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Climate Risk Assessment for Mountainous Communities of Tajikistan and Kyrgyzstan

IMPLICATIONS FOR HUMAN-WILDLIFE CONFLICT
FOCUS ON SNOW-LEOPARDS

For the Central Asian component of the UNEP flagship programme: “Vanishing Treasures - Climate resilient mountain ecosystems for resilient livelihoods and mountain flagship species”

Eirini Skrimizea, Alice Crespi, Tatiana Klisho, Kathrin Renner, Marc Zebisch

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Eurac Research
Center for Climate Change and Transformation
Drususallee 1
39100 Bozen
T +39 0471 055 055
info@eurac.edu
www.eurac.edu

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Authors: Eirini Skrimizea, Alice Crespi, Tatiana Klisho, Kathrin Renner, Marc Zebisch
Project Management: Alice Crespi
Scientific coordination: Marc Zebisch
Design and layout: Eurac Research
Photos:
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29: Eurac Research/Eirini Skrimizea

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Content

1 Introduction

UNEP's 'Vanishing Treasures' Programme supports climate change adaptation of vulnerable species in mountain regions such as in Hindu-Kush Himalayas (Bhutan), in Central Asia (Kyrgyzstan and Tajikistan) and in Virunga region (Rwanda and Uganda). The Programme is funded by the Grand Duchy of Luxembourg and aims to generate maximum synergy between climate change adaptation and biodiversity conservation by improving the adaptive capacity of mountain ecosystems while maintaining related ecosystem services, protecting mountain flagship species who are key to ecosystem functioning, and promoting alternative livelihoods for local communities. Eurac Research has been the contractor and responsible for the climate risk analysis in Central Asia under the technical supervision of UNEP and the programme advisors, and in close cooperation with designated implementing partners. Eurac Research supports the implementation of the 'Snow Leopard in Central Asia' component of the Programme through the elaboration of future climate scenarios and climate risk assessments in selected project regions and communities of Tajikistan and Kyrgyzstan.

This report presents the approach, methodological steps, and findings of the climate risk assessments for the Tajikistan and Kyrgyzstan project regions and communities under the 'Vanishing Treasures Programme'. Climate risk assessment is a crucial analytical step to understand and structure the climate risk and its underlying causes to eventually prepare, identify and select climate change adaptation actions. The climate risk assessments presented in this report have been developed with a community-centred focus and with the two main objectives of i) promoting sustainable land-use and livelihoods under climate change conditions, while considering 'external' socio-economic drivers, and ii) minimizing conflicts between Snow Leopard conservation and communities' livelihoods in the context of climate change. The communities under study are mountainous communities relying on livelihoods of mixed crop-livestock mountain agriculture, with a focus on livestock breeding for subsistence in Tajikistan, and market-oriented livestock breeding in Kyrgyzstan. Current human-wildlife interactions in the two areas, including the interaction with the snow leopard, refer primarily to livestock depredation by wild carnivores; pasture sharing between livestock and wildlife that constitutes snow leopard prey; and poaching.

In terms of approach, we follow and build upon the Impact Chain analytical approach (see section 3.2.1) described in detail in the Vulnerability Sourcebook (Fritzsche et al., 2014) and its Risk Supplement (GIZ and Eurac, 2017). To apply this analytical approach and assess each of the risk components and the overall risk, we combine quantitative data analyses (climate scenarios, climate indices and extremes, snow cover, glacier extent) with qualitative information that has been collected through participatory methods (workshops with experts, community consultations) and secondary sources. It has to be stressed that while the climate analysis (see sections 4.1 and 5.1) refers to national and project region levels, the assessment of climate risks focuses on the specific communities where community consultations and field visits took place, and for which a better understanding of climate impacts and vulnerability factors could be obtained (Barchidev and Gudara in Tajikistan; Bel-Aldy, Suusamyr, Ibraimov, Chong Kemin Village Districts in Kyrgyzstan – see sections 3.2.3, 4.2 and 5.2). For the visited communities in Tajikistan, the main climate risk identified and assessed refers to the risk of loss of livelihoods for livestock owners due to drought impact on pasture, and missing irrigation water for fodder and food production. For the visited communities in Kyrgyzstan, the main climate risk identified and assessed refers to the risk of loss of livelihoods for livestock owners due to drought impact on pasture, missing irrigation water for fodder and food production, and heat-exacerbated animal disease. The absence of water governance destroyed water irrigation channels and lack of investments in infrastructure development have been identified as major vulnerability factors and are currently the drivers of a mainly human-induced water stress in the visited communities of the two countries. In this report, we dive into the analysis of these climate risks and discuss their implications for human-wildlife conflict today and in the future up to 2050.

It has been widely reported that the effects of the predominantly dry climate of Central Asia will in future be further exacerbated by climate change, and that water-related risks are of central importance in a region of middle-income and low-income countries, where a large part of the population still relies on heavily irrigated agriculture and pastoralism, and where water stress could be a threat to regional stability. In this sense, the climate risk assessments presented in this report could be relevant to other mountain communities of the project regions or the broader Central Asia as well. Nevertheless, considering the complexity of mountain ecosystems, the still limited understanding of a wide range of environmental and socio-ecological parameters, knowledge data and gap constraints in Central Asia (Xenarios et al., 2019), any effort to generalize or transfer the insights presented here in other areas should be done with a lot of care and attentiveness to context-specific factors. In any case, the results of the two climate risk assessments can be used by the 'Vanishing Treasures' partners for cross-checking the climate-smartness of the snow leopard conservation actions and could provide the scientific basis for climate change adaptation planning in the studied communities.

To conclude, it has been previously acknowledged and we can confirm, as this was the case when conducting the climate risk assessments for the 'Vanishing Treasures' Programme, that 'understanding the dimensions and effects of climate change in extra-alpine mountain regions remains a research challenge because of limited availability of instrumental climate data' (Haag et al., 2021: 2). Action research and the engagement with local partners but also agropastoral communities, whose livelihoods are intertwined with their habitat and who possess traditional knowledge derived from close observations and interactions with their biophysical surrounding, have been necessary in order to address – to an extent – this lack of data, and obtain valuable information for the climate risk assessments presented in this report (Ibid.). At the same time, and considering that the climate risk assessment is a step before the development of climate change adaptation actions, the inclusion of the relevant communities in the process is necessary in order to build trust, ensure the development of adaptation actions that are meaningful to the communities, and contribute to the empowerment of the communities and actors on the ground rather than just to 'assisting' or imposing climate change adaptation agendas. The Impact Chains approach as applied in the context of the 'Vanishing Treasures' Programme proved to be a robust but also flexible analytical framework, capable to foster transdisciplinary climate research in the remote mountainous communities of Tajikistan and Kyrgyzstan. As such, we believe that the climate risk assessment approach and the methods presented in this report could be useful and could guide future climate risk assessments in the same or other challenging mountainous contexts. This report has been written also with the goal to support the transferability of the approach to other mountain regions.

Chapter 2 introduces the reader to the project regions and communities under study adopting a multi-scalar approach – from the national, to the project region and finally to the communities at the local level with references to external drivers with impacts at these scales, when necessary. Chapter 3 presents step-by-step the methodology followed for the conduction of the climate risk assessments from the climate data processing and analysis methods to the participatory workshops with experts and community consultations. Chapters 4 and 5 present the findings of the climate risk assessment for Tajikistan and Kyrgyzstan, respectively. For each country, we first present the results of the analysis in terms of climate signals and snow cover, and we then move on to focus on assessing the climate risk for the specific communities under study. Chapter 6 provides concluding remarks discussing the results on the two countries together.

2 Introduction to the project regions and communities under study

2.1 The project region and communities in Tajikistan

Tajikistan is a landlocked, mountainous country with half of its territory above 3,000m. It is home to some of the highest mountains in the world, including the Pamir and Alay ranges. Major areas of lower land are mainly in the north constituting part of the Fergana Valley, and in the southern Kofarnihon and Vakhsh river valleys, which form the Amu Darya. The largest rivers are the Syr Darya and the Amu Darya with the latter carrying more water than any other river in Central Asia. The current climate of Tajikistan is characterized by continental conditions even though with relevant spatial heterogeneities driven by strong elevation gradients (see section 4.1.1). Tajikistan is a largely agrarian country. Approximately 73% of the population of 9 million reside in rural areas; 49% of this rural population live below poverty line, making Tajikistan the poorest country in Central Asia (Xenarios et al., 2021). The agricultural sector contributes 22.6% in the national GDP (USAID, 2022). Extensive agriculture is mostly practiced in lowland areas; in the mountainous regions, where we focus on in this climate risk assessment, paid jobs are scarce and subsistence mountain agriculture based on livestock breeding and (less) on arable land plays a major role in the livelihoods of local communities together with remittances. In fact, Tajikistan's economy is perilously reliant on remittances, which in 2019 contributed 33% in the national GDP (Eurasianet, 2020).

The project region is located in the east of the country, where the Pamir mountains culminate in the complex Pamir Knot centred in the autonomous province Gorno Badakhshan Autonomous Oblast, and includes a representative transect through the Eastern Pamirs and the transitional areas towards the Western Pamirs[1] (Figure 1). Most territory of the Pamir mountains is rocky mountain terrain with permanent snow, glaciers, and debris. There are almost no trees, and the flora consists of low plants adapted to harsh conditions (Mętrak et al., 2015). In the eastern Pamirs a medium-mountain relief predominates on a high raised foundation. In the western Pamirs, where our fieldwork and community consultations took place, the relief is characterized by large relative elevations and narrow valleys with steep slopes. The highest summit of the Tajik Pamir, Peak Somoni (7,495m), and the largest alpine glacier, Fedchenko, are located there. The valleys and depressions are filled with outwash debris, so that almost the only suitable places for human settlement are the alluvial fans in the valleys of tributaries of the Panj River (Mętrak et al., 2015). Being strongly glacierized (permanent glaciers comprise 10-13% of the total area of the Pamir), the Pamir mountains are a major source of water supporting the irrigated agriculture and energy production in Central Asia (Ibid.) – where water is a strategic resource often at the centre of regional and small-scale conflicts.

[1] The Tajik Pamirs are generally divided into an eastern and a western part defined by the distinct topography and climate but also socio-cultural differences (Hoeck et al., 2017).

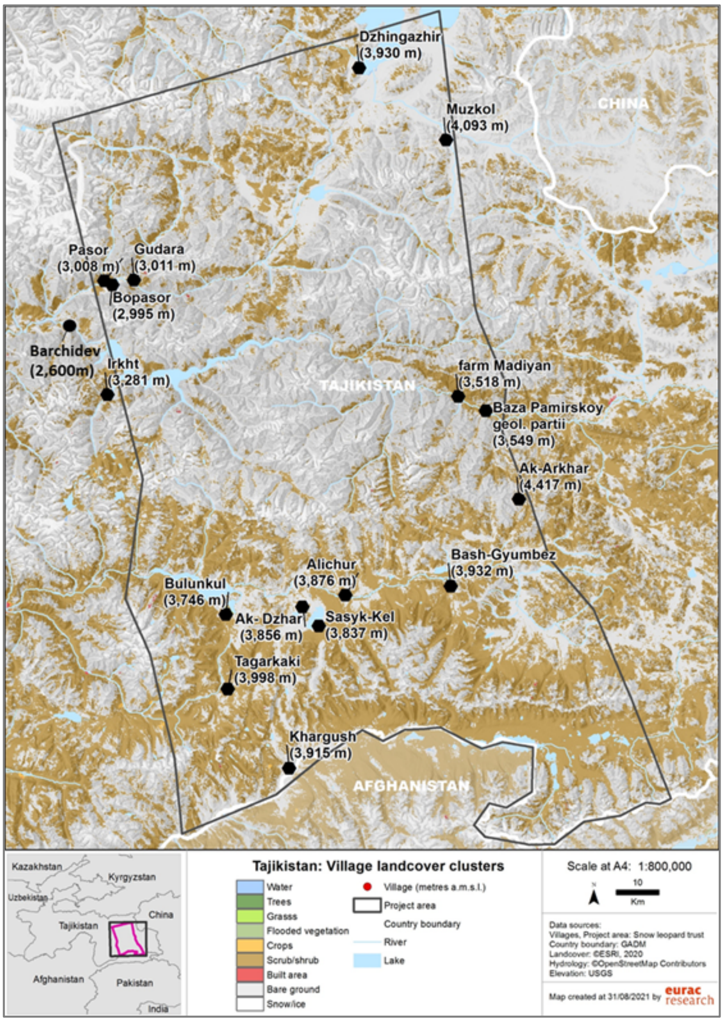

Figure 1: The project region in the east of Tajikistan with the communities, their elevations and land cover. Barchidev and Ghudara, the communities where the community consultations took place, are located in the North-West of the project region in the Bartang Valley.

In terms of climate, the Gorno Badakhshan Autonomous Oblast is characterized by arid and semi-arid climate and has many different microclimates (see section 4.1.2). Drawing from Michel (2021), the aridity is not only a result of precipitation-temperature ratios, but also caused by the fact that substantial parts of the winter precipitation are lost by snow subliming instead of melting and thus not contributing to soil moisture. For climate classification of the project region see section 4.1.2. Here we mainly report on data coming from meteorological stations of the project region[2]. The eastern Pamirs are a mountain desert with strongly arid and semi-arid climate conditions (Breu and Hurni, 2003; Mętrak et al., 2015; Michel, 2021). They receive less than 100mm precipitation annually and have mean annual temperatures around 0°C with the mean temperature of the coldest month below -15°C. To the southwest the project region's climate is less arid with higher overall precipitation, in spring and winter (Michel, 2021). In the western Pamirs around the Bartang Valley, a season with low rainfall from June until November is very prominent; the months July, August and September are without or almost without precipitation. This situation is typical for the gorged of the western Pamirs where the valleys

[2] Data from meteorological stations in the Gorno Badakhshan Autonomous Province can be found here https://en.climate-data.org/asia/tajikistan/gorno-badakhshan-autonomous-province-740/ and are presented and discussed in Michel (2021).

receive very little rainfall in contrast to the mountain slopes that with increasing elevation receive many times more precipitation. The accumulation of this precipitation as snow and snowmelt during the early summer causes peak flows in the rivers during the hottest months and allows for irrigated hill agriculture and the development of riparian woodlands in the valleys (Michel, 2021).

The Gorno Badakhshan Autonomous Oblast encompasses 63,700km2 and has only communities of approximately 213,000 inhabitants in total, of whom 87% live in rural areas (Breu and Hurni, 2003; Hoeck et al., 2007). While at least 85% of the territory of the province has no productive agropastoral potential (Breu et al., 2005), harsh temperature and precipitation regimes further constrain vegetation growth and contribute to higher energy consumption (Hoeck et al., 2007). The Famine Early Warning Systems Network (FEWSN, 2011) has performed a categorization of the livelihoods in Tajikistan for 'food security analysis and early warning'. According to the livelihood zones, the eastern Pamirs is a rather sparsely populated area where the mountainous communities are mostly unable to produce crops and thus their livelihoods concern mostly livestock breeding (yaks, goats and sheep) carried out in the nomadic tradition based on seasonal exploitation of resources at different altitudes. The main source of income for most of the population there is sale of animals and animal products. Barchidev and Ghudara, which are the particular focus of the climate risk assessment as this is where the community consultations took place (see section 4.2), are located in the Bartang valley in the north-western Pamirs. There, the land use of the traditional, predominantly Ismaili settlements consists of mixed mountain agriculture with crop cultivation on irrigated land (wheat, potatoes, carrots, onions, garlic, fodder crops) and livestock-breeding (goats, sheep, cows, less yak) mainly for subsistence (Figure 2). Better-off households have a certain income working as schoolteachers, retailers, doctors, taxi-drivers. Both livelihood zones lack access to the market due to remoteness, bad road conditions and winter weather conditions. In response to the marginal socio-ecological conditions and initially triggered by the economic collapse that followed in all countries of Central Asia upon the dissolution of the Soviet Union, the communities of the project region depend heavily on remittances.

Figure 2: 2A, 2B: View of Barchidev village from the two opposite banks of Murghab river. 2C Hay storage in Ghudara village. 2D Livestock grazing in the upper Bartang valley.

Other legacies of the past that continue to affect the lives of mountain communities in the project region include weak customary institutions and disappearance of formal regulatory institutions, environmental degradation, and lack of renewed infrastructure (Xenarios et al., 2019). The Tajik government structure is characterized by centralised decision-making with insufficient consideration of the specific needs of remote regions like mountain areas in national policy processes (Ibid). This lack of support from the government is illustrated in Barchidev and Ghudara through the lack of access to an otherwise currently available water resource due to insufficient water infrastructure and/or water infrastructure that is destroyed as it has not been maintained since the Soviet times. At the same time, the Water User Associations as a local institutional scheme introduced in Tajikistan, seem to have not been applied in these mountainous communities. Under these conditions, the communities base their livelihoods on solidarity, voluntary work, and seeking development and humanitarian support.

When it comes to the snow leopard, the overall status and patterns of distribution of snow leopard and its prey species in the project region in Tajikistan can be summarized as follows: Overall population size of snow leopards might be in the range of at least 20-25 individuals, possibly even many more, taking into account not yet researched suitable areas and availability of prey species (Michel, 2021). Numbers of recorded wild ungulates (Marco Polo argali and Ibexes) have fluctuated over the years due to poaching, protection efforts, livestock grazing, human disturbance as well as seasonal movements. The project region includes the Zorkul Strict Nature Reserve, a section of Tajik National Park, which includes the villages of Barchidev and Ghudara, the community-based wildlife management area of NGO ‘Burgut’ in the southern slopes of Northern Alichur Mountain Range, the planned community-based wildlife management area of NGO 'Guldara' in the upper reaches of the Bartang Gorge (see Michel, 2021).

2.2 The project region and communities in Kyrgyzstan

Kyrgyzstan is a landlocked, mountainous country. Approximately 94% of the country is above 1,000m elevation, and 40% is above 3,000 m. More than 94% of its territory is 1,000m, or more, above sea level, and 40.8% is above 3,000m. Over 80% of the country is within the Tian Shan mountain chain and 4% is permanently under ice and snow (WBG and ADP, 2021). The principal river is the Kara Darya, which flows west through the Fergana Valley into Uzbekistan. Across the border in Uzbekistan it meets another major Kyrgyz river, the Naryn. Issyk-Kul Lake, in the north-eastern Tian Shan is the largest lake in Kyrgyzstan. The current climate of Kyrgyzstan is characterized as extremely continental and arid with remarkable spatial heterogeneities due to its complex mountainous terrain (see section 5.1.1). The Kyrgyz Republic had a population of 6.5 million in 2019 (WBG, 2021). Most of this population live in the foothills of the mountains, and is centred around two urban conurbations, the capital Bishkek in the north, and between Osh and Jalal-Abad in the west. With 25.4% national poverty rate, Kyrgyzstan ranks among the poorest countries in the world (WBG and ADP, 2021). The Kyrgyz Republic's national economy has rapidly transitioned away from agriculture, which constituted 14.6% of GDP in 2017 (Ibid.). Nevertheless, agriculture still plays a crucial role as a source of employment, income, and food security for rural people (Scalice and Undeland, 2016). The Kyrgyz economy is vulnerable to external shocks owing to its heavy dependence on remittances (25% of GDP) and gold production (about 10% of GDP and 40% of exports) (WBG and ADP, 2021).

The project region is located in the north of the country, covering large sections of the Kyrgyz Alatoo Range and adjacent mountain ranges (Figure 3). More specifically, the project region includes the northern and southern main slopes of the Kyrgyz Alatoo Range, the east-west oriented, towards the west open Kemin valley with the southern main slope of Zaili Alatoo and the northern main slope of Kungey Alatoo, the intramontane basin of Suusamyr, a plateau-like valley at 2,000m and higher, and the Suusamyr(too) Range at its southern edges (see Michel, 2021). For a closer look to the project region, we focus on the locations of special interest to this climate risk assessment, which are the locations where the community consultations took place, and we go through them from south-west to the north-east of the project region: The Bel-Aldy Village District is located within the Naryn river valley, close to the Toktogul reservoir. The Suusamyr Village District is located at the big Suusamyr Valley, which lies at 2,000-2,500m between Suusamyr(too) and Kyrgyz Ala-Too ranges of Tian Shan mountains. The valley is predominantly used as alpine summer pastures and attracts herders from all the surrounding places. The Ibraimov Village District is located in the eastern part of Chüy Valley while its southern part spreads into Kyrgyz Ala-Too mountains in the north-east of the Kyrgyzstan project region. The Chong Kemin Village District is the northeast panhandle district of Chüy Region in the north-eastern of the Kyrgyzstan project region located in the Chong Kemin Valley. The Chong Kemin Valley includes a combination of wild and pastoral landscapes reaching 2,800 m in altitude.

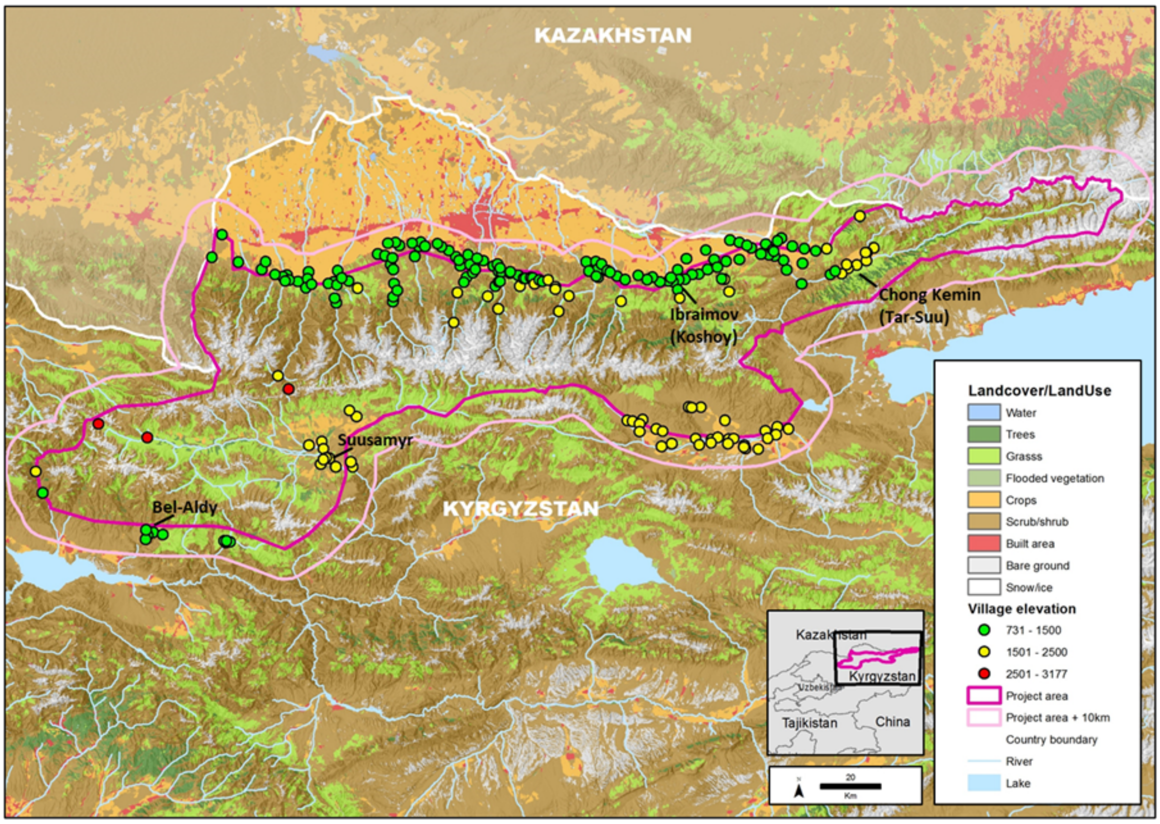

Figure 3: The project region in the north of Kyrgyzstan with the communities, their elevations and land cover. The community consultations included participants from the Bel-Aldy, Suusamyr, Ibraimov and Chong Kemin Village Districts. The locations of the consultations are the villages of Bel-Aldy, Suusamyr, Koshoy and Tar-Suu respectively.

In terms of climate, the project region is characterised by a high climatic diversity (see section 5.1.2). Generally, the highest mountains are the coldest areas and receive most of the precipitation, largely as snow. The lowlands and intra-montane basins are hotter and more arid. There are precipitation gradients between the western, central and eastern parts, with a decline in precipitation from west to east. Thus, the most arid zone is the Ferghana basin in the country's south, followed by the lowlands of the region surrounding Bishkek (Michel, 2021). According to the available data from the meteorological stations in the area (Ibid.), close to Chong Kemin and at the valley's elevation the climate is characterized by cold winters, warm summers and average precipitation of 220mm with a rainfall maximum in spring and lower, but still substantial, precipitation throughout the summer. In the northern foothills of the Kyrgyz Alatoo Range, close to the Ibraimov Village District, the temperatures and overall precipitation are higher than at the stations above. Rainfall is highest in spring while a drier period is in July-September. In Suusamyr, mean annual temperature and mean summer temperatures are lower, while precipitation is higher, and thus the climate is more humid with respect to the rest of the region.

In Kyrgyzstan, agricultural land makes up 55.2% of the land, which is comprised of about 7% arable land and 43% rangeland or pastures. More than half of the agricultural output comes from the livestock sector, which supplies meat and dairy for local consumption and for export (Scalice and Undeland, 2016). After the dissolution of the Soviet Union and the disintegration of the collective farms, more than 400,000 family farms emerged with an average size of 3ha and primarily located in rural mountain regions (Azarov et al., 2019). Similarly to what is happening at the country level, the communities of interest to this climate risk assessment focus on market-oriented animal breeding based on a mix of crop and pasture land around the settlements and in gradually higher elevations during the summer. Due to climatic conditions and lack of or destroyed water infrastructure, only a limited number of crops can be cultivated, and crop production mainly serves as source of livestock forage. In Kyrgyzstan, the main crop produced is wheat followed by barley, corn (maize), and fodder crops (lucerne, sainfoin). Potatoes, vegetables and legumes production has been increasing, signalling a gradual change in crop patterns towards more market-oriented production. Cattle, sheep, goats, and horses (Figure 4) are the main types of livestock bred in constantly increasing numbers (Mogilevskii et al., 2017). A problem that here seems to be much more intense than in the Tajikistan case is this of pasture degradation because of overgrazing against a backdrop of weak natural resource governance mechanisms and fragile ecological conditions. As FAO and IFAD (2021: 3) highlight: 'Kyrgyzstan's pasture conditions are worsening. A recent assessment undertaken by the Climate Resilience Cluster of Earth Observation for Sustainable Development estimates that 94% of pastures, over 69,900km2, are degraded at least during one season per year'. Livestock diseases are an additional pressure to Kyrgyzstan agricultural systems and a major barrier to value chain development (i.e., market-driven approach for supporting small enterprises and smallholder farmers to meet the quality, volume and compliance requirements of global brands, retailers and traders) (Robinson, 2020). Population growth, increasing urbanisation, changing lifestyles and increasing international market demand will likely further intensify agricultural and livestock systems in the future (Azarov et al., 2019).

Similarly, to Tajikistan, weak customary institutions and disappearance of formal regulatory institutions, environmental degradation and lack of renewed infrastructure are all legacies of the past that continue to affect the lives of mountain communities in the Kyrgyzstan project region (Xenarios et al., 2019). The Kyrgyz government structure is characterized by centralised decision-making with insufficient consideration of the specific needs of remote regions like mountain areas in national policy processes (Ibid.). This lack of support from the government is illustrated in the communities under study through the lack of access to an otherwise currently available water resource due to insufficient water infrastructure and/or water infrastructure that is destroyed as it has not been maintained since the Soviet times. This situation goes hand-in-hand with a non-sufficient pasture management by immature new institutions with limited enforcement power i.e., the Pasture Management Committees (Isaeva and Shigaeva, 2017; Xenarios et al., 2019).

When it comes to the snow leopard, no full estimate of the snow leopard numbers is available for the entire project region, but only local records. In 2019 the Snow Leopard Foundation Kyrgyzstan during a camera trap survey of the northern slopes of Kyrgyz Alatoo between Shamshy and Ak-Suu Valley recorded 16 individual snow leopards. Snow leopards have been confirmed also in the Chong Kemin Valley and at the southern slopes of Kyrgyz Alatoo, towards Suusamyr Valley (Michel, 2021). Prey availability may be a limiting factor for snow leopard presence, population size, reproductive success and survival in the project region. The project region includes the Chong Kemin National Park in the east, the central parts of the Kyrgyz Alatoo with Ala Archa National Park, the community-based wildlife conservation area of NGO 'Shumkar-Tor' in Kemin-Valley, and the NGO managed conservation area Shamshy in the Kyrgyz Alatoo.

Figure 4: A, B: Herder and grazing horses, 4C View of village in Bel-Aldy Village District, 4D View of the road from Tar-Suu village in Chong Kemin Village District.

3 Methodology

This chapter presents the material used and methods followed for climate data processing and analysis, and for the climate risk assessment.

3.1 Climate data processing and analysis methods

The climate assessment was performed at national and local scale for Tajikistan and Kyrgyzstan by integrating observational datasets and climate model simulations. The analysis was based on temperature and precipitation and on derived climate indices accounting for both mean and extreme conditions. The assessment was focused on the spatial distribution of climate features over the study area as well as on the evaluation of trends over both recent and future decades. Observations and model data were derived from multiple global sources and cover different spatial and temporal resolutions.

3.1.1 Observations

Climate observations are essential to analyse past and current climate conditions over the project region and can be used as reference to validate and calibrate model simulations. In particular, the historical time series of in-situ observations collected by national meteorological services represent the primary source of local climate information and can be used to derive gridded datasets providing a continuous description of the spatio-temporal climate distribution over the study domain. Due to the lack of national gridded observational products for the two countries and the difficulty to retrieve, check and process a suitable number of local records for the national climate assessment, the characterization of past and current climate was based on existing global products. The considered products include both observations and reanalysis data. In particular:

- CRU TS v4.04 (Climate Research Unit): 1961-2019 monthly mean temperature and precipitation gridded observation series at 0.5° spatial resolution. Source: Harris et al. (2020); https://crudata.uea.ac.uk/cru/data/hrg/
- GPCC (Global Precipitation Climatology Centre): 1961-2019 monthly precipitation gridded observation series at 0.5° spatial resolution. Source: Schneider et al. (2017); https://doi.org/10.5676/DWD_GPCC/FD_M_V2020_050
- ERA5: 1961-2020 hourly reanalysis series of minimum and maximum temperature and precipitation at 0.25° spatial resolution. Source: Hersbach et al. (2020); https://doi.org/10.24381/cds.adbb2d47
- ERA5-Land: 1981-2020 hourly reanalysis series of minimum and maximum temperature and precipitation at 0.1° spatial resolution. Source: Muñoz-Sabater et al. (2021); https://doi.org/10.24381/cds.e2161bac
- WFDE5: 1979-2019 hourly bias-adjusted ERA5 series of minimum and maximum temperature and precipitation at 0.5° spatial resolution. Source: Cucchi et al. (2020); https://doi.org/10.24381/cds.20d54e34
- CHELSA v2.1: 30-arc second resolution 1981-2010 monthly climatologies of temperature (maximum and minimum) and precipitation based on downscaled ERA5. Source: Karger et al. (2017); https://doi.org/10.16904/envidat.228.v2.1

The availability of multiple products allowed to better assess the robustness and uncertainty of the extracted information and to cover the input requirements for the analyses. In particular, CRU and GPCC monthly data were mainly used to analyse the mean climate conditions over recent decades, while climate indices measuring extreme conditions for the past were extracted from reanalyses thanks to their finer temporal resolution.

Both gridded observation datasets and reanalyses are fed by operational in-situ data available globally. However, availability of in-situ observations is significantly limited in high-elevation regions such as those located in Central Asia, so that a greater uncertainty has to be associated to the interpolated as well as modelled data over remote mountain areas. To assess the differences among the considered data sources, the spatial distribution of 1981-2010 seasonal climatologies, i.e., the 30-year averages, (Figure 5) and the regional mean annual cycles (Figure 6) were extracted and compared for both temperature and precipitation from each dataset.

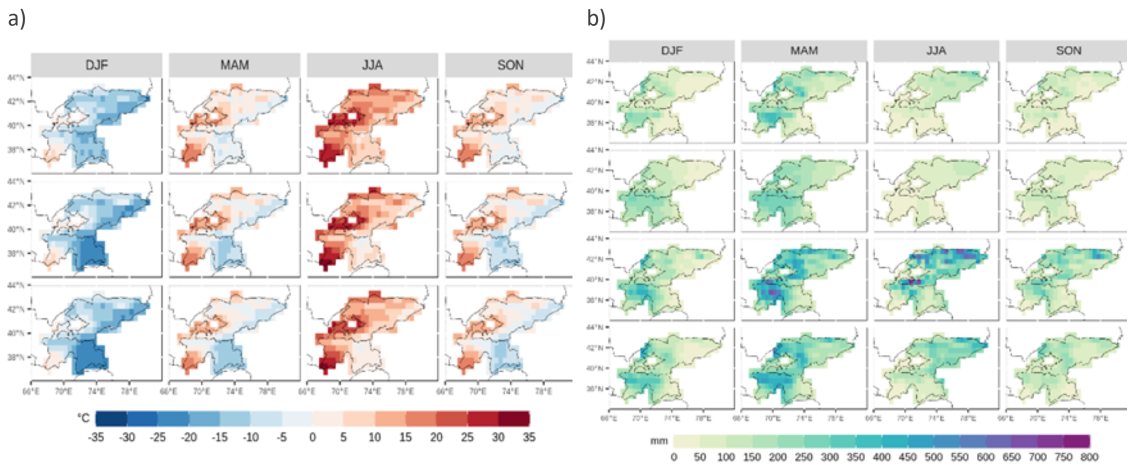

Figure 5: 1981-2010 seasonal climatologies of a) mean temperature and b) precipitation extracted from different climate products of Kyrgyzstan and Tajikistan. All datasets were regridded onto a common 0.5° resolution grid.

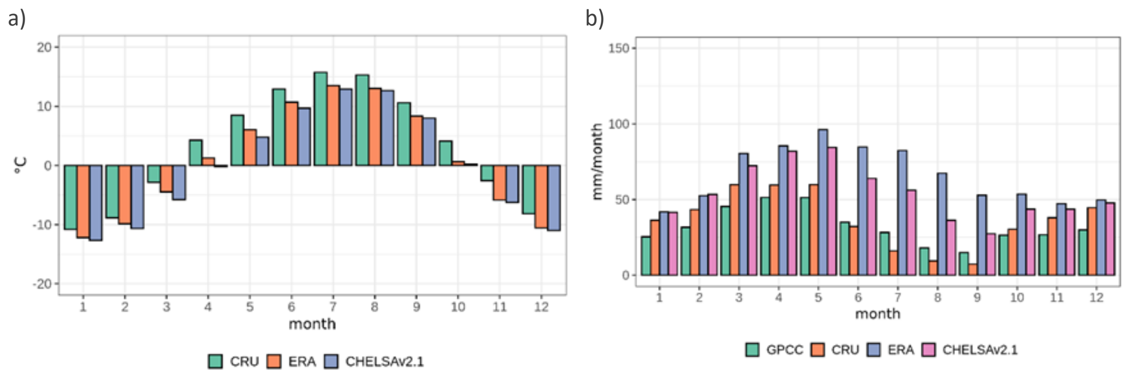

Figure 6: Mean annual cycle of a) mean temperature and b) precipitation over 1981-2010 for the area of Kyrgyzstan and Tajikistan extracted from different climate products. All datasets were regridded onto a common 0.5° resolution grid.

The datasets show a general agreement on temperature distribution in terms of both spatial patterns and annual cycle. Mean temperature was found to be slightly overestimated in CRU data with respect to the reanalyses, especially in Tajikistan over the high-mountain region of Pamir in the East. The discrepancies between observations and reanalyses are much more evident for precipitation with the latter reproducing wetter conditions in all months. This difference could be partly due to the low availability of rain-gauge data in mountains and remote regions leading to underestimations of interpolated observations in these areas. In addition, observation-based precipitation datasets can suffer from rain-gauge undercatch, especially in those areas where precipitation falls mostly as snow. Such issues are partly overcome in reanalyses, in which topographic effects are included in the physical modelling. However, ERA5 exhibits extremely wet spots, especially in western Tajikistan in spring and in northern Kyrgyzstan in summer and the annual cycle partly misses the precipitation minimum in summer/early autumn. CHELSA reports intermediate precipitation amounts with respect to ERA5 and observation products. CHELSA was obtained by means of a mechanistical statistical downscaling of ERA5 to 30-arc second resolution (~ 1km), and downscaled precipitation values were further adjusted by using GPCC data together with an undercatch correction (Karger et al., 2017). At the moment of the analysis, CHELSA v2.1 did not include daily time series, which could be used in place of original reanalyses to compute the climate indices and to downscale future climate projections (see below).

The downscaled reanalysis data at 1-km resolution from CHELSA v2.1 were used to derive proper information for the case study areas supporting the local climate risk assessment. In particular, 1981-2010 mean values of temperature, precipitation and several available bioclimatic indicators were used to identify and characterize the main climate zones of each case-study domain by means a cluster analysis based on the k-means method (Lloyd, 1957).

3.1.2 Future climate projections

3.1.2.1 CMIP6

Data on future climate projections for Tajikistan and Kyrgyzstan were retrieved from the state-of-the-art global simulations provided by the Coupled Model Intercomparison Project Phase 6 (CMIP6). More specifically, daily temperature and precipitation simulations from 1950 to 2100 were collected from an ensemble of 23 GCMs (Table 1Table 2) and for two selected scenarios (the so-called Shared Socioeconomic Pathways): SSP2-4.5, as a moderate emission scenario, and SSP5-8.5, as a high emission scenario. The GCMs of the ensemble have different spatial resolutions ranging from 2° to 0.7°.

Model	Grid
ACCESS-CM2	1.875x1.25
ACCESS-ESM1-5	1.875x1.25
BCC-CMS2-MR	1.125x1.125
CMCC-CM2-SR5	1.25x0.94
CMCC-ESM2	1.25x0.94
EC-Earth3	0.7x0.7
EC-Earth3-CC	0.7x0.7
EC-Earth3-Veg	0.7x0.7
FGOALS-g3	2x2.3
GFDL-ESM4	1.25x1
INM-CM4-8	2x1.5
INM-CM5-0	2x1.5
IPSL-CM6A-LR	2x1.268
KACE-1-0-G	1.875x1.25
KIOST-ESM	1.875x1.875
MIROC6	1.406x1.406

MPI-ESM1-2-HR	0.938x0.938
MPI-ESM1-2-LR	1.875x1.875
MRI-ESM2-0	1.125x1.125
NESM3	1.875x1.875
NorESM2-LM	2.5x1.89
NorESM2-MM	1.25x0.94
GFDL-CM4	1.25x1

Table 1: List of selected GCMs from CMIP6 and their corresponding spatial grids.

All models were evaluated against the available observation data in order to better assess the variability and discrepancies of ensemble simulations. To this aim, all model and observation data were regridded to a common 1.5°x1.5° grid and multiple metrics were computed. In particular, each model was compared with observations over the common period in terms of mean annual cycle, interannual variability, mean climate conditions, spatial distribution and long-term trends. Metrics include Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Error (ME), standard deviation and Pattern Correlation Coefficient (PCC).

For each variable, models were ranked based on the percentile method (25th, 50th, 75th) applied to each statistical measure and considering the amplitude of its values (Gnatiuk et al., 2020). The rank was used to evaluate the ensemble spread and to identify those models mostly deviating from the reference observations. The resulting model rank for temperature and precipitation was different so that it was not possible to identify a univocal subset of best-performing models. Despite a certain spread in the derived scores, no model was found to be affected by remarkable deviations and excluded from the national climate assessment. However, the results provide supporting information for the evaluation of single simulations and can be used in future analyses to identify proper subsets of best performing GCMs for Central Asia.

The national climate assessment was therefore based on the 23-model ensemble. All models were regridded to 0.5°x0.5° resolution in order to make them comparable with the spatial description derived from observations and reanalyses.

For each scenario and each model, the differences in 30-year mean climate conditions in 2011-2040 (near future) and 2041-2070 (middle future) were computed with respect to the reference period 1981-2010 for each point of the 0.5°-resolution grid. In addition, mean regional values, as spatial averages, were computed for Tajikistan and Kyrgyzstan, separately, and the annual time series of projected values up to 2100 were evaluated in order to analyse the long-term trends. The information from the model ensemble was summarized by computing the median and, as a measure of uncertainty, the interquartile range (25th-75th percentiles) of the model ensemble.

3.1.2.2 1-km CMIP6 projections: CHELSA database

The availability of climate information at a finer spatial resolution is relevant for performing the local risk assessment, especially in the mountainous terrain of case studies. Due to the lack of a suitable gridded datasets of time series based on local in-situ observations to be used as reference, it was not possible to derive local scenarios through the application of proper downscaling schemes. For this reason, we decided to base the analyses on already existing global products and in particular on the state-of-the-art 1-km downscaled CMIP6 projections made available by the CHELSA repository.

The data were bias-corrected by using a trend-preserving approach as in the Intersectoral Impact Model Inter-comparison Project ISIMIP (Lange, 2019) and then statistically downscaled to 1-km grid. A selection of 17 GCMs (Table 2) for SSP2-4.5 and SSP5-8.5 scenarios were retrieved by means of the chelsa_cmip6 Python package (https://gitlabext.wsl.ch/karger/chelsa_cmip6). The data are provided as 30-year averages at monthly resolution and cover temperature, precipitation and 19 bioclimate indicators. We retrieved data for three consecutive 30-year periods: historical (1981-2010), near future (2011-2041) and middle future (2041-2070). The data were retrieved for the following domain including both project regions in Tajikistan and Kyrgyzstan: 67.3°-80.3°E, 36.6°-43.3°N. The computational time had been approximately 250 hours.

For each scenario, the differences in the near future and the middle future periods were computed with respect to the historical period. Temperature and precipitation regimes and changes were analysed at both seasonal and annual scales. Most analyses supporting the risk assessment at case study and community level were mainly focused on the moderate SSP2-4.5 scenarios since it was considered the most realistic picture of the future evolution of global socio-economic conditions.

Institution	Model
INM	INM-CM4-8
EC-Earth-Consortium	EC-Earth3-Veg
BCC	BCC-CSM2-MR
NIMS-KMA	KACE-1-0-G
NOAA-GFDL	GFDL-CM4
INM	INM-CM5-0
EC-Earth-Consortium	EC-Earth3
NUIST	NESM3
CAS	FGOALS-g3
CSIRO-ARCCSS	ACCESS-CM2
MIROC	MIROC6
MPI-M	MPI-ESM1-2-LR
NOAA-GFDL	GFDL-ESM4
MOHC	UKESM1-0-LL
IPSL	IPSL-CM6A-LR
MRI	MRI-ESM2-0
CSIRO	ACCESS-ESM1-5

Table 2: List of 1-km downscaled CMIP6 models from CHELSA repository.

3.1.3 Climate indices and extremes

Besides mean temperature and precipitation, a selection of climate indices describing extreme climate conditions, such as heat and hydrometeorological extremes, was computed and analysed. In particular, we computed:

- Heat Wave days (HWD): number of days in a year under heat wave conditions, i.e., period with maximum temperature exceeding the 99th percentile from May to September over 1981-2010 for at least three consecutive days.
- Heat Wave frequency: number of heat wave occurrences in a year.
- Intense precipitation total (R95pTOT): annual sum of daily precipitation exceeding the 95th percentile computed from all wet days (> 1mm) in 1981-2010.
- Standardized Precipitation Index (SPI): it measures the deficit or surplus of cumulated precipitation over different temporal scales with respect to reference conditions.
- Standardized Precipitation Evapotranspiration Index (SPEI): it measures the climate water balance, i.e., the balance between precipitation and evapotranspiration, cumulated over different temporal scale and compared to reference conditions.

Both SPI and SPEI are standardized indicators that fit the input variables with a statistical distribution over a baseline and classify the drought conditions with a simple scheme related to standard deviations from the median. The negative and positive values of the indices depict wetter and drier anomalies with respect to the reference conditions, respectively. Based on the values of the indices, monthly conditions of dryness or wetness can be classified from low to extreme.

SPI and SPEI were computed on a monthly basis over 3 and 12-month accumulation periods in order to account for variability in different types of droughts. For instance, the 3-month scale represents anomalies of accumulated precipitation (SPI-3) or accumulated climate balance (SPEI-3) for the current month and for the two previous months. Such timescale is mainly used to describe meteorological and agricultural droughts, and it was selected to capture drought on a seasonal basis in the case study areas. In particular, the seasonal series of the indices were extracted by considering the 3-month cumulated values in May for spring (MAM), August for summer (JJA), November for autumn (SON) and February for winter (DJF). Longer accumulation periods, e.g., 12 months, allow to assess hydrological droughts. Potential evapotranspiration (PET) for SPEI computation was derived from mean temperature values by using the Thornthwaite equation (Thornthwaite, 1948). Available Python codes (https://github.com/monocongo/climate_indices) were implemented and input meteorological data were fitted to a Gamma distribution.

All listed climate indices were computed for past and future at national level based on the CMIP6 projections, SPI and SPEI were derived by using the whole spanned period 1951-2100 as reference for the standardization procedure. Due to the key relevance of water resources for the civil and agriculture usages in both countries and the occurrence of severe drought episodes in recent years reported by local authorities and threatening communities and activities, a specific focus was dedicated to the assessment of variability in heat and drought conditions in the study areas over the past decades. A specific attention was paid to the detection and analysis of drought events in 2021, when extremely dry conditions were reported for Central Asia from local communities as well as national monitoring services. This analysis also aims to evaluate to which extent available climate data and indicators are able to detect and characterize relevant extreme conditions occurred in the area. To this scope, SPI, SPEI and hot days indices were computed for the recent decades from ERA5 temperature and precipitation data at 0.25°x0.25° spatial resolution. In this case, 1981-2010 was used as reference baseline for all calculations.

The local scale analyses were focused on the detection of moderate dry conditions (-1.5 to -1) and severe dry conditions (-2 to -1.5) by counting for the number of months per years with SPI or SPEI values falling into these ranges. Besides single months experiencing anomalously dry conditions, we identified and analysed drought spells, i.e., prolonged periods of dry conditions. A drought spell was detected at any time the index value for a given month falls below -1 and remains negative for at least two consecutive months. The drought spell ends when the index value returns positive (Spinoni et al., 2019). To characterize such drought spells, various indicators such as onset, duration, severity, and magnitude were computed. Magnitude is the cumulative sum of index values within the duration of a drought event, whereas severity is their mean.

For the analysis of heat events, the maximum daily temperature from ERA5 reanalysis at 0.25° horizontal resolution was used and the number of days per year experiencing anomalous temperature values was computed. Hot days were defined as occurrences of daily maximum temperature above a percentile-based threshold computed over the baseline period. 90^{th} and 98^{th} percentiles were used to define moderate hot and extremely hot days, respectively.

All drought and hot day series were analysed for trends by means of the Theil-Sen test (Theil, 1950) for deriving the slope and the Mann-Kendall test (Kendall, 1975) for assessing the statistical significance. As visual example, the mean differences in drought indices and maximum temperatures in 1991-2021 over the countries with respect to 1961-1990 are reported in **Error! Reference source not found.**.

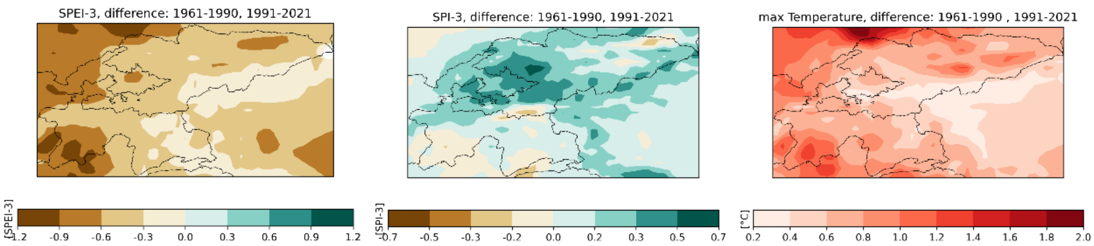

Figure 7: Spatial changes (absolute difference with respect to the baseline) in SPI-3, SPEI-3 and maximum temperature in the regional domain.

According to SPEI-3 the region experiences drier climatic conditions in 1991-2021 with respect to the past, while SPI-3 shows an opposite wetting tendency, especially in Kyrgyzstan. It can be explained by the fact that the latter is based on precipitation only and thus it does not take into account the role of increased temperature in reinforcing drought conditions. The increase in maximum temperature is in fact evident throughout the region and the spatial pattern of maximum temperature changes coincides well with that observed for SPEI-3.

3.1.4 Snow cover changes

Climate change can also be detected looking at changes in snow cover in the last decades. To better monitor these changes and understand snow dynamics, observations from surface stations, remotely sensed data, and model simulations were analysed for several mountain areas and documented in recent research publications (e.g., Beniston, 2012; Hammond et al., 2018, Notarnicola, 2020). More specifically, remotely sensed images can provide information on the spatial and temporal patterns of snow cover, thus representing an invaluable tool in remote and high-altitude areas, where only few ground stations are available.

Recently, Notarnicola (2020) presented a quantification of snow changes in global mountain areas by exploiting the full data set of MODIS imagery at 500-m ground resolution from the period 2000 to 2018.

This analysis reveals that around 78% of global mountain areas are undergoing a decline in snow cover characterised 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 the Northern Hemisphere.

For this climate risk assessment, the snow cover change calculated for global mountain areas by Notarnicola (2020) was applied for the two project areas extended to cover the period 2000 to 2020 (hydrological years from 2000-2001 to 2020-2021). It was then calculated for each project region which proportion of the area has a negative and which a positive trend in snow cover. It is also shown and quantified to which degree the trends are significant. In sections 4.1.4 and 5.1.4, maps show the spatial distribution of negative and positive snow cover trends, highlighting areas with a significant trend for Tajikistan and Kyrgyzstan respectively.

3.2 Climate risk assessment methods

This section presents the analytical approach and data collection and analysis methods followed for the conduction of the climate risk assessment in the two project regions. First, we present the Impact Chains analytical approach and method, and the way this has been finetuned for the needs of the VT programme. We move on to report on our work on defining spatial analysis units to further understand the project regions and, for the case of Kyrgyzstan, to guide the selection of communities for the community consultations. We conclude by presenting our main method for data collection: participatory workshops with experts and community consultations.

3.2.1 The Impact Chains approach

The climate risk assessment conducted for the needs of the VT programme follows and builds upon the Impact Chain analytical approach and method described in detail in the *Vulnerability Sourcebook* (Fritzsche et al., 2014) and its *Risk Supplement* (GIZ and Eurac, 2017). An Impact Chain is an analytical framework enabling to structure, understand and prioritise the factors (i.e., context-specific socio-ecological elements and mechanisms) that drive current climate risk in a specific case study. These factors are conceptualised and organised according to the Intergovernmental Panel on Climate Change (IPCC) AR5 definition of the risk components, i.e., hazard, exposure, and vulnerability (for definitions see GIZ and Eurac, 2017).

Error! Reference source not found. on the left presents the original and usual visual representation of the Impact Chains, where a case study's socio-ecological systems are 'deconstructed' so as to be attributed to the risk components. **Error! Reference source not found.** on the right shows an alternative visual representation of the Impact Chains, which we developed in the context of the VT programme and used in this report. While in its essence the approach is the same, the main visual and analytical difference in comparison to the original version is that the Impact Chains are organised according to the exposed socio-ecological systems of the communities under study in Tajikistan and Kyrgyzstan (i.e., water supply, winter pasture and hay, summer pasture, arable land and fodder fields, livestock, community/livestock owners) rather than according to risk components[3]. Other additions to the original Impact Chains include the 'underlying risk drivers' giving hints about the root-causes of vulnerability; the (preliminary) identification of 'adaptation options', due to our participation in discussions and assessment of adaptation interventions by the local project partners; and the identification of 'key risks'. With 'key risks' here we understand major, and mostly transversal throughout the communities under study, 'intermediate impacts' that refer to specific exposed systems of high value to the communities

[3] We got inspiration for this alternative visual and analytical approach, which became possible due to the general simplicity of the socio-ecological systems of interest per community, during our fieldwork and before the first community consultation in Tajikistan. The patterns observed in the way the socio-ecological systems function across communities and project regions permitted us to systematize the work and use the same Impact Chain 'template' for all the communities under research.

under study, thus they also constitute direct risks for the communities' livelihoods and contribute to the overall risk.

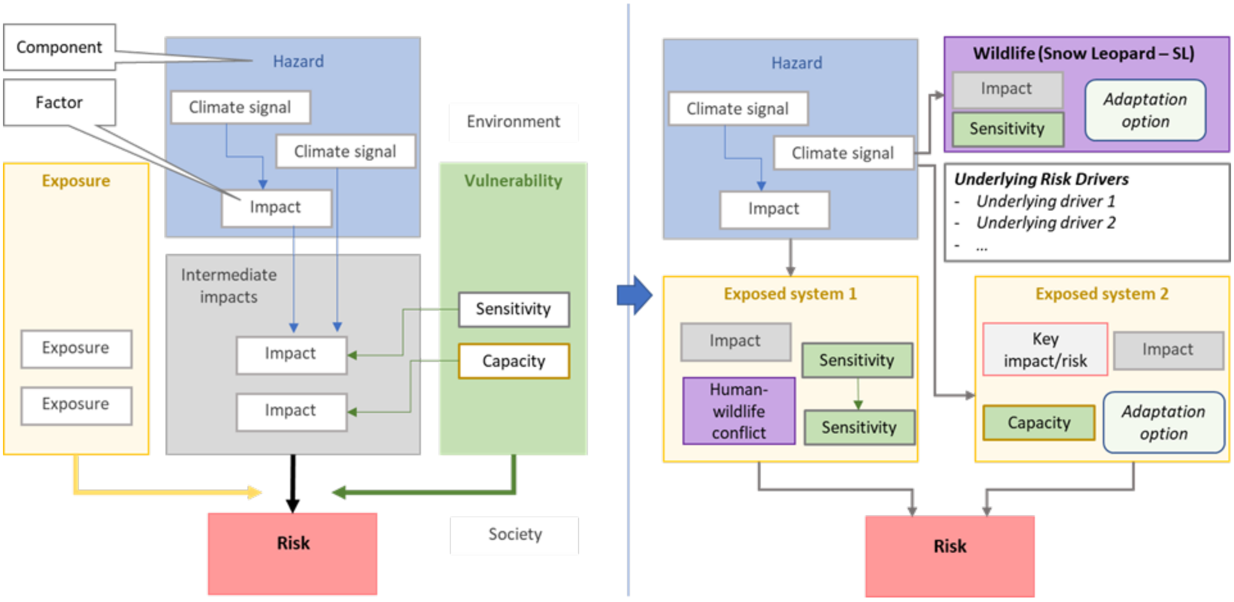

Figure 8: On the left, structure of an Impact Chain according to the Vulnerability Sourcebook. On the right, structure of an Impact Chain as developed for the Vanishing Treasures programme.

To apply this analytical framework and assess each of the risk components and the overall risk, the Impact Chains approach combines quantitative data analyses with qualitative information that is collected through participatory methods such as workshops with experts and/or local communities, as well as through secondary sources. This approach allows for data triangulation and the in-depth exploration of climate risk, valorising different types of knowledge. For the needs of the VT programme, the main quantitative data analysed concern the hazard component of the Impact Chains and refer to the national and local climate assessments and to the drought and heat analyses performed. For a detailed view on the quantitative data and methods used see section 3.1 in this report; for the results per project region see sections 4.1 and 5.1. Qualitative data were collected mainly through participatory workshops with experts and the communities (i.e., community consultations) according to the methods presented in section 3.2.3. This qualitative data was complemented and critically analysed together with qualitative information deriving from scientific literature, grey literature such as local press and other reports to inform particularly the exposure and vulnerability components of the Impact Chains.

After conducting the analysis as a complex account of the sum of the collected data, the final climate risk assessment outputs result from the combination of the hazard, exposure, and vulnerability components into one qualitative climate risk score. In the VT programme, this final assessment has been conducted and is presented in the form of tables per village for Tajikistan and per Village District for Kyrgyzstan (for an example see Table 3). Each table refers to the main risk identified for all the communities under study. The respective key risks are assessed in terms of the current and future (2030-2050) situations according to the risk components of hazard, exposure and vulnerability. The climate-hazard component for drought and heat was investigated and assessed considering reanalyses and CMIP6 future projections (see section 3.1). Exposure and Vulnerability components are assessed based on findings from our participatory approach (expert and community consultations) and following a relative assessment between communities. For the VT programme, vulnerability is assessed in two phases: one for the directly exposed elements (e.g., pastures) and one for the communities, which are exposed to the climate risks both directly and indirectly through the rest exposed systems (for more information on the criteria used see sections 4.3 and 5.3). The 'Risk assessed by the communities' row reports on communities' perceptions of the risk based on the results of the participatory voting that took place in each of the community consultations (see section 3.2.3). The 'Confidence of assessment' reports on the uncertainty we perceived to exist when assessing the risk components, on the divergence of the expert and community risk assessments, and on the divergence of perceptions reported within the communities. Finally, the 'Critical settings' row reports on social-ecological constellations of particularly high risk. The risk assessment scale includes very low, low, moderate, high, very high. 'Very low' signifies absence of risk while 'very high' is a situation where the function of the system under consideration is threatened.

Main **Risk**

	Current situation			**Future (2030-2050)**		
	Key Risk 1	**Key risk 2**	**Key risk 3**	**Key risk 1**	**Key risk 2**	**Key risk 3**
Hazard	High	High	Moderate	Very high	Very high	High
Exposure	Moderate	Low	Moderate	Moderate	Moderate	High
Vulnerability - Exposed systems - Community	Moderate Low	Moderate	Moderate	High Moderate	High Moderate	High Moderate
Risk	Moderate	Moderate	Moderate	High	High	High
Risk assessed by the communities	Very high	High	Moderate	Very high	Very high	Very high
Confidence of assessment	Moderate			Moderate – Low		
Critical settings						

Table 3: Example of table on Comprehensive Risk Assessment

The findings of the climate risk assessment have been validated and refined at different stages during follow-up consultations with local experts (Association of Nature Conservation Organizations of Tajikistan (ANCOT) for Tajikistan, Ilbris Foundation and Snow Leopard Trust (SLT) for Kyrgyzstan) and consultants working in the two project regions. By doing so, the Impact Chains application has engaged local partners throughout the whole risk assessment combining their knowledge, improving their comprehension of risk factors and contributing to the assessment of adaptation interventions to implement. At the same time, we should stress that the consultations and engagement with the local communities proved necessary not only for the needs of the climate risk assessment – that it would have been extremely difficult to be so accurately conducted by afar – but also for motivating interactions (within the communities and between communities and local partners) that could possibly permit a better integration of the 'Vanishing Treasures' Programme in the local context and more fruitful outcomes.

3.2.2 Spatial analysis units

In order to properly account for the physical and social heterogeneity of the study area in a spatially explicit climate risk assessment, the Tajikistan and Kyrgyzstan project regions were clustered into a limited number of more homogeneous areas using watersheds as main spatial analysis units. Watersheds were selected due to their relevance on water resources both from an ecological and a water management perspective. The watersheds were characterized by including information on glacier extent and local climate, and they were further merged into broader sub-regions based on the local knowledge of the VT partners on physical and socio-economic aspects of the communities per watershed (Figures 9 and 10). For the Kyrgyzstan case, the watersheds and the broader sub-regions were used to guide the selection of the locations where the community consultations took place (see section 3.2.3).

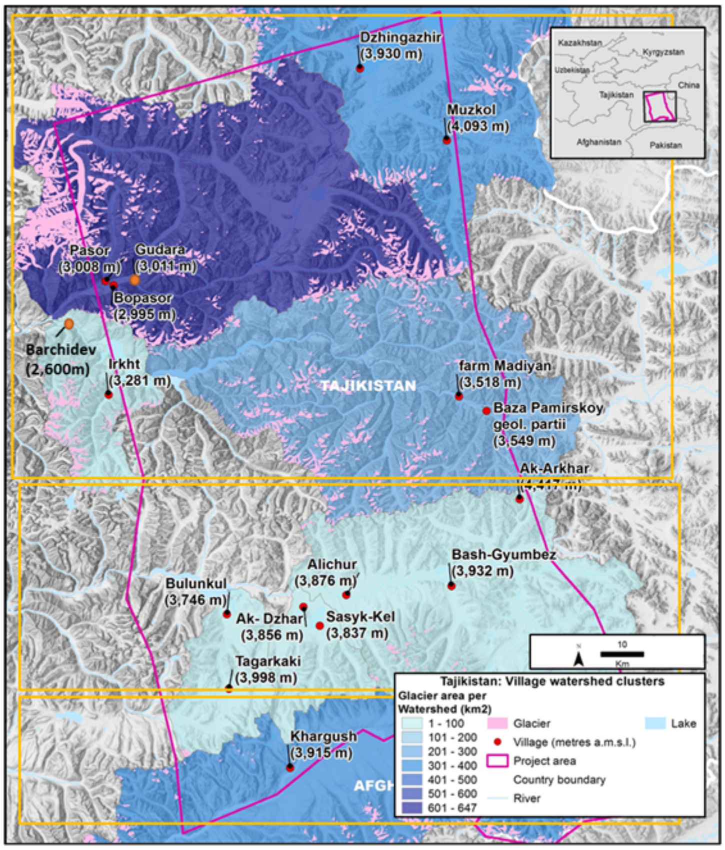

Figure 9: The spatial analysis units (watersheds) for the Tajikistan project region characterized in terms of glacier extent. In yellow frame the grouping of the watersheds as proposed by the local partners. The two orange points are the locations of the community consultations.

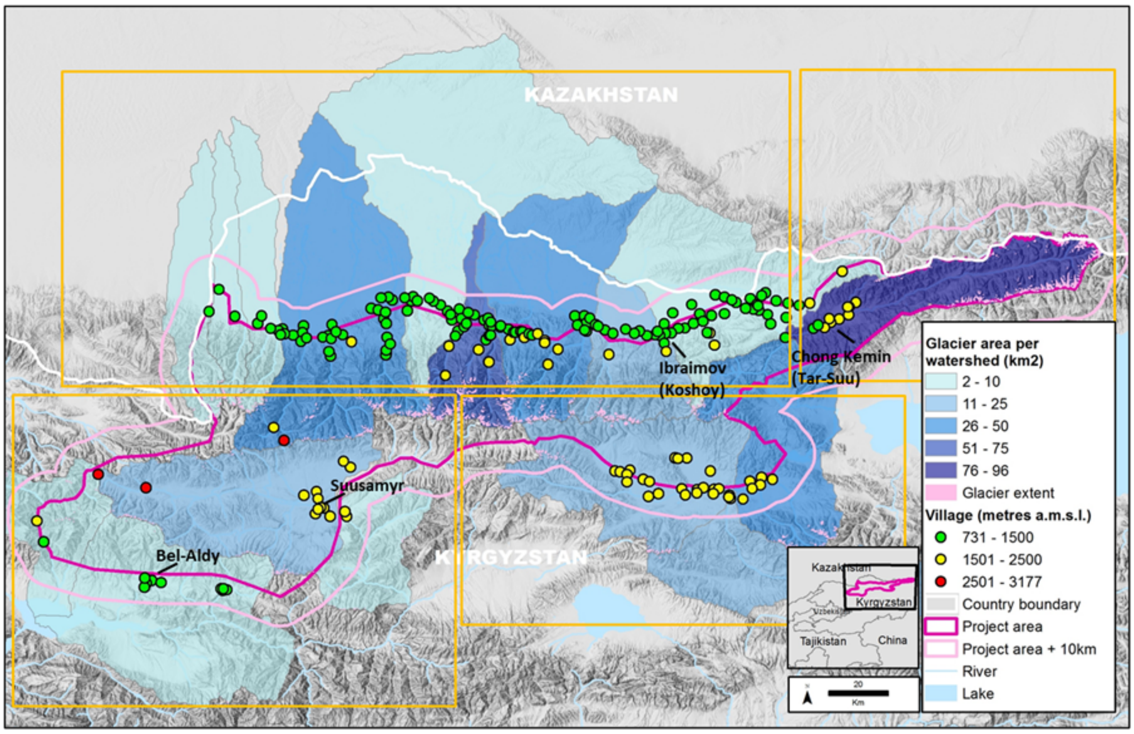

Figure 10: The spatial analysis units (watersheds) for the Kyrgyzstan project region characterized in terms of glacier extent. In yellow frame the grouping of the watersheds as proposed by the local partners. The locations of the community consultations are also presented.

For the watershed boundaries, we used a subset of the HydroSHEDS database, the HydroBASINS[4]. The HydroSHEDS database provides hydrographic data layers that allow for the derivation of watershed boundaries for any given location based on the near-global, high-resolution SRTM digital elevation model. Using this hydrographic information, watersheds (HydroBASINS) have been delineated in a consistent manner at different scales, and a hierarchical sub-basin breakdown of 12 levels has been created following the topological concept of the Pfafstetter coding system (Lehner and Grill, 2013). For both Tajikistan and for Kyrgyzstan we decided to work with HydroBASINS level 07 as they sub-divided the project regions in a manageable number of spatial analysis units without at the same time being too coarse. Due to the community-centred character of the climate risk assessment, we finally considered only the watersheds that include settlements focusing on the project regions and a 10-km buffer zone around them. The 10-km additional zone was used to align with the methods of the local partners SLT and ANCOT, and considering communities that are not within the limits of the project regions but have some of their pastures there.

The climate risk assessment's focus on heat and drought, led us to conduct a preliminary characterization of the watersheds based on glacier extent. Glaciers are important for the water-dependent livelihoods of the mountain communities of Central Asia especially in late summer and during drought spells. Glaciers delay the passage of water through the hydrological system and provide fresh water long after seasonal snow has depleted. During droughts, glacier melt can act as an important buffer (Pritchard, 2019). For the glacier extent, we used the Randolph Glacier Inventory 6.0[5]. This is a global inventory of glacier outlines that is intended for the estimation of total ice volumes and glacier mass changes at global and large-regional scales. For the glaciers that were on the border of the

[4] HydroBASINS database, https://hydrosheds.org/page/hydrobasins
[5] Randolph Glacier Inventory 6.0, https://www.glims.org/RGI/rgi60_dl.html

delineated watersheds due to data inaccuracy, the glacier was attributed to the watershed where most of its area is located. According to our preliminary analysis, we obtained an overview about the presence of glaciers per watershed, thus about the presence of a buffer to drought conditions, which was generally confirmed by the local partners and during the community consultations. Nevertheless, more elaborated analysis would be needed to this direction for more accurate and detailed results.

The climate characterization was performed by applying a cluster analysis of climate data on the two project regions in order to identify the main sub-domains sharing similar climate conditions. The cluster analysis was performed by means of the *k-means* method and applied to the 1-km downscaled ERA5 retrieved from CHELSA database. The analysis was based on the 1981-2010 climatologies of nine available indicators: summer maximum temperature, winter minimum temperature, annual mean temperature, precipitation of the wettest quarter, precipitation of the driest quarter, total annual precipitation, snow cover duration, growing season length and aridity index, i.e., the ratio of mean annual precipitation and mean annual potential evapotranspiration. The clustering was performed by using the package *stats* in R programming environment. The results of the climate clustering are reported in sections 4.1 and 5.1 in this report.

3.2.3 Participatory workshops with experts and community consultations

Due to the Covid-19 emergency conditions, preliminary Impact Chains were co-produced with VT partners online using MS Teams during four (two for Tajikistan and two for Kyrgyzstan) facilitated and interactive workshops between April and May 2021. These workshops helped to identify main exposed sectors/systems as well as the main perceived current climate threats for the communities in each project region. The preliminary Impact Chains highlighted two main risks: the 'risk of loss of livelihoods (income, subsistence) for livestock owners due to raising temperatures, heatwaves and droughts causing loss of animals, land degradation and forage shortage', and the 'risk of water scarcity to communities due to high temperatures and droughts. This application allowed to quickly collect initial information and get local and expert perceptions on the relevant climate risk factors and was used as a guide to investigate relevant data. We faced a certain difficulty to obtain fine-grained and community-level data for the areas of interest to the VT programme through secondary sources. To address this, we engaged in iterative interaction with the local partners, who provided information based on their knowledge and fieldwork results, while helping us check the relevance and accuracy of our considerations and preliminary findings.

In mid-September, the Covid-19 situation permitted to us and our VT partners to organize a field trip and a series of community consultations in the two project regions. The aim of those consultations was to inform our preliminary Impact Chains as analytical frameworks (i.e., identifying systems, factors and risks of relevance) and in terms of data collection at the community-level, and to motivate further discussions on the interventions together with the local partners. To select the communities of the consultations, together with the local partners we used three main criteria: i) hosting of planned interventions in the framework of the VT programme, ii) particular findings from previous fieldwork (e.g., Threat Assessment) of interest to the VT programme, and iii) high level of engagement with the local self-governments. For the Kyrgyzstan case an additional criterion used was the dispersion in space to cover the different identified subregions (see section 3.2.2). In Tajikistan, the more challenging context demanded to focus on those areas where the local partners have established stronger connections with the local communities. In recruiting the participants, the local partners used purposive sampling, seeking for information-rich actors representing a diversity of interests. Although gender balance was an aim when recruiting the participants, the consultations were dominated by men. Only in Chong Kemin in Kyrgyzstan the 50% of the participants were women.

In the Tajikistan project region, we conducted two community consultations together with ANCOT on the 24^{th} and 25^{th} November 2021. The consultations took place in Barchidev village and in Ghudara village in the Bartang Valley (Figure 9 and Figure 11A/11B). Additional villages that were visited are Khijez, Nisur, Poshorv and Ravmed. The participants included local residents, farmers, teachers, geologists, public servants and public officials. The consultation in Barchidev hosted 10 participants and lasted for 1h39mins while in Ghudara hosted 14 participants and lasted for 1h15mins. The consultations were conducted in Pamir language with direct translation from and to English. In the Kyrgyzstan project region, we conducted four community consultations together with Ilbris Foundation, SLT (with support from the Snow Leopard Foundation) and UNEP between 2 and 5 November 2021. Each consultation took place at a central village of a different Village District (Figure 10 and Figure 11C-11F): i) Bel-Aldy (Bel-Aldy Village District), ii) Suusamyr (Suusamyr Village District), iii) Koshoy (Ibraimov Village District), and iii) Tar-Suu (Chong-Kemin Village District). The participants included local residents, herders, heads of villages, veterinarians, representatives of Youth Committee, Pasture Committee, Statistics Committee, Water Management, Hunting Management and Elderly People Committee from the whole Village District. On average, each consultation hosted around 17 participants and lasted for about 3 hours. The consultations were conducted in Kyrgyz and Russian with direct translation from and to English.

The community consultations were organized into four sessions: i) Individual observation of climate impacts and risk, ii) semi-structured group interview and participatory mapping, iii) participatory voting on importance of key risks, iv) group discussion on interventions (see Annex 8.1 for the agenda). The first session included a presentation by Eurac on results from the climate data analysis and the socio-economic scenarios, and impactful Earth Observation data showcasing, for instance, glacier retreat at the territories of the communities. This presentation was appreciated by the communities, especially since many participants could observe several climate impacts on the ground but had not connected them to climate change thus far. For the second session, we developed a guide for semi-structured interviews that follows the structure of the Impact Chains in terms of the exposed socio-ecological systems of the communities (see Annex 8.2). It thus includes demographic questions on the communities, questions related to surface water supply, livestock and pasture management, arable land and fodder, and human-wildlife conflict. The issue of climate change was transversal throughout the clusters of questions. The participants replied to the questions and illustrated their responses on maps we had previously prepared sharing important information especially about vulnerability aspects (Figure 11C). In the third session, which took place only in Kyrgyzstan, the participants were invited to assess the importance of each key risk, which we had pre-defined at the early stages of our fieldwork, in terms of 5 scales from very low to very high risk (Figure 11D). This participatory voting is reported later in the report during the presentation of the final climate risk score per key risk (see Figure 11 on the process and sections 4.3 and 5.3 on the results). The final session concerned an open discussion on human-wildlife conflict and interventions desired by the communities. This session was facilitated mainly by the local partners and UNEP. For detailed reports on the results per community consultation see Annex 8.3 and 8.4.

Figure 11: Snapshots from the community consultations. A) Ghudara (Tajikistan), B) Barchidev (Tajikistan), C) Bel-Aldy (Kyrgyzstan), D) Suusamyr (Kyrgyzstan), E) Koshoy (Kyrgyzstan), F) Chong-Kemin (Kyrgyzstan).

4 Assessment of main climate risks for the villages in Tajikistan

This chapter presents the current climate and climate scenarios for the Tajikistan project region, and the results of the climate risk assessment for the villages of the community consultations.

4.1 Current climate and climate scenarios

4.1.1 National climate assessment

By looking at the national level, the current climate of Tajikistan is characterized by continental conditions even though with relevant spatial heterogeneities driven by strong elevation gradients. In the western lowlands, mean temperatures range from 0-10° C in winter to more than 30° C in summer, while in the eastern mountainous areas of Pamirs summer temperatures are around 5-10° C and drop below -20°C in winter months (Figure 12: 1981-2010 seasonal climatologies of a) mean temperature and b) total precipitation for Tajikistan. The maps are based on the 1-km downscaled ERA5 reanalysis from CHELSA database.

a). Extremely hot as well as cold conditions can be reached locally in the low-elevation and high-mountain locations, respectively (GIZ, 2020). The wettest conditions occur in late spring with a secondary precipitation maximum in winter months, while the lowest precipitation values occur in late summer and early autumn. As for temperature, precipitation regimes are highly heterogeneous over the country (Figure 12: 1981-2010 seasonal climatologies of a) mean temperature and b) total precipitation for Tajikistan. The maps are based on the 1-km downscaled ERA5 reanalysis from CHELSA database.

b). The western lowlands and the highest mountains in the East experience very dry conditions with annual precipitation generally lower than 400mm. Wetter conditions occur in northern and central Tajikistan with annual precipitation in the range 1,000-1,500mm and greater at the highest elevations.

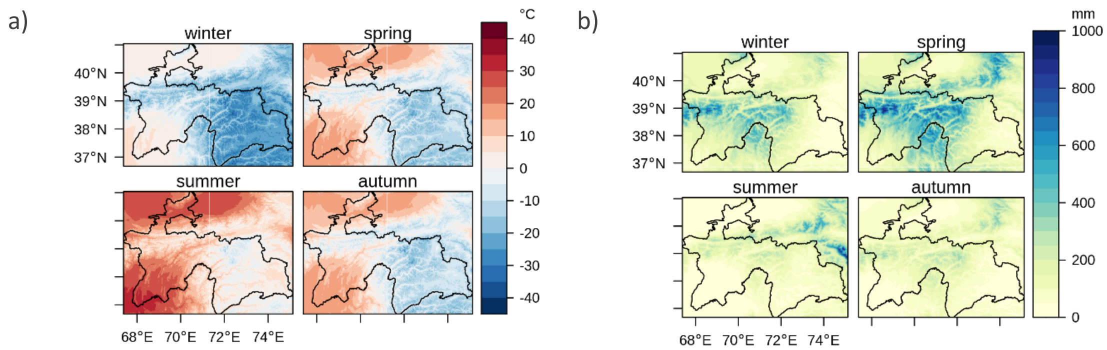

Figure 12: 1981-2010 seasonal climatologies of a) mean temperature and b) total precipitation for Tajikistan. The maps are based on the 1-km downscaled ERA5 reanalysis from CHELSA database.

At national level, a statistically significant increase was observed for temperature values from the CRU dataset over recent decades (1951-2010) at both annual and seasonal scale. The regional time series of annual precipitation shows a great interannual variability and no significant trend, but only a not significant tendency towards higher annual totals. No well-defined trend emerges for the seasonal amounts, even though they exhibit a not significant drying in spring and not significant increases in the other seasons. It is worth noting that a large uncertainty needs to be assigned to the findings due to the high variability of precipitation and the difficulty to describe the spatial heterogeneity in available datasets. The findings are in agreement with previous local studies and assessments (GIZ, 2020; Aalto et al., 2017).

The temporal evolutions of temperature and precipitation of Tajikistan over recent past are found mostly to continue in the future, based on the CMIP6 ensemble projections for two different scenarios (Figure 13: Boxplots of the seasonal changes in near (2011-2040) and middle (2041-2070) future for a) mean temperature and b) precipitation under SSP2-4.5 (green) and SSP5-8.5 (orange). Values represent the areal averages over Tajikistan. Seasons are defined as follows: March, April and May for spring (MAM), June, July and August for summer (JJA), September, October and November for autumn (SON), December, January and February for winter (DJF). The lower and upper hinges correspond to the interquartile range (IQR, 25th-75th percentiles) of the CMIP6 ensemble. The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from the hinge. The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. Values outside this range are considered outliers and reported individually.). In particular, a further warming is expected under both scenarios, especially in summer and autumn. The signal for precipitation is less clear, however a tendency towards increasing precipitation in winter is reported, especially in the second half of the century. In terms of spatial distribution, the greatest annual temperature increases are projected to occur in middle future in both upper and lower percentiles of the ensemble (Figure 14: Distribution of changes in a) mean annual temperature and b) annual precipitation in near (top) and middle future (bottom) with respect to 1981-2010 under the SSP2-4.5 scenario. The results are reported for the 25th and 75th percentiles of the CMIP6 model ensemble on a 0.5°x0.5° grid.

a). Projected changes of precipitation show a greater variability and opposite directions of change are even projected by the model ensemble for eastern Tajikistan in middle future (Figure 14: Distribution of changes in a) mean annual temperature and b) annual precipitation in near (top) and middle future (bottom) with respect to 1981-2010 under the SSP2-4.5 scenario. The results are reported for the 25th and 75th percentiles of the CMIP6 model ensemble on a 0.5°x0.5° grid.

b). We mostly focused on the intermediate scenario SSP2-4.5 since it was considered the most realistic one in representing the future global development of socio-economic conditions.

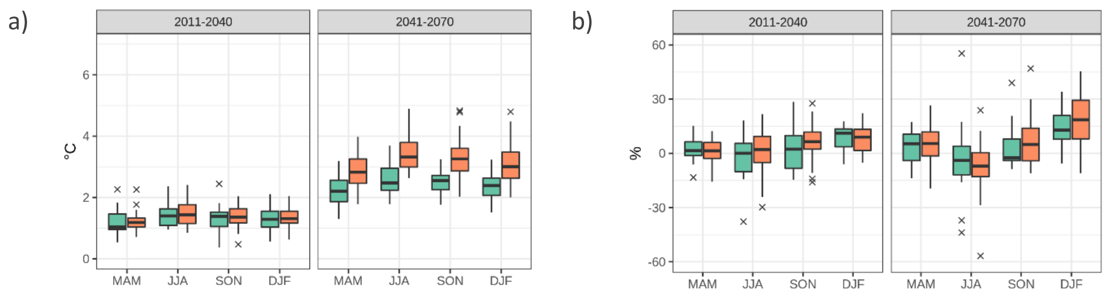

Figure 13: Boxplots of the seasonal changes in near (2011-2040) and middle (2041-2070) future for a) mean temperature and b) precipitation under SSP2-4.5 (green) and SSP5-8.5 (orange). Values represent the areal averages over Tajikistan. Seasons are defined as follows: March, April and May for spring (MAM), June, July and August for summer (JJA), September, October and November for autumn (SON), December, January and February for winter (DJF). The lower and upper hinges correspond to the interquartile range (IQR, 25th-75th percentiles) of the CMIP6 ensemble. The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from

the hinge. The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. Values outside this range are considered outliers and reported individually.

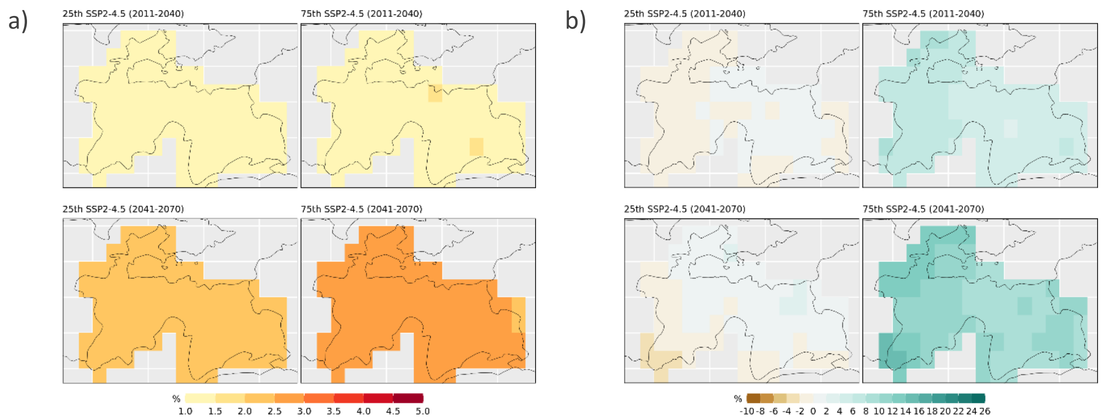

Figure 14: Distribution of changes in a) mean annual temperature and b) annual precipitation in near (top) and middle future (bottom) with respect to 1981-2010 under the SSP2-4.5 scenario. The results are reported for the 25th and 75th percentiles of the CMIP6 model ensemble on a 0.5°x0.5° grid.

Besides mean temperature, also extreme heat conditions are projected to increase over the country. The number of days per year characterized by heat wave conditions as well as the total number of heat wave events are expected to increase under both scenarios, especially in the second half of the century. In particular, by 2100 more than 60 days per year will be affected by extreme heat conditions if the ensemble median under the worst emission scenario is considered (Figure 15: Annual regional time series of a) heat wave days and b) heat wave events in Tajikistan based on CMIP6 ensemble projections under SSP2-4.5 (blue) and SSP5-8.5 (red). The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble.

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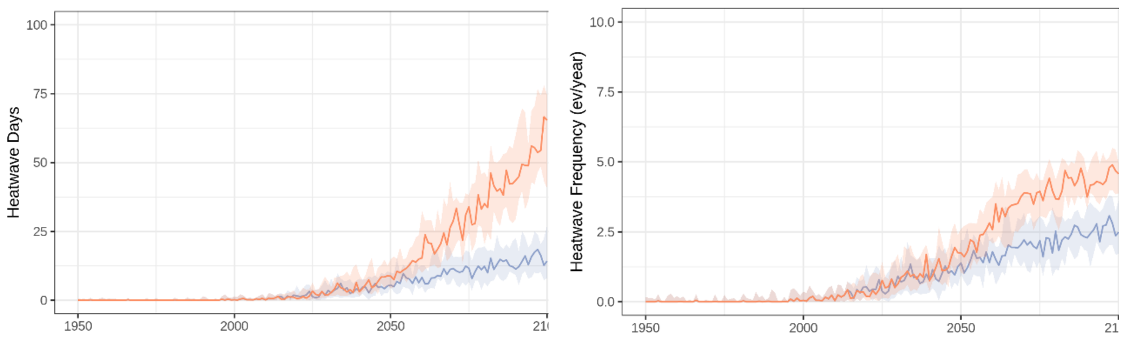

Figure 15: Annual regional time series of a) heat wave days and b) heat wave events in Tajikistan based on CMIP6 ensemble projections under SSP2-4.5 (blue) and SSP5-8.5 (red). The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble.

The annual totals of intense precipitation are also projected to increase by the end of the century under both scenarios, especially under SSP5-8.5 with an increase in total intense precipitation values of more than 50% by 2100 as median of the model ensemble (**Error! Reference source not found.**). The projected increment of intense precipitation is in agreement with the overall wetting tendencies projected for the country in the next decades.

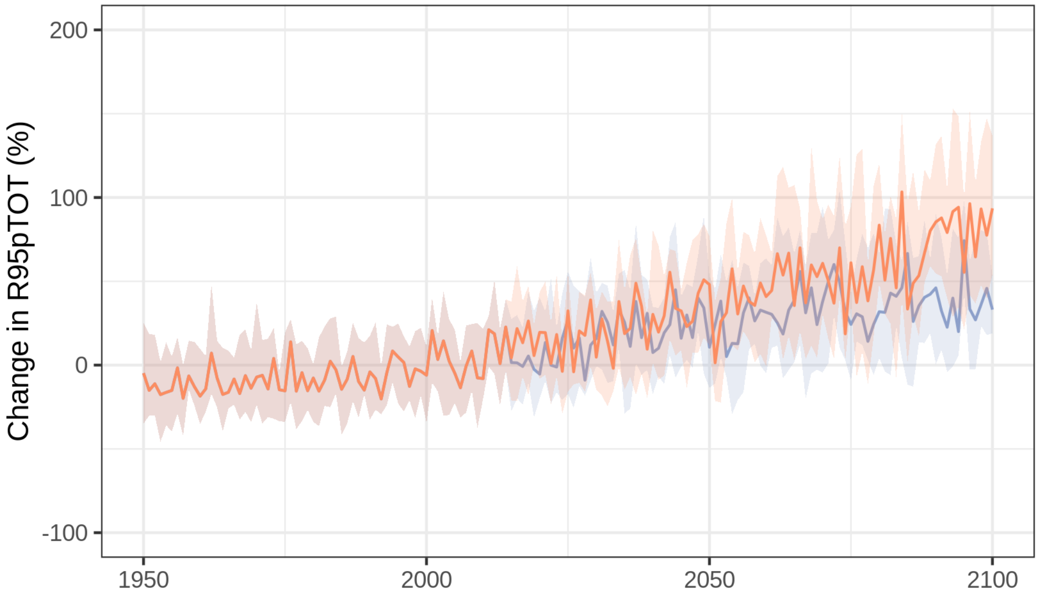

Figure 16: Annual time series of relative changes in intense precipitation totals (R95pTOT) for Tajikistan from CMIP6 projections under SSP2-4.5 (blue) and SSP5-8.5 (red). The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble.

Wet and dry conditions reported by SPI values further confirm the outcomes from the precipitation analysis with a statistically significant increase of wet conditions for yearly totals (i.e., 12-month cumulated values in December) and over 3-month cumulated precipitation in spring and winter under both scenarios. The drying trend in summer turns out to be significant if SSP5-8.5 is considered (results not shown). By performing the same assessment over SPEI values, the contribution of rising temperature plays a crucial role, and all trends are significant with projected drier conditions in spring, summer and autumn and wetter conditions in winter and on annual basis (Figure 17: Regional time series of SPEI for Tajikistan for yearly (SPEI-12 in December) and seasonal scales (SPEI-3 in May for spring, August for summer, November for autumn and February for winter) based on CMIP6 projections under SSP2-4.5 (blue) and SSP5-8.5 (red). The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble.

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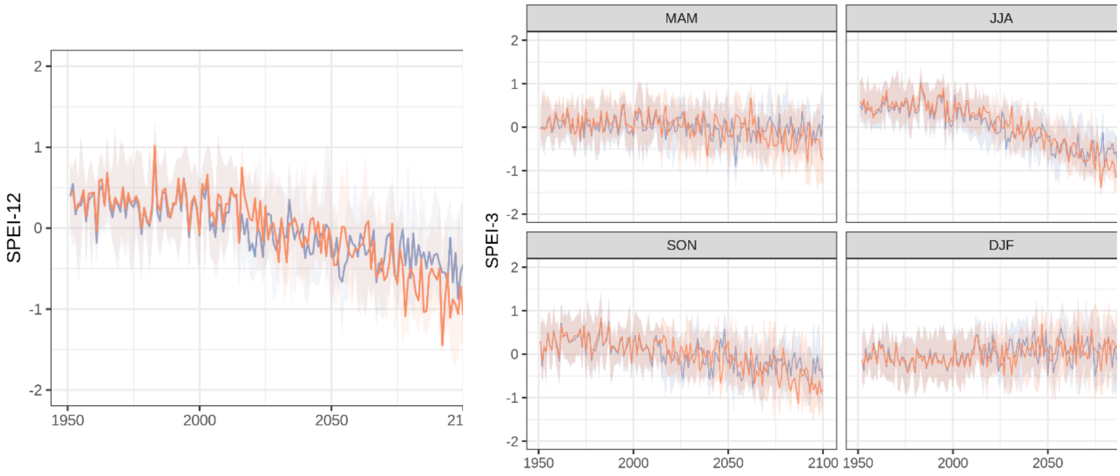


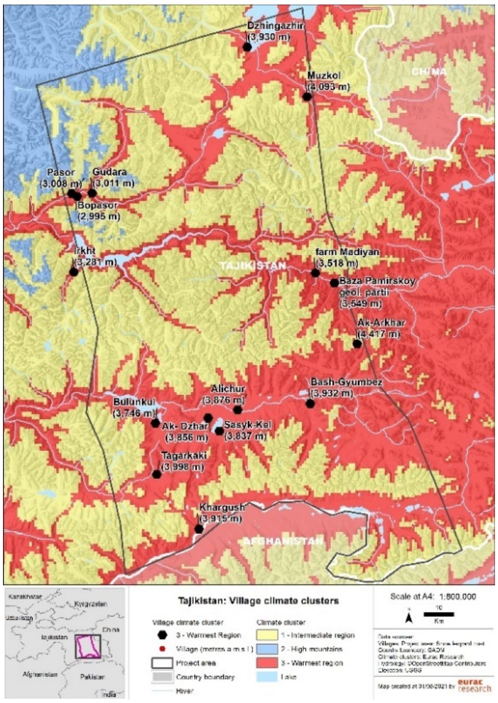
Figure 17: Regional time series of SPEI for Tajikistan for yearly (SPEI-12 in December) and seasonal scales (SPEI-3 in May for spring, August for summer, November for autumn and February for winter) based on CMIP6 projections under SSP2-4.5 (blue) and SSP5-8.5 (red). The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble.

4.1.2 Local climate assessment

Based on the cluster analysis performed on the 1981-2010 climatologies of the selected set of climate variables, three main climate sub-regions were identified for the case study area in Tajikistan. The climate classification was mainly driven by the different altitude ranges characterizing the project region and influencing the spatial distribution of climate conditions (Figure 18: Climate clusters for Tajikistan are displayed in panel a) and the mean values of climate indicators used for the classification are reported for each cluster in panel b). * Mean elevation was not used as input of the cluster analysis but only used for the region characterization.

). The two villages included in the risk assessment (Barchidev and Ghudara) are located in the 'warmest' climate region corresponding to the lowest elevation area.

a)



b)

	Intermediate region	High mountains	Warmest region
Maximum temperature in summer (°C)	5.7	0.9	10.4
Minimum temperature in winter (°C)	-29.8	-30.5	-26.6
Annual mean temperature (°C)	-12.9	-16.0	-8.4
Precipitation in the wettest quarter (mm)	193.3	398.5	117.3
Precipitation in the driest quarter (mm)	44.6	65.7	28.7
Annual precipitation (mm)	421.9	948.9	253.0
Snow cover length (days)	361	365	292
Growing season length (days)	3	0	62
Aridity index	1.3	4.2	0.5
Mean elevation (m) *	4691	4889	4043

Figure 18: Climate clusters for Tajikistan are displayed in panel a) and the mean values of climate indicators used for the classification are reported for each cluster in panel b). * Mean elevation was not used as input of the cluster analysis but only used for the region characterization.

This lowest elevation area is characterized by the warmest conditions, with mean temperature above 0°C from June to September and the lowest precipitation amounts all over the year (Figure 19: Mean annual cycles of a) mean temperature and b) precipitation for the three climate classes (orange for the High mountains, green for the Intermediate region and blue for the Warmest region).

). Despite the relatively dry conditions, the area is surrounded by high mountains and glaciers which guarantee water supply for agriculture and domestic use.

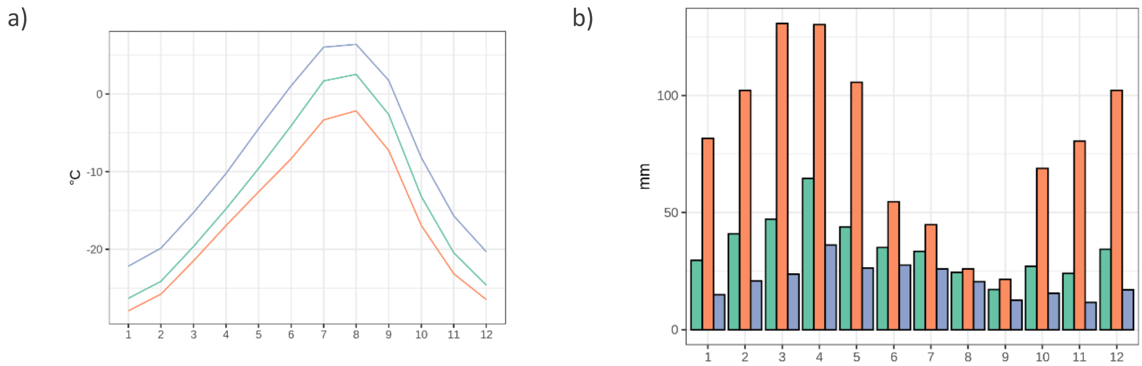


Figure 19: Mean annual cycles of a) mean temperature and b) precipitation for the three climate classes (orange for the High mountains, green for the Intermediate region and blue for the Warmest region).

In order to assess future climate change at the target area level, the CMIP6 projections of temperature and precipitation covering the study case were extracted and spatially aggregated. The warming under the moderate scenario SSP2-4.5 is expected to continue until the second half of the century and to slow down towards the end of the century. The greatest increase in temperature is expected to occur in summer and, secondary, in autumn (Figure 20: CMIP6 projections under SSP2-4.5 of mean annual and seasonal temperature anomalies for the case study area in Tajikistan. The anomalies are defined as annual differences with respect to the baseline 1981-2010. The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble. Historical simulations are reported in grey.). Precipitation is characterized by a larger variability in all seasons and on a yearly basis. However, if the ensemble median is considered, annual, spring and winter precipitation values show significant increasing trends all over the century of around +0.6%, +1.0% and +1.8% per decade, respectively (Figure 21: CMIP6 projections under SSP2-4.5 of annual and seasonal precipitation anomalies for the case study area in Tajikistan. The anomalies are defined as annual relative differences with respect to the baseline 1981-2010. The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble. Historical simulations are reported in grey.

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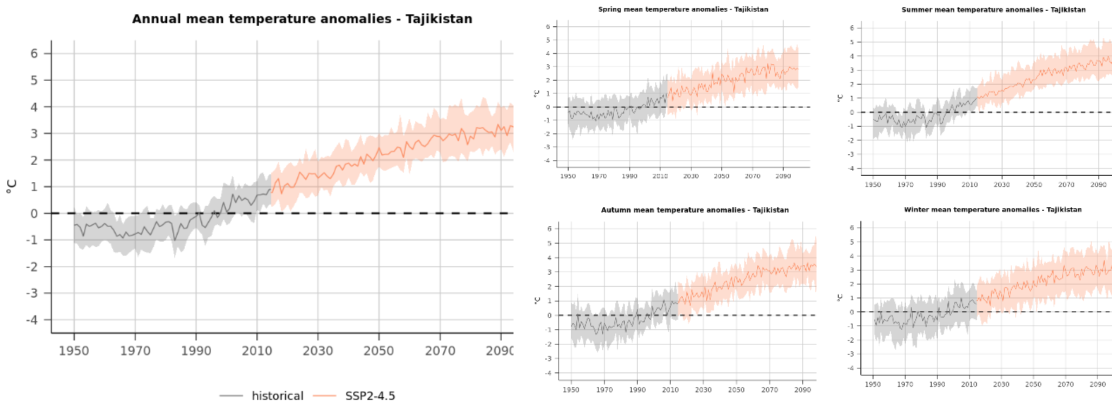


Figure 20: CMIP6 projections under SSP2-4.5 of mean annual and seasonal temperature anomalies for the case study area in Tajikistan. The anomalies are defined as annual differences with respect to the baseline 1981-2010. The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble. Historical simulations are reported in grey.

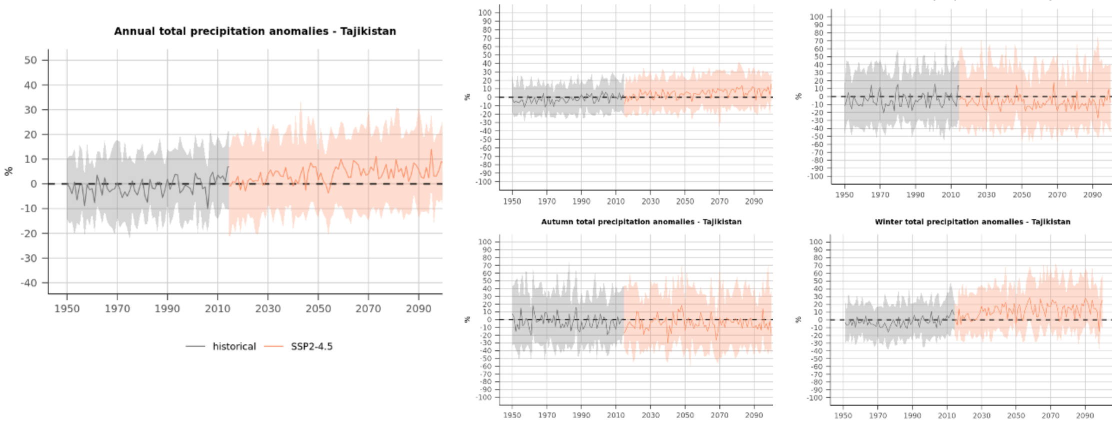
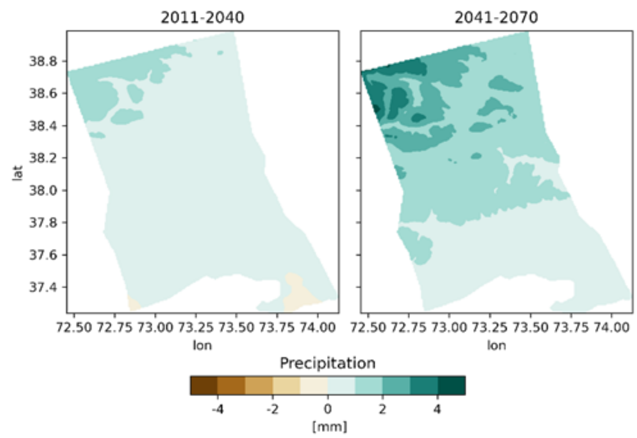


Figure 21: CMIP6 projections under SSP2-4.5 of annual and seasonal precipitation anomalies for the case study area in Tajikistan. The anomalies are defined as annual relative differences with respect to the baseline 1981-2010. The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble. Historical simulations are reported in grey.

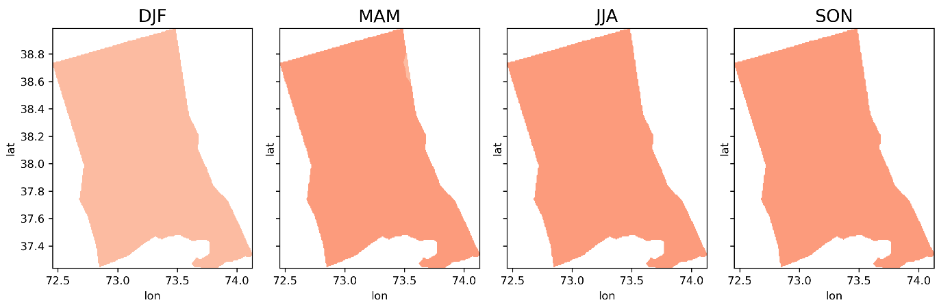
Besides the temporal evolution, the spatial distribution of the projected changes from the model ensemble in the near (2011-2040) and middle future (2041-2070) with respect to the baseline conditions (1981-2010). To this aim, the maps were based on 1-km downscaled CMIP6 projections from the CHELSA database. Temperature changes are homogenously distributed over the case study area in all cases (Figure 22: Seasonal changes of mean temperature in a) near (2011-2040) and b) middle (2041-2070) future with respect to the baseline (1981-2010) based on the model ensemble of downscaled CMIP6 projections at 1-km resolution.

and **Error! Reference source not found.**), while precipitation changes show a greater spatial variability (Figure 24: Seasonal absolute changes of precipitation in a) near (2011-2040) and b) middle (2041-2070) future with respect to the baseline (1981-2010) based on the model ensemble of downscaled CMIP6 projections at 1-km resolution.



and

Figure 25: Annual absolute changes of precipitation in near (2011-2040) and middle (2041-2070) future with respect to the baseline (1981-2010) based on the model ensemble of downscaled CMIP6 projections at 1-km resolution.). They confirm the projected increase of winter and annual precipitation, especially in the northern part of the area where the highest mountains are located.



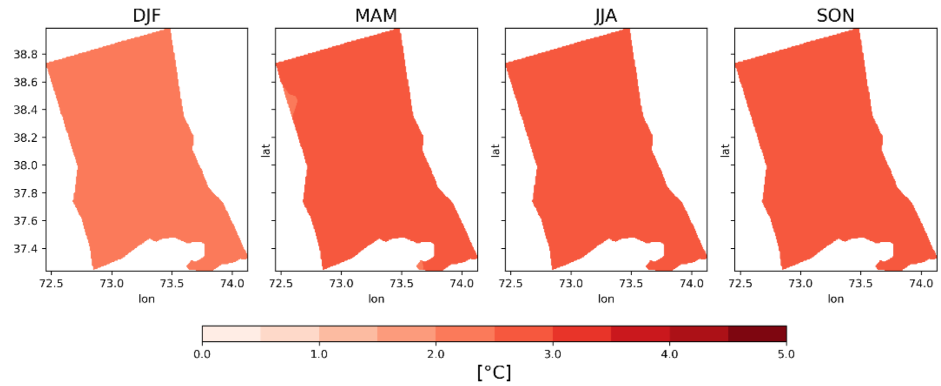


Figure 22: Seasonal changes of mean temperature in a) near (2011-2040) and b) middle (2041-2070) future with respect to the baseline (1981-2010) based on the model ensemble of downscaled CMIP6 projections at 1-km resolution.

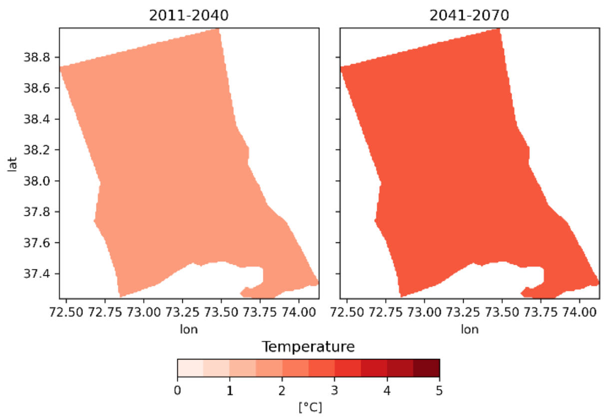
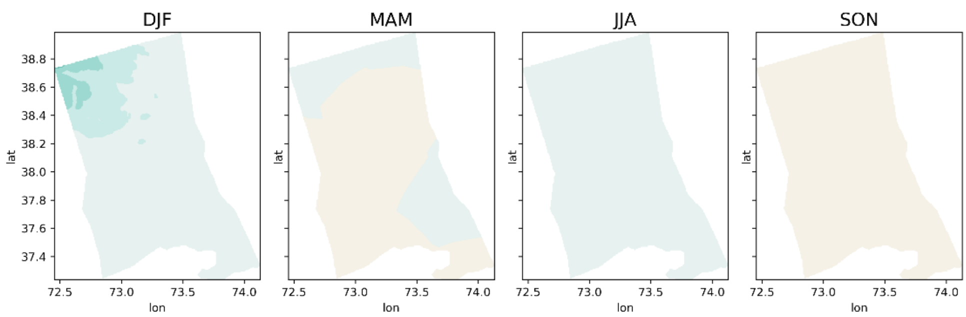


Figure 23: Annual changes of mean temperature in near (2011-2040) and middle (2041-2070) future with respect to the baseline (1981-2010) based on the model ensemble of downscaled CMIP6 projections at 1-km resolution.



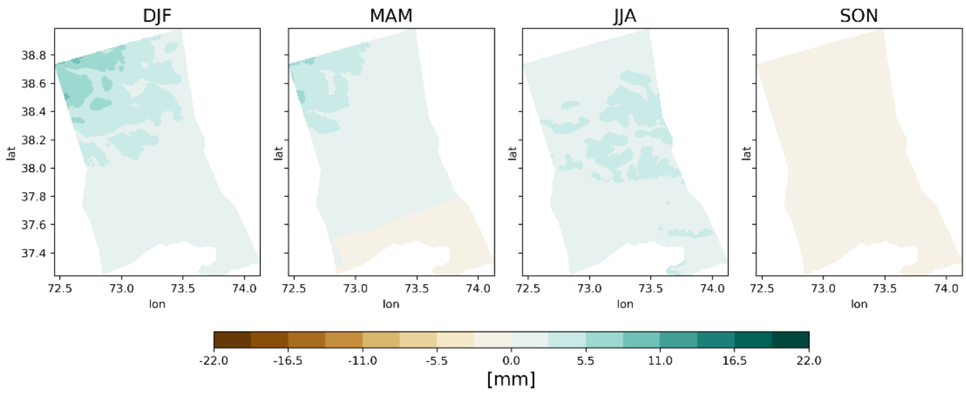


Figure 24: Seasonal absolute changes of precipitation in a) near (2011-2040) and b) middle (2041-2070) future with respect to the baseline (1981-2010) based on the model ensemble of downscaled CMIP6 projections at 1-km resolution.

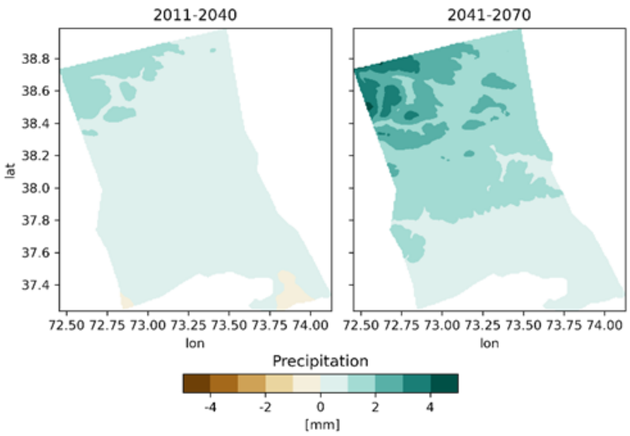


Figure 25: Annual absolute changes of precipitation in near (2011-2040) and middle (2041-2070) future with respect to the baseline (1981-2010) based on the model ensemble of downscaled CMIP6 projections at 1-km resolution.

4.1.3 Focus analysis on heat and drought

As regards SPI-3 monthly time series, no significant trend was depicted over the period 1970-2021 at both national and case-study scale (Figure 26: SPI-3 monthly regional series for a) Tajikistan and b) the case study area. Anomalous wet and dry conditions are coloured in blue and red, respectively.). This is in agreement with the results of the trend analysis of historical precipitation record for the country as shown in the previous paragraphs. SPI-3 values point out a high temporal variability and several past episodes of extremely dry conditions, especially in the 1970s and after 2000. Two prolonged dry spells are also observed in 2012-2015 and around 2020, especially at country level, while a particularly wet period occurred in the second half of the 1980s. The years 2020/2021 were mainly characterized by wet conditions in the project region, while at country level they were drier than usual.

In the following we focus on dry events, i.e., single months with index value below a certain threshold, and drought events/spells, i.e., prolonged period of drought as in the definition reported in section 3.2.1.

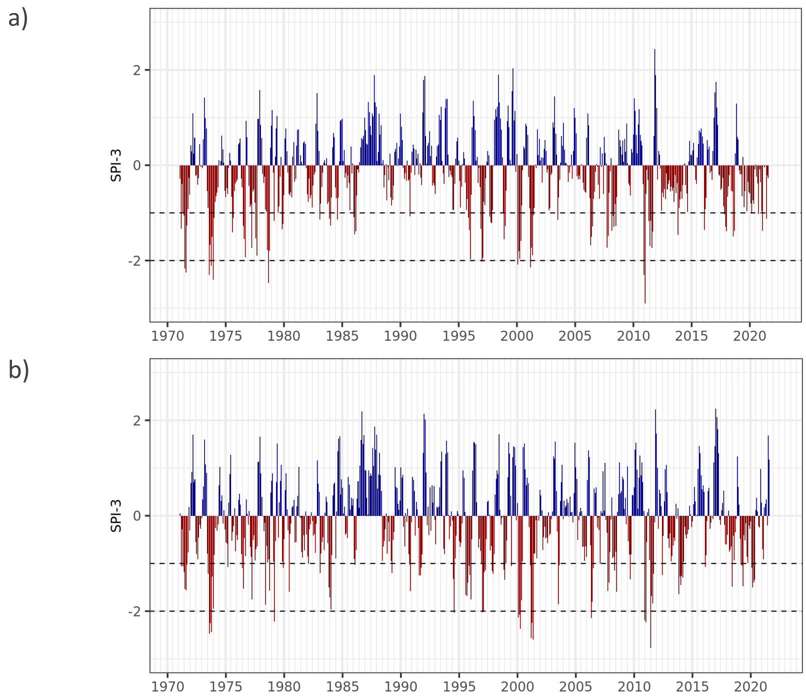


Figure 26: SPI-3 monthly regional series for a) Tajikistan and b) the case study area. Anomalous wet and dry conditions are coloured in blue and red, respectively.

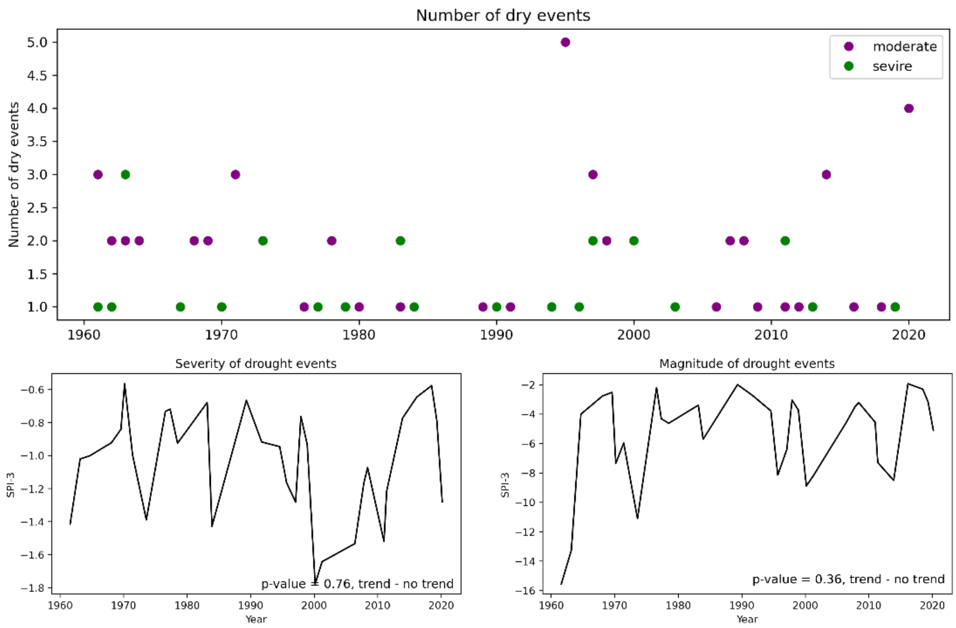


Figure 27: Annual count of dry events (top), severity (bottom left) and magnitude (bottom right) of drought spells derived from the mean SPI-3 series for the case study area.

It is hard to discern any trend towards increase in the severity or magnitude of drought spells based on the SPI-3 and their interannual behaviour is highly variable (Figure 27: Annual count of dry events (top), severity (bottom left) and magnitude (bottom right) of drought spells derived from the mean SPI-3 series for the case study area.

). By looking at the annual distribution of drought occurrences based on SPI-3, they were found to mostly occur in February (Figure 28: *Number of moderate dry events/severe dry events/droughts per month from a) SPI-3 and b) SPEI-3 for the case study area.*

a), however no trend towards drier conditions in winter based on SPI-3 was detected (not shown).

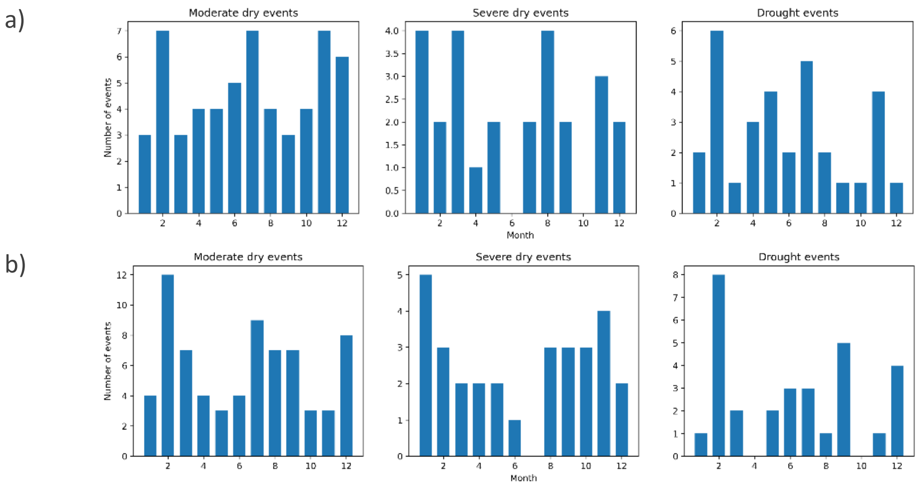


Figure 28: *Number of moderate dry events/severe dry events/droughts per month from a) SPI-3 and b) SPEI-3 for the case study area.*

The results from the SPI analysis confirmed the outcomes obtained for historical precipitation, which exhibited no significant trend in the analysed region.

In order to further assess drought occurrence, it is thus crucial to include the contribution of rising temperature driving increasing demand for evapotranspiration. As regards extreme-heat conditions, the number of hot days per year was found to increase in the case study area (Figure 29: *Annual count of days when maximum temperature exceed threshold of 0.90 (left-hand plot) or 0.98 (right-hand plot) percentile. The linear fit (black solid line) is reported only in case of statistically significant trend.*

). The occurrence of days with moderate hot conditions (above 90th percentile) exhibited a statistically significant increase of about 1.3 per decade, while no significant signal was depicted for more extremely hot conditions.

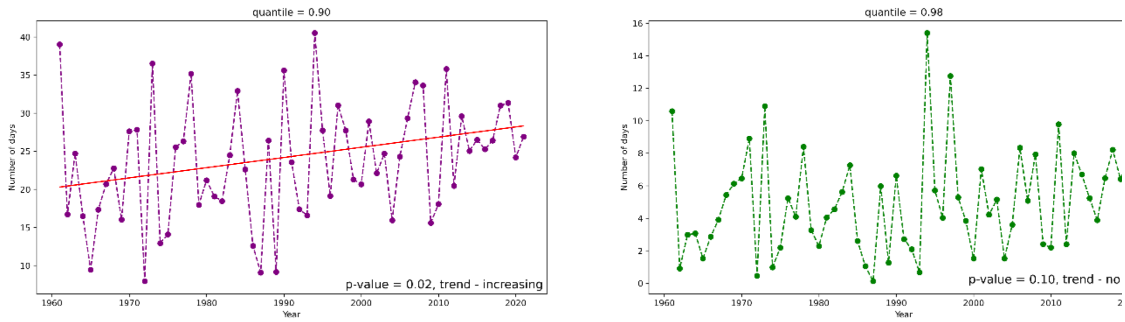


Figure 29: *Annual count of days when maximum temperature exceed threshold of 0.90 (left-hand plot) or 0.98 (right-hand plot) percentile. The linear fit (black solid line) is reported only in case of statistically significant trend.*

Due to the relevance of temperature, SPEI-3 series revealed more pronounced drought occurrences, especially in the most recent decades (Figure 30). However, no significant signal was observed for the annual series of severity and magnitude of identified drought spells (Figure 31: *Annual count of dry events (top), severity (bottom left) and magnitude (bottom right) of drought spells derived from the mean SPEI-3 series for the case study area.*

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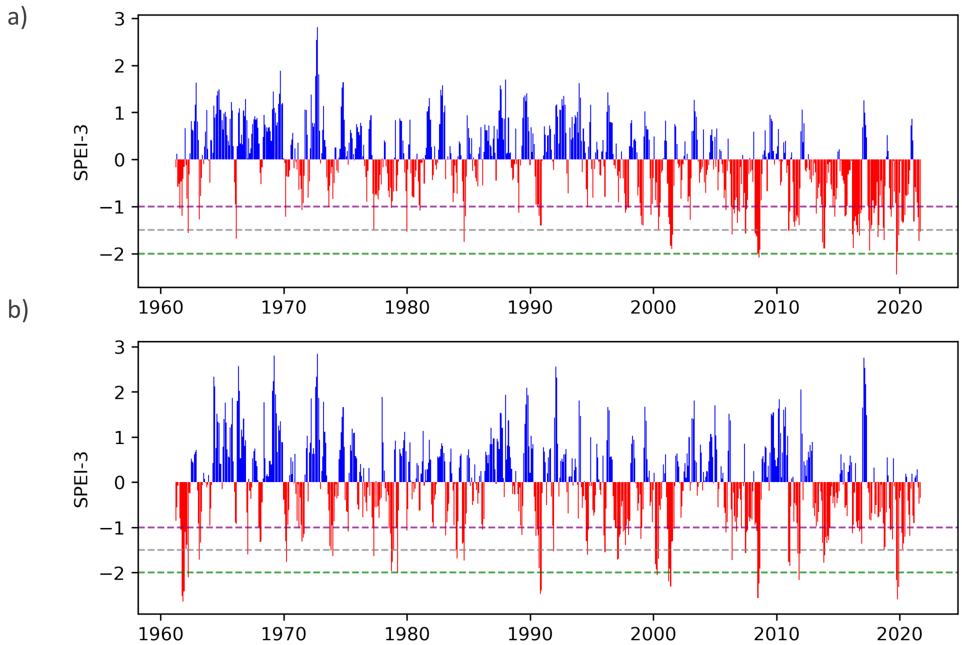

Figure 30: *SPEI-3 monthly regional series for a) Tajikistan and b) the case study area. Anomalous wet and dry conditions are coloured in blue and red, respectively.*

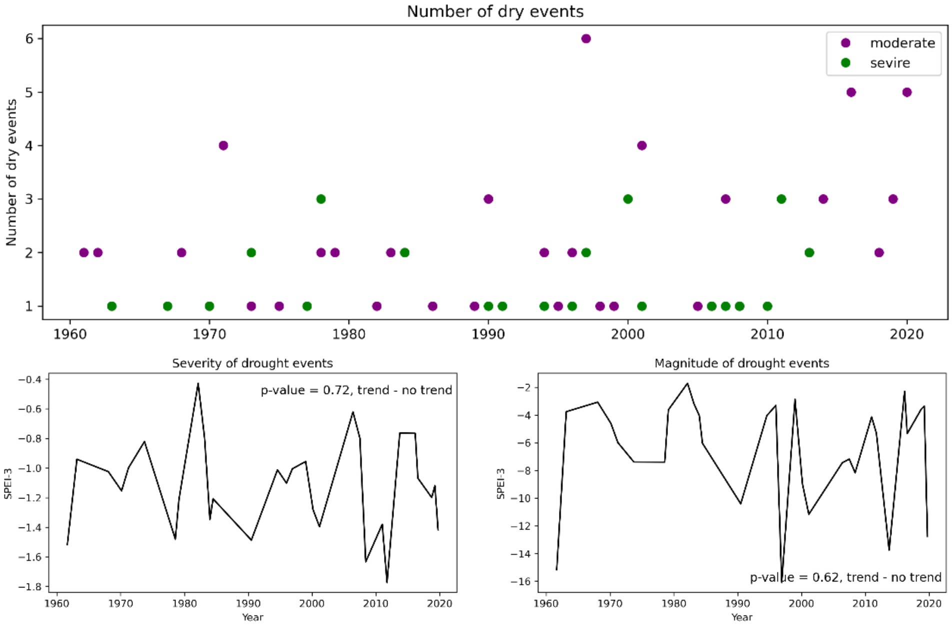

Figure 31: *Annual count of dry events (top), severity (bottom left) and magnitude (bottom right) of drought spells derived from the mean SPEI-3 series for the case study area.*

SPEI-3 values were also used to analyse the temporal variability of dry and wet conditions at a seasonal level by extracting SPEI-3 values in February for winter, May for spring, August for summer and November for autumn. Except for winter, all other seasons showed statistically significant decreases of SPEI-3 values, thus trends towards drier conditions. The most negative trend was observed for summer (**Error! Reference source not found.**).

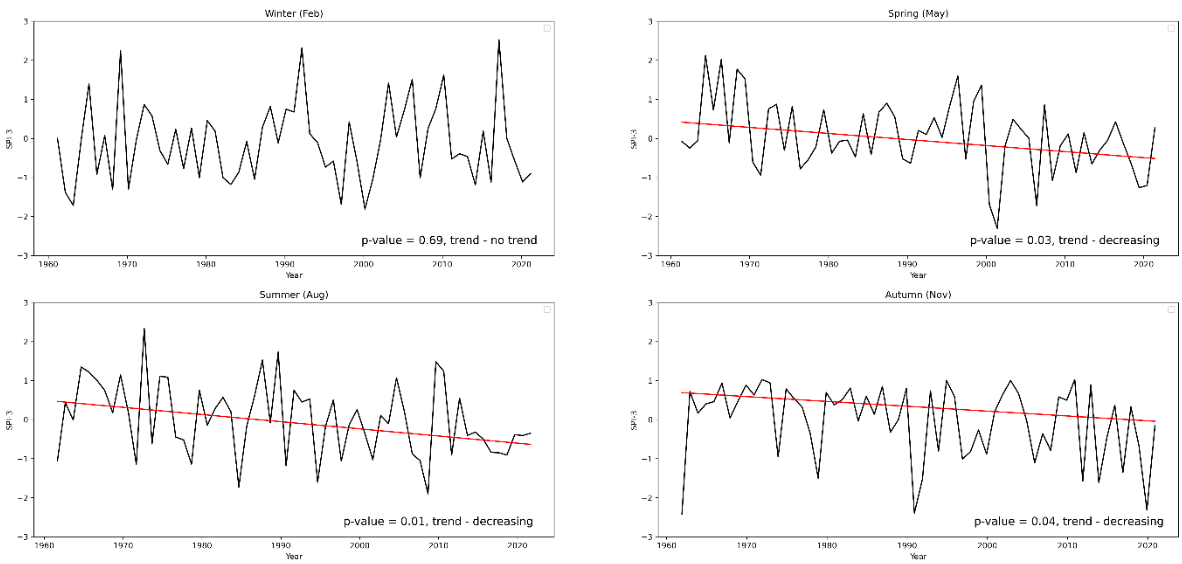

Figure 32: *Seasonal variability in SPEI index. Since index has been computed at 3-month accumulation scale, thus February represents winter, May – spring, August – summer, and November – autumn.*

Based on both SPI and SPEI analyses, recent years, and especially 2021, are not exceptional in terms of severe drought events (Table 4: *Onset, duration, severity and magnitude of drought spells in Tajikistan case study area based on SPI (left-hand columns) and SPEI (right-hand columns).*), which is not fully in agreement with the information reported by the local analyses and perception. Overall, since SPI and SPEI are based on precipitation and temperature only, they might be not enough to derive a comprehensive analysis of drought and other potential drivers should be integrated in the assessment such as snow cover, river runoff and glacier extent. For instance, since the temperature increase has been projected in the project region under all scenarios, a significant snow line retreat can be expected in the near and especially in middle and far future, when climate change is expected to be more pronounced. In addition, it is important to take into account the spatial resolution of input data which might be not fully suitable to derive a detailed characterization of local drought conditions over a rather limited domain.

SPI							**SPEI**					
N	Start date	End date	Duration (month)	Severity	Magnitude		N	Start date	End date	Duration (month)	Severity	Magnitude
1	31.07.61	31.05.62	11	-1.4	-15.6		1	31.08.61	31.05.62	10	-1.5	-15.2
2	28.02.63	31.01.64	13	-1	-13.3		2	28.02.63	31.05.63	4	-0.9	-3.8
3	31.08.64	30.11.64	4	-1	-4		3	31.01.68	31.03.68	3	-1	-3.1
4	31.01.68	31.03.68	3	-0.9	-2.8		4	28.02.70	31.05.70	4	-1.2	-4.6
5	31.07.69	30.09.69	3	-0.8	-2.5		5	31.03.71	31.08.71	6	-1	-6
6	28.02.70	31.01.71	13	-0.6	-7.3		6	30.09.73	31.05.74	9	-0.8	-7.4
7	31.05.71	31.10.71	6	-1	-6		7	31.07.78	30.11.78	5	-1.5	-7.4
8	31.07.73	28.02.74	8	-1.4	-11.1		8	28.02.79	30.04.79	3	-1.2	-3.6
9	31.07.76	30.09.76	3	-0.7	-2.2		9	28.02.82	31.05.82	4	-0.4	-1.7
10	30.04.77	30.09.77	6	-0.7	-4.3		10	28.02.83	31.05.83	4	-0.8	-3.2
11	30.06.78	31.10.78	5	-0.9	-4.6		11	31.12.83	29.02.84	3	-1.3	-4
12	28.02.83	30.06.83	5	-0.7	-3.4		12	30.06.84	31.10.84	5	-1.2	-6
13	30.11.83	29.02.84	4	-1.4	-5.7		13	30.06.90	31.12.90	7	-1.5	-10.4
14	30.04.89	30.06.89	3	-0.7	-2		14	31.07.94	31.10.94	4	-1	-4
15	30.09.91	30.11.91	3	-0.9	-2.8		15	31.12.95	29.02.96	3	-1.1	-3.3
16	31.07.94	31.10.94	4	-0.9	-3.8		16	30.11.96	31.01.98	16	-1	-16.1
17	31.08.95	29.02.96	7	-1.2	-8.2		17	31.12.98	28.02.99	3	-1	-2.9
18	31.01.97	31.05.97	5	-1.3	-6.4		18	29.02.00	31.08.00	7	-1.3	-9
19	30.11.97	31.01.98	4	-0.8	-3.1		19	28.02.01	30.09.01	8	-1.4	-11.2
20	30.11.98	28.02.99	4	-0.9	-3.7		20	31.05.06	30.04.07	12	-0.6	-7.4
21	29.02.00	30.06.00	5	-1.8	-8.9		21	30.06.07	31.01.08	9	-0.8	-7.2

22	31.03.01	31.07.01	5	-1.6	-8.2		22	31.05.08	30.09.08	5	-1.6	-8.2
23	31.05.06	31.07.06	3	-1.5	-4.6		23	31.12.10	28.02.11	3	-1.4	-4.1
24	31.10.07	31.12.07	3	-1.2	-3.5		24	30.09.11	30.11.11	3	-1.8	-5.3
25	31.05.08	31.07.08	3	-1.1	-3.2		25	30.09.13	31.01.15	18	-0.8	-13.8
26	31.12.10	28.02.11	3	-1.5	-4.6		26	29.02.16	30.04.16	3	-0.8	-2.3
27	31.05.11	31.10.11	6	-1.2	-7.3		27	31.07.16	30.11.16	5	-1.1	-5.3
28	30.11.13	30.09.14	11	-0.8	-8.5		28	30.09.18	30.11.18	3	-1.2	-3.6
29	29.02.16	30.04.16	3	-0.6	-1.9		29	31.03.19	31.05.19	3	-1.1	-3.4
30	30.06.18	30.09.18	4	-0.6	-2.3		30	30.09.19	31.05.20	9	-1.4	-12.8
31	30.04.19	31.07.19	4	-0.8	-3.2							
32	29.02.20	31.05.20	4	-1.3	-5.1							

Table 4: *Onset, duration, severity and magnitude of drought spells in Tajikistan case study area based on SPI (left-hand columns) and SPEI (right-hand columns).*

4.1.4 Snow cover changes

Figure 33 shows a negative snow cover trend for almost the entire project area (~75%) for the time period 2000 to 2020. Of those areas showing a reduction in snow cover in the last twenty years 1.6% were calculated to be significantly negative. In the southern part the snow cover change analysis resulted in positive trends (~18% of the project area), with less than 1% being significantly positive. For a small part of the project area (remaining 7%) a trend in snow cover could not be calculated as for those areas satellite imagery used to calculate the changes was not available for all 20 years. See section 3.1.4 for details on how the analysis was conducted.

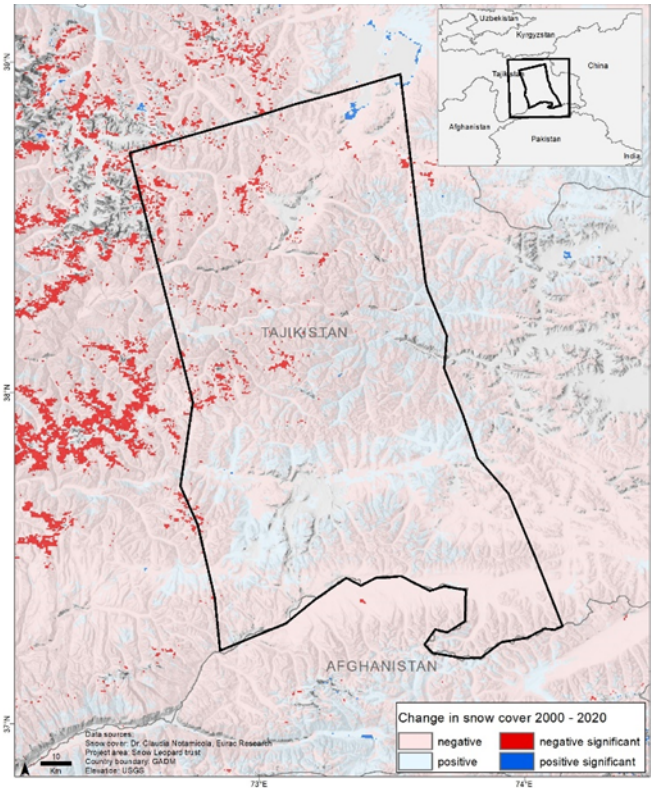

Figure 33: Map showing the change in snow cover in the time period 2000 to 2020 in the project region in Tajikistan. The significance of the trends is at 5% level of the Mann-Kendall statistics

4.1.5 Conclusions

- Clear trends towards higher temperatures in all seasons are depicted from observations and projections at both national and local (project region) level.
- No clear trends towards drier conditions are identified. At both national and local scale, precipitation is mainly found to increase in both current and future climate, mainly in winter.
- Based on SPI, i.e., the precipitation deficit, no trend in observed droughts for the project region is found even though drought events are frequent. SPI scenarios for Tajikistan confirm the wetting trends in winter and, secondary, spring.
- Based on SPEI, i.e., the water deficit, a clear trend towards more frequent and stronger droughts is found from observations for the project region, especially in spring, summer and autumn. Such seasonal trends towards drier conditions are also projected for the future by the national SPEI scenarios for Tajikistan.
- No exceptionally severe drought events are identified in 2021 for the project region based on both SPI and SPEI.

4.2 Main risk: Risk of loss of livelihoods for livestock owners due to drought and raising temperatures

For the Tajikistan visited villages, Barchidev and Ghudara, the main climate risk identified during our community consultations and fieldwork, and confirmed through discussions with the local partners, refers to the risk of loss of livelihoods for livestock owners due to drought impact on pasture, and missing irrigation water for fodder and food production. In the following section, the risk is represented by a general Impact Chain for the two villages, presenting main patterns observed throughout the territory. Sections 4.2.2-4.2.3 include information at village level. Section 4.3 presents the comprehensive risk assessments per village. Box 1 reports the current situation on human-wildlife conflict in the visited area and the potential effect of climate change on this for up to 2050. The results presented and discussed in 4.2.1 are based on both primary and secondary sources; sections 4.2.2-4.2.3 are based on the information collected in the two study sites and during the community consultations.

4.2.1 Overview of main risk (current and future situation)

While at least 85% of the territory of the Gorno Badakhshan Autonomous Oblast has no productive agropastoral potential (Breu et al., 2005), periods of drought – and in certain cases the extensive use of pastures – have caused pasture degradation reflected in a change in vegetation and less biomass in many parts of the high-mountain areas in the Pamirs (Akhmadov et al., 2006). Both in Barchidev and Ghudara, the community consultations' participants reported a perceived reduction in the grass in their summer pastures over the last years, which they attribute to overall drier conditions. More than the impact of droughts on pasture, our fieldwork has confirmed what has been previously highlighted in the scientific and grey literature: water for local food and fodder production is one of the most important factors for sustaining local livelihoods in the western Pamir Region; the lack of water due to the interplay of challenging socio-ecological conditions is the major factor limiting livestock numbers and causing food insecurity (Dörre, 2020; Robinson and Whitton, 2010). The challenging socio-ecological conditions refer to frequent drought spells (see section 4.1.3), the limited arable land due to the extreme topography of the Bartang Valley, the low productivity of this arable land, and the necessity for labour- and cost-intensive water supply and distribution infrastructure. All this mechanism unfolds in a socio-economic context of a highly precarious livelihood situation characterized by lack of resources and employment, energy insecurity, lack of motility (mobility potential) and a high *exposure* to additional environmental hazards (Blondin, 2021; Dörre, 2020). The abovementioned water-related risks in the area are illustrated in the Impact Chain discussed below (Figure 34).

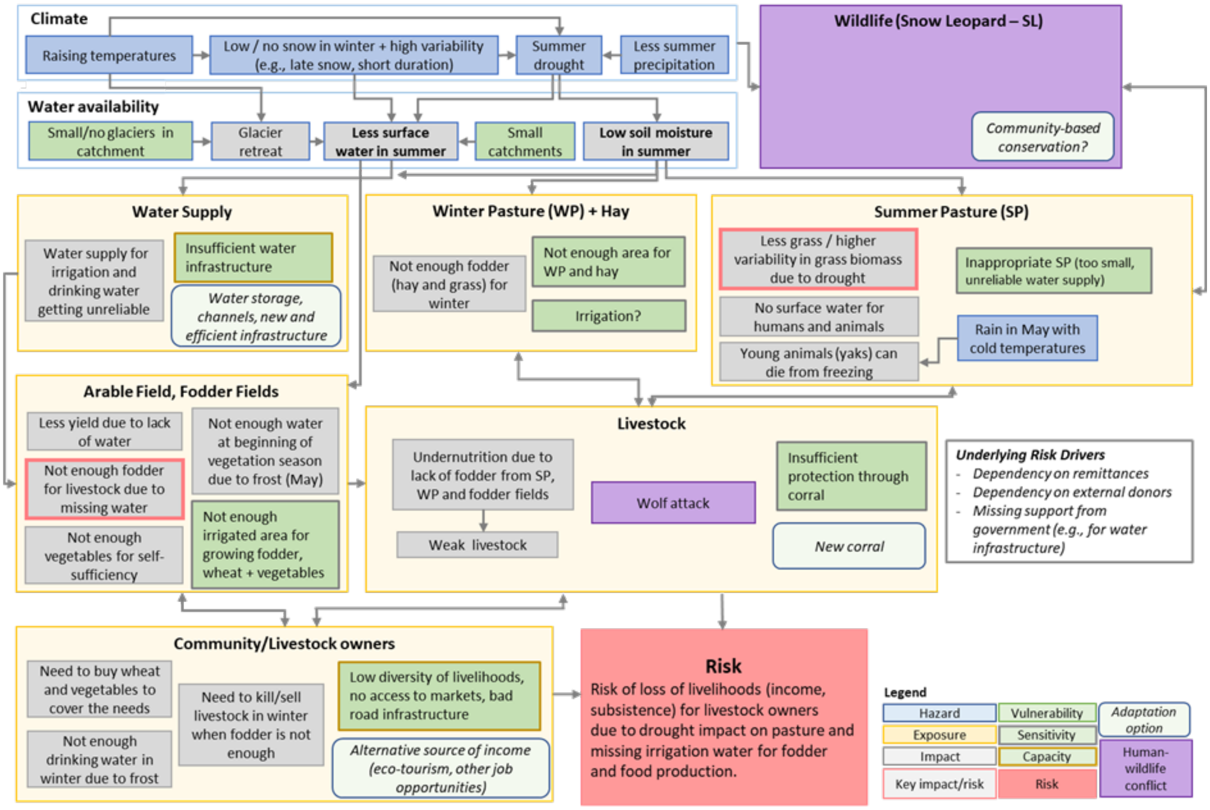

Figure 34: The Impact Chain for the visited villages in Tajikistan (Barchidev and Ghudara).

Current situation

Droughts as hazard events in the Tajikistan project region are triggered by raising temperatures, changes in seasonal precipitation patterns and high precipitation variability, which are all important climate signals to consider when discussing water availability in the area (see section 4.1). In order to cover both domestic and agricultural water needs, the visited villages rely on snow melt to recharge soil moisture on pasture and on snow melt and glacier melt to create runoff and river discharge, which is important for irrigation in fodder and food production. In addition, water resources are also necessary to generate electricity[6]. The region's water supply depends mainly on winter and spring precipitation, and (less) on summer precipitation. Indeed, winter and spring have been identified as important seasons for Central Asia because two thirds of the annual precipitation is falling during that time – predominantly as snow – and water reservoirs for summer in the form of snow and ice are built up (Haag et al., 2019; Knoche et al., 2017; Zhumanova et al., 2021). During these seasons, altered precipitation patterns together with warmer conditions can result in summer droughts with intermediate impacts on less surface runoff and low soil moisture, affecting the exposed water supply in irrigated fields and pasture productivity respectively. Even though precipitation shows only minor positive tendencies in most seasons similarly to what has been previously observed for Central Asia (Haag et al., 2019), remote sensing-derived snow cover observations show that snow cover duration and snow cover area over Central Asia are subjected to a large seasonal and inter-annual variability that directly affects the hydrological regimes of the surface runoff (Gerlitz et al., 2020). In terms of temperatures, these have been increasing in Central Asia, especially in winter and spring (Haag et al., 2019), contributing to cases of an earlier snowmelt, glacier retreat, and, overall, more arid conditions.

[6] In Tajikistan, water resources are used to generate about 95% of all electricity (Worldbank and Asian Development Bank, 2020).

Based on the Randolph Glacier Inventory 4.0, almost 10% or 12,500km^2 of the Pamirs are covered by glaciers (Knoche et al., 2017). While hydrological modelling in the Pamirs, so far, provides a puzzle of contradicting statements on past and future water resources and glacial melt, a recent study focusing on the Tajik Pamirs and the glaciated Bartang catchment[7], where the villages under study are located, concluded that in this part of the Pamirs glaciers are retreating and enhance river discharge and freshwater availability of the main receiving streams (Knoche et al., 2017). Nevertheless, within the next few decades settlements locally could be affected by water shortages during the vegetation period, when entire subbasins will be deglaciated. Under these conditions, the villages with small catchment areas and/or small glaciers within their catchment such as Barchidev are generally more vulnerable to drought impacts.

Exposed systems for the visited villages include the water supply, winter pasture and hay, summer pasture, irrigated land (arable and fodder fields), the livestock and, finally, the communities. Livestock is the main exposed livelihoods base in Barchidev and Ghudara, and in the broader area. Livestock ownership is generally limited; livestock is used for household consumption and is also sold according to need. The primary livestock animals are sheep, goats, cows, while Ghudara reported also yaks. Yaks play an important role in the local livestock economy, provide meat, milk and wool and are used for transportation in the context of tourism. While Barchidev reported a steady number of livestock due to lack of space and irrigated territory, in Ghudara livestock numbers are increasing signalling an increase in the exposure. In addition to livestock and similarly to the rest of the Bartangi households (Blondin, 2021), Barchidev and Ghudara practice small-scale subsistence farming. Arable and fodder fields are limited and concern mainly wheat, potatoes, carrots, onions, and garlic, and fodder crops (e.g., barley and alfalfa – Michel, 2021). In Barchidev, which is at a lower elevation than Ghudara, they grow also cucumber and cabbage.

Key risks arising refer directly to the exposed systems of pastures, irrigated land (arable and fodder fields), and livestock. These are i) pasture degradation with less grass/higher variability in grass biomass due to drought/low soil moisture, ii) lack of fodder for the livestock and food production due to drought/lack of surface water and insufficient water infrastructure. Key risks are not caused just by the primary hazards but especially because of the vulnerabilities embedded within the exposed systems.

The lack of space for winter pasture and hay, and inappropriate summer pasture due to space limitations and unreliable water supply are vulnerability factors contributing to the key risk of pasture degradation but also to the key risk of lack of fodder for winter. As in many parts of mountainous Central Asia, livestock breeding in the Pamirs is historically carried out in the nomadic tradition moving livestock from one grazing ground to another in a seasonal cycle, typically to lowlands in winter and highlands in summer. According to the community consultations, during the winter months, animals are kept inside and fed on fodder collected and produced during the summer months. This fodder is mainly hay and grass collected in July-August fand or around 3 months by meadows in valleys and at mountain slopes with higher productivity of grasses and forbs. In Ghudara, the yaks remain outside, grazing on the winter pasture. In autumn and spring, animals are grazed close to the villages in areas that many times are the same with the winter pastures (Breu et al., 2003). Groups of ten to fifteen families pool their animals together and undertake shepherding on a rotational basis, with a different person going with the animals each day and bringing them back to the village at night (Robinson, 2005). Both Barchidev and Ghudara reported a limited territory of productive nearby pastures pointing to the need for irrigation. Nevertheless, this seems to be less of a problem in comparison to the limitations experienced in terms of hay. According to livestock owners from Barchidev “The limited hay is our bottleneck. In 2017, we did not have enough hay due to limited snow and we had to kill and sell some of our animals. For this reason, we are now building an irrigation channel in order to irrigate some hay fields”. Ghudara reported a very similar situation with the increasing temperatures giving the hope for more water availability in winter (i.e., less frozen water in winter) and new opportunities to arise with an expansion

[7] The Bartang River basin north of the Gunt basin drains the entire Tajik South-East Pamirs before receiving the meltwaters of the Central Pamirs and the southern drainage of the Fedchenko glacier area.

of the fields that can be used for haymaking (and other fodder crops). During the summer the bulk of the village animals are grouped together and taken by a number of professional shepherds to the high summer pastures (3,500-4,700 m). These shepherds generally move with their families and are paid in cash, in kind and through access to milk products (Robinson, 2005)[8]. The increased summer pasture availability for Ghudara, as we move towards the high plateaus of the Eastern Pamirs, means that the animals will be moved several times in a summer between different pastures, moving higher as the season progresses. Barchidev, on the other hand, reported a more limited summer pasture, which is still considered enough for the needs of the livestock. The summer pastures for both villages are shared with other villages according to a specific carrying capacity decided at a central institutional level[9] and no conflicts were reported among villages. According to the community consultations' participants, south exposed pastures with unreliable surface water supply are more vulnerable to drought impacts. Here, we should mention that during the community consultations and the fieldwork we did not receive any information on increased pasture vulnerability to drought due to overgrazing, competition over pastures or limited mobility and 'underuse' of remote pastures (in contrast to Kyrgyzstan, see section 5.2.1). According to our literature review, overgrazing and related issues such as the intensive depletion of tereksen seem to be an issue mainly for the Eastern Pamirs (e.g., Breckle and Wucherer, 2006; Michel, 2021; Robinson 2005; Vanselow et al., 2012). Nevertheless, it is worth noting what Breckle and Wucherer (2006) stress that due to the significantly low biomass of the pastures in the western Pamirs grazing can always be categorized as overgrazing, making most of the summer pastures in the area 'greatly degraded'.

Important vulnerability factor contributing to the key risk of lack of fodder and food production is the limited arable land due to the extreme topography of the Bartang Valley and the insufficient water infrastructure for growing fodder, wheat and vegetables. Crop production in Barchidev and Ghudara is used mainly for feeding the livestock and subsistence and was reported to be insufficient to meet the households' needs. With most of the territory being barren, rocky mountain terrain with permanent snow, glaciers and debris, and only very limited biomass production, arable land is the scarcest resource in the Tajik Pamir environment (Breu et al., 2005). In fact, in the Western Pamirs arable land accounts for approximately 240 km^2, or as little as 0.4% of the total area of the GBAO (Ibid.). In the words of a livestock owner in Barchidev: "We do not have enough space. If we plant vegetables, we do not have space for wheat. However, wheat is the most important as it can be used both for bread and fodder, so we put priorities". Besides the limited territory and harsh environmental conditions, major vulnerability factor for the arable land is the lack of irrigation. Fodder, wheat and vegetables can only be produced under irrigation: small-scale gravity-flow irrigation systems divert water from the rivers that drain the snowmelt from higher mountains. Both Barchidev and Ghudara reported insufficient water infrastructure (Figure 35). Based on observations in the field and on the literature (Hill, 2013), new irrigation systems were developed during the Soviet times, which however have not been maintained and are currently destroyed and/or with important water losses. This old infrastructure and the water supply system is owned and managed by the communities, with no government support (Bossenbroek and Zwarteveen, 2014). The missing government support is an important underlying risk driver for the villages under study (see Figure 34). Considering that the creation, operation, and maintenance of water supply systems in the area is significantly labour- and cost-intensive (Dörre, 2020), the community consultations' participants reported that their hopes are set on receiving financial and material resources from international NGOs and donors – especially the Aga Khan Foundation – and putting the labour themselves (Hill, 2013). Barchidev is already in the process of developing a new irrigation channel for hay cultivation. Ghudara is in the search for funding for the same reason considering especially the new opportunities for arable land due to the increasing temperatures. In this sense, both villages report

[8] It should be stressed that this 'simple' vertical movement between lower and higher altitude pastures is valid for the Western Pamirs, where our fieldwork took place. According to the literature, movement of populations and animals on the high plateau areas of the Eastern Pamirs is much more widespread and complex, making use not only of altitude differences but also micro-climates associated with slope and exposure (Robinson and Whitton, 2010).

[9] Similar to what has been noted for Karakul, in the north-east of Barchidev and Ghudara, the pastureland in the area of our fieldwork can be categorized as common property or group property regime: resources are held by a limited group as common property and their use is established through an internal rule (Watanabe and Shirakasa, 2018). The regime used to manage land with natural resources affects both environmental sustainability and accessibility by the users (Watanabe and Shirakasa, 2018) and thus can further impact on the vulnerability of the system. This was beyond the scope of this climate risk assessment and further research is needed to this direction.

a high dependence on external donors, which seems to be rather common in the Bartang Valley area (see underlying risk drivers – Figure 34).

Figure 35: Functioning and destroyed irrigation channels in and around Barchidev village

The above discussion illustrates a socio-economic situation of persistent poverty characterized by the dominance of a subsistence-oriented (but often insufficient) mixed-mountain agriculture (livestock breeding and irrigated cultivations), the absence of employment opportunities, and a high level of dependence on remittances, development and humanitarian[10] support amidst a challenging environmental context. In this regard, poverty, the low diversity of livelihoods and remoteness are important vulnerability factors of the exposed communities. Poverty and the low diversity of livelihoods imply high food insecurity and decreased economic resilience because of the interplay of lack of basic income and high dependence on a sole livelihood activity directly influenced by climatic and ecological conditions. Except for schoolteachers, retailers, doctors, taxi drivers and retired people, few people living in the Bartang Valley have a regular source of income (Blondin, 2020; FEWS NET, 2011). Even more so than in the rest of Tajikistan, the people in the Pamirs depend heavily on remittances (Haider et al., 2020). Remittances add to the diversification of the livelihoods decreasing the vulnerability of communities to drought impacts and other environmental shocks at least in the short term, e.g., by permitting the purchase of food and fodder (Murakami, 2020). Remittances do not seem to be able to contribute in the self-sufficiency and economic vitality of the villages in the long-term though constituting in this way underlying risk drivers. The bad road infrastructure and the subsequent almost non-existent access to markets further entrench the communities' vulnerability. In fact, the Bartang valley is considered one of the most remote in Tajikistan since the only road into the valley is in a particularly bad state. Insufficient road infrastructure limits access to goods and services of paramount importance undermining food security, health and well-being. At the same time, only few people are

[10] According to Breu et al. (2005) a high rate of households in GBAO is dependent on food aid.

able to sell their crop surpluses or handmade knitted clothes in the city and the limited tourism to villages is further constrained by the lack of accessibility (Blondin, 2020).

Potential future situation (up to 2050)

Hazard: As thoroughly explained in the current climate and climate scenarios chapter (4.1), raising temperatures, high interannual precipitation variability and shifts towards more frequent and intense droughts characterize the main climate signals that are likely to increase the drought risk across the Tajikistan project region in the future.

Intermediate impact and key risks: The intermediate impacts and the key risks described in the Impact Chain (Figure 34) are expected to be relevant in the future and will probably mostly intensify, although possibly also new livelihood opportunities may arise in the higher altitudes. Climate change impact on surface runoff is unclear due to the uncertainty of future precipitation patterns, glacier and snow melt rates (Reyer et al., 2017). Overall, research indicates that in the future in Central Asia the hydrological regime is shifting towards a runoff from snowmelt earlier in the year leading possibly to less surface water in summer (Liang et al., 2021). This by itself could result in a situation of limited surface water in summer with increasing water shortages in the absence of water infrastructure for water storage. Moreover, across all Central Asia potential evapotranspiration due to warming increases exerting a drying effect on soils (Liang et al., 2021; Reyer et al., 2017). At the same time, the observed trend of higher surface temperatures leading to higher glacier melt rates and glacier shrinkage is expected to continue in the future and may partly counterbalance the impacts of early snow melt and high evaporation rates for communities with glacierised catchment in the next few decades up to 2050, with however an uncertain date of passing peak runoff (Reyer et al., 2017). The consequences of glacier shrinkage have not yet been investigated at the temporal and spatial scales that would allow discussing water management issues at local scale for the Pamir region (Pohl et al., 2017). The increasing temperatures will probably open-up livestock and grazing opportunities in the higher altitudes. Similarly, the higher temperatures and accordingly longer thermal growth season, if not limited by water availability from precipitation or sources of irrigation water, may facilitate the expansion of arable farming into higher altitudes (Michel, 2021). This may support the cultivation of new crops and production of fodder for livestock. Evidence suggests that the growing season has already become longer in Ghudara and other villages at high elevations in the Pamirs (Kassam, 2009). According to the community consultations, in the past, in Ghudara, wheat was rarely harvested because of frost damage but can now be regularly produced. Thus, both in Barchidev and Ghudara where winter fodder availability is a limiting factor for livestock numbers this climate change impact can cause an increase in livestock numbers putting pressure on pastures (Michel, 2021). This situation could potentially increase competition for water in conditions of drought and induce wildlife habitat fragmentation (for more information on human-wildlife conflict see Box 1). Floods, mudflows and avalanches may increase (for instance sudden and rapid glacial melts).

Exposure: Livestock is the main exposed livelihoods base in the villages and the broader area. With livestock numbers increasing in Ghudara – and with potentially new areas for fodder production and grazing – the risk will potentially increase in the future. With stable number of livestock in Barchidev, exposure will remain as such.

Vulnerability: The key risk of pasture degradation will most likely increase for the villages under study, except for the potentially newly irrigated areas. Vulnerability to the key risk of lack of fodder and food production is likely to increase if no investments are done in water infrastructure and if communities are not given the opportunity to diversify their livelihoods so as to improve their living conditions and adapt to future drought impacts. Considering the specific identity of the Bartangi communities and their attachment to their valley, this process should take place through community-based adaptation efforts that are sensitive to the community values and the local socio-ecological context. Scaling up community-owned initiatives (rather than imposing top-down adaptation actions) in terms either of water management or e.g., tourism development through both material resources but also capacity building is necessary to ensure respect for local values and desires, while empowering communities to choose and lead their development trajectories. Accessibility to basic products and services should be certainly improved, including the promotion of emergency mobilities to ensure evacuation or provisioning in contexts of food insecurity, environmental disasters or urgent need for healthcare (Blondin, 2020). In a broader scale, considering that unstable water availability is likely to increase the challenge of competing requirements for hydropower generation and agricultural production at times of rising overall demand due to projected population and economic growth in Central Asia, integrated water resources management and transboundary cooperation will also be key adaptation needs for the future.

Box 1. Risk of loss of livelihoods for livestock owners due to drought and raising temperatures and Human-Wildlife conflict in the visited villages in Tajikistan

Current situation

Human-wildlife interactions were reported both in Barchidev and Ghudara and refer primarily to livestock depredation by wolves in the villages and in the summer pastures. Snow leopards are not regarded as a major threat in the current situation as their habitat generally does not overlap with the areas used by the communities. According to the information we collected during the fieldwork, pasture sharing between livestock and wildlife that constitutes snow leopard prey does not seem to be an issue as well because of the presence of steep and/or high terrain that prevents livestock from grazing and constitutes refugium for wildlife in the summer pastures. This generally harmonious relationship between snow leopards and communities contributes both to avoiding loss of livelihoods and to snow leopard conservation. The lack of improved, modern corrals seems to be the main vulnerability factor contributing to intensification of the generally limited human-wildlife conflict that was reported in the two villages. In Barchidev, a new corral has been built close to the village by the Aga Khan Foundation and an additional one is needed in the summer pastures. Ghudara, on the other hand, lacks an improved corral both in the village and in the summer pastures (Figure 36).

It is worth mentioning here that Barchidev and Ghudara, together with the villages of Rukhch, Pasor, Bopasor are within the territory of the Tajik National Park, created in 1992 and designated as a United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Site in 2013. During our fieldwork the Tajik National Park was mentioned for its contribution in safeguarding wildlife from hunting, the (few) employment opportunities for villagers to become rangers and certain expectations on tourism development in and around the park (e.g., in Barchidev member of the community shared their vision for an organised camping area). So far, tourist activities have provided only few economic benefits to local communities mainly through homestays. For more information on the state of the Tajik National Park and the human-wildlife interactions in the Tajikistan project region see Shokirov et al. (2021).

Potential future situation

The future situation for human-wildlife conflict (focusing on snow leopards) will be defined by a complex combination of socio-ecological factors such as the impact of climate change on snow leopards and their habitat but also on their prey; the impact of climate change on communities and their adaptation actions; human population changes, livelihood strategies (including livestock numbers, pasture and water management), and conservation efforts.


Figure 36: A new corral in Barchidev (left) and an old corral in the summer pastures of Ghudara (right)

The increasing summer temperatures and the changes in water availability may directly affect snow leopards (Michel, 2021). Nevertheless, as highlighted by Forrest et al. (2012) 'the impacts of climate change [on snow leopards] will be manifested primarily through changes in the snow leopard's alpine habitat, rather than through direct physiological impacts of temperature and precipitation on snow leopards.' Models presented by Li et al. (2016) indicate that under scenario RCP 4.5 suitable habitat Tajikistan will slightly decrease by 1% for 2070, while under scenario RCP 8.5 it will slightly decrease by 4%. Preliminary results on snow leopard distribution modelling from research conducted in the context of the Vanishing Treasures programme also show the potential loss of habitat, especially in areas with lower elevation in Tajikistan (Humboldt-University Berlin unpublished data). Li et al. (2016) identify the Tian Shan-Pamir-Hindu Kush-Karakoram Mountain ranges as one of the three potential 'climate refugia' for snow leopards calling for establishing nature reserves and providing targeted conservation solutions. This is because herders and farmers interactions with snow leopards might increase in the future as communities follow shifting grasslands and croplands upward in elevation (IFAD, FIC, IEH 2013; Li et al., 2016) and/or expand to cover the needs of their developing livelihoods (i.e., livestock and – potentially – cropland increase). Thus, the exposure of the communities to human-wildlife conflict might increase but probably to a lesser extent in comparison to the Kyrgyzstan case (see Box 2).

Potential impact of climate change and land-use on vegetation in terms of composition, productivity and phenology will be probably the most important factor determining future habitat suitability and abundance of mountain ungulates and other prey species of snow leopard in the project region (Michel, 2021). While the complexity of the factors determining the composition of vegetation makes any predictions of vegetation change highly uncertain (Michel, 2021), with the grazing pressure potentially increasing (i.e., fodder availability is not a limiting factor for Barchidev and Ghudara anymore) and shifting in higher altitudes in the future, vulnerability is expected to increase with an intensification of human-wildlife conflict. To this it should also be added that reduced snow cover, accelerated snow melt and the disappearance of smaller glaciers could reduce water availability in some areas, possibly fragmenting the habitat of ungulates but also the suitability of pastures for livestock. Preliminary results on distribution modelling for ungulate species from research conducted in the framework of the Vanishing Treasures Programme show the impact of future climate conditions on their habitat suitability (Humboldt-University Berlin unpublished data). For argali, an upward shift in habitat and loss of suitability of bottom of valleys is predicted. However, this impact seems lower for the ibex. Such predicted shifts in habitat could lead to sharing landscapes with livestock and a higher competition over resources (e.g., forage, species and water), disease transmission and poaching, indirectly impacting snow leopard population.

Future human-wildlife conflict-related vulnerability per Village District will depend on the status and management of the pastures, the presence of inaccessible to livestock terrain in the Village District's territory, and the (further) establishment of anti-poaching measures and community-based conservation areas.

4.2.2 Barchidev village

Barchidev is located at the riverbank of the Murghab river[11] close to Lake Sarez (Figure 37). According to the community consultations' participants, the village has a steady population of 285 people. The exposed livelihood concerns livestock breeding mainly for subsistence purposes with 500 sheep and goats, and 70 cows that remain stable in terms of numbers due to limited territory and irrigated land.

Current situation

Barchidev, at an elevation of around 2,600m, belongs to the 'warmest region' climate class. Based on our preliminary analysis and as confirmed during the community consultations, Barchidev is located in one of the least glacierised catchments of the Tajikistan project region (glacier extent 1-100km^2). This lack of glacier in Barchidev's catchment is an important vulnerability to drought. The community consultations' participants reported a perceived increase in temperature and decrease in precipitation in summer. They also reported that 2021 was characterized by late snow (February/March) that resulted in less surface water in the summer season. Nevertheless, the people of Barchidev agreed that any limited water availability should not be attributed (only) to climate-related hazard events but mainly to the vulnerability referring to water supply, lack of water channels and destroyed water infrastructure from the Soviet times

With regard to the key risk of pasture degradation due to drought, Barchidev reported a relatively vulnerable situation of limited territory of productive nearby pastures with unreliable water supply. In the summer pastures, Barchidev reported that the assigned carrying capacity limits per pasture are respected, preventing pastures from degradation, while there is no competition between the villages for the use of pastures as the pasture is enough to cover the livestock's needs (Figure 37). The biggest challenging and critical vulnerability factor concerns the limited hay availability that can hardly sustain animals in winter. In Barchidev, livestock owners reported that hay collection takes place over three months around August in order to cover the needs of the animals for five months (November-March). Cows need the hay from November, while smaller livestock (sheep and goats) need the hay only from March as they are mostly able to cover their needs through pasture grazing until then. 2017 was highlighted as a particularly hard year: due to late snow and overall dry conditions hay was not enough and thus it became necessary either to kill or sell livestock. Concerned about future similar years, the Barchidev community is currently building an irrigation channel to increase hay productivity (funds and material are from the Aga Khan Foundation).

When it comes to the key risk of lack of fodder for the livestock and food production, due to the lack of arable land the limited hay availability cannot be compensated by fodder crops, further entrenching Barchidev's vulnerability. The participants of the community consultations reported lack of arable land to grow either fodder or wheat and vegetables. There is limited agricultural production of wheat, potatoes, carrots, onions, garlic, cucumber, cabbage, while the selection of crops is often selected strategically, e.g., wheat is prioritised due to its contribution both to food and fodder. In its current state

[11] The Murghab river is joined by the Ghudara river just below Sarez Lake. From the junction the river is known as the Bartang river.

the arable land cannot cover the needs of the community. According to the participants of the community consultations, the situation can be improved with the new irrigation channel.

Under these conditions and in lack of other employment opportunities, a high dependence on remittances (60% - migration to Russia) seems unavoidable and adds to the livelihood diversification decreasing the vulnerability to the risk of loss of livelihood due to drought impacts at least at the moment but adding to the uncertainty of the system for the future as underlying risk driver. Despite the persisting poverty and challenging environmental conditions, Barchidev reported an increasing quality of life reflected in access to energy, new infrastructure and other amenities.

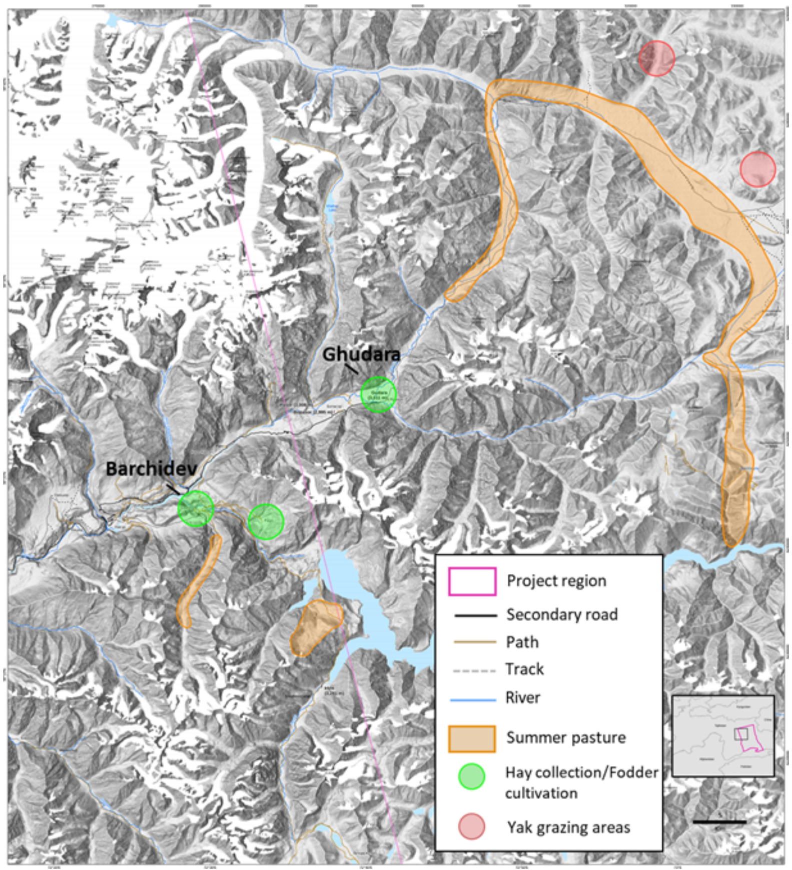

Figure 37: The results of participatory mapping for Barchidev and Ghudara. The participants indicated areas of hay collection and fodder cultivation – both of the two Southern locations were indicated by Barchidev, while Ghudara indicated the area around the village. The participants mapped also the locations of the summer pastures. The map shows the more limited summer pasture availability for Ghudara (the two Southern summer pasture areas) and the increased summer pasture availability for Ghudara, moving towards the high plateaus of the Eastern Pamirs. Ghudara village has also yaks that graze freely also in additional to the main pasture locations.

Potential future situation (up to 2050)

Hazard: A clear trend towards more frequent and intense droughts is found from observations for the whole Tajikistan project region.

Intermediate impact: Similar with the 'potential future situation' for both villages, see section 4.2.1.

Exposure: Livestock numbers are stable in Barchidev and thus the exposure to the risk is expected to remain the same.

Vulnerability: With limited glacier in catchment, Barchidev is expected to be vulnerable to droughts in the future. The key risk of pasture degradation will most likely increase, except for the potentially newly irrigated areas. Water infrastructure and management is key both for future livelihood diversification and for addressing the key risk of lack of fodder and food production, which is otherwise likely to increase in Barchidev. With 60% dependence in remittances, Barchidev's future vulnerability to lack of fodder will probably depend also on external economic factors. The community consultations' participants seemed interested and eager to attempt livelihood diversification through ecotourism, which could potentially decrease communities' vulnerability, but is dependent on the agendas of external donors and the capacity of the people in Barchidev to access this external support.

4.2.3 Ghudara village

Ghudara, a village severely affected by a 7.2-magnitude earthquake in 2015, is located at the riverbank of the Tanymas river at the northern reaches of the Bartang Valley (Figure 37). According to the community consultations' participants, the village has an increasing (due to birth-rates) population of 387 people. The exposed livelihood concerns livestock breeding mainly for subsistence purposes with around 1,040 sheep and goats, 200 cows and 60 yaks with increasing tendency.

Current situation

Ghudara, at an elevation of around 3,011m, belongs to the 'warmest region' climate class. Based on our preliminary analysis and as confirmed during the community consultations, Ghudara seems to have sufficient buffer to drought. The village is located in the most glacierised catchment of the Tajikistan project region (glacier extent 601-647km^2), which includes the famous 'Fedchenko Glacier', the longest glacier outside of the Earth's polar regions[12]. The community consultations' participants reported a perceived increase in temperature over the years, that has already favoured crop production: "20 years ago, we didn't grow wheat because it was very cold but now, we do grow wheat. In Barchidev it is warmer, they still have more wheat than us.". They also reported that 2021 was characterized by late snow (February/March) that resulted in less water in the summer season. Nevertheless, similarly to Barchidev, the people of Ghudara agreed that any limited water availability should not be attributed (only) to climate-related hazard events but mainly to the vulnerability referring to water supply, lack of water channels and destroyed water infrastructure from the Soviet times.

With regard to the key risk of pasture degradation due to drought, Barchidev reported a relatively vulnerable situation of limited territory of productive winter pasture (lack of water and grass, used only for yaks in winter). With 22,000 hectares of summer pasture, this was reported to be sufficient and in good quality to cover the needs of the livestock (Figure 37). Rain in May and cold temperatures were reported as climate signals that can lead to loss of young yaks. Similarly to Barchidev, the biggest challenge and critical vulnerability factor in Ghudara concerns the limited hay availability that can hardly sustain animals in winter. This is being addressed with the construction of a new irrigation channel, which was however paused due to lack of material and dependence on donors. The increasing temperatures though give the hope for more water availability in winter (i.e., less frozen water in winter) and new opportunities to arise with an expansion of the fields that can be used for haymaking (and other fodder crops).

[12] https://www.earthobservatory.nasa.gov/images/78967/fedchenko-glacier

When it comes to the key risk of lack of fodder for the livestock and food production, due to the lack of arable land the limited hay availability cannot be compensated by fodder crops, further entrenching Ghudara's vulnerability. There is limited agricultural production of wheat, potatoes, carrots, onions and garlic. Due to the presence of soil in the water coming from the Tanymas river and the increased opportunities to plant wheat and vegetables due to higher temperatures, Ghudara has planned a new irrigation channel in the framework of a development programme with the Aga Khan Foundation. However, at the time of our fieldwork funding was not available yet.

Despite the harsh conditions and the lack of other employment opportunities, Ghudara reported only a low dependence on remittances (5%). The remittances were said to be in any case an important support for the village and are used in the case of emergencies related to the loss of livelihoods, health issues and others. Despite the persisting poverty and challenging environmental conditions, Ghudara reported an increasing quality of life reflected in access to energy, new infrastructure and other amenities.

Potential future situation (up to 2050)

Hazard: A clear trend towards more frequent and intense droughts is found from observations for the whole Tajikistan project region.

Intermediate impact: Similar with the 'potential future situation' for both villages, see section 4.2.1.

Exposure: Livestock numbers are increasing and thus the exposure to the risk could increase.

Vulnerability: With a big glacier in catchment, Barchidev is expected to be less vulnerable to droughts in the future. The key risk of pasture degradation will most likely increase, except for the potentially newly irrigated areas. Water infrastructure and management is key both for future livelihood diversification and for addressing the key risk of lack of fodder and food production, which is otherwise likely to increase in Ghudara. With only 5% dependence in remittances, Ghudara's livelihoods are particularly vulnerable to environmental shocks including droughts.

4.3 Comprehensive Risk Assessments per village

This section presents Comprehensive Risk Assessment tables per village according to the method described in section 3.2.1. In what follows, the Comprehensive Risk Assessment tables (**Error! Reference source not found.** and **Error! Reference source not found.**) are presented followed by main explanations and justifications on the choices made organised according to the concepts in the rows of the table.

Tables per Village

Risk of loss of livelihoods (income, subsistence) for livestock owners in Barchidev village

	Current situation		**Future (2030-2050)**	
	Pasture degradation (drought/low soil moisture)	Lack of fodder (drought/lack of surface water)	Pasture degradation (drought/soil moisture)	Lack of fodder (drought/lack of surface water)
Hazard	Moderate	Moderate	High	High
Exposure	Moderate	Moderate	Moderate	Moderate

Vulnerability - Exposed systems - Community	Moderate	High	Moderate	High
	Moderate		Moderate	
Risk	Moderate	High	High	High
Confidence of assessment	Moderate		Low	
Critical settings	Critical is the missing / destroyed infrastructure for irrigation that could lead to water shortage for winter fodder production as well as food supply (wheat, vegetables) for the communities. The future exposure depends very much on the number of livestock. If the number of livestock increases, exposure and the pressure to the system will increase.			

Table 5: *Comprehensive Risk Assessment for Barchidev village*

Risk of loss of livelihoods (income, subsistence) for livestock owners in Ghudara village

	Current situation		**Future (2030-2050)**	
	Pasture degradation (drought/low soil moisture)	Lack of fodder (drought/lack of surface water)	Pasture degradation (drought/soil moisture)	Lack of fodder (drought/lack of surface water)
Hazard	Moderate	Moderate	Moderate	Moderate
Exposure	Moderate	Moderate	Moderate	Moderate
Vulnerability - Exposed systems - Community	Moderate	High	Moderate	High
	High		High	
Risk	Moderate	High	High	High
Confidence of assessment	Moderate		Low	
Critical settings	Critical is the missing / destroyed infrastructure for irrigation that could lead to water shortage for winter fodder production as well as food supply (wheat, vegetables) for the communities. The future risk depends very much on the further increase in the number of livestock. As a result, the risk for pasture degradation and lack of fodder for the future could be in all three villages either high or very high.			

Table 6: *Comprehensive Risk Assessment for Ghudara village*

Hazard

In both villages, drought as a current hazard is rated as 'moderate' both for pasture degradation and lack of fodder. In the future, these hazards are expected to be more severe for Barchidev making the future hazards' rates high. Due to the higher altitude, the future hazard situation in Ghudara is still rated as 'moderate'.

Exposure (current situation)

Considering the importance of the livestock for the survival of the communities and the approximately similar ratio livestock/person, exposure is assessed for both Barchidev and Ghudara as 'moderate'. In the future, exposure will probably remain 'moderate' for both villages as for Barchidev livestock numbers seem steady and in Ghudara only a small increase is foreseen.

Vulnerability (current situation)

For the key risk of 'pasture degradation due to drought', vulnerability was assessed based on information on pasture availability, quality and management. Both villages reported limited winter pasture but sufficient summer pasture of good quality, with no signs of overgrazing, no conflicts among villages and respect towards the carrying capacity limits per pasture. Hayfields are limited and in need of irrigation. Because of this, vulnerability is rated as 'moderate' for both villages. In the absence of adaptation actions, but assuming a steady grazing pressure, in the future, vulnerability is expected to remain 'moderate' for both villages.

For the key risk of 'lack of fodder due to drought', vulnerability was assessed based on the existence and quality of water infrastructure as well as the availability of natural resources – especially the missing presence of glacier within the catchment. For the current situation, both villages reported poor water infrastructure and limited arable land and thus vulnerability to lack of fodder and food is assessed as 'high'.

Both Barchidev and Ghudara reported limited arable land and a poor water infrastructure preventing them from achieving self-sufficiency in wheat, vegetables and fodder crops. Thus, vulnerability to the key risk of lack of fodder is assessed as 'high' for both villages. Considering the ongoing adaptation actions in both Barchidev and Ghudara (i.e., building of new water irrigation channels) that are however still uncertain on how they will unfold, we assume that future vulnerability to lack of fodder will remain 'high' for the two villages.

The overall vulnerability of the communities to all the key risks depends not only in the vulnerability of the most directly exposed elements (livestock) but also on the livelihood diversification and quality of life per village. We assume that a higher livelihood diversification reduces the vulnerability of the communities to the risk of loss of livelihoods for all the key risks. We also consider that remittances add to the livelihood diversification. Based on these, Barchidev was found to have higher level of livelihood diversification than Ghudara. Thus, vulnerability is assessed as 'moderate' for Barchidev and 'high' for Ghudara. For the future, we assume the degree of livelihood diversification to remain generally the same.

Risk (current and future situation)

Moving to the overall risk assessment results in the current situation, Barchidev and Ghudara are in 'moderate risk' in terms of pasture degradation and in 'high risk' when it comes to lack of fodder due to drought. For the future, both villages are in 'high risk' for the two key risks. Future risk will depend on the climate development but to a large extent also on socio-economic development and adaptation actions. Here we assumed that no major adaptation actions will be put in place for the Village Districts under consideration, although in sections 4.2.1-4.2.3 we briefly discuss possible evolutions for the future vulnerability situation in the villages.

Confidence

For the current situation, given the fact that the impact of rising temperatures and droughts linked to water shortage are already evident and relevant today, confidence is assessed as 'moderate'. For the future, confidence is assessed as 'low', considering the high complexity of the climate evolution and impact over the Pamir mountains, and uncertain development trends in the area.

Critical settings

Critical is the missing / destroyed infrastructure for irrigation that could lead to water shortage for winter fodder production as well as food supply (wheat, vegetables) for the communities. Although beyond the scope of this climate risk assessment, we should mention here that further work is needed in order to consider a more fine-grained, socially differentiated vulnerability to climate risks going beyond the community level. Previous research suggests that in the Pamirs, patterns of livestock mobility may differ according to the socioeconomic situation of households: 'Usually the larger the herd and the richer the household, the greater the distance between winter quarters and summer pastures' (Ludi, 2003: 121). This limited mobility of the poor households might signal an increased vulnerability to the key risk of pasture degradation. Within a general situation of poverty and food insecurity, the 'poor' and 'rich' households should be probably characterized as 'poor' and 'better-off'. Despite the probably limited inequalities in the area, research has shown that in the Western Pamirs these two different groups have different adaptive capacities and vulnerabilities to the risks under consideration (FES NET, 2011). Finally, women in the Pamirs have historically played an important role in the mix-mountain agriculture and are still responsible for the bulk of farming activities, including irrigation (Bossenbroek, and Zwarteveen, 2014). Male migration (mostly to Russia) implies an increased involvement of women in the livelihoods under study and thus a high exposure to climate risks. Further research is needed to understand the vulnerabilities but also adaptations to climate change of women and female headed-households (11% of the households in the Suvnob Jamoat, where Barchidev and Ghudara belong, are female-headed[13]) in the Pamirs.

[13] http://untj.org/jambi-project/index.php/maps-statistics/demography

5 Assessment of main climate risks for the Village Districts in Kyrgyzstan

This chapter presents the current climate and climate scenarios for the Kyrgyzstan project region, and the results of the climate risk assessment for the Village Districts of the community consultations.

5.1 Current climate and climate scenarios

5.1.1 National climate assessment

At national level, Kyrgyzstan experiences an extremely continental and arid climate with remarkable spatial heterogeneities due to its complex mountainous terrain. Temperature values range from -30°C to 5°C in winter and from -20°C to +25°C in summer with milder values in the inner lowlands especially in the northernmost part of the country (Figure 38: 1981-2010 seasonal climatologies of a) mean temperature and b) total precipitation for Kyrgyzstan. The maps are based on the 1-km downscaled ERA5 reanalysis from CHELSA database.

a). Precipitation distribution is largely heterogenous with the wettest conditions over Kungey Alatau in the North and over the Fergana Valley in the Central-West where mean yearly precipitation totals reach 2,500mm. The greatest precipitation amounts occur in spring and summer while autumn and winter are characterized by very dry conditions, especially in the north-eastern part of the country where total precipitation for the winter season is less than 100mm (Figure 38: 1981-2010 seasonal climatologies of a) mean temperature and b) total precipitation for Kyrgyzstan. The maps are based on the 1-km downscaled ERA5 reanalysis from CHELSA database.

b).

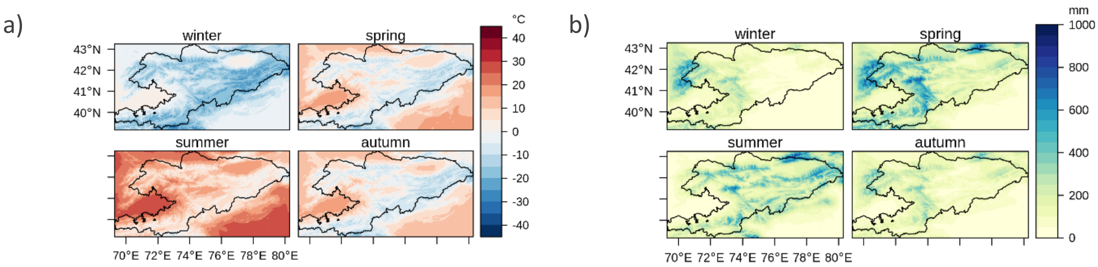

Figure 38: 1981-2010 seasonal climatologies of a) mean temperature and b) total precipitation for Kyrgyzstan. The maps are based on the 1-km downscaled ERA5 reanalysis from CHELSA database.

At national level, a statistically significant increase was observed for temperature values from the CRU dataset over recent decades (1951-2010) at both annual and seasonal scale with a greater positive trend in spring and, secondary, in winter. The regional time series of annual precipitation shows a great interannual variability and a weak wetting tendency even without statistical significance. No well-defined trend emerges for the seasonal amounts, even though they mostly exhibit not significant wetting tendencies. It is worth noting that a large uncertainty needs to be assigned to these findings due to the high interannual variability of precipitation and the difficulty to fully capture the actual spatial heterogeneity from available datasets. The findings are largely in agreement with previous local studies and assessments (Ilyasov et al., 2013).

The temporal evolution of temperature in Kyrgyzstan over the recent past was found mostly to continue in the future, based on the CMIP6 ensemble projections for two different scenarios (Figure 39: *Boxplots of the seasonal changes in near (2011-2040) and middle (2041-2070) future for a) mean temperature and b) precipitation under SSP2-4.5 (green) and SSP5-8.5 (orange). Values represents the areal averages over Kyrgyzstan. Seasons are defined as follows: March, April and May for spring (MAM), June, July and August for summer (JJA), September, October and November for autumn (SON), December, January and February for winter (DJF). The lower and upper hinges correspond to the interquartile range (IQR, 25th-75th percentiles) of the CMIP6 ensemble. The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from the hinge. The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. Values outside this range are considered outliers and reported individually.*). A further warming is expected under both scenarios, especially in summer and autumn. The future signal for precipitation is less clear, however a tendency towards increasing precipitation in winter is reported, especially in the second half of the century. In terms of spatial distribution, the annual temperatures are projected to increase by around 2-3°C in middle future throughout the country (Figure 40: *Distribution of changes in a) mean annual temperature and b) annual precipitation in near (top) and middle future (bottom) with respect to 1981-2010 under the SSP2-4.5 scenario. The results are reported for the 25th and 75th percentiles of the CMIP6 model ensemble on a 0.5°x0.5° grid.*

a). Projected changes of precipitation show a greater variability and the range of changes depicted by the model ensemble is rather broad. However, an increase of annual precipitation, especially in the middle future, is mostly reported by the available models all over Kyrgyzstan (Figure 40: *Distribution of changes in a) mean annual temperature and b) annual precipitation in near (top) and middle future (bottom) with respect to 1981-2010 under the SSP2-4.5 scenario. The results are reported for the 25th and 75th percentiles of the CMIP6 model ensemble on a 0.5°x0.5° grid.*

b).

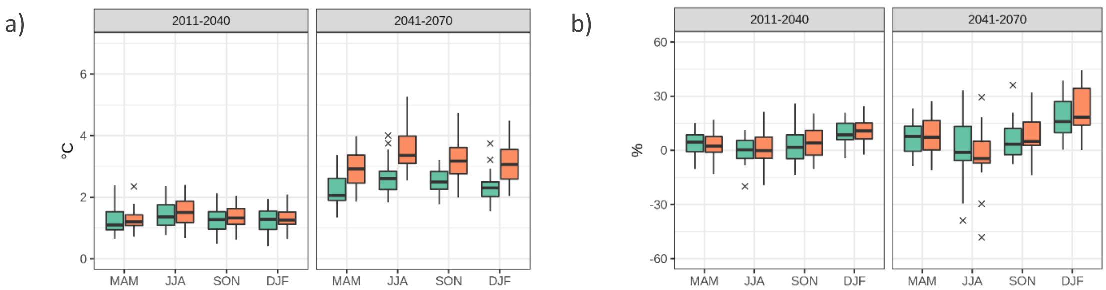

Figure 39: *Boxplots of the seasonal changes in near (2011-2040) and middle (2041-2070) future for a) mean temperature and b) precipitation under SSP2-4.5 (green) and SSP5-8.5 (orange). Values represents the areal averages over Kyrgyzstan. Seasons are defined as follows: March, April and May for spring (MAM), June, July and August for summer (JJA), September, October and November for autumn (SON), December, January and February for winter (DJF). The lower and upper hinges correspond to the interquartile range (IQR, 25th-75th percentiles) of the CMIP6 ensemble. The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from the hinge. The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. Values outside this range are considered outliers and reported individually.*

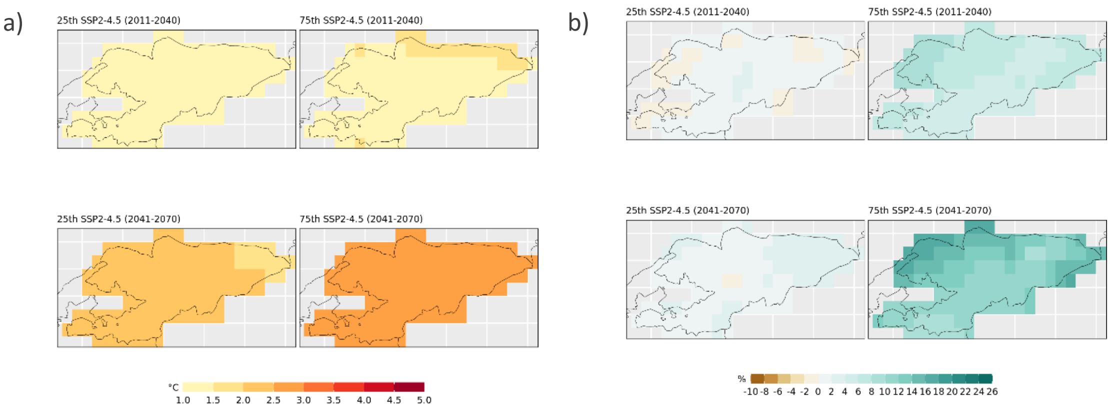

Figure 40: *Distribution of changes in a) mean annual temperature and b) annual precipitation in near (top) and middle future (bottom) with respect to 1981-2010 under the SSP2-4.5 scenario. The results are reported for the 25th and 75th percentiles of the CMIP6 model ensemble on a 0.5°x0.5° grid.*

Besides mean temperature, also extreme heat conditions are projected to increase over the country. The number of days per year characterized by heat wave conditions as well as the total number of heat wave events are expected to increase under both scenarios, especially in the second half of the century. In particular, by 2100 more than 50 days per year will be affected by extreme heat conditions if the ensemble median under the worst emission scenario is considered. Under SSP2-4.5, the increase of heat wave days and events per year is more limited and the indices remain within 20 days and 3 events per year, respectively (Figure 41: *Annual regional time series of a) heat wave days and b) heat wave events in Kyrgyzstan based on CMIP6 ensemble projections under SSP2-4.5 (blue) and SSP5-8.5 (red). The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble.*

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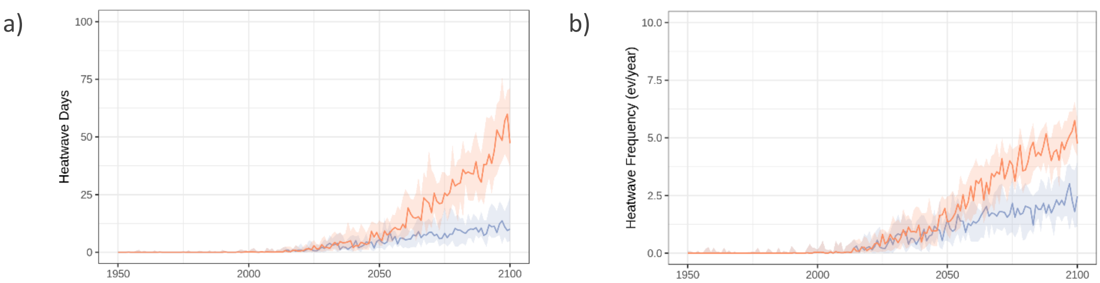


Figure 41: *Annual regional time series of a) heat wave days and b) heat wave events in Kyrgyzstan based on CMIP6 ensemble projections under SSP2-4.5 (blue) and SSP5-8.5 (red). The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble.*

The annual totals of intense precipitation are also projected to increase by the end of the century under both scenarios, especially under SSP5-8.5 with an increase in total intense precipitation values of more than 50% by 2100 as median of the model ensemble (**Error! Reference source not found.**). The projected increment of intense precipitation is in agreement with the overall wetting tendencies projected for the country in the next decades.

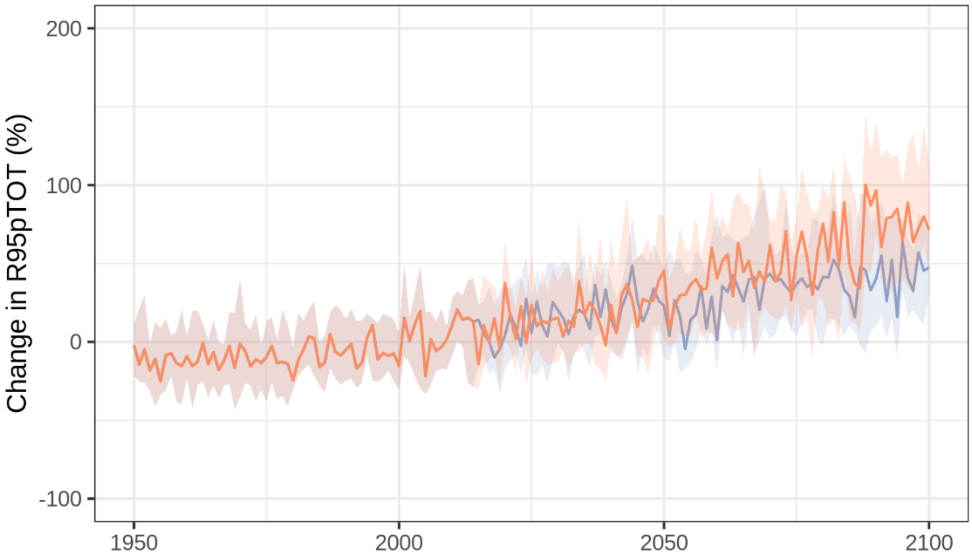


Figure 42: Annual time series of relative changes in intense precipitation totals (R95pTOT) for Kyrgyzstan from CMIP6 projections under SSP2-4.5 (blue) and SSP5-8.5 (red). The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble.

Wet and dry conditions reported by SPI values further confirm the outcomes from the precipitation analysis with a statistically significant increase of wet conditions for yearly totals (i.e., 12-month cumulated values in December) and over 3-month cumulated precipitation in spring, autumn and winter under both scenarios (results not shown). By performing the same assessment over SPEI values, the contribution of rising temperature plays a crucial role, and all trends are significant with projected drier conditions in spring, summer and autumn and wetter conditions in winter and on annual basis only (Figure 43: Regional time series of SPEI for Kyrgyzstan for yearly (SPEI-12 in December) and seasonal scales (SPEI-3 in May for spring, August for summer, November for autumn and February for winter) based on CMIP6 projections under SSP2-4.5 (blue) and SSP5-8.5 (red). The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble.

). The drying tendencies are slightly less pronounced than those for Tajikistan.

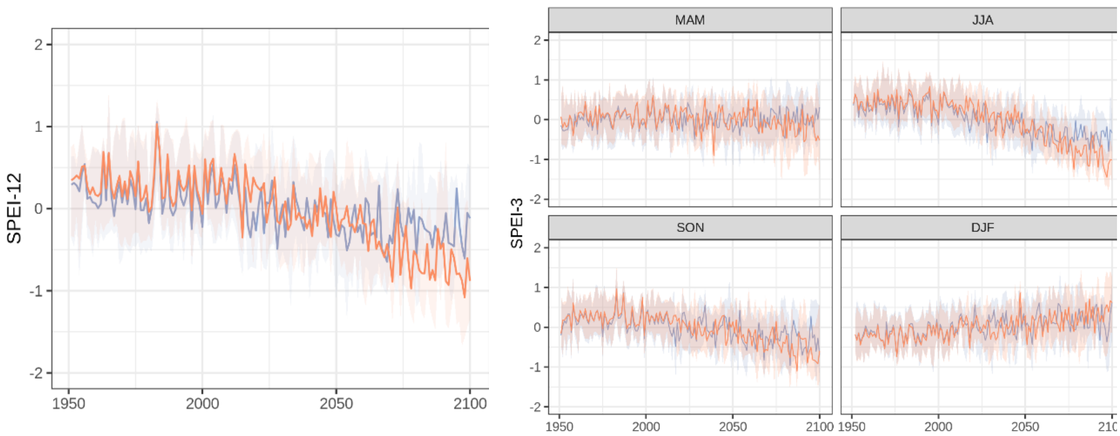
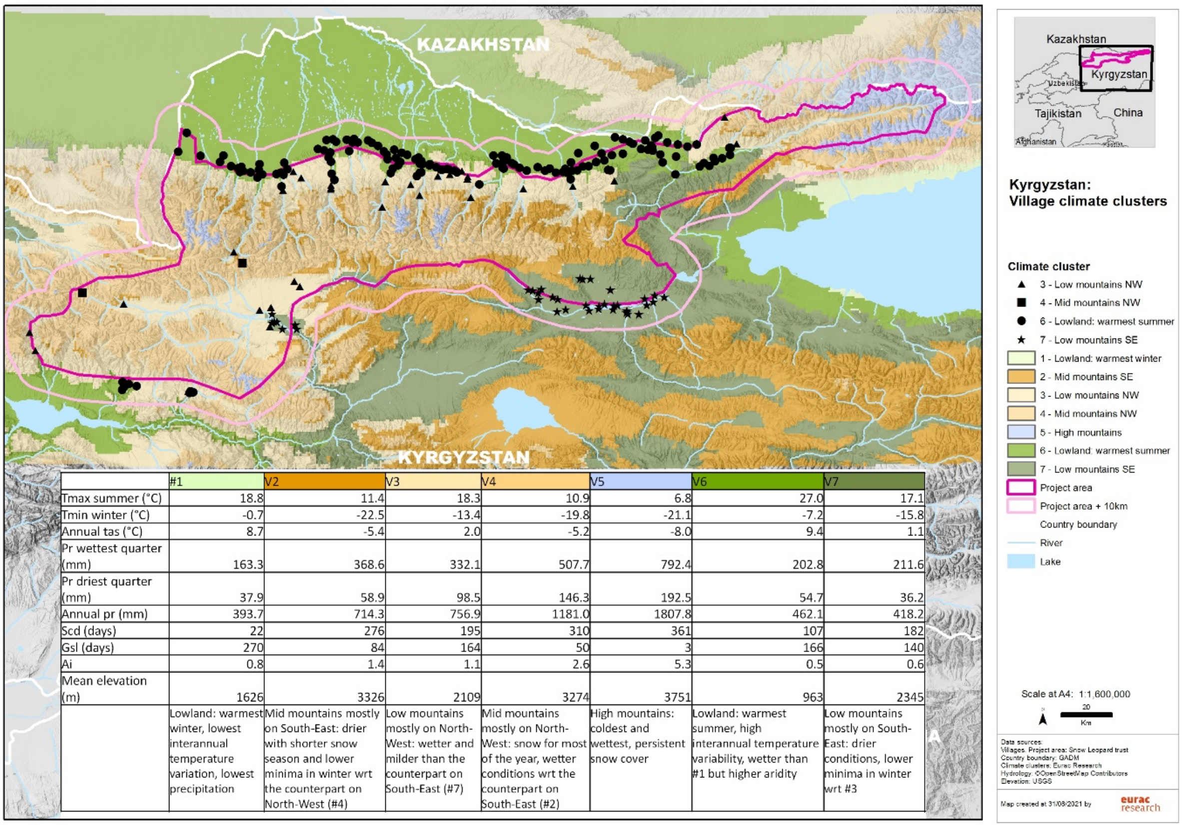


Figure 43: Regional time series of SPEI for Kyrgyzstan for yearly (SPEI-12 in December) and seasonal scales (SPEI-3 in May for spring, August for summer,

November for autumn and February for winter) based on CMIP6 projections under SSP2-4.5 (blue) and SSP5-8.5 (red). The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble.

5.1.2 Local climate assessment

Based on the cluster analysis performed on the 1981-2010 climatologies of the selected set of climate variables, seven main climate regions were identified for the project region in Kyrgyzstan which reflect the geographic heterogeneity of the country (**Error! Reference source not found.**). Besides the mild area closer to Lake Issyk-Kul, South-East and North-West were split into three main elevation ranges (low, middle and high elevation), but with drier and colder conditions in the South-East.



	#1	V2	V3	V4	V5	V6	V7
Tmax summer (°C)	18.8	11.4	18.3	10.9	6.8	27.0	17.1
Tmin winter (°C)	-0.7	-22.5	-13.4	-19.8	-21.1	-7.2	-15.8
Annual tas (°C)	8.7	-5.4	2.0	-5.2	-8.0	9.4	1.1
Pr wettest quarter (mm)	163.3	368.6	332.1	507.7	792.4	202.8	211.6
Pr driest quarter (mm)	37.9	58.9	98.5	146.3	192.5	54.7	36.2
Annual pr (mm)	393.7	714.3	756.9	1181.0	1807.8	462.1	418.2
Scd (days)	22	276	195	310	361	107	182
Gsl (days)	270	84	164	50	3	166	140
Ai	0.8	1.4	1.1	2.6	5.3	0.5	0.6
Mean elevation (m)	1626	3326	2109	3274	3751	963	2345
	Lowland: warmest winter, lowest interannual temperature variation, lowest precipitation	Mid mountains mostly on South-East: drier with shorter snow season and lower minima in winter wrt the counterpart on North-West (#4)	Low mountains mostly on North-West: wetter and milder than the counterpart on South-East (#7)	Mid mountains mostly on North-West: snow for most of the year, wetter conditions wrt the counterpart on South-East (#2)	High mountains: coldest and wettest, persistent snow cover	Lowland: warmest summer, high interannual temperature variability, wetter than #1 but higher aridity	Low mountains mostly on South-East: drier conditions, lower minima in winter wrt #3

Figure 44: Climate clusters for Kyrgyzstan are displayed together with the mean values for each cluster of climate indicators used for the classification. Mean elevation was not used as input of the cluster analysis but only used for the region characterization.

All classes experience similar temperature and precipitation annual cycles even though with different absolute values (Figure 45: Mean annual cycles of a) mean temperature and b) precipitation for the climate classes in Kyrgyzstan. 1 – lowland warmest winter; 2 – Mid mountains SE; 3 – Low mountains NW; 4 – Mid mountains NW; 5 – High mountains; 6 – lowland warmest summer; 7 – Low mountains SE.

). It is worth noting that, even for the high mountains, mean temperature in summer is above 0°C. Most villages are located in the lowland and low-mountain classes, especially in the northern lower elevation area where warmer but rather dry conditions occur and, thus, they might be more prone to drought spells, especially with further increasing temperatures.

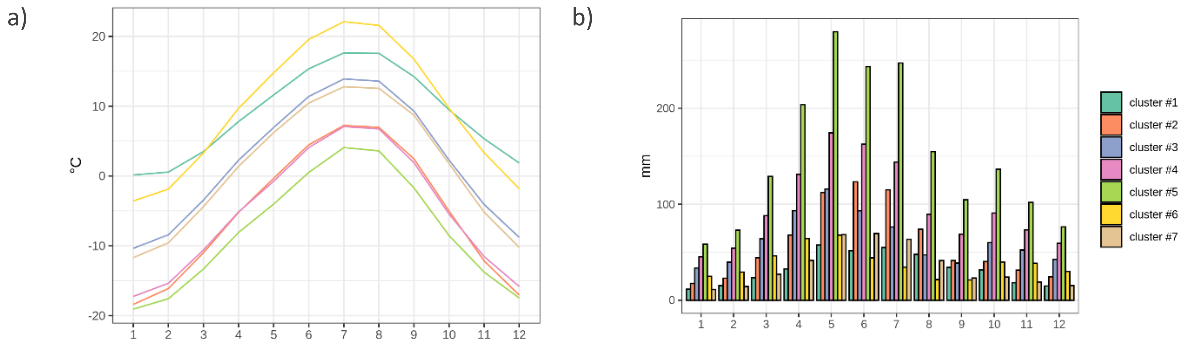


Figure 45: Mean annual cycles of a) mean temperature and b) precipitation for the climate classes in Kyrgyzstan. 1 – lowland warmest winter; 2 – Mid mountains SE; 3 – Low mountains NW; 4 – Mid mountains NW; 5 – High mountains; 6 – lowland warmest summer; 7 – Low mountains SE.

In order to evaluate the expected changes in local climate conditions in the future, CMIP6 projections until 2100 were aggregated by averaging the modelled temperature and precipitation values over the case study area. The warming trend is projected to increase on annual and seasonal scale and all increases turned out to be statistically significant. As for Tajikistan, the greatest warming is expected in summer and autumn (Figure 46: CMIP6 projections under SSP2-4.5 of mean annual and seasonal temperature anomalies for the case study area in Kyrgyzstan. The anomalies are defined as annual differences with respect to the baseline 1981-2010. The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble. Historical simulations are reported in grey.). Projected changes in precipitation are less evident and the spread of the model ensemble is larger than for temperature. However, if the ensemble median is considered, statistically significant increases in all cases except for summer are depicted over the entire period, with increases per decade of around +1.2% (year), +1.4% (spring), +0.8% (autumn) and +2.4% (winter) with respect to the 1981-2010 baseline (Figure 47: CMIP6 projections under SSP2-4.5 of annual and seasonal precipitation anomalies for the case study area in Kyrgyzstan. The anomalies are defined as annual relative differences with respect to the baseline 1981-2010. The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble. Historical simulations are reported in grey.

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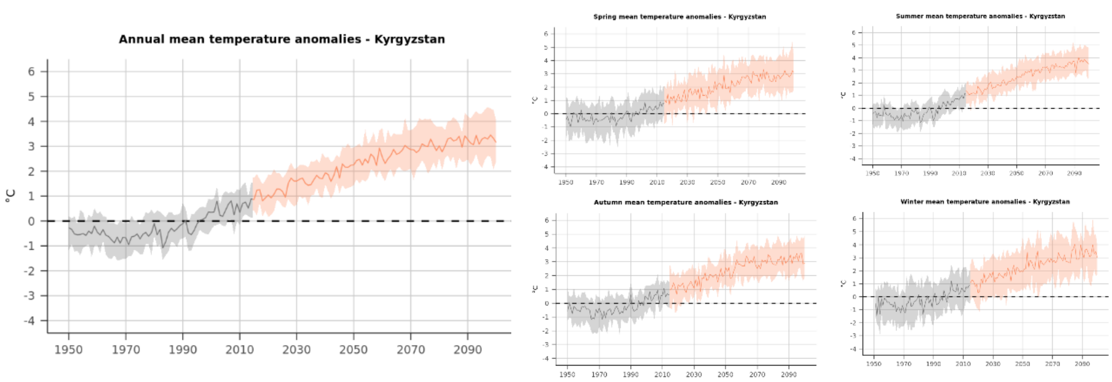

Figure 46: CMIP6 projections under SSP2-4.5 of mean annual and seasonal temperature anomalies for the case study area in Kyrgyzstan. The anomalies are defined as annual differences with respect to the baseline 1981-2010. The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble. Historical simulations are reported in grey.

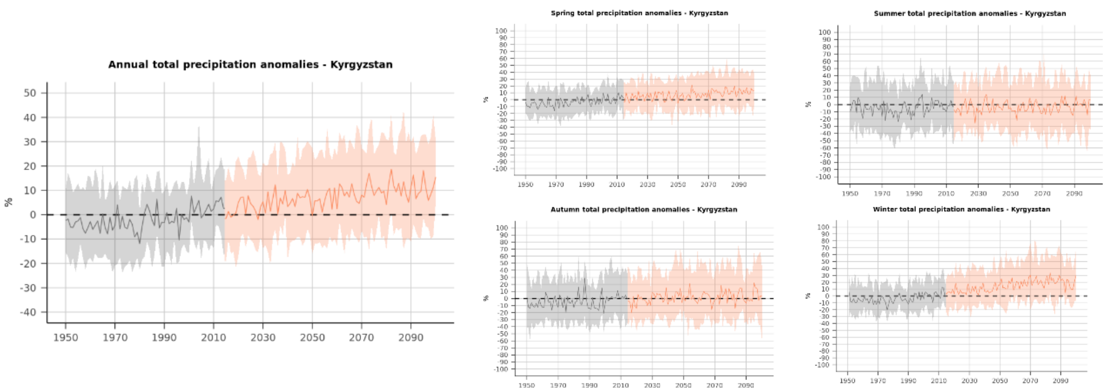

Figure 47: CMIP6 projections under SSP2-4.5 of annual and seasonal precipitation anomalies for the case study area in Kyrgyzstan. The anomalies are defined as annual relative differences with respect to the baseline 1981-2010. The solid line represents the ensemble median while the shaded area extends from the 25th to the 75th percentile of the ensemble. Historical simulations are reported in grey.

The spatial distribution of future changes was evaluated by means of the 1-km downscaled CMIP6 projections from CHELSA database. In particular, the changes in 30-year mean climate in near (2011-2040) and middle (2041-2070) future with respect to the baseline 1981-2010 were considered.

Temperature changes are homogenously distributed over the case study area in all cases, with the greatest warming in summer and autumn in middle future throughout the domain (Figure 48: Seasonal changes of mean temperature in a) near (2011-2040) and b) middle (2041-2070) future with respect to the baseline (1981-2010) based on the model ensemble of downscaled CMIP6 projections at 1-km resolution.

and **Error! Reference source not found.**). The precipitation changes show a greater spatial variability (Figure 50: Seasonal absolute changes of precipitation in a) near (2011-2040) and b) middle (2041-2070) future with respect to the baseline (1981-2010) based on the model ensemble of downscaled CMIP6 projections at 1-km resolution.

and **Error! Reference source not found.**). They confirm the projected increases of spring, winter and annual precipitation with the greatest increments in absolute terms in the western mountainous portion of the domain. Decreases in summer and autumn precipitation are shown, mainly in the north-western part of the project region. The negative changes for autumn precipitation values are not in agreement with the wetting trend derived from the projected time series over the area, which might be due to the different models included in the two ensembles as well as to the less remarkable trend for autumn with respect to the other seasons.

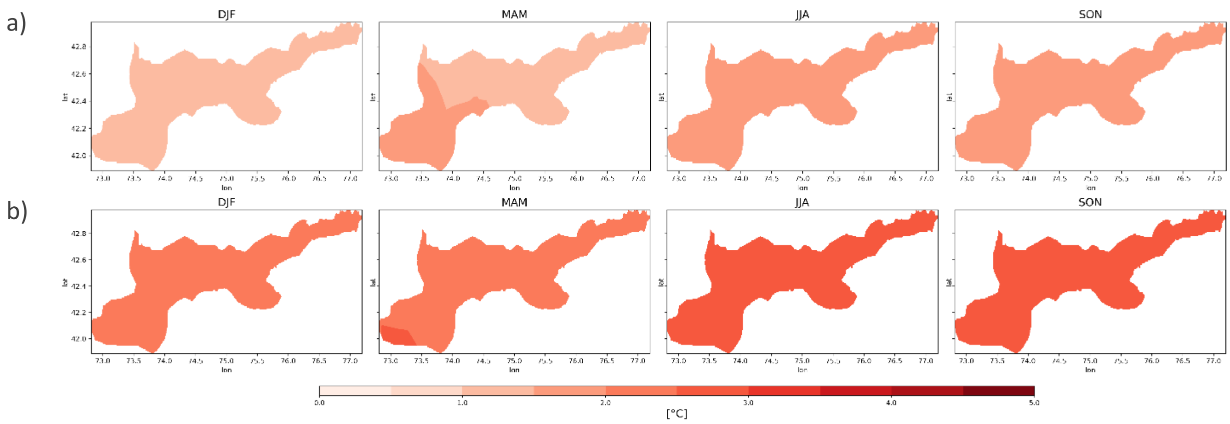

Figure 48: Seasonal changes of mean temperature in a) near (2011-2040) and b) middle (2041-2070) future with respect to the baseline (1981-2010) based on the model ensemble of downscaled CMIP6 projections at 1-km resolution.

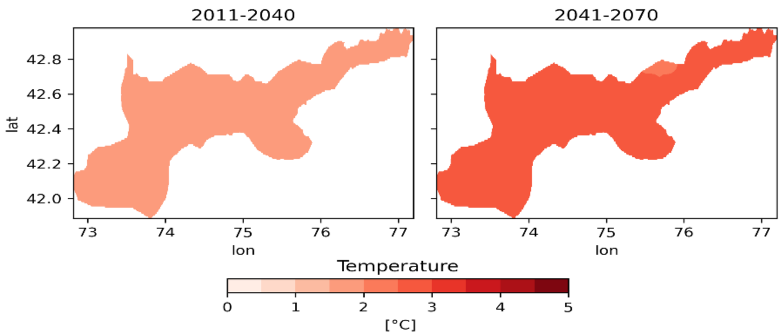

Figure 49: Annual changes of mean temperature in near (2011-2040) and middle (2041-2070) future with respect to the baseline (1981-2010) based on the model ensemble of downscaled CMIP6 projections at 1-km resolution.

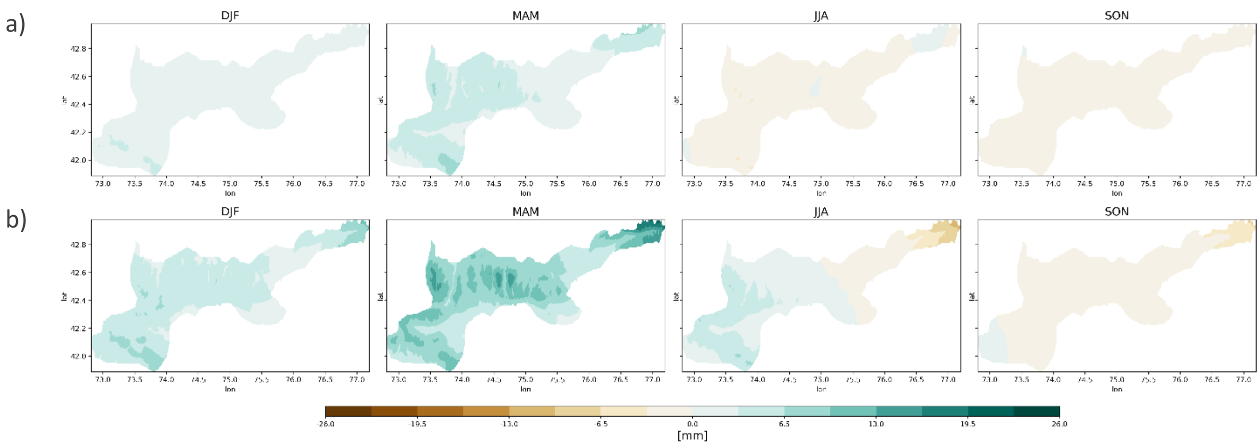

Figure 50: Seasonal absolute changes of precipitation in a) near (2011-2040) and b) middle (2041-2070) future with respect to the baseline (1981-2010) based on the model ensemble of downscaled CMIP6 projections at 1-km resolution.

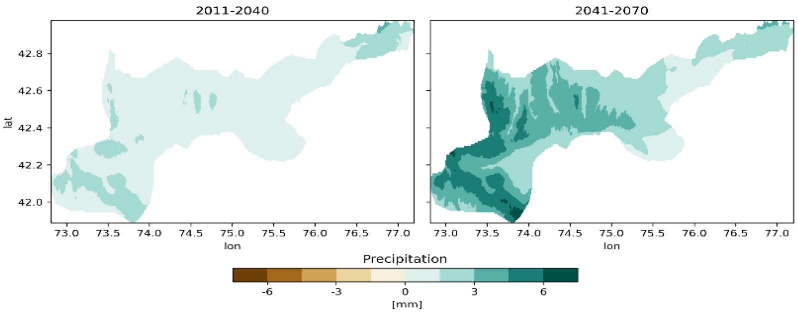

Figure 51: Annual absolute changes of precipitation in near (2011-2040) and middle (2041-2070) future with respect to the baseline (1981-2010) based on the model ensemble of downscaled CMIP6 projections at 1-km resolution.

5.1.3 Focus analysis on heat and drought

SPI-3 monthly time series did not depict any significant trend over the reviewed period at both national and case study scale (Figure 52: SPI-3 monthly regional series for a) Kyrgyzstan and b) the case study area. Anomalous wet and dry conditions are coloured in blue and red, respectively.). This coincides with the results of the trend analysis of historical precipitation record for the country, as shown in the previous sections. High temporal variability is observed, especially at the national scale. Several episodes of extremely dry conditions with effects of persistent droughts are detected in 1973-1890 and 2010-2015 (Figure 52: SPI-3 monthly regional series for a) Kyrgyzstan and b) the case study area. Anomalous wet and dry conditions are coloured in blue and red, respectively. and Table 7: Onset, duration, severity and magnitude of drought spells in Kyrgyzstan caste study region based on SPI (left-hand columns) and SPEI (right-hand columns).

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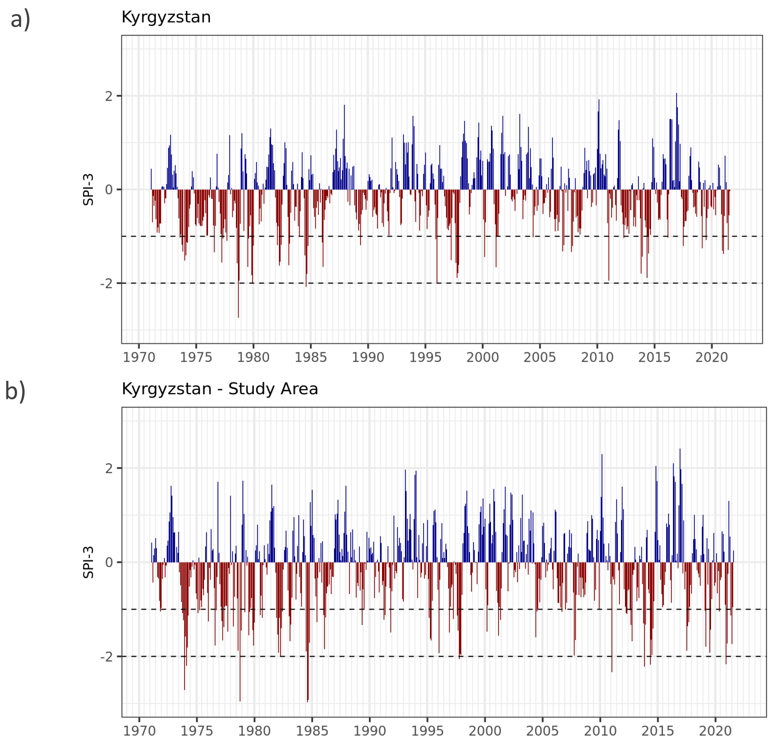

Figure 52: SPI-3 monthly regional series for a) Kyrgyzstan and b) the case study area. Anomalous wet and dry conditions are coloured in blue and red, respectively.

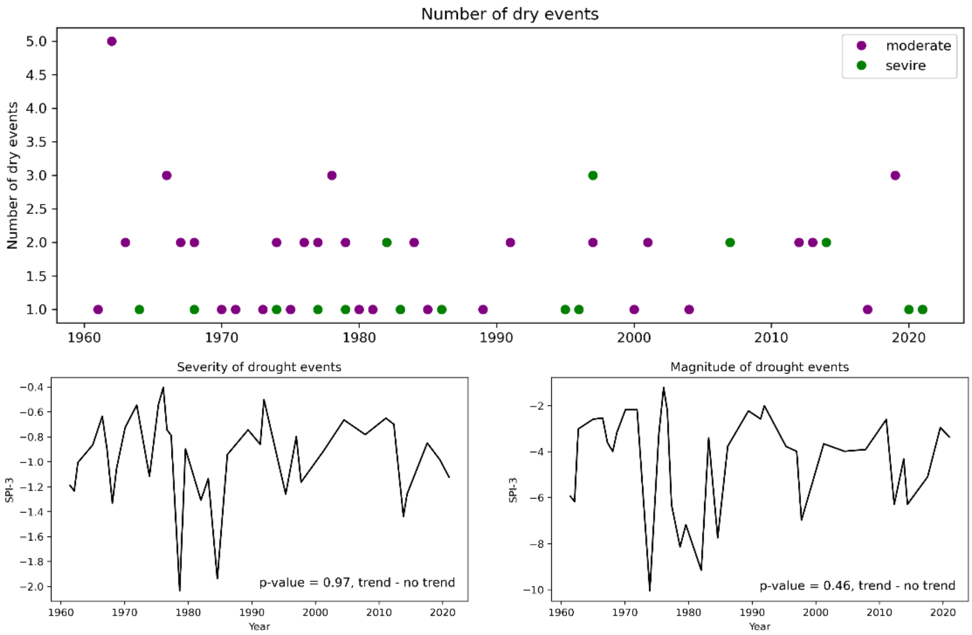

Figure 53: Annual count of dry events (top), severity (bottom left) and magnitude (bottom right) of drought spells derived from the mean SPI-3 series for the case study area.

The interannual variability in magnitude and severity of drought spells is relevant, therefore it is very difficult to detect any major shifts in drought behaviour. However, it can be noted that the year 1973 is exceptional due to the highest magnitude of the drought spells, that exceeds by a factor all the previous and subsequent events (Table 7: Onset, duration, severity and magnitude of drought spells in Kyrgyzstan caste study region based on SPI (left-hand columns) and SPEI (right-hand columns).

and Figure 53: Annual count of dry events (top), severity (bottom left) and magnitude (bottom right) of drought spells derived from the mean SPI-3 series for the case study area.

). According to the analysis based on both SPI and SPEI, droughts were found to mostly occur in February (Figure 54: Number of moderate dry events/severe dry events/ droughts per month from a) SPI-3 and b) SPEI-3 for the case study area.

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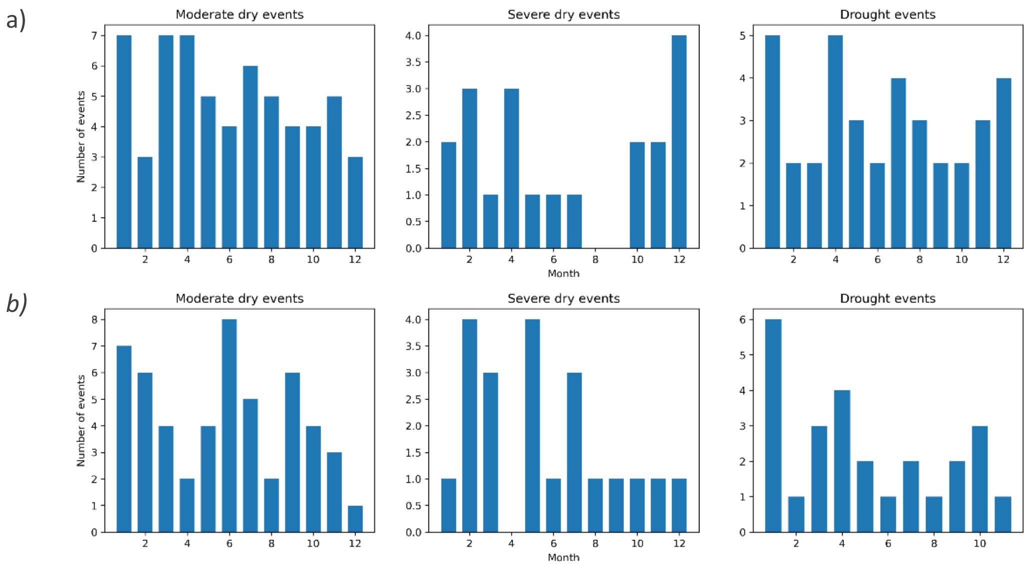

Figure 54: Number of moderate dry events/severe dry events/ droughts per month from a) SPI-3 and b) SPEI-3 for the case study area.

As in Tajikistan case, the inclusion of temperature contribution was important in order to better account for the role of evapotranspiration in determining drought conditions.

Extreme heat conditions have been quantified by the number of hot days per year, which revealed a significant increase in the occurrence of both moderate (above 90th percentile) and severe (above 98th percentile) conditions (**Error! Reference source not found.**).

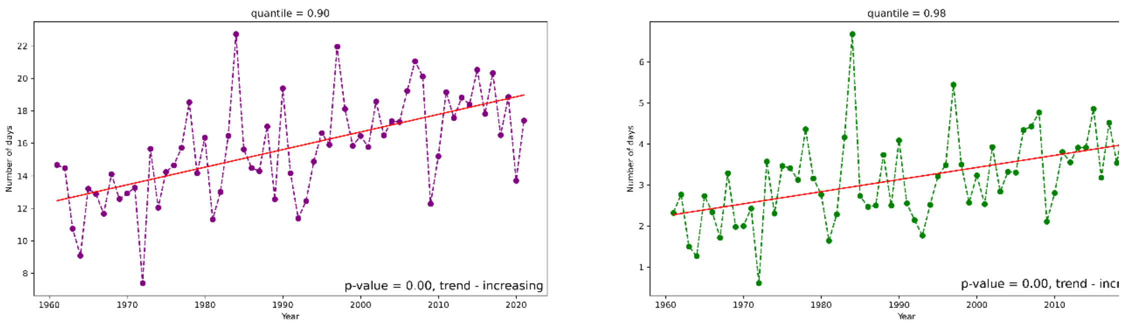

Figure 55: Annual count of days when maximum temperature exceed threshold of 90th (left-hand plot) and 98th (right-hand plot) percentile. The linear fit (black solid line) reports the statistically significant trend.

The relevance of temperature has an effect on the drought occurrences, so that drier conditions in the recent decades, especially since the late ‘90s (Figure 56: SPEI-3 monthly regional series for a) Kyrgyzstan and b) the case study area. Anomalous wet and dry conditions are coloured in blue and red, respectively.) were revealed. As also evident from the SPEI-3 monthly series (Figure 56: SPEI-3 monthly regional series for a) Kyrgyzstan and b) the case study area. Anomalous wet and dry conditions are coloured in blue and red, respectively.), the years 1997 and 2007 were characterized by the most severe drought spells at both national and project region scale (Figure 57: Annual count of dry events (top), severity (bottom left) and magnitude (bottom right) of drought spells derived from the mean SPEI-3 series for the project region area.

). However, no significant trend towards more frequent and severe drought events was observed.

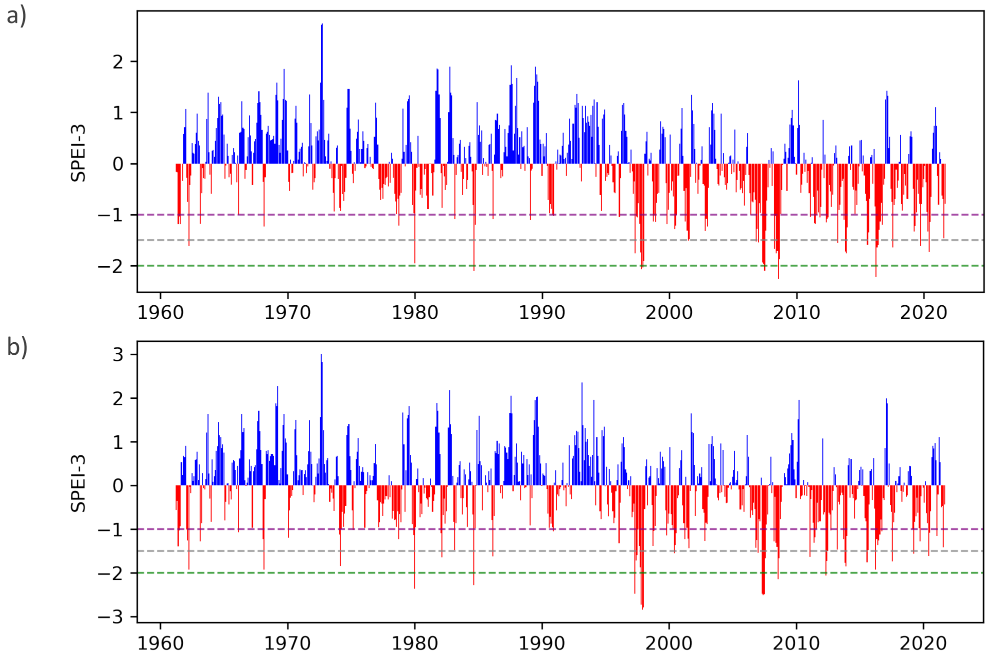

Figure 56: SPEI-3 monthly regional series for a) Kyrgyzstan and b) the case study area. Anomalous wet and dry conditions are coloured in blue and red, respectively.

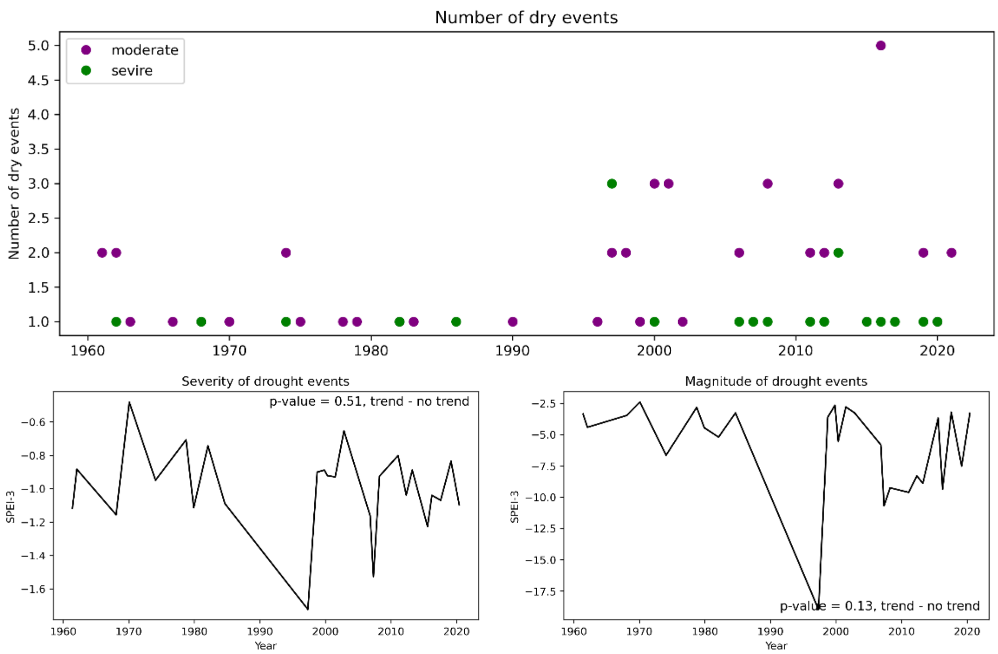

Figure 57: Annual count of dry events (top), severity (bottom left) and magnitude (bottom right) of drought spells derived from the mean SPEI-3 series for the project region area.

The temporal variability of dry and wet conditions was analysed by extracting SPEI-3 values in February for winter, May for spring, August for summer and November for autumn. Except for winter, all the seasons, especially summer, show statistically significant decreases of SPEI-3 values, thus trends towards drier conditions (**Error! Reference source not found.**), which coincide with the behaviour in Tajikistan case study area.

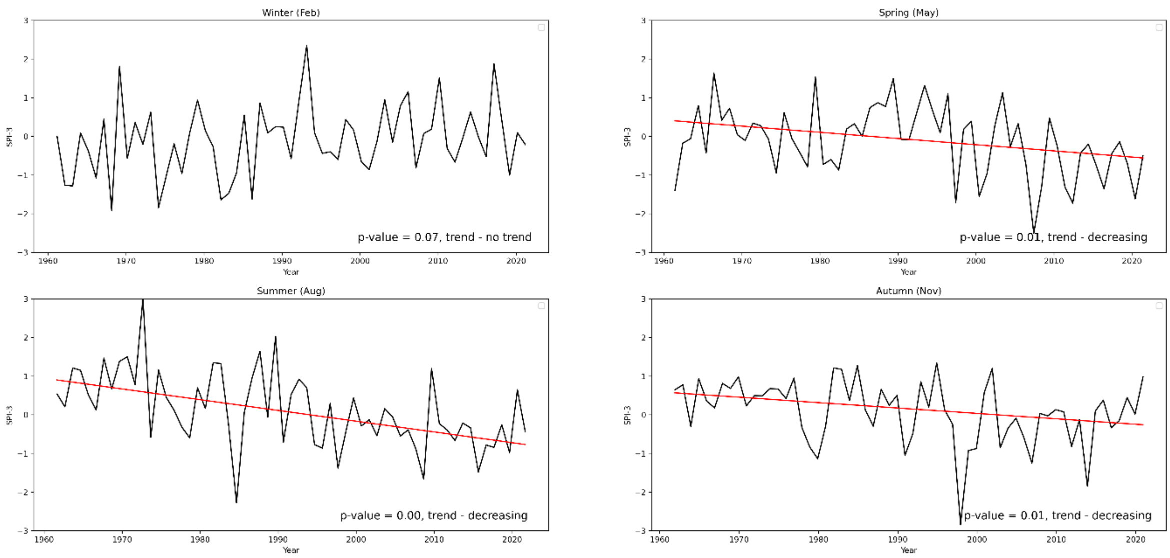

Figure 58: Seasonal variability in SPEI index. Since index has been computed at 3-month accumulation scales, thus February represents winter, May – spring, August – summer, and November – autumn.

Based on both SPI and SPEI analyses, recent years, and especially 2021, are not exceptional in terms of severe drought events (Table 7: Onset, duration, severity and magnitude of drought spells in Kyrgyzstan caste study region based on SPI (left-hand columns) and SPEI (right-hand columns).

Table 7: Onset, duration, severity and magnitude of drought spells in Kyrgyzstan caste study region based on SPI (left-hand columns) and SPEI (right-hand columns).

), which is not fully in agreement with the information reported by the local analyses and perception.

SPI						***SPEI***					
N	*Start date*	*End date*	*Duration (month)*	*Severity*	*Magnitude*	*N*	*Start date*	*End date*	*Duration (month)*	*Severity*	*Magnitude*
1	*31.05.61*	*30.09.61*	*5*	*-1.2*	*-5.9*	*1*	*31.05.61*	*31.07.61*	*3*	*-1.1*	*-3.4*
2	*31.01.62*	*31.05.62*	*5*	*-1.2*	*-6.2*	*2*	*31.01.62*	*31.05.62*	*5*	*-0.9*	*-4.4*
3	*31.08.62*	*31.10.62*	*3*	*-1*	*-3*	*3*	*31.01.68*	*31.03.68*	*3*	*-1.2*	*-3.5*

4	31.12.64	28.02.65	3	-0.9	-2.6	4	31.01.70	31.05.70	5	-0.5	-2.4
5	30.06.66	30.09.66	4	-0.6	-2.5	5	31.01.74	31.07.74	7	-0.9	-6.6
6	31.03.67	30.06.67	4	-0.9	-3.6	6	30.09.78	31.12.78	4	-0.7	-2.8
7	31.01.68	31.03.68	3	-1.3	-4	7	30.11.79	31.01.80	4	-1.1	-4.5
8	30.09.68	30.11.68	3	-1.1	-3.2	8	31.01.82	31.07.82	7	-0.7	-5.2
9	31.01.70	31.03.70	3	-0.7	-2.2	9	31.08.84	31.10.84	3	-1.1	-3.3
10	30.11.71	29.02.72	4	-0.5	-2.2	10	30.04.97	31.01.98	11	-1.7	-19
11	30.11.73	31.07.74	9	-1.1	-10.1	11	30.09.98	31.12.98	4	-0.9	-3.6
12	30.04.75	30.09.75	6	-0.5	-3.2	12	31.10.99	31.12.99	3	-0.9	-2.7
13	31.01.76	31.03.76	3	-0.4	-1.2	13	30.04.00	30.09.00	6	-0.9	-5.5
14	31.08.76	31.10.76	3	-0.7	-2.2	14	30.06.01	31.08.01	3	-0.9	-2.8
15	30.04.77	30.11.77	8	-0.8	-6.3	15	31.10.02	31.01.03	5	-0.7	-3.3
16	31.08.78	30.11.78	4	-2	-8.1	16	31.10.06	28.02.07	5	-1.2	-5.8
17	31.07.79	31.01.80	8	-0.9	-7.2	17	30.04.07	31.10.07	7	-1.5	-10.7
18	31.12.81	30.06.82	7	-1.3	-9.2	18	31.03.08	31.12.08	10	-0.9	-9.3
19	28.02.83	30.04.83	3	-1.1	-3.4	19	31.01.11	31.12.11	12	-0.8	-9.6
20	31.07.84	31.10.84	4	-1.9	-7.7	20	30.04.12	30.11.12	8	-1	-8.3
21	28.02.86	31.05.86	4	-0.9	-3.8	21	31.03.13	31.12.13	10	-0.9	-8.9
22	31.05.89	31.07.89	3	-0.7	-2.2	22	31.07.15	30.09.15	3	-1.2	-3.7
23	30.04.91	30.06.91	3	-0.9	-2.6	23	31.03.16	30.11.16	9	-1	-9.4
24	30.11.91	31.01.92	4	-0.5	-2	24	31.07.17	30.09.17	3	-1.1	-3.2
25	30.04.95	30.06.95	3	-1.3	-3.8	25	28.02.19	31.10.19	9	-0.8	-7.5
26	31.12.96	30.04.97	5	-0.8	-4	26	31.05.20	31.07.20	3	-1.1	-3.3
27	30.09.97	31.01.98	6	-1.2	-7						
28	31.03.01	30.06.01	4	-0.9	-3.7						
29	30.06.04	30.11.04	6	-0.7	-4						
30	31.10.07	31.01.08	5	-0.8	-3.9						
31	31.01.11	30.04.11	4	-0.7	-2.6						
32	30.04.12	31.12.12	9	-0.7	-6.3						
33	31.10.13	31.12.13	3	-1.4	-4.3						
34	31.05.14	30.09.14	5	-1.3	-6.3						

35	*31.07.17*	*31.12.17*	*6*	*-0.8*	*-5.1*							
36	*31.07.19*	*30.09.19*	*3*	*-1*	*-3*							
37	*31.12.20*	*28.02.21*	*3*	*-1.1*	*-3.4*							

Table 7: Onset, duration, severity and magnitude of drought spells in Kyrgyzstan caste study region based on SPI (left-hand columns) and SPEI (right-hand columns).

5.1.4 Snow cover changes

Error! Reference source not found. shows the trend in snow cover extent for the time period 2000 to 2020 for the project area in Kyrgyzstan. For most of the project area the snow cover trend is negative (~76% of the project area). Especially in the northern part the analysis shows a significant negative trend (18% of the areas with a negative trend). It is only in the southern part where the analysis showed a positive trend in snow cover (~19% of the project area). Less than 1% of the areas with a positive trend are significant. For approximately 5% of the study area no snow cover trend could be calculated as for those areas the satellite imagery used to calculate the changes was not available for all 20 years. See section 3.1.4 Snow cover changes for details on how the analysis was conducted.

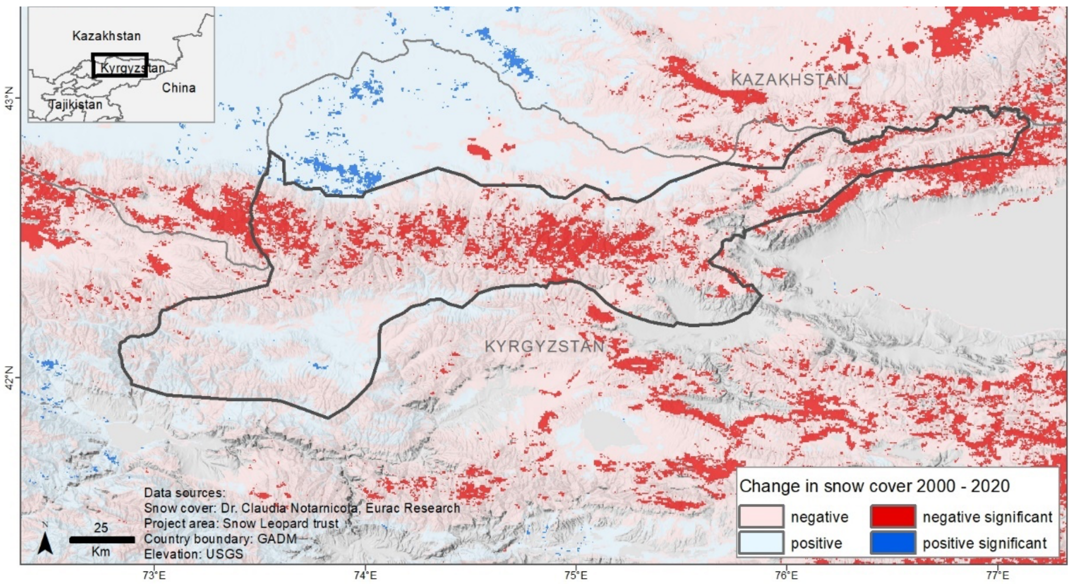

Figure 59: *Map showing the change in snow cover in the time period 2000 to 2020 for the study area in Kyrgyzstan. The significance of the trends is at 5% level of the Mann-Kendall statistics.*

5.1.5 Conclusions

- Clear trends towards higher temperatures in all seasons are shown from observations and projections at both national and project region scale.

- No significant precipitation trend in recent past is observed, while wetting trends are projected in future, mainly in winter. At local level, decreases in summer and autumn precipitation are projected in the north-western part of the project region.

- Based on SPI, i.e., precipitation deficit, no trend in droughts is shown from observations at both national and local level, even though several moderate and severe episodes occurred in recent decades. SPI projections for the country report mostly wetting trends, especially in winter.
- Based on SPEI, i.e., water deficit, more frequent and intense droughts are found to occur in recent years and clear trends towards drier conditions are observed in spring, summer and autumn. The national SPEI scenarios projected the same seasonal trends for the future.
- In most recent years, especially 2021, several drought episodes occurred in Kyrgyzstan and in the project region, however they were not exceptionally severe if compared to the rest of the record.

5.2 Main risk: Risk of loss of livelihoods for livestock owners due to drought and raising temperatures

For the visited Village Districts in Kyrgyzstan (Bel-Aldy, Suusamyr, Ibraimov, Chong Kemin), the main climate risk identified during our community consultations and fieldwork and confirmed through discussions with the local partners and desktop research, refers to the risk of loss of livelihoods for livestock owners due to drought impact on pasture, missing irrigation water for fodder and food production, and heat-exacerbated animal disease. In the following section, the risk is represented by a general Impact Chain, presenting main patterns observed throughout the four visited Village Districts. Sections 5.2.2-5.2.5 include information illustrating the Impact Chains at Village District level. Section 5.3 presents the comprehensive risk assessments per Village District. Throughout this chapter, Boxes report the current situation on human-wildlife conflict in the visited area (for the whole area and per Village District) and the potential effect of climate change on this for up to 2050. In section 5.4 we briefly refer to the findings from additional community consultations conducted by SLT. The results presented and discussed in 4.2.1 are based on both primary and secondary sources; sections 4.2.2-4.2.3 are based on the information collected in the four study sites and during the community consultations. The results presented and discussed in 4.2.1 are based on both primary and secondary sources; sections 4.2.2-4.2.3 are based on the information collected in the two study sites and during the community consultations.

5.2.1 Overview of main risk (current and future situation)

All the visited Village Districts in Kyrgyzstan reported a general situation of limited and unreliable water availability due to lack of infrastructure restricting the capacity for irrigated land, with incidents of water shortages due to a combination of drought conditions and social vulnerabilities. The community consultations' participants highlighted the experienced water shortages of 2021, which are also detected by our climate analysis (see section 5.1.3) and had a significant impact on the yields. The water shortages of 2021 been attributed by our participants, reports and the press to a mix of socio-ecological factors: low precipitation in spring and early summer, and cooler temperatures than usual in June leading to decreased snow melt (WFP, 2021); increased water needs due to the introduction of water-intensive crops (Aibalaeva, 2021); energy-water exchange between Kyrgyzstan and Kazahkstan/Uzbekistan (Eurasianet, 2021); significant water losses and limited capacity of soviet water canals (24KG, 2021). The role of precipitation and temporal patterns in determining the drought conditions was also confirmed by our analysis based on the drought indices SPI and SPEI. This example highlights some of the current complexity of water-related risks in the area as illustrated also in the Impact Chain discussed below (Figure 60).

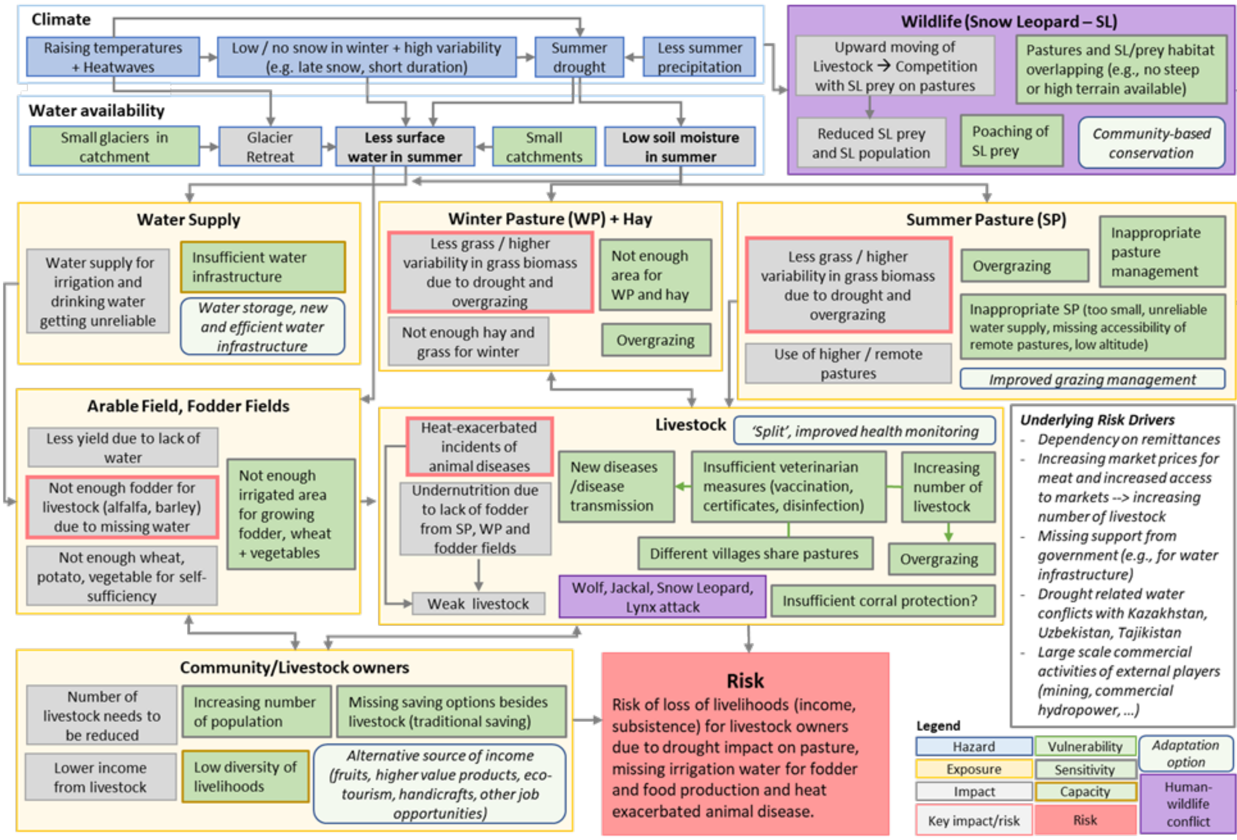

Figure 60: The Impact Chain for the visited Village Districts in Kyrgyzstan

Current situation

Similarly to Tajikistan, *droughts as hazard* events in the Kyrgyzstan project region are triggered by raising temperatures, changes in seasonal precipitation patterns and high precipitation variability, which are all important *climate signals* to consider when discussing water availability in the area (Zhumanova et al., 2021). In order to cover both domestic and agricultural water needs, the visited Village Districts rely, as most of Kyrgyzstan, on snow melt to recharge soil moisture on pasture and on snow melt and glacier melt to create runoff and river discharge, which is important for irrigation in fodder and food production. The region's water supply depends mainly on winter and spring precipitation, and (less) on summer precipitation (Pradhan, 2021). Indeed, winter and spring have been identified as important seasons for Central Asia because two thirds of the annual precipitation is falling during that time – predominantly as snow – and water reservoirs for summer in the form of snow and ice are built up (Haag et al., 2019; Zhumanova et al., 2021). During these seasons, anomalous precipitation amounts can result in summer droughts with *intermediate impacts* on less surface runoff and low soil moisture, affecting the exposed water supply in irrigated fields and pasture productivity respectively. While our data does not reveal any significant trends in precipitation similarly to what has been previously observed for Central Asia (Haag et al., 2019), remote sensing-derived snow cover observations show that snow cover duration and snow cover area over Central Asia are subjected to a large seasonal and inter-annual variability that directly affects the hydrological regimes of the surface runoff (Gerlitz et al., 2020). In terms of temperatures, these have been increasing, especially in spring and winter (Haag et al., 2019), contributing to cases of an earlier snowmelt, glacier retreat, and, overall, more arid summer conditions. Under these conditions, the Village Districts with small catchment areas and/or small glaciers within their catchment are generally more *vulnerable* to drought impacts.

Exposed systems for the visited Village Districts include the water supply, winter pasture and hay, summer pasture, irrigated land (arable and fodder fields), the livestock and, finally, the communities. Livestock is the main *exposed* livelihoods base in the Village Districts and the broader area. Livestock species include sheep and goats, cattle and horses, the latter being of particular importance due to its popularity in foreign markets (particularly in Kazakhstan) and for the production of kumys, fermented mare milk. Across the region, livestock numbers increase together with human population, living standards, markets prices and demand, signalling an overall increase in the *exposure*. The herds' owners' focus on increasing their size instead of focusing on breeds providing higher yields of meat, milk, or wool, further exacerbates the situation (SLT and Ilbris, 2021). Arable and fodder fields play a more minor role only in the lower altitudes. Irrigated arable lands are located mainly in Chong Kemin valley (potato, sugar beet, wheat, fodder crops) and in Suusamyr (barley, alfalfa). All visited Village Districts reported 'backyard' orchards for subsistence purposes.

Key risks arising refer directly to the exposed systems of pastures, irrigated land (arable and fodder fields), and livestock. These are i) pasture degradation with less grass/higher variability in grass biomass due to drought/low soil moisture and overgrazing, ii) lack of fodder for the livestock and food production due to drought/lack of surface water and insufficient water infrastructure, and iii) heat-exacerbated incidents of livestock diseases due to high disease transmission and lack of veterinarian measures. *Key risks* are not caused just by the primary *hazards* but especially because of the *vulnerabilities* embedded within the *exposed* systems.

Overgrazing and inappropriate pasture management seem to be the main *vulnerability* factors contributing to the *key risk* of pasture degradation (IFAD, n.d.). Similarly to Tajikistan, livestock breeding is historically carried out in the nomadic tradition moving livestock from one grazing ground to another in a seasonal cycle, typically to lowlands in winter and highlands in summer. This tradition was challenged by the sedentarization campaigns of the Soviet period (Karpouzoglou et al., 2020; Xenarios et al., 2019) and while the concepts of 'winter pastures', 'middle or spring/autumn pastures' and 'summer pastures' still exist, we see below that evidence from the visited Village Districts suggest that practices of transhumance have changed over the last years. The community consultations highlighted an intensive use of winter pastures. Winter pastures are typically located in the vicinity of the villages and while livestock during periods with little or no snow cover grazes the remnants of pasture vegetation, the animals are supplemented with hay mainly during periods of snow limiting access to fodder or shortage on pastures (Figure 61D). Meadows in valleys and at mountain slopes with higher productivity of grasses and forbs provide the opportunity of haymaking. The community consultations highlighted also an intensive use of 'middle or spring or autumn pastures' pastures. These pastures are becoming de facto summer pastures (used from March-June to late August-November depending on the local climate), even if they are not officially and historically considered as such, because the herders avoid going to the most remote – previously summer – pastures. The literature and fieldwork conducted by the SLT report a variety of explanations for the abandonment of the more remote pastures (SLT and Ilbris, 2021). The participants of some of our community consultations (Bel-Aldy and Suusamyr), especially the ones selling milk products, highlighted the vicinity to roads as an important parameter for pasture selection for summer and for avoiding the use of a remote pasture: the vicinity to roads equals direct access to markets as cars stop and buy the products. Lack of roads, infrastructure and water supply in the remote pastures were also reported as a factor hindering the use of remote pastures in Chong Kemin. This situation goes hand-in-hand with a non-sufficient pasture management by immature new institutions with limited enforcement power over the Village Districts, i.e., the Pasture Management Committees (Isaeva and Shigaeva, 2017; Xenarios et al., 2019). While theoretically pasture committees should assign sections of pastures to herders, this is not done in the visited Village Districts, which make use of pastures *'they always used'* without any updated, formal assignment process. In this regard, the Village Districts reported also conflicts over the use of pastures. Pasture overuse and mismanagement have brought up signs of pasture degradation of varying degrees across the four Village Districts. All four Village Districts reported signs of pasture degradation over the winter and summer pastures, which are often used by more than one Village Districts. In Suusamyr, the spread of caragana is evident and is a potential sign of overgrazing in the area (Figure 61C). The communities of Ibraimov

Village District, reported that these nearby pastures, which also overlap with a community-based conservation area, became so degraded due to overgrazing and lack of irrigation that since 2021 they had to start using the higher/remote pastures, with implications for human-wildlife conflict (Box 1).

Important *vulnerability* factor contributing to the *key risk* of lack of fodder and food production is the insufficient water infrastructure and thus the lack of arable land for growing fodder, wheat, and vegetables. Crop production in the four Village Districts is used mainly for feeding the livestock and subsistence and depends on some combination of satisfactory irrigation and (less) on the market demand. The visited Village Districts reported using their arable land mainly for fodder and wheat, and less for other crops such as potatoes, beet, carrots, apples and other fruit and vegetables. After harvesting, fields of fodder crops, grain and other crops can be used as winter pasture. There are variations between the Village Districts with regards to what extend and how they manage to cover their needs revealing different degrees of *vulnerability* among them. For instance, Bel-Aldy reported lack of irrigated land to grow fodder and occasions that livestock owners where obliged to buy from other areas; Suusamyr reported to have enough area for fodder and selling to other regions when these are dealing with dry years; wealthier livestock owners in Chong Kemin are used to buy supplementary fodder and hay from the market. In all cases, the Village Districts reported an insufficient water infrastructure, which can be summarized in the words of a livestock owner in Bel-Aldy: "*We have enough water on the mountains, but we do not have a way to collect this water. We want to build good channels in order to direct the water to the villages. In the Soviet times we had a good channel but it is destroyed. If we could build this channel, we would be able to have more arable land and use these places which were exploited in the past for fodder production."* Indeed, currently 'Kyrgyzstan possesses significant ground and surface water resources and utilizes 20-25% of available resources.' (WHO, 2015: 1). Based on observations in the field and on the literature, new irrigation systems were developed during the Soviet times, which however have not been maintained and are currently destroyed and/or with important water losses (Figure 61A). An absence of water governance, increased water losses, destroyed or out-dated (i.e., not responding to current needs) water irrigation channels, lack of (artificial) water storage and investments in infrastructure development have been identified as major *vulnerability* factors across the Village Districts, and are currently the drivers of a mainly human-induced water stress in the region (Hill et al., 2017). Additional pressure to the water resources mentioned during the community consultations is the commercial hydropower (see *Underlying Risk Drivers* in Figure 60), with hydropower production in winter leading to reduced water supply during the summer season (Gerlitz et al., 2020). This hydropower generation in the country connects to the competing claims over water resources between upstream (Tajikistan and Kyrgyzstan) and downstream (Uzbekistan, Turkmenistan, Kazakhstan) countries in Central Asia, creating a competitive transboundary system and an *underlying risk driver* that further increases the overall *vulnerability*.

Vulnerability factors related to the *key risk* of heat-exacerbated livestock diseases refer to the imports of livestock from abroad, insufficient veterinarian measures, and sharing of pastures. For the Kyrgyzstan project region, livestock diseases are one of the primary reasons for livestock loss together with accidents in the summer pastures (falling from cliffs) and wolf attacks (SLT and Ilbris, 2021). Summer pastures, which are often shared by different Village Districts, and mainly large livestock markets are seen as the points of disease transmission, especially because of animals being brought from abroad (Uzbekistan and Kazakhstan) without control or health certificate. Incidents of corruption were also reported, with bribes in order to provide a good health certificate. Mandatory vaccination rate in the Village Districts was reported to reach on average close to 80% or 90%. Nevertheless, there are regional differences in what is considered mandatory, and mandatory vaccination does yet not cover newly introduced diseases from abroad (SLT and Ilbris, 2021). It was especially in Suusamyr Village District that our consultations' participants reported a challenging situation: Suusamyr's territory is used as summer pastures by many Village Districts making the transmission of diseases a serious problem in the area. Although the current diseases should not be attributed to climatic variables, all the Village Districts reported that the hot and dry season seems to be exacerbating the situation with increased cases of blackleg and foot-and-mouth disease. Here, it should be also considered that there might not be enough vaccination for all heads of livestock since many livestock breeders don't give the exact number of livestock during livestock counting[14].

The above discussion illustrates a well-established livestock breeding monoculture with the growth-oriented goal to maximize livestock numbers against a fragile socio-ecological system. In this regard, the low diversity of livelihoods is an important *vulnerability* factor of the *exposed* communities. This monoculture implies a decreased economic resilience because of high dependence on a sole livelihood activity, which is directly influenced by climatic and ecological conditions, while putting substantial and increasing pressure on the environment that sustains it. While all Village Districts reported livestock breeding as by far the dominant livelihood strategy, we noted different levels of livelihood diversification among them. For instance, while Chong Kemin mentioned arable land, tourism, fish farming, sewing activities as part of the livelihood base, Suusamyr is based almost exclusively on livestock breeding with only a small contribution from remittances and tourism. Beekeeping (Figure 61B), apple growing, fish farms, green-houses and guest-houses are some of more or less successful additional livelihoods being developed across the visited Village Districts with the support from development actors and international organisations. Nevertheless, livestock breeding is a well-established and profitable activity that is also used as an investment opportunity with low costs, and often considered as an alternative to savings at banks, being rather difficult to be 'challenged'. When it comes to remittance-dependence, Kyrgyzstan has been ranked first in the world by the level of remittances to Gross Domestic Product (OECD, 2019). Remittances add to the diversification of the livelihoods decreasing the *vulnerability* of communities to drought impacts at least in the short term, e.g., by permitting the purchase of fodder (Murzakulova, 2020). At the same time, during the community consultations, remittances were also reported to sometimes be reinvested or temporarily stored in form of livestock, while they do not seem to be used to generate more sustainable agriculture practices (Murzakulova, 2020), constituting in this way *underlying risk drivers*. Additional *underlying risk driver* concerns the reported in all the Village Districts lack of support from the Kyrgyz government, which is illustrated for instance in the outdated water infrastructure in all the Village Districts. This lack of support is to an extent covered by development work either directly from donors or through ARIS[15] with infrastructural and/or capacity building projects (e.g., repairs of roads, irrigation, educational infrastructure, assistance to pasture committees etc.).

[14] In Kyrgyzstan, the official records on livestock numbers are not always reliable as livestock breeders tend to under-report the real number of livestock they own. A main reason for this practice is that increased numbers of livestock can be considered as income, which will then not justify social support funding from the government (information provided by Ilbris Foundation).

[15] ARIS is a joint (Community Development and Investments Agency) program of the World Bank, governments of Kyrgyzstan, Japan, and Germany, Japanese Foundation for Poverty Reduction, Asian Development Bank, and local self-governance institutions in Kyrgyzstan.

Figure 61: A Broken irrigation channel in Suusamyr, B Beehives as effort for livelihood diversification strategies, C The spread of caragana as sign of pasture degradation in Suusamyr, D Storage of hay and fodder in Bel-Aldy.

Potential future situation (up to 2050)

Hazard: As thoroughly explained in chapter 5.1, raising temperatures, high interannual precipitation variability and frequent occurrence of drought spells – especially in the lowland and low-mountain climate classes, where most of the communities are located – characterize the main *climate signals* that will possibly increase the drought risk across the Kyrgyzstan project region in the future.

Intermediate impact and key risks: The intermediate impacts and the *key risks* described in the Impact Chain (Figure 60) are expected to be relevant in the future and will probably mostly intensify across the Village Districts, although possibly also new livelihood opportunities may arise in certain cases. While there are not many studies dedicated to climate change impact assessment on water resources in Kyrgyzstan or Central Asia (Didovets et al., 2021), climate change impact on surface runoff is also partly unclear due to the uncertainty of future precipitation patterns, glacial and snow melt rates (Reyer et al., 2017). Overall, research indicates that in the future in Central Asia the hydrological regime is shifting towards a runoff from snowmelt earlier in the year leading possibly to less surface water in summer (Liang et al., 2021). This by itself could result in a situation of limited surface water in summer with increasing water shortages in the absence of water infrastructure for water storage. Moreover, across all Central Asia potential evapotranspiration increases exerting a drying effect on soils (Liang et al., 2021; Reyer et al., 2017). At the same time, the observed trend of higher surface temperatures leading to higher glacier melt rates and glacier shrinkage is expected to continue in the future and may partly counterbalance the impacts of early snow melt and high evaporation rates for communities with glacierised catchment in the next few decades up to 2050, with however an uncertain date of passing peak runoff (Reyer et al., 2017). According to a study of IFAD (IFAD, FIC, IEH, 2013), in the future, the increasing temperatures will probably result in less favourable conditions for livestock grazing in the lower altitudes (below 1,500m) – where most of the visited Village Districts are located (Bel-Aldy, Ibraimov, Chong Kemin) – and open-up livestock and grazing opportunities in medium (1,500-2,500m) and higher (more than 2,500m) altitudes. Similarly, higher temperatures and accordingly longer thermal growth season, may facilitate the expansion of arable farming (and winter fodder availability) into higher altitudes, if not limited by water availability from precipitation or sources of irrigation water (Michel, 2021). This situation would further increase the competition for water amidst reduced and unreliable water availability and could also increase wildlife habitat fragmentation (for more information on human-wildlife conflict see Box 2).

Exposure: Livestock is the main exposed livelihoods base in the Village Districts and the broader area. With livestock numbers increasing across all the Village Districts – and with potentially new areas for fodder production and grazing – the risk will potentially further increase in the future.

Vulnerability: If overgrazing and inappropriate pasture management proceed, the risk of pasture degradation will most likely be aggravated and expanded in space across all the Village Districts. While reducing the number of livestock through livelihood diversification is a valid adaptation option or an imposed necessity in cases (e.g., due to lack of fodder), this still seems difficult to be achieved considering the profitability and the long tradition of the sector. A renewed pasture planning through inclusive pasture governance processes at the local level is certainly needed and might be a more substantial adaptation action in the short-term. Additional infrastructure such as roads and corrals that could motivate the use of the remote pastures could possibly contribute to balance the grazing pressure, but this has to be considered together with a sustainable pasture management plan, aligned with conservation efforts. Vulnerability to the key risk of lack of fodder and food production is also likely to increase if no investments are done in water infrastructure from water storages to water channels. Considering that unstable water availability is likely to increase the challenge of competing requirements for hydropower generation and agricultural production at times of rising overall demand due to projected population and economic growth in Central Asia, integrated water resources management and transboundary cooperation will also be key adaptation needs for the future. Finally, considering that the imports of livestock from abroad will most probably increase and the sharing of pastures among Village Districts will intensify, vulnerability to heat-exacerbated livestock diseases is likely to increase except if more strict veterinarian measures are put in place.

Box 2. Risk of loss of livelihoods for livestock owners due to drought and raising temperatures and Human-Wildlife conflict in the visited Village Districts in Kyrgyzstan

Current situation

Human-wildlife interactions were reported by all the visited Village Districts and refer primarily to livestock depredation by wild carnivores; pasture sharing between livestock and wildlife that constitutes snow leopard prey (mainly ibex and argali but also marmot, wild boar and roe deer); and poaching.

Across all the four Village Districts, most depredation was reported by wolves and jackals, and takes place in villages and summer pastures alike. Depredation by lynx and only very few instances of snow leopard attacks were reported in the Ibraimov and Chong-Kemin Village Districts. Snow leopards are not regarded as a major threat in the current situation as their habitat generally does not overlap with the areas used by the communities (SLT and Ilbris, 2021). This generally harmonious (direct) relationship between snow leopards and communities contributes both to avoiding loss of livelihoods and to snow leopard conservation. In Bel-Aldy, the communities mentioned that the snow leopard uses their summer pasture as corridor for migration but this just for a brief period and without causing conflict.

The upward moving of livestock to the summer pastures, as *intermediate impact* of temperature and snow cover spatial and temporal patterns, brings the livestock closer to the habitat of snow leopard prey. Considering that all the visited Village Districts reported overgrazing and pasture degradation, together with a constant increase in the number of livestock, this situation can eventually lead to competition for resources between livestock and wild ungulates, with a possible decrease in wild ungulate populations, ultimately resulting in threats to snow leopard. Ongoing climate change in the Kyrgyzstan project region with *hazards* triggered by the tendencies for higher temperatures and droughts can also be contributing to this situation but it is difficult to distinguish from the faster and more intensively acting impact of inter-annual weather variability and degradation caused by land-use (Michel, 2021). More *vulnerable* are those Village Districts where the pastures and the wild ungulates habitat overlap because of lack of steep and/or high terrain that prevents livestock from grazing and constitutes refugium for wildlife[16]. While Bel-Aldy and Suusamyr reported steep and inaccessible terrain in their summer pastures, the Ibraimov Village District is more *vulnerable* in this regard. In the Ibraimov Village District, the summer pastures overlap with a community-based conservation area. Wild ungulates and livestock use the same pasture and besides the threat of pasture degradation for the wild ungulates, instances of disease transmission from livestock to wild ungulates have also been reported adding to the human-wildlife conflict.

Poaching is another *vulnerability* factor contributing to intensification of human-wildlife conflict that was reported in all the Village Districts. Ibraimov and Chong-Kemin Village Districts mentioned local initiatives (i.e., community-based conservancies with anti-poaching activities) that have been successful in limiting it; in Bel-Aldy and Suusamyr, poaching is still a problem decreasing the number of wild ungulates, thus of snow leopard prey, and intensifying human-wildlife conflict.

Potential future situation

The future situation for human-wildlife conflict (focusing on snow leopards) will be defined by a complex combination of socio-ecological factors such as the impact of climate change on snow leopards and their habitat but also on their prey; the impact of climate change on communities and

[16] Especially Ibexes (more than Argali) prefer the more rugged areas that have a combination of pastures interspersed with cliffs (GSLP, 2017).

their adaptation actions; human population changes, livelihood strategies (including livestock numbers, pasture and water management), and conservation efforts.

The increasing summer temperatures and the changes in water availability may directly affect snow leopards (Michel, 2021). Nevertheless, as highlighted by Forrest et al. (2012) 'the impacts of climate change [on snow leopards] will be manifested primarily through changes in the snow leopard's alpine habitat, rather than through direct physiological impacts of temperature and precipitation on snow leopards.' Models presented by Li et al. (2016) indicate that under scenario RCP 4.5 suitable habitat in Kyrgyzstan will slightly decrease by 1% for 2070, while under scenario RCP 8.5 it will slightly decrease by 2%. Preliminary results on snow leopard distribution modelling from research conducted in the context of the Vanishing Treasures programme also show a potential loss of habitat, especially in areas with lower elevation in Tajikistan (Humboldt-University Berlin unpublished data). Li et al. (2016) identifies the Tian Shan-Pamir-Hindu Kush-Karakoram Mountain ranges as one of the three potentials 'climate refugia' for snow leopards calling for establishing nature reserves and providing targeted conservation solutions. This is because herders and farmers interactions with snow leopards might increase in the future as communities follow shifting grasslands and croplands upward in elevation (IFAD, FIC, IEH 2013; Li et al., 2016) and/or expand to cover the needs of their developing livelihoods (i.e., livestock and – potentially – cropland increase). Thus, the *exposure* of the communities to human-wildlife conflict might increase. The Ibraimov Village District could be seen as an 'early warning' case for the rest of the visited communities: as mentioned in sections 5.2.1 and 5.2.4, pasture degradation due to overgrazing and lack of water in the summer pastures 'forced' the Ibraimov Village District to expand to previously under-utilised higher/remote pastures with potential new impacts on the wildlife refuges.

Potential impact of climate change and land-use on vegetation in terms of composition, productivity and phenology will be probably the most important factor determining future habitat suitability and abundance of mountain ungulates and other prey species of snow leopard in the project region (Michel, 2021). While the complexity of the factors determining the composition of vegetation makes any predictions of vegetation change highly uncertain (Michel, 2021), the community consultations for the visited Village Districts reveal an increasingly intensified land-use that has already led to pasture degradation and, in cases, the further expansion of human activities in space. With the grazing pressure potentially shifting in medium and higher altitudes in the future (IFAD, FIC, IEH, 2013), *vulnerability* is expected to increase with an intensification of human-wildlife conflict. To this it should also be added that reduced snow cover, accelerated snow melt and the disappearance of smaller glaciers could reduce water availability in some areas, possibly fragmenting the habitat of ungulates but also the suitability of pastures for livestock. Preliminary results on distribution modelling for ibex from research conducted in the framework of the Vanishing Treasures Programme show the impact of future climate conditions on the habitat suitability by an upward shift in habitat and loss of suitability of bottom of valleys (Humboldt-University Berlin unpublished data). Such predicted shifts in habitat could lead to sharing landscapes with livestock and a higher competition over resources (e.g., forage, species and water), disease transmission and poaching, indirectly impacting snow leopard population.

Future human-wildlife conflict-related *vulnerability* per Village District will depend on the status and management of the pastures, the presence of inaccessible to livestock terrain in the Village District's territory, and the (further) establishment of anti-poaching measures and community-based conservation areas.

5.2.2 Bel-Aldy Village District

The Bel-Aldy Village District, including the villages of Sary-Sögöt (1,312m), Korgon (1,100m) and Bel-Aldy (1,432m), is one of the 10 Village Districts of Toktogul District (Jabal-Abad Region) located within the Naryn river valley in the south-west of the Kyrgyzstan project region. According to the community consultations' participants, the Village District has a population of 5,074 (together with the migrants abroad), with 4-5% increase rate due to increasing birth rates. The exposed livelihood concerns livestock breeding for market purposes (50-60%) with exports to Kazakhstan, mainly horses (5000) and cows (5000), less sheep and goats. The results of the participatory mapping are presented in Figure 62; the human-wildlife conflict in the Bel-Aldy Village District is reported in Box 3.

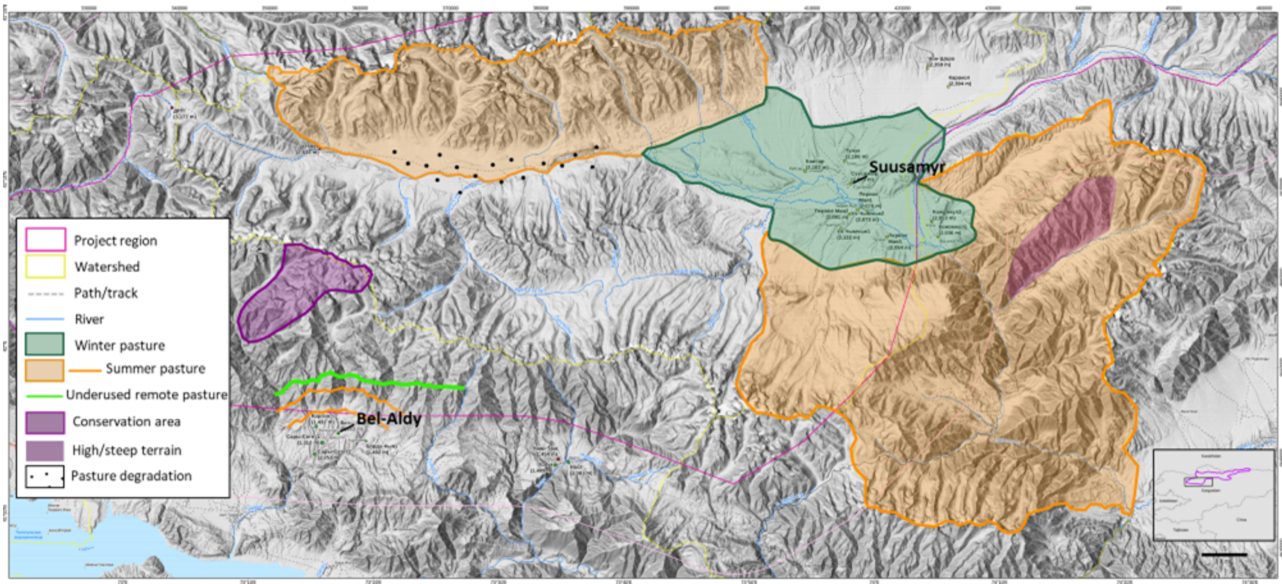

Figure 62: The results of participatory mapping for Bel-Aldy and Suusamyr Village Districts. Shown on the bottom-left of the map, the participants of Bel-Aldy (situated close to the Toktogul reservoir) indicated the location of their summer pastures and the location of the remote - currently underused – pasture, along with a community conservation area. Shown on the top and right of the map, the participants of Suusamyr indicated the areas of their winter and summer pastures. The summer pasture on the North-West of the Suusamyr Village District is popular among different Village Districts due to its proximity to a main road, which is located along the pasture's Southern borders. The intense use of this area of this summer pasture has resulted in degradation, as shown on the map. The summer pasture on the South-East of the Suusamyr Village District includes area of high and steep terrain that constitutes refugium for wildlife. Attention: The borders of the Village Districts are not shown on this map.

Current situation

The villages of the Bel-Aldy Village District belong to the 'Lowland warmest summer' climate class with high interannual temperature variability and high aridity. Based on our preliminary analysis and as confirmed during the community consultations, this Village District is located in one of the least glacierised catchments of the Kyrgyzstan project region (glacier extent 2-10km2) due to the relatively low mountain surroundings (up to 3,000m). This lack of glacier in Bel-Aldy's catchment is an important vulnerability to drought. Water availability in Bel-Aldy is missing the additional water buffer from glaciers in the summer months and thus mostly and directly dependent on snow and precipitation, which the community consultations' participants perceived as "unreliable source of water" over the last years due to high seasonal and inter-annual variability in precipitation. Nevertheless, the communities agreed that any limited water availability should not be attributed (only) to climate-related hazard events but mainly to the vulnerability referring to water supply, lack of water channels and destroyed water infrastructure from the Soviet times.

With regard to the key risk of pasture degradation due to drought and overgrazing, this was assessed as 'Very high' by the communities of the Bel-Aldy Village District with overgrazing and inappropriate pasture management to be the main vulnerability factors. During winter, the livestock is mainly being kept within the villages with fodder; from May to November the livestock is kept in gradually longer distances to the summer pastures without however reaching the more remote pasture (Figure 62). Herders seem to avoid the remote pasture due to its limited accessibility and distance from big roads, where they can sell their dairy products. This situation together with an increase in livestock numbers puts significant pressure on the nearby pastures, which were reported to be degraded due to overgrazing. The remote pastures, on the other hand, were reported to be in good condition. In Bel-Aldy, members of the pasture committee shared that they do register the number of animals the Village District has and try to allocate them to pastures, however with limited success due to lack of enforcement power. It seems a common practice for the communities to understate the number of livestock for tax purposes, and not to respect the official assignments of pastures.

The key risk of lack of fodder and food due to drought and insufficient water infrastructure was assessed as 'Moderate' by the communities with the insufficient water infrastructure to be the main vulnerability factor. The participants of the community consultations reported lack of arable land to grow fodder (corn, hey, barley, wheat), which is compensated using wild grass or by buying in the market. There is only limited agricultural production of apricots, apples, pears, cabbage, carrots, potatoes. Only the potato production is enough to cover the subsistence needs, the rest of which are covered through exchange of products between the villagers or by the market.

The key risk of heat-exacerbated incidents of livestock diseases due to high disease transmission and lack of veterinarian measures was assessed as 'Moderate' by the communities with the insufficient veterinarian measures for animals imported by Uzbekistan or Kazakhstan to be the main vulnerability factor. Bel-Aldy reported also corruption and the lack of a corral/split for livestock vaccinations and disinfections.

About 4% of the exposed communities in Bel-Aldy practices also bee-keeping with the ambition to access international markets but with limited relevant knowledge. A high dependence on remittances (50% or even 70-75% of the population) adds to the livelihood diversification decreasing the vulnerability to the risk of loss of livelihood for livestock owners at the moment but adding to the uncertainty of the system for the future as underlying risk driver: "This year we were not able to have enough, good hay so we used the remittances as well. If we didn't have the remittances, I am not sure what would happen to the livestock."

Potential future situation (up to 2050)

Hazard: Located in the lowland climate class, the Bel-Aldy Village District is expected to be particularly prone to drought and heat spells considering the further increasing temperatures.

Intermediate impact: Similar with the 'potential future situation' for all the Village Districts, see section 5.2.1.

Exposure: Although we do not have specific increase rate, livestock numbers are increasing in Bel-Aldy and thus the exposure to the risk is expected to increase in the future.

Vulnerability: With absence of glacier in catchment, Bel-Aldy is expected to be vulnerable to droughts in the future. If overgrazing and inappropriate pasture management proceed, the risk of pasture degradation will most likely be aggravated and expanded in space for Bel-Aldy. Nevertheless, the pasture committee has a new chairman who stated his intentions to enforce proper allocation of pastures and the rotation including the remote pasture in order to balance grazing pressure throughout the territory, a practice that could potentially reduce the vulnerability of the Village District in this regard. Road infrastructure seems to be key for the access to the remote pastures in Bel-Aldy. Moreover, during the community consultations some livestock owners of Bel-Aldy expressed their interest in diversifying their livelihoods (e.g., apple cultivation, agriculture, bee keeping, greenhouse), an adaptation that could potentially decrease the number of livestock and the vulnerability of communities to the risk in the future. According to the communities, this diversification of the livelihoods should be accompanied by technical support and capacity building e.g., in marketing and finance in order to be feasible and finally profitable. Water infrastructure and management is key both for future livelihood diversification and for addressing the key risk of lack of fodder and food production, which is otherwise likely to increase in Bel-Aldy. With at least 50% dependence in remittances, the livestock sector in Bel-Aldy is not self-sufficient and its future vulnerability to lack of fodder will probably depend also on external economic factors. Finally, the vulnerability to heat-exacerbated livestock diseases is likely to increase except if more strict veterinarian measures are put in place.

Box 3. Risk of loss of livelihoods for livestock owners due to drought and raising temperatures and Human-Wildlife conflict in the Bel-Aldy Village District

In Bel-Aldy most depredation was reported by wolves and jackals close to the villages. There are rarely attacks in the summer pastures both due to the presence of herders but also because of abundance of marmots as prey. The snow leopard uses the summer pasture as corridor for migration but this just for a brief period and without causing conflict. When it comes to vulnerability factors, Bel-Aldy reported to have enough and inaccessible to the livestock terrain that prevents human-wildlife conflict today and probably in the future: “Even if our herders or households reach the remote pastures there will not be conflict with wildlife because ungulates usually live on steep mountains, and we do not use those areas for the livestock”. Poaching was reported as important vulnerability factor for Bel-Aldy resulting in decreasing number in ungulates: “While after the Soviet Union the number of ungulates decreased due to the threat of starvation, the poaching now is for selling to officials and wealthy people and it is a big problem here”. The head of village government in Bel-Aldy is currently promoting the establishment of a community-based conservancy with anti-poaching activities similarly to Chong-Kemin.

5.2.3 Suusamyr Village District

The Suusamyr Village District, including the villages of Kaysar (2,105m), Kojomkul (2,054m), Birinchi May (2,068m), Tunuk (2,106m), Kyzyl-Oi (1,745m) and Suusamyr (2,080m), is one of the 13 Village Districts of Jayyl District (Chüy Region) located in the Suusamyr Valley, on the bank of the river Suusamyr in the south-west of the Kyrgyzstan project region. According to the community consultations’ participants, the Village District has a population of 7,700. The population has doubled over the last 15 years (5% increase rate per year) both because of births and immigration: “*We have good conditions for livestock and agriculture, this is why people decide to move to our area from other places”.* During the Soviet times, according to the strategic plan, Suusamyr was the centre of meat exports to all the other regions. The *exposed* livelihood concerns livestock breeding with 50,000 sheep and goats, 8,000 cattle, 8,000 horses, 200 yak with an increase rate of 10-15% per year; 60% of the people are occupied also with agriculture, and 10% also with tourism. The results of the participatory mapping are presented in Figure 62; the human-wildlife conflict in Suusamyr Village District is reported in Box 4.

Current situation

The villages of Suusamyr Village District belong to the ‘Low mountains Southeast’ climate class. Based on our preliminary analysis the Village District is in a more glacierised catchment in comparison to Bel-Aldy (11-25km^2). The community consultations’ participants reported a high dependency on snow and on the Suusamyr river (the third biggest river in Kyrgyzstan heading to the Toktogul reservoir) and perceive a decrease in the river's water flow in comparison to the 30 years ago, an increase in temperature, and tendency for less snow. Nevertheless, the communities agreed that any current water stress should not be attributed (only) to climate-related *hazard events* but mainly to *vulnerability* related to insufficient water supply due to water losses and old, often destroyed, water infrastructure from the Soviet times. Suusamyr also reported water pollution due to gold mining.

Regarding the *key risk* of pasture degradation due to drought and overgrazing, the community consultations' participants' opinions were diverse on the significance of the issue for Suusamyr ranging from 'Moderate' to 'Very high'. In the Suusamyr Village District, the surrounding of the villages is used as arable land and/or spring and autumn pasture (April-June and after the harvest in mid-September) without signs of degradation, according to the communities. Signs of pasture degradation with decreased biomass and thus more increased *vulnerability* due to overgrazing are evident on Suusamyr's summer pasture on the west of the Village District (Figure 62). In Suusamyr, the spread of caragana is evident and is a potential sign of overgrazing in the area (Figure 61C). Special attention is needed here as the pasture committees or other institutions that can afford it combat the spread of caragana by burning it or treating it with herbicides, which can have further negative effects on the pastures (SLT and Ilbris, 2021). This pasture does not officially belong to Suusamyr; it is a pasture that due to its proximity to a main road (and thus to the market), it attracts herders from different areas (also from Bel-Aldy), who use it without respecting the official assignment of the pasture sometimes both in summer and winter: *"We don't use the pastures according to the system of the Soviet Union. Then there were spring pastures, then summer pastures… Nowadays, everybody decides by themselves for how and where to graze so this is why biomass is degrading in this pasture."* According to the consultations' participants, during the Soviet times, this and other pastures used to belong to the Suusamyr Village District. After the collapse of the Soviet Union, Suusamyr was divided into smaller Village Districts and the pastures were re-assigned. The current Suusamyr is now claiming those previous pastures, 'invading' the pastures of other Village Districts. Pasture conflicts are an often and major issue in the area; the pasture committees are intervening without though being able to enforce regulations, adding to the *vulnerability* to pasture degradation.

The *key risk* of lack of fodder and food due to drought and insufficient water infrastructure was assessed as both 'Low' and 'Very high' by the communities with the lack of irrigated land due to insufficient water infrastructure to be the main *vulnerability* factor. Despite the limitations in terms of water supply due to lack of water infrastructure, the fodder production (mainly barley) was reported as sufficient both for self-sufficiency and for the market. For instance, in the dry year 2021, Suusamyr sold barley from 12,000ha to other regions that could not cover their needs. In the words of a farmer, Suusamyr is self-sufficient when it comes to sustaining and developing its livestock sector: *"We have both enough pastures and fodder so as to constantly increase the numbers of our livestock"*.

The *key risk* of heat-exacerbated incidents of livestock diseases due to high disease transmission and lack of veterinarian measures was assessed as 'Moderate' by the communities as most of the livestock of the Suusamyr Village District is vaccinated. The area is *vulnerable* to the transmission of new diseases both due to livestock imports from abroad and because of many sharing the same pastures with other Village Districts. However, the communities characterised the situation to be under control due to high vaccination rates. While the dry season does have an impact on sheep and horses, current challenges on livestock heath relate mostly to disease transmission among livestock.

The success of the livestock sector in the Suusamyr Village District has resulted in a low dependence on remittances (2-3% of the population): *"We have good lands, and we stay on these lands"*. In this sense, Suusamyr is more self-sufficient in terms of livelihoods in comparison to the other visited Village Districts but lacks the buffer remittances can provide to minimize risks in conditions of high uncertainty around agricultural income. In addition to livestock breeding but to a much smaller extent the *exposed* communities are occupied with internal horse milk tourism from spring to late summer (guest houses, horseback riding, fishing).

Potential future situation (up to 2050)

Hazard: Located in the "Low Mountains" climate class, the Suusamyr Village District is expected to be particularly prone to drought spells considering the further increasing temperatures.

Intermediate impact: Similar with the 'potential future situation' for all the Village Districts, see section 5.2.1.

Exposure: Livestock numbers are increasing in Bel-Aldy with an increase rate of 10-15% per year and thus the exposure to the risk is expected to increase in the future.

Vulnerability: If overgrazing and inappropriate pasture management proceed, the risk of pasture degradation will most likely be aggravated and expanded in space for Suusamyr. Pasture management is key in the case of Suusamyr as a revisiting of the pasture borders through collaboration between the different Village Districts is needed. When it comes to livelihood diversification for vulnerability reduction, the young generation supports the further development of tourism, ecotourism, bee-keeping and fish farms, and the women of sewing workshops, but are in need of technical assistance and training. Vulnerability to the key risk of lack of fodder and food production is likely to increase in the future if no investments are done in water infrastructure from water storages to water channels: *"Even if the weather is now good and this is good for livestock, we are aware that the glaciers are melting and we won't have water"*. Finally, the imports of livestock from abroad will most probably increase and the sharing of pastures among Village Districts will intensify, but vulnerability to heat-exacerbated livestock diseases could remain stable if the current control and vaccination measures stay in place. Suusamyr reported to be receiving significant support from ARIS, which could potentially contribute to reduce the vulnerability to the main risk in the Village District in the future.

Box 4. Risk of loss of livelihoods for livestock owners due to drought and raising temperatures and Human-Wildlife conflict in the Suusamyr Village District

In Suusamyr most depredation was reported by wolves and jackals close to the villages. Only one instance of a possible snow leopard attack was reported further away from the Village District's summer pastures. Suusamyr reported the presence of stray dogs that according to the communities do not pose any threat to wildlife as they are being shot (in absence of other measures to limit their presence). When it comes to *vulnerability* factors, Suusamyr reported the existence of steep terrain of higher elevation south of the village that constitutes refuge for wildlife, especially Ibexes (Figure 62).

Poaching is a *vulnerability* factor for Suusamyr as despite the presence of rangers the territory of the Village District is big and cannot be surveyed properly.

5.2.4 Ibraimov Village District

The Ibraimov Village District, including the villages of Koshoy (1,269m), Kara-Oy (1,124m), Kyzyl-Asker (1,070m), Lenin (643m), Lenin-Jol (1,232m) and Taldy-Bulak (1,069m), is one of the 10 Village Districts of Chüy District located in the eastern part of Chüy Valley while its southern part spreads into Kyrgyz Ala-Too mountains in the north-east of the Kyrgyzstan project region. According to the community consultations' participants, the Village District has a population of 5,200, which is generally increasing due to births despite an increased outmigration to Russia. The *exposed* livelihood concerns livestock breeding (90% of the population) due to the high profitability of the sector but also due to lack of other employment opportunities. The Village District reported 2,000 horses, 3,000 cattle (of which 2,000 milk cows kept at village), 7,000 sheep with an increase rate of 10-30% per year. The results of the participatory mapping are presented in Figure 63; the human-wildlife conflict in Ibraimov Village District is reported in Box 5.

Current situation

The villages of the Ibraimov Village District belong to the 'Lowland warmest summer' climate class with high interannual temperature variability and high aridity. Based on our preliminary analysis the Village District is located in a glacierised catchment with glacier extent between 11-25km^2 feeding the Kyrgyz Ala-Too mountains. The community consultations' participants reported a high dependency on snow and rain and perceive a general decrease in snow in winter and water from the Shamsy river in summer, noting that the summer of 2021 was particularly dry. Nevertheless, similarly to all the other Village Districts under research, the communities of the Ibraimov Village District highlighted that current unreliable water supply is mainly due to old water infrastructure (reservoir) and water losses, rather than due to the primary climate-related *hazards*. When discussing the *exposed* system of water supply, here the communities also stressed the lack of proper water governance due to the absence of a local water committee and new challenges arising from the *underlying risk driver* of new hydropower stations installed by private companies.

With regard to the *key risk* of pasture degradation due to drought and overgrazing, the community consultations' participants assessed the significance of the issue for Ibraimov as 'Very high'. Similarly to the case of Suusamyr, the Ibraimov communities 'invade' the pastures of other Village Districts commenting that *"After the Soviet Union collapsed the pasture borders were arranged in a poor manner. Each local self-government has a border, but this is not always respected and the livestock is sent to other pastures (not officially assigned to the Village District) because it is too much"*. This is happening in an unregulated way, as the Pasture Committee lacks planning and enforcement power. The Ibraimov Village District reported conflicts between villages over the use of pastures, but these conflicts referred only to the nearby pastures (winter and 'middle' pastures used as summer pastures). Indeed, the nearby pastures, within and surrounding the villages of the Village District, are assessed as highly *vulnerable* as they have become overgrazed due to an unregulated and intense use throughout the year. It seems that the *exposed* systems of nearby pastures exceeded their carrying capacity in the Ibraimov case. Since 2021, the degradation of these nearby pastures obliged the communities of Ibraimov to mobilise the more extensive grazing rotation system and to start using the remote pastures for two months during the summer (Figure 63). The summer and remote pastures overlap with a community-based conservation area raising concerns about human-wildlife conflict (Box 1 and Box 4).

The *key risk* of lack of fodder and food due to drought and insufficient water infrastructure was assessed as 'High' by the communities of the Ibraimov Village District with the insufficient water infrastructure to be the main *vulnerability* factor for livestock owners. The Ibraimov Village District reported that the number of livestock that can be sustained is limited by the lack of arable land to grow fodder (alfalfa, sainfoin, wheat) and to use as nearby pastures: *"If we had better irrigation system, we could support the nearby pastures. The productivity of the nearby pastures is low due to bad irrigation."* In cases of dry years, irrigation has to be limited to wheat (least drought resistant) and the rest of fodder had to be bought from other areas.

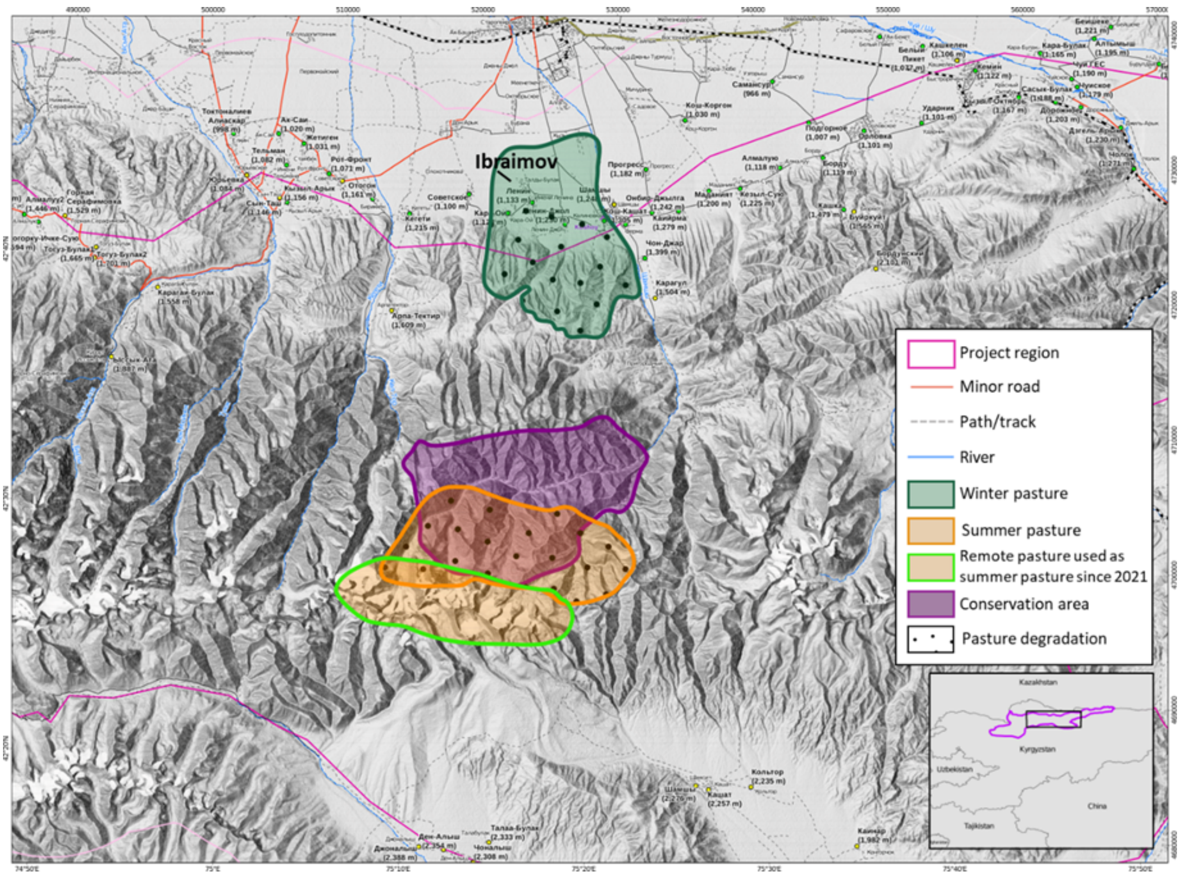

Figure 63: The results of participatory mapping for the Ibraimov Village District. The participants indicated the areas of Ibraimov's winter and summer pastures and the borders of a previously underused remote pasture that since 2021 is being used as summer pasture. Both the winter and summer pastures of the Ibraimov Village District show signs of degradation. The map also shows the overlap of a community conservation area with the summer pastures of the Village District, which denotes increased human-wildlife interactions. Attention: The borders of the Village District are not shown on this map.

The *key risk* of heat-exacerbated incidents of livestock diseases due to high disease transmission and lack of veterinarian measures was assessed as 'Moderate' by the communities of the Ibraimov Village District. The main risk for the area concerns new diseases arriving with livestock imports from abroad, while the communities reported that the dry seasons further contribute in the deterioration of animal health.

Although the short distance to Bishkek provides some job opportunities to the Ibraimov communities (e.g., taxi drivers), the communities' livelihoods are based almost exclusively on livestock (for meat and milk). Other means of income are sparse but include raspberry and apple growing selling to Russia and Kazakhstan (irrigation dependent). There is significant dependence of 30-40% on remittances (although, in the words of a farmer *"we are dependent on remittances less than in the south"*) that adds to the livelihood diversification and has been used to decrease the *vulnerability* to drought of the livestock sector, e.g., by purchasing fodder during dry conditions.

Potential future situation (up to 2050)

Hazard: Located in the "lowland warmest summer" climate class, the Ibraimov Village District is expected to be particularly prone to drought spells considering the further increasing temperatures.

Intermediate impact: Similar with the 'potential future situation' for all the Village Districts, see section 5.2.1.

Exposure: Livestock numbers are increasing in Ibraimov with an increase rate of 10-30% per year and thus the exposure to the risk is expected to increase in the future.

Vulnerability: If overgrazing and inappropriate pasture management proceed, the risk of pasture degradation will most likely be aggravated and expanded in space for Ibraimov. In fact, Ibraimov seems to have already reached a certain tipping point when it comes to pasture degradation, since the herders have now expanded to the remote pasture to balance grazing pressure. Together with pasture management, an investment on water infrastructure could also potentially decrease the vulnerability to the key risk of pasture degradation as it would ensure fodder for cows for milk production, which is the main alternative source to livestock and does not need the use of pastures. Vulnerability to the key risk of lack of fodder and food production is likely to increase in the future if no investments are done in water infrastructure. With at least 30-40% dependence in remittances, the livestock sector in Ibraimov is not self-sufficient and its future vulnerability to lack of fodder will probably depend also on external economic factors. Finally, the imports of livestock from abroad will most probably increase and the sharing of pastures among Village Districts will intensify, signifying a potential increase in the vulnerability to heat-exacerbated livestock diseases.

Box 5. Risk of loss of livelihoods for livestock owners due to drought and raising temperatures and Human-Wildlife conflict in the Ibraimov Village District

In Ibraimov most depredation was reported by jackals and wolves close to the villages and by lynx and snow leopard in the summer pastures. Ibraimov reported the presence of stray dogs that according to the communities do not pose any threat to wildlife as they are being shot (in absence of other measures to limit their presence). When it comes to *vulnerability* factors, the Ibraimov Village District reported the absence of steep terrain of higher elevation that constitutes refuge for wildlife, with their summer pastures overlapping with a community-based conservation area. Wild ungulates and livestock use the same pasture and besides the threat of pasture degradation for the wild ungulates, instances of disease transmission from livestock to wild ungulates have also been reported adding to the human-wildlife conflict. Poaching as a *vulnerability* factor is limited for Ibraimov exactly because of the conservation project running in the area. Nevertheless, the recent expansion of the Village District to the remote pastures could possibly intensify human-wildlife conflict in the area.

5.2.5 Chong Kemin Village District

The Chong Kemin Village District, including the villages of Tar-Suu (1,508m), Kalmak-Ashuu (1,532m), Shabdan (1,518m), Kyzyl-Bayrak (1,545m) and Tort-Kul (1,440m), is the northeast panhandle district of Chüy Region in the northern-east of the Kyrgyzstan project region. According to the community consultations' participants, the Village District has a population of 4,637 people. The population is increasing because of births and the outmigration seems more limited in comparison to other areas: *"The livelihood level here is good in comparison to the South and to the rest of the Chüy Region, 4/5 children stay and the one that leaves does so to make their own life better – not the life of the family."* The main economic activities in order of economic contribution are livestock, arable land, a well-developed tourism, fish farming, and sewing activities. The *exposed* livestock sector concerns 12,000 sheep/goats (increasing by about 300 heads or 2.5% per year), 1,400 cows and 1,500 horses, (increasing by 50 heads or 1.7% per year), and 380 yaks (increasing by 50 heads or 7% per year). The results of the participatory mapping are presented in Figure 64; The human-wildlife conflict in Chong Kemin Village District is reported in Box 6.

Current situation

The villages of the Chong Kemin Village belong to the 'Lowland warmest summer' climate class with high interannual temperature variability and high aridity. Based on our preliminary analysis, Chong Kemin is located in the most glacierised catchment of the Kyrgyzstan project region with glacier extent between 76-96km^2. While the area has been rich in water resources with only 30% of the water from this valley reaching downstream to other villages, the communities perceive a general decrease in water availability and a high interannual variability in pasture quality. For instance, according to the communities, Chong Kemin used to be famous for its potatoes in the Kyrgyzstan market but now the production is not sufficient due to a decreased water supply. Another example the communities shared is this of a specific water stream that reaches the villages and is used on a rotational basis by the households: *"this water stream was previously serving 10 households but now its capacity has decreased and is sufficient only for 4 households"*.

Regarding the *key risk* of pasture degradation due to drought and overgrazing, the Chong Kemin Village District assessed the significance of the issue as 'Very high'. In Chong Kemin, the livestock remains at the villages on the harvested fields and the surroundings until the end of May. According to the communities, ideally the livestock would be sent to the summer pastures in April but this is avoided as the summer pastures lack good settlements for the herders and corrals for the livestock. The communities observe pasture degradation of this close by pastures due to overgrazing but also dry conditions. *"The main problem is in the villages and at the surrounding winter pastures where the land is significantly degraded",* while signs of pasture degradation are observed also in specific locations of the summer pasture. The more remote pastures remain under-utilised and in better conditions (Figure 64).

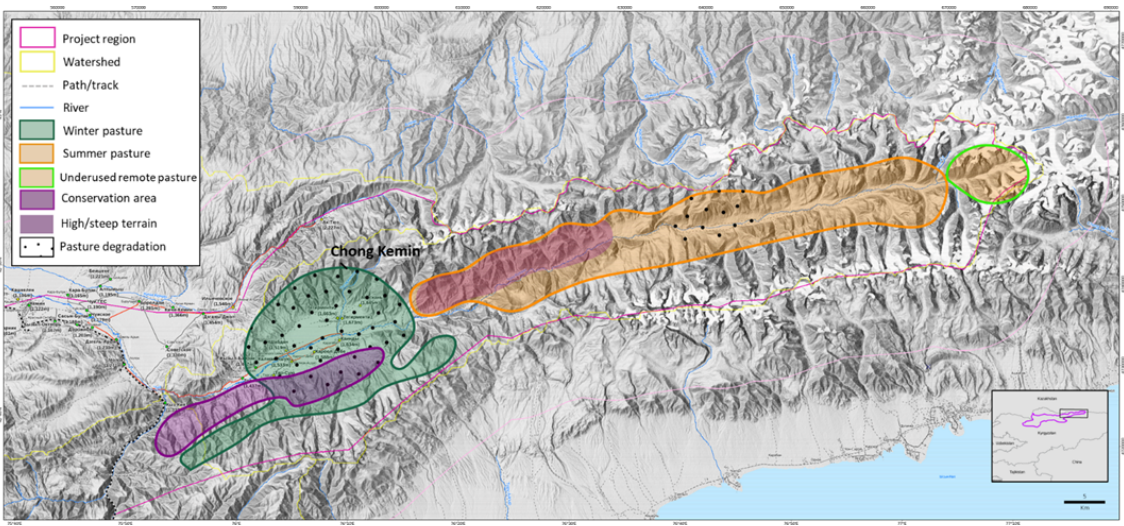

Figure 64: The results of participatory mapping for the Chong Kemin Village District. The participants indicated the areas of Chong Kemin's winter and summer pastures and the borders of an underused remote pasture. The winter pastures of the Chong Kemin Village District are degraded, while signs of degradation where also mapped for part of the summer pastures. Small part of the winter pasture overlaps with community conservation area, while the summer pasture includes area of high and steep terrain that constitutes refugium for wildlife. Attention: The borders of the Village District are not shown on this map.

The *key risk* of lack of fodder and food due to drought and insufficient water infrastructure was assessed as ‘High’ by the communities of the Chong Kemin Village District with the insufficient water infrastructure to be the main *vulnerability* factor for livestock owners. The communities reported lack of irrigated land for fodder, which is usually bought from other villages and the Chüy Region. Barley, wheat, clover, potatoes, beetroot are all not enough for self-sufficiency as the communities see the water supply getting unreliable. When discussing the *exposed* system of water supply, the communities stressed the need for additional irrigation channels to direct additional water streams to the irrigated land in the villages and their surroundings.

The *key risk* of heat-exacerbated incidents of livestock diseases due to high disease transmission and lack of veterinarian measures was assessed as ‘Moderate’ by the communities without being further discussed.

Similarly to Suusamyr, the Chong Kemin Village District was found to include communities with no dependence on remittances. Chong Kemin reported a well-developed tourism sector (guesthouses and handicrafts) and an interest to further develop to this direction, as well as an engagement with arable land, fish farming and sewing activities that despite the limited economic contribution in comparison to livestock breeding illustrate a degree of livelihood diversification. Here, the missing alternatives for savings, which adds to the ***vulnerability*** of the communities to the overall risk was explicitly mentioned and it seems to connect to a lack of confidence into commercial banks but also to some cultural aspects: *“We feel uncomfortable if we don’t see livestock around us in the village, that’s why we don’t put money in the bank and increase our livestock instead”*.

Potential future situation (up to 2050)

Hazard: Located in the Lowland warmest summer climate class, the Chong Kemin Village District is expected to be particularly prone to drought spells considering the further increasing temperatures. On the other hand, overall precipitation will still be above average compared to the other regions.

Intermediate impact: Similar with the ‘potential future situation’ for all the Village Districts, see section 5.2.1.

Exposure: Livestock numbers are increasing in Chong Kemin with an increase rate of around 3% per year and thus the exposure to the risk is expected to increase in the future.

Vulnerability: In Chong Kemin, the highly glacierised catchment could mean low vulnerability to drought in the short-term, if appropriate water infrastructure is in place to exploit the runoff. If overgrazing and inappropriate pasture management proceed, the risk of pasture degradation will most likely be aggravated and expanded in space for Chong Kemin. According to the communities, a corral and settlements for the herders in the summer pasture could permit an earlier in the year use of the summer pasture and decrease the vulnerability to pasture degradation of the winter pasture in the future. Vulnerability to the key risk of lack of fodder and food production is likely to increase in the future if no investments are done in water infrastructure. The lack of water infrastructure seems to be limiting also the opportunities for further livelihood diversification in the future increasing the vulnerability of the communities to the risk. The communities expressed their interest in apple, blackberry and raspberry orchards that could be potentially supported with novel water infrastructure: *“Kemin used to be popular with potatoes and we had potatoes as branded products. We could do the same with apples if we use a dropping irrigation system.”* Similarly to Suusamyr, women support the further development of sewing workshops but more marketing support is needed to understand the different livelihood options. Finally, the imports of livestock from abroad will most probably increase and the sharing of pastures among Village Districts will intensify, signifying a potential increase in the vulnerability to heat-exacerbated livestock diseases. However, we do not have enough information to confidently assess this future vulnerability for Chong Kemin.

Box 6. Risk of loss of livelihoods for livestock owners due to drought and raising temperatures and Human-Wildlife conflict in the Chong Kemin Village District

In Chong Kemin depredation was reported by wolves, jackals, less by snow leopards and lynx. Chong Kemin reported that there is interaction between wildlife and livestock in the pastures, and they mostly result in wolves' attacks. The local community-based conservancy is working successfully and the number of wildlife has increased in the area with ***vulnerability*** due to poaching to be limited.

5.3 Comprehensive Risk Assessments per Village District

This section presents Comprehensive Risk Assessment tables per Village District according to the method described in section 3.2.1. The climate-hazard component for drought and heat has been assessed as being similar across the four village districts. As such, it is the exposure and vulnerability components that differentiate the risk per village district. In what follows, the Comprehensive Risk Assessment tables are presented (Tables 8-11) followed by main explanations and justifications on the choices made organised according to the concepts in the rows of the table.

Tables per Village District

Risk of loss of livelihoods (income, subsistence) for livestock owners in Bel-Aldy Village District

	Current situation			**Future (2030-2050)**		
	Pasture degradation (drought/low soil moisture)	Lack of fodder (drought/lack of surface water)	Increased incidents of livestock diseases (heat)	Pasture degradation (drought/soil moisture)	Lack of fodder (drought/lack of surface water)	Increased incidents of livestock diseases (heat)
Hazard	High	High	Moderate	Very high	Very high	High
Exposure	Moderate	Moderate	Moderate	High	High	High
Vulnerability -Exposed systems	Moderate	High	High	High	Very high	Very high
- Community	Moderate			Moderate		
Risk	Moderate	High	Moderate	High	High	High
Risk assessed by the communities	Very high	Moderate	Moderate	Very high	Very high	Very high
Confidence of assessment	Moderate			Moderate – Low		
Critical settings	Small livestock owners with rain-fed or poorly irrigated fields, inefficient irrigation systems, livestock breeding on already degraded pastures without rotation. The future risk depends very much on the further increase in the number of livestock.					

Table 8: Comprehensive Risk Assessment for Bel-Aldy Village District

Risk of loss of livelihoods (income, subsistence) for livestock owners in Suusamyr Village District

	Current situation			**Future (2030-2050)**		
	Pasture degradation (drought/low soil moisture)	Lack of fodder (drought/lack of surface water)	Increased incidents of livestock diseases (heat)	Pasture degradation (drought/soil moisture)	Lack of fodder (drought/lack of surface water)	Increased incidents of livestock diseases (heat)
Hazard	High	High	Moderate	Very high	Very high	High
Exposure	High	High	High	Very high	Very high	Very high
Vulnerability - Exposed systems	Moderate	Moderate	Moderate	High	High	High
- Community	High			High		
Risk	High	High	High	Very high	Very high	High
Risk assessed by the communities	Low/ Moderate/ Very high	Low / Very high	Moderate	Moderate/ High/ Very high	Very high	Very high
Confidence of assessment	Moderate – Low			Moderate		
Critical settings	Small livestock owners with rain-fed or poorly irrigated fields, inefficient irrigation systems, livestock breeding on already degraded pastures without rotation. The future risk depends very much on the further increase in the number of livestock.					

Table 9: Comprehensive Risk Assessment for Suusamyr Village District

Risk of loss of livelihoods (income, subsistence) for livestock owners in Ibraimov Village District

	Current situation			**Future (2030-2050)**		
	Pasture degradation (drought/low soil moisture)	Lack of fodder (drought/lack of surface water)	Increased incidents of livestock diseases (heat)	Pasture degradation (drought/soil moisture)	Lack of fodder (drought/lack of surface water)	Increased incidents of livestock diseases (heat)
Hazard	High	High	Moderate	Very high	Very high	High
Exposure	Moderate	Moderate	Moderate	High	High	High
Vulnerability - Exposed systems	High	Moderate	Moderate	Very high	High	High
- Community	Moderate			Moderate		
Risk	High	Moderate	Moderate	High	High	High

Risk assessed by the communities	Very high	High	Moderate	Very high	Very high	Very high
Confidence of assessment	Moderate			Moderate-Low		
Critical settings	Small livestock owners with rain-fed or poorly irrigated fields, inefficient irrigation systems, livestock breeding on already degraded pastures without rotation. The future risk depends very much on the further increase in the number of livestock.					

Table 10: Comprehensive Risk Assessment for Ibraimov Village District

Risk of loss of livelihoods (income, subsistence) for livestock owners in Chong Kemin Village District

	Current situation			**Future (2030-2050)**		
	Pasture degradation (drought/low soil moisture)	Lack of fodder (drought /lack of surface water)	Increased incidents of livestock diseases (heat)	Pasture degradation (drought/soil moisture)	Lack of fodder (drought/lack of surface water)	Increased incidents of livestock diseases (heat)
Hazard	High	High	Moderate	Very high	Very high	High
Exposure	Moderate	Moderat	Moderate	Moderate	Moderate	Moderate
Vulnerability -Exposed systems	Moderate	Moderate	Moderate	High	High	High
- Community	Low			Low		
Risk	Moderate	Moderate	Moderate	High	High	Moderate
Risk assessed by the communities	Very high	High	Moderate	Very high	Very high	Very high
Confidence of assessment	Moderate			Moderate – Low		
Critical settings	Small livestock owners with rain-fed or poorly irrigated fields, inefficient irrigation systems, livestock breeding on already degraded pastures without rotation. The future risk depends very much on the further increase in the number of livestock.					

Table 11: Comprehensive Risk Assessment for Chong Kemin Village District

Hazard

In all Village Districts, drought as a hazard is rated as 'high' both for pasture degradation and lack of fodder, while heat's impact on incidents of livestock diseases is rated as 'moderate'. In the future, these hazards are expected to be more severe, making the future hazards' rates 'very high' and 'high' respectively.

Exposure (current situation): For all the three key risks exposure is assessed based on the number of livestock. With more than 70,000 livestock the exposure of Suusamyr to all key risks is assessed as 'high'. For Bel-Aldy (10,000 plus reported livestock), Ibraimov (12,000 plus reported livestock), and Chong Kemin (15,000 plus reported livestock) exposure is assessed as 'moderate'. Considering the increasing numbers of livestock, future exposure is assessed as 'very high' for Suusamyr, 'high' for Bel-Aldy and Ibraimov. With a much lower livestock increase rate for Chong Kemin, exposure is assessed as 'moderate' for the future.

Vulnerability (current situation)

For the key risk of 'pasture degradation due to drought', vulnerability was assessed based on information on pasture management (including number of livestock, pasture degradation, pasture dependence and pasture committee's role). All the Village Districts reported insufficient pasture management, which however seems sufficient to sustain the system in its current state and without still expanding to the good quality remote pastures that can be seen as a 'buffer'. Thus, in the Bel-Aldy, Suusamyr and Chong Kemin Village Districts, the vulnerability to the key risk of pasture degradation was rated as 'moderate'. On the other hand, the Ibraimov Village District seems to have reached a limit when it comes to the degradation and capacity of the nearby pastures and is already expanding to the remote pastures, which for years were remaining under-used and are partly overlapping with a community-managed conservation area. Because of this, the vulnerability of Ibraimov is rated as 'high'. In the absence of adaptation actions, vulnerability is expected to be 'high' for Bel-Aldy, Suusamyr and Chong Kemin and 'very high' for the Ibraimov Village District.

For the key risk of 'lack of fodder due to drought', vulnerability was assessed based on the existence and quality of water infrastructure as well as the availability of natural resources – especially the missing presence of glacier within the catchment but also taking into account the Village District's dependence on arable land. In the Bel-Aldy Village District, the poor water infrastructure and the direct dependence on rain and snowmelt together with the absence of glacier result in the need to mobilise the remittances for the lack of fodder and thus a 'high' vulnerability to lack of fodder. The rest of the Village Districts have also reported poor water infrastructure and limited arable land that increases the vulnerability to lack of fodder due to drought but they can sustain a much higher number of animals and are self-sufficient (i.e., Suusamyr), have access to certain infrastructure (i.e., reservoir in Ibraimov) or access to important area of glacier (i.e., Chong Kemin). Because of this, the vulnerability of Suusamyr, Ibraimov and Chong Kemin is assessed as 'moderate'. In the absence of adaptation actions, vulnerability is expected to be 'very high' for Bel-Aldy and 'high' for Suusamyr, Ibraimov and Chong Kemin.

For the key risk of 'increased incidents of livestock diseases due to heat', vulnerability was assessed based on the communities' reports on the extent of the problem, (lack of) vaccinations and certifications, and cases of pasture sharing among villages, which leads to higher vulnerability to livestock diseases. In the Bel-Aldy Village District, the reported lack of vaccinations and certifications, as well as the corruption around the management of livestock health result in a 'high' vulnerability to livestock diseases. The vulnerability of Suusamyr, Ibraimov and Chong Kemin to livestock diseases is assessed as 'moderate'. In Suusamyr and Ibraimov Village District, the situation was characterized as 'under control', while in Chong Kemin the specific key risk was identified more as a future rather than current challenge. For the future, with the increasing aridity, assuming a dynamic market in terms of import, and further pasture sharing among the Village Districts vulnerability is expected to increase for all Village Districts.

The overall vulnerability of the communities to all the key risks depends not only in the vulnerability of the most directly exposed elements (livestock) but also on the livelihood diversification and quality of life per Village District. We assume that a higher livelihood diversification reduces the vulnerability of the communities to the risk of loss of livelihoods for all the key risks as it adds to their economic resilience. We also consider that remittances add to the livelihood diversification, but they also reflect a certain level of outmigration, which is also important to consider when attempting to assess the economic dynamism and well-being of the population. Based on these, the Chong Kemin Village District was found to include communities with the highest level of livelihood diversification and quality of life, with 'low' vulnerability to the key risks. For the Bel-Aldy and Ibraimov Village Districts, the remittances contribute importantly to livelihood diversification motivating to assess the vulnerability of the communities to the key risks as 'moderate'. The percentage of livelihood diversification is then lower in Suusamyr, which is exclusively dependent on livestock breeding, and thus the vulnerability of the Suusamyr communities to the key risks is rated as 'high'. For the future, we assume the degree of livelihood diversification to remain generally the same across the Village Districts.

Risk (current and future situation)

Moving to the overall risk assessment results in the current situation, the future risk depends very much on the further increase in the number of livestock. As a result, the risk for pasture degradation and lack of fodder for the future could be in all three villages either high or very high. The Bel-Aldy Village District is in 'high risk' in terms of lack of fodder due to drought and 'moderate' risk in terms of pasture degradation and heat-exacerbated livestock diseases. For the future Bel-Aldy ranks high for all the key risks. The Suusamyr Village District is in 'high risk' for all the current key risks and in 'very high' risk for pasture degradation and lack of fodder in the future, while remains at 'high risk' for heat-exacerbated livestock diseases. The Ibraimov Village District is in 'high risk' in terms of pasture degradation due to drought but moderate risk when it comes to the other two key risks. For Ibraimov all future key risks are assessed as 'high'. The Chong Kemin Village District is currently in 'moderate risk' in terms of all the three key risks. In the future, Chong Kemin is in 'high risk' for pasture degradation and lack of fodder and in 'moderate' risk for heat-exacerbated livestock diseases. Future risk will depend on the climate development but to a large extent also on socio-economic development and adaptation actions. Here we assumed that no major adaptation actions will be put in place for the Village Districts under consideration, although in sections 5.2.2-5.2.5 we briefly discuss possible evolutions for the future vulnerability situation per Village District.

Confidence

In general, given the fact that the impact of drought and the implication of heat and dry weather for livestock diseases are already evident and relevant today, but the future development in the number of livestock is generally unclear, overall confidence is assessed as moderate. The differentiations in levels of confidence for the different Village Districts is then based on the divergence between the expert and community risk assessments and the different perceptions reported within the communities. The moderate-low confidence in the risk assessment of the current situation in the Suusamyr Village District reflects the significantly diverse perceptions among the communities' members on the importance of the key risks in the area. The moderate-low confidence in the risk assessment of the future situation in the Bel-Aldy, Ibraimov, Chong Kemin Village District is due to the fact that the communities assessed future risks usually as 'very high', while our assessment concludes in a 'high' future risk. This difference could be because our climate risk assessment has followed a relative approach, comparing – to an extent – the Village Districts.

Critical settings

The small livestock owners with rain-fed or poorly irrigated fields, inefficient irrigation systems, livestock breeding on already degraded pastures without rotation constitute all critical settings across the four visited Village Districts. Although beyond the scope of this climate risk assessment, we should mention here that due to increased inequalities among households in the livestock sector of Kyrgyzstan further work is needed in order to consider a more fine-grained, socially differentiated vulnerability to climate risks going beyond the community level. According to previous report by the SLT on the Central Tian Shan (GSLP, 2017), the distribution of livestock among households is very unequal, which means that increasing livestock numbers may not necessarily lead to improve livelihoods of impoverished people but rather enhance the wealth of already rich households. This can lead to an unequal socio-economic development with certain households more vulnerable to climate risks than others. Additional evidence suggests that wealthier livestock owners in Kyrgyzstan, more closely aligned with the former Soviet *kolkhoz* farming system and their associated power structures, often have a stronger claim over land, even up to the present, which can put them in a less vulnerable position than poorer herders (Karpouzolgou et al., 2020). During the recent water shortages of 2021, local reports highlighted the limited capacity of small livestock owners in accessing water resources in comparison to wealthier owners and small enterprises. Finally, male migration (to Bishkek or abroad) is inducing changes in work patterns with women increasingly involved in agriculture and livestock activities. This high exposure of women together with the fact that women in Kyrgyzstan have been disproportionally impacted by disasters in the past suggest that further research in the gendered vulnerability to climate risk is also required (Kelly et al., 2013).

5.4 Additional community consultations findings

On January and February 2022, SLT conducted two additional community consultations with a similar climate focus and format to the one reported in this document. The first consultation took place in Mantysh village with participants from the Kara-Suu Village District, and the second in Temen-Suu village with participants from the Ak-Suu Village District. The participants were deputies, village leaders, rangers, farmers, herders, veterinarians and others. Both of the Village Districts reported a perceived decrease in water availability that was attributed to glacier retreat, decreased rainfall and increased temperatures in winter, all resulting in overall drier conditions. The participants of the Ak-Suu Village District highlighted that particularly in the last five years they experience less rain and snowfall. In terms of livelihoods, livestock breeding is also here the main economic activity, and the key risks identified concern pasture degradation due to drought and overgrazing, and missing irrigation water for fodder and food production. Based on the findings of these consultations, and after exchanges with partners from SLT, it seems that the findings of the climate risk assessments presented in this document could possibly be reflecting the situation also of other Village Districts in Kyrgyzstan. Considering the physical and social heterogeneity of the project region, more research is needed and any attempt to transfer the conclusions presented in this document should be evaluated on a case-by-case basis.

6 General conclusions and outlook

This document presented the approach, methodological steps and findings of the climate risk assessments for the Tajikistan and Kyrgyzstan project regions and communities under the 'Vanishing Treasures Programme'. These climate risk assessments were developed with a community-centred focus and with the two main objectives of i) promoting sustainable land-use and livelihoods under climate change conditions, while considering 'external' socio-economic drivers, and ii) minimizing conflicts between Snow Leopard conservation and communities' livelihoods in the context of climate change. The climate risk assessments included the analysis of current climate and climate scenarios with focus analyses on heat, drought and snow cover changes, and the identification and assessment of major climate risks for the communities of interest through the application of the Impact Chains analytical framework and approach. To apply this analytical approach and assess each of the risk components and the overall climate risk, we combined quantitative data analyses with qualitative information that has been collected through participatory methods and secondary sources.

In both countries, we identified raising temperatures, seasonal precipitation changes and high precipitation variability as important climate components triggering drought conditions. Our climate analyses showcase a clear trend towards higher temperatures in all seasons in both countries (national and project region level). No clear precipitation deficit trend is observed, and precipitation is mainly found to increase in the future, mainly in winter, which could imply some positive impacts for water reservoirs for summer in the form of snow and ice. However, the increased evapotranspiration due to warmer conditions seems to contribute to a clear trend for more frequent and stronger droughts, especially in spring, summer and autumn, in both project regions. Drought events in the two project regions are expected to be mostly driven by temperature increase and are characterized by cases of earlier snowmelt, glacier retreat, and overall arid summer conditions with less surface runoff and low soil moisture. The agropastoral communities under study in both Tajikistan and Kyrgyzstan are directly depended on snow melt to recharge soil moisture on pasture and on snow melt and glacier melt to created run-off and river discharge, which is important for irrigation in fodder and food production. Thus, this climate risk assessment highlighted as major climate risk for the communities under study in both countries the risk of loss of livelihoods for livestock owners due to drought impact on pasture and missing irrigation water for fodder and food production. In Kyrgyzstan, the key risk of loss of livelihoods for livestock owners due to heat-exacerbated animal disease was also discussed.

While the hazards and their intermediate impacts seem to be generally similar across the two countries for the communities under study, and, except for warming-related ones, possibly not particularly alarming themselves, the vulnerabilities embedded within the exposed systems present certain differences signalling a more complex situation in Kyrgyzstan – as it has also been illustrated in the two Impact Chains (sections 4.2.1 and 5.2.1). In Tajikistan, the remote communities of Barchidev and Ghudara lack employment opportunities and access to market, and rely on subsistence-oriented (thus small-scale – and generally steady in terms of livestock numbers) mixed-mountain agriculture (livestock breeding and irrigated cultivations), remittances and development support amidst a 'limiting' environmental context. Here, the main vulnerability factors contributing to the key risk of pasture degradation are the space limitations and unreliable water supply; the main vulnerability factors contributing to the key risk of lack of fodder and food production are the limited arable land due to the extreme topography of the Bartang Valley and the insufficient water infrastructure. The ability to overcome the winter fodder bottleneck is perhaps the greatest challenge for the communities under study in Tajikistan. Poverty and the low diversity of livelihoods imply high food insecurity and decreased economic resilience because of the interplay of lack of basic income and high dependence on a sole livelihood activity directly influenced by climatic and ecological conditions. Insufficient road infrastructure limits access to markets for selling products but also access to goods and services of paramount importance undermining food security, health and well-being. In Kyrgyzstan, on the other hand, the communities under study rely on a well-established livestock breeding monoculture with the growth-oriented goal to maximize livestock numbers against a fragile socio-ecological system. Here, livestock numbers increase together with human population, living standards, markets prices and demand. Similarly to Tajikistan, an important vulnerability factor contributing to the key risk of lack of fodder and food production is the insufficient water infrastructure and thus the lack of arable land for growing fodder, wheat and vegetables. In fact, the climate risk assessments highlighted for both countries that the absence of water governance and investments in infrastructure development are currently the drivers of a mainly human-induced water stress in the communities under study. Nevertheless, in Kyrgyzstan, the main vulnerability factors contributing to the key risk of pasture degradation are overgrazing and inappropriate pasture management, parameters that were largely absent in the Tajikistan case. The high livestock numbers, together with a decrease in herders' mobility, intense use of pastures without rotation, and a non-sufficient pasture management by immature new institutions with limited enforcement power are all factors greatly contributing to current and future pasture degradation. The intensity and complexity of the livestock sector in Kyrgyzstan brought up the additional key risk of heat-exacerbated livestock diseases with the imports of livestock from abroad, insufficient veterinarian measures, and sharing of pastures being important vulnerability factors. Finally, the livestock breeding monoculture implies a decreased economic resilience because of high dependence on a sole livelihood activity, which is directly influenced by climatic and ecological conditions, while putting substantial and increasing pressure on the environment that sustains it. Similarly to Tajikistan, remittances add to the diversification of the livelihoods decreasing the vulnerability of communities to drought impacts at least in the short term, but they do not seem to be used to generate more sustainable agriculture practices. For both the Tajikistan and Kyrgyzstan cases, the key risks described are expected to be relevant in the future and will probably mostly intensify (especially in the absence of adaptation actions), although possibly also new livelihood opportunities may arise in the higher altitudes.

In terms of human-wildlife conflict, while in Tajikistan the interactions reported between humans and wildlife were rather limited and refer primarily to livestock depredation by wolves in the villages and in the summer pastures, in Kyrgyzstan the situation is again more complex and includes livestock depredation by wild carnivores (including snow leopard); pasture sharing between livestock and wildlife that constitutes snow leopard prey (mainly ibex and argali but also marmot, wild boar and roe deer); and poaching. The extensive ecological footprint of the livestock sector in Kyrgyzstan seems to be already putting pressure on the habitat of wildlife not only because of degradation of pastures currently under use, but also because of what it seems to be a gradual expansion towards more remote pastures – usually in higher elevation and potentially overlapping with wildlife habitat. Here, we highlighted the interesting case of the Ibraimov Village District that potentially showcases a pattern which could become more common in the future for Kyrgyzstan: pasture degradation due to overgrazing and lack of water in the summer pastures 'forced' the Ibraimov Village District to expand to previously under-utilised higher/remote pastures with potential new impacts on the wildlife refuges. Besides the role of overgrazing, herders' and farmers' interactions with snow leopards, its prey and broader wildlife, might increase in the future both in Tajikistan and Kyrgyzstan as communities follow shifting grasslands and croplands upward in elevation due to rising temperatures.

Although it is beyond the scope of this report and of the climate risk assessments presented here, it is worth briefly reflecting on implications of this analysis for identifying and developing adaptation actions. As mentioned above, water infrastructure and governance seem to be key adaptation actions in both countries, necessary to address the current mainly human-induced water stress of the communities under study. Besides, access to clean and safe water is a basic need and human right necessary to ensure the well-being of the communities in both countries. Adaptations through investments in water infrastructure and governance not only would ensure better access to water and water storage reducing current and future vulnerability to the identified climate risk, but would also support the diversification of the communities' livelihoods (e.g., with expansion and investments on arable land). The diversification of the communities' livelihoods is another adaptation option to decrease the vulnerability of the communities to the climate risk and reduce the pressure to the ecological systems that sustain their livelihoods. In Tajikistan, the remoteness of the communities seems to restrict other development opportunities; road infrastructure and accessibility to basic products and services should be improved (always with respect to local values and culture), especially considering the multi-hazard context of the Bartang Valley that threatens provisioning in contexts of food insecurity or urgent need for healthcare. Moreover, both our fieldwork and the literature reveal that Bartangis are characterized by a strong social capital expressed in collective voluntary action (e.g., to build or repair infrastructure), village-based solidarity funds (e.g., for health emergencies), and place attachment. This attribute of the communities should be acknowledged and supported so as to contribute in strengthening adaptive capacity and decreasing community vulnerability to drought impacts (Blondin, 2020). In Kyrgyzstan, while reducing the number of livestock through livelihood diversification seems a valid adaptation option in cases or an imposed necessity in cases, this still seems difficult to be achieved considering the profitability and the long tradition of the sector. A renewed pasture planning through inclusive pasture governance processes at the local level is certainly needed and might be a more substantial adaptation action in the short term. Additional infrastructure such as roads and corrals that could motivate the use of the remote pastures could possibly contribute to balance the grazing pressure but this has to be considered together with a sustainable pasture management plan, aligned with conservation efforts. In any case, any adaptation action should be considered both in the climate risk context and within the framework of sustainable development, including biodiversity conservation. Oversimplified approaches building on direct causal explanations (between e.g., high livestock numbers and pasture degradation) have limited instructive value and should be avoided. In this document, we have highlighted the complexity of the climate risk and vulnerability contexts in the two project regions and we stress that particular attentiveness is needed when considering adaptation actions: it is necessary to take into account interactions, feedbacks, multiple scales and the possibly redistribution or unequal decrease of vulnerability across space, society and species, as well as to consider issues of development as closely intertwined with climate change risks.

To conclude, as mentioned in the introduction, we believe that the climate risk assessment approach and the methods presented in this report could be useful and could guide future climate risk assessments in the same or other challenging mountainous contexts. In the 'critical settings' of the Comprehensive Risk Assessments (sections 4.3 and 5.3), we have highlighted the need for further research to consider a more fine-grained, socially differentiated vulnerability to climate risks going beyond the community level. It seems that both in Tajikistan and Kyrgyzstan poorer households are characterized by decreased mobility; in Kyrgyzstan, historical power structures and path-dependency seem to condition access to land; in both countries, male migration in search for remittances reconfigures women's roles and increases their exposure to climate risks. All these are issues that should be further investigated as they give rise to different vulnerabilities across households and social groups. Institutional capacities (e.g., pasture committees, water governance) and development challenges in the two project regions should also be further investigated.

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