UNIVERSITY OF CENTRAL ASIA

GRADUATE SCHOOL OF DEVELOPMENT

Mountain Societies Research Institute

2021 Annual Report

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Mountain Societies Research Institute

Annual Report 2021

MSRI Mission

The Mountain Societies Research Institute (MSRI) applies science expertise to study complex earth surface and environmental processes that affect mountain societies. Our interdisciplinary research focuses on improving livelihoods, managing natural resources, mitigating the effects of natural hazards and climate change, and building community resilience in these challenging environments. Headquartered at the Khorog, Tajikistan UCA campus, MSRI staff also teach classes at the undergraduate Earth and Environmental Sciences Department. MSRI is part of University of Central Asia's (UCA's) Graduate School of Development.

Mountain Societies Research Institute, University of Central Asia
Office in Tajikistan:
155 Qimatsho Imatshoev Street, Khorog, GBAO,
Republic of Tajikistan, 736000

Office in Kyrgyzstan:
138 Toktogul Street, Bishkek,
Kyrgyz Republic, 720001

www.msri.ucentralasia.org

Photo credits
On the cover (front): Sediment sampling in Muk Su river, Vaksh Catchment, Tajikistan.
Photo by Arnaud Caiserman.

On the cover (back): Rice fields in the Kara-Darya river basin - one of the most remittance-dependant areas in Jalal-Abad Oblast. Photo by Asel Murzakulova.

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Roy C. Sidle
Director of MSRI
Professor of Earth and Environmental Sciences
University of Central Asia

Director's Message

I am proud to be a part of MSRI as we head into 2022. The MSRI is focusing on important research that will positively impact mountain societies in Central Asia and conducting effective outreach to government agencies, NGOs, citizen groups, and academic institutes in Tajikistan and Kyrgyzstan. We emerge from the difficult times of 2019-2020 as a resilient and relevant team of researchers contributing to the natural resource management, ameliorating land degradation, sustainable water supply issues, key social dynamic questions, climate change adaptation, and cryosphere changes. In my fourth year leading MSRI, I see improved external fund raising, concentration on high-level publications, and a common focus on MSRI's mission and goals. We have made some very positive changes and additions to the MSRI team, and I see these continuing into 2022 and beyond.

Details of MSRI's accomplishments, including funded research projects, publications, invited presentations, short courses, and outreach activities can be found in this report, but the bottom line is that I have seen a remarkable improvement in the last few years which bodes well for the future. Several MSRI scientists have also strongly contributed to teaching within University of Central Asia's (UCA's) Earth and Environmental Sciences Department in courses on remote sensing and Geographic Information Systems, Climate Change, Natural Hazards, Hydrology, Environmental Impact Assessment, and Introduction to Earth and Environmental Sciences. When feasible, we have engaged UCA students in our research.

As we look to the future, we see our MSRI team well poised to become the leading mountain research institute within Central Asia. For that, I appreciate everyone's contributions.

Mountain Societies Research Institute

Photo: Azamat Azarov

Central Asia's vast mountain ranges provide 90% of the region's water, are rich in biodiversity and mineral wealth, support the Water Towers of the region, and are home to unique cultural communities that face difficult futures. Many of the natural hazards and related disasters that have always occurred in these mountains are accelerating because of poor land management and climate change. Creating sustainable livelihoods and building community resilience under these conditions is challenging. MSRI's mission is to generate knowledge for practical applications to tackle the myriad of interrelated issues facing mountain communities.

Headquartered at UCA's Khorog campus in Tajikistan, MSRI staff also teach in the undergraduate Earth and Environmental Sciences Department. MSRI also has a significant presence in Bishkek, Kyrgyzstan and a smaller office in Dushanbe, Tajikistan.

Research Areas

MSRI's research expertise and focal areas include:

- Natural hazards and disaster mitigation: hazard risk assessment and modelling, climate change effects; cryosphere hazards; landslides and debris flows; remote sensing applications
- Water supplies and management: climate change impacts on water sources; snow accumulation trends and interannual variability; flood assessment and mitigation; hydrological processes and water sources in cold regions; sediment sources, transport, and impacts
- Natural resources management: food security; climate-smart agriculture; reversing land degradation; biodiversity; soil erosion; reforestation benefits
- Mountain livelihoods and social dynamics: cross-border relations; gender equity; migration; sustainable infrastructure; natural resources governance; value-chain development; climate change adaptation; trans-boundary water issues.

Photo: Asel Murzakulova

MSRI Projects in 2021

Social Dynamics

Societies in Central Asia are experiencing a dynamic period of development. For the majority of residents, labor mobility from villages to urban areas has become a normalized life support practice. This entails multiple changes in land use, nutrition, social differentiation, and changes in the management of natural resources. Regional dynamics of social mobility are also affected by the spatial revision of national borders, which in many respects challenges lifestyles and rebuilds infrastructural connectivity among neighboring countries. Based on interdisciplinary research methods, MSRI contributes to the study of social dynamics at the intersection of interactions among societies, natural processes, and institutional changes. We help unlock the layers of ongoing social change by embedding our research as a bridge between academic knowledge, applied solutions, and policy interventions.

AGRUMIG 'Leaving Something Behind' - Migration Governance and Agricultural and Rural Change in 'Home' Communities: Comparative Experience from Europe, Asia, and Africa

With 281 million people living outside their country of origin as of 2020, migration plays a key role in reshaping social, economic, and political landscapes of the world. In view of the impact of migration in both sending and receiving countries, the University of Central Asia, MSRI in partnership with project ARGUMIG "Leaving Something Behind" – Migration Governance and Agricultural and Rural Change in "Home" Countries (supported by EU Horizont-2020 Program) has been conducting research on Rural Change and Rural Migration in Kyrgyzstan since 2019.

Kyrgyzstan is one of the most remittance-dependent countries in the world, where 30% of country's GDP is driven from migrant incomes. These remittances have substantially reduced poverty in Kyrgyzstan from 52% in 2000 to 25% in 2021. Asel Murzakulova, MSRI investigated on the impact of this mass labor migration on transformations in the agrarian sector of Kyrgyzstan.

As part of the research, MSRI researchers have interviewed 304 migrant households in three agro-ecological zones of Naryn, Jalal-Abad, and Batken oblasts. Findings indicate that

migration is a livelihood strategy which is equally important for all categories of farmers in the country. Remittances have significantly impacted the livestock sector. Although livestock investments have increased as remittances are being used by migrant families to purchase farm animals, the natural resource management system is cannot suitably adapt to these changes. Increases in farm animals raises raising concerns of pasture degradation.

Various issues are linked with migration, and thus it should be analyzed from a broader perspective. Migration leads to significant changes in food consumption; more carbohydrates and meat products are consumed in migrant households compared to fruits and vegetables. Ultimately this affects family health and quality of life. One of the many expected outputs of this project includes establishment of a positive migration philosophy, whereby evidence-based government solutions will be proposed based on tangible indicators and comparative analysis of agro-livelihood systems.

More information at: https://agrumig.iwmi.org/.

Development of Methodology for Mountainous Farming Systems Classification: Case Study of Tien Shan Mountains, Kyrgyzstan

In the mountainous regions of Kyrgyzstan, most of the local population is engaged in agropastoralism. The prevailing agricultural production systems consisting of smallholder family-based farms focus on raising livestock, which depends on fodder production and pastures around settlements and summer pastures in the uplands. These small-scale farms face problems of insufficient fodder production during winter along with pasture degradation due to overgrazing, resulting in poor animal health, reduced efficiency, and lower livestock productivity. This, in turn, has a negative impact on profitability and family income. Understanding the farm production system is crucial to implement interventions that contribute to improved crop and animal productivity and sustainable pasture management.

The study developed an appropriate and robust classification methodology to characterize and identify prevailing farming systems in lower and middle elevation mountains to ultimately assess sustainable development pathways. Data collected from 235 farms in 50 mountain villages of Chuy and Naryn provinces were analyzed by stepwise selection of classification parameters using multivariate analysis for farm delineation and subsequent farm typology. The analysis revealed two distinct mixed crop-livestock farming systems based on their socio-economic and agroecological characteristics. Recommendations to support agricultural development and sustainability in these two farming systems were developed. This classification methodology has advantages over traditional typologies based on farm size and legal status because the latter does not consider the diversity among size classes and ignores agroecological conditions as well as the socio-economic status of the farms.

These findings will benefit policymakers and development practitioners in efforts to promote rural development of mountain regions that will alleviate current socio-economic disparities. Such a classification approach can be adopted in similar mountain regions of Central Asia. Results of this research were submitted to a scientific journal in autumn 2021.

Photo: Roy Sidle

Land Degradation

Throughout rural areas of Central Asia, land degradation is a major concern affecting current agricultural and forest production by taking extensive land out of production or significantly decreasing productivity. Legacies of poor land management have contributed to land degradation with some drier regions on the brink of desertification. These unsustainable practices range from overgrazing, improper cultivation of erodible soils, poor irrigation practices, and inadequate planning of rural roads and trails. Land degradation is also affected by climate change, with extensive regions in Afghanistan experiencing prolonged droughts. As such, many areas of Central Asia are suffering from land degradation attributable to legacies of poor management practices. MSRI focuses our efforts on reversing these land degradation legacies by adapting more sustainable land use practices based on solid scientific concepts and remediation measures.

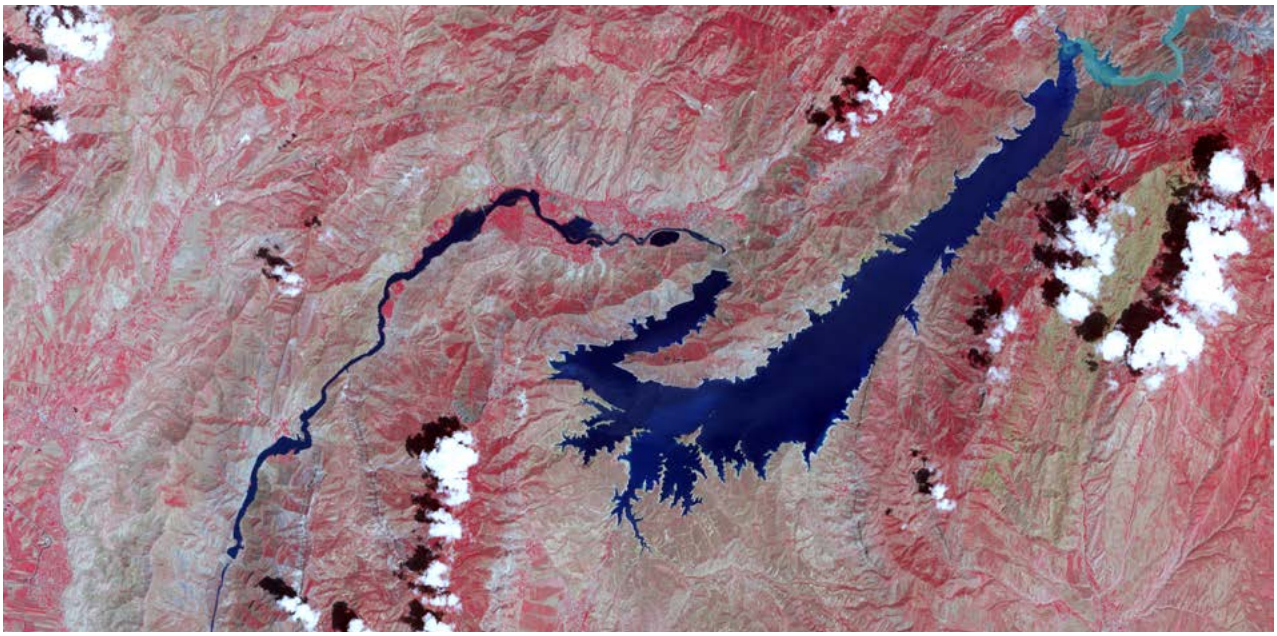
MSRI has been working on several World Bank funded projects in the Pamir-Alay range in northern Tajikistan where extensive gully, surface, and landslide erosion are contributing significant sediment loads within the Vakhsh River system. Some of this sediment is emanating from agricultural cropland and overgrazed areas. Our challenge is to better understand the relative sources of this sediment and the interactions with land use so that more sustainable land management practices can be implemented to reverse degradation trends. Not only is much productive land being lost, but these sediments pose huge issues for the large hydropower projects downstream in the Vakhsh River. Preliminary findings indicate that while that poor land management is contributing some sediment to the Vakhsh River system, much of the landslide and gully erosion is occurring in deep erodible glacial deposits.

Mapping and Valuing Ecosystems Services and Prioritizing Investments in Select Watersheds in Tajikistan to Support Sustainable Hydropower and Catchment Characterization in the Vakhsh Basin Upstream of Nurek Reservoir, Tajikistan

Two projects funded by the World Bank: *Mapping and Valuing Ecosystems Services and Prioritizing Investments in Select Watersheds in Tajikistan to Support Sustainable Hydropower & Catchment Characterization in the Vakhsh Basin Upstream of Nurek Reservoir, Tajikistan* were undertaken by MSRI in 2021. These studies concentrated on hydrogeomorphic processes in the Vakhsh Basin. The numerous dams on the Vakhsh River generate much of Tajikistan's electricity. MSRI examined sedimentation sources and transport related to the Rogun Dam reservoir. Sedimentation is the primary factor that reduces hydropower generation capacity of dams and is transported by runoff from poorly vegetated terrain to tributaries of the river discharge before settling in reservoirs such as Rogun and Nurek. Mass wasting (e.g., landslides, debris flows, dry ravel) and deep gully erosion contribute the highest sediment loads, often directly to channels.

To better understand these phenomena, MSRI collected water samples at various locations upstream of Rogun dam for two consecutive years. In Spring 2021, collected samples were sent to the laboratory at University of Central Asia, Khorog, where they filtered to assess suspended sediment loads. Moreover, a comprehensive field study was conducted by an MSRI team to examine sediment sources and collect sediment samples. During summer 2021, the team travelled upstream of two major tributaries, the Surkhob and Obikhingu, to collect sediment source samples. Chemical analysis of these samples is being conducted on these source samples by our project partner, Griffith University, Australia, to determine the composition of the sediments related to source. The results will help to better understand sediment sources and target these areas for land management interventions to reduce sediment transport into the Rogun reservoir. At the end of 2021, MSRI produced a comprehensive report of the characteristics of Vakhsh catchment, including land use, geology, hydrology, climate, and geomorphology to better understand the sediment origins.

Photo: NASA



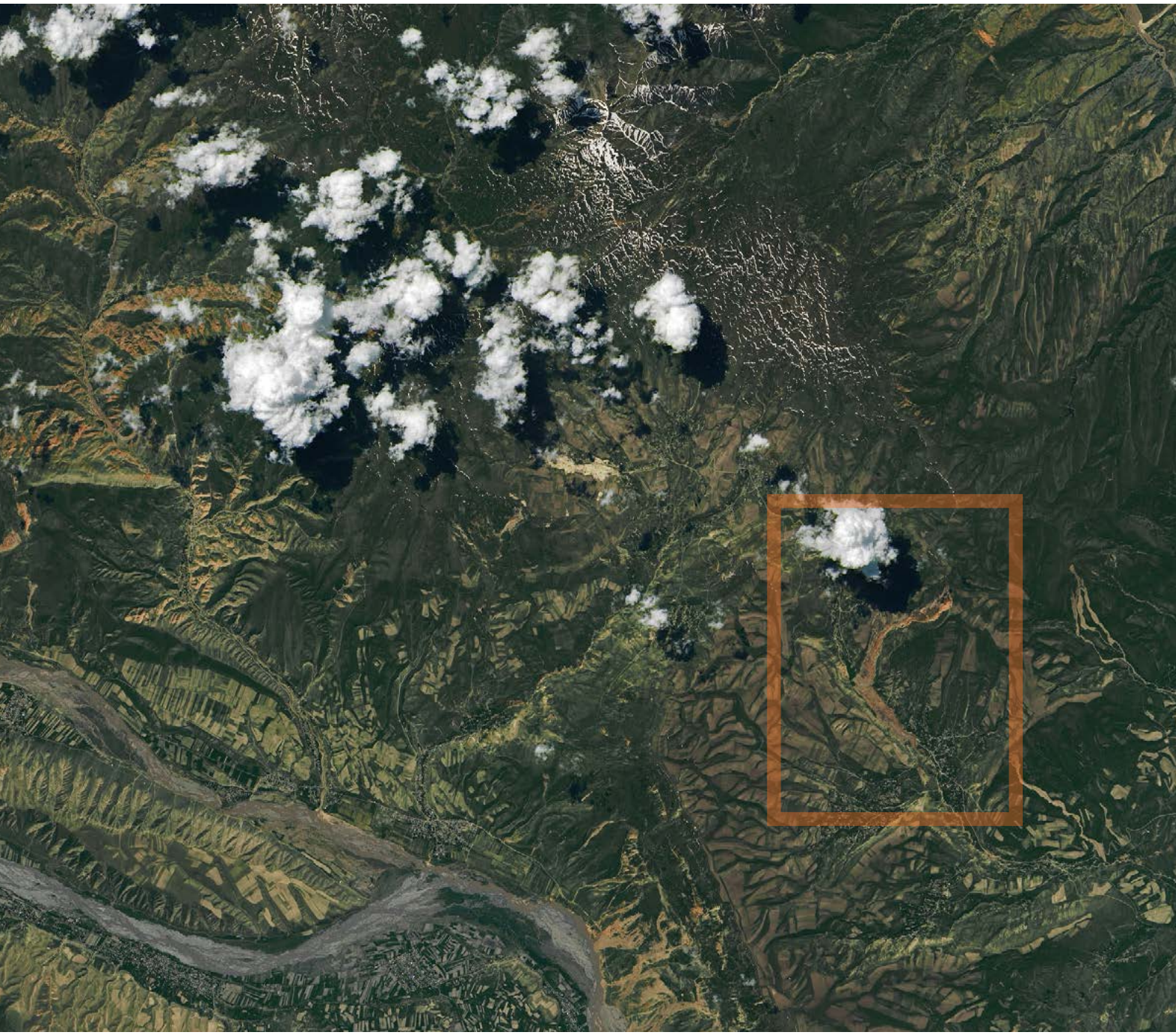


Photo: NASA

Natural Hazards and Disaster Mitigation

Our locations in the heart of the Tien Shan and Pamir underline the important role that natural hazards play on community livelihoods and shaping the landscape. Within a radius of several kilometres, we can see evidence of glacier hazards, snow avalanches, landslides, debris flows, rockfall, and episodic flooding. While these are all natural processes in this tectonically active terrain, many are exacerbated by human activities and climate change. Importantly, many of these hazards become disasters when they impact communities, their resources, and infrastructure. MSRI's research in this domain focuses on understanding the spatial and temporal extent of these hazards and how they intersect with mountain community livelihoods and welfare.

Climate Change Adaptation in Afghanistan (E3C)

Climate Change Adaptation in Afghanistan (E3C), initiated in 2018, is one of the largest projects in MSRI's portfolio. During 2021, MSRI continued implementation of the project with Aga Khan Foundation - Afghanistan (AKF-Afg) with the overall objective to improve resilience to climate change in communities and ecosystems within the Panj-Amu River Basin as well as the sustainability of their beneficial use for rural communities. Substantial work has focused on identifying the scope of Vulnerability Assessment and producing a set of Indicators and Assessment Protocols. Data for the Climate Change Vulnerability Assessment were collected during several field missions in target districts of Afghanistan.

UCA and AKF-Afg, in collaboration with the Wildlife Conservation Society (WCS) organized two capacity building trainings on scientific data collection for vulnerability assessment of ecosystems, biodiversity, and communities in target districts in the Panj Amu River basin. Ten days of training in Ishkashim district, Badakhshan was organized in April and May 2021 with 39 participants attending, including members of AKF-Afg, government officials from Directorate of Agriculture, Irrigation and Livestock (DAIL), officials from the National Environmental Protection Agency (NEPA), and UCA.

Landslides have an important impact on regional agricultural production, food security, economic activity, and other socioeconomic aspects. A basic analysis of landslide risk is needed to assess the socioeconomic factors of villages at risk. Similarly, the development and testing of the methods for assessing the impact and influence of landslides on livelihoods in the region are extremely important tasks. Another objective of the E3C project was to map the areas at risk of landslides in the Amu Panj basin to estimate the vulnerability of communities to this natural hazard. A report was prepared where assessed landslides were classified as rapid and slow, and the relative frequency of both landslide types were assessed related to slope gradient and aspect.

Another hazard that was assessed within the E3C project is snow avalanches in northern Afghanistan. Here MSRI mapped large snow avalanche deposit in the Amu Panj basin. To automatically delineate all large avalanche deposits in the entire basin within a reasonable amount of time, MSRI designed a script that is now available on Google Engine under the following name: Snow Avalanches Frequency Estimation (SAFE). Anyone can freely apply this code wherever avalanches exist; it was specifically designed for remote areas and low power computers since Google Engine enables anyone to use Google super computers. With SAFE, relevant authorities can now map all avalanches that occurred since the early 1990s using Landsat satellite archives and therefore target which villages, power lines, streams, and roads are impacted or blocked by avalanches.

Photo: Aziz Ali Khan

Photo: Maksim Kulikov

Natural Resources Management and Food Security

Residents of rural Central Asia rely heavily on natural resources for their livelihoods. Animal husbandry, agriculture and collection of non-timber forest products comprise the main sources of income for rural residents. These practices underline the importance of protecting and ensuring the sustainability of high mountain pastures, croplands, irrigated lands, and walnut fruit forests. Poor management and overuse have been exhausting these resources, thus human impacts are among the greatest threats. Furthermore, changing climate exacerbates these risks, lending complexity and unknown responses to this multidimensional socio-ecological system and providing increasing threats to food security.

MSRI conducts socio-economic and environmental research to reveal the patterns of human-nature relations and develop policies to solve these critical interactions related to natural resources management. Socio-economic research seeks to understand the income structure of local communities and their behavioral patterns regarding income diversification and preferences at household levels. Additionally, perceptions of climate change and its impact on daily lifestyles is investigated. These include household interviews, statistical analysis, and modelling of economic activities.

MSRI's environmental research investigates natural resources and associated human impacts. These include juniper forests, pastures, and walnut and fruit forests in the south of Kyrgyzstan. Studies revealed the spatial and temporal patterns of vegetation and species composition, as well as their relation to climatic parameters for modelling projected climate change impacts. The research involved field trips for data collection of plant species, their condition, degree of human pressure, and other parameters, including multispectral UAV remote sensing of vegetation. Spatial and temporal statistical analysis, artificial intelligence methods, and modelling supported by data from drones and satellites were used.

Conservation and Research of Wild Fruit Species in Western Tian Shan

This 2-year project in Western Tian Shan, funded by the Critical Ecosystem Partnership Fund (CEPF), initiated in 2021. Two nature protected areas of Kyrgyzstan were identified: Sary-Chelek Biosphere Reserve and Padysha-Ata Nature Reserve along with the Kara-Alma forestry unit. These areas represent the largest populations of Malus niedzwetzkyana, M. sieversii and M. kirghisorum as well as Pyrus korschinsky, which are very rare species, threatened with extinction due to human and climate change impacts. These species are wild ancestors of garden varieties of apples and pears and represent a valuable genetic pool. The project focuses on conservation, population increase, and improved management of these species.

Collection of walnuts and animal husbandry are among the few major income sources for local people, with walnut collection providing the largest and animal husbandry with the second-largest share to household income. This has resulted in overgrazing and selective planting and cutting, contributing to the suppression of natural regeneration and loss of genetic diversity.

The development component of the project is being conducted by our partner institution, Mountain Societies Development Support Programme (MSDSP). The project will directly address the issues of community-based conservation of wild fruit species through implementation of three interventions: i) formation of common interest groups (CIGs) in target communities; ii) propagation of target species and improvement of forest management; and iii) establishing market linkages between CIGs and potential value chain actors to increase household incomes.

The research component employs environmental and socio-economic surveys to understand the ecology of Malus niedzwetzkyana, M. sieversii and Pyrus korschinsky. MSRI assessed species occurrence and mapped tree groups in the forest using field plot surveys and UAV remote sensing. The Padysha-Ata and Sary-Chelek reserves and Kara-Alma forestry unit are covered by the survey to identify the presence of target species. Several field trips were conducted in these target areas with the aim to collect ecological data on the distribution of target tree species, assess human impact on the forest, and collect remotely sensed data using UAV.

A socio-economic survey was conducted to reveal local livelihood strategies and to understand development needs in the project areas. These surveys were conducted where communities have the greatest impact on the forest ecosystems inside protected areas, which represent the greatest populations of target species in the region.

Because of the sparse understanding of wild apples and other forest species, this study explores the role wild apples and other non-timber forest products have in local livelihoods around protected areas and identifies distinct groups of silvopastoral farming systems in these areas based on sets of attributes such as resource capacities, operational and production characteristics, and non-agricultural activities. Characterization of household farms helps to identify specific constraints and opportunities. Based on this, agricultural interventions and policies can be developed that aim to improve livestock production on farm households and reduce negative effects of grazing in the protected forest areas where wild apples and walnut trees grow. To accomplish this objective, MSRI surveyed 220 households in three target villages in summer of 2021.

Photo: Aziz Ali Khan

Crop Yield Forecasting Using Remote Sensing in Tajikistan (RS4CYF)

Monitoring croplands is imperative for crop health status, mapping, estimation of crop acreage, and yield forecasting. Reliable and timely statistics on accurate crop distribution and acreage are not available and are affected by serious discontinuities across most of the countries in Central Asia.

Remote sensing for crop yield forecasting is a project funded by the World Bank under its Agriculture Commercialization Project. The main goal of this project was to design a method and GIS portal for crop mapping and crop yield estimation using non-commercial satellite images and field data. The idea is to introduce remote sensing technology and methods into the Tajik national agriculture sector to facilitate the process of data collection, analysis, and information dissemination amongst local and international stakeholders and to provide up-to-date information and statistics on agriculture land use and crop yields forecasts to key governmental stakeholders prior to end of the agriculture season. This will significantly increase efficiency of data sharing and communication amongst Ministry of Agriculture of Tajikistan (MoA) and other governmental institutions involved in strategical planning related to agriculture and related sectors. An important contribution of the project is the adoption of advanced remote sensing technology, particularly in crop mapping and yield estimation by key actors in agriculture sector such as MoA.

Due to dissected mountain terrain and fragmented crop fields, accurate mapping requires high-resolution imagery. MSRI used 10 m Sentinel-2 data for crop mapping with images available online through the ESA portal in a near-time mode allowing timely access, subsequent crop classification, and yield forecast modelling employing ground data to calibrate results. A remote-sensing based model was developed using Sentinel-2 and SPOT-5 optical imagery, and field data were collected in 2020 for model calibration. Sentinel-2 data are free and have high temporal resolution enabling accurate classification of various crops and crop forecasting. Field data collected from three pilot districts (Shahrinav, Panjakent and Danghara) based on geographic and climatic characteristics enable the application of the developed method to similar regions. Based on the project methodology, a GIS online portal was developed in open-source software (MapServer, QGIS) and installed on the MoA local server. The model end-products such as seasonal cropland maps, agriculture statistics in districts, and crop yield estimates for main economical crops are available on the portal to relevant stakeholders.

As part of the capacity building and knowledge transfer phase, MSRI organized a series of trainings for MoA on GIS and the basics of remote sensing applications in agriculture, as well as the methodology developed to map crop areas and model crop productivity using open satellite imagery. The GIS portal is being tested by MoA and will be fully functional in 2022.

THRIVE Tajikistan: Enhancing Social Services, Governance, and Economic Inclusion in Border Regions

During 2021 MSRI continued working with its three partner institutes, Pamir Biological Institute (PBI), Pamir Agricultural Research Center (PARC), and Kulob Botanical Garden (KBG), to deliver goals of the THRIVE project. PBI completed field work and data collection of different spring and winter wheat varieties in Ishkashim, Tajikistan within the "Promotion of high yielding wheat crops through varietal screening to improve food security in Gorno-Badakhshan Autonomous Oblast (GBAO)" component. The main goal of this project was testing and trials of different spring and winter wheat varieties under specific ecological and climatic conditions in GBAO, and screening the best performing, most promising and disease resistant spring and winter wheat varieties for further proliferation and dissemination among key stakeholders, including local farmers and agriculture extension departments, as well as development NGOs in GBAO. PBI prepared a report based on research results; a scientific article will be submitted in 2022.

KBG is conducting the "Conservation and restoration of unique local wild relatives of local plants" project with the main goal to identify and map availability of wild relatives of fruits in mountains of Shamsiddin Shohin district in the Kulob region of south Tajikistan. Scientific expeditions were conducted along with efforts to conserve genetic resources of local fruit varieties and promote sustainable management of wild relatives of cultivated plants by establishing nurseries. In 2021, KBG organized two seminars for local farmers to attract attention to the impacts of forest clearing and benefits of conserving indigenous fruit trees. Many local varieties of plants and their relatives have the potential to withstand drought, cold, disease, and abiotic effects, thus are valuable sources of genetic material for future breeding and conservation. However, due to agricultural exploitation, intensive use of these natural resources has led to their depletion. Thus, education on conservation and sustainable use of such genetic resources of agrobiodiversity, including their wild relatives, was prioritized in these seminars. KBG distributed trees from established nurseries to local farmers for maintenance of biodiversity.

PARC has continued its project on "The assessment of existing status, future trends, and development of a sustainable yak production strategy to improve rural livelihoods and food security in GBAO, Pamir Tajikistan". This project aims to improve the genetic and productive qualities of Pamir yaks by internal selection, evaluation, and selection of good and high-yielding animals to enhance livelihoods of the local farmers and reduce poverty in Murgab, Tajikistan. In 2021, PARC mainly focused on insemination of local yaks with selected bulls as well collecting data from natural inseminated yaks. This process consists of collecting information on yak pregnancy duration and behavior.

Photo: Azamat Azarov

GEF - Developing the Country Programme Strategy

MSRI continued working on development of the Country strategy document for the Global Environment Facility Small Grants Program (GEF SGP) in Kyrgyzstan in 2021. The final document will guide activities of the Operational Phase – 7 of GEF SGP.

The development of this document included continuous interactions with local stakeholders and national partners to ensure wide representation. The GEF Country Program for Kyrgyzstan was finalized in 2021. The final version of the Program was approved by the donor and circulated to stakeholders at the national level for discussion and comments. Following this, on 16 July 2021, an online meeting took place to formally present and discuss the Program document. Comments from the meeting were incorporated into the final version of the document, translated to Russian, printed, and shared with the donor.

Balancing and Optimization of Multifunctional Use of Juniper Forests in Central Asia (JuniperCA)

With more than 4000 different species, the Pamir-Alay system is considered one of the biodiversity hotspots worldwide. In this context, forest ecosystems play a major role, and juniper forests are a dominate species in mountain regions of Central Asia. Since the beginning of the 20th century, the proportion of wooded areas in Tajikistan and Kyrgyzstan has reportedly decreased and the remaining juniper fragments are not being used sustainably. The forestry sectors of both countries have structural problems that currently do not permit regulated forestry. The aim of this project was to improve the capacities of forest administration and local stakeholders to act sustainably. A detailed investigation of juniper forest systems, including their distribution and use was conducted in Pasrud valley within Zerafshan watershed, Tajikistan.

High resolution satellite imagery with tri-stereo capabilities and in-situ data were used to map juniper forests and estimate forest biomass. Vegetation indices, textural characteristics, and a canopy height model were used as predictors in machine learning models to estimate forest biomass and other relevant attributes. Based on the best fit model, total area covered by juniper forests was mapped and biomass was estimated, including stocking rates and basal area.

The analysis of the social-ecological system revealed that a system of informal resource controls among local communities is largely tolerated by governmental officials. We mapped informal land-use rights of communities and legal requirements of juniper use. Through household interviews and participatory observations, the total use of juniper wood was estimated.

To assess sustainability of growth and use of juniper forests in the region, information on existing wood volume and biomass as well as growth patterns of these forests were needed.

As part of this study, 44 typical juniper forest stands in the Pasrud and Artuch Valleys were inventoried during two field seasons. Characteristic tree and stand data were assessed, tree cores for the determination of age and growth increment were extracted. In addition, stand structures and regeneration development were examined, fifteen sample trees were felled, and cores for diameter and height growth were analysed to generate a basic understanding of the present structure of juniper forests. These insights were used to derive a growth and yield model for single trees as well as to integrate all knowledge gained into a dynamic forest stand model that balances growth and harvest.

A management support system was developed to promote discussions on strategies in forest use policies in Tajikistan and Kyrgyzstan. The model is a time-dependent statistical model, which was applied using an approach that combines dynamic variables. The model components contain equations for stem number and volume, mean diameter at breast height, basal area, stand height, growth, and biomass. The model is adapted to specific site conditions and can accommodate inputs of intervention parameters. It can be used in mapping scenarios and discussing future stand developments. The three components of the model are: (1) a map collection that represents the juniper forest extent and distribution; (2) a simulation environment for specifying intervention and specific simulation run control parameters; and (3) a representation of juniper forest in cells.

As part of the project dissemination phase, an online symposium was held on 8-9 December 2021 in Dushanbe, Bishkek, and Berlin. Representatives from international and local stakeholders, including Tajik and Kyrgyz forest agencies participated to share and discuss project outcomes.

Photo: NASA

Water Resources

Water is undoubtedly the most precious resource in mountainous Central Asia, and whilst it is abundant in many of the mountain areas, the sustainable use of water for agriculture and communities leaves much to be desired. Coupled with local climate changes, many mountain communities are faced with uncertain water futures increasingly affecting livelihoods. Furthermore, sustainable river flows are vital to the large hydropower projects in the region. Given the challenges of providing spatially explicit climate information that controls runoff and streamflow for mountain communities, MSRI is relying on a combination of approaches to tackle this problem. Another important factor affecting water resources that MSRI is investigating the evolving role and importance of glacier and permafrost meltwater contributions to water supplies. Quantifying these sources and dynamics involves a heavy reliance on remotely sensed products that can separate rain and snowfall at granular scales combined with the sparse existing climate and flow records, and strategically positioned data collection with an eye towards developing citizen science participation to achieve better recognition of local issues.

Asia Emerging Opportunities (AEO USAID and Integra)

In late 2021 MSRI launched a project funded by USAID on "Climate Impacts on the water-Food-Energy Nexus due to Changing High Mountain Hydrology in Tajikistan" to address how changes in water supplies and associated runoff affect the production of hydropower and agriculture in Tajikistan. While climate change has been largely implicated in negative impacts on regional water supplies, we have found that 20-year climate trends varied widely across the Pamir of Central Asia. The high elevation glaciated portions of the Vakhsh basin have experienced temperature increases, but these increases appear to be offset by higher snowfall, thus resulting in little change in glacier mass in many areas. Shifts from snow to rainfall are somewhat evident in the central Pamirs due to warming, increasing the vulnerability of water supplies in this dry region. However, in lower elevation areas of the Panj and Vakhsh basins where there are larger-scale agricultural operations, little temperature change has occurred and there has been an overall increase in rainfall, thus potentially benefiting farmers. These early findings underline the importance of examining climate information through a narrower lens, as well as gaining better insights into year-to-year variability of snowfall. To address this latter point, MSRI is implementing a small field study on snow depth and water equivalent near the University of Central Asia campus in Khorog, Tajikistan.

The AEO project initiated in November 2021 and MSRI commenced work on Phase I that includes a national desk review of the studies on water monitoring in Tajikistan by governmental agencies, NGO activities, and academic and institutional research on water issues in the high mountains. USAID-Integra previously implemented a research program in Tajikistan and trained local agencies on snow and ice melt and precipitation contributions to river runoff using the CHARIS model (Contributions to High Asia Runoff from Ice and Snow) supported by remotely sensed data. The initial objective of the AEO project is to assess if and how local or international institutes have used this model after completion of the CHARIS program. To answer this question, a significant literature review was conducted using open-access English and Russian literature and interviews were conducted with relevant stakeholders involved in water monitoring in Tajikistan. The idea behind these reviews and interviews is to assess the status of water monitoring in Tajikistan and to target the gaps. Moreover, agencies involved in water monitoring were questioned on type of remote sensing products or models they use instead of CHARIS. Collected information will be compiled and a report will be submitted to Integra to implement Phase II of the project in 2022. Phase II will involve partnership with local agencies involved in precipitation, snow, and ice melt monitoring in Tajikistan.

Photo: Erkin Isaev

Photo: Erkin Isaev

MSRI hosted events and educational activities in 2021

Online meeting to discuss the final version of the GEF SGP Country Programme Strategy for OP7 Kyrgyzstan, 16 July 2021

MSRI received a grant from the Global Environment Facility Small Grants Programme (GEF SGP) to develop a Country Strategy for the Programme in Kyrgyzstan. As part of this collaboration, MSRI assisted GEF SGP in prioritizing its programme interventions in the country during the Operational Phase-7 of GEF.

During project implementation, the MSRI team met with multiple stakeholders at national and regional levels to collect opinions about activities that the Strategy document should cover. A short promotional video was developed in Russian and Kyrgyz to advertise the Small Grants Programme to local communities and explain the application procedures. Baseline information was collected from scientific publications to inform the strategic document. Furthermore, high-resolution satellite images of protected areas in Osh and Batken provinces, as well as climatic data, were purchased and analysed to add new information. This, together with information from stakeholder interviews formed the basis for the development of the Strategy plan. The draft of the plan in English and Russian was circulated to national and local stakeholders and discussed on 16 July 2021 during an online meeting where participants shared their opinions. Leading NGOs working in nature conservation and rural development were invited, such as UNDP, CAREC, CAIAG, MSDSP, NABU, WWF, Biom, FFI, RDF, Aris, AUCA, SLT, GIZ, Bio-KG, and others. The final document was printed and published electronically to reach all the stakeholders and potential grantees.

UNEP Afghanistan – Tajikistan Study Tour of Upper Catchment of Panj-Amu Darya Basin, 16- 26 August 2021, Khorog, Tajikistan

Photo: UCA

MSRI in collaboration with the UN Environment Programme (UNEP), organized a study tour for experts from Afghanistan and Tajikistan between 16-25 August 2021. The main purpose of this study tour was to develop and strengthen transboundary collaboration and support implementation of the provisions of the

Memorandum of Understanding (MoU) on environmental cooperation between the governments of Afghanistan and Tajikistan in the upper Panj Amu Darya Basin.

This study tour was targeted for mid- to senior level technical officials from Afghanistan and Tajikistan from both central and provincial governments and international organizations working in the region. The participants included specialists in the areas of biodiversity and protected area management, climate change adaptation, landscape and watershed management, water quality, and environmental impact assessment. Both countries were requested to nominate five experts in these topic areas from central and provincial governments. In addition, two members of Wildlife Conservation Society (WCS) Afghanistan and a member of United Nations Development Programme (UNDP) Afghanistan also participated.

More information: https://ucentralasia.org/news/2019/february/current-dynamics-of-the-border-areas.

Geographic Information System (GIS) and Remote Sensing (RS) Training for partner institutes under the THRIVE project, 26-31 August 2021, Khorog, Tajikistan

From 26 to 31 August 2021 MSRI organized a 5-day training for its partner institutes in Khorog, UCA campus. The main purpose of the training was to introduce participants to the use of GIS and RS in the context of thier research. The following topics were covered: develop basic concepts and understanding of GIS, its operation and uses, build capacity of staff members in GIS-based project management, supply background knowledge and understanding of principles of remote sensing, assess remote sensors and systems, and introduce image processing and map generation techniques.

Course on Climate Change and Climate Change Adaptation: Issues in Rural Kyrgyzstan, 3-5 October 2021, Bishkek, Kyrgyzstan

Photo: UCA

MSRI conducted a three-day course for 10 participants from the Mountain Societies Development Support Programme (MSDSP) in Bishkek, Kyrgyzstan on "Climate Change and Climate Change Adaptation: Issues in Rural Kyrgyzstan".

Prof Roy Sidle, Director of MSRI, along with Dr Maksim Kulikov, Dr Erkin Isaev, Dr Asel Murzakulova and Azamat Azarov, Research Fellows at UCA, conducted sessions on a range of topics, such as causes of climate change, earth system responses, uncertainties related to climate change predictions, risks and vulnerabilities, geohazards in Kyrgyzstan, and other related topics. The course also included exercises to understand the application of climate change related research in MSDSP projects.

More information: https://ucentralasia.org/news/2021/december/msri-organizes-course-on-climate-change-for-msdsp.

MSRI signed three Memorandum of Understandings (MoUs) on 12 November 2021 with the Government of Kyrgyzstan

The MoUs signed between the University of Central Asia, Tien Shan High Mountain Scientific Centre of the Institute of Water Problems and Hydropower National Academy of Sciences (TSHMSC), Agency on Hydrometeorology of the State Committee on Ecology and Climate (Kyrgyzhydromet), and the Ministry of Emergency Situations (MES KR), recognize and declare the need to work towards disaster risk reduction, climate change impacts, water management, and glacier degradation. UCA and the institutions of Kyrgyz Government also plan to conduct joint research activities, exchange of staff members, and collaborate in outreach activities.

More information: https://ucentralasia.org/news/2021/november/uca-and-kyrgyz-government-to-conduct-research-on-climate-change.

Teaching undergraduate courses in Earth and Environmental Sciences, UCA, Khorog Campus, Tajikistan

In support of the Department of Earth and Environmental Sciences (EES) of UCA, Roy Sidle, MSRI Director and Ben Jarihani have been teaching courses on Hydrology and Hydrogeology, Natural Hazards, Introduction to Remote Sensing and GIS, Advanced Remote Sensing and GIS, and Science Complexity and Impacts of Climate Change to undergraduate students at UCA. Prof. Sidle also contributed to a course on Environmental Impact Assessment and Introduction to Earth and Environmental Sciences. Both Prof. Sidle and Dr. Jarihani have been actively advancing the EES program curriculum.

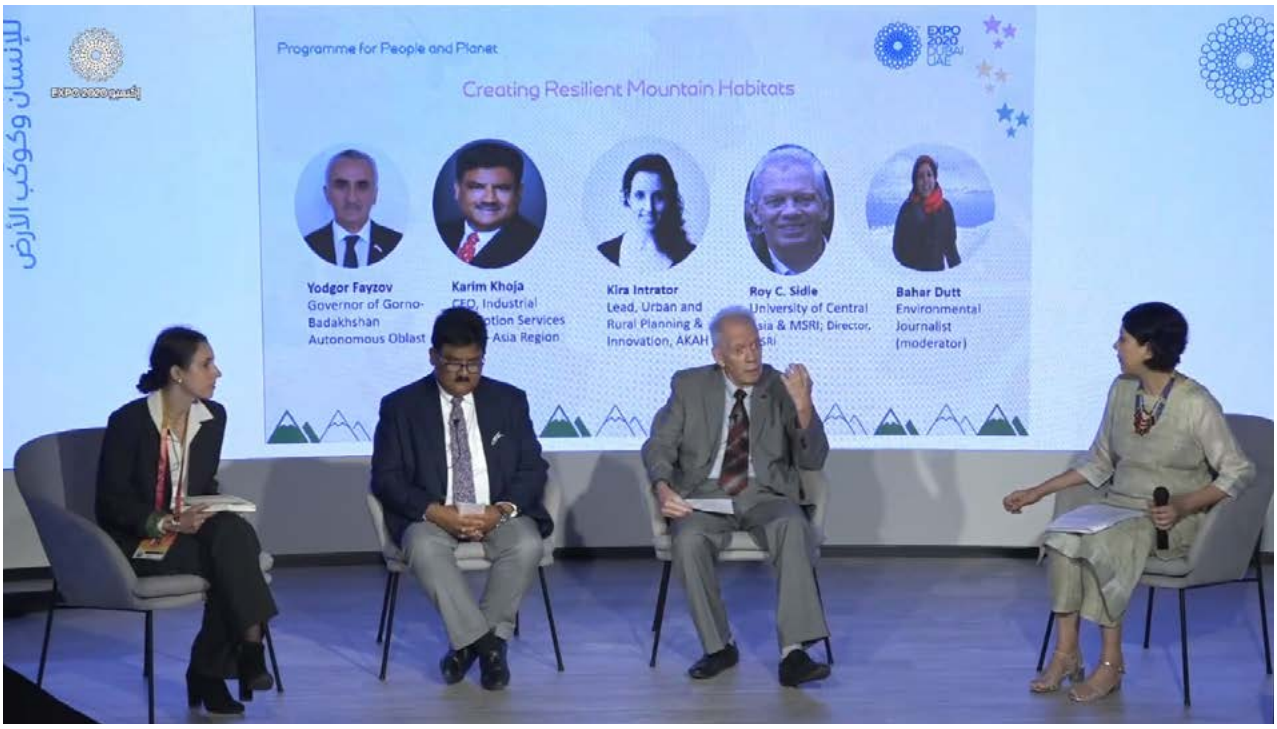


Photo: EXPO / FAO

Conferences & Workshops attended by MSRI staff in 2021

Special Global Innovation Research Seminar on "Dark Clouds Over the Silk Road – Sustainability Issues facing Mountainous Central Asia", 7 January 2021, Tokyo Univ. of Agriculture & Tech., Japan.

Online Presentation on Rural Migration in Kyrgyzstan: dynamics and challenges at the Research Colloquium of the Freie Universität Berlin, Germany, 12 January 2021.

Presentation on "Remote sensing technologies applications for agriculture" at the THRIVE Workshop, Aga Khan Foundation, Tajikistan, February 2021.

Keynote presentation (online) at the 1st TUAT-WISE International Mini-Symposium on Geomorphic Hazards, Tokyo Univ. of Agriculture & Tech. and Japan Soc. of Erosion Control Engr., 9 March 2021.

Online Presentation on "Assessment of the agricultural water budget in southern Iran using Sentinel 2 to Landsat 8 datasets" at the Webinar Series – "Remote Sensing Determination of Evapotranspiration: Algorithms, strengths and weaknesses, uncertainty and best fit-to-purpose" by FAO, March 2021, https://www.fao.org/in-action/water-efficiency-nena/webinars/en/

Online Presentation on "Climate Change in Kyrgyzstan" at the Youth Summit 2021 – Resilient recovery for people and planet Europe and Central Asia Regional Event: Engaging Youth to Increase Resilience to Disaster Risks in ECA, World Bank, 3 June 2021.

Online Presentation on "Emerging Technology: Drone and GIS in Kyrgyzstan" at the DRR: Knowledge Sharing from Youth and Young Professionals on their Innovation for Disaster Risk Reduction, UNESCO, 24 July 2021. https://en.unesco.org/news/toolkit-youth-and-young-professionals-platform-working-drr-using-their-science-engineering

Online Presentation on "Vertical and horizontal accuracy of mid-resolution and globally available Digital Elevation Models: the comparison of Alos-30, Alos-12 and SRTM-30 datasets in the Vakhsh watershed (Tajikistan)" at the Cold Hydrology Session in the Asia Oceania Geosci. Soc. 18th Annual meeting, 1-6 August 2021. https://www.asiaoceania.org/aogs2021/public.asp?page=home.html

Online Presentation on "Hydrodynamic modeling of atmospheric processes over Kyrgyzstan", 2021 ANSO-MISSPAD Annual Symp., Alliance of International Science Organizations, 3 August 2021. http://www.anso.org.cn/index/publications/202108/P020210819616388604295.pdf

Presentation on "Impact of Climate Change on Food Security and Health: Medicinal and Aromatic Plants (MAPs) in the Pamir Region of Tajik and Afghan Badakhshans" at National Conference on Biodiversity of Mountain Ecosystems of the Pamirs Related to Climate Change, Pamir Biological Institute, Khorog, Tajikistan, 6-7 August 2021.

Online Presentation on "Vegetation trend analysis in Batken oblast of Kyrgyzstan", International Geographic Society 2021 International Geographic Congress, Istanbul, Turkey, 16-20 August 2021. https://www.igc2020.org/en/

Presentation on "Hydrodynamic modeling of atmospheric processes over Kyrgyzstan", Summer school and symposium on "Knowledge Transfer and Data Sharing", National Academy of Science of the Kyrgyz Republic and Kyoto University, Kyzyl-Suu, Kyrgyzstan, 20-25 August 2021. http://iwp.kg/?m=202109

Presentation on "Tools for drought monitoring in Batken region", International Seminar "Geopark in Central Asia: areas for geotourism promotion and sustainable management of geological heritage, natural resources and disaster risk reduction", UNESCO, Batken, Kyrgyzstan, 18-21 September 2021. http://en.unesco.kz/new-aspiring-unesco-global-geopark-proposed-to-be-established-in-batken-region-kyrgyzstan

Presentation on "Impact of climate on life of local communities in the Isfara river watershed", Geological Expedition to the Future UNESCO Geopark, Southern Tien Shan, Kyrgyzstan, Bishkek, Kyrgyzstan, 18-20 September 2021. https://geoexplorersclub.com/paleontological-expedition-to-the-future-unesco-geopark-in-kyrgyzstan-august-2021/

Presentation on "COVID-19 impact and rural migrants' resistance cases" at the conference on "The impact of COVID -19 Pandemic on Migration and Migration Governance in Kyrgyzstan", OSCE Academy, Bishkek, Kyrgyzstan, 21 Sept. 2021. https://www.youtube.com/watch?v=xLh2J8qX6y4

Invited member on a panel discussion at Dubai Expo on "Reaching for the Stars: Sustainable and Climate Resilient Mountain Development" organized by the Italian Government, Mountain Partnership Secretariat (FAO), and AKDN. 7 Oct. 2021, United Arab Emirates.

Online Presentation on "Use of ecological calendar to predict climate change in GBAO, Tajikistan", Conference on Rhythms of the Land: Indigenous Knowledge, Science, and Thriving Together in a Changing Climate, Cornell University, USA, 11-13 October 2021. https://cals.cornell.edu/day-2-rhythms-land-indigenous-knowledge-science-and-thriving-together-changing-climate

Invited online lecture on "Landslide Characteristics, Processes, and Land Management Effects", James Cook University, Queensland, Australia, 10 October 2021.

Invited presentation (both in-person and online) at university-wide lecture on "The Water Towers of the Pamirs: climate change and mountain society impacts in Central Asia", Zayed University, UAE, 13 October 2021.

Presentation on "Migration and rural development: Kyrgyzstan case study", INCE Anniversary Conf., National Inst. for Economic Research Moldova, Chisinau, 11-20 October 2021. https://ince.md/en/

Presentation on "Air quality in Bishkek City", Alliance of Kyrgyz Universities for Green Economy and Sustainable Development Conf., AVZUR and GIZ, Bishkek, Kyrgyzstan, 20 October 2021. https://avzur.kg/?p=363

Online Presentation "How labor migration is transforming rural Kyrgyzstan: the experience of a village in the Isfara Valley", Sci. Seminar, Russian Acad. of Sciences, St. Petersburg, Russia, 21 October 2021. http://project1092903.tilda.ws/page22691790.html?fbclid=IwAR3k_wdFp6DeDFCUhiP14B8I2KN1cx8YSmFxy6iMvnyruMweIXW7k1jjRuk

Online Presentation on "Drought detection and modeling in Kyrgyzstan", 7th Annual Life in Kyrgyzstan Conference by UCA, Bishkek, Kyrgyzstan, 26-28 October 2021. https://lifeinkyrgyzstan.org/conferences/lik-conference-2021/

Panel Moderation of Session on "Climate Change: Technologies and Modelling" and Presentation on "Typological characterization of livestock-based farming systems to determine sustainable development pathways in Kyrgyzstan", 7th Annual Life in Kyrgyzstan Conference by UCA, Bishkek, Kyrgyzstan, 26-28 October 2021. https://lifeinkyrgyzstan.org/conferences/lik-conference-2021/

Online Presentation on “Digital Innovations and Challenges in Central Asia”, Water Pavilion at COP26 - Day 5 - Youth and Civil Society, UN Climate Change Conference, IWMI, 5 Nov. 2021. https://www.youtube.com/watch?v=bcnIC1OH44A&t=1s

Presentation on “The contribution of indigenous knowledge of medicinal and aromatic plants and their management to biodiversity conservation in the Pamir region of Tajik and Afghan Badakhshan”, Intl. Conf. on “The role of the education system in the effective solution of problems, protection and rational use of natural resources of the Pamirs”, Khorog, Tajikistan, 10 November 2021.

Presentation on “Biomass estimation of Juniper Forest: Social-ecological aspect of Juniper usage”, JuniperCA Final Symposium, UCA and German collaborators, Dushanbe, Tajikistan, 8-9 December 2021.

Presentation on “Climate Change and Vegetation Response: Looking for Vulnerable and Resilient Areas in Kyrgyzstan”, Climate modelling conference, International University of Kyrgyzstan, Bishkek, 10 December 2021.

Online Presentation on “Climate change impact to disasters in Kyrgyzstan and the ways of monitoring and prediction”, Climate Change and Extreme Event Conf. supported by “Exchanges and cooperation about Eurasian natural disaster reduction between the Earth spheres” Ministry of Education of China, 27 December 2021.

Photo: Muslim Bandishoev

Publications in 2021

Refereed Journal Publications

Asadi, H., et al. "Improving flow discharge-suspended sediment relations: intelligent algorithms versus data separation." *Water* 13, 3650. https://doi.org/10.3390/w13243650. **IF=3.53**

Bradshaw, J. K., et al. "Sediment and fecal indicator bacteria loading in a mixed land use watershed: Contributions from suspended sediment and bedload transport." *Journal of Environmental Quality* vol. 50, no. 3, 2021, https://doi.org/10.1002/jeq2.20166. **IF=3.866**

Caiserman, A., and Ghaleb F. "Spatial variability of evapotranspiration and pressure on groundwater resources: Remote sensing monitoring by crop type in the Bekaa Plain, Lebanon." *Journal of Applied Remote Sensing*, vol. 15, no. 01, 2021, https://doi.org/10.1117/1.jrs.15.014517. **IF=1.695**

Caiserman, A., et al. "Assessment of the agricultural water budget in southern Iran using Sentinel-2 to Landsat-8 datasets." *Journal of Arid Environments,* vol. 188, 2021, p. 104461, https://doi.org/10.1016/j.jaridenv.2021.104461. **IF=2.759**

Hussaini, Sayed M., et al. "Drought tolerant varieties of common beans (Phaseolus Vulgaris) in Central Afghanistan." *Agronomy*, vol. 11, no. 11, 2021, p. 2181., https://doi.org/10.3390/agronomy11112181. **IF=3.949**

Imaizumi, F., and **Roy C. Sidle.** "Effects of terrain on the occurrence of debris flows after forest harvesting." *Geografiska Annaler: Series A, Physical Geography,* 2021, pp. 1–14., https://doi.org/10.1080/04353676.2021.1932482. **IF = 1.391**

Khan, A. A. "Effect and impact of indigenous knowledge on local biodiversity and social resilience in Pamir region of Tajik and Afghan Badakhshan." *Ethnobotany Research and Applications,* vol. 22, 2021, https://doi.org/10.32859/era.22.03.1-26. **IF=1.025**

Khanarmuei, M., et al. "Assessment of an ensemble-based data assimilation system for a shallow estuary." *Estuarine, Coastal and Shelf Science,* vol. 257, 2021, p. 107389., https://doi.org/10.1016/j.ecss.2021.107389. **IF=3.229**

Khanarmuei, M., et al. "Assimilation of GPS-tracked drifter data to improve the Eulerian velocity fields in an estuary." *Estuarine, Coastal and Shelf Science,* vol. 262, 2021, p. 107575., https://doi.org/10.1016/j.ecss.2021.107575. **IF=3.229**

Mardani, Neda, et al. "Lagrangian data assimilation for improving model estimates of velocity fields and residual currents in a tidal estuary." *Applied Sciences,* vol. 11, no. 22, 2021, p. 11006., https://doi.org/10.3390/app112211006. **IF=2.838**

Murzakulova, A., et al. "Examining migration governance: Evidence of rising insecurities due to COVID-19 in China, Ethiopia, Kyrgyzstan, Moldova, Morocco, Nepal and Thailand." *Comparative Migration Studies,* vol. 9, no. 1, 2021, https://doi.org/10.1186/s40878-021-00254-0. **IF=4.417**

Murzakulova, A., "Sensuous nostalgia: insecurity in the borderlands of the Fergana Valley." *Roadsides,* vol. 006, 2021, https://doi.org/10.26034/roadsides-202100607.

Park, S., et al. "Assessing climate change impact on cropland suitability in Kyrgyzstan: Where are potential high-quality cropland and the way to the future." *Agronomy,* vol. 11, no. 8, 2021, p. 1490., https://doi.org/10.3390/agronomy11081490. **IF=3.949**

Raikes, J., et al. "Crisis management: regional approaches to geopolitical crises and natural hazards." *Geographical Research,* vol. 60, no. 1, 2021, pp. 168–178., https://doi.org/10.1111/1745-5871.12503. **IF=2.823**

Sidle, R.C. "Strategies for smarter catchment hydrology models: Incorporating scaling and better process representation." *Geoscience Letters,* vol. 8, no. 1, 2021, https://doi.org/10.1186/s40562-021-00193-9. **IF=4.375**

Vanmaercke, M., et al. "Measuring, modelling and managing gully erosion at large scales: A state of the art." *Earth-Science Reviews,* vol. 218, 2021, p. 103637., https://doi.org/10.1016/j.earscirev.2021.103637. **IF=12.038**

Other:

Arata, Y., et al. "The spatial variability of landslide occurrences and transported sediments induced by the 2018 Hokkaido Eastern Iburi earthquake, Japan." *EGU General Assembly Conference Abstracts.* 2021, https://doi.org/10.5194/egusphere-egu21-16062.

Kulikov, M., and **Zhyldyz Shigaeva.** "SGP Country Programme Strategy for OP7 Kyrgyzstan." Bishkek, 2021.

Murzakulova, A. "The object of Soviet Central Asian history: Canned cucumbers." *Oxford University Online Museum Exhibition,* Oxford University, https://www.cabinet.ox.ac.uk/pickled-cucumbers-kyrgyzstan-0.

Murzakulova, A. "The Soviet water legacy in Central Asia." The Diplomat, 31 Aug. 2021, https://thediplomat.com/2021/08/the-soviet-water-legacy-in-central-asia/.

Murzakulova, A. "Who does not exist in discussions of regionalization in Central Asia? A decolonial critique of the - discourse of integration and regionalization (in Russian)." *Central Asia Analytical Network*, https://www.caa-network.org/archives/22161?fbclid=IwAR1-8 bRkp1KyvcQQV0V3XuthgyovoEbFXXrDfbItGluPU5VkI0LfM6iMs0.

Ritonga, Rasis P., et al. "Does vegetation really affect earthquake-induced landslides? Preliminary analysis of worldwide database." *EGU21-10551,* Copernicus Meetings, 2021, https://doi.org/10.5194/egusphere-egu21-10551.

Ritonga, Rasis P., et al. "Influence of connectivity configurations and moisture on landslide mobility: 2018 Eastern Iburi earthquake Hokkaido, Japan." *AGU Fall Meeting Abstracts,* 2021, https://agu.confex.com/agu/fm21/meetingapp.cgi/Paper/847238.

MSRI Team

Professor Roy Sidle
Director

Hydrology, Natural Hazards, Earth Surface Processes, Environmental Sciences, Sustainability, and Natural Resource Management; research and outreach conducted in six continents; more than 220 papers published in international refereed journals.

Ben Jarihani
Associate Director, Senior Research Scientist

Hydrology, Climate Analysis and Change, Spatial Science, Natural Resources Management. GIS and Remote Sensing.

Asel Murzakulova
Senior Research Fellow

Social Conflicts, Natural Resource Management, and Migration.

Arnaud Caiserman
Postdoctoral Fellow

Land Use Planning, Spatial Analysis, Society and Environment, Vegetation Mapping, Climate Change Adaptation, Evapotranspiration, and Cold Region Hazards.

Azamat Azarov
Research Fellow

Agricultural Economics, Socioeconomics, Microeconomics, and Participatory and Interdisciplinary Research.

Aziz Ali Khan
Research Fellow

Food Security, Livelihoods Improvement, Agriculture, Forestry, Rangelands/Livestock, and Water Resources.

Erkin Isaev
Research Fellow

Spatial Analysis, Physical Geography, Environmental Analysis, Satellite Image Analysis, Satellite Image Processing, Vegetation Mapping, Numerical Modeling, Air Quality, Climate Change, Machine Learning.

Janyl Ismailova
Research Fellow

Information and Communication Technology (ICT) in Education, International Development, and Project Management.

Jyldyz Shigaeva
Research Fellow

Natural Resources Management and Pasture Governance.

Maksim Kulikov
Research Fellow

Biodiversity, Conservation, Natural Resource Management, Plant Ecology, GIS, Landscape and Plant Ecology, Pasture Management, and Land Use Change.

Samat Kalmuratov
Research Fellow of the food security and farming systems

Agricultural Management, Natural Resource Management, Social Economy, and Climate Change.

Elnura Omurbekova
Senior Research Officer & Bishkek Office Manager

Project Management and Administrative Work.

Parviz Nazarov
Postdoctoral Research Fellow

Quaternary Geology, Sedimentology, Geological Processes, Sequence Stratigraphy, Marine Geology, Paleogeography, Engineering Geology, Soil Mechanics, Climate Modelling, Climate Variability.

Aslam Qadamov
Postdoctoral Fellow

Land Use Planning and Management, Spatial Analysis, Satellite Image Analysis, and Vegetation Mapping.

Zulfiqor Khojazoda
Junior Research Fellow

Remote Sensing, Spatial Analysis, Landslides, Glaciology.

Muslim Bandishoev
Remote Sensing & GIS Expert

Remote Sensing, GIS, Mountain Agriculture, Glaciology, Climate Change, Spatial Data Infrastructure, and Disaster Risk Reduction.

Evgenii Shibkov
GIS Research Associate

Cartography, Spatial Analysis, and Remote Sensing

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138 Toktogul Street, Bishkek, 720001
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msri@ucentralasia.org
www.ucentralasia.org

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Coordinator: Janyl Ismailova, UCA
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Mountain Societies Research Institute

Office in Tajikistan:
155 Qimatsho Imatshoev Street, Khorog, GBAO,
Republic of Tajikistan, 736000

Office in Kyrgyzstan:
138 Toktogul Street
Bishkek, 720001
Kyrgyzstan

www.msri.ucentralasia.org