

**ASSESSING LAND DEGRADATION NEUTRALITY IN TÜRKİYE:
INCORPORATING MULTI-CRITERIA ANALYSIS INTO SUSTAINABLE LAND
MANAGEMENT
(GCP/TUR/065/GFF)**

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1. INTRODUCTION

Globally, 25 percent of the Earth's terrestrial areas are now degraded. This life-threatening trend shows no sign of abating and is even rising (IPCC, 2019). Countries have acted at both the national and international level to halt, mitigate or even reverse the course of this degradation, with the Sustainable Development Goals (SDGs) and the more recent UN Decade on Ecosystem Restoration (United Nations, 2019a, 2019b) giving the utmost priority to environmental concerns.

Türkiye's natural resources are also vulnerable to degradation and desertification (Türkeş et al., 2020) due to an array of challenges including population growth, climate change, desertification and drought, which have far-reaching consequences for its natural assets and people. The magnitude and breadth of the issues will worsen across the nation, exacerbated by human activities, according to predictions generated by several models. These issues thus require the immediate attention of every sector of society to build resilience and accelerate mitigation efforts. Yet, the weight of this responsibility undoubtedly falls heaviest on the shoulders of public institutions making critical decisions regarding land management. For this reason, legislative acts must prioritize stakeholders working to overcome these challenges and give them a solid foundation for project development and implementation, and access to finance.

Land degradation neutrality (LDN) is a holistic approach that transcends land management and encompasses multiple dimensions of sustainable development. It serves as a valuable ally in this endeavour, providing the tools and outputs necessary for informed decision-making. Through LDN mainstreaming, Türkiye can navigate the challenges of land degradation, safeguard its ecosystems, and contribute to the national and global pursuit of sustainable development.

Ecologically management of an environment that is compromised by multiple factors, interconnected in complex ways, requires more than access to relevant datasets. It demands systems able to blend the positive or negative effects of existing datasets, both spatially and temporally, in order to determine the actions to be implemented as part of LDN measures. In 2010, work began to enhance **Decision support systems (DSS)**, first developed in the 1980s, with artificial intelligence, in order to meet this demand (Keenan and Jankowski, 2019).

Decision support systems are invaluable tools that leverage technology and data-driven insights to aid in the complex process of making informed decisions across various domains. In the context of **sustainable land management (SLM)**, the most important instrument is the **Land Degradation Neutrality Decision Support System (LDN-DSS)**, a specialized GIS-based software framework designed to assist decision-makers, land managers and policymakers in achieving LDN goals. This state-of-the-art system integrates multiple data sources, including land-use data, soil health indicators and erosion assessments, to comprehensively evaluate the current state of land degradation. By providing a holistic view of land health, the LDN-DSS empowers stakeholders to formulate strategies for targeted sustainable land management. These strategies encompass a wide range of interventions, from conserving and restoring ecosystems to optimizing land use practices. The LDN-DSS is a pivotal tool in the global effort to combat land degradation and foster the responsible use of land resources to ensure a sustainable future.

The LDN-DSS does not just rely on international data; it is also enriched with domestic up-to-date data tailored to Türkiye's specific conditions. Data provided by the General Directorate of Combating Desertification and Erosion include the "Erosion Model", the "Turkey

Desertification Map” and the “Soil Organic Carbon Map”, among others, all of which are integrated into the system (ÇEM, 2017). Moreover, the system remains dynamic and is continually updated with data of sufficient detail and scale to ensure the most accurate results.

In order to leverage this wealth of information, the LDN Action Plan, guided by the LDN indicators of Land Cover, Land Productivity and Soil Organic Carbon, supplemented by Erosion data, assesses degradation trends in agricultural, forest and pasture lands. These assessments, when enriched by expert opinions, result in area-specific recommendations aimed at mitigating land degradation and promoting SLM practices.

The mandate for formulating policies and strategies to combat desertification and erosion is the responsibility of the General Directorate of Combating Desertification and Erosion (ÇEM, Turkish acronym) of the Ministry of Environment, Urbanization and Climate Change. It is believed that this document, crafted with the utmost care, will serve as a guiding light for the Directorate and for all institutions involved in ensuring sustainable land management in Türkiye.

This undertaking has been a collective effort, drawing on the dedication of colleagues, academia, institutions and organizations along with kind support of international experts. Their unwavering commitment to this cause has been instrumental in bringing this document to fruition.

As this document delves deeper into the intricacies of the LDN-DSS and Türkiye’s National Action Plan, it seeks to lay out how these projects might set the standard for supporting SLM strategies and accomplishing LDN goals. The following sections provide an exhaustive exploration of the LDN-DSS system including a detailed description, associated methodology, results and conclusions.

2. GENERAL APPROACH

LDN-DSS-SLM National Action Plan. Türkiye's plan for sustainable land management aims to achieve land degradation neutrality and ensure long-term sustainability. The methodology includes data collection, spatial analysis, modelling and stakeholder engagement. The plan combines a recognized indicator of land degradation, **land use change (LUC)**, with land productivity dynamics, soil organic carbon and country-specific soil erosion severity to assess land degradation. Tailored recommendations for sustainable land management are provided, emphasizing an integrated and participatory approach.

Türkiye aims to foster sustainable land use, enhance resilience and address land degradation challenges systematically. Land use change poses risks to Türkiye's semi-arid pastures, forests and wetlands due to factors such as population growth, urbanization, agriculture and infrastructure development. In this context, unsustainable practices degrade the land and compromise productivity, and infra and superstructure projects disrupt ecosystems and biodiversity. There is therefore a need for holistic land management approaches, including sustainable land use, ecological land-use planning and soil conservation. In particular, conservation and restoration of vulnerable areas are crucial for ecosystem services such as water regulation, carbon sequestration and nutrient cycling. Efforts to strengthen governance, protected areas, sustainable tourism and community engagement are also of importance to address the challenges created by land use change and land degradation, and for Türkiye to promote sustainable practices and safeguard its land resources for future generations.

Further discussion on land use change. The National Action Plan (NAP) in Türkiye for Land Degradation Neutrality (LDN) adopts a comprehensive approach to addressing land problems. It identifies four indicators: land use change (LUC), land productivity dynamics (LPD), soil organic carbon (SOC) and soil erosion intensity (EI). Land use change is considered as a degradation indicator itself and is not included in the interactive analysis for LDN sub-classes, which focus on LPD, SOC and EI interactions. The three-way interactions provide a nuanced understanding of degradation and help identify areas in need of immediate attention. The approach recognizes the interconnectedness of indicators and aims for targeted land management interventions. Spatial statistics play a crucial role in classifying and managing degraded lands within the LDN framework. Land use change is already considered degraded land and forms part of the restoration hierarchy.

Aerial statistics to include land use change. Statistical and spatial analysis techniques allow for insights into degradation patterns, the identification of hotspots and the prioritization of interventions. The restoration hierarchy emphasizes the need to prioritize the restoration of areas affected by land use change, promoting ecosystem recovery and sustainable land management. By integrating spatial statistics and the restoration hierarchy, decision-makers can allocate resources, implement restoration strategies and monitor progress toward LDN and ecosystem sustainability.

Interactions among LDN indicators versus a “one out, all out” approach. The “one out, all out” approach used in the LDN methodology assumes that if any of the indicators exhibit degradation, the entire area is considered degraded. However, this approach oversimplifies land degradation and may lead to overestimation and misallocation of resources. In contrast, an interaction approach that considers the interplay between indicators offers a more nuanced understanding of land degradation and allows for targeted interventions. The LDN

methodology embraces the interaction approach, analysing indicators such as land cover, productivity and soil organic carbon to identify specific causes and drivers of degradation.

Introduction of Soil Erosion Severity as an additional LDN indicator. The integration of the Soil Erosion Atlas (ÇEM, 2018b) with the LDN-DSS in Türkiye facilitates a comprehensive assessment of land degradation. Soil erosion has been added as an additional LDN indicator, allowing for the analysis of its interactions with other indicators. The reclassification of erosion classes and the consideration of SOC and LPD levels enable the identification of sub-classes within the LDN framework. This integrated approach provides a scientific basis for implementing targeted interventions, promoting land conservation and mitigating the adverse effects of erosion. The goal is to achieve LDN and ensure the long-term sustainable use of land resources in Türkiye.

Scoring. The LDN-DSS tool uses a scoring system to evaluate land degradation risk, assigning numerical values to indicators based on the observed level of degradation. High-risk classes receive a score of “1”, low-risk classes receive a score of “0” and medium-risk classes are assigned a value of 1/2. This scoring system generates a quantitative assessment of land degradation risk and helps establish a response hierarchy, prioritizing areas in need of immediate attention.

Sub-degradation classes. The scoring methodology in the LDN-DSS tool creates 18 sub-degradation classes by considering matches for the three indicators. This rigorous approach assigns scores to each indicator, allowing for the creation of new classes in the response hierarchy. It provides a robust method to quantify indicators, enabling targeted strategies for land degradation management and sustainable land use planning. These sub-degradation classes offer a nuanced understanding of degradation patterns, supporting evidence-based approaches and contributing to the goal of achieving LDN.

Untangling interactions. Untangling interactions between multiple LDN indicators can be simplified through strategies such as prioritizing indicators, using composite indicators and conducting separate analyses. Prioritization reduces complexity by focusing on the most relevant indicators. Composite indicators combine multiple indicators into a single index, streamlining analysis. Separate analyses for correlated indicators reduce complexity. However, interactions should be considered for assessing overall system health and sustainability. These strategies enable a clearer understanding of land degradation dynamics and support informed decision-making processes. Prioritizing indicators helps efficiently allocate resources and address the most critical factors driving land degradation. Consulting local experts can determine the most appropriate approach for a given situation.

Prioritization of process-based indicators. Process-based indicators capture underlying mechanisms and drivers, and provide dynamic and time-sensitive information compared to state-based indicators. By prioritizing process-based indicators, researchers gain insights into ongoing processes and causal relationships, enabling informed decision-making and effective management strategies. In the context of soil management and land degradation, prioritizing process-based indicators like soil erosion helps to understand its impact on LPD and SOC. Soil erosion affects soil structure, nutrient availability and water-holding capacity, directly influencing productivity and fertility. Prioritizing process-based indicators helps identify intervention points and develop targeted strategies for mitigating erosion, enhancing soil health and promoting sustainable land management.

Practical relevance. Untangling interactions between LDN indicators is not only theoretically important but also practically relevant for implementing sustainable land management. By simplifying analysis and interpretation through strategies like prioritizing indicators, using composite indicators and conducting separate analyses, a clearer understanding of land degradation dynamics is achieved, supporting informed decision-making. Recognizing indicator interactions provides insights into system health and sustainability, guiding effective strategies for ever-continuing improvement. This understanding is crucial for implementing sustainable land management, as it helps address drivers of land degradation through targeted interventions. Untangling indicator interactions identifies leverage points and prioritizes interventions for restoring and managing degraded lands. Thus, understanding interactions between LDN indicators is of practical relevance, supporting the implementation of targeted interventions and promoting sustainable land management for ecosystems and human well-being.

Response hierarchy. The LDN-DSS response hierarchy includes conservation, management and restoration subclasses with a total of 18 classes based on LPD x SOC x EI matches. Conservation involves protecting lands with sensitive indicators (LP, E or SOC). Management addresses two-way interactions of LPD-EI, LPD-SOC and EI-SOC, managing specific degradation risks. Restoration focuses on the critical three-way interaction of LPD-EI-SOC and two-way interactions from management, aiming to reverse land degradation.

Common restorative SLM practices, such as conservation tillage, cover crops, diverse plant species and efficient water management, can address land productivity dynamics, SOC and soil erosion. These practices also mitigate other land degradation issues, fostering sustainable land management and ecosystem health. By implementing comprehensive SLM strategies, it is possible to conserve and restore degraded lands and ensure long-term ecological productivity.

In conclusion, the LDN-DSS-SLM tool is a significant achievement for Türkiye, addressing land degradation and promoting sustainable land management. By integrating LDN, DSS technology and SLM practices, it offers a holistic framework for assessing and managing land degradation. The tool's multiple indicators provide valuable insights, guiding targeted interventions and resource allocation. It contributes to environmental sustainability, food security and rural livelihoods by addressing various forms of land degradation. However, continuous updates and monitoring are essential for its effectiveness. Overall, the LDN-DSS-SLM tool represents a crucial step towards achieving land degradation neutrality and supporting Türkiye's long-term development and conservation of natural resources.

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3. METHODOLOGY

3.1 The importance of sub-indicators

The world's land is being subjected to various forms of land degradation such as drought, vegetation decline, soil erosion, soil salinization and soil organic carbon decline, all of which negatively affect land productivity (Právělie et al., 2021).

External drivers/pressures such as climate change, natural disasters, population change, migration, globalization and others cause land degradation through soil erosion, decline in biomass, habitat loss, soil acidification, change in groundwater level/quality, and others. It is, therefore, crucial to determine what to measure (indicators) and how it should be assessed (metrics) in order to achieve the aims of the LDN approach. Though the United Nations Convention to Combat Desertification (UNCCD) has identified a minimum set of indicators to reflect the key processes that underpin land-based natural capital, it is also suggested that national authorities use other indicators, data and ground-based information to determine the amount of degraded land (UNCCD, 2021).

The quantification of land degradation is generally regarded as context-specific, making it difficult for a single indicator to fully capture the state or condition of the land (UNCCD, 2017). The UN Statistical Commission adopts the principle of “One Out, All Out” (1OAO) in which a significant reduction or negative change in any one of the three sub-indicators (land cover, land productivity and soil organic carbon) is considered to constitute land degradation (UNCCD, 2022).

As a supplement to the sub-indicators, erosion is included in the methodology to better understand the status of degradation, defining the best practices for sustainable land management.

3.2 Land cover

Land cover is the physical presence of vegetation on the surface of the Earth, as well as the distribution of water bodies and human-built infra and superstructures (Di Gregorio, 2005). It also refers to land resources (soil, water and biodiversity) that are used for agriculture, forest, human settlements and other purposes (FAO-GTOS, 2009). In this study, the CORINE Land Cover inventory (using a minimum mapping unit of 25 hectares for areal phenomena and a minimum width of 100 m for linear phenomena for the years 1990, 2000, 2006, 2012 and 2018, with a geometric accuracy of ≤ 50 m, ≤ 25 m, ≤ 25 m, ≤ 25 m and ≤ 10 m (Sentinel-2), respectively), was found to provide the most representative data, and was compared with the Türkiye National Land Cover Classes to classify mixed features such as transition and mosaic classes. CORINE Land Cover Classes were then adjusted to National Land Cover Classes and the final classification system was determined by a participatory workshop. The resulting Land Cover Map was classified in terms of tree cover, grassland, cropland, wetland, artificial, other land and water body (see Figure 1). ***The Methodology of Suggested Actions by using LDN-DSS*** study was conducted initially only for Tree Covered, Grassland and Cropland.

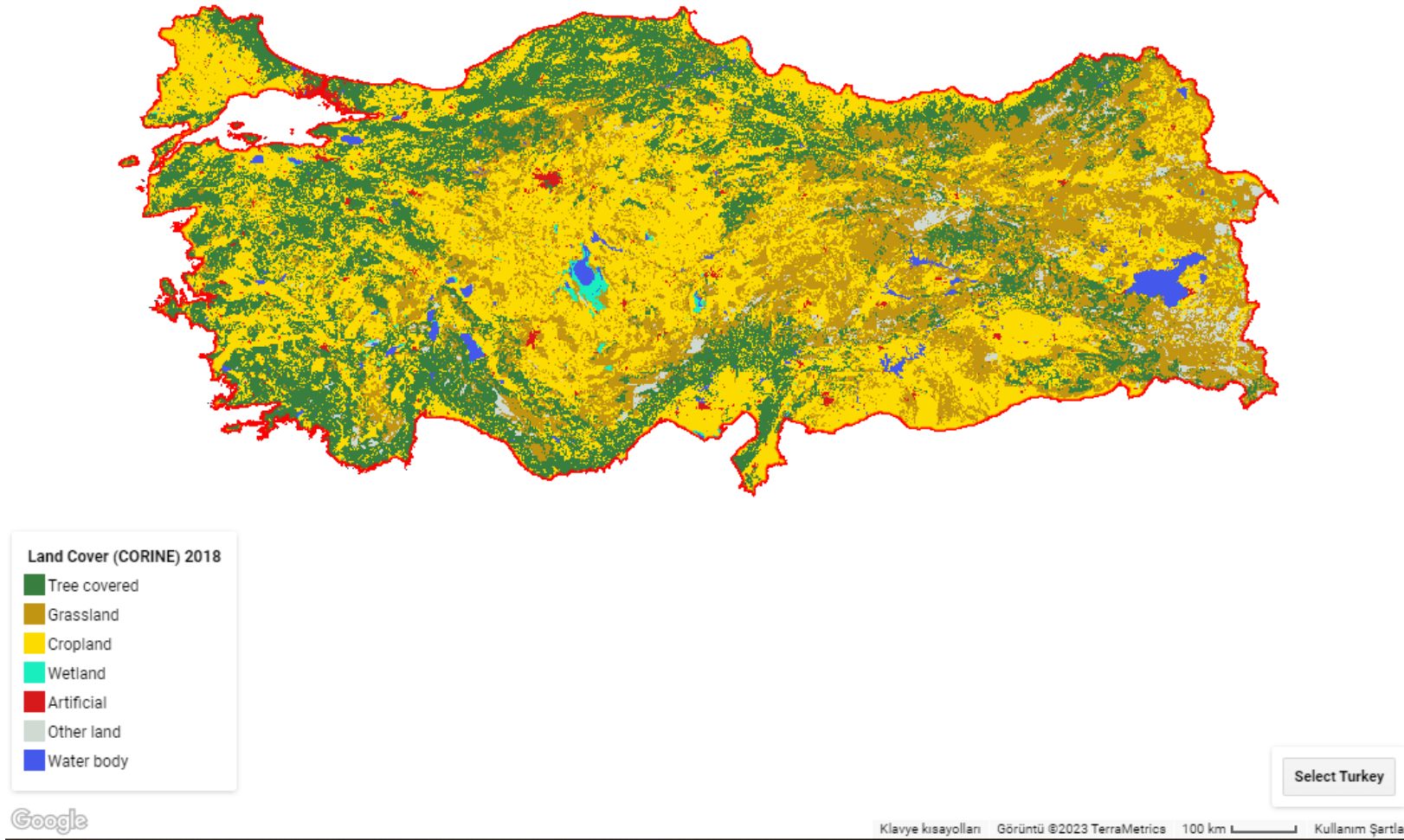


Figure 1. Land cover map of Türkiye – CORINE-Türkiye adjusted

3.3 Soil organic carbon

Soil organic carbon (SOC) is the carbon in the main component of soil organic matter (SOM) and supports key soil functions such as soil stability and nutrient cycling (FAO, 2017). Loss of SOC indicates a certain degree of soil degradation and is a key indicator of LDN. For some LDN interventions, SOC changes are directly linked with a change in land productivity and/or land cover. Consequently, SOC stock changes can be estimated using the indicators for land productivity and land cover. However, for SLM technologies and approaches that do not markedly change land cover or productivity, additional SOC-related metrics are necessary. SOC is a measure of overall soil quality related to nutrient cycling and soil aggregate stability and structure. It has direct impacts on water infiltration and soil biodiversity, soil vulnerability to erosion and, ultimately, the productivity of vegetation and in an agricultural context, yields. In this study, a SOC map (250 m resolution) produced by ÇEM (2018a) was used and SOC metrics were identified in ton C/ha/0-30 cm.

The National Soil Organic Carbon Map of Türkiye was first reclassified from 15 classes to 6 classes: very low (< 20 t/ha), low (20-30 t/ha), moderate low (30-40 t/ha), moderate-high (40–50 t/ha), high (50–70 t/ha) and very high (>70 t/ha); and subsequently reclassified into 2 classes: low (<40 t/ha) and high (> 40 t/ha) (see Figure 2).

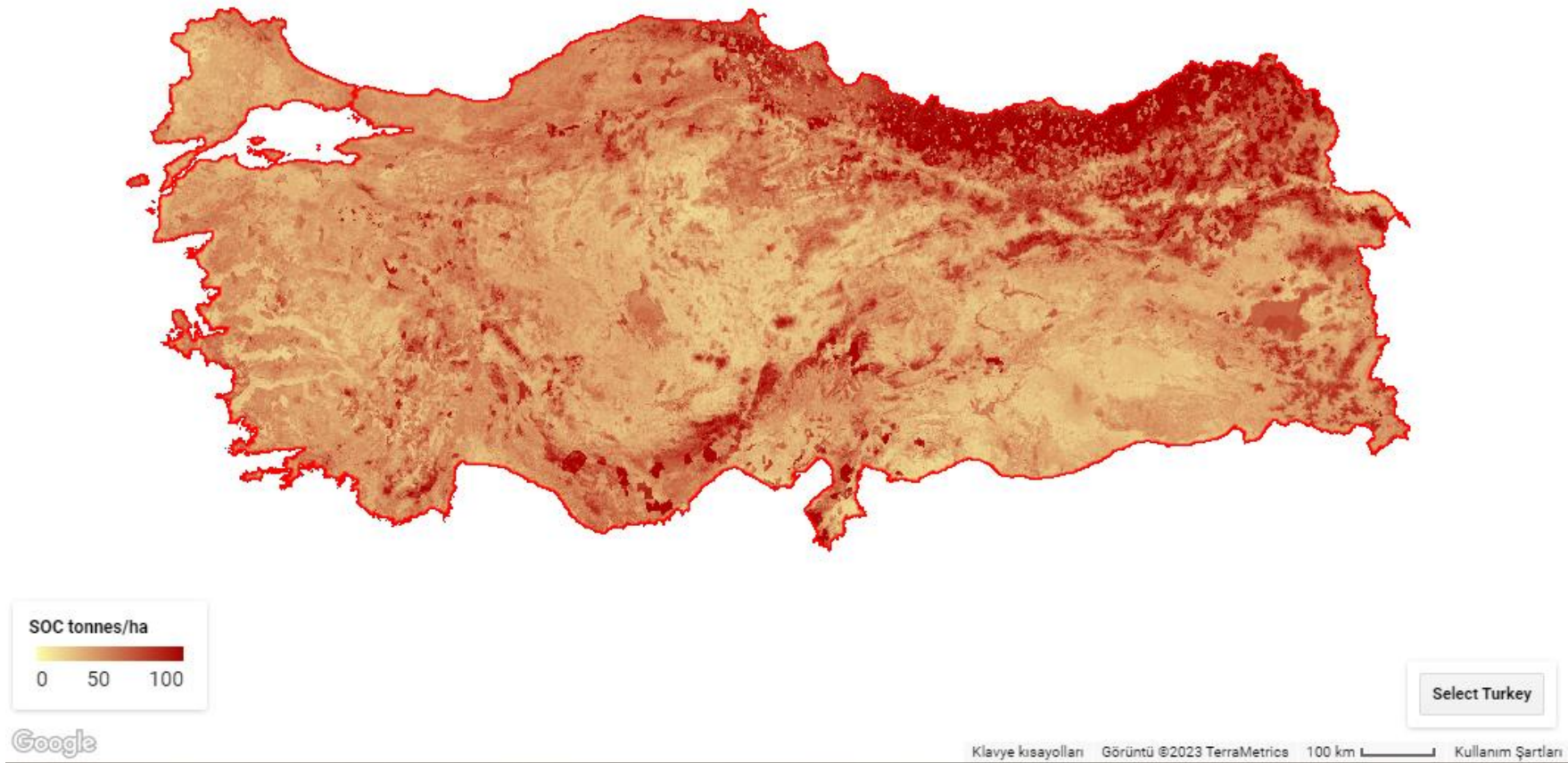


Figure 2. National soil organic carbon map of Türkiye

3.4 Land productivity

Land productivity data in the form of vegetation indices (direct observations) and their derived products are collectively regarded as the most reliable and independent approach to land productivity analysis, providing the longest consolidated period and a wide variety of operational datasets at various spatial scales. Various vegetation indices can be calculated from satellite data for use as a proxy for land productivity, with the Normalized Difference Vegetation Index (NDVI) being the most frequently employed (Didan, 2015). Numerous methods also can be used to analyse and extract insights from time series image datasets. For example, the UNCCD Good Practice Guidance (GPG) suggests three metrics derived from remotely sensed data to estimate changes in land productivity (trend, state and performance), as well as tools, such as Trends.Earth, which have been developed to support the calculation of such metrics globally (UNCCD, 2021). The choice of the most representative metric to assess land productivity dynamics represents a challenge, especially in large countries with contrasting environmental conditions, ecosystems and land uses, such as Türkiye. Different calculations based on the same Earth observation (EO) data can produce different results, highlighting the importance of integrating EO data with other sources of information, such as experts' knowledge, through participative processes. Accordingly, the UNCCD LDN reporting framework encourages countries to assess direct and/or indirect drivers of land degradation through participatory processes adapted to the national and local context.

In this context, Türkiye, as a country member of the UNCCD, and FAO under the framework of the GEF-funded project “Contributing to Land Degradation Neutrality (LDN) Target Setting by Demonstrating the LDN Approach in the Upper Sakarya Basin for Scaling up at National Level” (GCP/TUR/065/GFF), organized a participatory and data-driven workshop for the estimation of SO 1-2 (Trends in Land Productivity) indicator

Participants in the workshop discussed and took decisions to select the best available land productivity dynamics data, as well as the most appropriate algorithms to analyse these datasets, following UNCCD's PRAIS4 reporting manual guidelines¹ and SDG 15.3.1 Good Practice Guidance.²

The workshop participants reached a consensus to use the FAO-WOCAT co-developed model to assess land productivity. The model was produced using NDVI time series from MOD13Q1.006 Terra Vegetation Indices on 16-day intervals averaged at 250 m pixel resolution, integrated over each calendar year since 2000. The resulting land productivity dynamics map of Türkiye (see Figure 3) was classified from 36 categories into 5 LPD categories: declining, early sign of decline, stable but stressed, stable and increasing; and subsequently reclassified into three classes: declining (declining + early sign of decline), stable (stable but stressed + stable) and increasing.

¹ <https://prais4-reporting-manual.readthedocs.io/en/latest/index.html>

² www.unccd.int/sites/default/files/relevant-links/2021_03/Indicator_15.3.1_GPG_v2_29Mar_Advanced-version.pdf

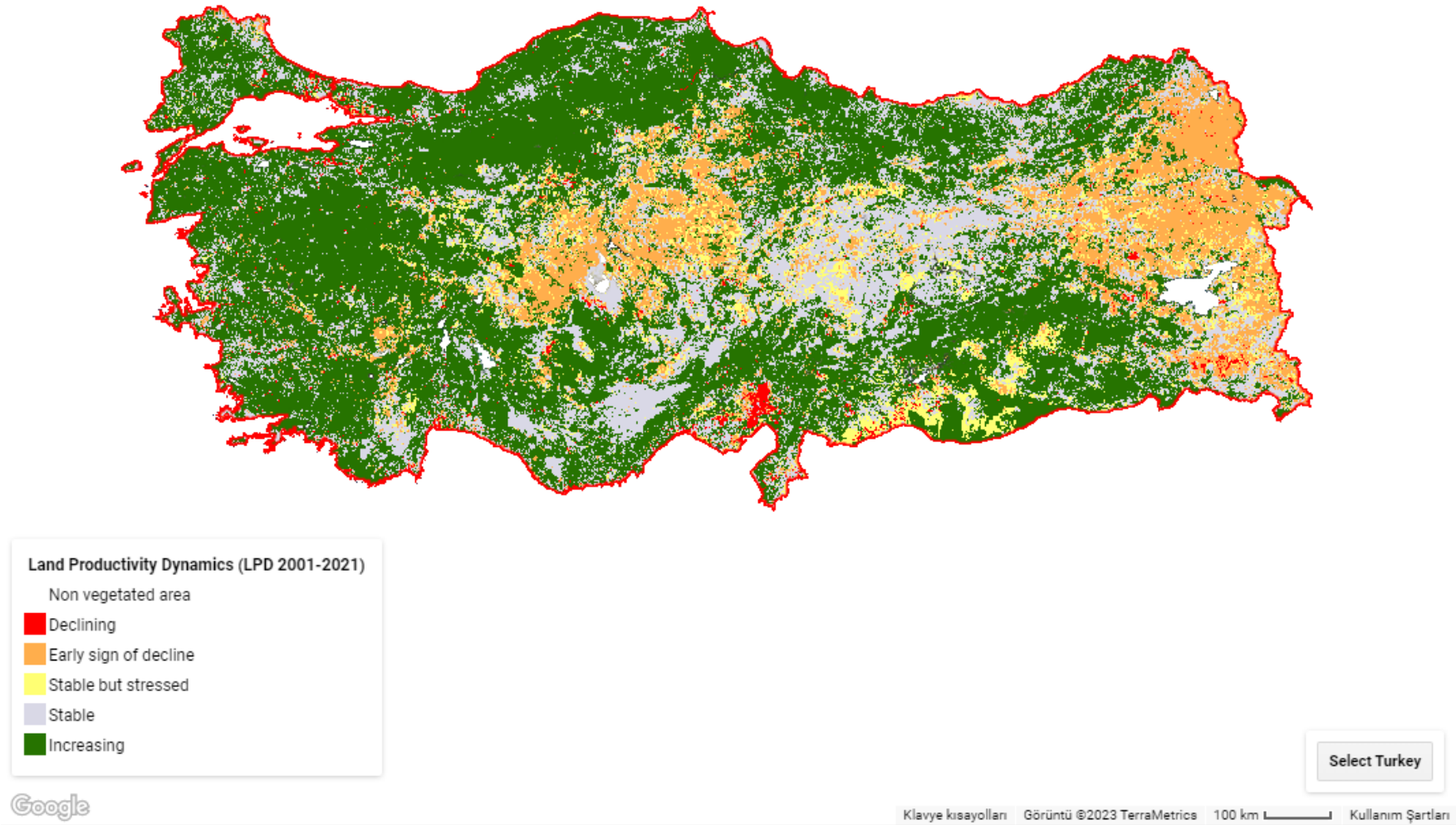


Figure 3. Land productivity dynamics map of Türkiye

3.5 Soil erosion

Erosion is a geological process causing earthen materials (i.e. soil rocks, sediments) to be worn away and transported over time by natural forces such as water or wind. Sometimes this process is accelerated by poor management or anthropogenic pressures on land. Estimating soil losses from erosion in basin-based management plans is an essential component of monitoring land degradation.

Türkiye has developed a Geographic Information System (GIS)-based software known as the “Dynamic Erosion Model and Monitoring System” (DEMIS) (ÇEM, 2018b), which is formulated to quantify soil erosion (A , ton ha⁻¹ y⁻¹). The current classification system of erosion is based on five classes: (very low erosion ($0 \leq A < 1$), low erosion ($1 \leq A < 5$), moderate erosion ($5 \leq A < 10$), severe erosion ($10 \leq A < 20$) and very severe erosion ($A \geq 20$). This was narrowed into three classes: low ($0 \leq A < 5$), moderate ($5 \leq A < 10$) and high ($A \geq 10$) for monitoring purposes (see Figure 4).

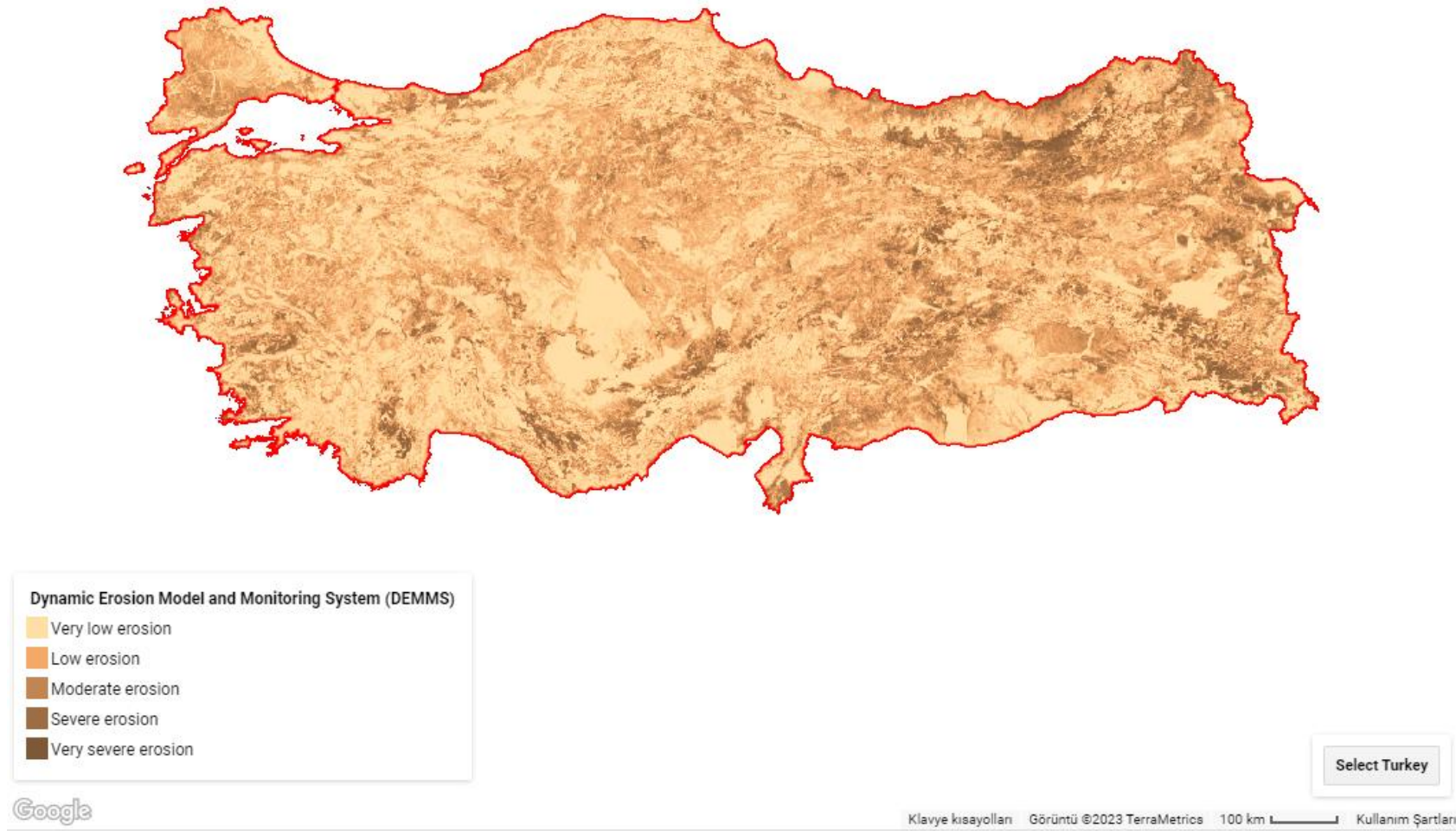


Figure 4. Soil Erosion Map of Türkiye

4. SUSTAINABLE LAND MANAGEMENT APPROACHES AND PRACTICES

Healthy land provides vital and invaluable environmental functions and ecosystem services, including provisioning, regulating, supporting and cultural services. It supports the production of food, fodder, fuel and fibre; regulates the severity of natural disaster risks; and provides cultural and spiritual services for human well-being. Currently, adverse effects of climate change, such as desertification, land degradation and drought (DLDD), are negatively impacting the delivery of ecosystem services that are essential for sustaining livelihoods and human well-being. In this context, sustainable land management not only presents land-based solutions to mitigate the impacts of these issues, it also ensures the preservation of biodiversity and the safeguarding of soil and water resources both quantitatively and qualitatively.

It is evident that the implementation of various practices under different SLM approaches constitutes the practical phase of achieving the goal of LDN. SLM practices aim to mitigate the impacts of climate change and enhance climate change adaptation on the one hand, while facilitating efforts to combat against desertification, land degradation and drought on the other. In short, SLM approaches and practices represent a holistic approach that takes into consideration biophysical, socio-cultural, and economic needs and values, to achieve long-term productive ecosystems.

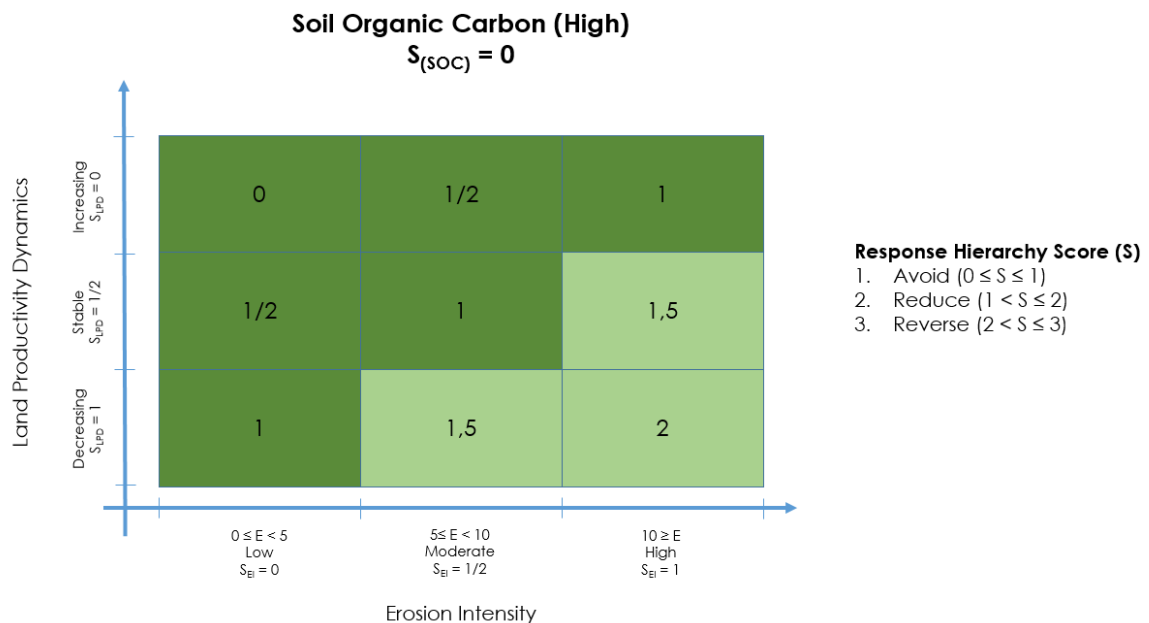
In Türkiye, given the importance and priority accorded to combating desertification and erosion in managed agricultural, forest and pasture lands, various administrative, cultural, vegetative and engineering control measures have been planned and implemented within the framework of numerous projects and programmes by responsible public authorities and institutions over many years. In this context, institutional authority and responsibilities can vary widely and comprehensively depending on the land cover, soil and water management practices.

This study largely adopts the SLM approaches prepared within the context of the UNCCD Science-Policy Interface (SPI) (Sanz et al., 2017). These approaches, generally categorized into 14 main headings, are provided below.

1. **Afforestation/reforestation:** Establishing and maintaining tree or forest cover on non-forest lands. The practice of reafforestation is the same but on land previously converted for other uses.
2. **Agroforestry:** Integrating trees with crops and/or animals in the same land unit, including afforestation on agricultural lands, pastures and various tree-agro-pasture systems.
3. **Minimum soil tillage:** Minimizing surface soil disturbance through actions applied at shallow depths or narrow strips.
4. **Reducing deforestation:** Measures to prevent or reduce forest removal, clearing or conversion to non-forest land.
5. **Soil erosion control:** Preventing or controlling wind or water erosion that breaks down soil aggregates, transports and causes soil fertility loss.
6. **Sustainable forest management:** Responsible management of natural and planted forests, combining productivity and conservation for sustainable benefits.
7. **Vegetation cover management:** Practices to enhance the quality, quantity and diversity of vegetation cover for various land uses. It includes managing invasive species.

8. **Water management:** Sustainable management of water resources, including groundwater, surface water and rainwater, to promote efficiency and prevent pollution and overuse.
9. **Integrated farming-grazing/livestock production systems:** The co-existence of crop production and livestock farming among different communities.
10. **Animal waste management:** Proper collection, processing, storage and utilization of solid manure and urine waste to recycle farm manures.
11. **Pest, fire and disease control:** Measures to manage, prevent or control fires, pests and diseases to reduce their impact on land and ecosystems.
12. **Forest restoration:** Technology for recovering degraded forest ecosystems, re-establishing forest structure, biodiversity and productivity.
13. **Grazing pressure management:** Measures to sustainably manage rangelands, preserving natural resources like vegetation cover, soil and water.
14. **Integrated soil fertility management:** Practices to optimize nutrient cycling and use in soil to enhance crop productivity.

As mentioned before, the LDN-DSS tool employs a specific scoring system to evaluate land degradation risk and establish a response hierarchy. The methodology assigns numerical values to each indicator based on the level of degradation observed. High-risk classes receive a score of “1”, low-risk classes receive a score of “0”, and medium-risk classes are assigned a value of 1/2. The methodology utilizes three indicators, namely land productivity dynamics (LPD), soil organic carbon (SOC) and erosion intensity (EI), to assess land degradation. LPD and EI are represented by three categories each, while SOC is represented by two categories. In the case of LPD and EI, classes indicating a high risk of degradation are scored as “1”, those indicating a low risk are scored as “0” and medium-risk classes are given a score of 1/2. For the SOC indicator, a high risk of degradation is scored as “1,” while a low risk receives a score of “0” (see Figure 5).



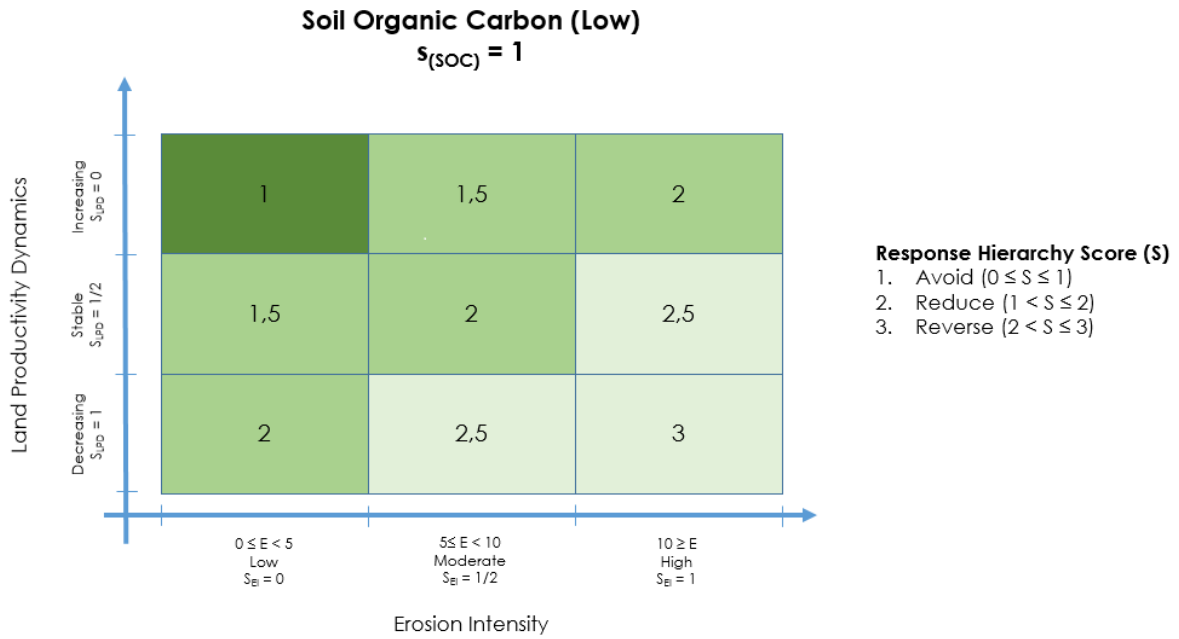


Figure 5. LDN response hierarchy scoring based on LPD, SOC and EI indicators

By applying this scoring system, the LDN-DSS tool generates a quantitative assessment of land degradation risk, allowing for the establishment of a response hierarchy. The scoring reflects the relative severity of degradation across different indicators and provides a basis for prioritizing interventions based on the urgency and extent of degradation observed. This methodology provides a structured and consistent approach to assess and prioritize interventions, facilitating decision-making processes for land degradation management and guiding the allocation of resources towards areas with the highest risk and in need of immediate attention.

As a result, the scoring methodology applied in the analysis yielded a comprehensive assessment of land degradation by considering possible matches of the three basic indicator rating classes ($3 \times 2 \times 3$), resulting in 18 sub-degradation classes. By utilizing scoring matrices, this approach rigorously assigns scores to each indicator based on its level of degradation, enabling the creation of new classes for the response hierarchy. The application of this scoring methodology provides a robust and scientific method for quantifying the levels of indicators, facilitating a systematic approach to prioritize interventions and address land degradation. The resulting sub-degradation classes offer a nuanced understanding of the diverse degradation patterns, allowing for targeted and tailored strategies in land degradation management and sustainable land use planning. This scoring methodology serves as a valuable tool in decision-making processes, supporting evidence-based approaches for sustainable land management and contributing to the broader goal of achieving Land Degradation Neutrality.

Under each LDN DSS response hierarchy, various three-way interaction subclasses have emerged based on different LPD $\times$ SOC $\times$ EI matches. The number of subclasses for conservation, management and restoration interventions are 7, 8 and 3, respectively, totalling 18 subclasses (see Figure 6).

Response Hierarchy	Scoring	Sub Classes (SOCxLPDxEI)	Activity Intensity	Description
Conservation	$0 \leq P \leq 1$	1. High x Increasing x Low 2. High x Stable x Low 3. High x Decreasing x Low 4. High x Increasing x Medium 5. High x Stable x Medium 6. High x Increasing x High 7. Low x Increasing x Low	Low	The diversity and number of Sustainable Land Management approaches and related practices are low. Offsetting land degradation is cost-effective. Restoration of biodiversity along with ecosystem functions and services is likely within one year ($1 \leq t < 2$ years).
Management	$1 < S \leq 2$	8. High x Decreasing x Medium 9. High x Stable x High 10. High x Decreasing x High 11. Low x Stable x Low 12. Low x Decreasing x Low 13. Low x Increasing x Medium 14. Low x Stable x Medium 15. Low x Increasing x High	Medium	The number of Sustainable Land Management approaches and related practices is moderate. Offsetting land degradation is moderately costly. The restoration of biodiversity along with ecosystem functions and services requires relatively long periods of time ($2 \leq t < 5$ years).
Restoration	$2 < S \leq 3$	16. Low x Decreasing x Medium 17. Low x Stable x High 18. Low x Decreasing x High	High	The diversity and number of Sustainable Land Management approaches and related practices are high. Offsetting land degradation is costly. Restoration of biodiversity along with ecosystem functions and services requires long periods of time ($t \geq 5$ years).

Figure 6. Response hierarchy (Avoid: Conservation, Reduce: Management, Reverse: Restoration) for various three-way interaction subclasses

LDN-DSS basically seeks to offer a brief overview and approach recommendation. This approach allows for the development of 18 subclasses. Then, by developing more subclasses with sensitive ground surveys in problem regions, relevant SLM interventions can be run individually or amalgamated more than one.

Conservation. Conservation involves conserving forest, agricultural and pasture lands through the avoidance of degradation. It comprises hierarchical responses with a total of seven subclasses, with a scoring range of 0 to 1 ($0 \leq S \leq 1$), where only one of the indicators, land productivity (LP), erosion intensity (EI) or soil organic carbon (SOC), is deemed most sensitive or critical in terms of degradation. The protection hierarchy as a combination of these three indicators, encompassing subclasses where land productivity dynamics are “decreasing”, soil organic carbon is “low” or erosion intensity is “high”. Protecting these lands requires low-intensity and low-cost implementation activities, supported by administrative and legal measures.

Management. The management hierarchy encompasses forest, agricultural and pasture lands that are to be managed by reducing degradation. It consists of the most critical subclasses resulting from the adverse interaction of at most two indicators among land productivity (LP), erosion intensity (EI) and soil organic carbon (SOC). This intervention type has a scoring range of ($1 < S \leq 2$) and comprises a total of eight subclasses. The management hierarchy also includes subclasses where either LP or EI, or both, have a moderate risk of degradation in conjunction with at least one critical indicator from the LDN indicators. It represents the intervention stage with the highest number of subclasses. Managing the lands under this hierarchy requires the implementation of moderately intense and moderately cost-effective SLM activities, accompanied by administrative and legal measures.

Restoration. The restoration hierarchy comprises forest, agricultural and pasture lands that undergo the restoration process by reversing the degradation. It involves the most critical class resulting from the adverse interaction of up to three indicators among land productivity (LP), erosion intensity (EI) and soil organic carbon (SOC). This intervention type is shaped by the combination of “Low x Decreasing x High” subclasses, and it has a scoring range of ($2 < S \leq 3$). The restoration hierarchy consists of a total of three subclasses. Additionally, the restoration hierarchy includes subclasses where either LP or EI, or both, have a moderate risk of degradation in conjunction with at least two critical indicators from the LDN indicators. It represents the intervention type with the least number of subclasses.

It is important to note that, while the focus may vary depending on land use types, prioritizing any of the three indicators – land productivity dynamics, soil erosion control or SOC enhancement – can yield positive outcomes across different land management scenarios. Integrated approaches that consider these interconnections are essential for sustainable land management and achieving LDN objectives. Some SLM scenarios are summarized here, taking three-way interactions into account for the LDN DSS tool.

The potential impacts of prioritizing each of the three indicators (land productivity dynamics, soil erosion and soil organic carbon) across managed land use types of agriculture, grazing land and forests for SLM approaches and practices are explored below.

1. Prioritizing Land Productivity Dynamics (LPD)

- **Agriculture.** Focusing on improving land productivity dynamics in agriculture can lead to increased crop yields, enhanced food security and economic benefits for farmers. Practices such as crop rotation, improved irrigation, and regenerative and precision agriculture can boost productivity. Additionally, the increased vegetation cover and root systems can help prevent soil erosion and promote SOC accumulation.
- **Grazing land.** Improved land productivity dynamics in grazing areas can result in higher forage availability, supporting livestock grazing. Proper grazing management practices, such as rotational grazing, reseeding of pastures and maintaining ground cover, can enhance land productivity. This, in turn, can reduce the pressure on forests and natural vegetation for grazing, helping preserve and enhance biodiversity.
- **Forests.** In forests, focusing on land productivity dynamics can lead to sustainable timber and non-timber forest product yields. Implementing selective logging practices, reforestation and sustainable forest management can maintain or enhance forest productivity. Healthy forests contribute to biodiversity conservation and carbon sequestration, indirectly benefiting SOC.

2. Prioritizing soil erosion intensity (EI)

- **Agriculture.** Prioritizing soil erosion control in agriculture involves implementing conservation practices like contour farming, terracing and cover cropping. Reducing soil erosion helps maintain topsoil integrity, which is essential for land productivity dynamics. It also minimizes sediment runoff into water bodies, preserving water quality.
- **Grazing land.** Erosion control measures in grazing areas, such as streambank fencing, reseeding and rotational grazing, can successfully mitigate soil loss. These practices protect grasslands and prevent sedimentation in water bodies, benefiting water quality. Reduced soil erosion indirectly supports land productivity dynamics by maintaining nutrient-rich soils.

- **Forests.** Preventing soil erosion in forests is crucial for preserving forest health and productivity. Strategies like erosion control structures, buffer zones along water bodies and sustainable logging practices safeguard against soil loss. Healthy forests contribute to stable ecosystem services and carbon storage.

3. Prioritizing soil organic carbon (SOC)

- **Agriculture.** Prioritizing SOC enhancement in agriculture involves practices like organic farming, cover cropping and reduced tillage. Increased SOC levels improve soil structure, nutrient retention and water-holding capacity, leading to enhanced land productivity dynamics. Higher SOC also reduces soil erosion vulnerability.
- **Grazing land.** In grazing areas, SOC enrichment can be achieved through practices like agroforestry, improved pasture management and manure management. Higher SOC enhances soil fertility, supporting forage production and land productivity dynamics. It also contributes to erosion control by stabilizing soil structure.
- **Forests.** Promoting SOC accumulation in forests can involve reduced-impact logging, afforestation and promoting natural regeneration. Enhanced SOC levels benefit forest health, productivity and biodiversity. SOC-rich soils resist erosion and support ecosystem resilience.

While the focus may vary depending on land use types, prioritizing any of the three indicators (LPD, soil erosion control or SOC enhancement) can yield positive outcomes across different land management scenarios. Integrated approaches and practices that consider these interconnections are essential for sustainable land management and achieving LDN objectives.

In Türkiye, addressing land degradation is a critical imperative to ensure the long-term sustainability of the country's landscapes and ecosystems. At the national scale, there is a substantial area of land that requires targeted interventions to combat degradation. These efforts are categorized into a response hierarchy consisting of avoidance, reduction and reversal (see Figure 7).

To avoid further land degradation, an extensive area of approximately 48 389 936 ha needs proactive measures. This includes strategies such as SLM practices, reforestation and afforestation, which aim to maintain existing land productivity and prevent degradation processes from occurring.

Additionally, there are approximately 24 915 233 ha of land where measures for reduction are essential. Reduction-focused interventions involve mitigating ongoing degradation processes, and include soil erosion control, improved agricultural practices and sustainable grazing management, to slow down the rate of land deterioration.

Furthermore, there is a critical need to reverse the impacts of degradation on approximately 3 063 551 ha of land. Reversal strategies aim to restore the land's productivity, soil health and vegetation cover. These may include reforestation efforts, soil restoration techniques and habitat restoration to bring back the affected areas to a more productive and sustainable state.

The comprehensive approach to land degradation in Türkiye addresses these vast areas through a combination of avoidance, reduction and reversal strategies, reflecting the nation's commitment to preserving its natural resources and landscapes for future generations.

In Türkiye, addressing land degradation through SLM approaches and practices requires a tailored response hierarchy specific to different land use types, including forests, grasslands and croplands. At the national scale, the focus is on conservation, management and rehabilitation efforts to combat land degradation effectively (Figure 7).

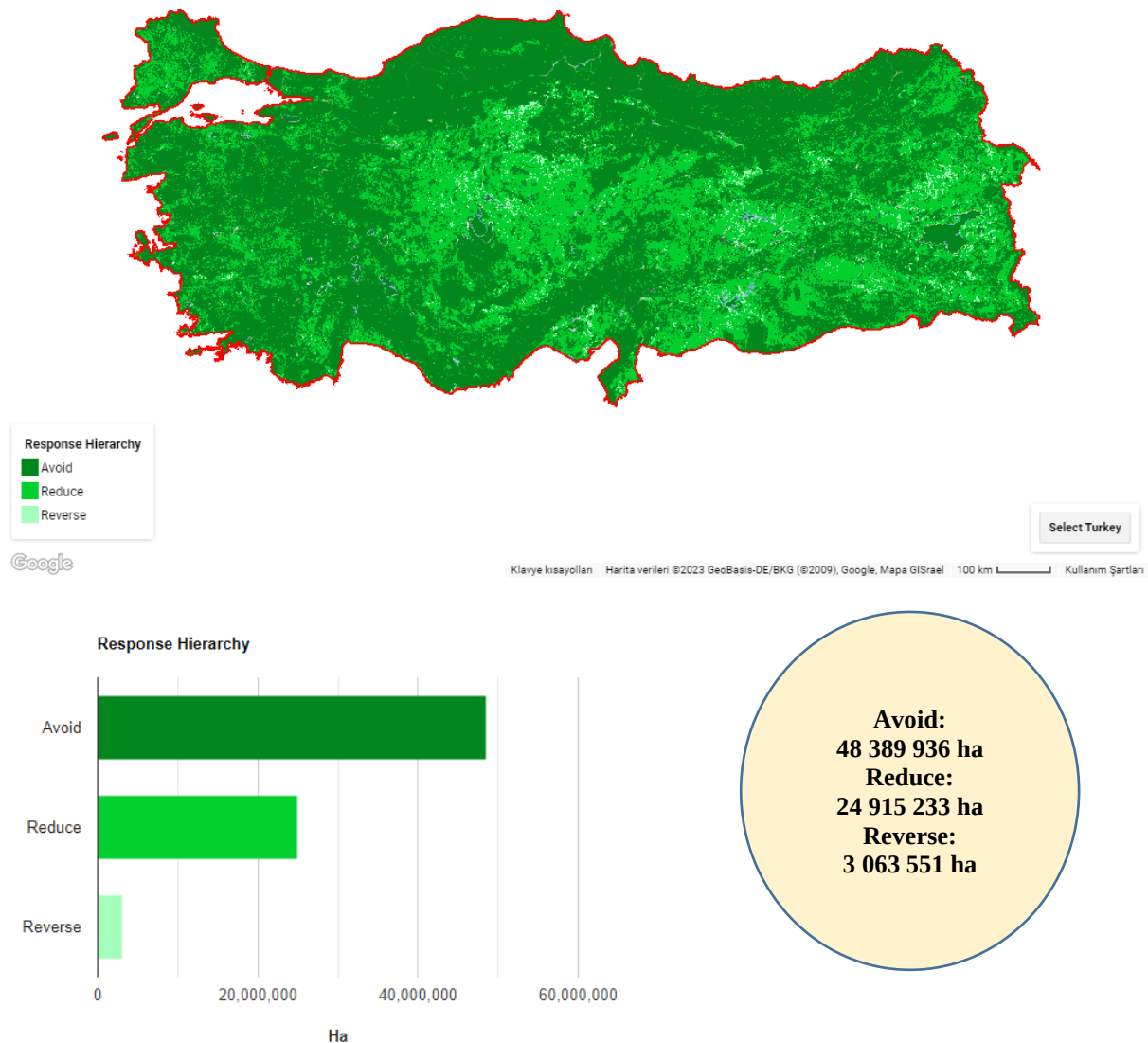


Figure 7. Spatial statistics for response hierarchy irrespective of land use types

Forest

Conservation. The majority of forested areas, encompassing approximately 18 665 265 ha (92.07 percent of the total forested land), are prioritized for conservation. This approach aims to preserve the existing forest ecosystems, protect biodiversity and prevent further degradation through measures such as strict conservation practices and protected area management.

Management. Around 1 557 809 ha (7.68 percent) of forested land are designated for management. This involves sustainable forest management practices that promote responsible timber harvesting, reforestation and the maintenance of ecosystem health and resilience.

Rehabilitation. A smaller portion of approximately 49.894 ha (0.25 percent) of forested land requires rehabilitation efforts. Rehabilitation focuses on restoring degraded forest areas, enhancing biodiversity and improving the overall health of forest ecosystems.

Grassland

Conservation. Within the grassland areas, comprising approximately 11 053 296 ha (54.79 percent of total grasslands), conservation efforts are emphasized. These practices aim to protect existing grassland ecosystems, preserve soil fertility and maintain habitat integrity through responsible land use (see Figure 8).

Management. A substantial portion of about 8 034 059 ha (39.82 percent) of grasslands is designated for management. Management practices focus on sustainable grazing, rotational grazing systems, and maintaining vegetation cover to prevent soil erosion and degradation.

Rehabilitation. Approximately 1 088 252 ha (5.39 percent) of grasslands require rehabilitation to reverse degradation processes. Rehabilitation strategies include reseeded, improving soil health and restoring the natural balance of grassland ecosystems.

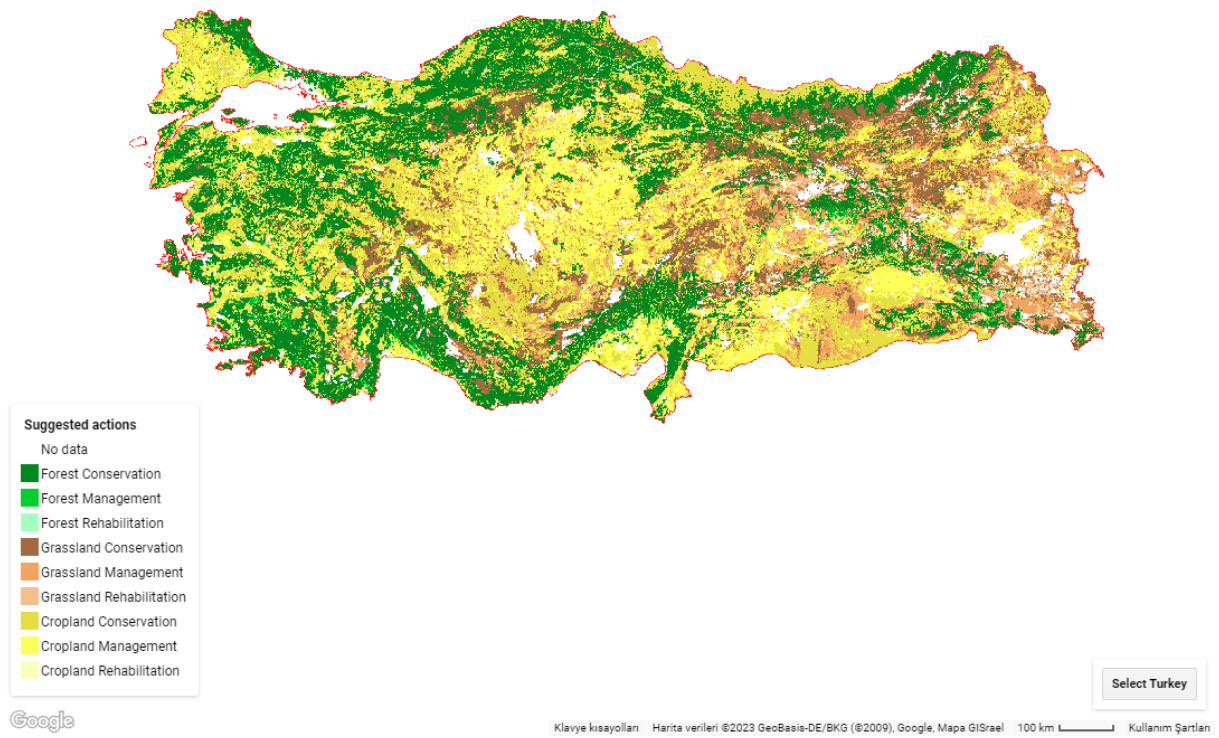
Cropland

Conservation. In cropland areas, which cover about 15 855 446 ha (49.52 percent of total croplands), the priority is on conservation practices. These practices involve responsible farming techniques, soil erosion control and the preservation of soil fertility to ensure sustainable agricultural productivity.

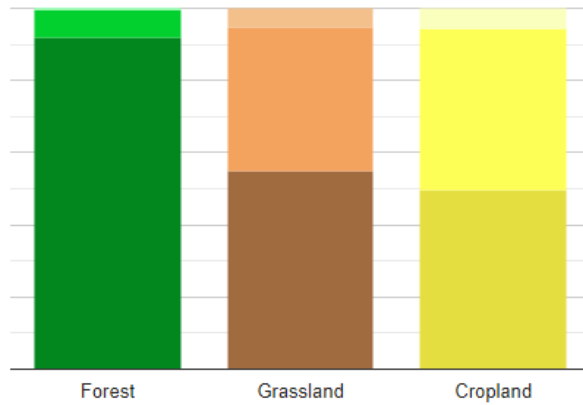
Management. A significant portion of approximately 14 292 282 ha (44.64 percent) of croplands is designated for management. Management efforts focus on implementing minimum tillage, crop rotation and nutrient management practices to enhance soil health and reduce erosion.

Rehabilitation. About 1 867 655 ha (5.83 percent) of croplands require rehabilitation to reverse degradation impacts. Rehabilitation strategies include re-establishing soil fertility, implementing agroforestry systems and restoring the overall productivity of cropland areas.

This comprehensive approach to response hierarchy and SLM practices underscores Türkiye's commitment to combating land degradation, protecting its natural resources and ensuring the sustainability of various land use types across the country.



Suggested actions



Forest

Conservation: 18.665.265 (92.07%)
 Management: 1.557.809 (7.68%)
 Rehabilitation: 49.894 (0.25%)

Grassland

Conservation: 11.053.296 (54.79%)
 Management: 8.034.059 (39.82%)
 Rehabilitation: 1.088.252 (5.39%)

Cropland

Conservation: 15.855.446 (49.52%)
 Management: 14.292.282 (44.64%)
 Rehabilitation: 1.867.655 (5.83%)

Figure 8. Spatial statistics for suggested SLM approaches and practices in terms of managed land use types of forest, grassland and cropland

5. LDN MAINSTREAMING USING A DECISION SUPPORT SYSTEM

The mainstreaming of LDN refers to the integration of the approach into all relevant land-based legislation, plans, projects and activities for implementation. Many institutions and organizations are already engaged in activities related to land management. In particular, public institutions, which are the main authorities in charge of land management, have to consider both the public benefit and the sustainable use of natural resources from an integrated perspective when carrying out their activities. Sustaining the income and welfare of communities dependent on land for their livelihoods, while ensuring the effective implementation of SLM practices, presents a significant challenge on the path to achieving the LDN targets.

User-friendly and easily accessible tools are critical for countries to integrate the LDN approach into their plans, policies and projects, and to set and achieve LDN targets. In this regard, the LDN-DSS provides decision-makers with an important guiding tool by allowing them to interpret various outputs with multifunctional options. In other words, the system streamlines and facilitates the adoption and mainstreaming of the LDN approach in all public institutions involved in land-based activities.

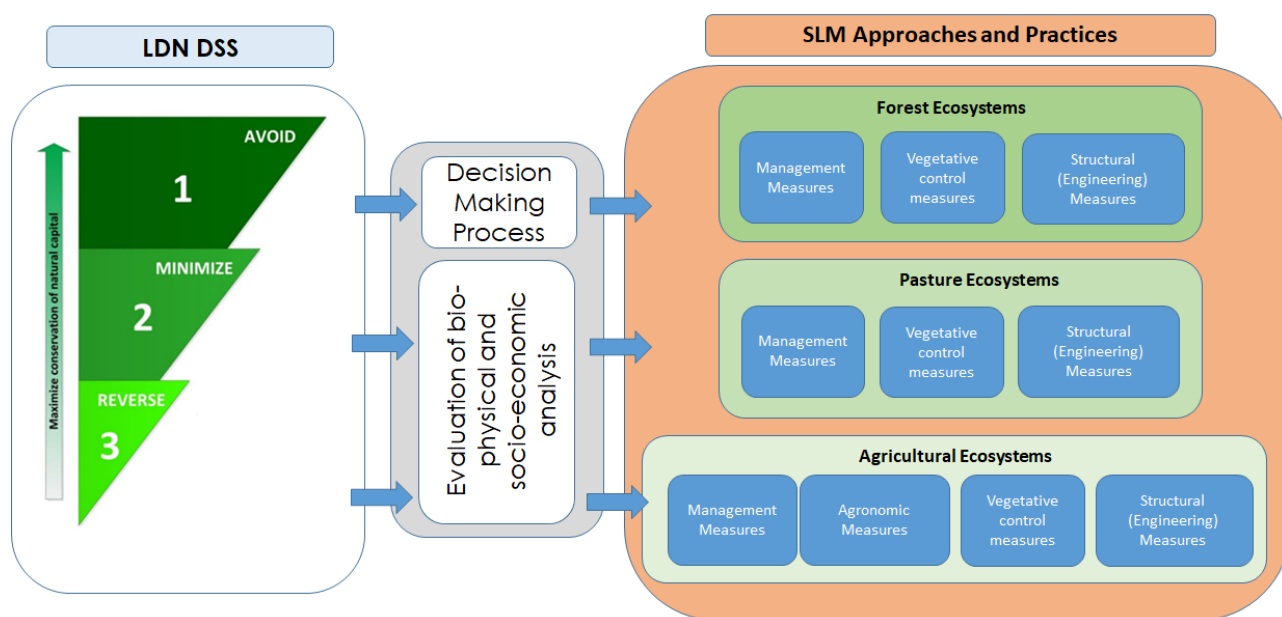


Figure 9. LDN-DSS-SLM systematics and decision-making process

Built upon the LDN Response Hierarchy adopted for LDN, the system provides a versatile platform for interpreting an extensive array of inputs. These inputs encompass diverse factors, including land use change, soil organic carbon, land productivity indices, Türkiye-specific erosion data and desertification vulnerability maps, among others. The system enables comprehensive analysis through various interactive features.

The outputs generated by the LDN-DSS play a crucial role in informing decision-making processes and offering tailored SLM approaches and recommendations, particularly for

agriculture, forest and pasture ecosystems (see Figure 9). These outputs serve as valuable tools in the development of plans and policies aimed at ensuring the long-term sustainability of land management and the successful mainstreaming of the LDN approach.

One of the foremost advantages of employing a shared LDN-DSS is its capacity for data integration (Chasek, 2019). This system serves as a centralized repository that seamlessly amalgamates data from diverse sources and institutions. Such integration ensures that stakeholders access comprehensive and real-time information concerning land degradation and sustainable land management. Moreover, the LDN-DSS cultivates consistency in data collection, analysis and reporting (Wunder and Bodle, 2019). This uniformity is indispensable for making well-informed decisions and monitoring progress towards LDN objectives. The eradication of discrepancies arising from distinct systems bolsters the reliability of land management assessments and strategies (Okpara et al., 2019).

The SDG 15.3.1 LDN target is directly and indirectly related to other SDGs. The main goals concerned are: No Poverty (SDG 1), No Hunger (SDG 2), Clean Water and Sanitation (SDG 6), Responsible Consumption (SDG 12) and Climate Action (SDG 13) (UNCCD, 2016b). Mainstreaming of the LDN approach therefore provides multidimensional benefits such as mitigation and adaptation to climate change, conservation of biodiversity, improvement of the welfare of affected populations, efficient use of water resources, and more. In this context, the LDN-DSS is an important facilitator to achieve the SDG targets. As shown in Figure 9, by focusing on the LDN Response Hierarchy, the system facilitates the mainstreaming of the LDN approach to achieve the SDGs by developing ecosystem-specific outputs and recommendations.

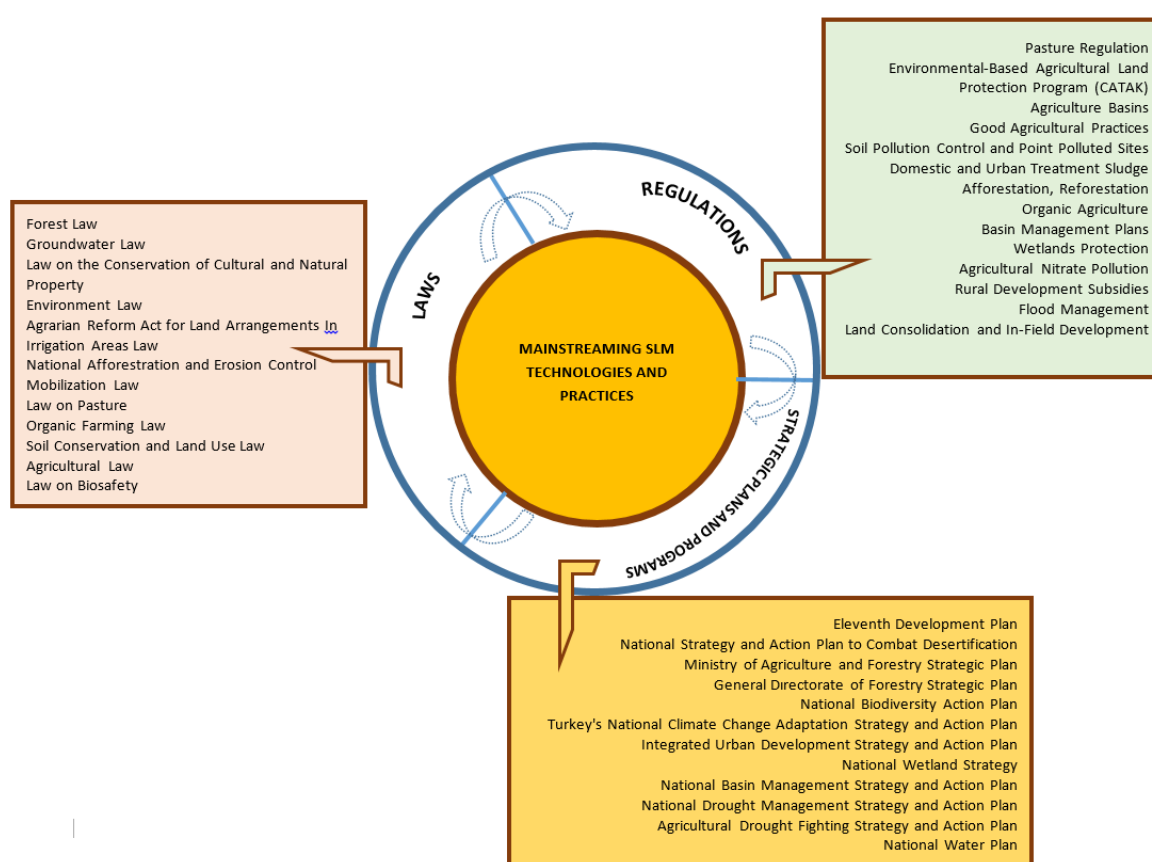


Figure 10 Integrating SLM approaches and practices into land based laws, regulations and strategic plans and programmes

In this context, the LDN-DSS serves as a pivotal enabler for translating the SDGs into practice. As shown in Figure 10, the system, by aligning with the LDN Response Hierarchy, facilitates the integration of the LDN approach, thus advancing progress towards the SDGs through the generation of ecosystem-specific outputs and recommendations.

Assessing sustainable land management within the context of Türkiye reveals the existence of a diverse array of laws, regulations, strategic plans and programmes (see Figure 10). Additionally, institutions carry out their activities based on accumulated experiences over time. To chart a new course for these ongoing traditional activities, it is imperative to comprehend and embrace the LDN approach.

Shared -SS contributes significantly to efficiency within land management practices (Bodle, (2018). Instead of each institution developing individual tools and databases, they can capitalize on the capabilities of the LDN-DSS. This streamlining of processes enhances overall efficiency, conserving valuable time and resources (Akhtar-Schuster, 2017).

Key institutions responsible for land management in Türkiye include: the Ministry of Environment, Urbanization and Climate Change (comprising the General Directorate of Combating Desertification and Erosion, the General Directorate of Spatial Planning, among others), and the Ministry of Agriculture and Forestry (housing the General Directorate of Forestry and General Directorate of Agricultural Reform). Moreover, the engagement of governmental institutions, the private sector, non-governmental organizations (NGOs), universities, research institutions and local communities plays a pivotal role in the mainstreaming process.

The LDN-DSS fosters collaboration among institutions, encouraging the exchange of findings, best practices and lessons learned (Cowie et al., 2018). This collaborative ethos is instrumental in devising more effective land management strategies, as institutions glean insights from one another's experiences and expertise (Kust, 2018).

The UNCCD's Technical Guide for Land Degradation Neutrality Target Setting underscores the importance of forging partnerships related to LDN. Integration of the LDN approach into governmental plans, policies and legislation is likewise crucial (UNCCD, 2016b). Equally significant is the active involvement of the private sector engaged in land-based activities and the development of incentive mechanisms within this framework. These measures bear immense significance, not only in realizing SDG 15 but also in advancing other interconnected SDGs.

6. STRATEGIC GOALS AND TARGETS

Türkiye's strategic goals within the framework of the National Action Plan (NAP) for Combating Desertification and Land Degradation represent a comprehensive and strategic approach aimed at combating land degradation nationwide. This plan underscores the promotion of sustainable land use approaches and practices.

Within the framework of the NAP, the primary objective of the LDN-DSS is to ensure the long-term resilience and productivity of Türkiye's land resources by striking a balance between land degradation and land restoration. The system is built upon a robust and multidisciplinary methodology that combines scientific knowledge, stakeholder engagement and data-driven analyses. This methodology is utilized to assess the current status of land degradation, identify priority areas for intervention and develop customized strategies for sustainable land management.

The NAP aims to foster collaboration among key stakeholders, policymakers and local communities, adopting an integrated and participatory approach to conserve and enhance Türkiye's ecosystems and natural resources. Through the implementation of these strategic objectives and their associated actions and indicators, Türkiye aims to pave the way for a more sustainable, resilient and prosperous future, ensuring the well-being of both its people and the environment for future generations. The strategic goals (targets) and outcomes (outputs), along with their respective actions and indicators, are detailed comprehensively below.

GOAL: EFFECTIVE USE OF THE LDN DSS IN LAND-BASED NATIONAL ACTIVITIES AND SCALING UP USE IN OTHER COUNTRIES					
TARGET 1: Strengthening the legislative background for implementation of the LDN DSS in SLM practices and policies					
Output 1.1 Strengthened legislation on land management	Activity 1.1.1 Gap analyses on existing legislation	Indicator 1.1.1 Workshops and meetings with institutions	Unit Number	Quantity 1	Years 2023–2025
	Activity 1.1.2 Preparation of legislative proposals and drafts	Indicator 1.1.2 Number of legislative proposals	Unit Number	Quantity 2	Years 2023–2025
TARGET 2: Ensuring the validity and widespread adoption of the LDN DSS					
Output 2.1 Increased cooperation and coordination among institutions	Activity 2.1 Identifying the requirements of the system in line with current developments through regular meetings with institutions	Indicator 2.1 Number of meetings	Unit Number	Quantity 2	Years 2023–2024
Output 2.2 Increased capacity of technical staff in institutions	Activity 2.2.1 Providing training to the staff of the institution on all technical details of the system	Indicator 2.2.1 Number of training sessions	Unit Number	Quantity 2	Years 2023–2024
Output 2.3 Integration of the relevant data of institutions into the LDN DSS	Activity 2.3.1 Meetings with the institutions	Indicator 2.3.1 Number of meetings	Unit Number	Quantity 10	Years 2023–2025
	Activity 2.3.2 Identifying existing available datasets and ensuring the integration of appropriate data into the system on the basis of the LDN approach	Indicator 2.3.2 Number of meetings Number of integrated databases	Unit Number	Quantity 3	Years 2023–2025
	Activity 2.3.3 Discussion of the current version of the system and updates in line with received feedback	Indicator 2.3.3 Number of workshops	Unit Number	Quantity 1	Years 2023
Output 2.4 Integrating socioeconomic data and climate scenarios into the system and supporting international reporting, Green Deal Action Plan Objectives and Türkiye's achievement of the 2053 Net Zero Emission Target	Activity 2.4.1 Collecting climate and socioeconomic data appropriate for reporting	Indicator 2.4.1 Number of scientific and technical studies	Unit Number	Quantity 2	Years 2023–2024
	Activity 2.4.2 Integrating the data	Indicator 2.4.2 Number of technical staff and consultants	Unit Person	Quantity 5	Years 2025

Output 2.5 Introducing the LDN DSS system to stakeholders working on land use and management, raising awareness about the LDN approach and the system, disseminating of using LDN DSS	Activity 2.5.1 Increasing the institutional and technical capacities of local, national and regional organizations that develop projects, and carrying out field studies on ecosystem and biodiversity planning on the basis of the LDN approach	Indicator 2.5.1 Number of workshops, training sessions and meetings	Unit Number	Quantity 3	Years 2023–2025
Output 2.6 Providing constant and up-to-date accessible information	Activity 2.6.1 Preparation of a User Guide accessible to all users	Indicator 2.6.1 Number of guidelines	Unit Number	Quantity 1	Years 2024
	Activity 2.6.2 Uploading the Guide to the LDN platform and related websites and ensuring its accessibility	Indicator 2.6.2 Number of websites where the guide is shared	Unit Number	Quantity 2	Years 2025
TARGET 3: Dissemination of suggested actions for SLM practices on the basis of the LDN DSS					
Output 3.1 Ensuring implementation of SLM practices with the help of the LDN DSS which was developed based on LDN response hierarchy	Activity 3.1.1 Conducting interviews with the relevant provincial organizations, discussing the applicability of SLM implementation suggestions, explaining the logical background of the methodology and the ATD QAS system, and ensuring the adoption of the approach	Indicator 3.1.1 Number of provincial and regional representative offices where meetings SLM Guidelines	Unit Number	Quantity 10	Years 2023–2025
	Activity 3.1.2 Using the LDN DSS as a tool for field activities	Indicator 3.1.2 Number of projects for which the LDN DSS is used as a tool	Unit Number	Quantity 5	Years 2023–2025
TARGET 4: Ensuring the use of the LDN DSS in international reporting carried out within the scope of land-based adaptation activities to climate change					
Output 4.1 Based on the IPCC Methodology, the LDN DSS contributes to the LULUCF reporting	Activity 4.1.1 Gap analysis on the use of the system for IPCC methodology	Indicator 4.1.1 Number of workshops, training sessions and meetings	Unit Number	Quantity 10	Years 2023–2025
	Activity 4.1.2 Ensuring cooperation with the institutions and organizations responsible for reporting	Indicator 4.1.2 Number of workshops, training sessions and meetings	Unit Number	Quantity 10	Years 2023–2025

	Activity 4.1.3 Sustaining the system dynamic with the continuous data flow provided, thus providing a baseline for the organizations that are responsible for reporting	Indicator 4.1.3 Number of reports	Unit Number	Quantity 3	Years 2023–2025
TARGET 5: Scaling up use of the LDN DSS in other countries					
Output 5.1 Facilitating use of the LDN DSS in ongoing and planning projects with other countries and regions, strengthening mutual interaction, and ensuring the transfer of technology and information	Activity 5.1.1 Presenting the LDN DSS in international meetings, events, workshops and training sessions	Indicator 5.1.1 Number of international events and meetings attended	Unit Number	Quantity 9	Years 2023–2025
	Activity 5.1.2 Ensuring use of the LDN DSS as a tool in international and regional cooperation and projects	Indicator 5.1.2 Number of international and regional cooperation and projects realized	Unit Number	Quantity 3	Years 2023–2025

7. THE SIVRIHIAR CASE

The project “Contributing to Land Degradation Neutrality (LDN) Target Setting by Demonstrating the LDN Approach in the Upper Sakarya Basin for Scaling up at National Level (GCP/TUR/065/GFF)”, executed by the Ministry of Environment, Urbanization and Climate Change and the FAO Regional Office for Europe and Central Asia (FAO-SEC), sought to develop a model for LDN target setting planning and decision making at the national level and for demonstration in the Upper Sakarya Basin by: (i) strengthening the enabling environment for LDN, (ii) introducing a Decision Support System (DSS) for LDN, (iii) demonstrating the LDN approach in the Upper Sakarya Basin, and (iv) upscaling LDN experiences, monitoring and evaluation. As part of the project’s third component, “Increasing Land Productivity and Soil Organic Carbon, and Ensuring the Development of Land Cover”, a series of land demonstration studies were carried out. In 2021–2022, research on increasing soil organic matter by employing crop rotation, a noted sustainable soil management technique, (UNCCD, 2016b) was conducted in Eskişehir province in the region of Sivrihisar (see Figure 11).

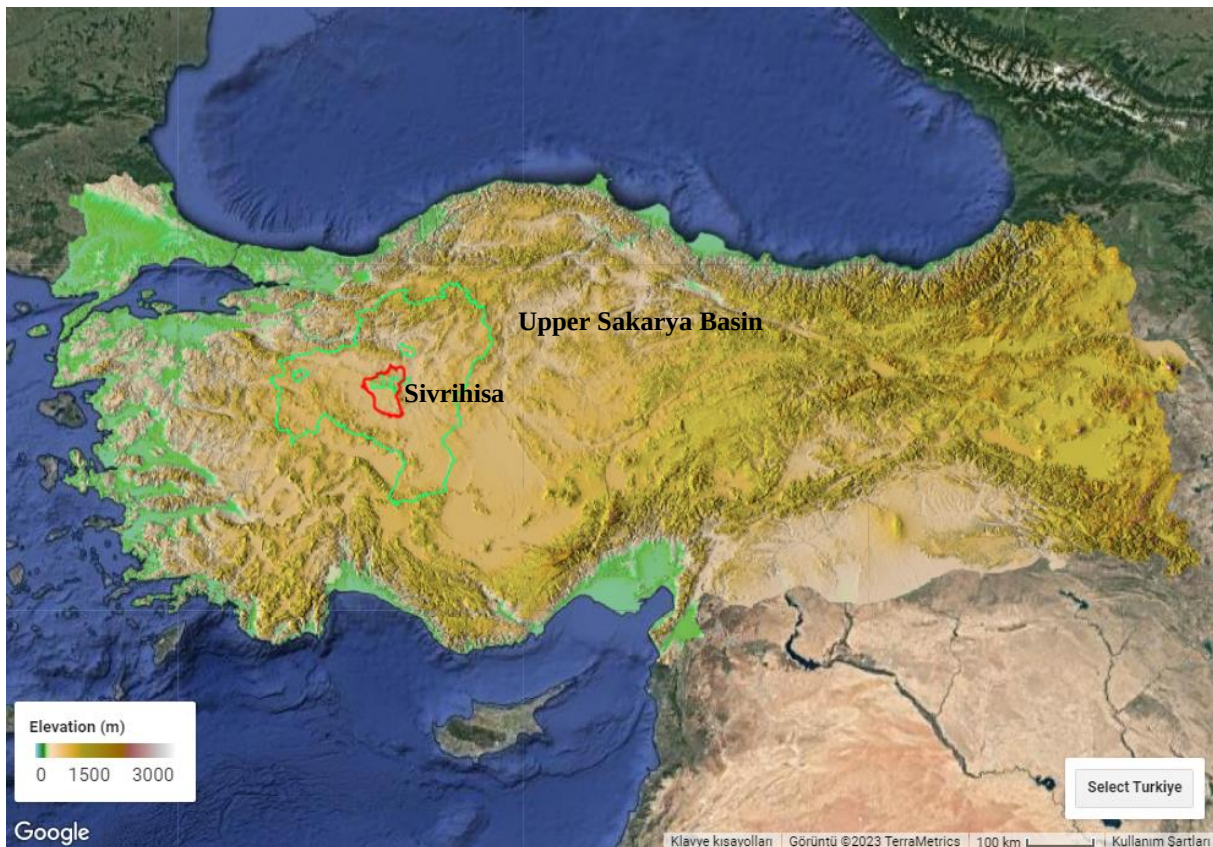


Figure 11. Location of Sivrihisar in the Upper Sakarya Basin

The selection of areas for the demonstration plots in Sivrihisar followed expert recommendations and were verified by the DSS. All the areas identified by the DSS are under threat of decreasing organic matter and desertification (see Figure 12 and Figure 13).

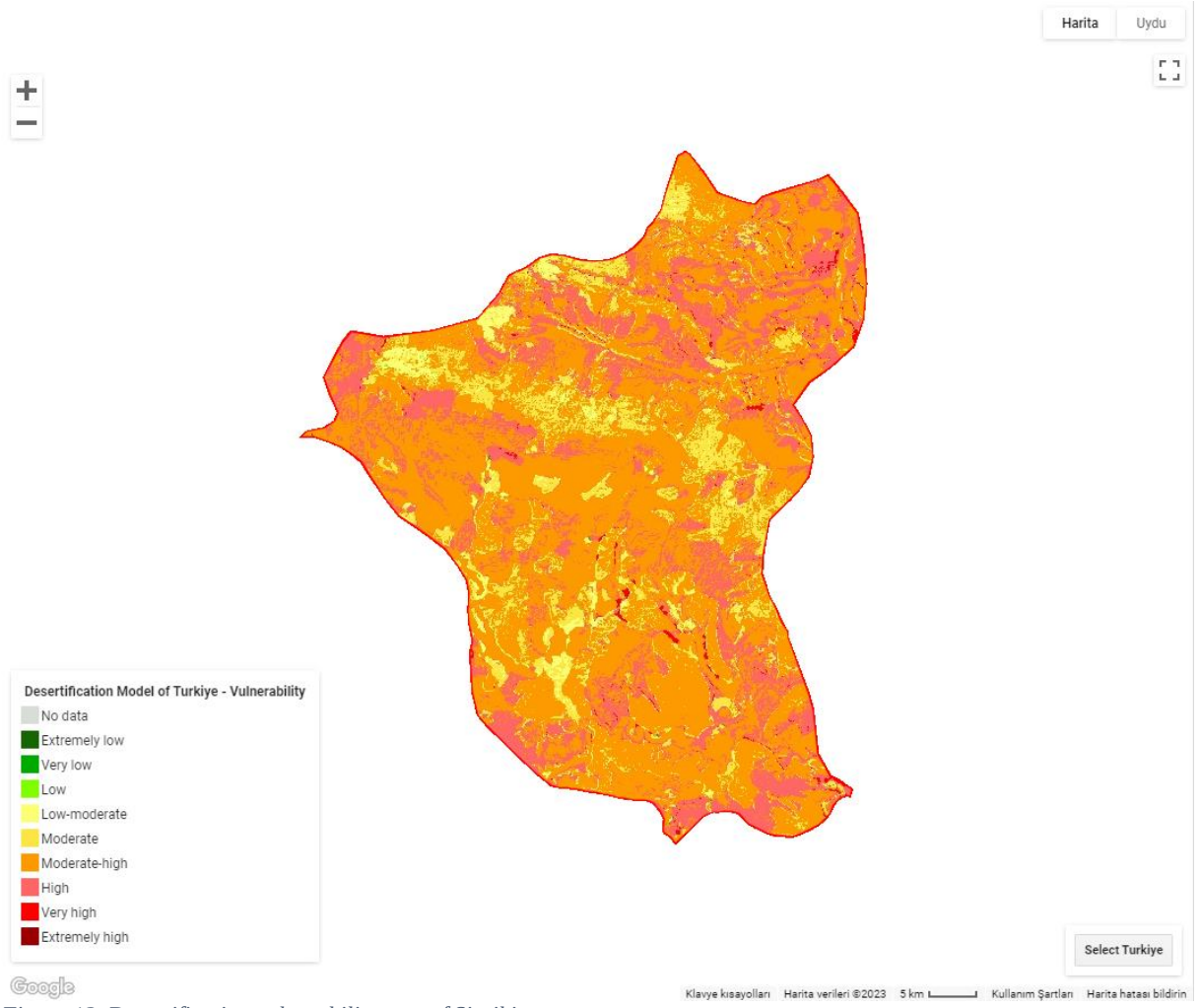


Figure 12. Desertification vulnerability map of Sivrihisar

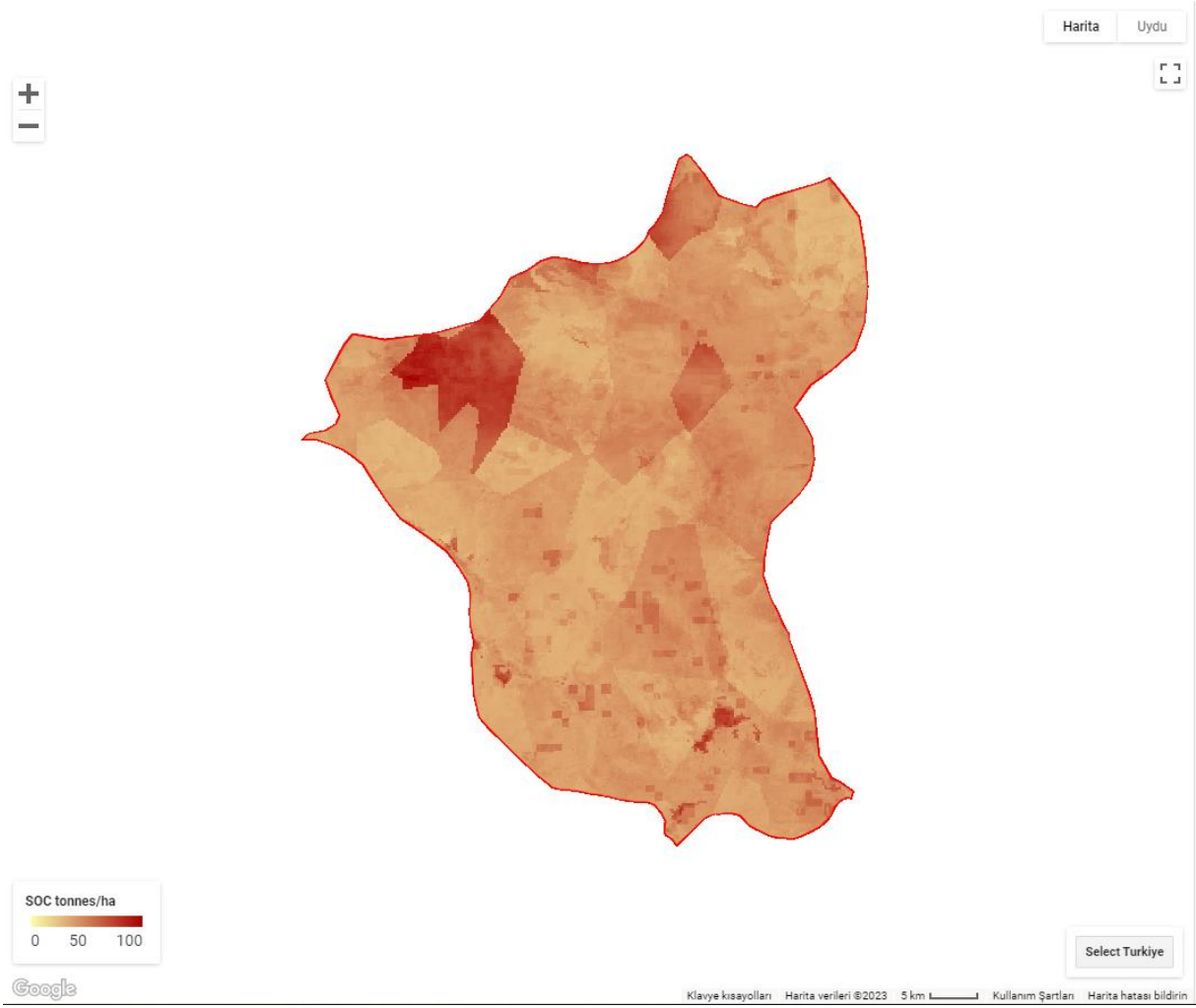


Figure 13. Soil organic carbon map of Sivrihisar

The Köppen climate classification for Sivrihisar is “Csa”, a hot summer Mediterranean climate. Annual precipitation usually falls in winter, measuring 227 mm from 1991 to 2021. Rainfall often occurs at sites where irrigation is impractical, and where only one crop is harvested per year. In rainfed fields, monoculture (cereals) dominate, providing lower inputs to soil organic carbon. Soils are prone to wind erosion due to a lack of vegetation following the harvest of cereals. Accordingly, the level of biomass production in rainfed agriculture was determined as low by the DSS.

Crop rotation and soil amendments rich in organic matter are recommended to promote land management principles on arid and semi-arid soils with low organic matter and biomass production, due to the climate and soil property limitations (Liu et al., 2006; Magdoff and Weil 2004). Instead of artificial fertilizers, leguminous-grain crop rotation was used in the demonstration plots in conjunction with leonardite, an organic soil conditioner that will improve the soil’s water-holding capacity and enrich the physical and chemical qualities (Gerke, 2022).

According to the project’s participative goals, crop rotation and leonardite demonstrations were undertaken in farmer plots selected in collaboration with the provincial and district directorates of the Ministry of Agriculture and Forestry. Certified seeds (free of weeds and pests) of the chickpea Azkan variety, known for its high yield, were used during the crop rotation process.

Leonardite, which naturally comes from lignite deposits and contains humic and fulvic acids, was applied as a source of organic matter.

Leonardite application resulted in much greater yields in chickpea production in all the locations (Figure 14). The average chickpea yields in the 27 sites was 1 488 kg/ha in the leonardite-applied plots and 959 kg/ha in 34 plots without leonardite application. The yield gain with leonardite application per hectare, across a total of 30 ha, was calculated to be 530 kg. The average yield increase following application of leonardite was 55 percent, with gains even higher in some locations. For instance, the difference between treated and untreated plots was 93.8 percent at Plot 714 and Plot 2 738 (see Figure 14).

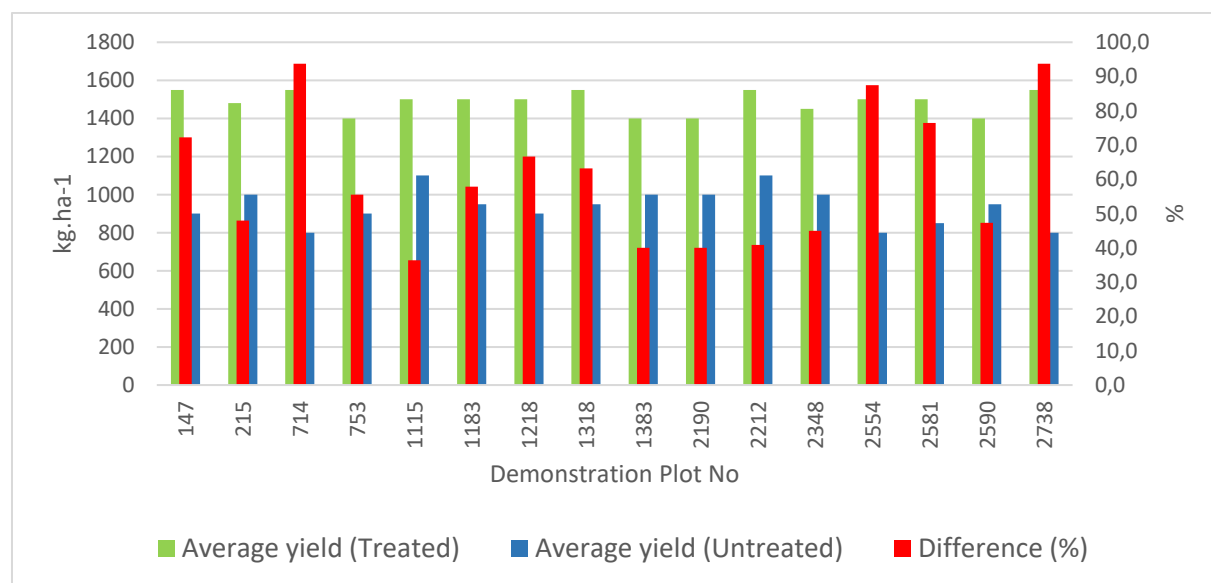


Figure 14. Effect of leonardite application on plots

The deployment of SLM techniques for LDN in Sivrihisar has served as a case study demonstrating that economic gains may be obtained while safeguarding the environment. Leonardite treatment and chickpea cultivation in Sivrihisar's arid agricultural soils, with minimal organic carbon and predominantly grain monoculture, have had a significant impact. Importantly, application of this treatment does not require significant financial resources or labour.

It is important to highlight here the response of the land to even the smallest change in management. Such responses are likely a result of soils being managed outside the purview of SLM, which has caused their yield capability to be lowered to the absolute minimum. Farmers attempt to cover this gap with a high degree of external input, due to the reduction in soil fertility, or otherwise abandon the land because their economic assets are insufficient to remedy the issue.

In the present instance, it has been clearly established that the use of thematic DSS data for LDN studies can contribute favourably to appropriate site selection and techniques for SLM.

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