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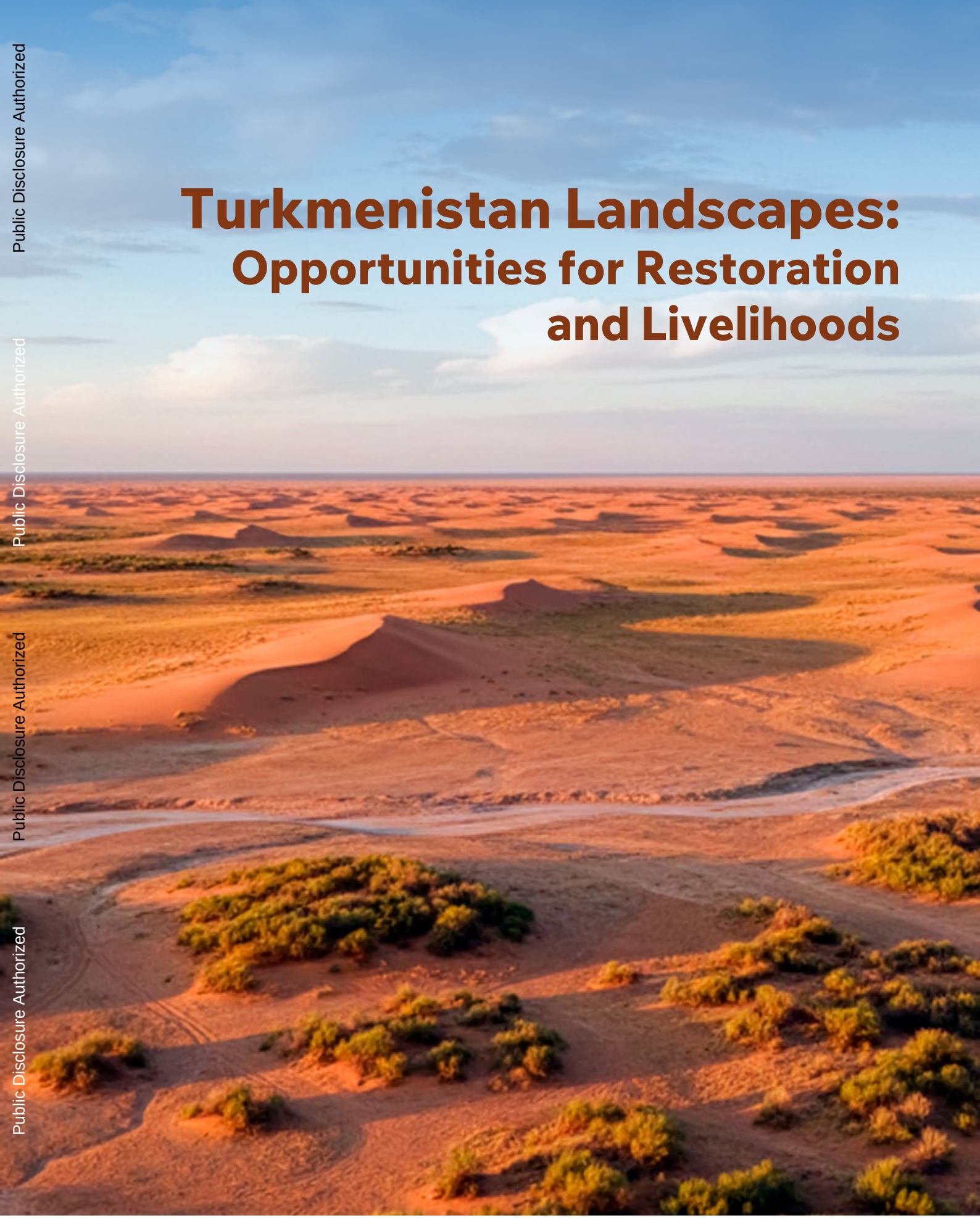
Turkmenistan Landscapes:
Opportunities for Restoration and Livelihoods



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Turkmenistan Landscapes:
Opportunities for Restoration and Livelihoods

February 2026

About the Report

This report is a demand-driven just-in-time rapid study stemming from Turkmenistan's interest in joining the IBRD regional RESILAND program for Central Asia, which focuses on land degradation and addresses the urgent need for climate change adaptation in response to land degradation, desertification, and excessive livestock grazing. Recognizing Turkmenistan's commitment to reversing these environmental challenges, the analytical study used stakeholder consultations and scientific research results provided by the National Institute of Deserts, Flora and Fauna, the Ministry of Environment Protection of Turkmenistan, as well as remote sensing technologies and ecosystem modeling, leveraging both global and national data.

The report was prepared in response to the Institute's interest in analytical work to support government-led restoration efforts in a specific geographic area of the country (three local areas of interest [AOIs] discussed in the report). It has been reviewed and endorsed by the Institute.

The report serves as the first step toward joint actions of Turkmenistan and the World Bank under the Central Asia Resilient Landscape Restoration Program (RESILAND CA+ Program). The World Bank RESILAND CA+ Program, launched in 2019, provides Central Asia countries with a regional framework for landscape restoration to increase the resilience of regional landscapes and finances analytics and advisory, and supports investment projects in these countries. The Program includes projects to support activities with regional spillovers, namely (i) improved connectivity and integrity of natural resources across borders, (ii) increased resilience of key regional infrastructure prone to the impacts of land degradation (for example, roads and railways), (iii) increased resilience of transboundary communities benefiting from more productive landscapes and livelihood opportunities, and (iv) increased GHG mitigation due to restored landscapes. The Program also supports a Regional Exchange Platform open to all countries in Central Asia for high-level dialogue to support harmonization of policies and approaches between countries on landscape restoration, designed as a component of the projects and executed by the Regional Environmental Centre for Central Asia (CAREC).

The report Turkmenistan Landscapes: Opportunities for Restoration and Livelihoods focuses on degradation hotspots and land restoration opportunities mapping, providing an estimate of the costs and benefits of land restoration, as well as cost of inaction and recommendations. The findings from the study are being used for the development of country-specific, science-informed development action plans to tackle the issues.

In alignment with the World Bank Country Engagement Note, this report will primarily contribute to the first pillar, "Addressing Global and Regional Challenges," by engaging Turkmenistan in the World Bank Group's Central Asia regional initiatives, such as RESILAND CA+. The land restoration activities discussed in the report aim to conserve biodiversity, address air pollution, and promote climate-resilient agricultural practices. The report's recommendations will not only facilitate climate adaptation and mitigation efforts but also address the associated social and economic challenges.

Together, these efforts by the government and partners in Turkmenistan can meet objectives of jobs, food production, and economic prosperity for the population as investing in landscape restoration is critical to address the complex nexus of local livelihoods, land degradation, climate change, environmental security, and economic growth. The RESILAND CA+ Program is offered as a mechanism for tackling these issues, and, thus, increasing the resilience of landscapes and people in the region. A regional program is considered as effective approach to making a significant impact in the region and aligns with Turkmenistan's willingness to enhance cooperation. Since borders areas are hotspots for land degradation and poverty and restoring land can provide a dual benefit of increased productivity and improved livelihoods, and address risks to communities and infrastructure, regional cooperation is needed to harmonize approaches and harness the ecological and economic benefits across shared corridors. In this context, national approaches would not be as effective in affecting landscape restoration. A regional program is also aligned with countries' changed vision of addressing the degradation of regional public goods by coming together as one region.

More information on the work of the World Bank can be found at https://www.worldbank.org/en/country/turkmenistan.

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Acronyms

AOI	Area of Interest
BAU	Business-as-Usual
BCR	Benefit-Cost Ratio
CMIP	Coupled Model Inter-comparison Projects
CSA	Climate-Smart Agriculture
FOLU	Forestry and Other Land Use
GCM	General Circulation Model
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IUCN	International Union for Conservation of Nature
MRV	Monitoring, Reporting, and Verification
NbS	Nature-Based Solutions
NIDFF	National Institute of Desert, Flora and Fauna
NDC	Nationally Determined Contribution
NGO	Nongovernmental Organization
NIDFF	National Institute of Deserts, Flora, and Fauna
R&D	Research and Development
PES	Payments for Ecosystem Services
PPP	Public-Private Partnership
PV	Present Value
RCP	Representative Concentration Pathways
RIOS	Resource Investment Optimization System
SAVI	Soil-Adjusted Vegetation Index
SPEI	Standardized Precipitation Evapotranspiration Index
SSP	Shared Socioeconomic Pathways
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change

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This report was prepared by the World Bank with contributions from the National Institute of Deserts, Flora and Fauna (NIDFF), the Ministry of Environment Protection of Turkmenistan. The work was prepared under the World Bank's RESILAND CA+ Program that seeks to help affected rural communities across Central Asia in restoring landscapes; protecting lives and livelihoods; and increasing resilience to further desertification, landscape degradation, and climate change.

The report was produced by a core World Bank team under guidance from **Sanjay Srivastava**, Regional Manager for Environment and **Andrei Mikhnev**, Country Manager for Kazakhstan and Turkmenistan, and led by **Paola Agostini**, Lead Natural Resources Management Specialist, **Peter Kristensen**, Lead Environmental Specialist, and **Asferachew Abebe**, Senior Environmental Specialist. The core team included from the World Bank **Elena Strukova Golub**, Senior Environmental Economist; **Anna Gorbacheva**, Environmental Specialist; **Sepul Barua**, Environmental Economist; and **Jorge Leon Sarmiento**, Applied Ecology Specialist.

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Executive Summary

Turkmenistan faces significant environmental and climate-related challenges, with widespread land degradation, increasing salinization, water scarcity, and vulnerability to climate change impacts. Approximately 4.9 million hectares (ha) of land are currently degraded, with projections indicating an expansion to 6.3 million ha by 2050 under a business-as-usual (BAU) scenario. These trends threaten national food security, rural livelihoods, and economic development, especially given that agriculture employs half the country's labor force and contributes 10 percent of gross domestic product (GDP).

This analytical study — developed under the World Bank's Central Asia Resilient Landscape Restoration Program (RESILAND CA+) — aims to identify strategic land restoration opportunities and inform policy and investment planning for resilient landscape management in Turkmenistan. The study employed remote sensing technologies, ecosystem modeling, and extensive stakeholder consultations to assess the extent and impacts of land degradation, identify opportunities for landscape restoration, and evaluate the costs and benefits of restoration.

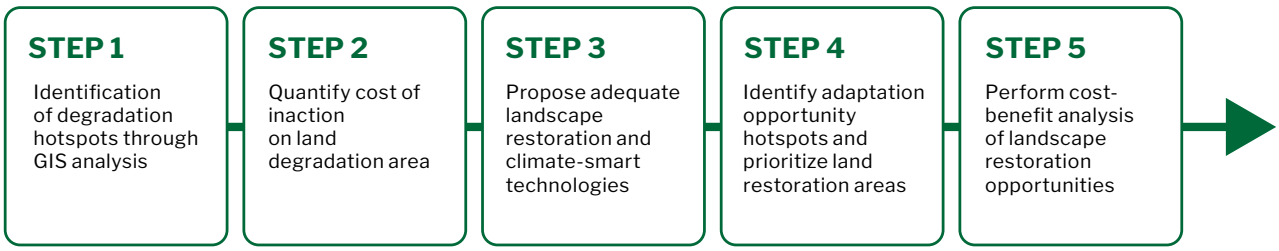
Key Messages

1. Restoration interventions in Turkmenistan could prioritize a national-level portfolio targeting the restoration of 0.63 million ha with a budget of US$45 million. The hotspots of adaptation opportunity have the highest potential for landscape restoration and adaptation actions to reduce land degradation and cover about 15 percent of severely degraded lands in forests, croplands, pastures, and wastelands (desert).
2. The three areas of interest with local feasibility of restoration actions—Dashoguz, Ahal, and Altyn asyr—allow to restore the same total area at a lower cost. The restoration could be carried out in five-year windows, focusing on one region at a time, with nature-based solutions tailored to different land-cover types, aiming to decrease crop production costs, increase agricultural and livestock productivity, reduce infrastructure damage, enhance ecosystem services, and lower greenhouse gas (GHG) emissions.
3. From an economic perspective, in Turkmenistan, it is significantly cheaper to take restorative actions with an average cost of US$97 per hectare per year than incur land degradation cost of inaction compared to the US$119 per hectare per year. Moreover, the benefits of restorative actions, including GHG removal, average US$1,588 per hectare per year and far exceed the costs.

Approach and Methodology

This study employs the landscape approach to identify degradation hotspots in different landscapes and explore opportunities for landscape restoration. Figure E1 provides an overview of the study's flow and logic.

Figure E1. Methodology used in this report



The study proposes a prioritized suite of climate-smart technologies tailored to Turkmenistan's four major land-cover types: Croplands (conservation agriculture, crop diversification), Pastures (rotational grazing, silvopastoral systems), Forests and Shrublands (reforestation, vegetation restoration), and Wastelands (phytomelioration with licorice planting and improved drainage). Each approach was validated through expert consultations and adapted to the degradation context and feasibility of the intervention areas.

Policy and Investments Recommendations

To scale up restoration efforts and overcome institutional, technological, and financial barriers, the report recommends the following:

- Integrating landscape restoration into the national adaptation strategy and rural development plans.
- Enhancing data availability, technical equipment, monitoring systems, and cross-sector coordination.
- Developing regional and national restoration portfolios to optimize public spending and donor support.
- Establishing an enabling environment and frameworks for green finance, carbon credit markets, and restoration bonds.
- Promoting knowledge exchange and capacity building through research institutions and extension services.

Conclusion

Turkmenistan has a unique opportunity to align its ambitious economic growth with environmental sustainability and climate resilience. Investing in landscape restoration delivers strong returns, enhances national food and water security, and contributes to regional stability. The RESILAND CA+ Program offers a platform for coordinated action, and this report provides the analytical foundation to guide impactful investments and policies.

1. Introduction

1.1. Context and Background

Turkmenistan has a unique opportunity to invest and ensure its ambitious economic growth becomes more sustainable. A more sustainable economic growth model based on the efficient use of natural resources would reduce land degradation, pollution, climate and environmental impacts, and strengthen resilience to climate change. It could also help strengthen Turkmenistan's economic competitiveness in a more climate - and environmentally aware global marketplace. To grow sustainably, the country needs to safeguard its natural capital. The main environmental issues that affect economic growth, people resilience, and natural capital are described below.

Turkmenistan spans a land area of 47 million ha, with 84.6% of it allocated to agriculture. Most of the agricultural land is used as pastures, about 4 percent from the land area are arable land, and the remainder consists of perennial plantations and other uses. Land use efficiency is shaped by natural reclamation, irrigation, and economic factors unique to each region. Currently, two-thirds of irrigated land requires reclamation improvements, primarily due to secondary salinization — a key driver of irrigated land degradation. Agriculture accounts for 92 percent of water resource consumption, with irrigation systems experiencing significant inefficiencies and high losses due to outdated infrastructure. Salinization typically occurs on poorly drained lands where groundwater levels range from 2–3 m, with seasonal fluctuations of 0.8–1.0 m. Additionally, deflation and soil erosion present significant environmental challenges. Addressing these environmental issues through targeted measures will mitigate land degradation, support rehabilitation where needed, and optimize land resource protection.

Turkmenistan is considered vulnerable to the impacts of climate change and ranked 117 out of 181 countries in the 2020 ND-GAIN Index.[1] The country's climate is highly continental and arid (cold semi-arid), influenced significantly by its vast desert regions, such as the Karakum Desert, which covers much of the country. Turkmenistan experiences high temperatures (average day temperatures of 38–40°C and night temperature of 25–30°C between June and August) and low precipitation levels (range 76–380 mm annually), resulting in a very arid climate zone. This is further exacerbated by its geographic features such as the proximity to the Caspian Sea and the highlands of Turkmenistan. Climate change is expected to worsen these conditions, making the region even drier and warmer, with significant implications for water resource management and agricultural productivity. Average temperatures are projected to rise by 5.1°C in Turkmenistan by the 2090s, relative to the 1986–2005 baseline under the highest emissions pathway (RCP8.5) with the pace of warming significantly exceeding the global average (World Bank Group and Asian Development Bank 2021).

[1] The ND-GAIN Country Index summarizes a country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience. It aims to help governments, businesses and communities better prioritize investments for a more efficient response to the immediate global challenges ahead https://gain.nd.edu/our-work/country-index/rankings/.

Climate change heightens the risk of drought and desertification in Turkmenistan. Lowland pastures occupy most of the country's territory, traditionally providing services to rural communities. Excessive herds on pastures lead to overgrazing, stripping the land of its vegetative cover and resulting in erosion of topsoil. This is aggravated by deforestation as well as mechanized destruction during engineering and construction works. Around 70 percent of all pastures show various levels of degradation. According to the United Nations Convention to Combat Desertification (UNCCD 2019), 30.39 percent of the country's population is exposed to land degradation and 20.75 percent to drought. On average, land degradation in Central Asia costs over 5 percent of regional gross domestic product (GDP) (ELD Initiative 2016), and this strongly affects the agriculture sector, which accounts for 50 percent of total employment and contributes 10 percent of the GDP. About 48 percent of the total population lives in rural areas and depends on livestock and crop cultivation; thus, the economy's livelihoods and food security depend on this sector's sustainability.

More frequent and more severe droughts and desertification create favorable conditions for the emergence of dust storms throughout Turkmenistan. In the Aral Sea region of Turkmenistan, 600,000 tons of solid aerosol particles (salts) from the Aral Sea side is deposited annually — 430,000 tons to the irrigated zone and 170,000 tons to the desert zone. These processes lead to a 70–80 percent reduction.[2]

Ninety five percent of the flow of the Amu Darya River is diverted for irrigation which contributes to the river's inability to replenish the Aral Sea. The country's remaining few and mostly shallow and unevenly distributed rivers contribute 5 percent for irrigation. The Karakum river in Turkmenistan — one of the world's largest irrigation and water supply canals — and has opened new tracts of land to agriculture, especially cotton. With increasing temperatures, reduced precipitation, evapotranspiration, and increasing water demand, Turkmenistan will likely suffer from even greater salinization and water scarcity.

Soil contamination has negative effects on the water-agriculture nexus. Soil and groundwater contamination with agricultural chemicals, pesticides, salinization, and water logging of soil due to poor irrigation methods have economic and health consequences. Irrigation water often does not meet the state standards for mineral content — chlorides and sulfates are excessive and have led to the salinization of more than 60 percent of agricultural land.

The Caspian Sea suffers significantly from oil refining and extraction pollution, untreated sewage, offshore oil fields, and industrial waste. This has reduced fish production, thus exacerbating overfishing and depletion of several fish species. The pollution also affects human health and subsequent GDP loss due to high air pollution concentration resulting from industrial pollution, implying increased healthcare costs.

Turkmenistan faces significant water scarcity, with only 940 m^3 of water available per square kilometer annually.[3] Per capita, the country's water resources availability is limited to 0.16 thousand m^3 per year. The hydrographic network is unevenly distributed, with the central, northern, and western regions having no rivers. Amu Darya, the largest river in Central Asia, flows along Turkmenistan's eastern border, stretching 1,000 km through the country out of its

[2] Data provided by the National Institute of Desert, Flora and Fauna (NIDFF).

[3] 1999 data provided by NIDFF.

total 2,520 km length. Southern Turkmenistan's river network includes the Murghab, Tedzhen, Atrek, and smaller rivers from the northeastern Kopetdag slopes. Across the country, there are approximately 3,000 watercourses, totaling 14,300 km in length. However, 95 percent of these rivers have channels shorter than 10 km, with only 40 rivers having a permanent flow. Lakes are not a prominent feature of Turkmenistan's hydrography, primarily found in the Uzboy dry river channel, floodplains, and natural depressions. Notable examples include the Sarygamysh Lake (2,200 km^2) and freshwater lakes in Western Uzboy, such as Yaskhan, Kara-Tegelek, and Topyatan. To the west, the Caspian Sea borders Turkmenistan, stretching 1,200 km from north to south. It spans an area of approximately 380,000 km^2 with a water volume of 78,000 km^3 and an average salinity of 12.8 percent. The Caspian Sea is subject to significant long-term level fluctuations.

In 2021, almost all water resources in the country — 92 percent — went to agricultural needs. Another 5 percent was used by industry, and only 3 percent went to household needs (Turkmen State Publishing Service and UN 2023). As part of the Socio-Economic Development Program for 2019–2025, reclamation works will be carried out on 289,140 ha to improve the condition of irrigated lands. The government has earmarked US$2 billion for these efforts from 2019 to 2025 (Government of Turkmenistan 2019a). The Karakum Canal, a 1,380-km-long artificial canal, plays a critical role in irrigated agriculture and provides drinking water to major industrial cities. Turkmenistan's irrigation infrastructure includes over 44,200 km of irrigation systems, 36,000 km of drainage collectors, 16,000 water management facilities, 15 reservoirs, 238 inter-farm water pumping stations, approximately 2,500 local pumping stations, and 962 wells.

Investments and actions to restore degraded drylands in Turkmenistan can prevent future land degradation, decrease risk of sand and dust storms, and enhance national food security. Land restoration and conservation measures are required on two-thirds of irrigated lands. Irrigated land suffers mostly from secondary salinization, which is formed on poorly drained irrigated lands with a groundwater level of 2–3 m and a seasonal amplitude of 0.8–1.0 m. Desert-sand pastures are mostly impacted by deflation and soil erosion: 50.5 percent of desert pastures are subject to low wind erosion — 45.0 percent moderate and 4.5 percent severe. In the areas of industrial and transport development of deserts, the processes of deflation of sandy soil are taking place, which requires work on sand fixation.[4]

Against this background, in May 2022, Turkmenistan approved its nationally determined contribution (NDC) to the Paris Climate Agreement, aiming for a 20 percent reduction in greenhouse gas (GHG) emissions by 2030 (Government of Turkmenistan 2022). The NDC contains an adaptation component and notes that the agriculture and water management sectors have a high vulnerability to climate change and require urgent adaptation action. Turkmenistan's saxaul forest[5] and the woody area are showing a degradation trend (UNECE and FAO 2019). The study identified that saxaul and Tugai forests were in the greatest need of

[4] Data provided by the NIDFF.

[5] The saxaul tree (*Haloxylon ammodendron*) is vital for Turkmenistan due to its exceptional ability to thrive in arid, saline, and sandy soils, particularly in the expansive Karakum Desert. It is one of the elements in combating desertification by stabilizing mobile sand dunes, reducing wind erosion, and protecting infrastructure such as roads and settlements from encroaching sands. Saxaul also supports biodiversity by creating microhabitats in harsh desert environments and contributes to climate change mitigation through carbon sequestration. Additionally, it has traditional importance as a source of fuelwood for local communities, making it a key species in national land restoration and sustainable land management efforts.

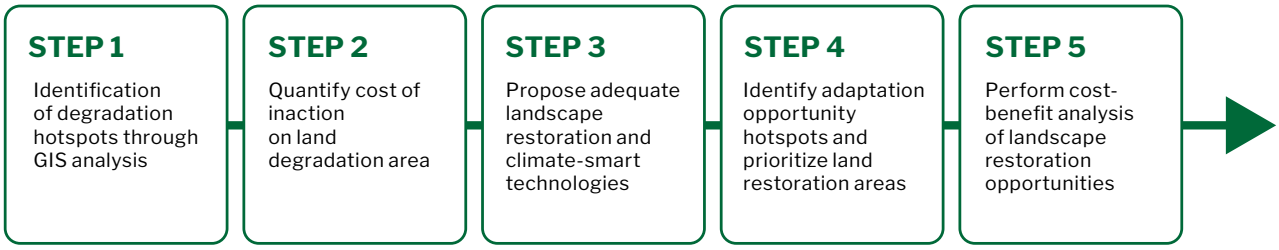
restoration. Turkmenistan's National Forest Program 2021–2026 prioritizes the restoration and afforestation of saxaul forests to combat the erosion of deserts and protect settlements from wind-blown sand. The program also contains plans afforestation of the area around Lake Altyn asyr and to plant 4 million trees as shelterbelts.

1.2. Report Objective

This study aims to provide policy makers with information to address land degradation in Turkmenistan, by identifying hotspots of land degradation and declining land productivity along with areas of adaptation opportunity where landscape restoration can best offset these trends under changing climate conditions. The report also analyses the costs of land degradation ('cost of inaction') compared to investing in adaptation technologies 'cost of action'. With this, the study aims to facilitate consensus-building with national and international stakeholders and not only make the case for scaled-up investment in adaptation and landscape restoration efforts but also provide guidance on where to start.

This study employs the landscape approach to identify degradation hotspots in different landscapes and explore opportunities for landscape restoration. Figure 1 provides an overview of the study's flow and logic.

Figure 1. Schematic of methodology used in this report



1.3. Methodology

The methodology applied in this study included the following steps:

Step 1. Identification of land degradation hotspots through GIS analysis

Analyze land degradation indicators and trends

- Establish the historical baseline for land degradation trends using vegetation conditions, using data on SAVI from 2014 to 2024.
- Classify degraded areas into one of three vegetation condition categories: Poor, Average, or Good.
- Calculate area of land subjected to future land degradation at a national scale with a continuation of current degradation trends up to the middle of the century.
- Increased drought risk (Standardized Precipitation Evapotranspiration [SPEI] value decrease) and extreme Heat Risk Index (occurrence of days above extreme temperature thresholds) were used as indicators of risk factors for agriculture, livestock, and human well-being. The following climate scenarios were used: SSP2–4.5. and SSP3–7.0. for 2040–2059 period.

Identify hotspots of land degradation:

- Develop a map of land degradation hotspots at a national scale that identifies areas that are most vulnerable to land degradation.
- Analyze the feasibility of interventions. Non-feasible areas for restoration are defined as areas with an elevation higher than 3,500 m (where very little human activities occur) and slopes steeper than 30 degrees (difficult implementation of restoration measures); also, protected areas with IUCN categories I–IV are excluded as their objective is conservation. Validation of degradation areas and feasibility assessment of interventions are done through expert consultations with the NIDFF of the Ministry of Nature Protection of Turkmenistan. Three priority areas are selected for restoration.

Step 2. Quantify cost of inaction on land degradation area:

- Evaluate physical losses from agriculture and ecosystem service. The cost of inaction on land degradation in Turkmenistan is defined as the difference between the outputs — in monetary terms — of good-quality land and degraded land. The market valuation approach is used for valuing the costs in terms of foregone crop and livestock production and the benefit-transfer method is used for foregone ecosystem services. For monetizing GHG emissions, the shadow price of carbon is used.

Step 3. Propose adequate landscape restoration and climate-smart technologies

- Prioritize one climate smart technology per each land cover class

Step 4. Identify adaptation opportunity hotspots and prioritize land restoration area:

- Use spatial modeling of ecosystem services and identify the set of integrated landscape management interventions in the hotspots of adaptation opportunity with the highest potential for landscape restoration and adaptation actions to reduce land degradation.
- Hotspots of opportunity were identified by combining the following variables: Gross Primary Productivity (to favor areas with high agricultural activity), Degradation Trend Intensity or slope (to favor areas where interventions can stop or reverse degradation trends detected during baseline period), Density of Livestock Production (to favor areas where interventions can reduce grazing pastures and boost livestock production), and Population Density (to favor areas with higher rural populations, maximizing the social impact of the interventions). These hotspots cover about 15 percent of severely degraded lands in forests, croplands, pastures, and wastelands (desert) (0.63 million ha in adaptation opportunity hotspots from 4.3 million ha severely degraded lands in the same biomes). Resulting portfolios were filtered to remove non-feasible areas.
- Four portfolios for the selection of the future adaptation hotspots are used: one is at the national level and three local: Dashoguz, Ahal, and Altyn asyr portfolios selected based on consultations with local specialists and the set of criteria described in Chapter 5.
- Modify portfolios with increased restoration area to identify priority investment areas beyond the initial constraint of 0.63 million ha.

Step 5. Perform cost-benefit analysis of landscape restoration opportunities

- Estimate the values of ecosystem services lost due to inaction in the land degradation hotspots;

- Estimate the values of ecosystem services that can be prevented from being lost or that can be gained due to action (that is, if interventions recommended in the hotspot areas were implemented); and
- Estimate the costs of implementing the recommendations. The result is a benefit-cost ratio of action for each biome and for the country as a whole.
- The report is structured as follows: Section 2 summarizes the assessment results of identification of current land degradation hotspots and future trends. Section 3 presents the costs of inaction on land degradation. Section 4 presents the potential for landscape restoration and climate-smart technologies to offset the observed trends in degradation. Section 5 presents the map of future adaptation opportunity hotspots and identifies the set of integrated landscape management interventions in the hotspots of adaptation opportunity with the highest potential for landscape restoration and adaptation actions to reduce land degradation. Section 6 presents the costs of action and the benefits from these investments into landscape restoration and climate-smart technologies, estimating benefit-cost ratios (BCRs) for each portfolio of investments. Finally, Section 7 provides overarching policy recommendations for addressing the following barriers: (a) institutional and policy, (b) technological and knowledge, and (c) financial.

Key terms and indicators used in the assessment of risk and opportunity hotspots

Portfolio: Spatially explicit set of priority areas for sustainable technology implementation. Selection of areas is based on spatially explicit criteria, and is limited to available budget for the scenario of investment.

Budget: The total amount of resources or land that is subject to optimization. These are the bounding conditions for the portfolio optimization routine. In this study the budget was varied from the initial 4.3 million ha to identify high priority areas by reducing the number of hectares available.

Criteria: Spatially explicit variables that were considered for the selection of the portfolio. In this study the selection of priority areas considered the speed of land degradation, risks from climate change, primary productivity of vegetation, livestock density, and population density.

The Resource Investment Optimization System model (RIOS): A spatial optimization software developed by the Natural Capital Project at Stanford University. This software uses a multicriteria approach for the selection of intervention areas in a GIS environment.

Interventions: The set of technologies for which the spatial optimization routine is executed. This corresponds to the sustainable technologies evaluated: Conservation Agriculture, Rotational Grazing, Forest Conservation, Wasteland Reclamation.

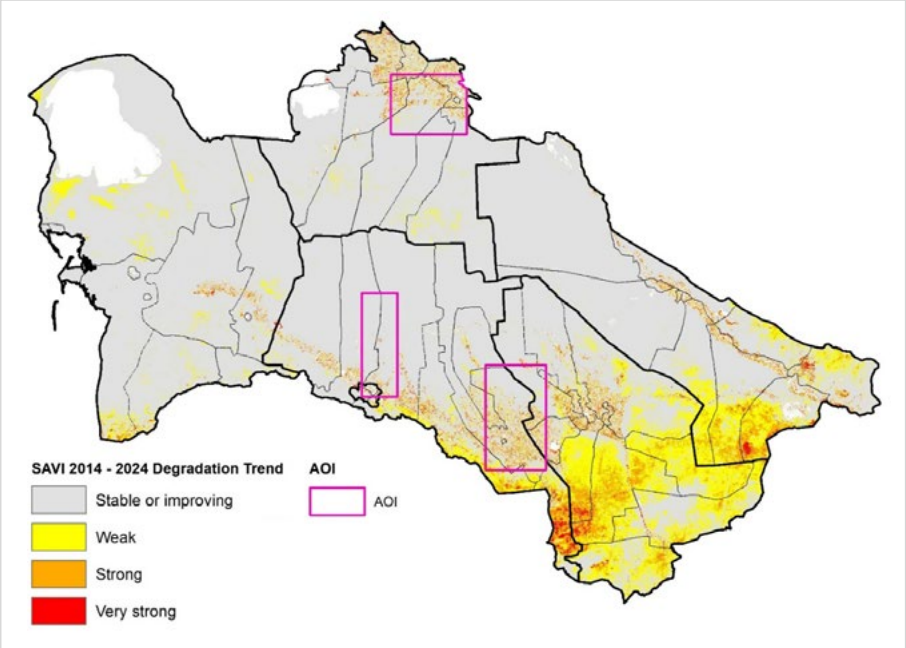
2. Identification of Land Degradation Hotspots at the National Level in Turkmenistan

2.1. Land Degradation Trends

Land degradation trends or Hotspots of Degradation monitor the changes in vegetation indexes through time. Their objective is to identify areas where negative trends are detected, since this implies that for the reference period in those areas there is a constant loss of vegetation productivity year after year. This is interpreted as an ongoing land degradation process and that area is identified as a Degradation Hotspot. This result can be used to prioritize those areas for technology implementation with the objective of halting an ongoing land degradation process before it is too late for the technologies to be effective or economically practical. The rationale is that these sustainable technologies can reduce or even revert the degradation process.

The methodology used to identify Land Degradation Hotspots involves calculating degradation trends by analyzing the direction and slope of multi-annual vegetation index measurements. The yearly average SAVI7 measurement serves as the key indicator of negative changes during the historical period (2014–2024), highlighting areas experiencing degrading trends. Regions exhibiting steep declining slopes are classified as 'Land Degradation Hotspots'. By applying a threshold of −1 standard deviations, a categorical map of Degradation Hotspots is generated. Moreover, a 'Very Strong Degradation Trend' is identified when the degradation trend exceeds the −3 standard deviations threshold (Figure 2).

Figure 2. Land degradation trends using yearly average SAVI measurement as the indicator during the historical period (2014–2024)



Source: Original elaboration for this publication.
Note: Map is overlaid with the three areas of interest (AOIs) selected for restoration.

Analysis shows that the proportion of land that is in very strong degradation trend degraded over total land area of the country is around 10 percent, and the total amount of land in degradation trend with strong and weak degradation trends is around 22 percent of the country. Land degradation mostly affects natural ecosystems, primarily grasslands with 45 percent of its area in degradation trend and croplands with 32 percent (Table 1). The observed spatial patterns reveal a notable distinction between the continuous degradation trends prevalent in the natural areas of the southern region and the scattered or interspersed degradation observed in croplands. This contrast underscores a significant point: the degradation of natural ecosystems appears to stem from overarching factors, notably climate-related influences, affecting these environments. Conversely, within intensive agricultural landscapes, the degradation seems to be driven by localized factors at a smaller scale, likely arising from the management or mismanagement of individual agricultural plots.

Table 1. Total area of Turkmenistan in degradation trend

	Forests		Shurblands		Grasslands		Croplands		Deserts	
Km²	Total area	in Degradation trend	Total area	in Degradation trend	Total area	in Degradation trend	Total area	in Degradation trend	Total area	in Degradation trend
Ahal	22	3	5,126	700	16,859	7,218	10,569	3,016	59,815	1,086
Ashgabat	6	1	76	16	431	86	150	42	115	28
Balkan	19	5	2,490	159	29,857	2,486	1,523	353	84,228	2,423
Dashoguz	3	1	2,442	607	584	39	7,097	2,075	62,871	1,509
Lebap	74	28	4,719	885	18,693	11,325	5,274	2,090	66,209	2,640
Mary	4	1	4,511	1,554	40,139	26,965	7,354	2,831	33,700	7,387
Totals	**128**	**39**	**19,364**	**3,922**	**106,563**	**48,120**	**31,967**	**10,408**	**306,938**	**15,072**
%		**30.59**		**20.25**		**45.16**		**32.56**		**4.91**

Source: Original to this publication.

2.2. Key Drivers of Land Degradation

The drivers of land degradation or drivers of land improvement encompass a range of natural, anthropogenic, and policy-related factors that influence the processes leading to either the deterioration or recovery of land resources. Understanding these drivers is critical for formulating effective land management strategies aimed at reversing degradation and promoting landscape restoration. To identify and assess land degradation trends, land use in Turkmenistan is categorized into five primary types: deserts, grasslands, croplands, shrublands, and forests. Each category is subject to specific pressures and dynamics that drive degradation or, conversely, offer opportunities for sustainable management and improvement. The following sections outline the principal drivers of land degradation associated with each land-use type, providing a basis for targeted interventions and informed policy development.

Grasslands. Water availability and irrational grazing are the most critical land degradation drivers influencing pasture degradation in Turkmenistan. The estimation in Table 1 above shows that about half of the desert grasslands in the country are affected by land degradation, greatly reducing the availability of their resources. This undermines the natural provision of fodder, for which there is increasing demand with a growing livestock sector in Turkmenistan. In the arid conditions of Turkmenistan, livestock farming frequently surpasses the land's natural carrying capacity, primarily due to overgrazing or unregulated grazing practices. This unsustainable use of rangelands contributes to pasture degradation, soil compaction, and a significant loss of native vegetation. Turkmenistan has made significant efforts to construct water sources in desert areas, but vast stretches — amounting to millions of hectares — still lack adequate irrigation. As a result, their forage potential remains largely underutilized. The limited number of watering points and their uneven distribution have led to concentrated grazing around accessible sources, contributing significantly to pasture degradation, particularly in the vicinity of water points and settlements. To address this, it is essential to continue expanding and improving water infrastructure, while also seeking sustainable solutions to enhance pasture conditions, prevent further degradation, support increased livestock productivity, and enable the policy environment (Annamukhammedov et al. 2014).

Croplands. More than 30 percent of cropland in Turkmenistan is experiencing degradation, driven primarily by three interrelated factors:

- **Unsustainable agricultural practices,** including low crop diversification and excessive use of agrochemicals;
- **Poor water management,** where over-irrigation without proper drainage leads to waterlogging, and poor irrigation techniques contribute to soil salinization;
- **Policy-related constraints,** such as insufficient incentives for farmers to invest in soil fertility and limited public support for soil health initiatives.

These issues are further exacerbated by climate change, which is reducing the availability of water for irrigation-dependent farmers and increasing the frequency and severity of sand and dust storms (SDS). Waterlogging and salinization have contributed to a 20–30 percent decline in crop yields in recent years (World Bank and ADB 2021). SDS can cause significant agricultural damage by physically harming crops, burying seedlings under sand deposits, and impairing photosynthesis by covering plant surfaces with dust. They also negatively affect water resources, reducing the efficiency of irrigation systems.

In the Dashoguz and Lebap velayats — regions that together account for over 70 percent of Turkmenistan's agricultural land — climate change has intensified the occurrence of natural disasters. A notable example is the 2020 salt dust storm, which destroyed up to 100 percent of crops in the affected areas. Major sources of SDS in the region include the Karakum Desert, the lowlands of the Caspian Sea, and the Kyzylkum Desert.

Forests and shrublands. Our data show that natural forest extending over 12,900 ha which is <0.1 percent of its land area, and about 1,936,400 ha of shrubland (about 4 percent of total land area) with a share of degraded forest—about 30 percent for forest and 20 for shrubland.

United Nations Economic Commission for Europe (UNECE) defines three major drivers of forest degradation and deforestation: **(a) excessive grazing** of livestock preventing natural regeneration of vegetation and damaging young saplings; **(b) climate change** increases frequency of droughts and leads to rising temperatures which hinder tree growth and regeneration, leading to the deterioration of forest health and productivity; **(c) illegal logging** disrupts forest ecosystems and reduces biodiversity. Addressing these challenges requires comprehensive strategies that include climate adaptation measures, regulation of grazing practices, and enforcement against illegal logging activities.[6] There are three types of forests in Turkmenistan: mountainous forests, desert forests, and tugai forest (FAO and UNECE 2019). It is recommended that Turkmenistan adopts sustainable forest management practices and promotes the regeneration of endemic species on a large scale.

Deserts. To accurately capture land degradation trends across grasslands, croplands, and forests, desert areas were classified as a distinct land-use category. A relatively low proportion—only 5 percent—of desert land reported as undergoing further degradation over the past decade. This is largely because these areas are already extensively degraded and offer limited potential for additional deterioration. The Karakum Desert, which covers more than 70 percent of Turkmenistan's territory and is primarily composed of wasteland, is a major hotspot for SDS.

Land degradation in the desert landscape is driven by two primary factors. The first is climate change, which intensifies existing climatic conditions favorable for SDS formation, including a highly continental climate, low levels of precipitation and humidity, high wind speeds, sparse vegetation cover, and processes such as deflation and surface corrosion. **The second driver is human activity**, particularly overgrazing, unsustainable agricultural practices, and infrastructure development (for example, construction of roads, railways, and energy facilities), all of which contribute significantly to desertification and land degradation in the desert area (UNCCD and CAREC 2020).

2.3. Land-Cover Condition Class

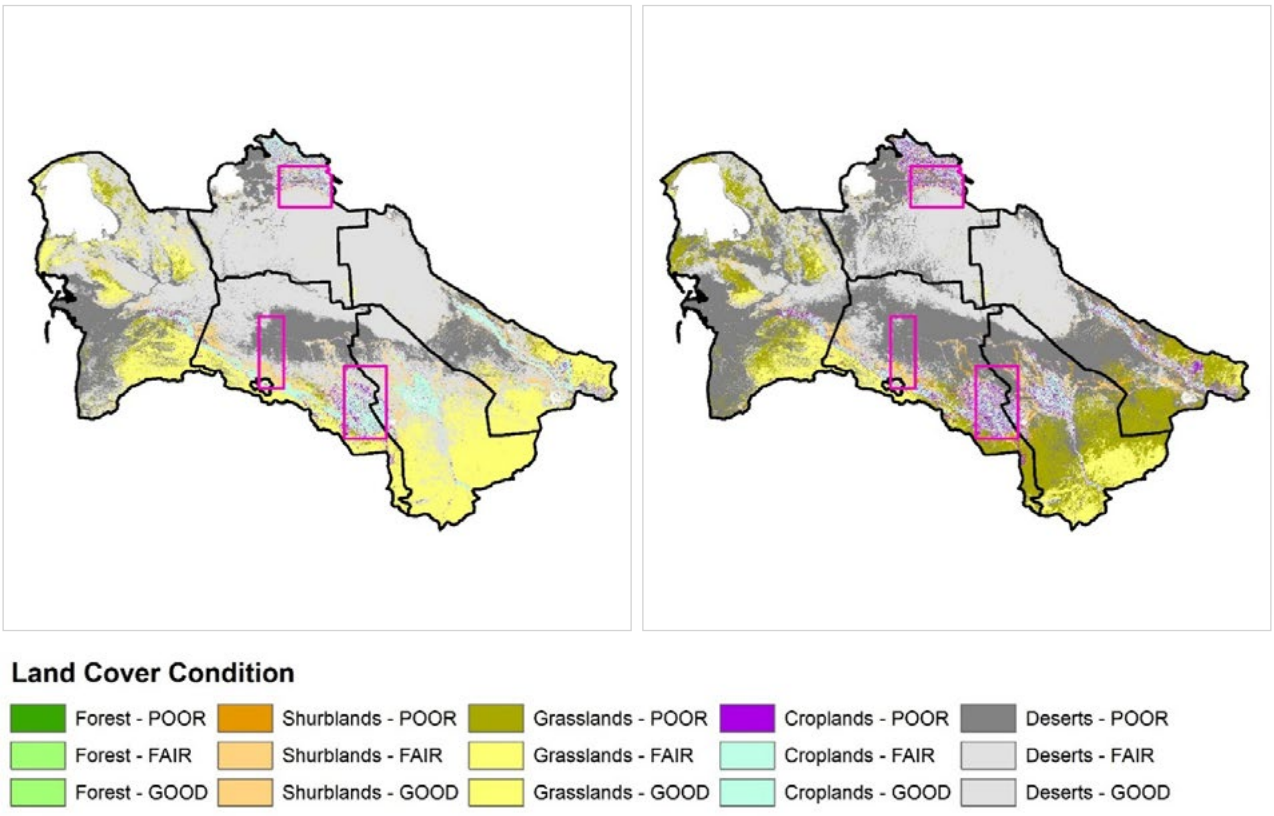
Degradation trend mapping discussed in this report serves as a key indicator of vegetation productivity changes over time, specifically emphasizing negative or declining trends. Conversely, land-cover condition mapping involves assessing the implications of these degradation trends on future landscapes. Since land degradation mapping detects the speed at which photosynthetic activity is being reduced, when combined with the statistics from the baseline period it is possible to map the areas that in the future (2035 to 2050) will present vegetation conditions that are comparable with the areas in **POOR** condition in the baseline period. When a pixel in the baseline period that has a condition of **FAIR** or **GOOD** crosses the statistical thresholds of its land-cover class into a **POOR** condition in the future due to a strong degradation trend it is considered a degradation process.

[6] UNECE *Country Profile: Forest Landscape Restoration in Turkmenistan Accessed* April 11, 2025. https://land.unece.org/forests/en/knowledge-hub/forest-landscape-restoration/forest-and-forest-landscape-restoration-caucasus-and-central-asia/countries-profile-forest-landscape-restoration/turkmenistan

The methodology used to identify land-cover condition involves evaluation of photosynthetic activity of each land-cover class during the baseline period (2014–2024). Each land-cover class is dominated by major ecosystem types, and each one has different phenology patterns that can be categorized using descriptive statistics. Each 100-m pixel within each land-cover class presents an average photosynthetic activity during the baseline period that can be either within the average range for the class (−1 to +1 standard deviations), under the average for the class (less than −1 standard deviations) or above the average for the class (higher than 1 standard deviation). This allows to classify each pixel within each class as either in **POOR**, **FAIR**, or **GOOD** condition, and determine from the change in photosynthetic activity during the baseline period if it is in degradation trend.

The change in the area within each land-cover condition class classified as **POOR** is an indicator of future risk that can be the consequence of the detected trends during the baseline period if no actions are taken or if the current degradation processes continue. It is an indicator of potential future degradation and is referred to in the GIS files of this study as the business-as-usual (BAU) scenario (Figure 3).

Figure 3. Land-Cover Condition Classes of areas in POOR, FAIR and GOOD conditions under baseline conditions 2014–2024 (left map) and BAU scenario 2035–2050 (right).

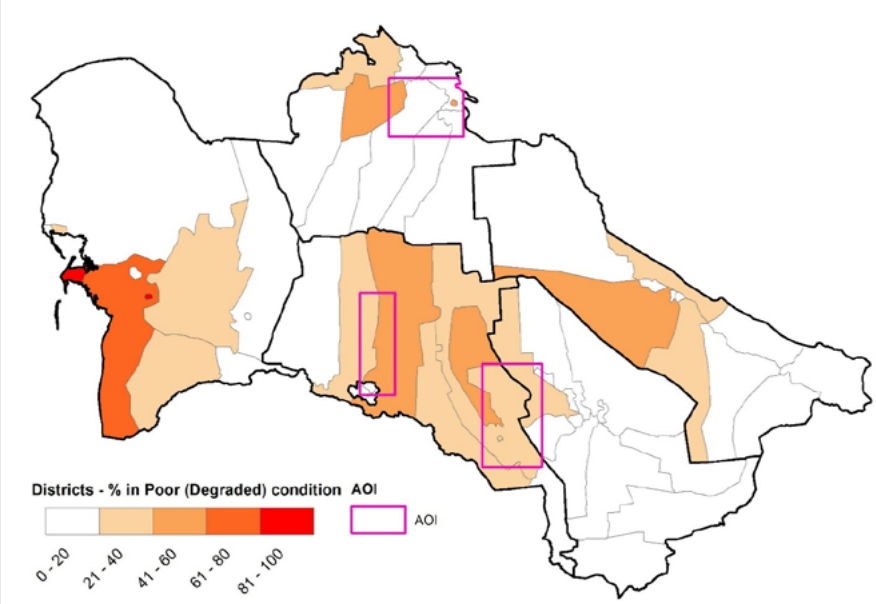


Source: Original elaboration for this publication.

Note: Map is overlaid with the three AOIs selected for restoration. Climate scenario SSP3–7.0. is used for the BAU scenario (see Chapter 3.3 Climate Change Risks).

Changes in condition across all ecosystems were detected in all regions, but the largest areas of potential degradation of condition if current trends are maintained in the future are mostly concentrated in the south, southeast, and northern grassland areas of Turkmenistan. Table 2 resumes the changes of areas in POOR condition from the baseline year 2024 against the BAU/No action scenario up to 2050 (Figure 4).

Figure 4. Percentage of degraded land (land transitioning from GOOD and FAIR to POOR condition) per district (etrap) from the baseline (year 2024) scenario against the BAU or No action scenario up to 2050



Source: Original elaboration for this publication.
Note: Map is overlaid with the three AOIs selected for restoration.

Table 2. Changes of areas in POOR condition from the baseline (year 2024) scenario against the BAU/No action scenario

	Forests in Poor		Shurblands in Poor		Grasslands in Poor		Croplands in Poor		Deserts in Poor	
Km²	Baseline	BAU	Baseline	BAU	Baseline	BAU	Baseline	BAU	Baseline	BAU
Ahal	9	13	33	760	1,850	9,876	2,376	4,338	20,713	37,662
Ashgabat	1	1	0	5	13	56	18	43	7	33
Balkan	7	10	55	480	8,649	18,993	408	645	29,288	47,441
Dashoguz	0	0	69	469	155	422	1,638	3,065	8,920	19,255
Lebap	5	16	301	1,719	1,851	16,121	844	2,038	14,067	25,644
Mary	0	1	21	1,270	423	24,040	731	2,460	5,766	23,295
Totals	**22**	**41**	**479**	**4,702**	**12,941**	**69,509**	**6,014**	**12,588**	**78,761**	**153,331**
%	**17.36**	**32.37**	**2.47**	**24.28**	**12.14**	**65.23**	**18.81**	**39.38**	**25.66**	**49.96**

Source: Original estimation for this publication.

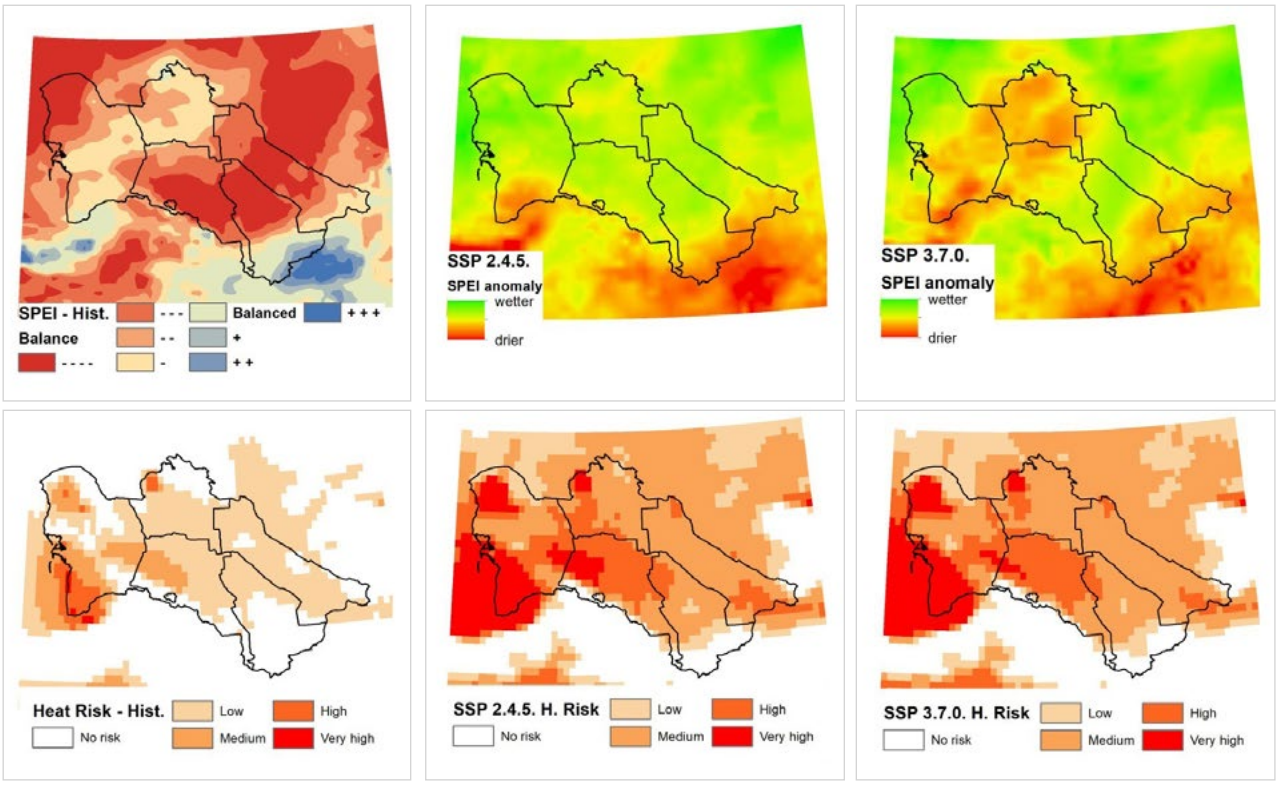
The prevailing trend across the country indicates an overall negative trajectory toward land degradation, with Lebap, Ahal, and Mary velayats being the most severely affected. These regions are experiencing significant degradation in croplands, and the extent of degraded lands in agricultural landscapes (including croplands and livestock grazing areas) is expected

to increase the most in these regions (Table 1). Grasslands, deserts, and croplands are the ecosystems in which the effects of land degradation trends are expected to have more severe effects in the extent of degraded areas in the future. Urgent intervention is imperative in these areas, as the rate of land degradation is projected to escalate rapidly, potentially resulting in a twofold increase of land in POOR condition by 2050 if proactive measures are not implemented. Conversely, desert regions exhibit a notably low extent of degradation, possibly attributed to algorithmic limitations in detecting seasonal land degradation in regions already characterized by sparse vegetation cover.

2.4. Climate Change Risks

Climate change risk was assessed using General Circulation Model (GCM) ensemble data for two Coupled Model Inter-comparison Projects (CMIP6) SSP scenarios, 2–4.5 and 3–7.0, with the aim of selecting a climate scenario for land restoration portfolio generation. These two shared socioeconomic pathways (SSPs) were selected to represent two possible future emissions scenarios, only lower or optimistic (SSP2–4.5) and one higher or pessimistic (SSP3–7.0). For these two SSPs, the period between 2040 and 2059 was used. Two variables were selected as the main risk factors: SPEI anomaly and Heat Risk Index. SPEI was selected since it represents the water balance in a yearly aggregation, with negative numbers representing deficit risk. For rain-fed areas these low values assume a drought risk, while for irrigated areas they present a higher irrigation demand due to increased evapotranspiration and lower precipitations. Heat Risk Index was selected since it is an indicator of heat stress risk both to humans and livestock due to the occurrence of days above critical heat thresholds.

Figure 5. Climate risk factor analysis using SPEI and Heat Risk Index indicators



Source: Original elaboration for this publication.

Both indicators were assessed by aggregating the average magnitude of the anomalies between historical conditions and the 2040–2059 multi-GCM ensemble data. Higher risks correspond to reduced SPEI values and increased Heat Risk Index values[7] (Figure 5). Across both climate change scenarios, worsening conditions follow a similar pattern with higher indicators of risk in the south and southwest of the country. The main difference between both the scenarios is in the dryer belt expanding across the north of the country in the pessimistic SSP3–7.0. scenario.

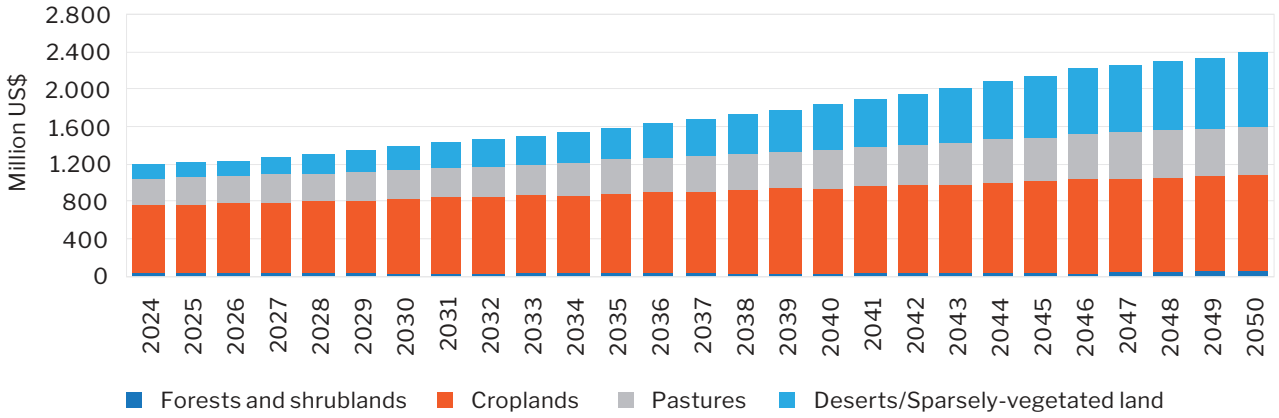
Spatial patterns of degradation hotspots from historical analysis of vegetation activity correlate with areas at higher climate risk. The spatial distribution of land degradation hotspots, as identified through historical analysis of vegetation activity, exhibits correlations with regional climate risks. Specifically, areas characterized by increased SPEI anomalies (less humid to more dry conditions) and those exhibiting rising Heat Risk Index levels display similar patterns of degradation hotspots over the past decade. This convergence of trends suggests a link between land degradation trajectories and increased drought and heat stress. Consequently, this analysis indicates that the pessimistic scenario associated with SSP 3–7.0, characterized by heightened climate-related risks, is more plausible than SSP2–4.5 or optimistic scenario. As a result, these risk factors from SSP3–7.0 were selected for portfolio generation.

[7] Heat Risk Index: Categorization of the occurrence of days above four thresholds for designated Heat Risk Variable. Heat Index Risk Categorization includes heat index: 35°C, 37°C, 39°C, and 41°C. If at least 0.5 day surpassed the highest threshold, then the highest category is given, reflecting that "at minimum one day of the year experienced the highest heat level." Risk Factor Categorization: 0–4 represents Low–Extreme Risk.

3. Cost of Inaction on Land Degradation

The annual average costs of inaction[8] on land degradation in Turkmenistan are estimated to be nearly US$667 million in present value (PV) terms[9] (equivalent to nearly 2.7 percent of the country's GDP) over 2024–2050. The undiscounted costs of inaction are currently just over US$1,193 million and will increase to nearly US$2,384 million in 2050 if no restoration actions are taken, that is, BAU scenario (Figure 6). Land degradation in Turkmenistan incurs costs through foregone crop and livestock production,[10] GHG emissions and foregone ecosystem services, as well as through damage to infrastructure,[11] notably, on irrigation, hydropower, and transportation. Currently, over 4.9 million ha of land in Turkmenistan is degraded. Under the BAU scenario where no restoration actions are taken, the total area of degraded land will expand to nearly 6.3 million[12] in 2050, and the severity of degradation will increase because of anthropogenic causes and climate change. These factors combined will increase the costs of inaction in the future.

Figure 6. Total costs[a] of inaction on land degradation in Turkmenistan



Source: Authors' estimation.[13]
Note: a. Undiscounted.

8 The cost of inaction on land degradation in Turkmenistan is defined as the difference between the outputs—in monetary terms—of good-quality land and degraded land.

9 An 8 percent discount rate is used. This is determined by following the guidance given by World Bank (2016). Discounting Costs and Benefits in Economic Analysis of World Bank Projects. Washington D.C. All costs, investments and benefits figures in this paper are in 2023 constant US$.

10 Livestock products included in the estimation of costs of inaction are meat and milk production by cattle, sheep, goats and buffalos and wool production by sheep.

11 Due to a lack of sufficient in-country background data, the benefit-transfer method is used to estimate the economic value of foregone crop and livestock production, and ecosystem services and damage to infrastructure in Turkmenistan. The relevant value estimates of the above impacts from Armenia and Tajikistan (World Bank 2023, 2024, 2025a, 2025b, and 2025c) are used in the benefit-transfer method. For monetizing GHG emissions, the shadow price of carbon is used. A shadow price of carbon of US$108 per tCO_2eq—as per the World Bank's Greenhouse Gas Accounting Guidance for FY 2023— is used for the first year of analysis (2024). The price increases gradually to reach US$193 per tCO_2eq in 2050.

12 According to the NIDFF of Turkmenistan, the annual rate of expansion of the degraded land in Turkmenistan is estimated to be just under 1 percent.

13 The costs of inaction on degradation under each land-cover type in a particular year are the product of degraded land area and average costs of inaction per ha for that land-cover type in that particular year. As explained in Footnote 12, the average costs of inaction per ha for each land-cover type in different years — in terms of foregone crop and livestock production, and ecosystem services and damage to infrastructure — are estimated by using the benefit-transfer method by using relevant data from two countries in the Central Asia region: Armenia and Tajikistan (World Bank 2023, 2024, 2025a, 2025b, and 2025c).

The agricultural sector (that is, croplands and pastures combined) is the biggest contributor to land degradation costs. Through foregone crop and livestock production and GHG emissions, the sector on average contributes more than US$513 million (in PV terms) in costs of land degradation each year over 2024–2050. This is equivalent to 2.1 percent of Turkmenistan's GDP. The undiscounted costs of the agricultural sector due to land degradation will increase over time under the BAU scenario as the area of degraded croplands and pastures will expand and the severity of degradation will increase (Figure 6).

The overall average unit cost of degradation in Turkmenistan is US$119 per ha per year (in PV terms) over 2024–2050. The unit cost varies widely across the land-cover types depending on their respective output levels. Croplands—being the most productive lands in the country—have the highest costs of degradation (US$638 per ha per year, in PV terms) while the deserts have the lowest (US$38 per ha per year) (Table 3).

Table 3. Average unit costs of inactions in land degradation in Turkmenistan

Land-cover types	Average unit costs[a], US$/ha/year (in PV terms)
Forests and shrublands	252
Croplands	638
Pastures	120
Deserts / Sparsely vegetated lands	38
Overall	**119**

Source: Authors' estimation.[14]
Note: Over 2024–2050.

[14] The average unit cost of inaction on land degradation for a land-cover type are estimated by dividing the PV of annual costs of inaction by the summation of degraded area from 2024 to 2050 for that land-cover type.

4. Prioritize Restoration Options

For this study, one key climate-smart technology was selected for each of the four major land-cover types, based on consultations with local specialists. These technologies represent land restoration practices that not only rehabilitate degraded land but also enhance its resilience to climate change. Climate-smart technologies aim to mitigate climate impacts, adapt to evolving environmental conditions, and ensure long-term sustainability in land restoration efforts. The selection of specific technologies supports decision-makers in efficiently allocating resources and making informed choices about where and how to implement restoration activities.

Degraded lands will be restored in a series of short phases, each lasting approximately five years. During each phase, restoration efforts will focus on one region of the country before moving to another region for the subsequent five years. This ensures that restoration activities are ongoing at the national level every year. All land-cover types will be included in each phase, and land-cover-specific restoration actions, such as climate-smart technologies, will be implemented.

The four prioritized restoration actions are: (1) Conservation of agriculture and crop diversification (croplands); (2) Rotational livestock or rotational grazing and silvopastoral system (pastures); (3) Revegetation or forest conservation and reforestation (forests and shrublands); and (4) Wasteland reclamation through phytomelioration and collector-drainage networks. According to the NIDFF of Turkmenistan, the approach for restoring wastelands (that is, former croplands turned to deserts due to heavy degradation) will be different from that for croplands with less severe levels of degradation. For restoring wastelands with salinity, licorice (*Glycyrrhiza glabra L.*) will be planted in a five-year rotation.[15] When licorice is harvested five years after planting, crops will be cultivated under conservation agriculture and crop diversification practices. The technologies are summarized in Figure 7.

Figure 7. Integrated technological suite for resilient landscape restoration

CONSERVATION

Conservation of agriculture and crop diversification (croplands)

Crop rotation of the main strategic crops with crops of the legume family (*Fabace L.*): alfalfa (*Medicago L.*), licorice (*Glycyrrhiza L.*), adopt precision farming, a part of climate-smart agriculture techniques

ROTATIONAL LIVESTOCK

Rotational grazing and silvopastoral system (pastures)

To improve the pastures of the sandy desert, it is recommended to create year-round pasture phytocenoses and do water harvesting

REVEGETATION

Forest conservation and reforestation (forests and shrublands)

Protective forest shelterbelts help to weaken the wind force, delay the movement of sands, and humidify the air in the surface layer.

WASTELAND RECLAMATION

Restoration of barren lands by reducing the degree of salinization through halophyt crop production (phytomelioration) and collector-drainage networks

Source: Original elaboration for this publication based on NIDFF 2024.

[15] There are four species of licorice in the country, *Glycyrrhiza glabra L.*, which is the most common and low-maintenance one, is prioritized for this study.

5. Prioritize Land Restoration Area

5.1. General Information about Two Types of Land Restoration Portfolios

Landscape restoration, resilience building, and adaptation of forests, mountains, and agricultural lands to climate and disaster risks require the implementation of a suite of conservation and resilience-building technologies. Introducing these technologies in an integrated manner can lead to substantial benefits in terms of ecosystem services that are translated into yield and income gains and reduction of negative effects of degradation in Turkmenistan's forests and productive lands. Identifying hotspots of land degradation and hotspots of adaptation opportunity where the benefits of landscape restoration have the greatest potential to offset negative trends allows for the identification of areas with the highest potential for returns on investments for landscape restoration. Also, an evaluation of investment needs is critical in developing adequate adaptation planning and financing options that are sustainable and improve livelihoods.

The restoration priority portfolio or the adaptation 'hotspot' areas are defined as geographic explicit products, focused on the identification of the most suitable places for the implementation of sustainable technologies and management practices. It was generated using a spatial optimization software called Resource Investment Optimization System (RIOS) model. The model combines biophysical, social, and economic data to help users identify the best locations for protection and restoration activities to maximize the ecological return on investment, within the bounds of what is socially and politically feasible. In case of Turkmenistan the RIOS tool integrates the following aspects to realize the simulation of activity portfolios: (a) set of criteria for optimization, the objectives of the portfolio, (b) budget to be optimized, the number of resources (budget or spatial extent) itemized by technology.[16]

Turkmenistan portfolios are optimized for four main objectives aiming at preventing further land degradation.

- Maximize the impact on rural population: areas with higher numbers of rural inhabitants are favored.
- Maximize the impact on livestock production: areas with higher densities of livestock (FAO LSU[17] criteria) are favored.
- Maximize the impact on high agricultural output areas: areas with higher gross primary productivity (biomass/carbon) averages during the past 20 years are favored.
- Combat land degradation: areas with strong rates of vegetation productivity decrease are favored.

[16] The RIOS approach was selected in this study because it provides an efficient way to optimize priority areas for landscape intervention without having to run multiple implementation scenarios through ecosystem services models to identify areas with the highest return on investment. Due to time and resource constraints, such a scenarios-based approach was not feasible; instead the approach taken in this study was to use the heuristic optimization model RIOS to identify the portfolio of priority areas, then run the resulting portfolio through ecosystem services models to estimate the improvements gained by implementation.

[17] FAO LSU refers to a unit of measure, a Livestock Unit (LSU), used by the Food and Agriculture Organization of the United Nations (FAO) to standardize livestock populations and analyze data across different species and age groups. An LSU is defined as the grazing equivalent of one adult dairy cow producing 3,000 kg of milk annually.

Two types of portfolios were formulated for Turkmenistan: a national level portfolio and the portfolio focused on the AOIs described below.[18] Both portfolios used the same equal distribution of total hectares per activity, with the total hectares in the national portfolio proportionally distributed within the three AOIs based on the area of each selected windows. Both portfolio approaches, national and AOI, adhere to the area target of 0.63 million ha for restoration activities, which represents 12.8 percent of the currently degraded land and 10 percent of the total degraded land projected for 2050. The budget allocated for the national portfolio is US$45 million — when 0.63 million ha is equally distributed among various land-cover types (Table 4) — while the budget for the AOI portfolio was calculated based on the average unit costs of the technology per hectare per year.

Portfolios are built around four principal technological packages described in the Chapter 4: Conservation of natural landscapes (forests, shrublands, deserts); Rotational livestock, for example, sustainable management of livestock grazing areas (pastures and grasslands); Revegetation, for example, reforestation/revegetation of degraded natural landscapes; Wasteland reclamation of severely degraded cropland areas. The allocation of the area for interventions in forests, pastures, croplands, and wastelands are proportional to the extent of degradation predicted in each of those biomes by 2050 (Table 4). Altogether, this portfolio would entail investments across 1.3 percent of the total area of the country.

Table 4. Areas targeted for selection of priority areas for restoration.

Biome	Area targeted (ha)	Average unit costs[a], US$/ha/year (in PV terms)	Area per technology	Budget per technology, US$
Forests and shrublands	6,600	52	157,500	8,190,000
Croplands	142,000	42	157,500	6,615,000
Pastures	64,000	113	157,500	17,797,500
Wastelands	416,000	79	157,500	12,442,500
Overall	**630,000**	**97**		**45,045,000**

Source: Original estimation for this publication.[19]
Note: a. Over 2024–2050

Three AOIs have been identified for high-resolution mapping (30 m) to assess priority areas and degradation trends. The AOIs were determined in consultation with the NIDFF, under the Ministry of Nature Protection of Turkmenistan. The selection was based on budgetary constraints, policy priorities, and the higher likelihood of successfully implementing land restoration projects. Detailed descriptions of these territories are provided below.

- **The first area is in Northern Turkmenistan, Dashoguz Province, Gubadag District (Dashoguz Portfolio).** It is located within the Lower Amudarya river oasis where irrigated land is adjacent to desert landscapes (sandy pastures). Many lands are abandoned and not used

[18] Both types of portfolios used the same configuration in RIOS software, the only difference being the use of higher resolution dataset for land cover between the portfolio runs. Pixels of 250 m were used for the national portfolios and 30 m for the AOI portfolios.

[19] The average unit costs of land restoration for a land-cover type are estimated by dividing the PV of annual costs of restoration by the summation of area under restoration from 2024 to 2050 for that land-cover type. See Chapter 6 for more details.

due to land degradation (salinization and overgrazing) (The problem is salinization of soils, close groundwater table, which is aggravated by the great need to flush the soil with water for cultivation of crops.) These lands have been used for irrigated agriculture for thousands of years, and there may have been unsustainable land use in cultivation and irrigation.

- **Second, desert-sandy pasture area is located within Central Karakum desert, one of the main pasture cattle breeding areas of Turkmenistan (Ahal Portfolio).** Many small, desert settlements with about 6,000 wells are located here. The area around two major wells (Bahardok well and nearby Mamedyar well) were prioritized for restoration. Compared to other wells, the population here is quite large. Around each well, overgrazing and reduced plant cover creates highly disturbed areas or mobile sand dunes, which then form SDS that affect local communities, roads, and economic facilities (according to the Institute of Desert, Flora and Fauna, the average diameter of disturbed sands at each well is 1.7 km).
- **The third district covers a small part of Tedzhen oasis, the northern part of Babadaikhan District** *(30–50 km to the north - Mamur well)* **(Altyn asyr Portfolio).** This territory has saline irrigated lands adjacent to swampy, flooded lands, degraded pasture vegetation, some parts of the Main Tedzhen collector. The predominant type of landscape degradation is salinization of soils of moderate and strong degree, waterlogging of soils, and degradation of pasture vegetation.

AOIs were selected based on following criteria:

1. **High ecological value:** It has the potential to improve biodiversity by connecting habitats and enhancing wildlife corridors with nearby protected areas. For Dashoguz — Kaplankyr reserve, for Central Karakum — Kopetdag reserve and Bereketli-Karakum; Tedzhen — Kopetdag reserve sections.
2. **Water availability:** Access to water resources in the selected territories is critical for the survival of newly planted vegetation and the overall success of restoration efforts.
    a. **Dashoguz portfolio:** Water supply from the Amu Darya River through irrigation and drainage-collector systems.
    b. **Ahal portfolio:** Water from the Karakum River (Karakum Canal) supports irrigated lands, playing a vital role in restoration activities.
    c. **Altyn asyr portfolio:** The region has a long history of irrigated agriculture, leveraging water from the Tedzhen River and the Karakum River (Karakum Canal) for land reclamation. However, salinization and a high groundwater table present challenges. These issues are partially addressed by diverting drainage collectors into Turkmen Lake Altyn asyr.
3. **Accessibility and location:** The area offers convenient proximity to major cities, roads, and infrastructure. The three largest cities are Ashgabat, the capital (with approximately 1 million people), Dashoguz (around 230,000 people), and Tedzhen (about 77,000 people), which is a significant cultural and economic center in the southern part of the country.
4. **Long-term sustainability:** Given the need for ongoing management, maintenance, and the climate resilience of restored ecosystems, ensuring the long-term sustainability of actions is critical. The selected areas host experimental sites from research institutions,

where scientists and other personnel could potentially provide the necessary support and monitoring to maintain and sustain these efforts

a. **Dashoguz:** This location hosts experimental plots from the NIDFF and the Turkmen Agricultural Institute, where land degradation processes are studied.

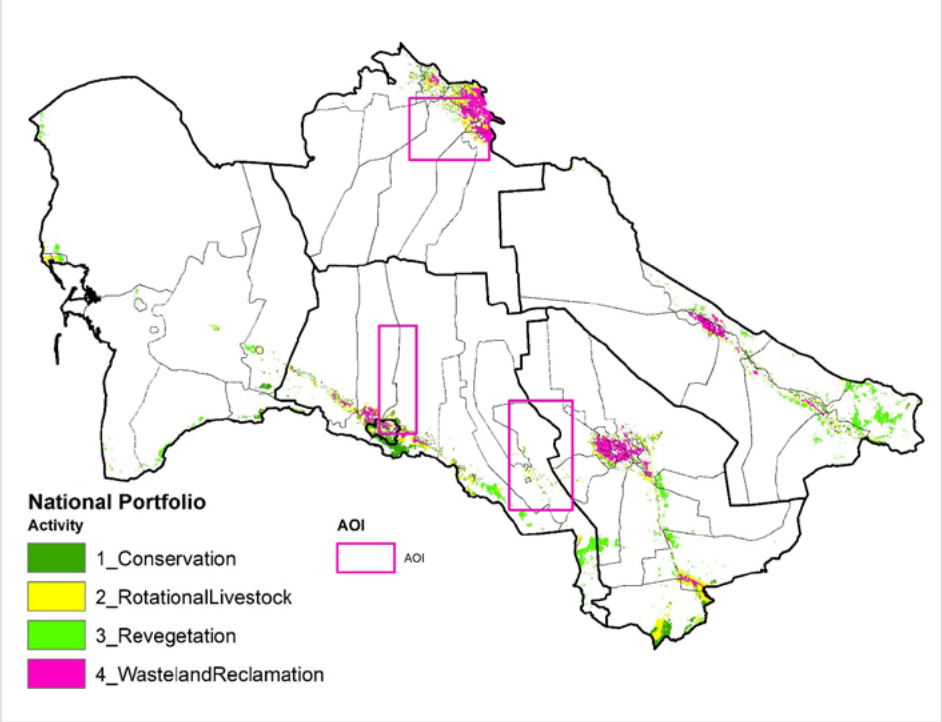
b. **Ahal:** The Karakum field station of the NIDFF is located here, where research on desertification, land degradation, and restoration processes is also conducted.

c. **Altyn asyr:** This area contains experimental plots where the NIDFF conducts scientific and experimental research.

5.2. National Land Restoration Portfolio Description

The national-level portfolio of restoration interventions is illustrated in Figure 8 and demonstrates alignment with two of the three AOIs owing to the importance of maximizing impacts directly on the rural population (higher population density) and focusing on areas with high agricultural productivity (higher gross primary productivity). While opportunities for implementation of the four prioritized technologies exist across various agricultural landscape in the country, the systematic approach used by RIOS, with a restricted budget that is close to 5 percent of the total area of the country, tends to concentrate the investments in densely populated areas with intensive agriculture activity. Land degradation has a visible impact on selected portfolio areas, particularly in rangelands where the population density is lower. This effect is evident in the priority areas for revegetation activities, which are predominantly located in the south and southeast of the country.

Figure 8. National-level portfolio of restoration interventions based on RIOS modeling, showing the priority areas selected for the 4 technologies given the budget and area targets



Source: Original elaboration for this publication.

Note: Pixel size has been increased to facilitate the visualization of selected locations and does not reflect the exact extent of activities or total area accordingly to map scale. The three selected AOIs are also overlayed. National-level portfolio of restoration interventions is overlaid with the three AOIs selected for restoration.

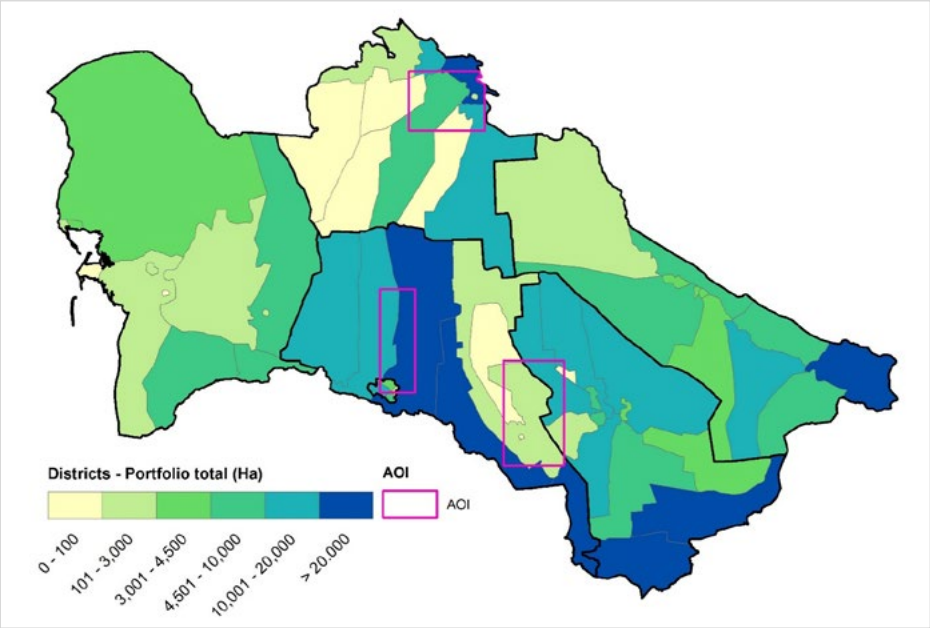
The distribution of priority areas across the regions of the country is presented in the Table 5 and Figure 9.

Table 5. Land area distribution per each technology per velayat

Province / Ha	Technology				% province
	Rotational		Wasteland		
	Conservation	Livestock	Revegetation	Reclamation	
Ahal	55,425	31,500	46,025	17,169	23.86%
Ashgabat	14,681	6,888	75	3,069	3.93%
Balkan	10,194	6,481	15,025	75	5.05%
Dashoguz	10,344	28,131	356	57,050	15.24%
Lebap	13,088	11,144	61,494	20,706	16.92%
Mary	53,613	73,025	34,400	59,169	35.00%
Total Result	**157,344**	**157,169**	**157,375**	**157,238**	**629,125**

Source: Original elaboration for this publication.

Figure 9. The area (hectares) of prioritized areas using national portfolio approach by district



Source: Original elaboration for this publication.
Note: District-level priority areas are overlaid with the three AOIs selected for restoration.

5.3. Three Prioritized Area of Interests-focused Portfolios

The portfolio for the three AOIs is designed to spatially represent the target restoration area, considering the budget allocated for each technology per hectare per year. The principle is that spatially focused implementation of technologies reduces implementation costs and maximizes their impact in the agricultural landscapes selected. Much more meaningful returns can be expected if the 0.63 million ha are strategically concentrated within agricultural landscapes that collectively span the country's diverse ecological zones. This targeted approach enables more efficient use of resources by minimizing infrastructure costs associated with land restoration activities, while also maximizing the reach and impact of interventions—ensuring that a greater number of people benefit from the ecosystem goods and services generated.

AOI-focused portfolios follow the same prioritization criteria as the national portfolios using RIOS, considering the speed of land degradation, the risks from climate change, the gross primary productivity of vegetation, the livestock density and population density, but they are designed using higher spatial resolution datasets. The benefit of this is a more accurate mapping of land use and cover, and better capture of land degradation dynamics from SAVI observations. While the national portfolio runs on MODIS data at 250-m resolution, the three regional portfolios are based on Landsat imagery at 30-m resolution. The processing algorithms for land degradation and land-cover condition mapping remain the same, only the satellite sensor used is different. All other criteria used for portfolio formulation remain consistent with the national portfolio since they are already at the higher resolution available. Consequently, regional portfolios provide their priority areas with greater detail than the national portfolio.

For each AOI portfolio, the initial national budget was proportionally allocated between the three windows using the total extent of each AOI. This results in a different area targeted for restoration and corresponding budget, but together, they sum up to the same implementation cost and spatial footprint of the national portfolio.

The main difference between the AOI-focused and national portfolios is that the optimization algorithm was provided with the option to reallocate the budget within the activities when areas of higher returns (higher vegetation productivity) or higher impact (higher population density) are present and lumped together spatially. This results in the portfolio having the freedom to concentrate hectares in Rotational Livestock and Wasteland Reclamation activities and borrow available hectares from Conservation and Revegetation activities.

AOI-focused portfolios tend to favor densely populated areas within each AOI window and produce more continuous or compact recommendations than the national portfolio mostly for two reasons. Given the smaller size of each AOI with respect to the degree of variation present at the national scale for variables such as climate change risk or gross primary productivity the other variables with higher local variation increase their importance on the selection of areas: Degradation trend and Population Density. Secondly, when the national budget is focused in these smaller windows the prioritization addresses around 35 percent of the total AOIs area, so the portfolio generator can produce continuous blocks of interventions in the landscape, an ideal situation for project implementation in the reality.

Land restoration interventions across 0.63 million ha within three AOIs are estimated to cost approximately US$35.7 million. This is lower than the projected US$45 million under the national portfolio scenario, primarily due to the use of differentiated technology packages tailored to each of the two portfolio scenarios. However, this cost reduction is accompanied by comparatively lower environmental benefits and reduced GHG emission mitigation potential. Land restoration interventions within the proportionally distributed targeted area of 0.63 million ha among the three AOIs resulted in a total approximate implementation cost of US$35.7 million (US$8.5 million, US$11.3 million, and US$15.9 million, respectively). This cost is lower compared to restoration efforts under the national portfolios (US$45 million), primarily due to the varying proportions of the selected technologies and the price per hectare for each technology implementation (Table 6). Figure 10 visualizes the portfolios for each of the three AOI windows prioritizing technology use in the modeled restoration area. However, it is important to note that the environmental benefits will not be achieved at the same level.

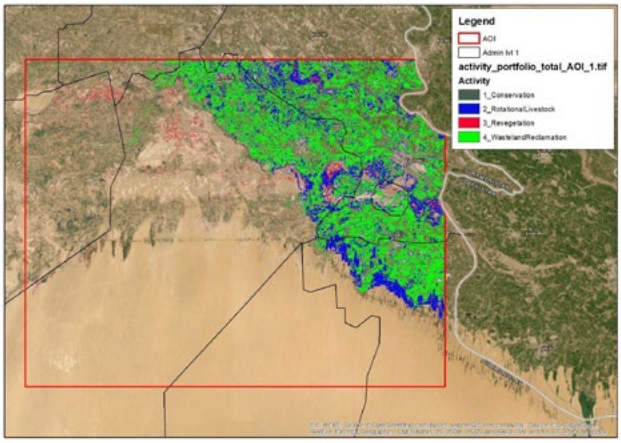
Table 6. Aligning the number of hectares targeted for restoration with the implementation costs per portfolio

Total area targeted for restoration, ha		Biome	Area by biome, ha	Average costs per ha	Implementation costs (US$, millions)
Dashoguz portfolio	195,000	Forests and shrublands	102,603	52	8,5
		Croplands	22,355	42	
		Pastures	28,433	79	
		Wastelands	34	113	
Ahal portfolio	158,000	Forests and shrublands	32,266	52	15,9
		Croplands	154,580	42	
		Pastures	58,237	79	
		Wastelands	28,357	113	
Altyn asyr portfolio	277,000	Forests and shrublands	54,800	52	11,3
		Croplands	92,967	42	
		Pastures	33,114	79	
		Wastelands	16,783	113	
Total	**630,000**	**n.a**	**629,574**	**n.a**	**35,7**

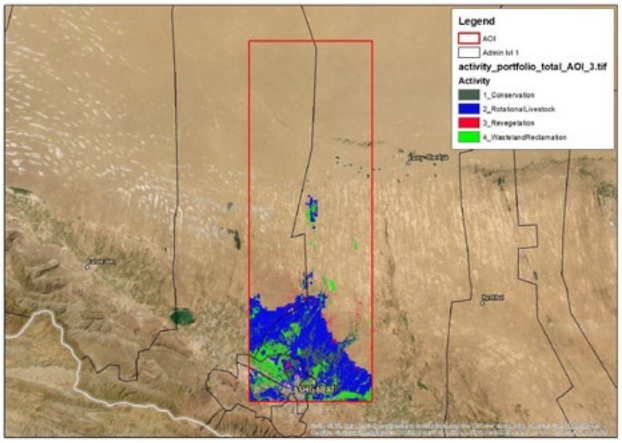
Source: Original analysis for this publication.
Note: n.a - not applicable.

Figure 10. AOI-focused portfolio of restoration interventions based on RIOS modeling, showing the priority areas selected for the four technologies, given the budget and area targets

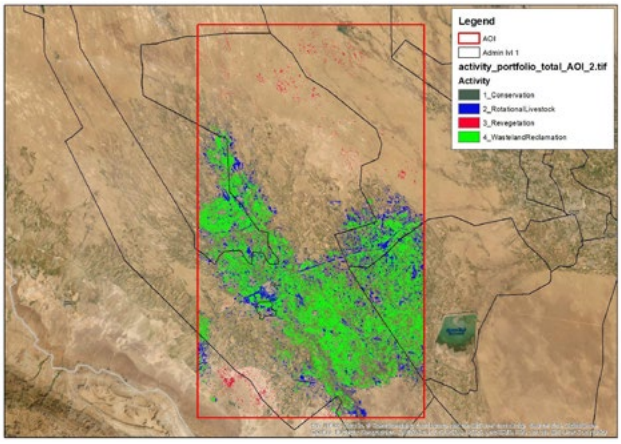
a. **Dashoguz Portfolio**



b. **Ahal Portfolio**



c. **Altyn asyr Portfolio**



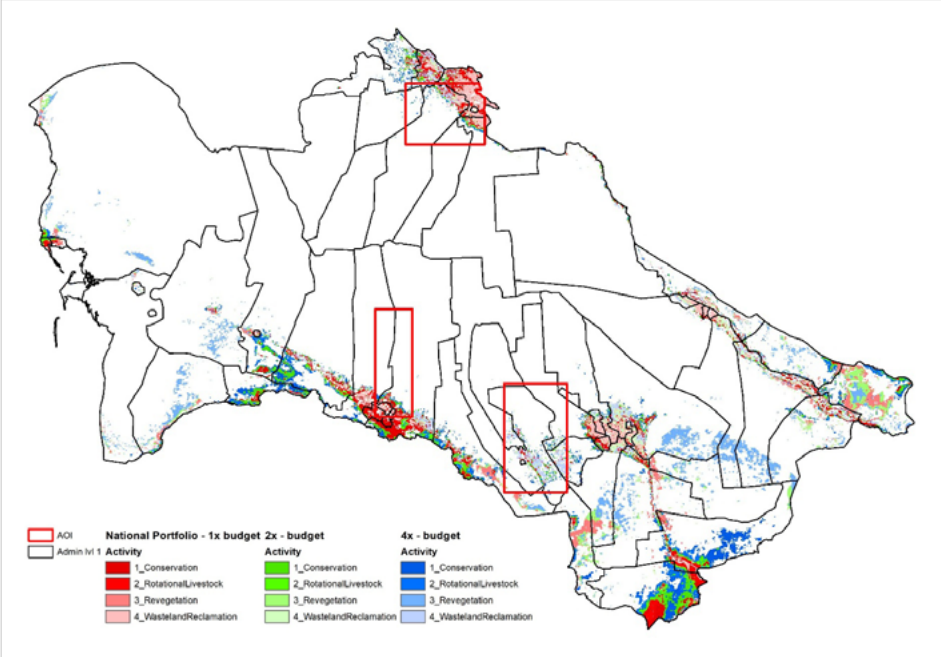
Source: Original elaboration for this publication.

5.4. Modification of Portfolios with Increased Restoration Area

Portfolio optimization algorithms were modified by varying the available budget and targeted hectare count. This variation facilitates the prioritization of resource allocation, highlighting the relative importance of each investment alternative or pixel within the portfolio.

For the national portfolio, increasing the restoration area by a factor of 2 and then 4 results in expanded restoration portfolios reaching up to 2.4 million ha (Figure 11). The increased restoration area aims to identify priority investment areas beyond the initial constraint of 0.63 million ha. This expansion provides a more comprehensive resource assessment for identifying investment opportunities across all regions of Turkmenistan, extending beyond previously restricted geographic selections. Moreover, the increased restoration area enables exploration of alternative investments that may be ineligible or impractical for implementation due to factors such as stakeholder concerns, political climate, accessibility limitations, or security risks. Ultimately, this approach can guide long-term investment priorities if the national budget allocation of 0.63 million ha represents the initial step in a comprehensive and sustainable technology investment plan for Turkmenistan.

Figure 11. National portfolio of restoration interventions based on RIOS modeling, showing the initial area targeted for restoration: 1x (red shades), doubling area - 2x (green shades), and quadrupling area - 4x (blue shades), with corresponding restoration areas ranging from 0.63 to 2.4 million ha

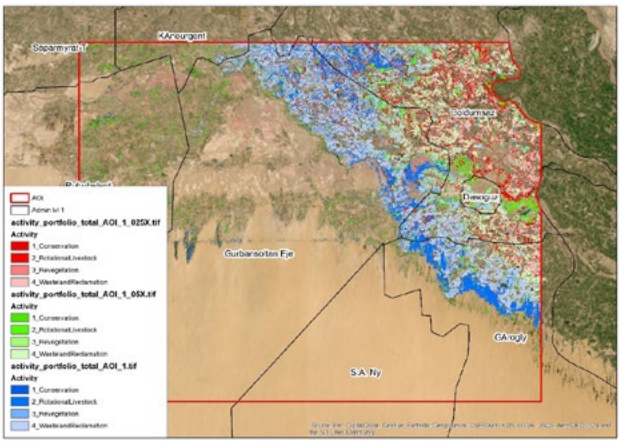


Source: Original elaboration for this publication.

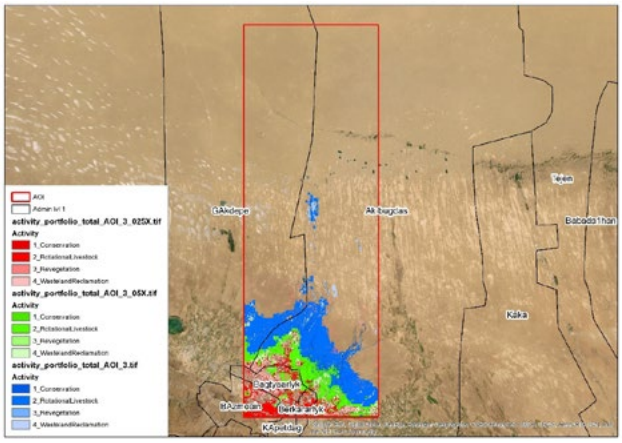
Stepwise reduction of restoration area (budget) for each AOI allows the development of a timeline for the resilient landscape restoration strategy (Figure 12). By forcing the algorithm to focus its selection on a subset of areas, optimal for the area, the reduced-budget portfolios can inform a timeline toward achieving the final objective of 0.63 million ha of landscape restoration in the three AOIs while maximizing ecosystem services. Portfolio optimization algorithms were applied to NPT portfolios by scaling up the targeted restoration area of 0.63 million ha. Two scenarios were tested: doubling the initial target (2x factor) and quadrupling it (4x factor). The initial national targeted restoration area resulted in portfolios encompassing virtually the entirety of agricultural landscapes within each AOI, leading to suboptimal portfolio allocation. The spatial patterns observed in previous iterations are enhanced under this framework, signaling improved localized prioritization at the AOI level.

Figure 12. AOI-focused portfolio of restoration interventions based on RIOS modeling, showing the initial area targeted for restoration: 1x (red shades), doubling area - 2x (green shades), quadrupling area - 4x (blue shades), with corresponding restoration areas ranging from 0.63 to 2.4 million ha

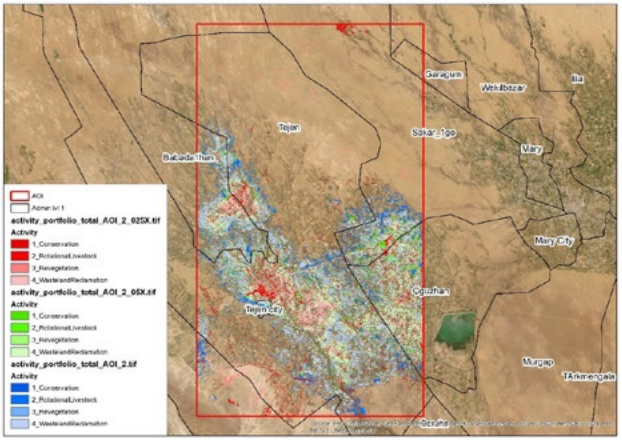
a. **Dashoguz Portfolio**



b. **Ahal Portfolio**



c. **Altyn asyr Portfolio**



Source: Original elaboration for this publication.

Next steps for prioritization of restoration areas. Portfolio optimization algorithms offer further potential through nuanced adjustments beyond simply changing total hectares or budget allocation. Current versions focus on environmental variables, social impact, and agricultural yields, but neglect cost-effectiveness differences among various activities. A more sophisticated approach would prioritize activities based on a combination of these factors, potentially leading to greater geographical reach at a lower overall cost. This could involve prioritizing low-cost per hectare technologies such as pastures or rotational livestock systems over those with higher environmental returns. This type of approach would result in equal area portfolios where investments in pastures or rotational livestock technologies could be reduced to 50 percent~33 percent, increasing the available budget for the other three technologies and resulting in 10 percent~15 percent more hectares affected at the same total cost.

6. Costs and Benefits of Restoration Action

Over 2025–2050, the average annual investment required for restoring 0.63 million ha[20] of Turkmenistan's degraded land — distributed by land-cover-wise targets, which are not equal, but maximize economic return on investment — is just under US$40 million in PV terms[21] (0.16 percent of GDP). The degraded lands will be restored in a series of short windows (of approximately five years). In each window, restoration will be done in one region of the country at a time before moving to another region for the next five years. This means at the country level, restoration actions will take place every year. All land-cover types can be included in each window. Land-cover-appropriate restoration actions, that is nature-based solutions (NbS) will be taken. The proposed restoration actions are conservation of agriculture and crop diversification (croplands), rotational grazing and silvopastoral system (pastures), and forest conservation and reforestation (forests and shrublands). According to the NIDFF, the approach for restoring wastelands (that is, former croplands turned to deserts due to heavy degradation) will be different from that for croplands with less severe levels of degradation. For restoring wastelands with salinity, licorice (a leguminous root crop) will be planted in five-year rotation. When licorice is harvested five years after planting, crops will be cultivated under conservation agriculture and crop diversification practices. The restoration of croplands, pastures, forests, and shrublands will result in a decrease in crop production costs, an increase in the production of crops and livestock products (that is, milk, meat, and wool), a reduction in infrastructure damage, an enhanced supply of ecosystem services, and a reduction in GHG emissions.

The average annual benefits of restoring 0.63 million ha of degraded land are just over US$175 million[22] in PV terms (0.71 percent of GDP) over 2025–2050. The land restoration in the country is economically viable. The Net Present Value of the benefits (that is, benefits net of corresponding costs) including GHG removal for the period mentioned above is nearly US$3.7 billion. The global benefits (that is, GHG removal) account for over 10 percent of the total benefits and the rest, nearly 90 percent, are the local benefits.[23] The BCRs [24] suggest that

[20] The area of targeted land for restoration is 12.8% of the currently degraded land and 10% of the total degraded land in 2050 under the business-as-usual (BAU) scenario where no restoration actions are taken in Turkmenistan. The targeted land includes 416 000 ha of wastelands, 142 000 ha of degraded pastures, 64 000 ha of degraded croplands and 6 600 ha of degraded forestlands.

[21] The investment required for restoring degraded land under each land-cover type in a particular year is the product of land area under restoration and average costs per ha for that land-cover type in that particular year. The average costs of restoration per ha for each land-cover type in different years are estimated by combining relevant data provided by the NIDFF of Turkmenistan, and from three countries in the Central Asia region: Armenia, Tajikistan and Uzbekistan (World Bank 2023, 2024, 2025a, 2025b, and 2025c).

[22] This includes GHG removal benefits. Without GHG removal, the annual average benefit is just over US$161 million in PV terms (0.65 percent of GDP).

[23] The total local benefits (that is, without accounting for GHG removal) are nearly US$ 3.3 billion. The annual total benefits of restoring degraded land under each land-cover type in a particular year are the product of land area under restoration and average benefits per hectare for that land-cover type in that particular year. The average local benefits of restoration per hectare for each land-cover type in different years are estimated by combining relevant data provided by the NIDFF and from three countries in the Central Asia region: Armenia, Tajikistan, and Uzbekistan (World Bank 2023, 2024, 2025 a, b,c). The shadow price of carbon is used for valuing GHG removal benefits. See Footnote 8 for more details. A sensitivity analysis is conducted with a carbon price range of US$10 per tCO_2eq to US$400 per tCO_2eq (see Annex 1).

[24] BCRs for the AOI portfolios will be different from that of the national portfolio. This is because the proportions of target area under different land-cover types in the AOI and national portfolios are different. This suggests the need for conducting separate cost-benefit analysis before choosing an AOI portfolio.

every dollar invested in land restoration actions in Turkmenistan will give a return of nearly 4.5 dollars when GHG removal is accounted for (Table 7). The BCR is slightly lower when GHG removal is not accounted for. It can be noted here that the BCR of wastelands is much lower than croplands as the former requires a much higher up-front investment due to the high level of degradation (Table 7).

Table 7. BCR of restoration of different land-cover types

Land-cover type	BCR	
	Without GHG removal	With GHG removal
Forests and shrublands	9,91	10,56
Croplands	8,71	9,54
Wastelands	4,41	4,72
Pastures	1,27	1,71
Overall	**4,05**	**4,41**

Source: Authors' estimation.

From the economic point of view, it is significantly cheaper to take restorative actions than not taking any action at all and letting the degraded area expand with increased severity of degradation in Turkmenistan. The benefits of the actions far exceed the costs. While in PV terms, the overall average cost of inaction is US$119 per ha per year (Table 3), the cost of action is US$97 per ha per year (Table 8). The benefit of actions—on average—is US$1,588 per ha per year with GHG removal accounted for (Table 8).

Table 8. Average unit costs and benefit of land restoration in Turkmenistan

Land-cover types	Average over 2025–2050; US$/ha/year (in PV terms)		
	Costs	Benefits	
		Without GHG removal	With GHG removal
Forests and shrublands	52	519	553
Croplands	42	363	398
Wastelands	113	498	533
Pastures	79	100	135
Overall	**97**	**1,446**	**1,588**

Source: Authors' estimation.[25]

Land restoration in Turkmenistan is economically viable even when GHG removal benefit is not accounted for. The return on investment in restoration actions decreases marginally in comparison to the case where such benefit is accounted for. According to the sensitivity analysis, the cost-benefit analysis indicators are sensitive in varying degrees to the changes in the key parameters such as discount rate, carbon price, and licorice yield and price, and the direction of sensitivity is plausible (Table 6). This suggests that the economic analysis is robust.

[25] The estimation method of average unit costs of restoration is as explained in Footnote 18. The average unit benefits of land restoration for a land-cover type are estimated by dividing the PV of annual benefits of restoration by the summation of area under restoration from 2024 to 2050 for that land-cover type.

7. Bringing It All Together: Recommendations for Land Investments to Restore Ecosystem Services and Livelihoods in Turkmenistan

Key national social and economic development programs and strategies framing landscape restoration opportunities

The Government of Turkmenistan recognizes the significant challenges posed by land degradation and is actively undertaking measures to promote land restoration and environmental sustainability to improve livelihoods. As part of its commitment to sustainable development, Turkmenistan submitted NDC committing to an unconditional 20 percent reduction in emissions by 2030, compared to 2010 levels, under a BAU scenario as well as ratified international, regional, and bilateral agreements and conventions in the field of environmental protection. These include the United Nations Convention to Combat Desertification (UNCCD), the Convention on Biological Diversity (CBD), and the UN Framework Convention on Climate Change (UNFCCC) (UNCCD and CAREC 2020).

These legal and institutional frameworks support the implementation of integrated policies for the rational use of arable land, pastures, and forest resources, and they promote more balanced agricultural production and land-use planning. Turkmenistan's policy efforts are guided by a number of key national strategies and programs:

- **National Program for Socio-Economic Development for 2025–2052 and the medium- term Presidential Program for 2022–2028.** The Presidential Program approves action plans for developing agriculture, environmental protection, and climate change adaptation. These plans emphasize water-saving technologies, innovative scientific and technical advancements, new seed development, and modernized irrigation systems (Government of Turkmenistan 2021).
- **Turkmenistan's Agricultural Development Program for 2019–2025** sets targets to improve efficiency, ensure food security, and promote sustainability in the agricultural sector. Key elements include the diversification of agricultural production, adoption of efficient irrigation systems and water-saving technologies, and the development of specially protected natural areas to conserve biodiversity.
- **The National Forest Program of Turkmenistan for 2021–2025** along with its accompanying Action Plan, focuses on expanding forested areas and improving forest management through state registration of forest lands. It sets a goal to afforest approximately 30,000 ha by 2025, with an annual target of planting 3 million seedlings for new plantations of deciduous, coniferous and fruit trees, vineyard, and desert plants, supporting climate mitigation and biodiversity restoration.[26]

[26] UNECE Country Profile: Forest Landscape Restoration in Turkmenistan Accessed April 11, 2025. https://land.unece.org/forests/en/knowledge-hub/forest-landscape-restoration/forest-and-forest-landscape-restoration-caucasus-and-central-asia/countries-profile-forest-landscape-restoration/turkmenistan.

- **The National Aral Program of Turkmenistan for 2021–2025** provides for active measures to combat climate change and solve the problems of the Aral crisis, combined with the accelerated development and implementation of resource-saving and environmentally friendly technologies.
- **National Strategy of Turkmenistan on Climate Change,** updated in 2019, reaffirms the country's commitment to international climate obligations under the UNFCCC and the Paris Agreement. The strategy outlines a range of adaptation measures for key sectors including agriculture, water resources, soil and land management, ecosystems, and forestry (Government of Turkmenistan 2019).

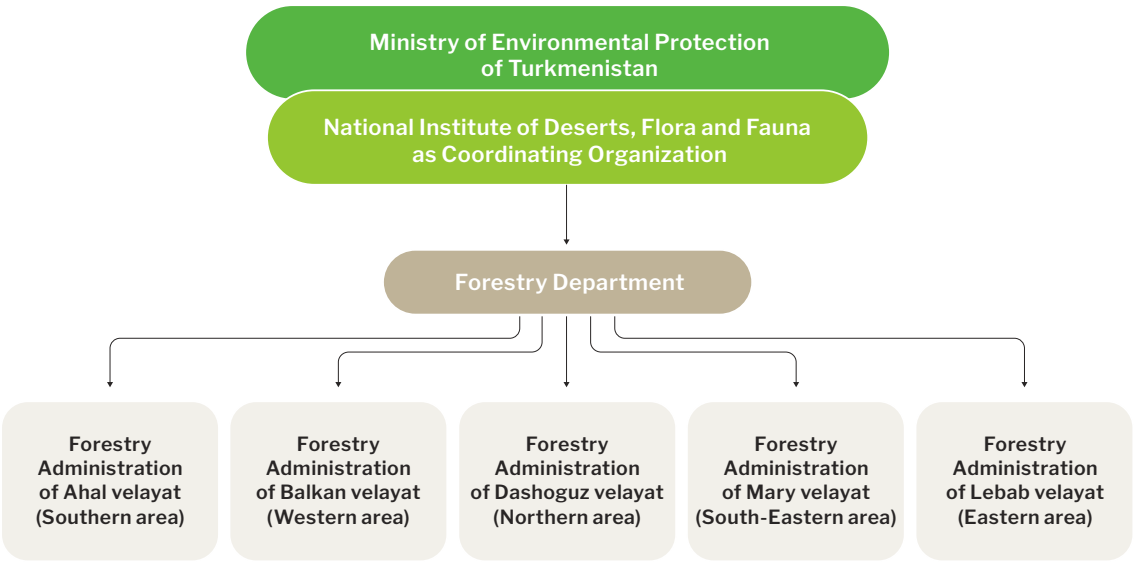
Driving Sustainable Land Management: The Role of the National Institute of Deserts, Flora, and Fauna

The National Institute of Deserts, Flora, and Fauna (NIDFF) established in 1962, operates under the Ministry of Environmental Protection and is headquartered in Ashgabat. As Turkmenistan's leading research institution on arid ecosystems, NIDFF plays a pivotal role in studying desertification, biodiversity conservation, and sustainable land use across the country's predominantly desert landscapes.

The institute actively collaborates with international organizations and participates in global environmental initiatives. Turkmenistan was among the first countries to join the UNCCD in 1996. The Governmental Commission for the Development of the Concept and Strategy of Actions to Combat Desertification designated the Institute of Deserts of the Academy of Sciences of Turkmenistan—now NIDFF under the Ministry of Environmental Protection—as the lead institution responsible for developing the National Action Program to Combat Desertification. NIDFF also serves as the national coordinating center for UNCCD-related activities. Through its multidisciplinary research and policy support, it plays a key role in advancing Turkmenistan's efforts in environmental protection, sustainable development, and climate change adaptation. Given its mandate and expertise, the institute is well-positioned to serve as the national coordinating center for landscape restoration activities (see Annex 1).

Over many years, NIDFF has developed and applied an effective methodology to mitigate sand drift and wind erosion affecting various engineering structures — both existing and under construction — in the Karakum Desert. The institute has also implemented forest restoration initiatives as part of broader land rehabilitation efforts. See Annex 2 images below illustrate these activities.

Figure 13. Proposed Institutional Framework for Implementing Activities for the Degraded Lands Restoration



Source: NIDFF.

Recommendations

By investing in adaptation opportunity hotspots to restore ecosystem services and improve livelihoods, Turkmenistan could establish a framework to promote the adoption and create a supportive environment for the planning and financing of landscape restoration projects.

Recommendations for Overcoming Institutional and Policy Barriers

Turkmenistan's landscape restoration efforts face a number of difficulties due to institutional and policy challenges. These include limited data and in-depth research using modern methods, a fragmented approach to land-use management, and lack of technical facilities. International land restoration initiatives can address these challenges by promoting data collection, cross-sectoral collaboration, and inclusive planning.

- **Promote landscape restoration and sustainable land management.** Integrate landscape restoration into the broader framework of the national policies to ensure alignment of initiatives across diverse land-use types. Key actions include crop rotation and diversification, sustainable application of fertilizers, rehabilitation of degraded lands, and the adoption of salt-tolerant crops and native vegetation to enhance soil health and ecosystem resilience.
- **Strengthen water resource management:** Enhance coordination of adaptation efforts in the water and irrigation sectors by developing district-level integrated rural land-use plans. This includes investing in advanced irrigation technologies, improving canal infrastructure and maintenance, and promoting the reuse of secondary water sources to optimize efficiency and ensure long-term water sustainability. Support policy frameworks that promote efficient, on-demand irrigation services.

- **Create an enabling environment for innovations** in landscape restoration through international cooperation for climate research and development (R&D) and invest in setting up laboratories.

Recommendation for Enhancing the Adoption of Technologies, Data Management, Knowledge, and Research

Turkmenistan has extensive experience in land restoration and has developed localized landscape restoration technologies specific for arid land. These technologies can be scaled and applied across large areas and various land uses. However, they are often context-specific, requiring different innovations for different situations. Additionally, the same innovation may be applied in different contexts, but the application parameters may vary. Therefore, knowledge sharing on regulating parameters between different contexts is essential.

The following are some options to address the technological barriers:

- **Create knowledge exchange and networking platforms on successful application of techno-logies in different contexts, with options for scaling up in similar contexts**. Knowledge and successful strategies on land restoration should be shared among the stakeholders including farmers and other private sector actors through networking platforms. This will help advance and adapt restoration technologies at a faster rate across the country.
- **Strengthening institutional capacity for climate adaptation, land restoration and water management, increase investments in R&D, and promote regional cooperation to address transboundary water issues.** These measures include developing early warning systems, drought risk management, and disaster preparedness strategies.
- **Develop a national strategy to support integrating national, regional, and local landscape management at the project level with the participation of the private sector.** Currently, Turkmenistan does not have a national policy anchoring the landscape restoration portfolio within a broader adaptation plan. Therefore, a national restoration strategy will help integrate landscape management and climate-smart agriculture (CSA) across national, regional, and local levels, involving the private sector.
- **Enhance on-farm water management:** Promote the adoption of advanced water-efficient technologies, such as drip and high-efficiency sprinkler irrigation systems, to optimize water use at the farm level. Establish a comprehensive national system for water measurement and accounting to improve monitoring, allocation, and sustainable management of agricultural water resources.
- **Spread awareness on the double benefits of technology uptake.** Many technologies discussed in this report to reverse land degradation trends and improve ecosystem services provision also have direct benefits of cost-effectiveness, improved food security and/or conserving water resources, to name a few. Greater public awareness and education on sustainable land management is also pivotal to achieving long- term food security and environmental sustainability.

Recommendations for finance and Investments

The analysis presented in this report highlights priority areas for landscape restoration, costs of action, and benefits of action. These findings are also relevant for national landscape restoration initiatives. Large-scale landscape restoration projects should prioritize opportunity hotspots. By prioritizing investments in these hotspots, the country gains more per dollar spent in terms of increased productivity of landscapes and ecosystem services, thus permitting higher returns for further expanding into other areas in the medium to long term.

Solutions to address public finance barriers:

- **Develop landscape restoration portfolios targeting each region's different landscape degradation challenges to prioritize spending based on where the highest benefits are achievable.** In the face of limited funds for landscape restoration, there is a need for targeted investments in the interventions that have the most benefits for the local community. To improve spending efficiency, one could establish landscape restoration portfolios at the province level to target spending better. Such a policy would allow Turkmenistan to achieve substantial positive outcomes in the face of financial barriers.
- **Integrated approach within governments to increase budget for restoration of landscapes from different sectors:** Convene multi-donor roundtables for large-scale resource mobilization for landscape restoration. The opportunity hotspots and investment needs identified for the two scenarios (the national and provincial) provide scope for different donors and actors to make investments in different provinces and sectors (agriculture, water, or forests). This offers a collaboration space among donor organizations for pooling funds for investment in opportunity hotspots while leveraging investment synergies.
- **Use Public Expenditure Review as a key instrument to optimize public spending, ensuring that investments in landscape restoration contribute effectively to building resilient and sustainable landscapes.** The recommended instrument will identify the efficiency of the use of public funds and expenditures in different sectors and at different levels of government, and will contribute to strengthening the organization of landscape restoration activities.
- **Develop a carbon credits framework to provide a financial incentive to restore landscapes.** The revenue from carbon credits can be used to fund further degraded landscape restoration activities, creating a sustainable funding mechanism that supports ongoing resilience efforts. Quality carbon credits require building a realistic and credible baseline at the jurisdictional level, providing permanent GHG emission reductions that are ensured by robust monitoring and verification. Solid benefit-sharing mechanism could help engage local communities. As the demand for carbon credits grows, it can lead to the development of new markets and financial instruments that support restoration activities. This can increase the flow of capital into the Forestry and Other Land Use (FOLU) sector and promote the adoption of best practices for resilient landscapes.
- **Develop architecture for green finance:** Promote the use of green finance (private and public) for investing in landscape restoration through carbon credits, payments for ecosystem services (PES), green bonds, cross-sectoral platforms for budget planning, public-private partnerships (PPPs), and so on.

Solutions to address private finance barriers:

- **Develop a green taxonomy to encourage investment in landscape restoration projects.** A green taxonomy is a standardized green classification system that translates environmental objectives into criteria for specific economic activities for investment purposes. Green taxonomy is a tool for policy makers to encourage sustainable activities, to prevent 'greenwashing' and to direct private sector's investments toward sustainable activities that achieve environmental objectives.
- **Mainstream investing in landscape restoration:** Turkmenistan can attract impact investors for landscape restoration projects by (a) highlighting the environmental and social benefits; (b) partnering with research institutions to estimate long-term financial returns associated with agricultural productivity, reduced disaster risks, and ecotourism attributed to landscapes restoration; (c) building trust and transparency through a strong legal framework; (d) implementing a streamlined investment process; (e) establishing standardized contracts; (f) engaging stakeholders through community involvement and ensuring communities' buy-ins; and (g) encouraging PPPs. By implementing these strategies, Turkmenistan can attract significant investment in its landscape restoration projects.
- **Issue restoration bonds:** Turkmenistan can attract restoration bonds for landscape restoration projects by developing a comprehensive national restoration strategy, quantifying the expected environmental and social benefits, ensuring bond issuance viability, and enhancing creditworthiness through international organizations or foundations. To address investor concerns, Turkmenistan should implement robust monitoring and evaluation frameworks, define exit strategies for bond investors, target impact investors with a strong track record in environmental or sustainable investing, and publicly demonstrate Turkmenistan's commitment to landscape restoration through government policies, budget allocations, and partnerships with environmental nongovernmental organizations (NGOs). By demonstrating these steps, Turkmenistan can build trust with potential bond issuers and investors, making restoration bonds a more attractive option for financing landscape restoration projects.
- **A monitoring, reporting, and verification (MRV) system for GHG emissions covering agriculture, forestry, and livestock sectors should be developed.** The system should comply with relevant requirements of reporting under the Paris Climate Agreement and UNFCCC and should be consistent with voluntary carbon market standards, for example, Verra and/or Gold Standard. In this manner, the MRV system will help realize the potential for GHG emission reduction from land restoration, establish the carbon crediting system and attract international climate finance to Turkmenistan.

8. Conclusion and Areas for Follow-Up Analyses

Given the importance of the agriculture, forestry, and water sectors in Turkmenistan's economy and the required continuous increase in resilience to climate change, there is a clear case for reversing degradation trends and adapting to climate change. The issue is no longer one of if but instead of how, when, and where land restoration should be given priority in view of their investment returns. This study aimed to provide both complete and partial answers to these questions.

To mobilize funding for landscape restoration in Turkmenistan, the government could take the lead in developing portfolios of degraded landscape restoration projects, in each velayat/district, prioritizing expenditures based on where the greatest benefits can be achieved, in line with national objectives and budgetary constraints. This detailed approach enables decision-makers to choose a specific allocation strategy within each unit, allowing decisions to be made based on the cost-effectiveness of different technologies at each administrative level. Organizing roundtables with donor involvement will facilitate the development of architectural carbon credit markets, the issuance of bonds for landscape restoration, and provide green finance and green taxonomy, with targeted social investments to restore degraded land and reduce private sector risk through guarantees.

This report also provides a starting point for investment area prioritization. While selecting parameters for investment prioritization is a political decision, it is informed by technical insights derived from the analysis of ecosystem service provision and the estimated potential for restoration. By combining spatial data with the policy context, the report offers a structured approach to guide evidence-based decision-making.

The current assessment is a demand-driven, just-in-time analytical study initiated in response to Turkmenistan's expressed interest in joining the IBRD-financed regional RESILAND CA+ Program, which supports resilient landscape restoration across Central Asia. This engagement can be further deepened and expanded to align with national priorities and ongoing policy dialogues. To enhance and build upon the current analysis, the following technical activities are proposed:

- **Facilitate technical consultations on the nexus between water management and land degradation,** emphasizing integrated solutions that address irrigation inefficiencies, soil salinization, bad drainage, and unsustainable land-use practices.
- **Conduct a comprehensive review of existing policy and institutional frameworks governing** land-use, degradation, and restoration, with the aim of identifying regulatory gaps, opportunities for harmonization and reform, and aligning national approaches with international best practices in sustainable land governance.
- **Assess a portfolio with the range of technologies per land use suitable for addressing various forms of land degradation.** The results will help better tailor investment packages that are cost-effective, context-specific, and aligned with the country's evolving priorities

and climate resilience objectives. The current set of restoration techniques provides a useful foundation for broad-scale planning; however, it remains insufficient for guiding investment allocation at the local level, where more detailed, site-specific assessments are required to inform implementation.

- **Examine transboundary ecosystems and corridors** where coordinated interventions may generate regional benefits, particularly in water management and areas affected by desertification and dust storms, to support integrated and collaborative landscape restoration efforts.

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Annexes

Annex 1: Sensitivity analysis of the return on restoration investment with carbon prices

Carbon (US$/ tCO_2eq)	EIRR (%)[27]	EBCR[28]
10	38.09	4,19
50	38.57	4,28
100	39.17	4,39
200	40.35	4,61
300	41.49	4,84
400	42.61	5,06

Annex 2: Examples of Sustainable Land Management Practices in Turkmenistan

This annex presents photographs that capture the essence of sustainable land management practices implemented across Turkmenistan. Curated by NIDFF, these images offer a visual narrative of the sustainable approaches and techniques employed to preserve and enhance the country's unique landscapes.

Figure A.1.1. Cultivation of pistachio and almond in the Central Karakums: From seed to a mature tree

Source: NIDFF.

[27] The Economic Internal Rate of Return (EIRR) is a measure used to assess the overall economic value of restoration activities. This percentage represents the rate of return at which the net present value of all economic benefits and costs of a project equals zero.

[28] The Economic Benefit-Cost Ratio (EBCR) is a metric used to evaluate the economic feasibility of a project by comparing the total expected benefits to the total expected costs. An EBCR greater than one indicates that the benefits of a project exceed its costs, suggesting that the project is economically viable and potentially beneficial.

Figure A.1.2. Sand consolidation using reed mats with planting of shrubs inside cages

Source: NIDFF.

Figure A.1.3. Afforestation in the Kopetdag foothills near Ashgabat to prevent negative impacts of climate change

Source: NIDFF.

Figure A.1.4. Black saxaul reforestation in the Karakum Desert

Source: NIDFF.

Turkmenistan Landscapes: Opportunities for Restoration and Livelihoods

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