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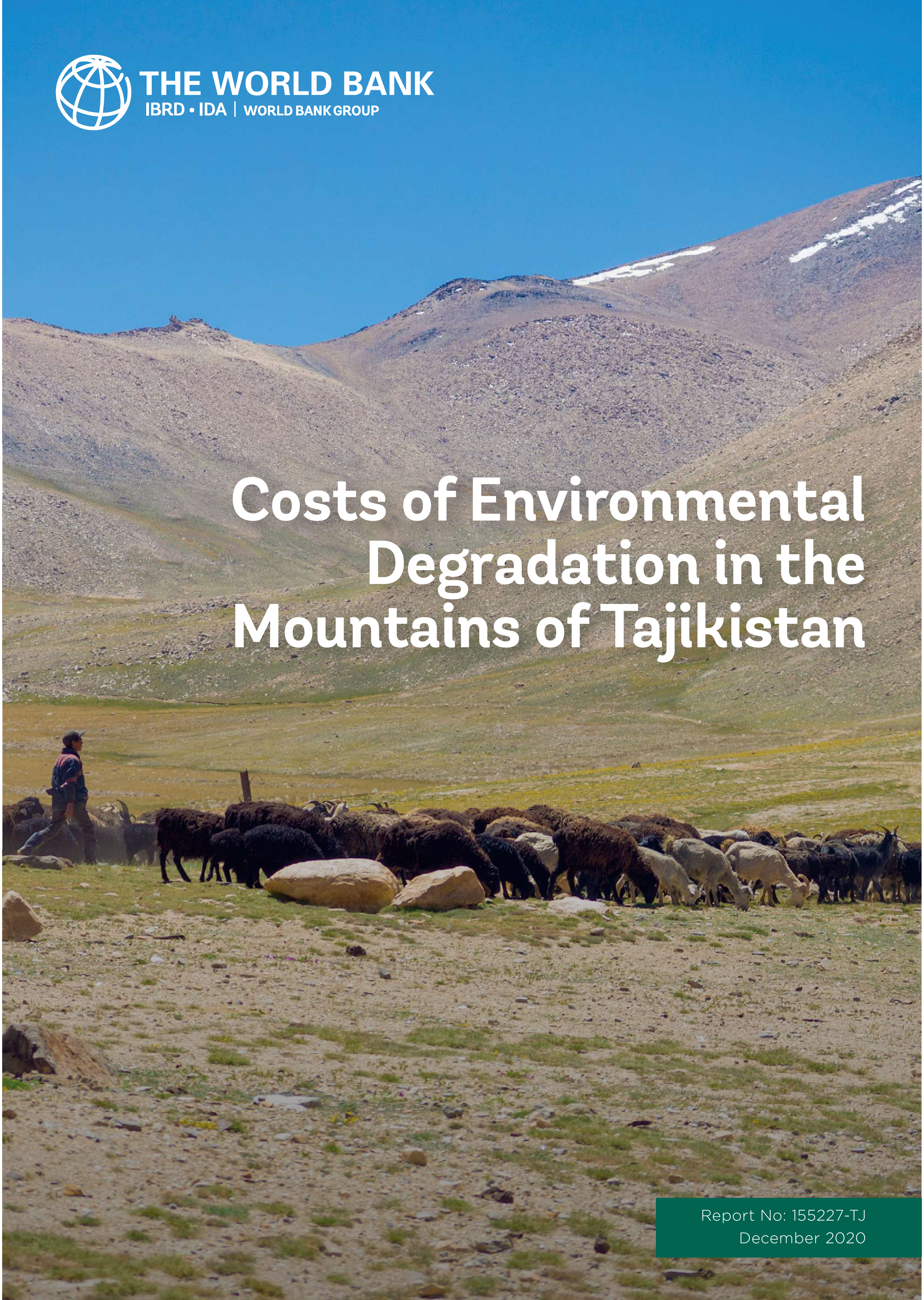
Costs of Environmental Degradation in the Mountains of Tajikistan



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December 2020

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WORLD BANK GROUP
Environment, Natural Resources & Blue Economy

ICARDA
Science for resilient livelihoods in dry areas

T A J I K I S T A N

Costs of Environmental Degradation in the Mountains of Tajikistan

December 2020

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Abbreviations and acronyms

ATT	Average Treatment Effect on the Treated
ATU	Average Treatment Effect on the Untreated
CEP	Committee on Environmental Protection
DRS	Districts of Republican Subordination
ELD	Economics of Land Degradation
ESR	Endogenous Switching Regression
FILM	Full Information Maximum Likelihood
GBAO	Gorno-Badakhshan Autonomous Region
GDP	Gross Domestic Product
ha	hectare
ICARDA	International Centre for Agricultural Research in the Dry Areas
IV	Instrumental Variables
IWWIP	International Winter Wheat Breeding Program
LD	Land Degradation
LDN	Land Degradation Neutrality
LUCC	Land Use and Land Cover Change
MODIS	Moderate Resolution Imaging Spectroradiometer
OLS	Ordinary Least Squares
PSM	Propensity Score Matching
TEC	Total Economic Cost
TAAS	Tajik Academy of Agricultural Sciences
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total Economic Value
TJS	Tajikistan Somoni
UNCCD	United Nations Convention to Combat Desertification
WB	World Bank

Currency equivalents

Exchange rate for 2019 used in calculations

Currency unit = Somoni (TJS)

TJS 1.00 = US$ 0.10

US$ 1.00 = TJS 9.70

Contents

Table of Figures

Table of Tables

Photo Credit: ICARDA / Sanobar Khudaybergenova.

Foreword

Nature has given Tajikistan a precious advantage over its neighbors, earning its name—with 90% of its land being mountainous up to an elevation of 7,495 metres—as the 'roof of the world'. The multi-hued lakes, the western Pamir peaks (that beg to be climbed), and the high passes through the Ferghana valley and the Kuramin range are a sight to behold, enthralling even the most experienced travellers, despite being home to some of the poorest communities in Tajikistan. It comes as no surprise that these natural resources make for a solid foundation for the country's wealth, accounting for 14% of it, in comparison to just 1% in mountainous countries like Switzerland.

Land degradation, soil erosion, and climate change continue to threaten the value of these natural resources, impacting almost all of Tajikistan's land, especially its croplands. These factors are estimated to be responsible for a 3% to 5% loss in GDP in affected countries worldwide and a major contributing factor to low agricultural productivity; they are felt most keenly by the poor, whose livelihood is often dependent on natural resources. This is driven by poor land use practices, including water resource management and irrigation practices, deforestation, and overgrazing. This study fills an important void by helping Tajikistan to value its natural resources at national and subnational levels in order to support a transition towards sustainable development. For the first time, land degradation-induced impacts and losses have been given a human face and a comprehensive economic stocktaking with updated estimates and a consistent methodological approach across crop fields, forests, pastures, as well as in terms of the damage to assets, property, infrastructure, and human health.

This study reveals that the impact of land degradation comes at a heavy price. It highlights the urgency of the matter and confirms the severity of the challenges Tajikistan faces, as well as the fact that the cost of inaction is unacceptably high. Conservative estimates of Tajikistan's total economic cost from land degradation is between US$574 million and US$950 million (equivalent to between 8.1% and 13.4% of GDP or 0.3% of Central Asia's regional GDP in 2019). The major economic cost is related to yield (crop and crop residue) loss in crop lands, including those abandoned or fallowed to regenerate (equivalent to 7.5% of GDP), followed by the cost of land degradation-induced health problems (equivalent to 2.5% of GDP) and biomass loss in natural pastures (equivalent to 1.7% of GDP). The World Bank Environment Natural Resources and Blue Economy practice supports informed decision-making through such analysis and using methodologies based on fundamentals of environmental economics and natural capital accounting. This study illustrates why Tajikistan is in a better position to seize growth opportunities, weigh land degradation costs and climate risks, and identify synergies when they understand the repercussions of policy and investment choices, especially state budget allocations, and are equipped with new evidence and data.

These findings are an opportunity for Tajikistan to shape its response as a leader for managing natural resources and combatting climate change nationally and within the region. This study recognizes that the first steps towards this direction would be to account for these losses in state budget allocations to soil, water, air, health protection, and related sectors in order to implement preventive and mitigative measures so as to avoid the detrimental effects of environmental degradation. A further step would be to reflect these findings and recommendations in the country's National Development Strategy and Government plans and priorities. This would also support us in the planning and implementation of regional and global commitments, especially Astana Resolution and the ECCA30 partnership.

These findings provide decision makers with a new set of analytical tools to address land degradation issues and mainstream climate change adaptation and integrated landscape management into national priorities and investment programs. The World Bank has committed to support interventions through an integrated landscape management approach to avoid deforestation and promote landscape restoration and sustainable forest management across up to 120 million hectares of forests in 50 countries by 2025. The World Bank has also committed to support at least 15 countries that are members of International Development Association to implement or update their National Biodiversity Strategies and Action Plans covering terrestrial and marine biodiversity or similar national action plans.

This study is part of the Central Asia Resilient Landscape Program (RESILAND), the objective of which is to reverse land degradation in the Central Asian countries.

The World Bank, through an integrated landscape approach, helps countries to meet national development objectives, such as reducing poverty and increasing economic growth, while delivering on their global goals and commitments related to forests, biodiversity, and climate change in an integrated and cost-effective manner. The study will serve as basis for the allocation of investments under the new integrated landscape restoration operation to be funded by the World Bank and inform the Regional RESILAND program for Central Asia and help to strengthen further regional analytic tools in line with the Country Partnership Framework for Tajikistan. The World Bank is committed to continuing its support for Tajikistan in order to strengthen the integrated and sustainable management of terrestrial ecosystems in landscapes and corridors, restore degraded lands to improve ecosystem services and implement "nature-smart" interventions in sectors, such as agriculture, to ensure that development does not erode natural capital but instead generates positive forest, ecosystem, and biodiversity outcomes. The World Bank appreciates the continued efforts of development partners in achieving this, and it works in close collaboration to assist the country's vulnerable population groups by improving natural resource management and transitioning to a sustainable development pathway for Tajikistan's economy.

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Acknowledgements

This report was prepared by a team led by Drita Dade, Senior Natural Resources Specialist, with the core team composed of Elena Strukova, Senior Environmental Economist, and Paola Agostini, Lead Natural Resources Specialist, and a team from ICARDA (International Center for Agricultural Research in the Dry Area) led by Yigezu A. Yigezu (Senior Agricultural Economist) and Akmal Akramkhanov (Senior Scientist - Water, Land, Management and Ecosystems). The report was supported through final publication by Leela Raina, Environmental Economist, and consultants, from the World Bank (WB). The team would like to extend their appreciation to Tanzila Ergasheva, Tajik Academy of Agricultural Sciences (TAAS); Abdusalim Juraev, Committee for Environmental Protection (CEP) Tajikistan; and Murodjon Ergashev, CEP, Tajikistan, who contributed to report production through data collection, consultations, and validations. The Ministry of Agriculture, Ministry of Transport, Committee on Environmental Protection, Tajik Academy of Agricultural Sciences, the Soil Science Research Institute, and the Institute of Botany were instrumental in providing feedback, data collection, validation, and overall guidance. This study also benefitted from the valuable insights and comments of Teklu Tesfaye, Senior Agriculture Economist, Jen JungEun Oh, Senior Transport Specialist, Haileyesus Adamtei, Senior Highway Specialist, Klas Sanders, Environmental Economist, and Camilla Sophie Erencin, Environmental Economist. The team would also like to thank Sascha Djumena (Tajikistan Country Program Coordinator, World Bank), Jane Olga Ebinger (Program Leader, World Bank), Jan-Peter Olters (Tajikistan Country Manager, World Bank) and Kseniya Lvovsky (Practice Manager, World Bank) for their encouragement and support.

The World Bank team would like to express its sincere gratitude gratitude to government officials and experts for their insights and generous cooperation during the study. A workshop at launch and one at finalization have helped to shape the design and validate the results of the study. These events were jointly hosted by the Tajik Academy of Agricultural Sciences (TAAS) and the State Committee on Environmental Protection (CEP) of Tajikistan. The workshop brought together 69 delegates from five Central Asian countries and partner organizations, alongside agricultural research organizations, academia, financial and international institutions, non-governmental agencies, and policy makers. The team appreciates the discussion on local and international experiences with regards to environmental degradation and ecosystem services evaluation which have enriched the quality of this publication.

We would especially like to thank our donor partners for this study: PROFOR (Program for Forestry). PROFOR is a multi-donor partnership that provides knowledge, tools, and in-depth analysis to facilitate the contribution of forests to poverty reduction, sustainable economic development, and the protection of global and local environmental services.

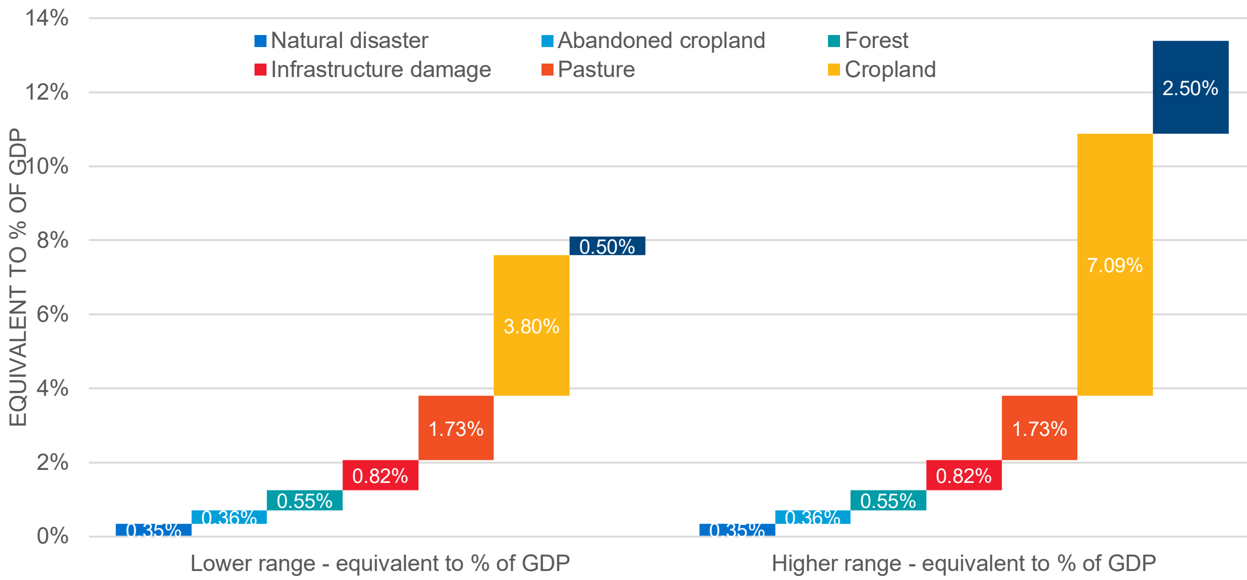
Executive Summary

This report is based on a comprehensive study which attempts to estimate the total economic cost of environmental degradation in Tajikistan. The study covers all major sources of land degradation-induced economic losses and improves on past studies in Tajikistan in several areas: 1) Unlike past studies which were limited either thematically, geographically or in scale, this study provides estimates on all sources of land degradation-induced economic losses, namely: biomass loss in all three biomes (crop lands, forests, and pastures), damages to infrastructure, health problems and natural disasters; 2) It tries to provide province-specific estimates, which were aggregated using the appropriate weights (mostly land area under each biome, or density of infrastructure in each province) that can inform provincial and national governments' policy actions; 3) It tries to develop a theoretically sound and consistent method that can be applied to all dimensions of land degradation-induced losses; 4) The study uses primary survey data to generate new and credible estimates of yield losses in wheat fields which, with some simplifying assumptions, were then used to generate estimates for yield losses in the other crops; 5) The study also uses official statistics and expert estimates on important variables to generate new estimates on some of the components of land degradation-induced losses for where no provincial or national estimates existed; 6) Every effort is made to document all theoretical underpinnings, the procedures and models used, data sources, and simplifying assumptions made during estimations, which are expected to be useful for building on this work in the future. Acknowledging that some of the parameters and assumptions made could be contentious, the report aims at providing a conservative estimate and considers two sets of assumptions to provide a range instead of a point estimate of the total economic cost of land degradation (LD) in Tajikistan.

Methodologically, the calculation of costs involved the use of concepts and methods from bio-physical, environmental agricultural, and socio-economic disciplines. A major methodological and data leap in this study is that an econometric analysis was carried out using primary production data from a representative sample of 690 farm households in Tajikistan in order to generate credible and statistically defendable estimates of the impact of land degradation on wheat yields. A shortage of time and financial resources as well as the unavailability of essential data on some variables has limited the scope of this where costs arising from other sources of loss such as air pollution, water supply, sanitation and hygiene are excluded. However, though important, the total economic losses due to these problems are estimated to be much less than the major causes of economic loss included in this study.

In the areas where credible data and estimates are not available, this study makes all possible attempts to make expert estimates and invoke very conservative assumptions for generating estimates representing the minimum possible cost to Tajikistan. This study estimated the minimum total economic cost of land degradation in Tajikistan in 2019 to be between US$539 million and US$950 million, equivalent to 8.1% and 13.4% of GDP, respectively (Figure 1 and Table 1). These estimates are conservative, and we believe that the actual cost of land degradation in Tajikistan is likely to be much higher. However, even the conservative estimates are high enough to gain the attention of national and international stakeholders. As the lower end of the range is extremely conservative, all the detailed discussions provided in the document focus on the upper bound, which we believe is still low but closer to the reality. The major economic cost is related to yield (crop and crop residue) loss in crop lands including those abandoned or fallowed to regenerate (equivalent to 7.5% of GDP) followed by the cost of land degradation-induced health problems (equivalent to 2.5% of GDP) and biomass loss in natural pastures (equivalent to 1.7% of GDP). Costs related to land degradation-induced damages on infrastructure, loss of woody biomass, and natural disasters constitute costs equivalent to 0.8%, 0.6% and 0.4% of GDP respectively.

Figure 1: Estimated Cost of Environmental Degradation by Category.



The policy implication of these results is that these levels of losses are too high to ignore. Previous studies, both in Tajikistan and in other similar countries, reveal that the cost of inaction is much higher than the cost of action. Left unchecked, the magnitude of land degradation is expected to increase, especially with climate change, and extreme weather events, which will see the cost of inaction rise even further. Therefore, the government of Tajikistan, its national and international development partners, civic societies, and all citizens should join forces in raising awareness about the gravity of the situation and take concerted efforts to prevent further degradation, as well as take mitigative measures to improve the situation.

While the authors are confident that the estimates in this report can be trusted with some level of confidence, and hence can be used for policy decisions, we admit that that the scope and quality of this report was limited by time and the lack of data. Given how important it is to monitor the cost of land degradation, manage its progress and set priorities and develop strategies to mitigate and prevent land degradation, studies such as this one, play a vital role.

However, embarking on such large studies to generate estimates which provide a complete picture thematically, geographically, and in scale, poses major challenges and is too ambitious for a very small project such as this. Without measurement data on various impact indicators, a study such as this can only rely on expert estimates and existing literature to fill the gap, which to a certain extent can reduce the quality and credibility of the resulting estimates. One solution may be to assemble different multi-disciplinary teams of experts to carry out a series of studies, each focusing on just one aspect of the environment. Such studies would take many years and need to be of sufficient depth – and use the best available data and methods – to generate more credible estimates at a provincial level that can be aggregated to a national scale.

Table 1: Summary of Total Economic Cost of Land Degradation in Tajikistan – using conservative parameters and assumptions

Type of value	Estimated costs of environmental degradation per year (Million US$)							
	In all crop lands	In natural forests	In natural pastures	In abandoned crop lands	In the form of land slides	In the form of infrastructure damage	In the form of health problems	Total
1. Use value	267.8	38.0	122.4	25.3	24.5	58.0	35.5	536.0
2. Non-use value	1.5	0.7	0.4	-	-	-	-	2.6
TOTAL	**269.4**	**38.7**	**122.8**	**25.3**	**24.5**	**58.0**	**35.5**	**538.6**
Equivalent to % of GDP	*3.8%*	*0.6%*	*1.7%*	*0.4%*	*0.4%*	*0.8%*	*0.5%*	*8.1%*

Objective of the study

Rural livelihoods in Tajikistan heavily rely on natural resources and the agriculture sector. A large proportion of the rural population depends on agriculture, and weather-related calamities are exerting increasing pressure on natural resources and agricultural sectors – the major contributors to Tajikistan's GDP. The resulting environmental degradation has taken a significant toll on the economic and sustainable development of the country. Despite the significant importance of the issue for Tajikistan's current and future economic growth, the negative effects of environmental degradation are missing from the country's economic analysis and government priorities, and are not considered in its medium-term macro projections. In order to address these concerns, the overall objective of this study is to enhance the understanding of the economic costs of environmental degradation, and to promote improved management and planning at national and subnational levels in Tajikistan.

The specific objectives of this report are three-fold:

a) To provide more complete and updated estimates of the total economic costs of environmental degradation arising from different sources in Tajikistan, using the most recent data available;

b) To provide a theoretically sound and consistent methodological approach (and templates) that can be readily used by experts in national organizations responsible for natural resources management;

c) To provide a basis for decision makers in national organizations (ministries, agencies, institutes) to incorporate the results of this and future studies in policy making.

The available research on the costs of Tajikistan's environmental degradation is outdated (almost a decade old) or focuses on specific aspects of the problem (pastures, arable land, cost of natural disasters, etc). With regards to natural disasters, the research doesn't explicitly link them to environmental degradation. it is important that the Government of Tajikistan has an accurate (to the limits of available data), up-to-date and aggregated on macro level estimate of the total economic costs of environmental degradation. This will inform both the authorities and the public of the costs (direct and alternative) they are paying, and help the government to include environmental degradation measures in future strategic government planning.

Key findings

- Tajikistan is suffering from several types of land degradation-induced problems. This report considers losses in several domains such as: i) agricultural croplands; ii) forests; iii) pastures; iv) infrastructure, such as roads, buildings, facilities; v) human health and vi) destruction of assets, property and infrastructure caused by natural disasters.
- Estimates needed to be inferred and associated to environmental degradation based on the available data and have been made as a result of scientifically justifiable assumptions.

- The primary data available for wheat production provided a good background and a testable dataset in order to estimate biomass losses caused by environmental degradation. Along with some necessary adjustments, the results allowed us to predict the losses in other crops.
- This study estimated the minimum total economic cost of land degradation in Tajikistan in 2019 to be between US$574 and US$950 million, equivalent to 8.1% and 13.4% of the country's GDP, respectively. At the same time, it is acknowledged that these estimates are likely to be much less than the actual value. However, even this conservative estimate is large enough gain the attention of national and international stakeholders.
- The major economic cost is related to yield (crop and crop residue) loss in crop lands including those abandoned or fallowed to regenerate (equivalent to 7.5% of GDP) followed by the cost of degradation-induced health problems (equivalent to 2.5% of GDP) and biomass loss in natural pastures (equivalent to 1.7% of GDP). Costs related to land degradation-induced damages on infrastructure, loss of woody biomass, and natural disasters constitute costs equivalent to 0.8%, 0.6% and 0.4% of GDP respectively.
- The policy implication of these results is that these levels of losses are too high to ignore, particularly when past studies in Tajikistan and other similar countries reveal that the cost of inaction is much higher than the cost of action. Left unchecked, the magnitude of land degradation is expected to increase, especially when climate change, and the resulting extreme weather events are factored in.
- State budget allocations to soil, water, air, health protection and related sectors need to take into account these costs in order to implement preventive and mitigative measures so as to avoid the detrimental effect of environmental degradation losses.

Photo Credit: ICARDA / Sanobar Khudaybergenova

Chapter 1. Introduction

The republics of Central Asia – Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan – face severe challenges in land management with ensuing economic, social, and environmental crises. Driven by the historic development of irrigation projects, often unsupportable increases in livestock numbers on rangelands, and agricultural land conversion in steppe areas, land degradation has become a serious issue in the region and threatens the current and future livelihoods of rural populations. Although estimates vary and can be imprecise, land degradation is estimated to be quite extensive in Central Asia, ranging from 4% to 10% of cropped land, 27% to 68% of pastureland and 1% to 8% of forested land. In total, this represents 40% of 66% of the areas degraded in each country (Quillérou et al., 2016).

Tajikistan has an area of 141,379 km2 and an estimated population of 9,126,600 people (Tajstat, 2019). Tajikistan is bordered by Afghanistan to the south, Uzbekistan to the west, Kyrgyzstan to the north, and China to the east. About 93% of Tajikistan is mountainous, dominated by the Alay Range in the north and the Pamir Mountains to the southeast, which include the highest elevations in the country. More than half of the country is more than 3,000 meters in elevation. The lowest elevations are in the northwest, the southwest, and the Fergana Valley, which dominates Tajikistan's far northern section. The mountain chains are interspersed with deep valleys formed by a complex network of rivers. The eastern mountains contain many glaciers and lakes. The Fedchenko Glacier, which covers 700 km2, is the largest non-polar glacier in the world (FRD, 2007).

The major environmental problems in Tajikistan are the degradation of land and water, deforestation, and decreased biodiversity (Olimova and Olimov, 2012). Being one of the most land-deprived countries in Central Asia, land degradation in the country aggravates the scarcity of land, and is therefore one of the main problems the rural population faces. Nearly 10,000 hectares (ha) of irrigable land is not used due to soil salinization and other reasons (Akhmadov, 2010). The same study documented that 59% of the total land in Tajikistan is affected by soil erosion where 15% is marginally washed-off, 21% is moderately washed-off and 24% is intensely washed-off. The study also indicated that the Gorno-Badakhshan Autonomous Region (GBAO) is the most affected by wind erosion with 40% of the land affected, while 23% of Sogd province is also affected by wind erosion. Soil salinity also affects about 15% of the total irrigated land in the country. These changes are comparably different than situation in the late 1970s and early 1980s (Figure 2 and Figure 3) where 37% of the land was subject to water erosion of different levels and almost 27% constituted strongly dissected mountain and highland areas with fragments of undeveloped soils, indicating these soils were subject to strong erosion processes.

Tajikistan's pastures are located on steep hills where the risk of erosion is high. In recent years pastures have been overused, exacerbating erosion and leading to the degradation of summer (90%) and winter (92%) pastures. In overgrazed areas, particularly on bluegrass and sedge pastures, the culture content in plants is progressively changing. As a result, pasture productivity is declining substantially (Akhmadov, 2010; Quillérou et al. 2016).

Given the country's mountainous geography, only 5% of the land is arable. Despite this natural restriction, agriculture remains the key source of the population's income and of Tajikistan's economy. Agriculture accounts for 53% of total employment, about a quarter of total GDP, and 39% of tax revenues, predominantly through the export of cotton (FAO, 2018, ADB, 2016). Tajikistan is a net importer of food and wheat, making the country highly dependent on market prices. Affected by adverse, possibly climate change-induced weather conditions, the relative contribution of agriculture – which was the economy's dominant sector before 2014 – has declined markedly (WB, 2019). The agriculture sector is characterized by low productivity, thereby affecting local livelihoods, especially for two thirds of the population which live in rural areas and are heavily dependent on agriculture for their income and consumption. Land fragmentation, underdeveloped and poor agricultural practices, poor linkage of producers to input, output and credit markets and land degradation are among the main causes of Tajikistan's agricultural sector's poor performance (CACILM, 2016). Arable land is in short supply, at 0.15 ha per capita nationally and 0.2 ha per capita taking into account only the rural population. Such smallholding puts farmers in a vicious cycle of poverty without adequate investible capital on the land, and hence they fail to tap into the full production potential of the land. This limits the country's ability to pursue sustainable intensification of their production systems, without which, the country would not be able to produce enough to feed its growing population.

Figure 2: Soil Erosion Map with number of Contours Describing Process or Status of Erosion.

Map was developed in the late 1970s and early 1980s by the Soil Science Research Institute, Tajikistan (issued by the main directorate of geodesy and cartography under Council of Ministers of USSR in 1984).

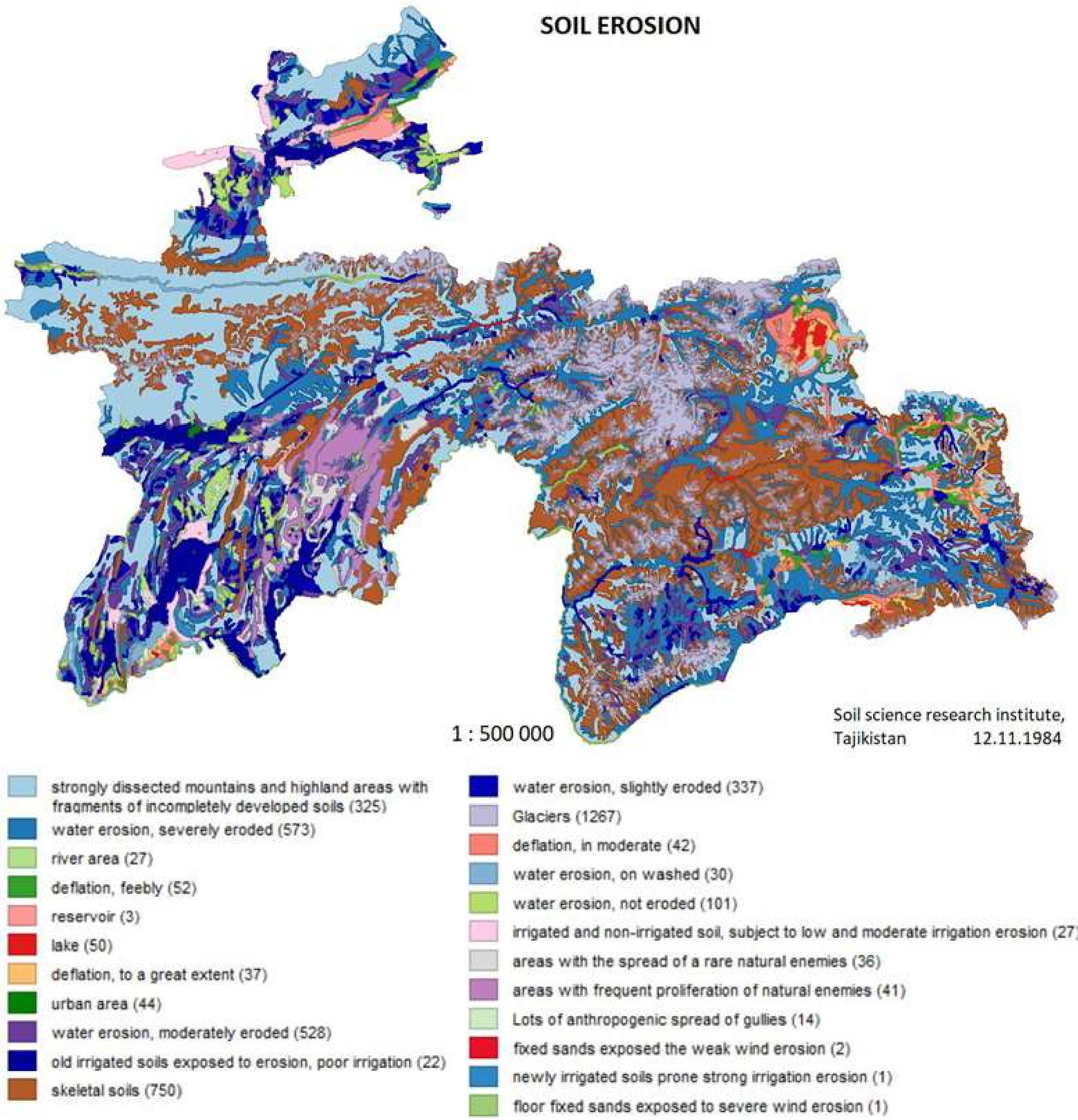
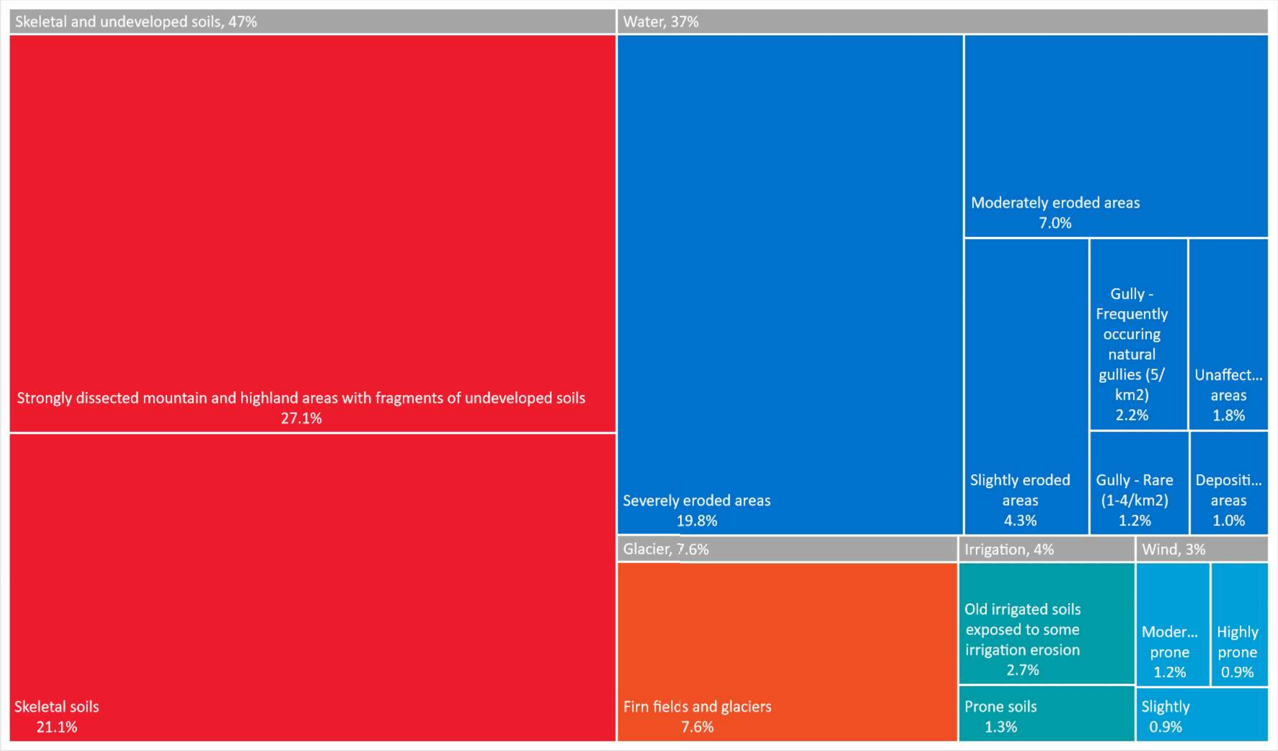


Figure 3: Share of Total Country Area Subject to Different Erosion Status or Processes.

Estimation of erosion affected areas is based on the map developed in late 1970s and early 1980s by the Soil Science Research Institute, Tajikistan (issued by the main directorate of geodesy and cartography under Council of Ministers of USSR in 1984).



Crop production in Tajikistan relies heavily on traditional practices which may not necessarily be sustainable. These practices are also directly or indirectly responsible for low agricultural productivity. For example, current average wheat yields stand at about 2.8 tons/ha which is 12.5% lower than the global average of 3.2 t/ha (FAOSTAT, 2018). Yigezu et al. (2019) reported that only 35% of wheat farmers in Tajikistan are currently using improved varieties of wheat which have been released since 2005. The remaining 65% of farmers that use old varieties are missing the opportunity to produce 330 kg/ha (15.5%) more wheat than they are currently able to produce using the old varieties. If the improved varieties were to be accompanied with the recommended packages of management practices, they have the potential to give yields of up to 8 ton/ha.

A lack of incentives – particularly the disincentive effects of poor connection to the market – also contributes to farmers' lack of motivation to use improved technologies. Normally, when markets function well and a grain quality grading system exists, market signals are transmitted to farmers through the gradient of prices for differentiated qualities of products. Moreover, when the market is efficient, transaction costs are lower, leading to higher prices received by farmers – thereby providing farmers the incentive to adopt improved technologies and practices to produce higher quantity and quality of grain and straw.

The total value of Tajikistan's landscape (forests, croplands and pasturelands) was evaluated at 12% of the total wealth of the country which is slightly lower than the 14% figures in Turkmenistan and Ukraine and substantially higher than the 1% in Switzerland (Lange et al., 2018), hence Tajikistan's reliance on natural capital is vital. Land degradation across the entire landscape, caused by both natural (UNDP-UNEP, 2012) and anthropogenic (Saigal, 2003) factors, is increasingly affecting both the economy and the quality of life in Tajikistan. The resulting loss of arable land is affecting the rural poor who depend directly on what the land can provide for their survival and livelihood. Tajikistan is one of the countries most affected by Climate Change (Glacier melting, droughts, flooding, landslides, etc.), which acts as a multiplier in the vicious cycle of land degradation, decreases in agriculture productivity, water pollution and multiplier in the vicious cycle of land degradation, decreases in agriculture productivity, water pollution and sedimentation, increased disasters, destruction of infrastructure and loss of lives. Since 1991, 4% of Tajikistan’s total land has been completely destroyed by land degradation as a result of unsustainable agriculture practices (UNDP-UNEP, 2012; GoT, 2009).

Afforestation is an important mitigation strategy for land degradation. Therefore, the positive trend in Tajikistan’s forest areas since 1997 indicates that Tajikistan has been doing well at least in terms of stopping land degradation associated with new deforestation. On the other hand, agricultural production on steep slopes and marginal land, poor water management/irrigation practices (waterlogging and salinization), overgrazing and deforestation are identified as the major contributors to land degradation in Tajikistan (UNDP-UNEP, 2012). Dunstan et al. (2004) documented that agricultural practices are second only to overgrazing as a major contributor to land degradation in Africa, the effects of which are immediately felt by farm households and even the urban poor. This is also true in Tajikistan where current poor agricultural practices and the expansion of agricultural land (i.e., expansion of agriculture land into marginal lands) show that much needs to be done in order to prevent and mitigate against agricultural land degradation. As the agriculture sector constitutes about a quarter of Tajikistan’s GDP, any deterioration in the quality of agricultural land leads to reduction in productivity and increased costs of production – thereby adversely affecting the country's economy in general, and rural communities in particular. While only 7% of the country is considered suitable for economic land use, about two thirds of Tajikistan's population live in rural areas and depend on agriculture for their livelihoods.

Despite the urgency and significance of the issue for Tajikistan, there is lack of attention to the short and medium-term detrimental effects of environmental degradation in the country’s National Development Strategy and Government plans and priorities. In 2013 the combined costs of air, water and soil protection were equivalent to 0.1% of GDP (UNECE 2017), which is several orders of magnitude lower than the estimated costs of environmental degradation resulting from air and water pollution and soil loss. These facts show that something urgently needs to be done to stop further degradation, mitigation measures need to be put in place to improve the condition of agricultural lands. The first step would then be to measure how much the degradation of agricultural land is costing the country which can then be used as a yardstick to weigh the cost-effectiveness of preventive and/or mitigative measures that will be put in place. The objective of this study is therefore to enhance the understanding of the economic costs of environmental degradation for improved management and planning at national and subnational levels inTajikistan. By placing dollar values on the economic and ecological costs of different forms of land degradation, this report aims to raise awareness of the gravity of the situation, help in priority setting, and provide the information needed to formulate better land management plans in Tajikistan.

1.1. Costs of environmental degradation

Land degradation is a generic term that is used to describe the detrimental changes related to the resource base of the landscape including soil, water, vegetation, air, climate, rocks, and relief (Stocking and Murnaghan, 2001). The United Nations Convention to Combat Desertification (UNCCD) defines land degradation as “any reduction or loss in the biological or economic productive capacity of the land resource base”. Land degradation includes all processes that diminish the capacity of land resources to perform essential functions and services in ecosystems which are caused by two interrelated complex systems: the natural ecosystem and the human social system where, the interactions between the two determine the success or failure of resource management (Berry, 2003).

Over the years, several efforts have been made to assess and quantify the scale of degradation for different components of the land resource. Table 2 summarizes estimates of degradation globally and in the region. UNCCD (2013) reports the global economy will lose a whopping US$23 trillion by 2050 through land degradation, whereas the cost of taking immediate action, estimated to be around US$4.6 trillion, is only a fraction of the predicted losses.

Credible data on the extent and cost of land degradation in Central Asia in general and Tajikistan in particular is scarce (Wolfgramm et al. 2011). Even though some studies (Quillérou et al., 2016; Mirzabaev et al. 2016; Shukurov et al., 2016, UNDP-UNEP, 2012) were carried out after 2011, most of these studies either focused on a small area, relied predominantly on estimates made by prior studies, focused only on one aspect of land degradation, and used a narrow definition of terms or used parameter estimates from other countries or regions. Available estimates suggest that out of more than 14 million ha land area of Tajikistan, 11.6 million ha (82%) suffers some level of erosion, out of which 4.8 million ha is agricultural land (representing 98% of total agricultural land).

Almost three-quarters (74%) of Tajikistan’s population lives in rural areas (TAJSTAT 2018), a proportion that has remained stable over the past 20 years. Predictably the agriculture (including forestry) sector accounted for two-thirds (66%) of employment until 2013, which fell to 61% in 2017 (TAJSTAT 2018). These statistics demonstrate how heavily Tajikistan’s economy and its population’s livelihoods rely on agriculture and natural resources.

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Natural disasters such as mudflows and landslides are occasionally caused by mismanagement, however it is often difficult to distinguish between natural or anthropogenic causes of such events without proper monitoring and the availability of spatial data. Wuepper et al. 2019 estimated the soil erosion rate in Tajikistan at 18 Mg/ha/year, while in monetary terms Sartori et al. (2019) estimates soil erosion to cause US$0.8 million of losses, equivalent to 0.01% of global GDP (a loss of US$8 billion).

Recommendations to prevent erosion are multiple, each will have different potential of reducing soil loss. For example, Bühlmann et al. (2010) estimated low-cost solutions such as contouring, fodder plants, and drainage ditches can reduce soil loss by 11%, 16%, and 53%, respectively. At the same time, more expensive measures result in a much larger reduction in soil loss for example, agroforestry could reduce erosion by as much as 63%, while when its combined with terracing, soil loss can be reduced by up to 93% (Buhlmann et al. 2010).

Estimation of the economic values of land degradation heavily depends on the assessment of the extent of the degradation. Economic valuation is further complicated by the lack of market prices for some ecosystem services and market distortions which undermine the ability of market prices to reflect the true value of ecosystem services.

Different components of the total economic value (TEV) of land or total economic cost (TEC) of land degradation can be estimated using a variety of valuation methods, which can be classified as market and non-market demand-based. Where markets for the resource or its services exist, assessment is relatively straightforward. Tilahun et al. (2018) provide detailed description of methods available for valuation of natural resources and environmental assets.

To determine TEC of LD or TEV lost, it is essential to identify the affected environmental resources and the associated losses in social, economic, and environmental benefits. The economic values of the benefits that are lost are can then be used as the estimates of land degradation costs. Gregersen et al. (1995) distinguish between two broad categories of the costs of land degradation: namely, the loss of use and non-use values. Costs associated with the loss of use values are further classified into two – costs of loss of direct and indirect use values. Costs associated with the loss of non-use values are also broadly classified into three – costs of loss of option values, existential values and bequest values.

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The Economics of Land Degradation (ELD) attempts to make economic valuations of the impact of land degradation based on the calculation of potential benefits forgone due to land degradation which represents a cost to society associated with inaction while the benefits from land restoration correspond to the cost of land degradation. Methodologically, past valuation efforts for land degradation predominantly relied on cost-benefit analysis (mostly using secondary data complemented with expert and individual estimates) to compare the total economic benefits of land restoration to the economic costs of restoring degraded land.

Quillérou and Thomas (2012) argue that economic valuation has mostly focused on the use value of provisioning and cultural services, with limited valuation of non-use value of cultural services. No unique valuation method has been applied following methodological developments, varying study objectives, and data availability constraints. These factors impair coherent and consistent estimation of the total economic value of land degradation across countries. Quillérou and Thomas (2012) stress the importance of having analysis at national levels, rather than on smaller areas and hotspots.

There have been some efforts for the estimation of the costs of Land Degradation in Tajikistan. Reports by WB (2008) and UNDP-UNEP (2012) provide national-level estimates for the TEC of LD (Table 3). Estimates by WB (2008) put total figure at TJS690 million per year, which was equivalent to 9.5% of GDP in 2006. The UNDP-UNEP (2012) study estimated total annual losses of revenue as a direct result of land degradation to be US$442 million, which was equivalent to 7.8% of GDP in 2010. This however excludes the cost of degradation in forests, indirect use values of land (such as loss of soil carbon that would have otherwise been stored in the soil), cost of land degradation-induced property damages and associated costs of interrupted services and costs related to health problems induced by land degradation. Hence these figures can be considered as conservative estimates because direct and indirect damage costs were not included. Nevertheless, such estimates indicate the magnitude of environmental damage that need to be considered for remediation efforts at the national scale.

More recently, the ELD initiative carried a study in all five Central Asian countries (Mirzabaev et al. 2016; Quillérou et al., 2016). The case study (Shukurov et al., 2016) estimated the deficit from all degraded land at US$0.50–0.54 million in Fayzabad district of Tajikistan. Mirzabaev et al. (2016) estimated annual costs of land degradation due to LUCC between 2001 and 2009 at US$500 million, equivalent of 10% of GDP (Table 3).

Table 2: Environmental degradation ranges globally and in central Asian countries in different land domains

#	Country/region	Degradation range, %	Area/Doman	Source
1	Global	33	Total area	FAO (2015)
2	Global	20	Cultivated land	Bai et al. (2008)
3	Global	30	Forest land	Bai et al. (2008)
4	Global	10	Grassland	Bai et al. (2008)
5	Central Asia	40-100	Total area	Quillérou et al. (2016)
6	Central Asia	4-10	Cropped land	Quillérou et al. (2016)
7	Central Asia	27-68	Grassland	Quillérou et al. (2016)
8	Central Asia	1-8	Forest land	Quillérou et al. (2016)
9	Kyrgyzstan	30	Highland pasture	Quillérou et al. (2016)
10	Turkmenistan	70	Grassland	Quillérou et al. (2016)
11	Uzbekistan	50	Irrigated land	Quillérou et al. (2016)
12	Tajikistan	60	Irrigated land	Quillérou et al. (2016)
13	Tajikistan	0-97	Cultivated land	Quillérou et al. (2016)
14	Tajikistan	85	Grassland	Quillérou et al. (2016)
15	Tajikistan	89	Total area	UNDP-UNEP (2012)
16	Tajikistan	10	Land productivity	Tsvetnov and Belugin (2019)
17	Tajikistan	40	Rainfed area	Wolfgramm et al. (2011)
18	Tajikistan	22 severe; 38 moderate	Irrigated land	Wolfgramm et al. (2011)
19	Tajikistan	22 severe; 30 moderate	Forest land	Wolfgramm et al. (2011)

Table 3: Estimated costs of environmental degradation in Tajikistan

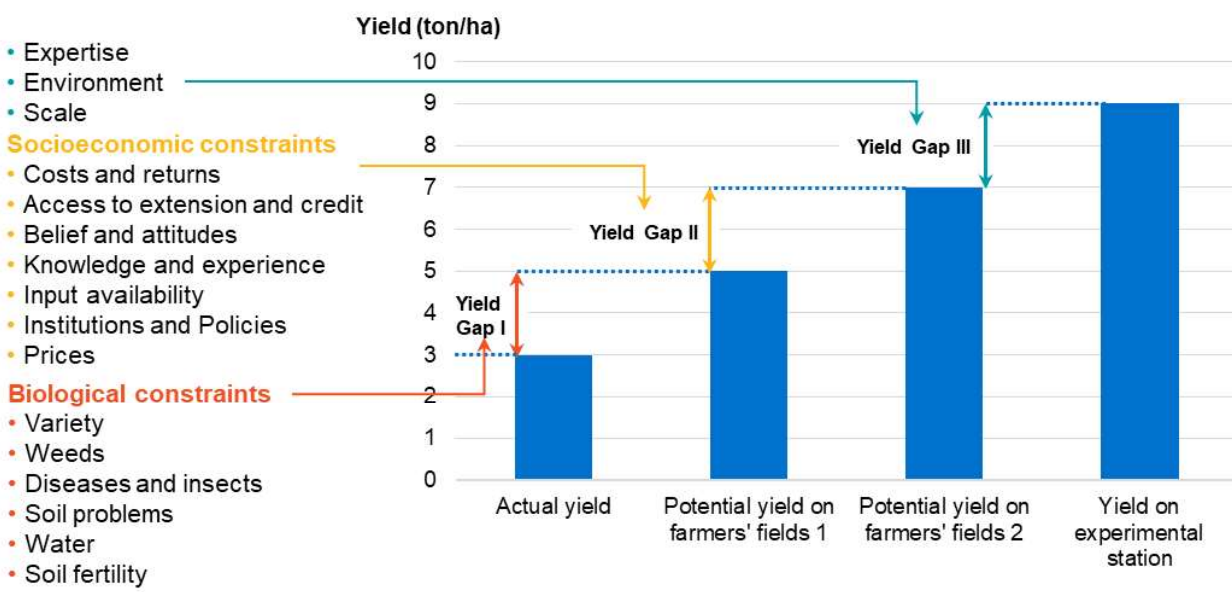
#	Costs of losses, Million US$	Equivalent to % of GDP	Year	Area/Domain	Source
1	200.5	9.5	2006	Total environmental degradation	WB (2008)
2	78.5	3.7	2006	Land degradation, soil erosion, fertility loss and salinity	WB (2008)
3	33.4	1.6	2006	Natural disasters	WB (2008)
4	32.6	1.5	2006	Inadequate water supply, sanitation, hygiene	WB (2008)
5	21.5	1.0	2006	Indoor air pollution	WB (2008)
6	15.7	0.7	2006	Rangeland degradation	WB (2008)
7	9.6	0.5	2006	Urban outdoor air pollution	WB (2008)
8	4.9	0.2	2006	Lead poisoning	WB (2008)
9	4.4	0.2	2006	Deforestation	WB (2008)
10	500.0	10.0	2001/ 2009	Annual cost of land degradation	Mirzabaev et al. (2016)
11	442.0	7.8	2010	Total costs from land degradation	UNDP-UNEP (2012)
12	208.3	3.7	2010	Abandoned cropland	UNDP-UNEP (2012)
13	138.1	2.4	2010	Degradation of arable land	UNDP-UNEP (2012)
14	95.9	1.7	2010	Degradation of pastureland	UNDP-UNEP (2012)
15	800,000	0.0	2011	Soil erosion	Sartori et al. (2019)

Chapter 2. Methodology

In this study, the estimate of the total cost of land degradation covering both direct and indirect use values is made using a combination of econometric analysis and benefit transfer approaches (please see Annex I and II for the details). The main assumption behind all estimates made in this study on the impacts of land degradation on crop/pasture/forest yields, is that no intervention will restore the land to its full potential and hence the land which is ranked the best in its current state can serve as the reference against which all other lands can be compared (Figure 4). We first generated estimates of crop and straw/hay/wood and timber yields per ha under the following scenarios: 1) severe land degradation; 2) moderate land degradation; and 3) low degradation scenarios. Then, the difference between yields under (3) and under (1) is considered as the yield loss due to severe land degradation and the difference between yields under (3) and (2) as an estimate of yield loss due to moderate land degradation. Here, under low land degradation scenario, it is more likely that there is some non-zero level of yield loss. However, as argued above, as it is difficult to estimate what that level of yield would be if the land is intact with no land degradation at all, and more so because it is impossible to assume that land can be fully restored to its 100% potential, for the purpose of this study, we assumed that yield loss under (3) is zero – i.e. under current scenarios, (3) represents the best level of land quality that can be achieved with all the necessary investment the country can make. Once the yield losses per unit area of moderately and severely degraded lands under different land uses and covers is determined, then they are used to make estimation of the costs of loss of direct and indirect use values due to land degradation. General background, description of the estimation procedures followed, description of models used, and detailed exposition of the Excel-based templates used for estimation and aggregation of costs of land degradation are provided in Annex I and Annex II .

Given the challenges of finding reliable data and the short amount of time that was available for this study, its scope was limited, and methodologically ad hoc, but logical approaches were mostly used with the exception of the regression analysis that we used for the estimation of loss in wheat fields. As a result, acknowledging the difficulty of generating precise estimates of the extent and cost of land degradation in the different ecosystem services, we aimed to generate a range instead of point estimates at every level. Then, during aggregation of the results, we provide a range of the estimates so as to allow the reader to decide which one to take. Our argument is that the extent of land degradation in Tajikistan is so high that even if we present the conservative estimates, they are still very high, which should alarm those who have the power to do something about it.

Figure 4: Exposition of the yield gap analysis



2.1. Objective and scope

Past studies on costs of environmental degradation in Tajikistan are almost a decade old. Moreover, they focus on specific aspects of the problem (pastures, arable land, cost of natural disasters) and do not explicitly link natural disasters with environmental degradation. According to Mirzabaev et al., (2016), Tajikistan saw an estimated 8% loss in GDP in 2010 as a direct result of land degradation with the cost of inaction six times higher than the cost of action. Despite the significant importance of the topic for Tajikistan's current and future economic growth, the negative effects from environmental degradation are missing from the country's economic analysis and Government priorities, and are not taken into account in its medium-term macro projections.

It is important for the Government of Tajikistan to have an accurate (to the limits of available data), up-to-date and aggregated macro level estimation of the total economic costs of environmental degradation. This will inform the authorities and the public on the direct and indirect costs of land degradation to the country and convince the Government to include measures to mitigate environmental degradation in future strategic government planning. The study also aims to develop local capacity for such a study by directly involving local partners from the Committee on Environmental Protection (CEP) and the Tajik Academy of Sciences (TAAS) as well as by engaging with experts from key ministries including the Ministry of Agriculture, the Ministry of Finance, and the Ministry of Economy.

The main objective of this study is therefore to generate credible and up-to-date estimates for the total economic cost of land degradation in Tajikistan. The study will generate national and provincial estimates of land degradation in the three major biomes, namely: 1) Croplands; 2) Pastures; and 3) Forests. The study will also include estimation of the cost of land degradation-induced infrastructure damage, health problems and costs of natural disasters related to land degradation in each of the four provinces. Given the challenges of estimating the costs of natural resource and environmental degradation, the study also aspires to develop more logical, consistent, and easier approaches to estimate the costs of land degradation in the different biomes. While we use a regression method for estimation of land degradation costs in crop lands, we develop Excel-based templates for the estimation of land degradation costs in pastures and forests as well as for the estimates of damage to infrastructure, health problems, and natural disasters. We hope that the templates will provide a foundation for future studies where the estimates can be updated replacing the old parameters with updated ones. This study will apply the new approach and employ Excel-based templates to generate estimates of land degradation in each of the different biomes and socio-economic infrastructures in each province which is then aggregated at a national level.

2.2. Data

Credible data on the extent and cost of land degradation in Central Asia in general and Tajikistan in particular, is scarce (Wolfgramm et al., 2011). The study used a combination of official statistics and survey results as well as estimates from local experts during workshops and agency visits (see Annex Outreach activities). The need to use of a mix of data also stems from the fact that some of the available figures are difficult to use as their sources are mostly unknown, and their generation procedure is not reliable or not consistent with the literature. Therefore, as much as possible, this study tries to gather raw data from official government documents, published and unpublished research results, and from consultations with national experts in the relevant fields. In few cases where no reliable data was obtained, we used the benefit transfer approach to infer the values of the parameters based on published and unpublished reports with due reference to the source. The benefit transfer method involves the use of parameter estimates or valuation results from studies carried elsewhere, either within or outside the study area and sometimes for different time periods. Some of the data for which we invoked the benefit transfer approach include grain to biomass ratio, average forest and pasture yields for the different levels of land degradation, average price of CO_2, erosion (ton/ha), soil bulk density, total cost of health problems (see Tables in Annex V for the complete list). This work provides a good foundation for future improvements where the templates with all the parameters will be available to national and international researchers, who can replace the parameters with new and/or more precise values from credible sources and update the estimates at shorter intervals of less than five years. Descriptions of the data used in this report for the estimates of the different land degradation-induced costs are provided below.

2.2.1. Estimation of yield loss in wheat fields and other crops

In this study, land degradation is conceptualized in two layers. First, we tried to classify land degradation differences across provinces. These are captured by a regression model. Then, we classify lands within each province into three categories (slightly degraded, moderately degraded and highly/severely degraded). For the within-province differences we make a conservative estimate of 10% yield losses between lands with the successive degradation levels (from least degraded to moderately degraded and from moderately degraded to highly degraded lands) in Sogd, Khatlon and GBAO.

Data for regression-based estimation of yield loss due to land degradation comes from 690 farm households surveyed in the three major wheat-producing provinces of Tajikistan, namely: Khatlon, Sogd and Districts of Republican Subordination (DRS). Some of the secondary information about localities were obtained from government agriculture officers, village leaders and local guides. Survey details and analysis are presented in Annex III.

2.2.2. Estimation of yield loss in forests

Data for forest area per each province was obtained from official statistics. Estimates of degradation rate were based on feedback during consultation workshops, and in follow up activities to fine-tune resulting estimates expert opinion was requested to confirm.

2.2.3. Estimation of yield loss in forages

Data for pasture area per each province was obtained from official statistics. Estimates of degradation rates were based on national expert estimates.

2.2.4. Estimation of cost of land degradation-induced infrastructure damage

Data for the extent of infrastructure damage is obtained from CEP's official records and any data gaps are filled by a systematic approach for generating estimates by experts on the field.

2.2.5. Estimation of cost of land degradation-induced health problems

Generating reliable estimates of the health impacts of land degradation requires large scale data collection and modelling which are beyond the scope of this study. Therefore, past estimates from UN (2012) were taken and adjusted based on the objectives of this study and the authors' own opinions and assumptions.

2.3. Study's limitations

While the authors are confident that the estimates generated in this report can be trusted with some level of confidence and hence can be used for policy decisions, we admit that that the scope and quality of this report was limited by time and the unavailability of data. Given the importance of monitoring the cost of land degradation and the progress in managing it and for priority setting and developing strategies for their mitigation and/or prevention, such studies play important roles. However, embarking on such large studies to generate estimates which provide a complete picture thematically, geographically, and in scale, poses major challenges and prove to be too ambitious for a very small project such as this. Without measurement data on various impact indicators, a study such as this can only rely on expert estimates and the literature to fill the gap, which to a certain extent can reduce the quality and credibility of estimates that come out.

Photo Credit: ICARDA / Sanobar Khudaybergenova.

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Chapter 3. Results and discussion

3.1. Cost of land degradation in crop lands

Ideally, we would suggest using the Endogenous Switching Regression (ESR) model to estimate the impact of land degradation on yield. However, in our data, we found that endogeneity is not a problem, and hence resorted to the use of the Ordinary Least Squares (OLS) regression (See Annex IV for more details on estimation method and results).

In this study, we make a conservative estimate of 10% yield losses between lands with the successive degradation levels (from least degraded to moderately degraded, and from moderately degraded to highly degraded lands) in Sogd, Khatlon and GBAO. Then, based on the total area under wheat in each province and the estimated shares of the different land degradation levels in total provincial cereal and legume lands provided by the national experts, we estimate that Tajikistan is losing a total of 209,506 tons of cereal and legume which represents about 20% of total national cereal and legume production, showing that land degradation has substantial food security implications in Tajikistan. Including the value of straw, value of soil carbon lost from wheat fields, and the reduction in the bequest value of land due to land degradation, the total economic cost of land degradation in cereal and legume fields is estimated at US$130 million annually, which represents costs equivalent to 1.8% of GDP[1] out of which the major loss is due to loss in consumptive uses (Table 4).

As there were no data that can be used for estimation of the impacts of land degradation in all other crop lands (vegetables, fruits, cotton, etc.), we assumed the same impact of land degradation in all other crops and across degradation levels. Therefore, by applying proportional reduction in the yields across the provinces, we estimated the total economic cost of LD in cotton fields to be US$53 million (equivalent to 0.7% of GDP), in potato fields to be US$46 million (equivalent to 0.7% of GDP), in vegetable fields to be 269 million US$ (equivalent to 3.8% of GDP) and in fruit lands to be US$7 million (equivalent to 0.1% of GDP). Along with the losses in cereal and legume fields, the total economic cost of land degradation in all crop lands is estimated at US$505 million which is equivalent to 7.1% of GDP (Table 5).

Table 4: Summary of annual costs of land degradation on all cereal and legume lands in Tajikistan

	Cost category (Million US$)					
Province	**Consumptive uses**	**Non-consumptive uses**	**Indirect uses**	**Non-use values**	**Total cost**	**Equivalent to % of GDP**
Sogd	47.9	0	0.4	0.4	48.7	0.7%
Khatlon	66.8	0	0.6	0.5	68.0	1.0%
GBAO	2.2	0	0.0	0.0	2.2	0.0%
DRS	10.5	0	0.3	0.1	10.9	0.2%
Total Tajikistan	**127.4**	**0**	**1.3**	**1.0**	**129.8**	**1.8%**
Equivalent to % of GDP	*1.8%*	*0.0%*	*0.02%*	*0.01%*	*1.8%*	

Land which grows vegetables (including potato) accounts for 62% of total loss, which seems counterintuitive. However, this is explained by the very high yields which average about 20 tons/ha – almost ten times the yield in cereal and legume lands. The price of vegetables is also higher than wheat prices – on average about double the wheat prices used for the calculation of total economic loss in grain

[1] The GDP of Tajikistan in 2018 was 68.8 Billion TJS which at an exchange rate of 1US$=9.7 TJS, is equivalent to 7.1 Billion US$.

fields. Though it is logical to us, we acknowledge that this result might be contentious. Therefore, we made an extremely conservative assumption that, after controlling for all confounding factors (input quantities, management practices, and rainfall), land degradation accounts for only 10% of the differences in vegetable yields. With this assumption, the total economic cost of land degradation land degradation in vegetable fields is US$34 million, equivalent to 0.5% of GDP, making the total cost of land degradation in all crop fields is US$270 million (equivalent to 3.8% of GDP), which we believe is still a sizeable amount (Table 6).

Table 5: Summary of annual costs of land degradation on all crop lands in Tajikistan - using higher boundary parameters

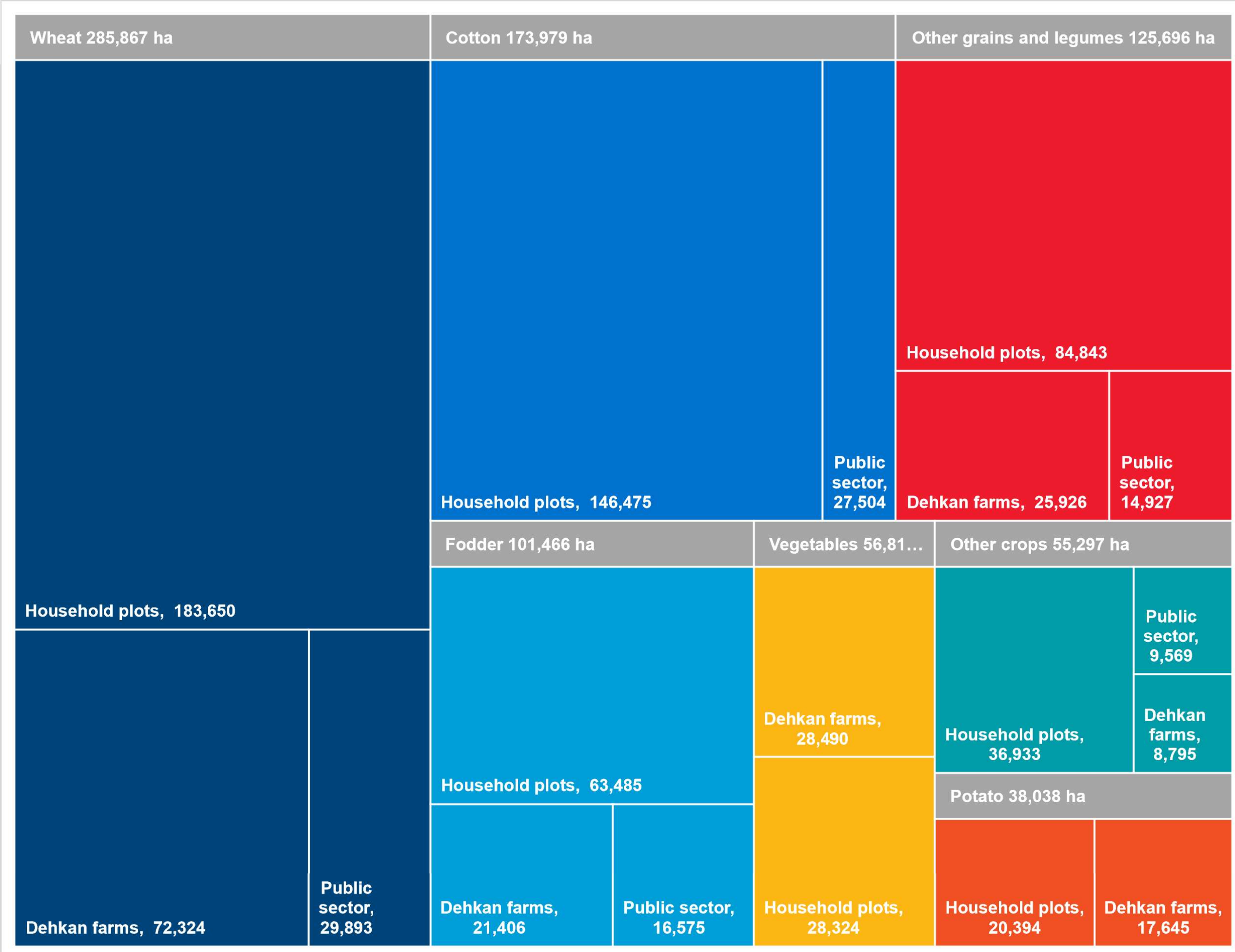
	Cost (Million US$/year) of land degradation by crop type						
Province	Cereals & legumes	Cotton	Potatoes	Vegetables	Fruits	Provincial Total	Equivalent to % of GDP
Sogd	48.7	16.9	25.6	92.1	4.4	187.7	2.6%
Khatlon	68.0	35.5	13.6	152.3	2.1	271.5	3.8%
GBAO	2.2	0.0	0.0	0.0	0.0	2.3	0.0%
DRS	10.9	0.5	6.8	24.4	0.9	43.5	0.6%
Total cost	**129.8**	**52.9**	**46.1**	**268.7**	**7.5**	**505.0**	**7.1%**
Equivalent to % of GDP	*1.8%*	*0.7%*	*0.7%*	*3.8%*	*0.1%*	*7.1%*	

Khatlon province suffered the highest economic cost, followed by Sogd and DRS respectively. Once again, the total area where vegetables are grown provides the explanation for such differences where the area under vegetables in Khatlon is almost double, triple and five times larger than that of Sogd, DRS, and GBAO, respectively (Figure 5). Moreover, 10% of the total cropland in DRS is estimated to have low land degradation (reference yield) where biomass yield loss is zero (against which all other yields are to be compared).

Table 6: Summary of annual costs of land degradation on all crop lands in Tajikistan - using extremely conservative and lower boundary parameters and assumptions

	Cost (Million US$/year) of land degradation by crop type						
Province	Cereals & legumes	Cotton	Potatoes	Vegetables	Fruits	Provincial Total	Equivalent to % of GDP
Sogd	48.7	16.9	25.6	11.5	4.4	107.2	1.5%
Khatlon	68.0	35.5	13.6	19.1	2.1	138.3	2.0%
GBAO	2.2	0.0	0.0	0.0	0.0	2.3	0.0%
DRS	10.9	0.5	6.8	3.1	0.9	22.2	0.3%
Total cost	129.8	52.9	46.1	33.8	7.5	270.0	3.8%
Equivalent to % of GDP	*1.8%*	*0.7%*	*0.7%*	*0.5%*	*0.1%*	*3.8%*	

Figure 5: Crop area disaggregated by ownership types in Tajikistan as per 2018 (Tajstat 2019)



3.2. Cost of land degradation in forests and pastures

The cost of land degradation in forests and pastures was calculated in the same way as that for croplands except that the woody biomass and hay yield losses were not generated from regression models, but instead from a combination of past literature and estimates by experts.

3.2.1. Cost of land degradation in forests

Provincial total areas of forested land were first obtained from official government sources. Then, national forest experts were asked to estimate the percentage distribution of provincial forest lands into three categories (forest with low, medium and high deforestation). Based on the average biomass yield of 82 tons/ha for Asia (FAO, 2000) and data on types of trees grown in Tajikistan (FAO, 2005), experts estimated biomass yield in the different categories (please refer to Tables in Annex V). The annual average national deforestation rate was estimated at 2.5%, which varies between 2% in low deforestation areas to 3% in high deforestation areas. Accordingly, a total of 809,977 tons of woody biomass is being removed by deforestation every year which has an estimated value of US$23 million which is equivalent to 0.3% of GDP. Including the non-consumptive values of forests (particularly the potential loss of revenue from hunting due to land degradation), indirect use values (value of carbon that could have been sequestered in the forest lost due to land degradation), and bequest values of forest, the total economic cost of land degradation-induced loss in forests is estimated at US$39 million, which is equivalent to 0.6% of GDP (Table 7).

Table 7: Summary of annual costs of land degradation-induced loss in forests in Tajikistan

	Cost category (Million US$)					
Province`	Consumptive uses	Non-consumptive uses	Indirect uses	Non-use values	Total cost	Equivalent to % of GDP
Sogd	7.0	-	4.6	0.2	11.8	0.2%
Khatlon	10.6	-	7.0	0.3	17.9	0.3%
GBAO	0.6	-	0.4	0.0	1.1	0.0%
DRS	4.3	-	2.9	0.1	7.3	0.1%
Total Tajikistan	22.5	0.0	15.4*	0.7	38.7	0.6%
Equivalent to % of GDP	*0.3%*	*0.0%*	*0.2%*	*0.0%*	*0.6%*	

**Including medicinal plants, hey and honey production (0.6 Million US$)*

While figures equivalent to 0.6% of GDP is large enough to warrant the attention of all stakeholders, this value is believed to be underestimated because soil erosion in forests (regardless of the deforestation level) is assumed to be zero, and hence the value of soil carbon lost is assumed to be zero. Moreover, the current forested area is believed to be much smaller than it was 50 or 100 years ago. Therefore, by considering only the current forest area of 422,000 ha, we are underestimating the economic cost of land degradation in forest lands.

3.2.2. Cost of land degradation in pastures

The total area of pastureland in the Tajikistan's four provinces was obtained from official government sources (please refer to Tables in Annex IV). Tajikistan has a total of 3.8 million ha of pasture lands where Khatlon and DRS possess 32% and 28% of total national pastureland respectively. Experts estimated that there is less overgrazing in pastures in GBAO than the rest of the country while overgrazing is more prevalent in Sogd. Local pasture experts estimated that the total amount of hay that can be harvested from undegraded pastureland is about 1.1 ton/ha. Then, the difference between 1.1 ton/ha and the current hay yield (please refer to Tables in Annex IV) is considered the amount of biomass production lost per ha in each category of degradation of pasture lands. Accordingly, it is estimated that Tajikistan is losing about 2,243,166 tons of hay due to land degradation in pasture lands which is valued at US$109 million or equivalent to 1.5% of GDP. Ignoring the non-consumptive values of pastures (particularly the share of pastures in the potential loss of revenue from hunting due to land degradation as the wildlife graze in natural pastures), indirect use values (value of carbon that could have been sequestered in the degraded pasture lands), and bequest values of pastures, the total economic cost of land degradation-induced loss in pastures is estimated at US$123 million, equivalent to 1.7% of GDP (Table 8).

Table 8: Summary of annual costs of land degradation-induced loss in pasture lands in Tajikistan

	Cost category (Million US$)					
Province	Consumptive uses	Non-consumptive uses	Indirect uses	Non-use values	Total cost	Equivalent to % of GDP
Sogd	21.5	-	2.4	0.3	24.1	0.3%
Khatlon	32.8	-	4.4	0.5	37.8	0.5%
GBAO	26.8	-	2.2	0.4	29.5	0.4%
DRS	27.4	-	4.8	0.4	32.6	0.5%
Total Tajikistan	**108.6**	**-**	**13.8**	**0.4**	**122.8**	**1.7%**
Equivalent to % of GDP	*1.5%*	*0.0%*	*0.2%*	*0.0%*	*1.7%*	

3.3. Cost of land degradation-induced infrastructure damage

The calculation of the total economic cost of land degradation-induced damages to infrastructure started by agreeing (within the study team) types of infrastructure which we believe are susceptible to damages due to land degradation. As a result, we agreed to include only transport infrastructure including paved, unpaved and secondary roads, rail roads, and airport runways), irrigation canals, buildings, and telephone/electricity poles. Then, we gathered data on the total length (or quantity) of each of these infrastructures and consulted official documents and experts to make estimation of the percentage of each infrastructure type damaged by land degradation (flood/erosion) every year. We also get estimates of the average repair cost per unit (km for transportation infrastructure and irrigation canals and number of buildings) damaged by land degradation. Accordingly, we estimated that 7,820 km of paved roads, 1,407 km of unpaved roads, 2,415 km of local roads, 49km of rail roads, and 0.65 km of airport runways are being damaged every year due to land degradation-related causes costing Tajikistan a total of US$15 million (equivalent to 0.2% of GDP) for repairs and US$37 million (equivalent to 0.5% of GDP) as forgone economic benefits due to interruption of services until the infrastructure is repaired making the total economic cost of land degradation-induced infrastructure damage in Tajikistan to be US$53 million or equivalent to 0.7% of GDP (Table 9).

Table 9: Summary of annual costs of land degradation-induced damages to infrastructure in Tajikistan

	Cost category (Million US$)			
Province	**Cost of repair of road, rail & airport runway damages**	**Value of forgone services due to damage on road, rail & airport runways**	**Total cost of damage on road, rail & airport runways**	**Equivalent to % of GDP**
Sogd	2.0	5.1	7.0	0.1%
Khatlon	8.8	0.6	9.4	0.1%
GBAO	0.3	10.3	10.6	0.2%
DRS	4.3	21.3	25.5	0.4%
Total Tajikistan	**15.3**	**37.2**	**52.5**	**0.7%**
Equivalent to % of GDP	*0.2%*	*0.5%*	*0.7%*	

3.4. Cost of crop lands abandoned due to land degradation

For the estimate of the impact of land degradation on abandoned lands, we assumed that the total crop that would have been produced from these lands is completely lost. We also assumed that the efforts to restore the abandoned lands would at most get result in these lands attaining a moderate (not slight) land degradation level. Therefore, the yield that is lost due to the abandonment of these lands is estimated by taking the average wheat yield of 2,190 kg/ha for fields with average land degradation obtained from the survey. Given that the total crop area that becomes unusable and therefore is left fallow (or abandoned) due to severe land degradation in Tajikistan is estimated at 30,000 ha (Olimova and Olimov, 2012; GoT, 2016). By multiplying the total abandoned wheat area by the average yield of 2,190 kg/ha, we estimated that Tajikistan is losing a total of 70,200 tons of cereals and legumes costing the country a total of US$25 million which is equivalent to 0.4% of GDP. This is a conservative estimate, because if we assumed that the abandoned lands can be restored to attain land degradation levels that can be classified as slightly degraded, then the average yield that we should use would be much higher than what we have used for the moderately degraded lands, and hence the estimate of loss would have been higher.

3.5. Cost of land degradation-induced health problems

Tajikistan is facing major environmental problems, such as air and water pollution, and land erosion, resulting in severe adverse impacts on human health. Environmental damages are estimated to have a considerable economic cost, including the cost of adverse health impacts, corresponding to equivalent to 5% of GDP (UNECE, 2012). Assuming that land degradation accounts for only 50% of total cost of environmental degradation-induced health problems, we estimate that the total economic cost of land degradation-induced health problems in Tajikistan is US$177 million, which is equivalent to 2.5% of GDP out of which, 70% is assumed to be related to direct use value and the remaining 30% related to indirect use value.

Environmental degradation can contribute to air pollution. It also induces the use of more chemical inputs to augment the productivity loss which, along with higher precipitation and irrigation, can cause leaching of these chemicals into surface and ground water sources with serious human and animal health implications. However, as the report (UNECE, 2012) does not provide a breakdown of the total economic cost of environmental degradation-induced health problems highlighting the different components of the environment in causing health problems, the estimates above, although reasonable, may be sources of contention, and cast doubt on the validity of our estimates. Therefore, we also considered an extremely conservative assumption that land degradation-induced health problems in Tajikistan account for only 10% (instead of 50%) of the total environmental degradation-induced health problems (i.e., equivalent to only 0.5% of GDP). Under this stringent assumption, we estimate the total cost of land degradation-induced health problems to be US$35 million, which is still substantial.

3.6. Cost of land degradation-induced natural disasters (emergencies)

In Tajikistan, several land degradation-induced natural disasters occur, including landslides, snow avalanches, mud flows, rock falls and heavy floods. While land degradation-induced damages to infrastructure, and natural disasters generally affect similar assets, properties, and infrastructure, the scale of damage from natural disasters is generally so severe, that the property/infrastructure/assets cannot be repaired and hence have to be replaced. Based on an existing database (LA, 2017) which provides seven-year data (2011-2016), we estimate the average annual total cost of replacement of buildings and other infrastructure damaged by snow avalanches, mud flows, rock falls, and heavy floods at US$25 million, equivalent to 0.4% of GDP. We believe that this could be an underestimate of the total cost because a study carried in 2004 (UNECE, 2004), reported that given the very mountainous nature of the country, and the severe land degradation that has taken place over the years, about 50,000 landslides occur annually in Tajikistan.

3.7. Total economic cost of land degradation in Tajikistan

Tajikistan is suffering from several types of land degradation-induced problems. In this report, we consider losses that are induced by land degradation: 1) in crop fields; 2) in forests; 3) in pastures; which also caused damages to 4) infrastructure; 5) human health; and also led to complete destruction of assets, properties and infrastructure. Based on original calculations we made, and estimates borrowed from past literature and databases, our conservative estimates of total economic cost of land degradation in Tajikistan is US$950 million, equivalent to 13.4% of GDP (Table 10). Considering the second and extremely conservative sets of parameters and assumptions made for the estimate of total costs of land degradation in vegetable-growing lands and on human health, the total economic cost of land degradation is estimated at US$574 million, equivalent to 8.1% of total GDP (Table 11). Therefore, the conservative estimate of the total cost of land degradation in Tajikistan is between US$574 and US$950 million (equivalent to between 8.1% and 13.4% of GDP). We acknowledge that these estimates are more likely to be much less than the actual value, but the upper bound is closer to reality. However, even the extremely conservative estimate of the lower bound of the total economic cost of land degradation which accounts for the equivalent of 8.1% of the country's GDP is large enough to gain the attention of all national and international stakeholders.

Table 10: Summary of total economic cost of land degradation in Tajikistan – using higher boundary parameters and assumptions

	Estimated costs of environmental degradation per year (Million US$)							
Type of Value	In all crop lands	In natural forests	In natural pastures	In abandoned crop lands	In the form of land slides	In the form of infrastructure damage	In the form of health problems	Total
1. Use value	500.8	38.0	122.4	25.3	24.5	58.0	177.4	946.4
1.1 Direct use value	498.6	22.5	108.5	25.3	24.5	-	124.2	803.7
1.2 Indirect use value	2.2	15.4	13.8	-	-	58.0	53.2	142.7
2. Non-use value	2.3	0.7	0.4	-	-	-	-	3.5
TOTAL	**503.1**	**38.7**	**122.8**	**25.3**	**24.5**	**58.0**	**177.4**	**949.9**
Equivalent to % of GDP	*7.1%*	*0.6%*	*1.7%*	*0.4%*	*0.4%*	*0.8%*	*2.5%*	*13.4%*

Table 11: Summary of total economic cost of land degradation in Tajikistan – using extremely conservative and lower boundary parameters and assumptions

	Estimated costs of environmental degradation per year (Million US$)							
Type of Value	In all crop lands	In natural forests	In natural pastures	In abandoned crop lands	In the form of land slides	In the form of infrastructure damage	In the form of health problems	Total
1. Use value	267.8	38.0	122.4	25.3	24.5	58.0	35.5	536.0
1.1 Direct use value	265.6	22.5	108.5	25.3	24.5	-	24.8	446.5
1.2 Indirect use value	2.2	15.4	13.8	-	-	58.0	10.6	89.5
2. Non-use value	1.5	0.7	0.4	-	-	-	-	2.7
TOTAL	**269.4**	**38.7**	**122.8**	**25.3**	**24.5**	**58.0**	**35.5**	**538.7**
Equivalent to % of GDP	*3.8%*	*0.6%*	*1.7%*	*0.4%*	*0.4%*	*0.8%*	*0.5%*	*8.1%*

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Chapter 4. Conclusions and Recommendations

Several studies have attempted to generate estimates of land degradation in Tajikistan. However, all the studies have been limited by the rigor, depth and breadth of their analysis as well as by the geographic and thematic coverage of the estimates. Most of these studies have also mainly relied on past estimates and do not necessarily provide their source of data, methods used, or the assumptions made. While we admit that this study is not perfect, to the extent possible and within the limits of time and financial resources that were available, we have tried to introduce improvements in all fronts. The major contributions of this study are:

1. It provides estimates on the major land degradation-induced problems including biomass loss in all three biomes (crop lands, forests, and pastures), damages to infrastructure, health problems and natural disasters;
2. It tries to provide estimates at the level of each province, which were aggregated using the appropriate weights (mostly land area under each biome or density of infrastructure in each province);
3. It tries to develop a theoretically sound and consistent method that can be applied to all dimensions of land degradation-induced losses;
4. The study uses primary survey data to generate new and credible estimates of yield losses in wheat fields which, with some simplifying assumptions were then used to generate estimates for yield losses in the other crops;

The study also uses official statistics and expert estimates on important variables to generate new estimates on some of the components of land degradation-induced losses.

The objective of this study is to generate very conservative but credible estimates of the total economic cost of land degradation in Tajikistan. As a result, where necessary, data on important variables are not available from credible sources, conservative estimates of the variables are used in the calculations. Accordingly, the minimum total economic cost of land degradation in Tajikistan in 2019 is estimated to be between US$574 and US$ 950 million (i.e., equivalent to between 8.1% and 13.4% of GDP). These estimates are conservative, and we believe that the actual cost of land degradation in Tajikistan is likely to be much higher than even the upper bound of US$950 million. This report, including what follows below, is based on the upper bound of the estimate. However, even the extremely conservative estimate of US$574 million is high enough to get the attention of national and international stakeholders.

The major economic cost is related to yield (crop and crop residue) loss in crop lands including those abandoned or fallowed to regenerate (equivalent to 7.5% of GDP) followed by the cost of land degradation-induced health problems (equivalent to 2.5% of GDP) and biomass loss in natural pastures (equivalent to 1.7% of GDP). Costs related to land degradation-induced damages on infrastructure, loss of woody biomass, and natural disasters constitute costs equivalent to 0.8%, 0.6% and 0.4% of GDP respectively.

The policy implications of these results are that these levels of losses are too high to ignore, and past studies in Tajikistan and other similar countries reveal that the cost of inaction is much higher than the cost of action. Left unchecked, the magnitude of land degradation is expected to increase, especially with climate change, causing extreme weather events which will increase costs further. Therefore, the government of Tajikistan, its national and international development partners, civic societies and all citizens, should join forces in raising awareness of the gravity of the problem and exert concerted efforts to prevent further degradation. They also need to take mitigative measures to improve the situation, as the returns to such investments, as documented by past studies, are high.

Estimates of the total economic value of land degradation using a single study in a country like Tajikistan where, data on crucial variables is not readily available, is a very ambitious effort. While it is possible to generate some informative figures as is done in this report, the team acknowledges uncertainty in estimated values, and we may not have sufficient confidence on the precision and credibility of some of the estimates generated. Assembling different multi-disciplinary teams of experts to carry a series of studies each focusing on the estimate of land degradation costs on only one component of the natural or environmental resource-base, might help in overcoming this challenge and in generating more credible estimates that can be aggregated to the desired levels. As the magnitude of such a large study may be expensive both in terms of cost and human resources, studies that focus only on one component at a time might be wise. By focusing on one component at a time, such detailed studies may provide a reliable basis for future studies which might focus on collecting more detailed data on other aspects of land degradation while making slight adjustments to account for time-varying variables and hence in building credible evidence on the TEV of land degradation.

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Annex I Estimation methods

AI.1. Background

Most past economic valuations are based on comparisons with a counterfactual that refers to a scenario with no land degradation. This implicitly assumes that after the interventions, land will be restored to 100% of its potential, which might not be the case depending on the specific context (Quillérou and Thomas, 2012). We argue that these assumptions are unrealistic as it is difficult, if not impossible, to know what the land attributes would have been had degradation not taken place (the counterfactual). As argued by Quillérou and Thomas (2012), interventions may also not restore land to its original state, and hence the benefits of action and the costs of inaction may be overestimated. Due to a lack of data, UNDP-UNEP (2012) for example, presented the economic loss from agricultural lands that have been abandoned as the only cost of land degradation in agricultural lands. Mirzabaev et al. (2016) also estimate the cost of land degradation without the costs of land degradation due to lower soil and land productivity within the same land use. However, in reality, given the large magnitude of current agricultural lands which are degraded at varying levels, the reduction in yield potential in those degraded agricultural lands could possibly represent a much higher impact of degradation on agricultural lands than the forgone benefit from abandoned agricultural lands because the total land that is abandoned is much less than the total area under cultivation. A related challenge in the ELD literature is that most studies embark on very ambitious goals of making estimates of the full cost of land degradation in the total land area of a country/region which makes it necessary to rely heavily on expert estimates and invoke many assumptions which may not necessarily be realistic, at least under some scenarios.

In view of its importance and the complexity of measuring the TEV of land degradation in croplands, this paper proposes an econometrics-based approach involving more rigorous analysis of field-level crop production data. The paper also demonstrates the potency of the approach by applying it to nationally representative survey data. To generate TEV of land degradation at national level, we, to the extent possible, also made efforts to generate estimates for cost of land degradation on forests and pastures, and land degradation-induced damages on infrastructure and health problems using the newly proposed method.

In this study, we follow Gregersen et al. (1995) to classify the total value of land resource into two broad categories: Use and non-use values (Figure 6). Use values are further classified into direct and indirect use values. Direct use values are again classified into consumptive and non-consumptive use values. Consumptive use values include the values of ecosystem services that are produced on the land for direct consumption (such as grain and straw on crop fields, wood and timber on forest lands, hay and leafy biomass from pastures, etc.). Non-consumptive use values refer to the values of recreational, educational and research, benefits that can be derived from the particular type of land under consideration. Indirect use values are classified into four categories: Watershed and soil protection and nutrient recycling, Gas (carbon dioxide and oxygen) exchange, carbon storage and climate stabilization, Habitat and protection of biodiversity and species, and aesthetic, cultural and spiritual values. Non-use values of a natural resource or environmental asset are also classified into three broad categories: option values (values of the option of not using it in the present time), existential values (the values of its mere existence) and bequest values (the value of the ability to bequeath it to future generations).

For the purpose of making a quantitative estimate of the use values of land, we borrow the concept of yield gap analysis (van Ittersum & Cassman, 2013). In yield gap analysis, comparison is made between different production scenarios which include: 1) average yields obtained using a new technology (e.g., variety) under a highly controlled environment with optimal management practices on experimental stations managed by experts; 2) average yields obtained on farmers' fields using the new technology managed by farmers but with close follow up by researchers; 3) average yields obtained on farmers' fields using the new technology managed by farmers with no follow up by researchers or subject matter specialists; 4) average yields obtained on farmers' fields using the old technology managed by farmers with no follow up by researchers or experts (Figure 7).

While the difference between (1) and (4) is often used as a measure of yield gap, it is often unrealistic as it is difficult (if not impossible) for farmers to have a controlled environment on their fields and for the typical farmer to have the knowledge and expertise equivalent to researchers or experts. Therefore, the more logical and realistic comparison would be between items (3) and (4). That represents the additional yield that can be expected from adoption of the new technology by the typical (average) farmer. The same concept is also used in productive efficiency analysis (Aigner et al., 1977) where farmers producing on the production frontier instead of experimental yields are used as the reference (Figure 8).

Figure 6: Classifications of total use of a natural resource or environmental asset. source: adapted from Gregersen et al. (1995)

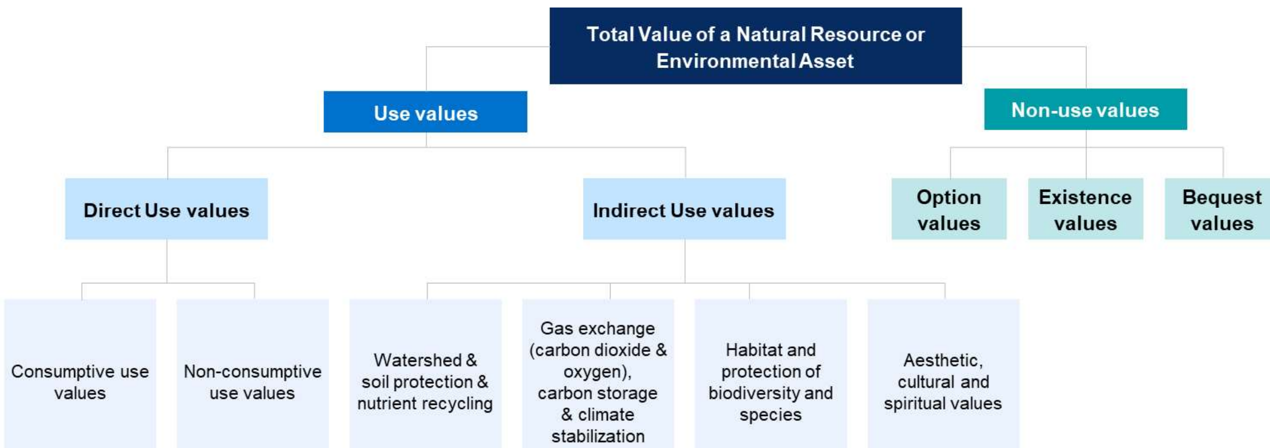


Figure 7: Exposition of the yield gap analysis

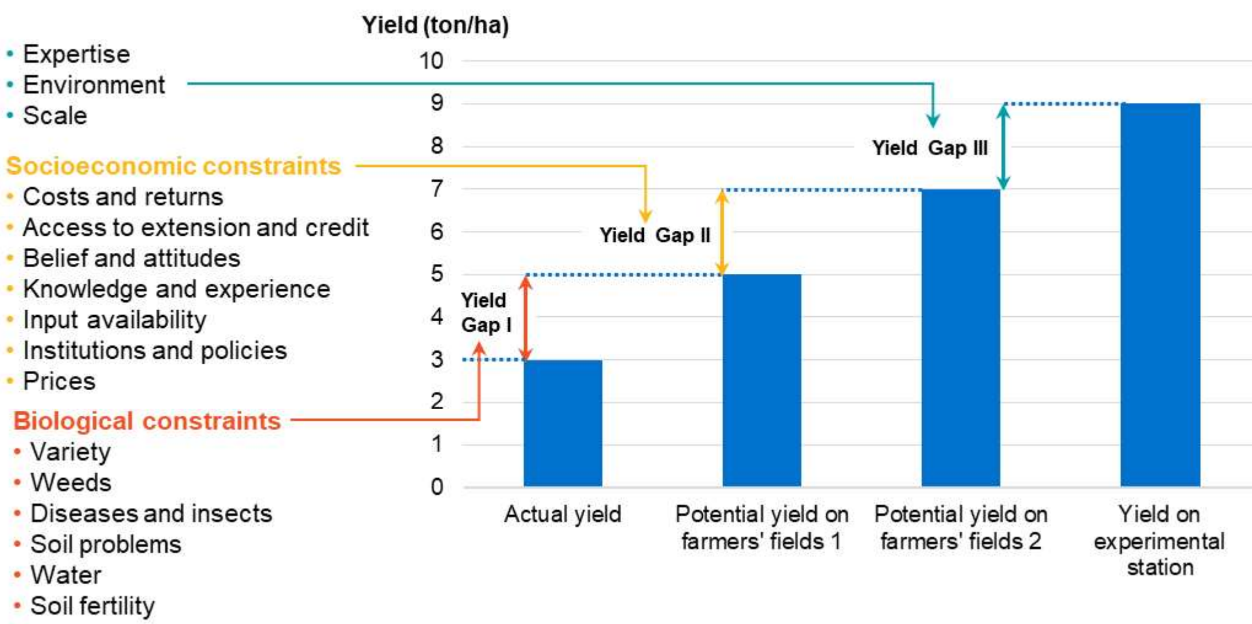
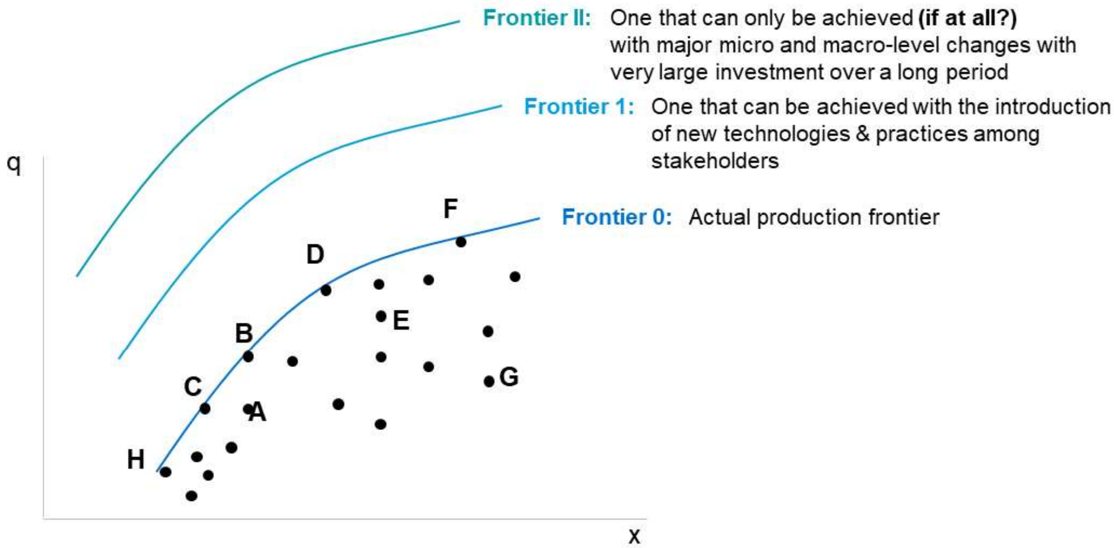


Figure 8: Exposition of the production frontier and the effect of technological change



AI.2. Estimates of direct use values of land lost due to land degradation

Regression-based method for estimation of crop yield loss due to land degradation

The direct use values of crop lands, particularly cereals, are for the production of grain and straw. Therefore, we first estimate the amount of cereal grain lost per unit area under low, moderate and severe land degradation scenarios. Then, we use estimates of biomass yield to grain ratio from the literature to estimate straw yield loss from the grain yield loss we estimated. The non-use values of cereal crop lands can also be estimated as revenue per unit area from recreation, education and research, etc. under the three land degradation scenarios where the difference between the revenue from the land with low degradation and moderately and severely degraded lands represent the cost of lost non-use value of land under moderate and severe land degradation scenarios respectively.

If field-level production data is available, econometric methods can be employed to estimate the yield losses under the three land degradation scenarios with higher precision. As management practices and farm and farmer conditions (including quantities of inputs applied) vary substantially among farmers in production, especially of cultivated crops, forests, and pastures, bivariate comparison of mean yields can be highly misleading. As a result, estimates of local average treatment effects (Imbens and Angrist, 1994) has been the focus of the impact evaluation literature. One of the main challenges in this pursuit is related to establishing counterfactuals, as the problem of endogeneity due to selection bias and/or omitted important variables is often inherent. Several econometric approaches can be used to address the problem of endogeneity during analysis of quasi-experimental and observational data. Imbens and Wooldridge (2009) provide a good review of the literature and the developments in causal inference and impact assessment. Propensity Score Matching (PSM) due to Rosenbaum and Robin (1983) is by far the most widely used in terms of improving causal inference and estimation of local average treatment effects (Henderson and Chatfield, 2011; Jalan and Ravallion, 2003). PSM helps in correcting biases introduced only by observable covariates (Heckman and Vytlacil, 2007). Therefore, results from PSM can sometimes be misleading since unobservable factors such as skills and motivation can influence not only the outcome but also the program participation decision thereby leading to confounding errors (See Austin 2008 for critical review of PMS). To overcome this problem, two other methods, endogenous switching regression (Maddala and Nelson, 1975) and instrumental variables (Angrist and Pischke, 2009) methods have been proposed. Both methods account for endogeneity due to omitted variables and selection bias introduced by both observable and unobservable factors and are potent to correct for it.

The instrumental variables (IV) approach (Angrist et al., 1996) is by far the most effective method. The IV method requires that the “instrument” meets three important conditions: (1) the instrument has to be associated with the treatment, (2) the instrument does not affect the outcome except through the treatment – also known as the exclusion restriction assumption, and (3) the instrument does not share any causes with the outcome. The reliability of the results from instrumental variables regression depends on the fitness of the instrument in fulfilling the above conditions (Imbens 2004). Therefore, in order to measure the impact of land degradation, it is important to identify an instrument(s) which is (are) correlated with land degradation (or with farmers’ decision to prevent land degradation but uncorrelated with the unobserved factors that influence the yield (Shiferaw et al. 2014). However, finding a good instrument for land degradation and indeed for most treatments is very difficult. Therefore, we recommend using the endogenous switching regression (ESR) approach for the measurement of the impacts of land degradation on the use values (i.e., on crop/hey/wood yield). As mentioned above, the difference in yields between degraded and non-degraded crop/forest/pasture fields cultivated by farmers may not only be due to observable factors such as soil characteristics and quantities of inputs, and other agronomic practices, but also due to unobserved factors such as the motivation, abilities, and skills of the farmers. The unobserved factors may also have effects on the level of soil degradation creating the problem endogeneity. Therefore, the use of the ESR to account for both observable and unobservable endogeneity of the land degradation status of the crop fields would require simultaneously estimating the function for the status of land degradation (equation 1) and the outcome equation (yield) for each group of land degradation status. Detailed description of the formulation of the ESR model is provided below.

AI.3. Detailed description of the formulation of the endogenous switching regression (ESR) model

Following Shiferaw et al. (2014) the ESR can be formulated as follows. It is theoretically expected that farmers will decide to prevent land degradation when the expected utility received from the prevention (D_1^*) is greater than the utility received from not preventing LD (D_0^*). Since utility is not observable, the prevention decision is observable (via some way of measuring the high quality of the soil) and the decision whether to prevent land degradation or not is treated as a dichotomous choice: D =1 if $D_1^* > D_0^*$ and D = 0 if $D_1^* < D_0^*$. Thus, the prevention decision (proxied by for example high quality soil on the field) can be modelled as:

$D_i^* = Z_i\beta + \varepsilon_i$ with $D_i = 1 \; if D_i^* > D_0^*$, otherwise $D_i = 0$ (1)

Then, the outcome variable (in our case wheat yield) can be specified in the form of a crop response function as:

$y_1 = X_1\omega_1 + \epsilon_1 \; if \; D = 1$ (2)

$y_0 = X_0\omega_0 + \epsilon_0 \; if \; D = 0$ (3)

where y_i is a vector of dependent variables representing outcomes (yield) for farmers who prevented land degradation and hence have high quality soil (y_1) and those who didn’t and hence have poor quality soil (y_0), X_i is a matrix of explanatory variables, ω_i is a vector of parameters to be estimated, and ϵ_1, and ϵ_0 are error terms.

The error terms from the three equations ε, ϵ_1, and ϵ_0 are assumed to have a trivariate normal distribution with mean vector zero and the following covariance matrix:

$$cov(\varepsilon, \epsilon_{1,}\epsilon_0) = \begin{bmatrix} \sigma_{\epsilon 0}^2 & \sigma_{\epsilon 1 \epsilon 0} & \sigma_{\epsilon 0 \varepsilon} \\ \sigma_{\epsilon 1 \epsilon 0} & \sigma_{\epsilon 1}^2 & \sigma_{\epsilon 1 \varepsilon} \\ \sigma_{\epsilon 0 \varepsilon} & \sigma_{\epsilon 1 \varepsilon} & \sigma_{\varepsilon}^2 \end{bmatrix} \quad (4)$$

where σ_{ε}^{2} is the variance of the selection equation (equation 1), $\sigma_{\epsilon 0}^{2}$ and $\sigma_{\epsilon 1}^{2}$are the variances of the outcome equations for those who didn't implement preventive measures and those who did respectively while $\sigma_{\epsilon 0\varepsilon}$ and $\sigma_{\epsilon 1\varepsilon}$ represent the covariance between , ϵ_1, and ϵ_0. If ε is correlated with ϵ_1, and ϵ_0, the expected values of ϵ_1, and ϵ_0 conditional on the sample selection are non-zero:

$$E(\epsilon_1|D = 1) = \sigma_{\epsilon 1\varepsilon}\frac{\phi(Z_i\omega_i)}{\Phi(Z_i\omega_i)} = \sigma_{\epsilon 1\varepsilon}\lambda_1 \quad (5)$$

$$E(\epsilon_0|D = 0) = \sigma_{\epsilon 0\varepsilon}\frac{-\phi(Z_i\omega_i)}{1-\Phi(Z_i\omega_i)} = \sigma_{\epsilon 0\varepsilon}\lambda_0 \quad (6)$$

Where ϕ and ϕ are the probability density and the cumulative distribution function of the standard normal distribution, respectively. If $\sigma_{\epsilon 1\varepsilon}$ and $\sigma_{\epsilon 0\varepsilon}$ are statistically significant, this would indicate that the decision to prevent land degradation and the outcome variable of interest (i.e., wheat yield in our case) are correlated suggesting evidence of sample selection bias (i.e., farmers who have prevented land degradation are inherently those who would get higher yields even if they didn't). Therefore, estimating the outcome equations using OLS would lead to biased and inconsistent results and Heckman procedures (Heckman and Vytlacil, 2007) are normally used. In the face of heteroscedastic error terms, the full information maximum likelihood (FILM) estimator can be used to fit an endogenous switching regression that simultaneously estimates the selection and outcome equations to yield consistent estimates. The ESR can be used to compare the actual expected outcomes of farmers who prevented land degradation (7) and those who didn't (8), and to investigate the counterfactual hypothetical cases that the those who didn't prevent did prevent (9) and those who prevented land degradation did not prevent (10) as follows:

$$E(y_1|D = 1) = X_1\omega_1 + \sigma_{\epsilon 1\varepsilon}\lambda_1 \quad (7)$$

$$E(y_0|D = 0) = X_0\omega_0 + \sigma_{\epsilon 0\varepsilon}\lambda_0 \quad (8)$$

$$E(y_0|D = 1) = X_1\omega_0 + \sigma_{\epsilon 0\varepsilon}\lambda_1 \quad (9)$$

$$E(y_1|D = 0) = X_0\omega_1 + \sigma_{\epsilon 1\varepsilon}\lambda_0 \quad (10)$$

Finally, we calculate the average treatment effect on the treated (ATT), i.e., the average treatment effect on the fields where the farmer prevented land degradation, as the difference between (7) and (9) and the average treatment effect on the untreated (ATU), i.e., on those on which land degradation was not prevented, as the difference between (10) and (8). We also compute the effect of base heterogeneity for the group of preventers (BH1) as the difference between (7) and (10), and for the group of non-preventers (BH2) as the difference between (9) and (8). A number of factors such as varieties used and the amounts of irrigation, fertilizers, seed, pesticides, herbicides, labor and tillage, farm and farmer characteristics such soil color, texture, province (as a proxy for climatic conditions), sex, age, and farming experience of farmer are included as explanatory variables in the yield response (outcome) function. Likewise, several variables including sex, age, and farming experience of the household head, access to credit, total agricultural land owned, soil color, location in the water distribution network, years since zero tillage was started, and distance to market were included in the selection equation (i.e., in the land degradation prevention equation).

The treatment effect estimates from the ESR model are per unit area (say per ha). Then, based on official statistics on the total wheat area in each province and data obtained from the survey on soil quality of each field, percentage share in total wheat area of degraded and undegraded fields in each province is established. Then, by multiplying the yield loss per unit area by the total degraded area in each province, an estimate of the total yield loss (in metric tons) in each province due to land degradation is generated. As production of wheat in Tajikistan is predominantly for local consumption, the average price of wheat in the local markets in the province under consideration is used to estimate the value of the yield lost due to land degradation in each province. Here, it is important to note that the yield loss estimates are generated by keeping all other factors (weather, quantities of inputs, farm and farmer characteristics etc.) the same.

Therefore, the treatment effects that are estimated provide yield loss purely resulting from difference in land degradation only. Then, the percentage shares in total area of fields in the different land degradation categories are used as weights for aggregation of the estimates of treatment effects (i.e., the impact of land degradation) from provincial levels to the national level. Version 15 of the Stata software (Stata, 2017) was used for all econometric estimation in this study.

The loss in straw yield is estimated by applying the average biomass yield to grain ratio of 1.55 obtained from a study carried in Czech Republic and Austria between 2010 and 2012 (Konyalina et al., 2014). Then, the per unit losses in straw are aggregated to provincial and national levels following the same procedures as in the aggregation of grain losses described above. These regional and national yield loss estimates are then used as parameters in an Excel-based template (described in Annex II) for the estimation of costs of land degradation in crop fields.

Annex II Description of the excel-based template for estimation of the cost of land degradation

AII.1. Direct use values

For the estimation of direct use values lost due to land degradation in all biomes (crop fields, forests, and pastures) and in damaged infrastructure, due to natural disasters and land degradation-induced health problems, we developed an Excel-based template the conceptualization of which is described as follows.

A) Cost of loss of direct use values associated with land degradation-induced biomass loss in the three biomes (crop fields, forests and pastures)

The total economic cost of land degradation (TEC_LD) in a county is given by:

$$\mathrm{TEC\_LD} = \sum_{p=0}^{P} \mathrm{TEC\_LD}_p \qquad (1)$$

where $\mathrm{TEC\_LD}_p$ is total economic cost of land degradation in province *p* and P represents the total number of provinces (which in the Tajik case is 4) where,

$$\mathrm{TEC\_LD}_p = \mathrm{TEC\_LDB}_p + \mathrm{TECO\_LD}_p \qquad (2)$$

Where $\mathrm{TEC\_LDB}_p$ and $\mathrm{TECO\_LD}_p$ respectively are total economic costs of land degradation-induced loss in biomass and cost of other land degradation -induced problems including damaged infrastructure, health problems and natural disasters.

$$\mathrm{TEC\_LDB}_p = \sum_{i=0}^{I} \mathrm{TEC\_LDB}_{ip} \qquad (3)$$

$$\mathrm{TECO\_LD}_p = \sum_{k=0}^{K} \mathrm{TECO\_LD}_{kp} \qquad (4)$$

Where ∑ is the summation operator, $\mathrm{TEC\_LDB}_{ip}$ is the total economic cost in province p of land degradation in biome *i*, $\mathrm{TECO\_LD}_{kp}$ is total economic cost in province p of other land degradation-induced problem category *k* (infrastructure damage, health problem, natural disaster, etc.)*,* and *I and K* represent the total number of biomes and the number of other land degradation-induced problem categories considered.

The first step in this approach involves classification of total land under each biome into three broad categories *j* of land degradation (low, medium, and severe). This is best done when micro-level measurement data (such as levels of soil organic matter content in crop fields or volume of biomass per ha of forest or pastures) is available for each farm or total crop, forest and pastureland in each village or district for all provinces in the country. If such data is not available (which is often the case), a combination of measurement data from past studies or government documents as well as expert estimations can be used. Once the classification of all lands based on degradation level is made, then estimates of the share (in %) of each degradation level *j* in total provincial area of biome *i* in province *p* (AS_{ijp}) should be made based on the available data, expert estimates, or a combination of the two where $\sum_{j=0}^{v} \mathrm{AS}_{\mathrm{ijp}} = 100\%$. Then, total economic cost in province p of LD in biome *i* ($\mathrm{TEC}_{\mathrm{LDB}_{\mathrm{ip}}}$) can be computed as:

$$\mathrm{TEC\_LDB}_{ip} = \sum_{j=0}^{J} \mathrm{AS}_{\mathrm{ijp}} * \mathrm{TEC\_LDB}_{ip} \qquad (5)$$

where J = the total number of levels of land degradation, which in our case is 3 (low, medium, and severe).

The total economic cost of land degradation in a given biome type *i* in lands with degradation level *j* in province *p* (TEC_LDB_{ijp}) is computed as the product of the total amount of land degradation-induced loss of production of biomass (in tons) of biome *i* in a land categorized as having degradation level j in province p ($TLBPB_{ijp}$) and the price for biome type *i* in US$ per ton in province *p* (PB_{ip}); i.e.,

$$\mathrm{TEC}_{\mathrm{LDB}_{\mathrm{ijp}}} = \mathrm{PB}_{\mathrm{ip}} * \mathrm{TLBPB}_{\mathrm{ijp}} \qquad (6)$$

Another important piece of information that should be computed using micro-level measurement data such as field-level survey for crops and actual measurements for forests and pastures is the biomass yield per unit area (e.g. per ha) of land under biome *i* in a land classified as having land degradation level of *j* in province *p* (BY_{ijp}). This can be yield of grains, vegetables, or fruits and other useful biomass for crops, total volume of woody biomass that can be harvested from a forest land and total amount of hay and other feed material that can be harvested from a pastureland per unit area. If measurement data is not available, this information needs to be generated from past research, official statistics and records, expert estimates or a combination of all three. Then, applying the yield-gap concept, the biomass yield in lands classified as having low degradation is used in this approach as the reference yield, i.e., the highest attainable yield under current conditions. Therefore, the magnitude of land degradation-induced biomass yield loss (in tons) for biome *i* in a land categorized as having degradation level *j* in province *p* (BYL_LD_{ijp}) can be computed as the difference between biomass yield in lands categorized as having *Low* degradation in province *p* ($BY_{i,LOW,p}$) and biomass yield in lands categorized as having degradation level of *j* in province p (BY_{ijp}) where, biomass yield loss in lands categorized as having *Low* degradation in province *p* ($BYL\_LD_{i,LOW,p}$) would be zero and that under land that is classified as having severe land degradation level will be the highest while that under land that is classified as having moderate land degradation level will be somewhere in between the two. Mathematically, the land degradation-induced biomass yield loss per unit area (BYL_LD_{ijp}) can be computed as:

$$\mathrm{BYL}_{\mathrm{LD}_{\mathrm{ijp}}} = \mathrm{BY}_{\mathrm{i,LOW,p}} - \mathrm{BY}_{\mathrm{ijp}} \qquad (7)$$

Once the per unit area biomass yield loss for biome i, in land type j and province p (BYL_LD_{ijp}) is estimated, then the total amount of land degradation-induced loss of biomass production (in tons) of biome *i* in a land categorized as having degradation level *j* in province *p* ($TLBP_{ijp}$) can be computed as the product of: 1) the share (in %) of each degradation level *j* in total area of biome *i* in province *p* (AS_{ijp}); 2) total area of biome i classified as having degradation level of j in province p (A_{ijp}); and 3) The per unit area land degradation-induced biomass yield loss (in tons) for biome *i* in a land categorized as having degradation level *j* in province *p* (BYL_LD_{ijp}), i.e.,

$$\mathrm{TLBP}_{\mathrm{ijp}} = \mathrm{AS}_{ijp} * \mathrm{A}_{ijp} * \mathrm{BYL\_LD}_{ijp} \qquad (8)$$

In cases where multiple products or commodities are produced (such as grain and straw for wheat for example), then the same procedure should be applied to generate the value lost in each product type or commodity (c) as:

$$\mathrm{TLBP}_{\mathrm{ijpc}} = \mathrm{AS}_{ijp} * \mathrm{A}_{ijp} * \mathrm{BYL\_LD}_{ijpc} \qquad (8.1)$$

Where, BY_LLD_{ijpc} represents the per unit area land degradation-induced biomass yield loss for commodity c of biome *i* in a land categorized as having degradation level *j* in province *p.*

The total value of land degradation-induced loss in production of biome *i* in a land categorized as having degradation level *j* in province *p* ($TVLBP_{ijp}$) can therefore be computed as the sum of the product of the total amount of land degradation-induced loss of biomass production (in tons) of commodity c of biome *i* in a land categorized as having degradation level *j* in province *p* ($TLBP_{ijpc}$) and average market price of biomass of commodity c for biome i in province p (AP_{ipc}):

$$\mathrm{TVLBP}_{\mathrm{ijp}} = \sum_{c=1}^{C} \left(\mathrm{TLBP}_{\mathrm{ijpc}} * \mathrm{AP}_{ipc}\right) \qquad (9)$$

The choice of price for each product (commodity) will depend on the purpose of production of the specific product of each biome in the province. For example, in the case of wheat – as both the grain and straw are produced predominantly for local consumption mostly within the province – average prices of wheat grain and wheat straw in the local markets in the province under consideration should be used.

Then, following Pearce and Markandya (1987) for valuation of social cost of natural resource depletion, we use the concept of marginal opportunity cost (MOC) to estimate the total economic cost of land degradation as the value of production that has been lost because farmers, communities, and the government chose not to invest in preventing land degradation. Therefore, the total economic cost of land degradation in land used for the production of biome *i* which has degradation level of *j* in province *p* (TEC_LD_{ijp}) is equal to the total value of land degradation-induced loss in production of biome *i* in a land categorized as having degradation level *j* in province *p* ($TVLBP_{ijp}$), i.e.,

$$\mathrm{TEC\_LD_{ijp}} = \mathrm{TVLBP_{ijp}} \qquad (10)$$

The total national economic cost of land degradation in land used for the production of biome *i* which has degradation level of *j* (TEC_LD_{ij}) is calculated as the sum across all provinces of the total economic cost of land degradation in land used for the production of biome *i* which has degradation level of *j* in province *p* (TEC_LD_{ijp}), i.e.,

$$\mathrm{TEC\_LD_{ij}} = \sum_{p=1}^{z} \mathrm{TEC\_LD_{ijp}} \qquad (11)$$

B) Cost of loss of direct use values associated with other land degradation-induced problems

In addition to the loss in biomass production in agriculture, land degradation can also damage assets and properties, including infrastructure (paved, unpaved, and local (secondary) roads, bridges, rail roads, airport runways, irrigation infrastructure, telephone and electricity poles) and other assets such as buildings, trees, human life, domestic and wild animals, etc. To estimate the costs of land degradation-induced damage of assets, the first step would be quantifying the magnitude of asset damaged or destroyed due to causes related to land degradation. Then, we can use the repair/replacement cost approach and use the unit cost of repairing/replacing each type of infrastructure damaged/destroyed by causes induced by the land degradation. Then, the product of the per unit cost and the total length or magnitude of the infrastructure damage would give an estimate of the cost of land degradation-induced infrastructure damage.

To generate estimates of the total economic cost in province p of other land degradation-induced problem category *k* ($\mathrm{TECO\_LD}_{kp}$) mentioned in equation (4), we use similar concept but slightly different approach to the one used for land degradation-induced cost in land under different biomes described above. The approaches used for estimation of total economic cost of land-degradation-induced damage/destruction for each specific type of asset are described below.

B1) Cost of loss of direct use values associated with land degradation-induced damages to transportation infrastructure

The total economic cost of other land degradation-induced problem category k for transportation infrastructure in province p ($\mathrm{TECO\_LD}_{kp}\ (Trans\_infra)$) is computed as the sum of total economic cost of land degradation-induced damages on all transportation infrastructure types t in province p ($\mathrm{TECO\_LD}_{tp}$) , i.e.,

$$\mathrm{TECO\_LD}_{kp}(Trans\_infra) = \sum_{t=1}^{T} \mathrm{TECO\_LD}_{tp} \qquad (12)$$

Where T is the total number of types of transportation infrastructure considered.

For infrastructure including roads (paved, unpaved and local secondary roads), rail roads, airport runways, irrigation infrastructure, buildings, and other fixed assets prone to damage by land degradation or natural disasters related to land degradation, the following data are needed:

1) Total length (in km) of each type of transportation infrastructure (t) including paved roads, unpaved roads, local (secondary) roads, railroads, airport runways in each province p ($TLTI_{tp}$);
2) Percentage of transportation infrastructure that is damaged due to land degradation-induced problems in the year under consideration ($STID_{tp}$);
3) Average cost (in US$/km) of repair for of infrastructure type t in province p which was damaged in the year under consideration but can be repaired ($ACRKM_{tp}$);

Then, total economic cost of land degradation-induced damages on all transportation infrastructure types t in province p ($\mathrm{TECO\_LD}_{tp}$) mentioned in equation (12) can be computed as the product of 1-3 in the above list, i.e.,

$$\mathrm{TECO\_LD}_{tp} = STID_{tp} * TLTI_{tp} * ACRKM_{tp} \qquad (13)$$

B2) Cost of loss of direct use values associated with land degradation-induced damages to assets and infrastructure other than transportation

The same procedures used for estimating land degradation-induced damages to infrastructure can be used for damages in other assets and infrastructure such as irrigation canals, buildings, electric and telecommunication poles, fallen trees, vehicle breakage or overturning due to bad roads, etc. When length in km is not applicable, we use number, physical quantities, areas, etc. and hence the costs should also be adjusted to be per the unit used.

B3) Cost of loss of direct use values associated with land degradation-induced health problems

Land degradation also leads to soil that can easily be blown into the air by wind. While this is a phenomenon that happens almost always at varying levels, the most pronounced occurrence is when dust storms are created, causing air pollution. This often leads to respiratory tract-related sicknesses including allergies and asthma. Indirect estimates of these costs can be figured out by collecting data from the ministry of health on the number of people treated for respiratory problems and then estimating the percentage of those which were sick due to air pollution related to dust and dust storms. Then, once an estimate of the average treatment cost per patient of respiratory problems is received, which, when multiplied by the number of such patients would give an estimate of the total cost of dust-related health problems. There are also other forms of land degradation-related health problems including contamination of water bodies by agricultural chemicals and industrial waste. Estimating such costs is often difficult and requires detailed and careful study by teams of experts.

In order to estimate the total economic cost of land degradation-induced health problems, we use the same concept as in Section B1 above, where the cost of treatment for those sick from land degradation-induced diseases is used as a proxy measure. To this effect, the following information will be needed:

1) Total number of people who contracted sickness type (*s*) such as upper respiratory problems, stomach problems, and other health problems that can be related to, but may or may not have been caused by land degradation in province p (TPS_LD_{sp}) in the year under consideration;
2) Share of land degradation in total cases of sickness of type (s) in province p in percentage ($SLDS_{sp}$);
3) Average cost of treating an incidence of sickness type (s) per person in province p in US$ (ACT_{sp});

Then, the total economic cost of land degradation-induced sickness of type (*s*) in province p (TEC_LDS_{sp}) can be computed as the product of items 1-3 above, i.e.,7

$$\mathrm{TEC\_LDS}_{sp} = SLDS_{sp} * TPS\_LD_{sp} * ACT_{sp} \qquad (14)$$

and the total economic cost of land degradation-induced health problems in province p (TEC_LDS_p) can be computed as the sum across all sickness types s of the economic cost of land degradation-induced sickness of type (s) in province p (TEC_LDS_{sp}), i.e.,

$$\mathrm{TEC\_LDS_p} = \sum_{s=1}^{S} \mathrm{TEC\_LDS_{sp}} \qquad (15)$$

B4) Cost loss of direct use values associated with land degradation-induced natural disasters

L and degradation can also cause or increase the frequency of weather-related natural disasters including landslides, snow avalanches, rock falls, mud flows and heavy floods. These are different from the costs of infrastructure damage discussed in Section B1 above. While the infrastructure damage discussed in Section B1 refers to minor incidences that happen at different magnitudes and scales every year, the natural disasters may be infrequent, and the locations affected can vary from year to year. Moreover, the damages associated with natural disasters are of large magnitude, often requiring full replacement/reconstruction of the assets/infrastructure damaged. Therefore, estimation of such costs requires collection of long-term data and take an average for the annual figures where the years with small or no disasters are also included into the calculation.

The same procedures used for the estimation of total economic cost of land degradation-induced damage to transport infrastructure can also be used to estimate the cost of land degradation-induced natural disasters in province *p* ($TECO\_LD_p$ (Nat_disa)). The only change will be this category refers to extreme disasters and hence the damages are often irreparable, and the assets are completely destroyed. Therefore, we use costs of total replacement, reconstruction, or rebuilding. The data that will be needed will be:

1) Total quantity of assets type (*a*) destroyed in province *p* ($TQAD\_LD_{ap}$)[2]. This includes: total length (in km) or number, or area (in m^2 or Km^2), or quantity, etc. of each type of asset (a) including paved roads, unpaved roads, local (secondary) roads, railroads, airport runways, irrigation canals, residential, business, hospital, school, etc. buildings, trees, vehicles, domestic and wild animals, etc. that were completely destroyed or killed in each province *p*;
2) Average cost (in US$/per unit) of replacing (reconstructing) the asset type (*a*) which were completely destroyed in province *p* in the year under consideration ($ACRCPU_{ap}$).

Then, the total economic cost of land degradation-induced disasters for asset (a) in province p ($TECO\_LD_{ap}$ (Nat_disa) can be computed as the product of items 1 and 2 above, i.e.,

$$\mathrm{TECO\_LD_{ap}}(Nat\_disa) = \mathrm{TQAD\_LD}_{ap} * \mathrm{ACRCPU}_{ap} \qquad (16)$$

Finally, the total economic cost of all damages due to land degradation-induced natural disasters in province p ($TECO\_LD_p$(Nat_disa)) can be computed as:

$$\mathrm{TECO\_LD_p}(Nat\_disa) = \sum_{a=1}^{A} \mathrm{TECO\_LD}_{ap}\,(Nat\_disa) \qquad (17)$$

Where A is the total number of asset types.

AII.2. Indirect use values

A. Cost of loss of indirect use values associated with land degradation-induced biomass loss in the three biomes (crop fields, forests and pastures)

Land degradation in cropland, forests, and pastures also causes losses in indirect use values which include watershed and soil protection and nutrient recycling, gas (carbon dioxide/oxygen) exchange, carbon storage and climate stabilization, habitat and protection of biodiversity and species and aesthetic, cultural and spiritual values. Once again, these indirect use values can be estimated per unit area of land with different land degradation scenarios and the costs of this in terms of lost indirect use values. Then the total economic cost of the indirect use values lost can also be calculated following the same procedures as in the direct use values described above. However, measurement of the indirect use values is very complex, and requires special expertise which this research team does not have. As a result, only the cost of land degradation-induced loss in soil carbon is estimated. The same procedure as in the estimation of total economic cost of loss of direct use values associated with land degradation-induced loss of biomass in the three biomes can

[2] Due to the complexity of attaching dollar values to human life, the cost of people killed due to natural disasters may be left but the number of people who lost their lives due to land-degradation-induced problems may be mentioned in the report.

be used here as well except that instead of the total biomass that can be produced under each level (i) of land degradation, here we use the total amount of carbon that is sequestered in land with degradation level of (i) and the global price of carbon is used instead of price of the biomass under consideration.

B. Cost of loss of indirect use values associated with land degradation-induced damages to infrastructure

When assets such as infrastructure is damaged, the services and uses they provide are interrupted. For example, when a road is damaged, the number of trucks, cars and people that can commute is reduced or completely halted depending on the level of damage. Therefore, the estimates of the costs of this need to be factored in. For example, if a road is damaged, it's necessary to estimate the number of people who can't travel to work, the goods and services that are not brought to the market, and the economic values that are not generated, etc. This is extremely difficult to figure out, but government ministries often have estimates of the cost of interruption per day per km. The product of this cost and the length (in km) of total damaged road by scale of damage would provide an estimate of the total value of services forgone due to land degradation-induced damage.

C. Cost of loss of indirect use values associated with land degradation-induced health problems

When people are sick due to land degradation-induced problems, they either have to stay at home or are hospitalized, so cannot work. As a result, there is economic implications that can be approximated as the product of the average number of days the typical patient with sickness type (s) misses work and his/her average daily salary/wage. By multiplying then this value with the total number of land degradation-induced patients in the province, we can generate the total cost of loss of indirect use values associated with land degradation-induced health problems.

D. Cost of loss of indirect use values associated with land degradation-induced natural disasters (emergencies)

During natural disasters, transportation and other services are interrupted, and people get sick and become absent from work. All these disruptions of services and work have economic implications, and the total indirect economic cost of such disruptions in province p (TIECp (Nat_disa)) needs to be estimated. Generating such estimates is very difficult but government emergency and disaster management offices often have estimates of such disasters. If the contribution of land degradation to natural disasters (SND_p) can somehow be estimated, then the total economic cost of disruptions due to land degradation-induced natural disasters in province *p* ($TIEC\_LD_p$ (Nat_disa)) can be computed as the product of the share of land degradation in total disasters (SND_p) and the total economic cost of disruptions due to natural disasters in province *p* ($TIEC_p$ (Nat_disa)),

i.e., $\mathrm{TIEC}_{\mathrm{LD}_\mathrm{p}}(Nat_{disa}) = \mathrm{SND}_p * \mathrm{TIEC}_p(Nat\_disa)$ (18)

Annex III Estimation of yield loss in wheat fields and other crops

In this study, land degradation is conceptualized in two layers. First, we tried to classify land degradation differences across provinces. These are captured by a regression model. Then, we classify lands within each province into three categories (slightly degraded, moderately degraded and highly/severely degraded). For the within-province differences we make a conservative estimate of 10% yield losses between lands with successive degradation levels (from least degraded to moderately degraded and from moderately degraded to highly degraded lands) in Sogd, Khatlon and GBAO.

Data for regression-based estimates of yield loss due to land degradation comes from a farm household survey conducted in the three major wheat-producing provinces of Tajikistan, namely: Khatlon, Sogd and Districts of Republican Subordination (DRS). A total of six districts were selected randomly for inclusion into the sample. National experts estimated that the adoption level for the newly introduced varieties from International the Winter Wheat Breeding Program (IWWIP) was only about 10%. Therefore, using power analysis, the minimum sample size needed to ensure confidence and precision levels of 95% and at least 3% for capturing adoption levels of up to 15% was determined to be 690. This sample was evenly distributed among the six districts with 115 farmers each. Depending on the sizes of the districts, random samples of 2-3 communities were selected from each sample district, resulting in 17 communities in the whole sample. Again, depending on the size of the communities, a random sample of 2-4 villages was drawn from each community resulting in 41 villages in the whole sample. The sample of 115 households allocated for each district was then distributed across the sample villages in the district based on their proportional population sizes (Table 12).

As presented in Table 12, the total sample comprises of 690 farm households located in three provinces, six districts, 17 communities and 41 villages. Enumerators from local research institutes were used to collect data during the survey. Enumerators were selected based on previous similar experience, educational background and their availability during survey dates. The Enumerators were then trained by ICARDA and CIMMYT agricultural economists to ensure proper understanding and clarity of all questions in the structured questionnaire that was used for the survey. Some of the secondary information about localities was obtained from government agriculture officers, village leaders and local guides.

The survey was carried mainly to assess the level of adoption and impactsof improved wheat varieties originating from the joint ICARDA-CIMMYT IWWIP. During the survey, farmers were asked several questions related to household demographics, assets ownership, information networks, wheat varietal knowledge and use and production-related data for each of the 690 wheat fields cultivated by the 690 sample farm households (1 field each) and some information on consumption and marketing of wheat. Summary statistics for some of the relevant variables is provided in Table 13.

We used the survey data for the purpose of estimating the loss of biomass in wheat fields due to land degradation. While information about the level of land degradation in each field is best obtained through soil sampling and rigorous laboratory analysis, due to limited time and funds, this was not possible. Therefore, farmers were asked to provide their subjective assessment of the soil depth in their field as shallow, medium or deep. Farmers were also asked the area size of their wheat field, quantities of each input they used, management practices they applied, including the timing of application of inputs. When we analyzed the summary statistics, we noticed that the sample farmers' subjective judgments of the depth of their wheat fields were inconsistent where we found that the average yield in fields assessed by farmers as of medium depth had higher yields than those assessed as shallow, which is consistent with the theoretical expectation. We also found that the average yield in fields assessed by farmers as shallow, was higher than those classified as deep, which is counterintuitive. This is possible if the farmers apply more fertilizers and other inputs in their fields with medium and poor soil qualities than those assessed as deep. To rule this out, we estimated a multiple linear regression where yield is regressed on all quantities of inputs, management practices, and variables representing farmers' assessment of the soil quality in their field.

This analysis also showed that the depth of soil in the field and yield did not have statistically significant association. Therefore, we approached the soil scientists at the TAAS who suggested to use provincial level soil quality differences for the analysis of land-degradation-induced yield loss in crop fields. To this effect, the scientists provided us with evaluation and relative ranking of the soils in the four provinces of Tajikistan (Table 14).

Analysis of the data in Table 14 showed that the DRS province had soils with the highest overall quality (a proxy indicator of the level of land degradation) in Tajikistan. Therefore, the study team has decided that after controlling for all quantities of inputs, management practices, level of rainfall, level of irrigation water, and intensity of pest and weed during the growing season, the average yield in DRS can be used as the reference (representing yields from crop fields with low land degradation) against which yields of all other provinces are compared.

In addition to the average yield differences between those in DRS on one hand and Khatlon, Sogd and GBAO on the other, which were obtained from the regression estimation described in Annex I, conservative values of parameters (presented in Annex II), values (presented in Annex V) and simplifying assumptions (presented in Annex VI) are used for generating the needed data for the estimation of the total economic cost of land degradation in Tajikistan.

Average yields for each crop for each of the four provinces are obtained from official statistics (TAJSTAT 2018). Then the same percentage yield differences across provinces obtained from the regression estimates for wheat fields are assumed for all the other crops (both annual and perennial). The same 10% yield loss between successive land degradation levels within provinces is assumed for estimation of the cost of land degradation.

Table 12: Distribution of sampled farming households by province, district, community and villages

Provinces	Districts	Community	# of villages	# of Households
DRS	Hissor	Durbat	2	29
		Mirzo Rizo	2	43
		Somon	2	43
Khatlon	Bokhtar	Mehnatobod	3	40
		Sarvari Istiklol	2	26
		Zargar	4	49
	Dusti	Dekhqonobod	2	35
		Gulmurodov	3	28
		Jilikul	4	52
	Khamadoni	Dashtigulo	2	40
		Mehnatobod	2	28
		Turdiev	2	47
Sogd	B.Gafurov	Ovchikallacha	4	84
		Yova	2	31
	Mastchoh	Mastchoh	2	39
		Navbahor	1	30
		Obburdon	2	46
Total			**41**	**690**

Source: Household survey (2016).

Table 13: Summary statistics for selected variables

Variable		Min	Average	Max
Proportion of farmers with higher than secondary school education		0	0.9	1
Farming experience (years)		1	16.2	56
Wheat area (ha)		0.2	1.6	25
Total cultivated area (ha)		0.4	3.1	25
Proportion of farmers who assessed their wheat fields as having	high soil salinity (0=No, 1=Yes)		0	0.3
	medium soil salinity (0=No, 1=Yes)	0		0.3
	low soil salinity (0=No, 1=Yes)	0		0.3
	deep soil (0=No, 1=Yes)	0		0.03
	medium depth soil (0=No, 1=Yes)	0		0.7
	shallow soil (0=No, 1=Yes)	0		0.2
Family size		4	9.8	20
Sex (1=male, 0=female)		0	0.9	1
Farmer attend wheat variety demonstration and/or field day (1=yes, 0=no)		0	0.2	1
Quantity of seed used (kg/ha)		200	214	320
Quantity of N fertilizer used (kg/ha)		100	205	250
Quantity of P fertilizer used (kg/ha)		10	49	80
Yield (kg/ha)		950	2,129	4,800
Net margins (Million TJS/ha)		0.2	2.7	7.8
Wheat consumption (kg/capita/year)		18.7	38.9	115

Table 14: Comparison of soil conditions in the provinces of Tajikistan

Province	Rank Salinity (1= least and 4=highest)	Rank Soil Depth (1= deep; 4= shallow)	Rank Soil fertility	Rank overall soil condition^ (1-good; 2- satisfactory; 3- bad
DRS	2	1	In general, it is close to satisfactory, since naturally fertile soils are mainly distributed i.e. brown carbonate soils, but a strong manifestation of erosion processes affects the general condition of soil fertility. All lands on certain slopes	2
Sogd	3	2	Soils are considered naturally infertile (sandy, stony, gypsum-bearing, etc.). The main problems are high rockiness up to 35%, close occurrence of groundwater, salinization and low soil fertility. Irrigation and wind erosion are developed	3
Khatlon	4	1	Salinization, close occurrence of groundwater, and low soil fertility. In some areas of Yavan, Dangara is ravine erosion	3
GBAO	2	1	Lack of land, erosion processes and natural low fertility of lands are very common	3

^Note: ranks are relative to the other provinces.

Annex IV Estimation Method and Results of Cost of Land Degradation in Crop lands

Before applying the Endogenous Switching Regression (ESR), one must check if endogeneity is indeed a problem and hence if ESR is appropriate. To this effect, we carried the Hausman specification test (Hausman, 1978) to determine if endogeneity is a problem, i.e., if there are unobservable factors and/or factors excluded from the regions which simultaneously affect farmers' decision to maintain high soil quality on their wheat fields and the level of wheat yields that the farmers obtain. The test result showed that endogeneity is not a problem. The statistically insignificant correlation coefficients (rho_1 and rho_2) also suggest the absence of endogeneity and self-selection problems. In such cases, the OLS regression gives the most efficient estimates and hence we used OLS.

The OLS results showed that several variables have significant effects on wheat yields in Tajikistan. For example, if everything is taken as equal, the typical female farmer obtains about 314 kg/ha (14%) higher yield than a typical male farmer, which is in quite a contrast with the typically held perception that male farmers are more productive. Moreover, if a typical farmer adds one more round of irrigation from the current average of 1.1 to 2.1 irrigations, then the farmer would obtain on the average 232.78 kg/ha (11%) higher yield (Table 15).

The adoption of improved wheat varieties also increases yield by about 175 kg/ha, i.e., if a farmer uses a more recent improved variety, s(he) would get 175 kg/ha more yield that than what they would if they were to use local (old improved varieties). Land degradation has the highest effect on wheat yields where, after controlling for all other confounding factors (i.e., if they were to use the same quantities of inputs, apply the same management practices, and face the same biotic stresses), the typical farmers in Sogd and Khatlon receive on average 555 kg/ha (25%) and 457 kg/ha (21%) less yield than what a typical farmer would obtain in DRS, which is the province identified as having the highest soil quality (i.e., low soil degradation) in Tajikistan.

The regression results above are consistent with the bivariate comparison of yields across the three provinces included in the survey where the average yields (kg/ha) in DRS, Sogd and Khatlon respectively are 2,320; 2,086 and 2,094. These figures show that the average yield in DRS is higher than that of Sogd and Khatlon by a little over 200 kg/ha which is less than what we found in the regression results. This shows that the average application levels of inputs is higher in Sogd and Khatlon. For example, while 67% and 25% of the farmers in Sogd and Khatlon are using more recent improved varieties of wheat, the level of adoption in DRS is only 23%. The typical farmer in Sogd applies, on average, 0.4 more irrigations than those in DRS and Khatlon while farms in Khatlon have labor input of almost double that of DRS and Sogd.

Yields in the three categories of land degradation in Sogd are then determined in such a way that the area-weighted average of the mean yields in the three land degradation categories are equal to the observed average yield of 2319 kg/ha in DRS where yields in the least degraded lands (2590kg/ha) are 10% higher than those in moderately degraded lands(2354 kg/ha) which in turn are 10% higher than those in the severely degraded lands (2119 kg/ha). As discussed in the data section above, the 10% yield difference between highly and moderately degraded lands and between moderately and severely degraded lands was a very conservative estimate by the authors. We apply the 555kg/ha and 457kg/ha yield reductions in Sogd and Khatlon obtained from the regression relative to DRS across the corresponding land degradation levels in the two provinces to generate the yield levels at the average national input application levels with the typical management practices. Given that GBAO was not included in the survey, the study team decided to take the average of yield levels in Sogd and Khatlon as representative of the yield levels in GBAO. As wheat constitutes 80% of total cereal and legume-growing lands, we assumed that the total economic value lost in wheat fields is representative of all cereal and legume lands and hence applied the parameters for wheat to all cereal and legume areas.

Table 15: Model results from the ordinary least squares (ols) regression of yield on several variables

yield (kg/ha)	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Gender of HH	-314.036	99.25411	-3.16	0.002	-508.9232	-119.148
lower educ of HH	55.524	74.58351	0.74	0.457	-90.92252	201.9702
Age of HH	.889	3.88012	0.23	0.819	-6.728705	8.508696
Ag Exp of HH	-4.045	4.317751	-0.94	0.349	-12.52308	4.432915
Tot land cultivated	-21.439	13.40312	-1.60	0.110	-47.75693	4.877697
Frequency of tillage	-76.966	150.7113	-0.51	0.610	-372.8913	218.9587
Use of improved variety	175.172	74.94061	2.34	0.020	28.02455	322.3196
Seed quantity (kg/ha)	.533	2.735192	0.19	0.846	-4.83759	5.903627
N -fertilizer (kg/ha)	1.987	.7193155	2.76	0.006	.5753403	3.400124
P-fertilizer (kg/ha)	9.699	4.709236	2.06	0.040	.4524753	18.94585
Herbicides (0=No, 1=Yes)	74.206	36.93741	2.01	0.045	1.678789	146.7336
Pesticides (0=No, 1=Yes)	1146.715	6478.966	0.18	0.860	-11574.88	13868.31
labor (days/ha)	58.899	8.185605	7.20	0.000	42.82669	74.97191
Irrigation freqency	232.782	84.43421	2.76	0.006	66.99329	398.5701
Precipitation	33.131	98.96175	0.33	0.738	-161.1824	227.4446
High pest intensity	246.098	154.3173	1.59	0.111	-56.90676	549.1039
High weed intensity	-239.747	217.0345	-1.10	0.270	-665.8992	186.4047
Red soil	45.198	80.46159	0.56	0.574	-112.79	203.1861
Grey soil	66.818	97.69855	0.68	0.494	-125.0151	258.6513
Khatlon Province	-457.496	120.5694	-3.79	0.000	-694.2367	-220.7553
Sughd Province	-555.802	125.4531	-4.43	0.000	-802.1316	-309.4719
_cons	1254.313	747.4981	1.68	0.094	-213.4159	2722.041

Source: Authors' own estimation.
Note: HH stands for household head.

Annex V Parameter values used in estimation

Table 16: Parameter values used for estimation of total economic cost of land degradation in Tajikistan

Parameter	Value	Source
Average annual discount rate (for 7-year)	9.8%	http://mecometer.com/whats/tajikistan/central-bank-discount-rate/
Average price of wheat grain in Tajikistan US$/ton)	369	Local market prices
Average price of cotton in Tajikistan (US$/ton)	495	Local market prices
Average price of potatoes in Tajikistan (US$/ton)	299	Local market prices
Average price of all vegetables in Tajikistan (US$/ton)	825	Local market prices (averaged across all vegetables)
Average price of all fruits in Tajikistan (US$/ton)	894	Local market prices (averaged across all fruits)
Average price of wood in Tajikistan (US$/ton)	28	Local average market prices of woody biomass
Average price of hay in Tajikistan (US$/ton)	48	Local market prices
Straw:grain yield ratio in Tajikistan	1.2	Morgunov et al. (2003)
Price of CO_2 ($/ton)	10	https://openknowledge.worldbank.org/handle/10986/31755 License: CC BY 3.0 IGO
Erosion (ton/ha)	18	Wuepper et al. (2019)
Conversion factor from % humus to % of C	0.58%	https://www.agric.wa.gov.au/measuring-and-assessing-soils/what-soil-organic-carbon
Soil bulk density (g/cm3)	1.5	https://www.soilgrids.org
GDP of Tajikistan in 2018 in Billion US$	7.1	
Exchange rate in 2019 (1US$ in Tajikistan Somoni)	9.7	https://www.ceicdata.com/en/indicator/tajikistan/exchange-rate-against-usd
Total arable land In Tajikistan that is left fallow to regenerate itself (or abandoned) (ha)	30,000	Expert estimate
Total cost of health problems induced by environmental problems equivalent to % of GDP	5%	UN (2012)

Table 17: Percentage level of humus in the topsoil in the provinces of Tajikistan

(Estimates by national soil experts)

	Humus in the topsoil, %		
Province	Low	Medium	High
Sogd	1.0	0.7	0.5
Khatlon	1.3	0.8	0.5
GBAO	1.0	0.7	0.5
DRS	1.5	1.0	0.7
Total Tajikistan	**1.2**	**0.8**	**0.5**

Table 18: Cost of replacement of buildings and other infrastructure destroyed by natural disasters (landslides, snow avalanches, mud flows, rock falls, and heavy floods)

Province`	Total cost of damage on other infrastructure caused by land degradation (Million US$) in a typical year	Equivalent to % of GDP
Sogd	13.2	0.19%
Khatlon	3.3	0.05%
GBAO	4.3	0.06%
DRS	3.6	0.05%
Total Tajikistan	**24.5**	**0.45%**

Source: https://livingasia.online/la_data/tj/no-la_set/

Table 19: Crop areas and their classification in terms of the level of land degradation

Province	Total area (ha)						Percentage of grain area by degree of land degradation (low, medium, severe)			
	Grains	Cotton	Potatoes	Vegetables	Fruits	Total	Low	Modest	Severe	Total
Sogd	126,318	50,765	16,063	16,189	4,484	213,819	25%	55%	20%	100%
Khatlon	199,886	119,550	9,693	30,497	2,480	362,106	20%	60%	20%	100%
GBAO	5,830	0	2,466	632	253	9,181	15%	50%	35%	100%
DRS	79,531	3,663	12,393	12,427	2,697	110,711	10%	65%	25%	100%
4Total Tajikistan	**411,565**	**173,978**	**40,615**	**59,745**	**9,914**	**695,817**	**20%**	**59%**	**21%**	**100%**

Table 20: Forest areas, their classification in terms of the level of deforestation and average wood production

Province	Total forest area (ha)	Percentage of forest area by deforestation level (intact or low, moderate and severe deforestation)^				Average yield of woody biomass (ton/ha) by degradation category~			
		Low	Modest	Severe	Total	Low	Modest	Severe	Total
Sogd	119,600	30%	30%	40%	100%	130	95	50	88
Khatlon	186,600	40%	30%	30%	100%	120	90	45	89
GBAO	12,600	40%	30%	30%	100%	110	80	40	80
DRS	103,600	40%	30%	30%	100%	90	65	33	65
Total Tajikistan	**422,400**	**37%**	**30%**	**33%**	**100%**	**115**	**85**	**43**	**83**

Sources : ^National expert estimates, ~ Global Forest Resources Assessment 2000.

Table 21: Pasture areas, their classification in terms of the level of degradation, and average pasture yield

Province	Total forest area (ha)	Percentage of pasture area by degree of land degradation (low, medium and severe)^				Average pasture yield of hay (ton/ha) by degradation category~			
		Low	Modest	Severe	Total	Low	Modest	Severe	Total
Sogd	785,100	44%	32%	24%	100%	0.6	0.5	0.4	0.5
Khatlon	1,222,800	43%	34%	23%	100%	0.6	0.5	0.4	0.6
GBAO	734,100	48%	30%	22%	100%	0.4	0.3	0.3	0.4
DRS	1,086,700	42%	39%	18%	100%	0.7	0.6	0.3	0.6
Total Tajikistan	**3,828,700**	**44%**	**34%**	**22%**	**100%**	0.6	0.5	0.4	0.5

Sources: ^National expert estimates, ~ National expert estimates.

Table 22: Repair cost of transportation infrastructure damaged by land degradation (mainly due to erosion and flooding)

Infrastructure type	Province	Total distance in the country including bridges, km	Infrastructure affected by land degradation in a typical year, %	Total damage induced by land degradation in a typical year, km	Average cost of repair or reconstruction (TJS/km)	Total annual cost of damage caused by land degradation in a typical year, TJS
Paved Roads	Sogd	2,848	82%	2,335	7,875	18,391,894
	Khatlon	4,110	79%	3247	23,014	74,723,183
	GBD	1,122	41%	460	2,556	1,175,581
	DRS	2,251	79%	1,778	23,127	41,127,046
	Total Tajikistan	**10,331**	**75.7%**	**7,821**	**56,572**	**135,417,704**
Non-paved Roads	Sogd	639	18%	115	694	79,789
	Khatlon	1,051	21%	221	8,555	1,888,152
	GBD	1,605	59%	947	1,099	1,040,603
	DRS	594	21%	125	543	67,696
	Total Tajikistan	**3,889**	**36%**	**1,407**	**10,890**	**3,076,241**
Local (secondary) roads	Sogd	4,204	18%	757	694	524,937
	Khatlon	4,749	21%	997	8,555	8,531,716
	GBD	476	59%	281	1,099	308,615
	DRS	1,811	21%	380	543	206,394
	Total Tajikistan	**11,240**	**21%**	**2,415**	**10,890**	**9,571,662**
Rail roads	Sogd	291	5%	15	3,938	57,254
	Khatlon	423	5%	21	11,507	243,600
	GBD	0	5%	0	1,278	0
	DRS	263	5%	13	11,564	152,293
	Total Tajikistan	**978**	**5%**	**49**	**28,286**	**453,147**
Airport runways (airstrips)	Sogd	4	5%	0	7,875	1,575
	Khatlon	4	5%	0	23,014	4,603
	GBD	2	5%	0	2,556	256
	DRS	3	5%	0	23,127	3,469
	Total Tajikistan	**13**	**5%**	**1**	**56,572**	**9,902**
Total/average cost of damage to transportation infrastructure	Sogd	7,986	40%	3,222	5,914	19,055,449
	Khatlon	10,337	43%	4,486	19,034	85,391,253
	GBD	3,205	53%	1,688	1,496	2,525,055
	DRS	4,922	47%	2,297	18,094	41,556,899
	Total Tajikistan	**26,451**	**44%**	**11,693**	**41,519**	**148,528,657**

**figures rounded*

Source: For roads, Committee for Environmental Protection (CEP) and national expert estimates.
For airports https://en.wikipedia.org/wiki/List_of_airports_in_Tajikistan#Airports.

Table 23: Forgone economic and social benefits due to transportation infrastructure damaged or hampered by factors related to land degradation

(mainly due to interruptions of road, rail and air transportation and associated mechanical damage and repair cost due to erosion, flood, and dust storms originating from Tajikistan)

Infrastructure type	Province	Total distance in the country, km	Percentage of infrastructure affected in a typical year by land degradation	Average number of days infrastructure affected by land degradation stays unrepaired, days/year	Average economic benefits lost due to infrastructure affected by land degradation, TJS/day	Total benefits lost due to delay or interruption of transportation, TJS/year
Paved Roads	Sogd	2,848	82%	30	648	45,420,417
	Khatlon	4,110	79%	30	50	4,889,831
	GBD	1,122	41%	30	1,498	20,673,299
	DRS	2,251	79%	30	3,594	191,745,898
	Total Tajikistan	**10,331**	**76%**	**30**	**1,145**	**262,729,444**
Non-paved Roads	Sogd	639	18%	30	142	490,675
	Khatlon	1,051	21%	30	13	88,725
	GBD	1,605	59%	30	2,156	61,245,885
	DRS	594	21%	30	955	3,575,298
	Total Tajikistan	**3,889**	**36%**	**30**	**1,063**	**65,400,584**
Local (secondary) roads	Sogd	4,204	18%	30	142	3,228,168
	Khatlon	4,749	21%	30	13	400,911
	GBD	476	59%	30	2,156	18,163,889
	DRS	1,811	21%	30	955	10,900,445
	Total Tajikistan	**11,240**	**21%**	**30**	**304**	**32,693,412**
Rail roads	Sogd	0.2	5%	2	324	6
	Khatlon	0.2	5%	2	25	1
	GBD	0.6	5%	2	749	44
	DRS	0.2	5%	2	1,797	38
	Total Tajikistan	**1.2**	**5%**	**2**	**742**	**88**
Airport runways (airstrips)	Sogd	4.0	5%	1	648	130
	Khatlon	4.0	5%	1	50	10
	GBD	2.0	5%	1	1,498	150
	DRS	3.0	5%	1	3,594	539
	Total Tajikistan	**13.0**	**5%**	**4**	**5,791**	**829**
Total/average cost of damage to transportation infrastructure	Sogd	7,695	42%	13.6	330	49,139,395
	Khatlon	9,914	45%	15.6	29	5,379,478
	GBD	3,206	53%	25.5	1,925	100,083,267
	DRS	4,659	49%	18.3	2,232	206,222,218
	Total Tajikistan	**25,474**	**46%**	**29.9**	**764**	**360,824,357**

Source: Expert estimates.

Annex VI Assumptions made for estimation of the cost of land degradation in Tajikistan

As a number of parameters were not readily available, the study team has – in consultation with experts in the respective fields ¬– made the following assumptions (Table 24). As the main objective of the study is to generate credible estimates, we were conservative in the choice of values of parameters so that the total economic cost of land degradation estimated in this study will be the minimum estimate. The rationale behind this decision is that if one or more parameters are over(under)estimated, there is a usual tendency by experts, donors and/or policy makers to dismiss such estimates. However, if the estimates prove to be substantial even in the face of conservative estimates of parameters, then we believe that all concerned stokeholds will be alarmed about the extent and cost of land degradation and hence find motivation to do something about it.

Table 24: Assumed values of different parameters for estimation of total economic cost of land degradation in Tajikistan

Parameter	Value	Source
Yield difference between fields with deep and moderate soil depths in the same province	10%	Conservative estimate by local experts
Yield difference between fields with moderate and shallow soil depths in the same province	10%	Conservative estimate by local experts
Value of non-consumptive uses in all crop fields, forests and pastures	0	No data was available, and the study team did not have the expertise to make estimates or assumptions. Therefore, the most conservative value of 0 is used.
Gains in the bequest value of an asset due to future advances in technology.	0	While we can estimate it from the trend, we chose to use a conservative value of 0.
Yield loss in the 10% of grain fields in DRS which are classified as least degraded	0	Applying the concept of yield gap analysis, the yield loss in the best soils in DRS (10% of total land) is assumed to be zero. The yield level in these fields is used as the benchmark against which all other fields in DRS and the other provinces are compared.
Yield of other biproducts in potato, vegetable and fruit areas	0	While crop residues from wheat and other cereals and legumes are known to have value, and hence are included in the calculation of loss, no crop residues of any value is assumed for vegetables and fruits.
Share of soil qualities in total yield differences between provinces	80%	After controlling for all input quantities, rainfall level, number of irrigations, pest and weed infestation, management practices, and location factors, we assumed that other differences such as elevation and temperature account only 20% while differences in soil qualities account for 80%.
Prices and yields of all other cereals and legumes	Same as wheat	Out of total cereal and legume-growing areas in Tajikistan, wheat constitutes 80%. Therefore, for simplicity, the total area under cereals and legumes is treated in this study as wheat area and the regression results on yield and market prices of wheat are applied for all cereal and legume areas.
Cost of repairing railroad	50% of cost of repairing paved roads	Authors own assumption
Cost of repairing airport runway	100% of cost of repairing paved roads	Authors own assumption
Share of land-degradation in total health problems induced by environmental problems	50%	Authors own assumption

Annex VII Outreach Activities

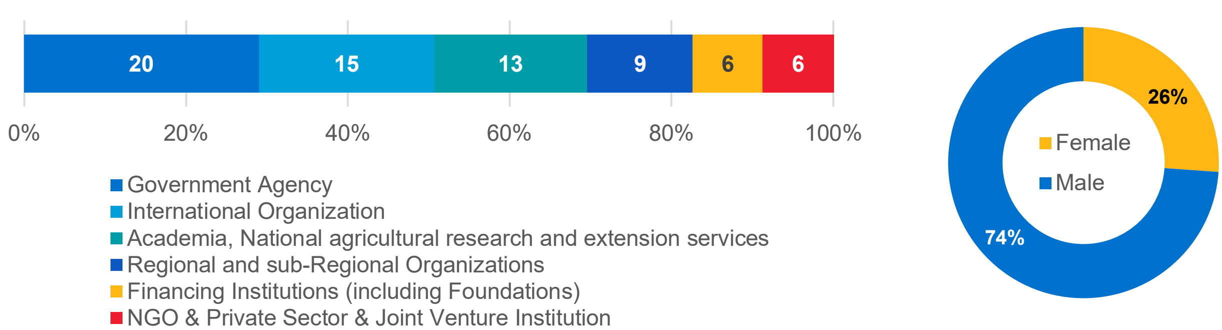
AVII.1. Inception workshop

The joint workshop was held on the 27th of September 2019 in Tajikistan's capital, Dushanbe to conduct the regional consultation for Central Asian Climate Information Platform (CACIP) as well as to launch the study on the assessment of Costs of Environmental Degradation (CoED) in Tajikistan. The event was jointly hosted by the Tajik Academy of Agricultural Sciences (TAAS) and the State Committee on Environmental Protection (CEP).

The workshop brought together 69 delegates from five Central Asian countries and partner organizations, alongside agricultural research organizations, academia, financial and international institutions, nongovernmental agencies and policy makers (Figure 9). Alongside CACIP demonstrations, the participants discussed local and international experiences on environmental degradation, and ecosystem services evaluation.

The event was shared for media outreach at the Regional Program for Sustainable Agricultural Development in Central Asia and Caucasus in English and Russian news. The video reportage and interviews of Mr. Jan-Peter Olters, the World Bank Country Manager for Tajikistan, and Turkmenistan, and Mr Ram Sharma the Regional Coordinator at ICARDA-Central Asia and Caucasus can be found at this link. The materials of the Joint workshop have been shared in the repositories of MELSpace, as well as on the Monitoring, Evaluation & Learning (MEL), Twitter page: @MEL_CGIAR. The workshop report is available as separate document.

Figure 9: Number of participants during inception workshop disaggregated by organization type and gender



AVII.2. Final Workshop

The final workshop was held on the 17th of December 2019 in Dushanbe, to present approaches, collected data, and calculation templates to estimate costs of environmental degradation. The purpose of presenting these detailed approaches and calculation templates was to introduce and transfer easy-to-use methods to estimate costs with software (i.e. Excel) tables which are commonly available in most of the offices. Another objective was to validate preliminary results and fine-tune used values based on feedback from organizations attending the event. The event was kindly hosted and chaired by the Committee on Environmental Protection and the organization of workshop was facilitated by TAAS. The workshop featured 32 participants representing government organizations, academia and research institutions and several international organizations based in Tajikistan (Figure 10). The event and resulting discussions were covered in mass media; Table 25 provides links to published material.

Figure 10:Number of participants during final workshop disaggregated by organization type and gender

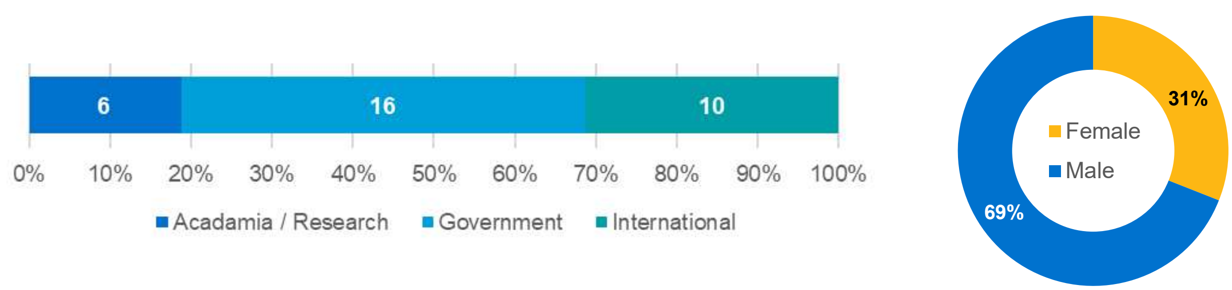


Table 25: Links to materials posted from final workshop

Online – Committee on Environmental Protection	Online – Aarhus Centres Tajikistan	In print
http://tajnature.tj/?p=7257&lang=ru	*https://www.aarhus.tj/seminar-po-ocenke-degradacii-okrujayushei-sredi/*	*Newspaper “People and Nature*
		

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