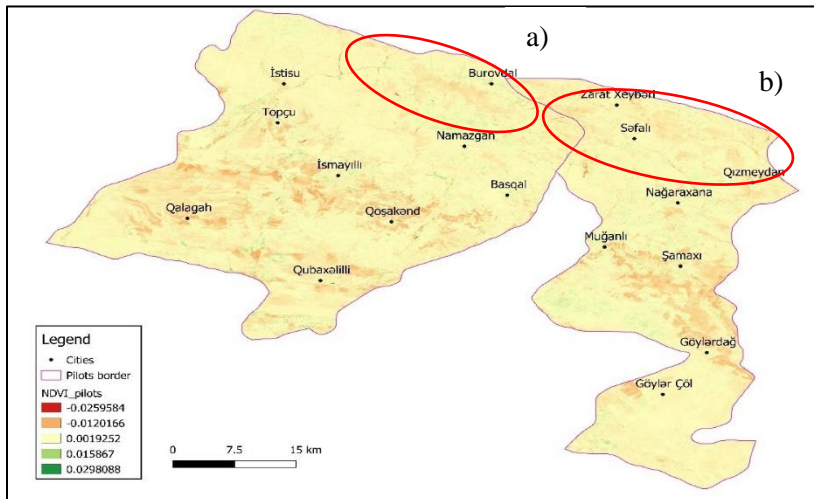


Figure 25 - NDVI changes from 1987 to 2019 extracted from the Google Earth Engine platform

In particular, while the red coloured parts near İsmayilli and Şamaxı cities account for sudden changes in NDVI trend due to cropland management, the NDVI negative trends in the norther part of İsmayilli and

Shamakhi, within the red circle a) and b) in Figure 25, captured land degradation in summer pastures. GIZ experts, currently involved in pasture management studies, pointed to these areas as hotspots of degradation mainly due to the increase in the number of cattle (Figure 26b) and a generalized increase of agricultural land with conversion from pasture to cropland (Figure 26a). This is particularly relevant in the southern parts of the two rayons, where such conversion is triggering an earlier move of livestock from foothill areas to the high elevation summer pastures (ECOserve projects reports²²).

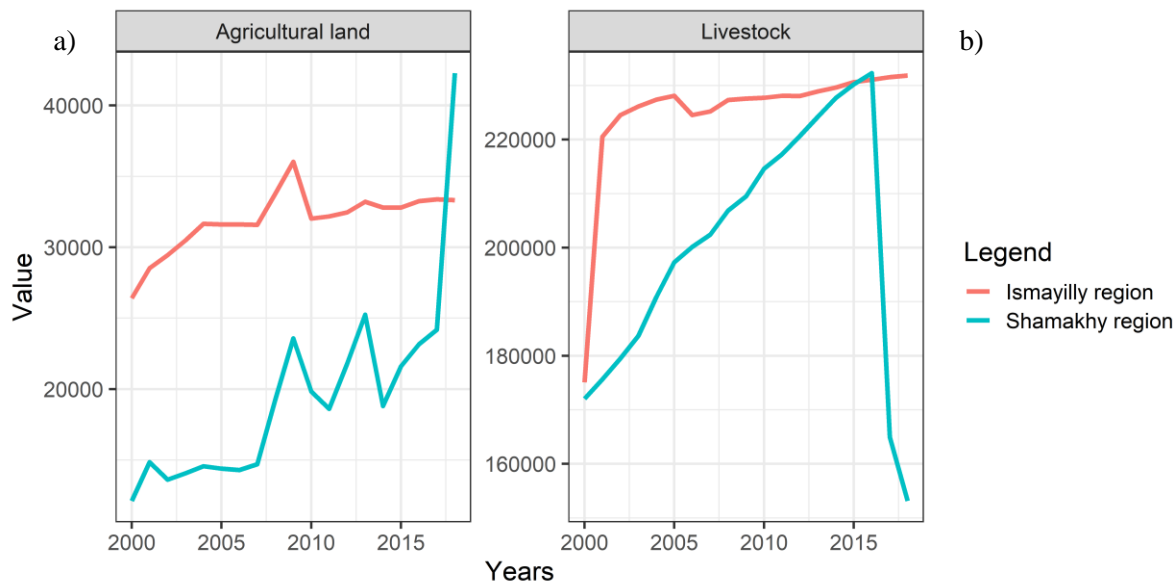


Figure 26 - Time series of agricultural land and livestock number for the two pilot areas from 2000 to 2018. Recent and sudden changes in both agricultural land and the number of livestock need to be further investigated.

Overall, current **moderate** climate-**hazard** conditions (i.e. heavy precipitation events) together with a **high vulnerability** of rural economies relying on their livestock and the ongoing land degradation process due to overgrazing are the main components of a **high risk of erosion in Ismayilli and Shamakhi**, especially in steep slopes. **Future** risk conditions are expected to increase to **very high** driven by the increase in the vulnerability component (Table 8).

Statements have a high confidence for the current situation, since land degradation is reported from different independent experts. They are supported by the RUSLE-based index and can be observed even in satellite imagery. Future risk increase depends on the further development of grazing / overgrazing linked to the increasing number of livestock and consequent high pressure on pasture areas and their management (i.e. conversion of cropland into pasture areas).

Table 8 - Summary of the risk of erosion (on steep slopes) in Ismayilli and Shamakhi for the current and future (2050-2080) situations

Summary Table: Risk of erosion (on steep slopes)				
Current Situation		Future (2050-2080)		
Shamakhi	Ismayilli	Shamakhi	Ismayilli	

²² <http://biodivers-southcaucasus.org/about>

Hazards (heavy rain)	Moderate	Moderate	Moderate / High	Moderate / High
Vulnerability	High	High	High/ Very High	High/ Very High
Exposure	High	High	High	High
Risk	High	High	High/ Very High	High/ Very High
Confidence of Assessment	High		Moderate	
Critical settings	Arable land (wheat) on steep slopes, intensively grazed and degraded national pastures in higher mountain regions. Improper construction of roads contributes to erosion and landslides.			

6 Discussion on climate risks in Azerbaijan’s mountains

Climate projections depict a homogeneous exacerbation of future temperature over the whole Azerbaijan. However, even moderate changes in temperature conditions can lead to severe impacts in vulnerable mountain areas. This is due to the type of natural ecosystems and human activities adapted to specific mountain conditions. Moreover, impacts in mountains can generate consequences both locally (e.g. decrease in snow cover conditions) and downstream (e.g. reduction of water availability in foothill areas).

Temperature increases are driving **drought** conditions exacerbation in terms of frequency, duration and severity with particular reference to the western part, both in the north and south, where the Greater Caucasus mountains are located. Mountains play a fundamental role as water towers, providing essential ecosystem services. The generalized worsening of climate conditions is already putting great pressure on intensive human activities. Many agricultural fields at mid elevation and especially in foothill areas are particularly exposed to changes in water availability and increase in evapotranspiration. Moreover, the existing conditions of little and old irrigation infrastructures from the Soviet time and the lack of an Integrated Water Resource Management system were identified by the experts as the main vulnerability factors. This is especially relevant for Shamakhi having lower resources for risk reduction, but higher agricultural areas exposed to potential consequences that can affect its rural economies. Nevertheless, in both Ismayilli and Shamakhi, adaptation options should prepare for future impacts from drought events increasing coverage and efficiency of irrigation infrastructures to reduce current water losses while keeping low water demand for agriculture. Moreover, a better coordination of water management from upstream to downstream would better prepare to the increasing of drought conditions, but also increase human awareness and competences to deal with water-related hazards, such as floods.

Heavy precipitation events are expected to have a higher increase mostly in the eastern parts of Azerbaijan (Figure 8b) and mostly due to the direct influence of the Caspian Sea on the near land. In particular, change in precipitation severity would put great pressure on urban areas where most of the people live and where pluvial flood is mostly expected. In case of Ismayilli and Shamakhi, risk of **flood** was rated as moderate. This result was due to the combination of increasing heavy precipitation conditions, especially during winter, counterbalanced with little population living in the two rayons compared to the high population density areas along the coast. Nevertheless, the lack of flood maps and the limited resources to deal with

floods of the two rayons have a clear contribution as vulnerability factors that needs to be addressed for future flood events adaptation.

Forests in the pilot areas are subjected to limited pressure from anthropogenic activities (i.e. deforestation), but they are mainly subjected to high temperature stress during summer. Experts pointed to overgrazing, drought, wildfires and tourism as factors contributing to forest damage. Moreover, a natural forest composition was identified as a factor to better bear pressure from heat stress and possible pest diseases. Within this context, Ismayilli was rated as higher than Shamakhi in terms of natural composition making it less vulnerable to potential damages. In addition, natural forest cover also plays a relevant role in erosion reduction. The multiple benefits from forests areas and the link with rural economies should be considered when planning reforestation strategies to cope with the increase of erosion and land degradation. These results are in line with the findings from the ClimaEast project where reforestation activities were implemented together with local stakeholders, hence supporting the many rural economies relying on forests ecosystem services and their risk protection effects.

Erosion processes are one of the main risks in Ismayilli and Shamakhi as in other parts of Azerbaijan. The combination of climate exacerbation, the very high pressure from an increasing number of livestock and overgrazing, and the steep and low vegetated pilot areas are the main factors contributing to their high risk. These common features across vast areas of Azerbaijan mountain regions should be better evaluated incorporating rainfall intensity maps, local data on soil type, land cover maps, pasture movements and agricultural land management strategies. Finally, a better understanding of the community social dynamics related to pasture and agricultural practices can support the identification and implementation of strategies with effective and long-lasting effects on erosion processes.

7 Conclusions and outlook

This study provided an application of the Impact Chains methodology in the pilot areas of Ismayilli and Shamakhi to support decision making in climate adaptation planning. The analysis assessed potential vulnerability hotspots and climate impacts in the future, allowing the identification of the risk components (hazard, exposure and vulnerability) and their underlying factors that lead to risk conditions in the two rayons. Each factor was assessed considering open source datasets due to the limited local data availability and to support the methodological replicability in other mountain regions. Whereas information was missing or not enough to understand the risk factors, data-driven analysis and indices-based assessments were combined with opinions from local stakeholders and experts to characterize dynamics and processes at the local level. By doing so, this study was able to integrate different data sources to characterize local risk processes and their causes.

The final qualitative risk assessments pointed to **drought** and **erosion** as the main risk processes that are already affecting the two pilot areas. While climate change is expected to affect hazards frequency, duration and severity, future exposure and vulnerability levels should be reduced through the implementation of adaptation strategies. The assessment highlighted the need of coupling centralized management of natural resources (e.g. modernisation of irrigation infrastructures and implementing an IWRM) with initiatives supporting local communities and their socio-economic activities (e.g. cropland and pasture management) to reduce their current vulnerability levels and prepare for future climate impacts. This is particularly relevant for Shamakhi due to the local conditions of large cropland extensions exposed to drought hazards with low coverage of irrigation infrastructures and financial resources to reduce drought impacts. Conditions of severe erosion processes are also recognized in other parts of Azerbaijan, calling for the need

of reducing the anthropogenic pressure on pasture while implementing land management practices to support forested areas.

The current lack of economic and human resources for risk reduction in both rayons hinders the implementation of large-scale strategies. For this reason, adaptation strategies improving soil covers and water retention should be investigated and prioritized. By doing so, strategies would have simultaneous beneficial effects on both drought and erosion risk processes.

Future improvements in the impact chains application should consider the integration of socio-economic indices and their scenarios to better characterize levels of exposure and vulnerability. Social, cultural and economic conditions are fundamental requisites to identify and implement adaptation strategies with local stakeholders. Finally, impact chains can be further steered to include interdependencies among single risks to better integrate and combine different risk processes within the assessments, especially looking at the upstream-downstream dependencies. Such perspective would allow to identify hotspots of risk on a larger scale, supporting the selection of risk reduction strategies triggering beneficial effects across different areas and risks processes for climate change adaptation.

8 Methods transferability to other mountain regions of Azerbaijan

The risk assessment in this study mainly focused on mountain characteristics and their vulnerability to climate change impacts. For the climate-related **hazards**, the quantitative results were elaborated for larger areas than for mountain areas in Ismayilli and Shamakhi. Open global datasets provided information on climate-related indices for different scenarios and over the whole Azerbaijan. This is particularly relevant in case of extension of the analysis to other mountain areas in Azerbaijan, especially if climate scenarios can be coupled with past time series observations of meteorological parameters to bias correct regional model to local climate conditions.

Moreover, the analysis on changes in snow covers duration and of the last day of snow was extrapolated from the recent global study on mountains developed in Eurac Research. Information on past snow changes are hence readily available for the whole Greater Caucasus and easily accessible for climate change impact assessments in other mountain regions in the World.

Analysis of **exposure** and **vulnerability** were mainly based on the combination of remote sensing analyses with local qualitative opinions and information using the Impact Chains methodology. Impact Chains can be extended to analyse risk processes in other mountain regions through the combination of available data with local information that are usually scarce, of varying quality and difficult to access. In such cases, risk assessments can be extended to other mountain areas through the application of a mix of data-driven methods (e.g. RUSLE based index and NDVI analysis) and qualitative approaches (e.g. questionnaire on vulnerability conditions) based on workshops and expert's assessments in order to capture physical and socio-economic characteristics involved in risk processes. Overall, risk assessments need to be carried out in close collaboration with local agencies, ongoing projects and stakeholder in order to benefit from mutual sharing of information and local knowledge, hence creating synergies and supporting adaptation strategies to climate change.

Annex

Climate change vulnerability factors characterization

Dear Sir or Madam,

Thank you very much for taking your time to answer this questionnaire as part of the United Nations Environmental Program project “Strengthening Capacities to Assess Climate Change Vulnerability and Impacts to Shape Investments in Adaptation Technology for Azerbaijan’s Mountain Regions”.

Who are we?

We are researchers from Eurac Research, located in Bolzano (Italy) specialized in risk and climate change assessments (<http://www.eurac.edu/en/research/mountains/remsen/Pages/default.aspx>) .

Why this questionnaire?

We are collecting data to characterize factors affecting vulnerability to climate change in Ismayilli and Shamakhi. Based on the information you will provide in this questionnaire, we will be able to better understand local characteristics of vulnerability involved in climate change impacts and adaptation strategies.

All the information you will provide in this questionnaire will be used at an aggregated level, analysed in an anonymous way and will not be published.

How this questionnaire works?

This questionnaire is structured in **4 parts**, for a total of 34 questions: part 1 is dedicated to drought hazards, part 2 focuses on flood hazards, part 3 deals with forest damages and part 4 looks at the management settings. We ask you to answer according to your expertise and in case you do not want/know to answer you can always skip and go to the next question.

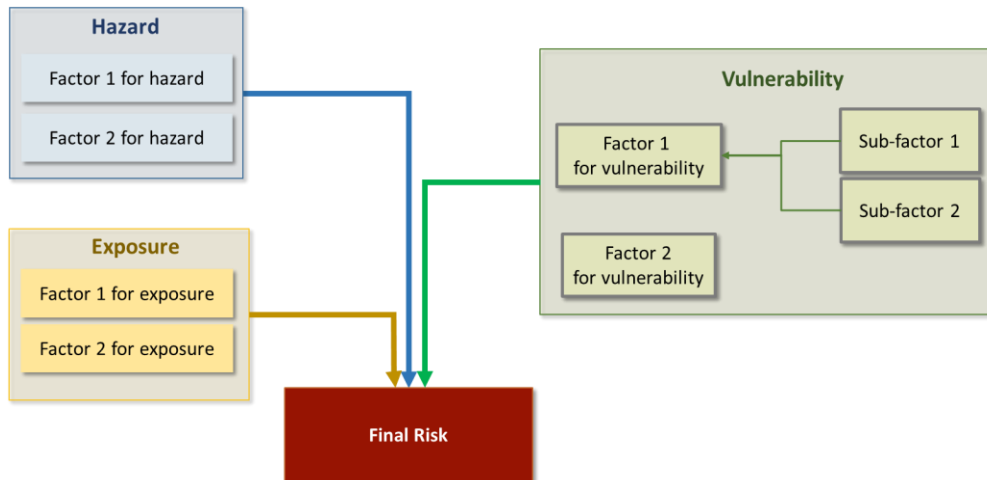
The questionnaire will take about 20 minutes.

In the following figure we reported a graphical explanation of **risk** events as the combination of:

1. **hazard** (a climate-related event that may cause damages to people, properties and livelihoods),
2. **exposure** (the presence of people, properties and livelihoods that could be adversely affected),
3. **vulnerability** (factors characterizing the level of susceptibility of exposed elements to be adversely affected).

For each component we already identified some factors, but we need your expertise to assess the **vulnerability** factors for the two regions Ismayilli and Shamakhi.

For example, the existence of modern irrigation infrastructures is considered as one vulnerability factor contributing to drought risk reduction in agricultural areas. However, we need your opinion to understand how far such factor contributes to risk reduction in Ismayilli and Shamakhi regions.



You can provide us your knowledge both writing your expertise in open questions and ticking one level of risk reduction contribution for each question. We would like you to evaluate how far certain factors can contribute reducing specific risk. For this reason, you can choose among **four levels of risk** as explained in the following table:

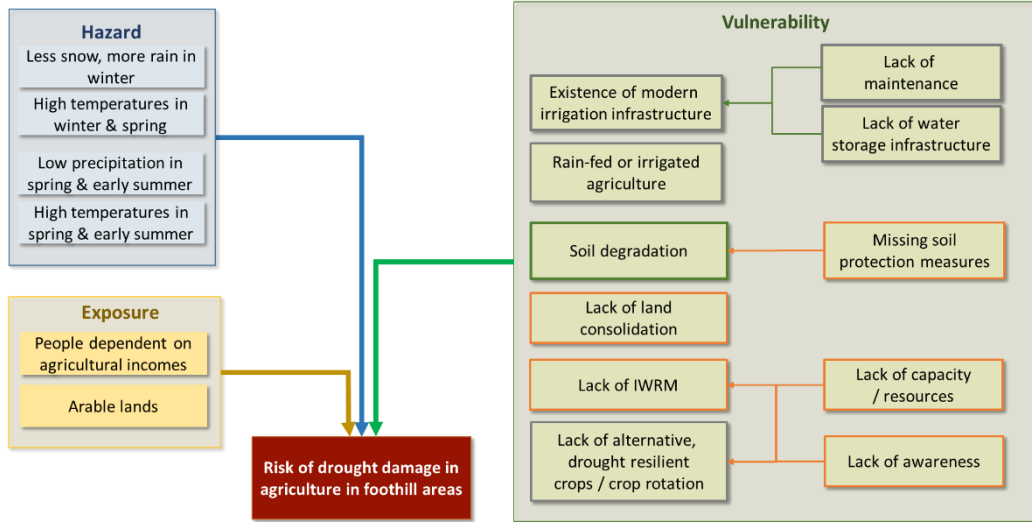
None	The factor has no or very little effects on local risk processes Example: irrigation infrastructures are completely absent in the area
Low	The factor has low effects on local risk processes Example: irrigation infrastructures are partially used to reduce agricultural drought risk
Medium	The factor has medium effects on local risk processes Example: irrigation infrastructures are mainly used to reduce agricultural drought risk
High	The factor has high effects (economic, ecological and health) on local risk processes Example: irrigation infrastructures substantially reduce agricultural drought risk

The project staff thank you for your collaboration and for your valuable contribution.

In case you are interested to know more, or you want to ask a question, please feel free to contact:

Stefano.terzi@eurac.edu

Risk of drought



1. Do you agree that we should consider drought risk due to their agriculture impacts in Ismayilli and Shamakhi?

- I fully disagree I disagree I agree I fully agree I don't know

The following vulnerability factor (as reported in the figure example above) was identified as relevant to assess drought risk in Ismayilli and Shamakhi regions:

- **Existence and maintenance of irrigation structures**

2. Are there any irrigation structures (for example: dam systems or distribution systems) in Ismayilli and Shamakhi regions?

- Yes, only in Ismayilli Yes, only in Shamakhi Yes, in both regions No, in none of them I don't know

3. If yes, please indicate which areas are in a particularly critical state? (for example: extension of irrigation structures or of a collaborative system):

Ismayilli:

Shamakhi:

4. Are there any spatial differences in the maintenance of irrigation structures between Ismayilli and Shamakhi regions?

- Yes No I don't know

5. If yes, please indicate which areas are in a particularly critical state? (for example: no maintenance of irrigation structures):

Ismayilli:

Shamakhi:

6. How much percentage of land is covered with a functioning irrigation infrastructure? And what is your opinion on their contribution to reduce drought risk?

	Irrigation coverage in %					Contribution to risk reduction			
	0-20	20-40	40-60	60-80	80-100	None	Low	Medium	High
Ismayilli									
Shamakhi									

7. What other factors do you think affect agricultural drought risk in the two regions (for example, water management systems):

8. If you answered to the previous question, please describe the current conditions in the two regions:

Ismayilli:

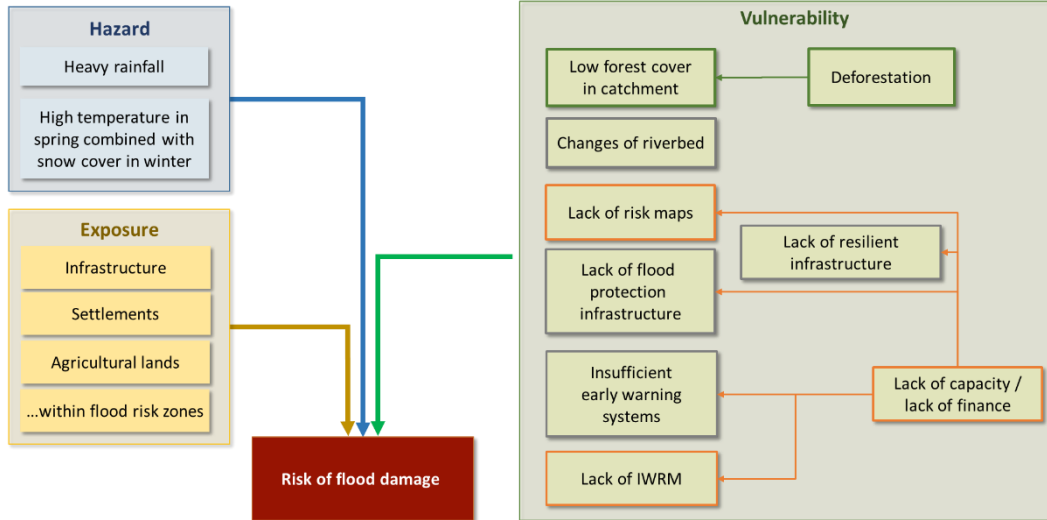
Shamakhi:

<hr/>	<hr/>
<hr/>	<hr/>
<hr/>	<hr/>

9. Do you want to add any other comments?

Risk of flood





10. Do you agree that we should consider flood risk due to their impacts on settlements and people in Ismayilli and Shamakhi?

- I fully disagree
 I disagree
 I agree
 I fully agree
 I don't know

The following vulnerability factors (as reported in the figure example above) were considered as relevant to assess flood risk in Ismayilli and Shamakhi regions:

- **Flood protections and early warning systems**

11. Are there any flood protections (for example: barriers, dams) or early warning systems in Ismayilli and Shamaxi regions?

- Yes, only in Ismayilli
 Yes, only in Shamakhi
 Yes, in both regions
 No, in none of them
 I don't know

12. If yes, please indicate which areas are in a particularly critical state? (for example: due to the lack of an early warning system):

Ismayilli:

Shamakhi:

13. To which extent flood protection systems or early warning systems are currently operational? And what do you think is their contribution to reduce flood risk?

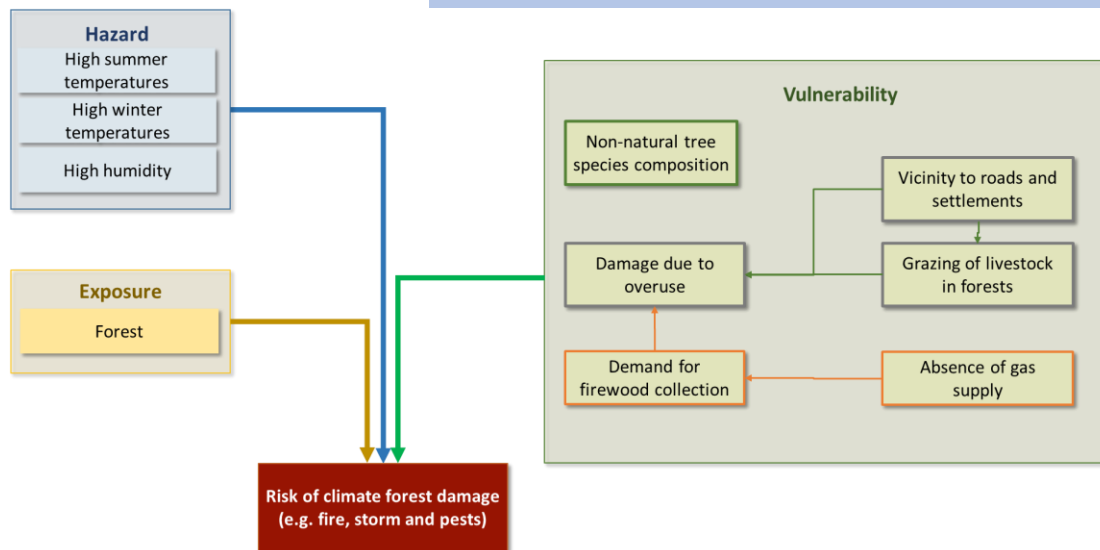
	Operationality in %					Contribution to risk reduction			
	0-20	20-40	40-60	60-80	80-100	None	Low	Medium	High
Ismayilli									
Shamakhi									

14. What other factors do you think affect flood risk in the two regions (for example, changes of riverbed)

15. If you answered to the previous question, please describe the current conditions in the two regions:
Ismayilli: _____ Shamakhi: _____

16. Do you want to add any other comments?

Risk of forest damages



17. Do you agree that we should consider risk of climate forest damage in Ismayilli and Shamakhi?

- I fully disagree I disagree I agree I fully agree I don't know

The following vulnerability factors (as reported in the figure example above) were considered as relevant to assess risk of forest damages in Ismayilli and Shamakhi regions:

- **Forest composition**

18. Are there any forest management plans to preserve natural forest composition in Ismayilli and Shamakhi regions?

- Yes, only in Ismayilli Yes, only in Shamakhi Yes, in both regions No, in none of them I don't know

19. If yes, please indicate which areas are in a particularly critical state? (for example: due to the lack of forest management):

Ismayilli:

Shamakhi:

20. To what extent forest composition is close to natural? And how effective do you think is its effect reducing risk of climate forest damages (for example from fire, storm and pest diseases)?

	Composition close to natural in %					Contribution to risk reduction			
	0-20	20-40	40-60	60-80	80-100	None	Low	Medium	High
Ismayilli									
Shamakhi									

21. What other factors do you think affect forest natural composition in the two regions?

22. If you answered to the previous question, please describe the current conditions in the two regions:

Ismayilli:

Shamakhi:

23. Do you want to add any other comments?

• **Forest disturbance**

24. Are there any livestock farming activities or firewood collection which are disturbing forest ecosystems in Ismayilli and Shamakhi regions?

- Yes, only in Ismayilli
 Yes, only in Shamakhi
 Yes, in both regions
 No, in none of them
 I don't know

25. If yes, please indicate which areas are in a particularly critical state? (for example: forest reforestation is in danger due to livestock presence):

Ismayilli:

Shamakhi:

26. How much percentage of forest is affected by livestock farming activities and firewood collection? And how much do you think they contribute to risk of climate forest damages?

	Forest affected in %					Contribution to risk reduction			
	0-20	20-40	40-60	60-80	80-100	None	Low	Medium	High
Ismayilli									
Shamakhi									

27. What other factors do you think affect livestock farming presence and firewood collection in the two regions (for example, subsidies if present)

28. If you answered to the previous question, please describe the current conditions in the two regions:
 Ismayilli: _____ Shamakhi: _____

29. Do you want to add any other comments?

30. Do you think there are other important factors related to forest damages?

Yes	No
<input type="checkbox"/>	<input type="checkbox"/>

31. If yes, which one?

General factors

The following vulnerability factors can have multiple effects on different natural hazards (for example, on drought, floods and forest damaging events).

- **Integrated Water Resources Management (IWRM)**

32. Is there an Integrated Water Resources Management for Ismayilli and Shamakhi?

Yes, only in Ismayilli Yes, only in Shamakhi Yes, in both regions No, in none of them I don't know

33. Do you think an Integrated Water Resources Management was useful against the following hazards?

Drought:

		Contribution to risk reduction			
		None	Low	Medium	High
Ismayilli					
Shamakhi					

Flood:

		Contribution to risk reduction			
		None	Low	Medium	High
Ismayilli					
Shamakhi					

- **Financial and human resources**

34. To which extent local administrations in the two regions have risk reduction capacities (including financial and human resources)?

Drought:

		Risk reduction resources			
		None	Low	Medium	High
Ismayilli					
Shamakhi					

Flood:

		Risk reduction resources			
		None	Low	Medium	High
Ismayilli					
Shamakhi					

Thank you for your contribution to the questionnaire!