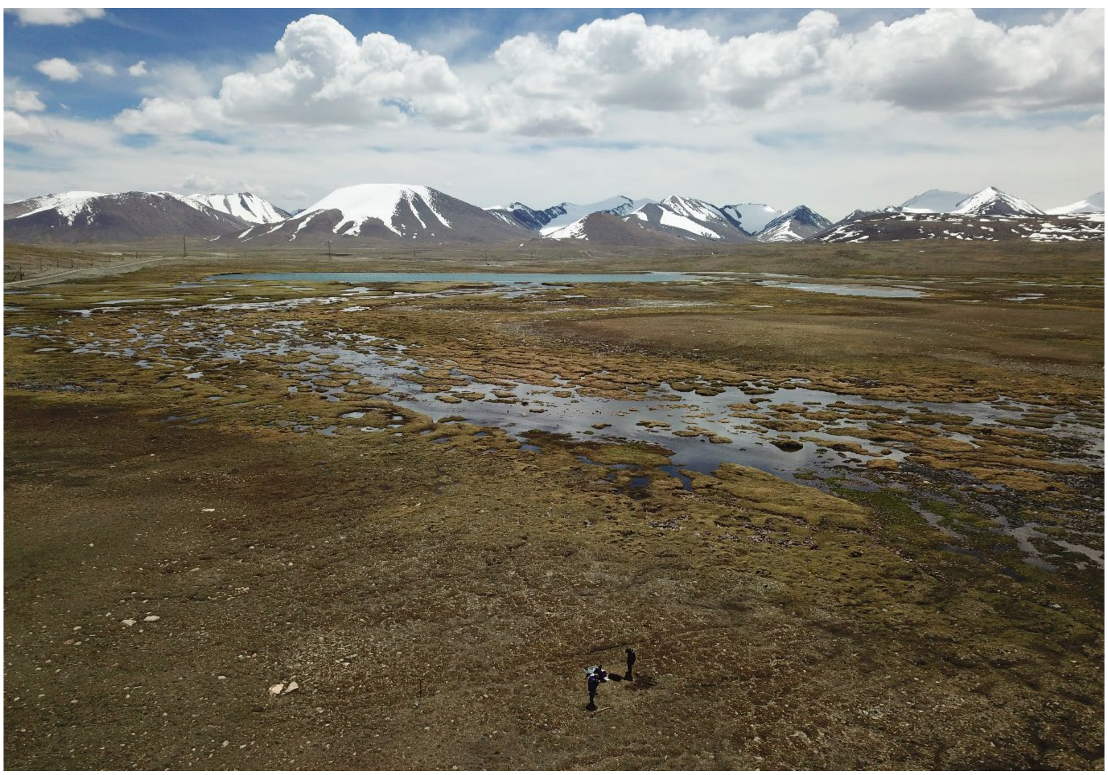
On behalf of:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Method for organic carbon stock assessment and improvement of Land Degradation Neutrality and climate change reporting on agricultural ecosystems in Kyrgyz Republic



February 15, 2021

CARB-ASIA MANUAL

This publication is part of the overarching GIZ ("Deutsche Gesellschaft für Internationale Zusammenarbeit"[1]) program "Capacity Development for climate policy in the countries of South East, Eastern Europe, the South Caucasus and Central Asia, Phase III".

This project is part of the International Climate Initiative (IKI). The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag.

About CARB-ASIA

CARB-ASIA is an interdisciplinary project of soil scientists and resource economists from Humboldt University of Berlin as well as Kyrgyz universities, NGOs, and state authorities that jointly developed a method to assess carbon stocks for different land-use types in Kyrgyz Republic. Based on a national survey of the current state of soil carbon stocks, implications for sustainable land use are derived, which contribute to the protection and increase of carbon stocks in the soils and improve climate monitoring and reporting for agricultural ecosystems according to international standards.

Acknowledgements

This Handbook is the result of the joint efforts of many people who invested much of their experience, enthusiasm, and work into its successful compilation. First and foremost, we greatly appreciate the financial support of the "Deutsche Gesellschaft für Internationale Zusammenarbeit" (GIZ) and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) that funded the project under the International Climate Initiative (IKI). Furthermore, we are particularly indebted to our collaborators and supporters in Kyrgyz Republic, among others, the political representatives of the Kyrgyz Ministry of Agriculture, Food Industry and Melioration (the National Focal Point of UNCCD), the National Statistical Committee, and the State Agency for Environmental Protection and Forestry. Our special thanks go to academic colleagues from the American University of Central Asia, the National Academy of Science, Kyrgyz National Agrarian University, and the Kyrgyz Research Institute of Agriculture. In this context, we wish to express our special gratitude to colleagues from the Kyrgyz Soil Science Society who shared the efforts of organizing and conducting the work. Moreover, gratitude is owed to the advisors and consultants from the national and international organizations, such as GIZ, FAO, ICRAF, World Bank, and UNCCD.

Authors: Margarete Korintenberg, Anastasia Gotgelf, Ermek Baibagyshov, Renate Judis, Ulan Kasymov, Judith Walter, Stephan Lange, Paul Neetzow, Klaus Eisenack, Jutta Zeitz

This manual can be cited as follows:
M. Korintenberg, A. Gotgelf, E. Baibagyshov, R. Judis, U. Kasymov, J. Walter, S. Lange, P. Neetzow, K. Eisenack, J. Zeitz (2021): Method for organic carbon stock assessment and improvement of Land Degradation Neutrality and climate change reporting on agricultural ecosystems in Kyrgyz Republic, Soil Science and Resource Economics Group, Humboldt-Universität zu Berlin, Germany.

---

[1] As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

Table of Contents

List of Figures

List of Tables

Abbreviations

ARIS	Kyrgyz Republic´s Community Development and Investment Agency
BD	Bulk Density
$BD_{fine\ soil}$	Bulk Density of the Fine Soil
CAREC	Regional Environmental Centre for Central Asia
CBD	Convention on Biological Diversity
CO_2	Carbon dioxide
CH_4	Methane
DADO	District Agrarian Development Offices
EVI	Enhanced Vegetation Index
FAO	Food and Agriculture Organization
FI	Input Factor
FLU	Land Use Factor
FMI	Forest Management Inventory
GEF	Global Environment Facility
GHG	Greenhouse gas
GIS	Geographical Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GAFA	Expert Committee Forest Analysis
IPCC	International Panel on Climate Change
KA5	German Soil Science Mapping Guide – „Deutsche Bodenkundliche Kartieranleitung"
KNAU	Kyrgyz National Agrarian University
Kyrgyzgiprozem	Kyrgyz State Design Institute of Land Management
LDN	Land Degradation Neutrality
LMG	Management Factor
MAFIM	Ministry of Agriculture, Food Industry and Melioration of the Kyrgyz Republic
MRV	Monitoring Reporting Verification
NDVI	Normalized Difference Vegetation Index
NFI	National Forest Inventory
NGO	Non-governmental organization
NSC	National Statistical Committee of the Kyrgyz Republic
PUC	Pasture User Committee
RPAS	Republican Soil Agrochemical Station

SAEPF	State Agency of Environmental Protection and Forestry under the Government of the Kyrgyz Republic
SALR	State Agency for Land Resources
SDGs	Sustainable Development Goals
SOC	Soil Organic Carbon
SOC_{Stocks}	Soil Organic Carbon Stocks
STAP	Scientific and Technical Advisory Panel
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNECE	United Nations Economic Commission for Europe
WB	World Bank

Executive Summary

In 2016, the United Nations (UN) adopted the Sustainable Development Goals (SDGs) with 169 sub-goals. Sub-goal 15.3 aims for a "Land Degradation Neutral" (LDN) world by 2030, to be achieved through national efforts of the UN member states. Since 2018, countries supporting LDN have been requested to report to the UN on the state and change of state of three globally recognized indicators: land use, land productivity (recorded as net primary production), and soil organic carbon stocks (SOC_{stocks}) within their national borders. Accordingly, land degradation is neutral when all indicators show at least no deterioration of their status. Reporting can be done using the global dataset provided by the Secretariat of the United Nations Convention to Combat Desertification (UNCCD) (Tier 1), although the UNCCD recommends that indicators shall be compiled based on national data (Tier 2 and Tier 3). Previous experience from various countries shows that the use of global datasets sometimes leads to inaccuracies. However, there is a lack of national data available, especially for the indicator SOC_{stock}. The SOC_{stock} indirectly provides information on the humus content of soils and is thus an indicator of soil health. It is also highly relevant to climate change since a loss of soil carbon releases greenhouse gases into the atmosphere and accelerates global warming.

In 2017, Kyrgyz Republic declared its participation in the national measuring of LDN. The first LDN report, prepared by the national LDN working group in 2018, identified serious gaps in national carbon stock data and provided recommendations for the development of LDN assessment and monitoring. The German-Kyrgyz project "Development of Methods for the Assessment of Carbon Reservoirs and for the Improvement of Climate Reporting of Agricultural Ecosystems of Central Asia" (CARB-ASIA) builds on previous work of the LDN working group and aims to develop and test the applicability of an improved method for assessing SOC_{stocks} in Kyrgyz Republic and to propose ways to institutionalize such an assessment tailored to the possibilities in Kyrgyz Republic.

The results of this project have been discussed in various forms (e.g. during interviews and expert consultations, workshops and online discussions) with representatives of government institutions (the Kyrgyz Ministry of Agriculture, Food Industry and Melioration; the National Statistical Committee; State Agency for Environmental Protection and Forestry), international organizations, and NGOs as well as national experts from science and research. The proposed method is scientifically based and adapted to international standards. We hope that the recognition of the data generated using this method as official data will facilitate monitoring and reporting to UNCCD. It also provides opportunities for coordinated monitoring and reporting to other international conventions and initiatives, such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD). The adoption and implementation of the proposed method can therefore serve as an important step towards the country's efficient compliance with international requirements.

The proposed method assumes that similar carbon stocks can be expected for comparable combinations of site conditions. For this purpose, representative units for SOC_{stocks} were selected for Kyrgyz Republic. As a first step, land cover, elevation, and climate were identified as relevant factors influencing SOC_{stocks} in Kyrgyz Republic. Since a high correlation was found between temperature and elevation, precipitation was used as a single site factor for the climate input data. Due to a lack of national data for these three factors, freely available global datasets were used, including the UNCCD data for land cover. The datasets were classified with regard to their representativeness and superimposed in a grid in order to determine representative units. In a second step, representative units occupying more than 1% of the country's territory were investigated and sampled, with subsequent laboratory analyses of soil samples in Kyrgyz Republic according to national standards. Account was taken of the representativeness within an area, the small-scale heterogeneity of SOC content, as well as relevant factors, in particular, bulk density of the fine soil ($BD_{fine\ soil}$), coarse soil content, and root mass. In a third step, SOC_{stocks} were calculated for the representative units and for the different classes of land cover, elevation, and precipitation.

In order to operationalize LDN, it is necessary to ensure a standardized method like the one proposed here. The standardization requires official approval by the Ministry of Agriculture, Food Industry and Melioration of the Kyrgyz Republic as the national body responsible for LDN monitoring and reporting, and by other relevant organizations. This is essential to derive LDN indicators and to help build monitoring and reporting capacities at the national level.

Our project highlights the multidimensional nature of land-related information governance. It is not only about technical aspects of land data production and processing, but also about the human and organizational layers. Their interplay determines how data and information are generated and used in the interactions between relevant institutions and the wider Kyrgyz society.

For the human layer, we identified strong indications of an acute shortage of soil specialists and experts in remote sensing in the country. This makes application of the proposed method a challenging task. Therefore, we propose to strengthen capacity building of Kyrgyz specialists in close cooperation with UNCCD, Kyrgyz and international universities, research centres, and NGOs. The CARB-ASIA project is contributing to this effort.

Considering the current organizational structure, we identified indications of institutional fragmentation and weak cooperation between some governmental and non-governmental organizations. This makes the management of relevant information less effective in the country. Thus, establishing a permanent national working group on LDN to facilitate inter-ministerial and cross-sectoral cooperation is recommended. This would be a crucial step towards creating a coordination mechanism of integrated land use and management planning across scales and sectors to ensure stakeholder input to national and international decision-making and reporting. This could be achieved by establishing a group under the government of the Kyrgyz Republic at the initiative of the Ministry of Agriculture, Food Industry and Melioration of the Kyrgyz Republic (the UNCCD Focal Point in Kyrgyz Republic). This would enable the emphasis to be placed on capacity building in responsible ministries and sectors, as well as funding the necessary measures to achieve LDN.

For the technical layer, a more centralized system would improve the management and evaluation of data on land use and agriculture developments. Effectiveness and efficiency would rise with the creation of a single information system where land data are stored and which can be used for the monitoring and assessment of LDN and other purposes such as land planning and agricultural development at regional or national levels. This information system can be effectively managed if it is placed and institutionalized within one permanent body (e.g. the State Agency on Land Resources) and if the system ensures its technical compatibility with other information systems. This will ease interagency cooperation through land data exchange. More attention on the demand side of the data-production chain would strengthen the system – how land-related information is expected to be used by policymakers, land managers, and users beyond those directly involved in LDN reporting.

Chapter 1. Introduction

1.1 CARB-ASIA Project and main objectives

In 1997, Kyrgyz Republic ratified the United Nations Convention to Combat Desertification (UNCCD) as well as the United Nations Framework Convention on Climate Change (UNFCCC). As a result, the country is obliged to report regularly on SOC_{stocks} and related greenhouse gas emissions. However, there is a lack of evidence-based methods for inventorying and evaluating soils and the land-use systems. Because the baseline values are missing, assessments of changes in the carbon stock and of greenhouse gas emissions require considerable improvement. Most importantly, the transferability of results and publications into the international context is very difficult since the method of soil classification and soil analyses that are used in Kyrgyz Republic partly differ from international methods.

The CARB-ASIA project supports the development of a scientifically sound method for assessing the carbon storage of soils in various categories of land use in Kyrgyz Republic. First, it proposes a scientific state-of-the-art method to assess SOC. Second, the project aims to identify the general organizational and institutional conditions for transparent and comprehensible SOC_{stocks} inventory and reporting. The method primarily focuses on the main land-cover types in Kyrgyz Republic – cropland, grassland, and forest areas – and complies with international standards. The project thus makes a methodological contribution to improve national reporting towards international obligations and to achieve Land Degradation Neutrality (LDN) in Kyrgyz Republic. This is an important milestone for the inventory of climate-related data and forms the basis for determining the absolute differences in SOC_{stocks}. The method and the results produced will meet international standards, such as representativeness, good documentation, quality assessment, indication of uncertainties, and long-term availability. Based on the generated data and knowledge, Kyrgyz experts will be able to develop recommendations for the protection and increase of SOC_{stocks} and enable evidence-based development of adapted and sustainable land-use strategies. Furthermore, the project formulates recommendations for the practical organization of the developed method in Kyrgyz Republic, including steps for data generation, aggregations, and reporting which help meet the UN obligations in a cost-efficient way.

The project was implemented in close cooperation and coordination with the national authorities (Ministry of Agriculture, Food Industry and Melioration; State Agency of Environmental Protection and Forestry under the Government of the Kyrgyz Republic; National Statistical Committee; Kyrgyz State Design Institute of Land Management; Republican Soil Agrochemical Station; State Agency for Land Resources), United Nations Development Programme, GIZ Bishkek, as well as with NGOs (Camp Alatoo; Kyrgyz Soil Science Society) and the universities of Kyrgyz Republic (American University of Central Asia; the National Academy of Science; Kyrgyz National Agrarian University; the Kyrgyz Research Institute of Agriculture). All these organizations have made important contributions to the development of the proposed method as well as recommendations for its implementation.

Chapter 2. Background

2.1 Land Degradation Neutrality (LDN)

2.1.1 The goal and objectives of LDN

The LDN concept aims to address the environmental challenge of land degradation in terms of "neutrality" by 2030. This means maintaining or enhancing the land-based natural capital, avoiding its net loss. To this extent, LDN corresponds to "a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales and ecosystems" (UNCCD 2015). The following objectives support this vision (UNCCD 2017):

- maintaining or improving the sustainable delivery of essential ecosystem services, such as provision of food and fibre, carbon sequestration, regulation of water supply, conservation of biodiversity and cultural heritage
- maintaining or improving productivity, in order to enhance food security
- increasing resilience of the land and populations dependent on the land to impacts of climate change or other shocks
- seeking synergies with other social, economic, and environmental objectives
- reinforcing responsible and inclusive governance of land.

This vision allows a systemic approach to land degradation by relating the state of the land-based natural capital to the drivers and pressures, the consequent impact, and human responses. Main factors that cause land degradation are land-use changes (such as conversion from forest to agriculture) and unsustainable land-management practices (such as use of fertilizers or intensive monocultures). These land-use changes in turn, are generally caused by either natural (weather extremes, e.g. drought) or human factors (e.g. education, knowledge, access to support services). Such systemic changes can be perceived as risks since they may impede the achievement of LDN and, more broadly, the desired livelihood outcomes. Therefore, understanding the linkages between these pressures and the effects on land-based ecosystem functions and services is crucial to plan interventions needed to limit the drivers and pressures (UNCCD 2017).

The principle of neutrality is designed to help land-use decision-makers to maintain or do better than "no net loss" (as a minimum standard) by balancing anticipated losses with measures that allow for achieving equivalent gains within individual land types. Planning for neutrality should be linked to long-term land-use planning, whereby decisions are based not only on threats of serious or irreversible damage within a particular site, but also the contribution of each of those decisions to the goal of neutrality at the landscape or national level (UNCCD 2017).

Actions to achieve LDN include land-management measures to avoid or reduce degradation, combined with efforts to reverse degradation through restoration or rehabilitation of land that has lost productivity. In this regard, LDN encourages the design and use of better land-management practices (e.g. sustainable land management) and better land-use planning that will improve economic, social, and ecological sustainability for present and future generations. For further information on mechanisms for achieving neutrality, please see the UNCCD official Report of the Science-Policy Interface (UNCCD 2017). The CARB-ASIA project mainly deals with LDN assessment, monitoring, and reporting issues, which form the basis for possible interventions in achieving LDN.

MAIN FACTS: The goal and objectives of LDN

- *LDN is "a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales and ecosystems" (UNCCD 2015).*
- *The objectives of LDN are:*
  - *maintaining or improving the sustainable delivery of ecosystem services*
  - *maintaining or improving productivity, in order to enhance food security*
  - *increasing resilience of the land and populations dependent on the land*
  - *seeking synergies with other social, economic, and environmental objectives*
  - *reinforcing a responsible and inclusive governance of land.*

2.1.2 Assessing LDN

An assessment of the present state, trends, and drivers of land degradation is needed to set clear LDN targets, make decisions on potential interventions, forecast changes in land-based natural capital, and track progress. For the assessment, the use of a minimum set of three indicators (and associated metrics) that reflect land-based natural capital and its associated ecosystem services is recommended:

- land cover
- land productivity (assessed as net primary production)
- carbon stocks (assessed as soil organic carbon stocks of the upper 30 cm).

These indicators can address changes in the system in different ways. For instance, the metric for land productivity (net primary production; e.g. can be obtained from the FAO Global Land Cover SHARE database) captures relatively fast changes, while the metric for soil organic carbon stocks (tonnes of carbon per hectare (tC/ha) to 30 cm) reflects slower changes that suggest trajectory and proximity to thresholds. The land-cover indicator can be quantified using indices derived from Earth observation data, such as the Normalized Difference Vegetation Index (NDVI) or Enhanced Vegetation Index (EVI) and provides a first indication of changing vegetation cover, to some extent as proxy of the underlying use, and of land conversion and resulting habitat fragmentation (UNCCD 2017). Proposed UNCCD progress-reporting indicators and associated metrics are also considered for monitoring SDG indicator 15.3.1 "Proportion of land that is degraded over total land area".

The land-cover indicator serves as the basis for the evaluation of all indicators: productivity and SOC_{stock} should always be calculated for one land-cover class (e.g. "grassland" or "cropland") (UNCCD 2017). An area-based approach is prioritized for reporting purposes: it is not the qualitative extent or the change in degradation that must be reported, but rather the quantitative change in land degradation in percent per unit (Orr et al. 2017).

LDN monitoring aims at assessing changes in the values of selected metrics of indicators of land-based natural capital from their initial values, or baseline, thus the actual state at time “t0”. The time to be set as the baseline is to be chosen by each country. The principle of neutrality thus implies that land-based natural capital is maintained or enhanced between the time of implementation of the LDN conceptual framework and a future date when progress is monitored. Changes in the absolute numerical values of indicators detect either positive or negative trends (or gains or losses according to neutrality principle). Since the aim is to achieve LDN with no net loss, the minimum level of ambition of a LDN target should equal the baseline for a given year (UNCCD 2016, 2017). Countries may set a more ambitious target to improve the land-based natural capital above the baseline, or in rare circumstances, a country may have an LDN target acknowledging that losses exceed gains, if a country anticipates negative changes associated with past decisions, which are challenging to counterbalance for the time being. Monitoring achievement of neutrality will quantify the balance between the area of gains (significant positive changes in LDN indicators, i.e. improvement) and area of losses (significant negative changes in LDN indicators, i.e. degradation) within each land type across the landscape (UNCCD 2017). LDN is evaluated according to the "one-out, all-out" principle. It implies that gains in one of the measures cannot compensate for losses in another. Therefore, if one of the indicators shows a negative trend, LDN is not achieved, even if the others are substantially positive (UNCCD 2017). Conversely, if at least one shows a positive trend and the other two are neutral, a gain in natural capital is recorded. Proposed indicators and associated metrics are suitable proxies for the ecosystem services resulting from land-based natural capital. It is important to note that ecosystem services are all complementary and not additive parts of land-based natural capital. This has implications in terms of detecting individual measures for each indicator, while assessing all three indicators with a single aggregated value is pointless as it would prevent the interpretation of individual measures at the national level.

Setting the LDN baseline and assessing land degradation trends require reliable data. The UNCCD's approach to collecting the three indicators consists of a **three-tiered process** to ensure national freedoms and take account of national data availability (UNCCD, CBD, FAO, STAP 2016):

- Tier 1: standard method: global remote-sensing data, georeferenced data, modelling
- Tier 2: national statistics, national remote-sensing data
- Tier 3: surveys, studies, and terrain data.

According to LDN recommendations (UNCCD 2017), monitoring and reporting should be primarily based on national data sources (e.g. standardized national official data) (Tier 2 or 3). Global data sources (Tier 1) have very low resolution and are not suitable for many regions in the world, for example mountainous regions such as Kyrgyz Republic with high surface heterogeneity. They should only be used in the absence of national data or as a complement to such data. The UNCCD Parties are required to communicate on measures undertaken to implement the convention. The process of national reporting is an essential tool to enable effective planning and implementation of the convention and the achievement of the strategic objectives at global and national levels. The information communicated by the Parties through reporting is also valuable for other stakeholders that work on the implementation of the UNCCD at national and local levels.

MAIN FACTS: The goal and objectives of LDN

- *Three main indicators are used for monitoring and reporting on LDN: Land cover, Land productivity (assessed as net primary production), Soil organic carbon stocks (assessed as soil organic carbon stocks of the upper 30 cm).*
- *LDN is achieved if none of the three indicators show a deterioration by 2030 compared to the baseline (one-out, all-out principle). The baseline is the reference status of the respective indicators at a time chosen by each country.*
- *The UNCCD's approach to collecting the three indicators consists of a three-tiered process to ensure national freedoms and take account of national data availability:*

  Tier 1: standard method: global remote-sensing data, geodata, modelling

  Tier 2: national statistics, national remote-sensing data

  Tier 3: surveys, studies, terrain data.
- *UNCCD proposed progress-reporting indicators and associated metrics are also considered for monitoring SDG indicator 15.3.1 "Proportion of land that is degraded over total land area".*

2.2 LDN in Kyrgyz Republic

Kyrgyz Republic has many fragile ecosystems, which, especially through anthropogenic influence, are prone to degradation (Kyrgyz Republic 2018). About 66% of the approximately six million citizens of Kyrgyz Republic live in rural areas (Kyrgyz Republic 2018). About 54% of the country's land is used for agriculture (Ministry of Agriculture, Food Industry and Melioration 2014). Half of it already shows various forms of degradation (Kyrgyz Republic 2018). Grassland, which accounts for about 45% of the agricultural land, shows partly severe degradation due to overgrazing (Ludi 2003; Crewett 2012; Kerven et al. 2012). In addition, an increasing number of extreme weather events, such as the drought years 2012 and 2014, led to yield losses (UPAGES Report 2016, Kyrgyz Republic 2018).

Changes in the agricultural and forestry sectors that happened after the collapse of the USSR also affected the condition of the land. The land fund structure changed drastically due to the new political, social, and economic context, particularly with the initiation of agrarian and land reforms. Compared with other Central Asian countries, Kyrgyz Republic was most radical in restructuring agricultural enterprises, privatizing land, and promoting individual farming (Bloch 2002). Cultivated agricultural land and livestock were privatized and distributed, but state ownership was retained for forests, pastures, and water (Bichsel et al. 2011). As a result of decentralizing the political and economic system some land-management responsibilities were transferred to the village administration (aiyl ökmötü), which was introduced in 1996. In a national context, such transformations can become a barrier to sustainable land use, as smallholder farmers are more vulnerable to shocks and have less capacity to cope with external risks.

The Kyrgyz government has recognized the continuing degradation of land as an urgent problem for the agricultural sector and food security. Within the UNCCD framework, Kyrgyz Republic adopted a national action plan in 2014 and formulated national goals with respect to LDN in 2017 (Kyrgyz Republic 2014).

The Ministry of Agriculture, Food Industry and Melioration of the Kyrgyz Republic (MAFIM) is the focal agency responsible for LDN monitoring and reporting. The first reporting process was organized in 2018. In preparing the first report, an important role was assigned to an inter-ministerial expert working group. The expert working group was mainly in control of the computation of the indicators at the national level, developing the methodological fundamentals for the indicators as well as designing and implementing the reporting. In the first report, the main features of national data collection and development of LDN-indicators based on these national data were specified. Further, the working group verified the applicability of global UNCCD data to national indicator use (Kyrgyz Republic 2018). The results of this work are summarized in the following sections.

2.2.1 National data for land-cover indicator development

To determine the land-cover indicator, national land-registry data were used. The State Institution "Cadastre" is responsible for quantitative data collection. The data are collected in accordance with the state administrative form of reporting on the availability of land in the Kyrgyz Republic and its distribution by category, owner, land user, and site.

For forest-covered areas, data from the National Forest Inventory (NFI) can be used. NFI is one of two levels of the forest accounting system, which is carried out in all forests regardless of their ownership and departmental affiliation. The results of NFI are used for political or legislation purposes. The inventory is conducted as needed. In the first NFI, supported by FAO and conducted in 2008–2010, a network of tracts (test areas) was established in the field, which were subject to periodic updating with the use of instrumental assessment methods. In 2017, with the support of the World Bank, a second NFI was launched, which is accompanied by field studies and use of remote-sensing methods (satellite images).

In the second NFI, more accurate data at a district level and satellite images are being used. The second NFI's focus is placed on building capacity of national experts as well as on giving the tools and developed materials to the State Agency of Environmental Protection and Forestry (SAEPF) (as all data processing within the first NFI in the 2010s and analysis were performed by external organizations).

In the first LDN report, a small difference was identified by comparing global land-cover data with national data for 2010, due to differences in national and international methodological frameworks, due to the use of different category systems of land types. The LDN working group concluded that this problem can be solved by disaggregating national data and bringing them in line with international standards, and therefore UNCCD global data are applicable to a national land cover-change indicator (Kyrgyz Republic 2018).

2.2.2 National data for land-productivity indicator development

At the national level, there is no common indicator on land productivity. However, there is a number of accompanying indicators in the national statistical reporting system, which may also indicate trends in land productivity. The following indicators measure productivity trends by land-use type: pasture productivity, agricultural productivity, and forest productivity.

Data on pasture productivity can be obtained from geobotanical surveys conducted by the Kyrgyz State Design Institute of Land Management (Kyrgyzgiprozem) on an annual basis. The data are collected within the framework of a geobotanical survey over the whole territory of the country, covering the most common types of pasturelands. However, the number of such observations has been decreasing recently and are carried out on a rather selective basis. Since the pasture reform in 2009, when a community-based pasture management system was introduced, pasture monitoring has become a responsibility of the Pasture User Committees (PUCs). PUCs collect information inter alia on pasture territory and its condition (including qualitative assessment of pastures). District Agrarian Development Offices (DADOs) play an important role in data generation from PUCs and their communication to the pasture department of MAFIM by processing the data in the online portal of the ministry. Operators of pasture databases at MAFIM check the data and compile district, regional, and national reports based on these data. As a result, annual analysis, for instance the dynamics of pasture degradation, is conducted based on these data.

Agricultural productivity is monitored at the national level through yields throughout the country. Primary data are collected at the district level and are then aggregated for regional and national levels. The National Statistical Committee (NSC) oversees the annual data collection. The collection of forest data is carried out within the framework of the National Forest Inventory (NFI) and Forest Management Inventory (FMI). The FMI determines the needs of operational economic planning at the level of forest communities (development of management plans) and is conducted once every 10 years. The forest inventories are financed from the state budget and implemented by SAEPF.

2.2.3 National data for soil organic carbon indicator development

Out of the three LDN indicators, assessment and monitoring of carbon stocks poses a major challenge since there is no functional system for SOC data collection and processing in the country. Currently, a calculation of SOC is based on laboratory analyses of humus with an application of a factor of 1.7, performed by the Republican Soil Agrochemical Station (RPAS) subordinated under the Kyrgyzgiprozem. However, this method of estimating SOC is mainly known for soils in irrigated arable land as it has been always of economic interest. This is why, since 1994, soil assessments have been mainly conducted on this type of land. The first report on LDN concluded that, in the absence of national SOC data, UNCCD (global level) mapping materials can be used to estimate the content of SOC (Kyrgyz Republic 2018). This conclusion is based on comparing available national data for several areas that have been selected as degradation hot spots with UNCCD global data. Soil assessments in Kyrgyz Republic are made fragmentarily on a selective basis and have various purposes. There are officially two main reasons for soil data collection and processing in Kyrgyz Republic performed by Kyrgyzgiprozem:

1) *Broad-scale (national) monitoring of soil quality for economic assessment*. This information is needed for a qualitative assessment of land and is communicated to the State Cadastre. There are two types of Cadastre assessment: qualitative and quantitative. Quantitative is about the amount of land area of different land types (in ha). Qualitative assessment is about soils – soil appraisal. Ultimately, soil appraisal is essential for economic assessment of the land and its potential: how much yield one can get. This information could also be used for land taxation, land buying and selling, etc.

Such soil assessments are made every 15 to 20 years and are conducted district wide. In Kyrgyz Republic there are 40 districts and, on average, RPAS can manage one district per year. If it is a big district, then one in two years; for smaller districts, two in one year. All districts are assessed in sequence. Each district has several rural districts. Every rural district is assessed. Soil inspections are made across the surface of 115 ha, with one soil profile (2 m-depth) and four short cores (1 m-depth) per 23 ha. RPAS takes one soil sample from the soil profile. No repeat samples are taken, nor is any account taken of the small-scale heterogeneity of the soils. The short cores are needed for verification for a soil type, intrusions, etc. Assessments include chemical analysis of 12 different parameters: soil salinization, content of nutritional elements, humus, etc.

RPAS has been conducting broad-scale soil assessments since 1968, which equals to three rounds of soil assessments at the national level since then (1968-75, 1975-85, 1985-1994). Currently, RPAS is checking and standardizing soil assessments from former years. Archived data are used to monitor dynamics: for example, there is a clear 10 to 15% decrease of humus content in the soils since the agrarian reform in 1991.

Based on the observed changes, new cartographic material (analogue maps) is produced manually as GIS data are not available. Maps are produced in triplicate: local authorities get one, a second is kept at Kyrgyzgiprozem, and the district land registry office keeps the third one. RPAS issues recommendations for local authorities based on the observed changes, for example, what could be done to improve soil fertility. However, there is no information on how or if local authorities use this information. Each spring since 2015, RPAS conducts regional seminars on soil-use practices and measures to improve soil quality. RPAS provides MAFIM with the information on percentage of degraded, rocky, or salinized land in Kyrgyz Republic, which is then used for national reporting. According to RPAS experts, the efficiency of such broad-scale soil assessments appears to be decreasing. One could still conduct soil monitoring but focus rather on a more detailed soil analysis (agrochemical one).

2) *Agrochemical soil inspections* are conducted to ensure reasonable use of fertilizers for getting more sustainable and planned yields. Until the early 1990s, there used to be a state programme where all farms (arable land) were inspected for soil conditions (agrochemical characteristics) and based on the inspection an agrochemical map was produced. The map was used to make decisions regarding organic mineral fertilizer use. Because of the land reform and subsequent privatization of land, there was no longer interest in such an analysis and agrochemical soil inspections were no longer conducted. Only since 2012, have agrochemical soil inspections begun to resume because farmers began showing an interest in soil quality and soil analysis. Every year the demand for such analyses has been growing. However, there are no GIS data available for this either.

MAIN FACTS: LDN in Kyrgyzstan

- *Progressive land degradation poses a major threat to the agricultural sector in the country.*
- *Within the UNCCD framework, Kyrgyzstan has formulated national goals in the area of LDN in 2017.*
- *The Ministry of Agriculture, Food Industry and Melioration of the Kyrgyz Republic (MAFIM) is a focal agency responsible for LDN monitoring and reporting.*
- *In preparing the first report (2018), an important role was assigned to an inter-ministerial expert working group (LDN working group). In the first report, the main features of national data collection and development of LDN-indicators based on these national data were specified. The following Table reflects the current organizational structure of LDN assessment and monitoring in Kyrgyzstan (Kyrgyz Republic 2018):*

LDN-assessment and -monitoring in Kyrgyzstan		
Land Cover Indicator *1) Land registry data in accordance with national reporting requirements (Gosregistr → NSC)* *2) Data for forest-covered areas are taken from the national forest inventories (SAEPF)*	**Land Productivity Indicator** *Three regular national indicators are used to measure land productivity:* *1) Pasture productivity - Geobotanical inspections/surveys on national level (RPAS, Kyrgyzgiprozem)* *2) Agricultural productivity - Annual data collection based on agricultural statistical reporting (NSC)* *3) Forest productivity - Data collection as part of forest inventories (SAEPF)*	**SOC Indicator** *1) Calculation of SOC based on laboratory analysis of humus with application of a factor of 1.7 (RPAS, Kyrgyzgiprozem)* *Use of the UNCCD data (Tier 1)*

2.3 Soil Organic Carbon (SOC) Indicator

Definition and relevance of soil organic carbon

Carbon exists in soils in two forms. First, as inorganic carbon, which is mostly bound in carbonates and enters the soil either lithogenically or pedogenically. Second, as **soil organic carbon (SOC)** that originates from dead biomass and excrement and consists of plant, fungal, and animal material. It can also be incorporated into the soil anthropogenically, for example in the form of fertilizers. SOC is quantitatively the most important element in humus and accounts for up to 58% of mineral soils (Blume et al. 2010). SOC is therefore used by default (e.g. for global reporting) as an indirect measure of humus content and can be calculated using the following formula (Eckelmann et al. 2005):

$$\boldsymbol{humus\ content}\ (\%\ \boldsymbol{per\ mass}) = \mathbf{1.72} * \boldsymbol{SOC}\ (\%\ \boldsymbol{per\ mass}) \tag{1}$$

Organic source material is subject to various decomposition processes, in which it is broken down, mineralized, and worked into deeper layers by soil organisms. Some of it then becomes stabilized in the soil. Litter materials reside in the soil only for a short time. More strongly converted humic substances have a longer dwell time, because they are present in a more stable form in organo-mineral compounds, for example, clay-humus complexes, and are partially protected from rapid decomposition.

At the end of the carbon cycle, SOC returns to the atmosphere as carbon dioxide (CO_2) or methane (CH_4) through heterotrophic soil respiration by soil organisms depending on whether conditions are oxidative or reductive. Additional losses may be caused by leaching of dissolved carbon or wind and water erosion. In the undisturbed carbon cycle, a balance between supply and degradation of SOC is established, resulting in relatively stationary levels.

Humus is of high relevance for soil health, soil diversity, yield, and climate. The organic material consists of molecular compounds with large surface areas and many hydrophilic and hydrophobic binding sites, resulting in a high cation exchange capacity. This allows nutrients to be bound well, thus increasing soil fertility. Inorganic and organic pollutants can also be bound well, impeding their displacement into deeper layers and into the groundwater. Humus has a high water-holding capacity. Consequently, it significantly improves the buffer capacity of a soil against extreme environmental influences, such as contamination of the soil with heavy metals or prolonged drought. Furthermore, humus promotes a stable soil structure, especially in the topsoil, through microstructure formation and aggregation. This reduces soil losses due to erosion. The dark colour of humus, which has a low albedo (radiation reflection), improves the heat balance of the soil. Consequently, soil with a high humus content can absorb heat well. In addition, high humus content serves as a direct source of nutrients for flora and fauna and as an indicator of soil fertility.

Due to its high carbon storage, maintaining or building up high humus or peat content can help to stabilize the global climate by reducing CO_2 emissions into the atmosphere. SOC has therefore become a global indicator in the climate reports of the UNCCD and Intergovernmental Panel on Climate Change (IPCC).

MAIN FACTS: Definition and relevance of soil organic carbon

- *Soil organic carbon (SOC) originates from dead biomass and excrement consisting of plant, fungal, and animal material.*
- *SOC is quantitatively the most important element in humus and accounts for up to 58% of mineral soils.*
- *Humus is of high relevance for soil health, soil diversity, yield, and climate.*

Influencing factors on soil organic carbon

In many studies, **land cover and land use** are among the major factors influencing SOC_{stocks} in the topsoil (Lal 2004; Wiesmeier et al. 2011; Wang et al. 2012; Adhikari et al. 2014; De Brogniez et al. 2015; Jacobs et al. 2018). For example, forest and grass sites tend to store more SOC than crop sites (Wang et al. 2012; Dorji et al. 2014). This is due to the higher input of organic biomass and often a better distribution of the material through denser rooting and higher soil activity in soils of forest and grassland soils. In croplands, the biomass input is strongly reduced due to harvesting, resulting in a decrease of SOC_{stocks}. Intensive and especially turning tillage, which leads to the destruction of soil aggregates and an increasing oxygen supply, can release stabilized SOC for decomposition. Tillage and a lack of vegetation cover on arable land can also lead to SOC losses due to increased oxygen supply or wind and water erosion. Land-use changes, such as clearing of forests for agricultural use, or conversion of grassland or steppe into arable land, can change the balance of humus build-up and decomposition.

Climatic conditions are also relevant. Solar radiation, temperature, precipitation, and associated evapotranspiration significantly determine the vegetation distribution in anthropogenically unaffected landscapes and thus the input and quality of organic material in the soil. Studies show a linear negative correlation between rising temperatures and decreasing SOC_{stocks}. At elevated soil temperatures, microbial activity increases as do associated rates of humus decomposition (Schimel et al. 1994; Doblas-Miranda et al. 2013, Zhao et al. 2017). For precipitation, on the other hand, studies find a positive correlation with SOC_{stocks} (Doblas-Miranda et al. 2013; Jacobs et al. 2018). Jacobs et al. (2018) partly attribute this to the increasing vegetation cover following increased water supply. High precipitation levels in combination with waterlogged soils or high groundwater levels cause high soil moisture. In many studies, soil moisture has a positive effect on SOC_{stocks} (Post and Kwon 2000; Jacobs et al. 2018) because, under anaerobic conditions, decomposition is lower due to reduced microbial activity. Oxygen availability is therefore a further influential factor.

Not only the quantity of SOC_{stocks}, but also the **chemical composition of the source materials** significantly determine the speed of decomposition (Schimel et al. 1994; Blume et al. 2010). Some macromolecular components of plants or microorganisms, such as lignin or wax, have structures that are difficult to degrade and poor decomposability and thus lead to SOC accumulation in the soil. Additionally, **pH** has an influence. It determines the availability of nutrients and influences formation of new minerals and soil structures, humification, and clay displacement. Plants and microorganisms each have different optimal pH ranges. For example, a very high or low pH-value can inhibit microbial activity and lead to reduced decomposition and higher SOC_{stocks}. At the same time, however, plant growth can be inhibited under these conditions.

Another influential factor is the **soil texture**. There is a close positive correlation between clay content and SOC_{stocks} (Schimel et al. 1994; Lal 2004; Blume et al. 2010; Jacobs et al. 2018). Like a rising pH-value, clay has a strong effect on soil structure and promotes the formation of aggregates. Clay-humus complexes stabilize SOC. In addition, water saturation causing anaerobic conditions occurs more frequently in clayey soils due to the higher proportion of fine pores and therefore higher SOC_{stocks}.

In mountain regions, the influence of **topography** is also significant. Mountain landscapes often show a strong heterogeneity, which is characterized by a high variability of coarse soil content, initial substrate, and microclimate. This can lead to an equally heterogeneous SOC distribution. In addition, high erosion rates are typical in mountains and affect the topsoil. Slope position, inclination, and shape can also have fine-scale effects. On a broader scale, elevation is a strong influential factor. Many studies find a positive correlation between elevation and SOC_{stocks} (Dai and Huan 2006; Griffiths et al. 2009; Wang et al. 2012;

Dieleman et al. 2013; Doblas-Miranda et al. 2013; Prietzel and Christophel 2014; Dorji et al. 2014; Tashi et al. 2016; Simon et al. 2018). Increasing SOC_{stocks} are primarily caused by decreasing temperatures with elevation and therefore less microbial activity (Garten et al. 1998; Dai and Huang 2006; Leifeld et al. 2009; Dieleman et al. 2013; Dorji et al. 2014; Tashi et al. 2016). Exposure also plays a significant role. Often, north-facing slopes have a higher SOC accumulation than south-facing slopes due to their lower irradiation and lower evapotranspiration in the Northern Hemisphere (Figure 1), which has been described in many studies (Garcia-Pausas et al. 2007; Dorji et al. 2014).

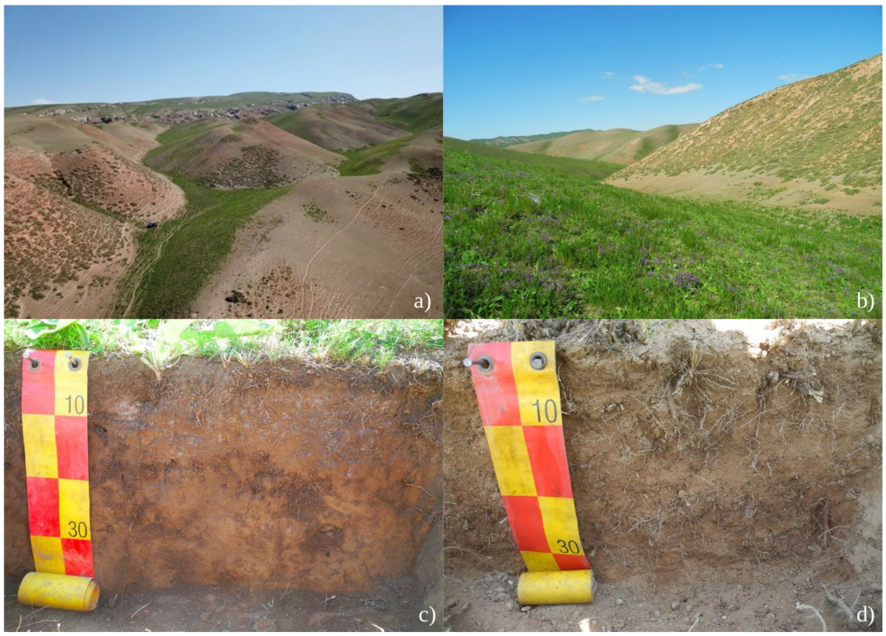


Figure 1: Kyrgyz grassland location with a densely vegetated northern slope and sparse vegetation on the southern slope, a) from above, b) in the area, c) soil profile on the northern slope, d) soil profile on the southern slope

MAIN FACTS: Influential factors on soil organic carbon

The main influential factors on soil organic carbon stocks are: land cover, land use, climatic conditions, chemical composition of the source material, pH, soil texture, and topography.

Calculation of soil organic carbon

The SOC_{stock} is calculated by multiplying the fine soil content in tonnes per hectare by the measured SOC content (Wolff and Riek 2006; Jacobs et al. 2018).

The **fine soil content** is the mass of fine soil (soil particles <2 mm) in a certain unit area and defined depth (Jacobs et al. 2018). To calculate the fine soil content, bulk density (BD) and measured or estimated coarse soil content or proportions must be determined (Wolff and Riek 2006; Jacobs et al. 2018).

The **coarse soil content** includes all grain fractions ≥2 mm. It can be determined in terms of area-percent, for example via a visual estimate of the profile wall or by sampling; or it might be determined in terms of volume-percent, which derives from the measured and estimated values of coarse soil content and a conversion factor of 0.66 (Wolff and Riek 2006; Jacobs et al. 2018). When determining SOC_{stocks}, it is conventionally assumed that no SOC is stored in the coarse soil (Jacobs et al. 2018).

The **BD**, a parameter for soil density, is the mass of an undisturbed soil sample, dried at 105 °C, in relation to its volume (GAFA A2.2 2009). Its determination can be incorrect in soils with high coarse content or strong root penetration (Figures 2 & 3). In order to minimize these errors, the BD of only the fine soil ($BD_{fine\ soil}$) should be determined by subtracting the coarse soil content and root mass from the BD of the whole soil (Wolff and Riek 2006). If a very high coarse soil content prevents any BD measurement, a pedotransfer function can be used. An example is the function according to Renger et al. (2009), where BD depends on humus content and fine soil content (Wolff and Riek 2006; Jacobs 2018). However, pedotransfer functions are usually subject to high errors and might overestimate BDs by up to 25% (Wolff and Riek 2006).

Figure 2: High coarse soil content in Kyrgyz soils

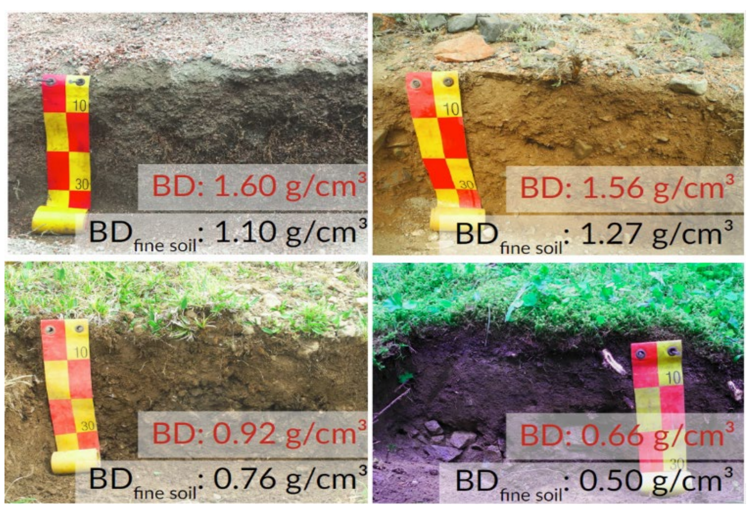
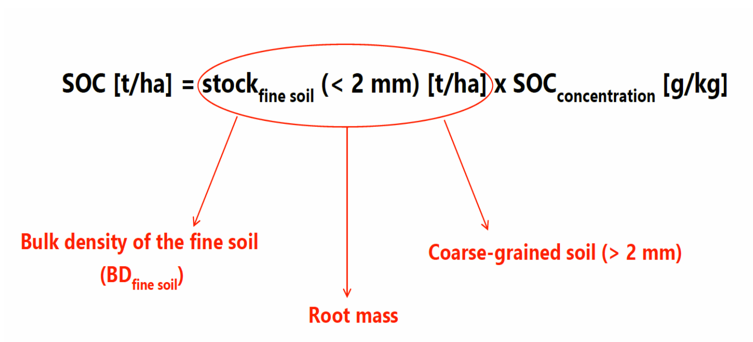


Figure 3: Comparison of bulk density and bulk density of the fine soil in Kyrgyz soils

MAIN FACTS: Calculation of soil organic carbon

- *The SOC_{stock} is calculated by multiplying the fine soil content (soil particles < 2 mm) in tonnes per hectare by the measured SOC contents.*
- *The fine soil content is the mass of fine soil in a certain unit area and defined depth.*
- *To calculate the fine soil content, bulk density of the fine soil ($BD_{fine\ soil}$), measured or estimated coarse soil content, and the root mass must be determined.*
  - *The coarse soil content includes all grain fractions ≥ 2 mm.*
  - *Generally, it is assumed that no SOC is stored in coarse soil.*
  - *Living root material is no part of SOC_{stocks}.*
  - *The $BD_{fine\ soil}$ is the mass of an (undisturbed) soil sample dried at 105 °C, in relation to its volume after subtracting the coarse soil content and root mass.*



Chapter 3. Method for soil organic carbon stock recording in Kyrgyz Republic

The Kyrgyz humus surveys do not provide a basis for LDN reporting. Lack of data is the main reason, followed by lack of representativeness of surveys due to spatial heterogeneity or missing reporting of uncertainties. In addition, the parameters important for the calculation of SOC_{stocks} – $BD_{fine\ soil}$, coarse soil content, and root mass – are not included, and therefore a calculation of SOC_{stocks} is not possible. The presented method aims to allow the nationwide determination of SOC_{stocks} in Kyrgyz Republic. It is based on the assumption that similar stocks can be expected from similar combinations of site conditions which influence SOC_{stocks}.

To capture the variability inherent in spatial SOC distribution, representative units were identified. For this purpose, relevant factors influencing the SOC_{stocks} were determined. The choice was also influenced by data availability. The factors **land cover**, **elevation**, and **climate** (mean annual temperature and sum of annual precipitation) were selected as relevant for Kyrgyz Republic. Using soil-type data according to Mamytov (after Gottschling 2006) was also considered. The traditional Kyrgyz classification of soil types differentiates the upper levels of the hierarchy according to geographical and land-use aspects, making the factors elevation and land cover redundant. Relevant influential factors, such as texture and initial substrate, are not considered in the available soil data according to Mamytov.

Finally, the representative units for Kyrgyz Republic were determined. Each unit encompasses a combination of the influential factors **land cover, elevation,** and **climate**. For each representative unit, three areas were selected for field surveys and samples were taken for SOC_{stocks} calculation. The SOC data can be used for modelling to predict SOC in unsurveyed areas using the relevant environmental impact factors.

MAIN FACTS: Method for soil organic stock recording in Kyrgyzstan

- *The current Kyrgyz humus surveys do not provide a basis for LDN reporting, as they do not take heterogeneity within an area into account and the sampled areas are not representative of the whole of Kyrgyzstan. Reference data do not exist either. Further, no data exist for bulk density of the fine soil, coarse soil content, or root mass, and therefore a calculation of SOC_{stocks} is not possible.*
- *The developed method is intended to determine the SOC_{stocks} for Kyrgyzstan.*
- *As a first step, representative units were identified.*
  - *These units encompass the main factors influencing the SOC_{stocks}, which are backed up with available data.*
  - *Land cover, elevation, and climate were identified as relevant influential factors.*
  - *For each representative unit, three locations for site surveys were chosen and samples were taken, from which the SOC_{stocks} were calculated.*

3.1 Identification of representative units

The analysis of the representative units was carried out using *ArcGIS* (*esri*, version 10.5.1). The land cover, elevation, and climate data were taken from global and generalized datasets. To accommodate the **representative units**, the three datasets were transformed to the same spatial resolution and then classified. Classification was based on a trade-off between heterogeneity of SOC_{stocks} and number of representative units. Subsequently, the classified datasets were superimposed in one grid with a combined raster containing the respective information of the three influential factors per pixel.

For **land cover,** global data provided by the UNCCD were used for the six main classes occurring in Kyrgyz Republic at a 300 m spatial resolution (Figure 4). Three land-cover classes were excluded from the selection. For LDN, only land-based SOC_{stocks} are to be reported, and therefore the class "Waterbodies" was not used. For the class "Artificial surfaces", very low SOC_{stocks} can be assumed and representative sampling, for example of sealed surfaces, could not be implemented within the project and thus this class was excluded. The "Other land" class includes rocky or ice-covered surfaces and was also excluded. This left "Grassland", "Cropland", and "Tree-covered areas" as the three land-cover classes to be assessed.

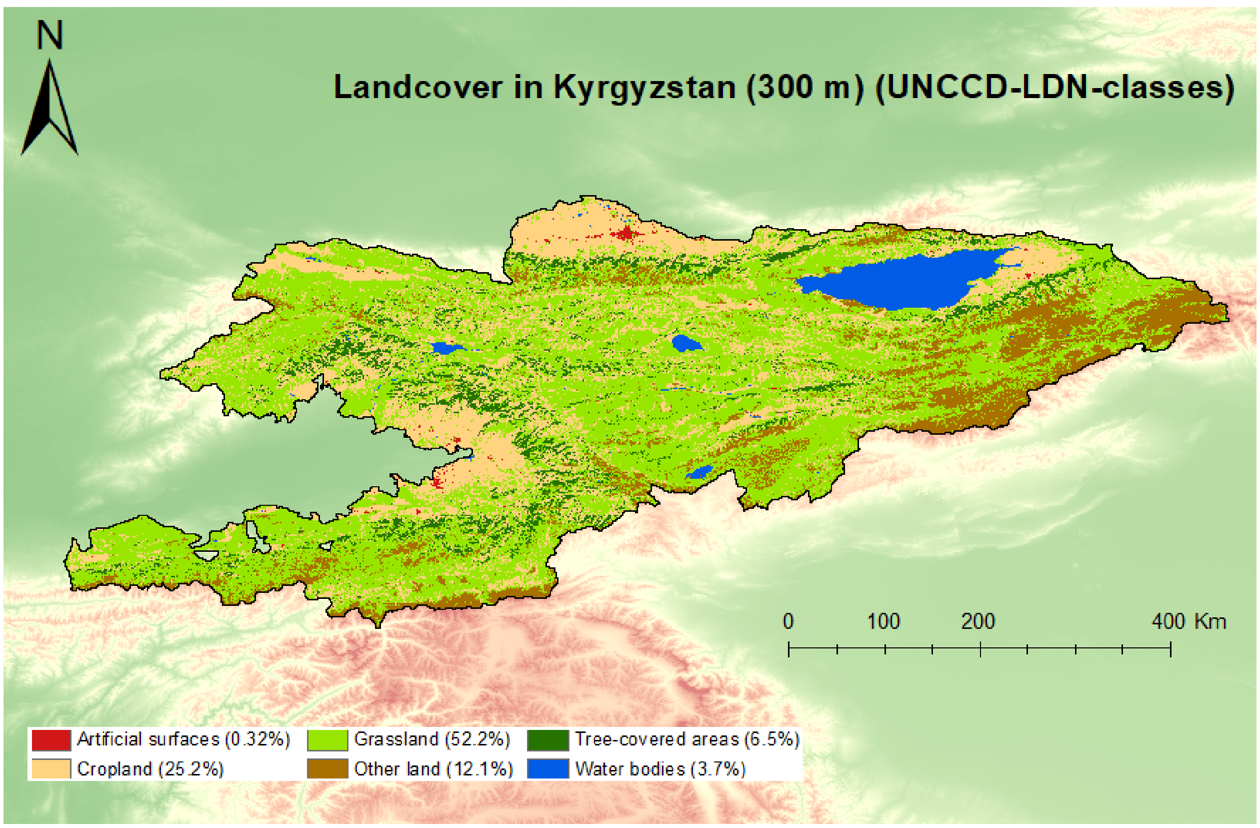


Figure 4: Main classes of land cover in Kyrgyz Republic at 300 m resolution (own representation, data: UNCCD 2018)

A global digital terrain model with a spatial resolution of 90 m was used (Figure 5) to define the **elevation classes**. Data originated from the Shuttle Radar Topography Mission (SRTM) of NASA in 2000 and were processed by the Consortium for Spatial Information (CGIAR-CSI 2019). The raster data were then transformed to a spatial resolution of 300 m and the WGS 1984 projection according to the UNCCD land-cover class data. Eight equidistant elevation classes from <1,000 m to >4,000 m were selected in 500 m steps (Table 1). It was assumed that the SOC_{stocks} do not change significantly within 500 m elevation steps as they track well the vegetation zones which are closely related to SOC.

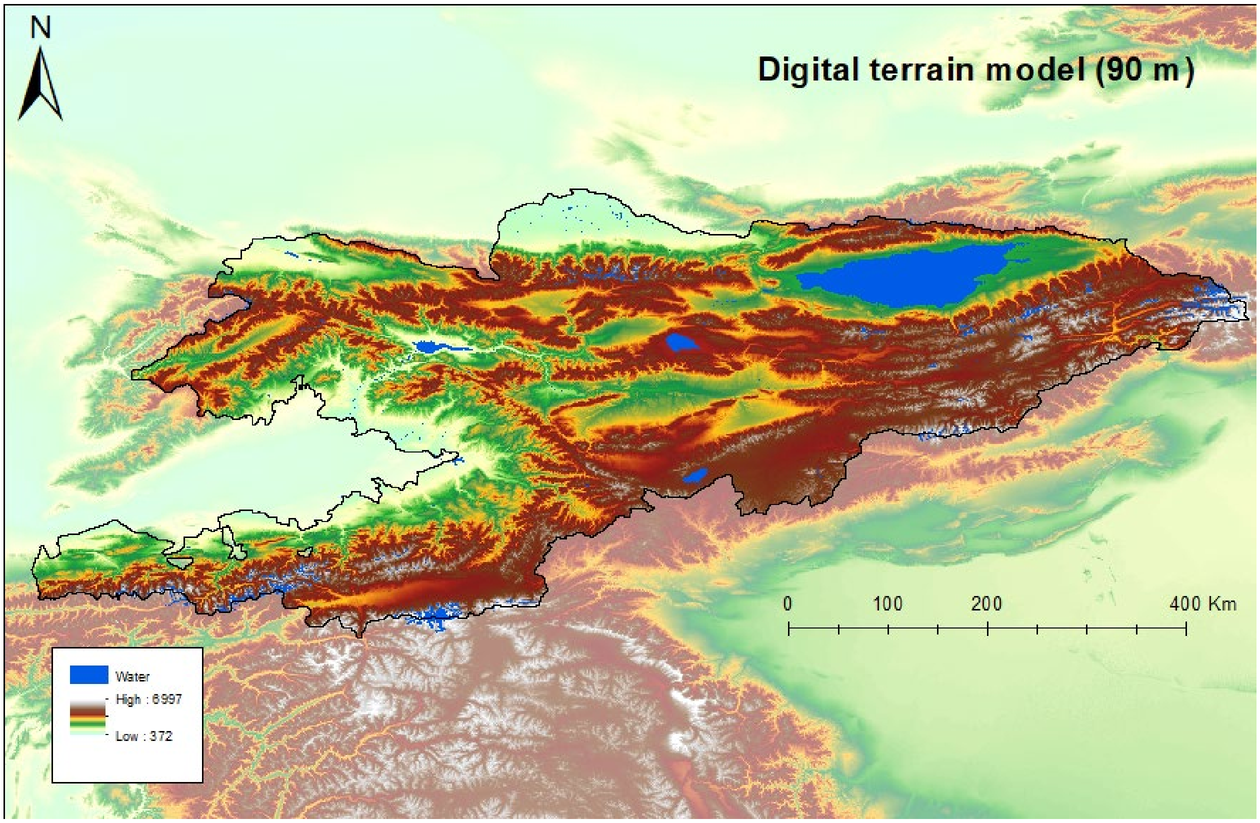


Figure 5: Digital elevation model in 90 m resolution (own representation, data: NASA-SRTM, Consortium for Spatial Information 2019)

Precipitation and temperature data from the WorldClim Version2 dataset were used (Fick and Hijmans 2017). The average temperature data showed a close correlation with the elevation data and were thus already covered by the elevation classes. Therefore, only the precipitation data were used for the climate input data (Figure 6). These are based on data from 13,763 weather stations and consist of monthly mean values from 1970 to 2000 in grid format at various resolutions (Fick and Hijmans 2017). The highest available resolution of 1 km was chosen and then interpolated to 300 m. The monthly values were summed up to annual values to obtain the mean annual precipitation totals for the above period. The values were divided into three classes (Table 1). Here, too, the selection was done primarily to ensure representativeness.

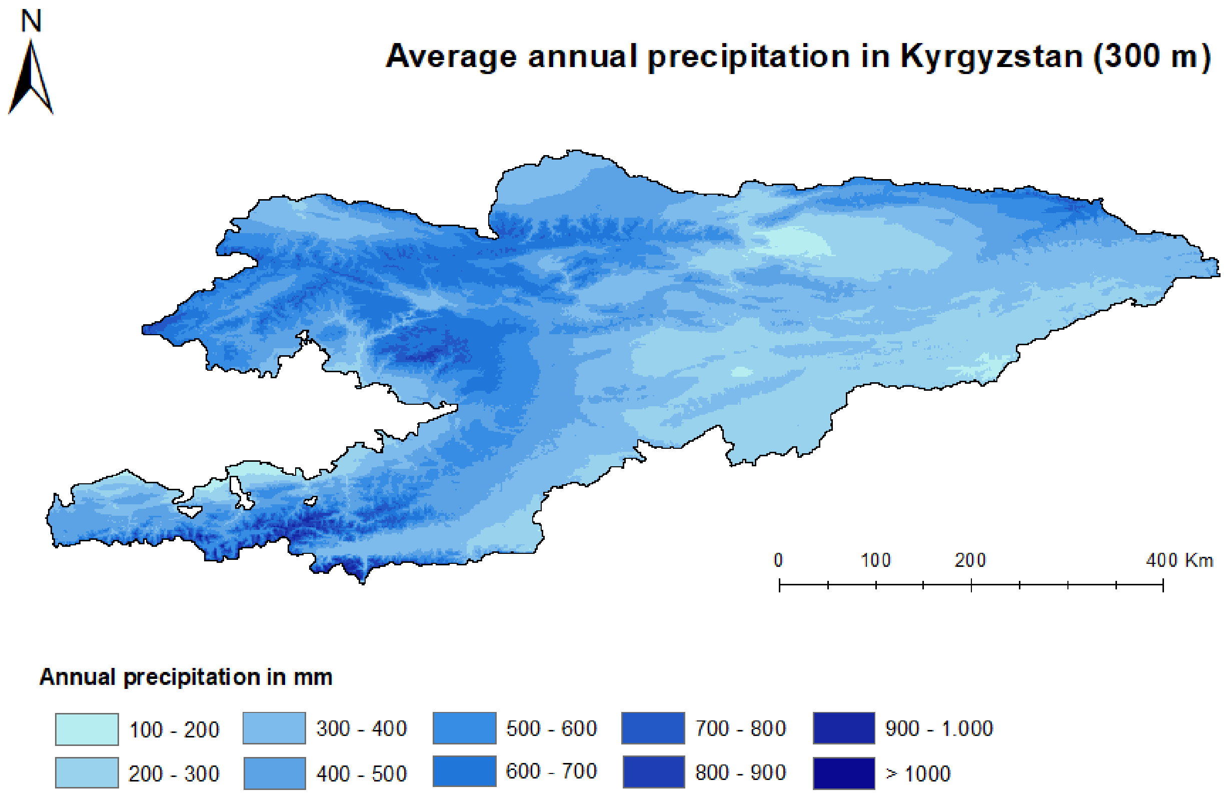


Figure 6: Mean annual precipitation (mm) in Kyrgyz Republic (own presentation, data: Fick and Hijmans 2017)

Table 1: Classes of the three influential factors

Land cover	Elevation [m]	Precipitation [mm/a]
Tree-covered areas	<1,000	<300
Grassland	1,000 – 1,500	300 – 600
Cropland	1,500 – 2,000	>600
Artificial surfaces	2,000 – 2,500	
Other land	2,500 – 3,000	
Waterbodies	3,000 – 3,500	
	3,500 – 4,000	
	>4,000 m	

After superimposition of the three classified datasets, the area percentages of the respective combinations of the representative units were calculated and all combinations with an area percentage >1% selected. They covered 80.62% of the SOC-storing land areas and comprise the most common representative units in Kyrgyz Republic (Table 2).

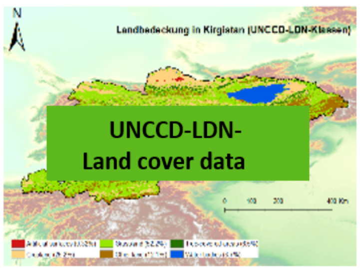
The largest coherent areas were selected from each unit. A validation of land-cover classification was conducted before the field survey with high-resolution images from *Google Earth Pro*. For each unit, a minimum of three areas were selected being both as large as possible and feasible for sampling. The locations of the sampling points can be seen in Figure 18 in Appendix A.

Table 2: Representative units

Land-cover class	**Elevation class [m]**	**Precipitation class [mm/a]**	**Proportion of land surface [%]**
Grassland	3,000 – 3,500	300 – 600	8.05
Grassland	2,500 – 3,000	300 – 600	7.23
Grassland	2,000 – 2,500	300 – 600	6.94
Grassland	1,500 – 2,000	300 – 600	5.92
Grassland	3,500 – 4,000	300 – 600	5.80
Cropland	<1,000	300 – 600	4.53
Cropland	1,000 – 1,500	300 – 600	4.32
Grassland	3,500 – 4,000	<300	4.19
Cropland	3,000 – 3,500	300 – 600	3.98
Cropland	1,500 – 2,000	300 – 600	3.62
Grassland	1,000 – 1,500	300 – 600	3.41
Grassland	3,000 – 3,500	<300	3.27
Cropland	2,500 – 3,000	300 – 600	3.18
Cropland	2,000 – 2,500	300 – 600	2.41
Grassland	3,000 – 3,500	>600	2.40
Grassland	2,000 – 2,500	<300	2.39
Tree-covered areas	2,500 – 3,000	300 – 600	2.09
Grassland	3,500 – 4,000	>600	2.07
Grassland	1,500 – 2,000	<300	1.86
Tree-covered areas	2,000 – 2,500	300 – 600	1.70
Grassland	2,500 – 3,000	<300	1.26
			∑80.62

MAIN FACTS: Selection of representative units

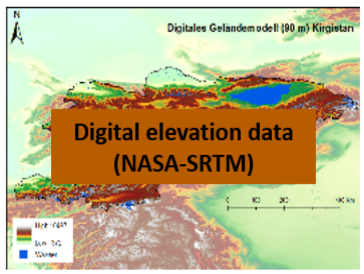
- *Data for the three influential factors land cover, elevation, and precipitation were combined in an ArcGIS project to accommodate the representative units for SOC_{stocks} in Kyrgyzstan.*
- *The area percentages of the respective combinations were calculated and all combinations with area percentages >1% selected.*



- 300 m-resolution

- 6 classes:

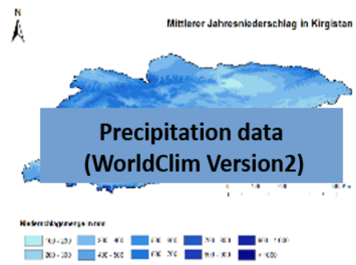
- „Tree-covered areas“
- „Grassland“
- „Cropland“
- „Artificial surfaces“
- „Other land“
- „Waterbodies“



- 90 m-resolution

- 8 classes:

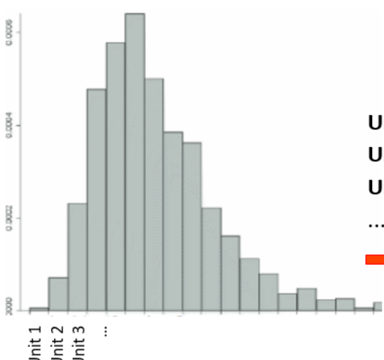
- < 1,000 m bis > 4,000 m in 500-m-steps



- 1,000 m-resolution

- 3 classes:

- < 300 mm
- 300-600 mm
- > 600 mm



Unit 1: land cover class A + elevation class B + precipitation class C
Unit 2: land cover class A + elevation class C + precipitation class B
Unit 3: land cover class A + elevation class D + precipitation class A
...

Selection of the most common units (> 1% area fraction) for sampling – three areas per unit

3.2 Field methods

To identify the most **representative sampling location** within an area, a semi-qualitative approach was used. The dominant topographic structures and dominant land-cover subclasses were estimated. Basically, the central area was sampled if possible (Figure 7). If slopes were dominant, sampling was done on the central slope. If there were north- and south-facing slopes each with a length of at least 300 m, and if they were accessible for sampling, one sampling point for each slope was chosen (Figure 8). In these cases, the average of both profiles were used to determine SOC of the respective unit. In addition, care was taken to exclude small-scale factors influencing the SOC_{stocks} that were not directly attributable to land use. These could be, for example, construction work, animal excretions, landslides, or wash-ups. Visible influential factors were noted that could be attributed to the land use, such as irrigation.

Figure 7: Sampling point on a plain grassland site

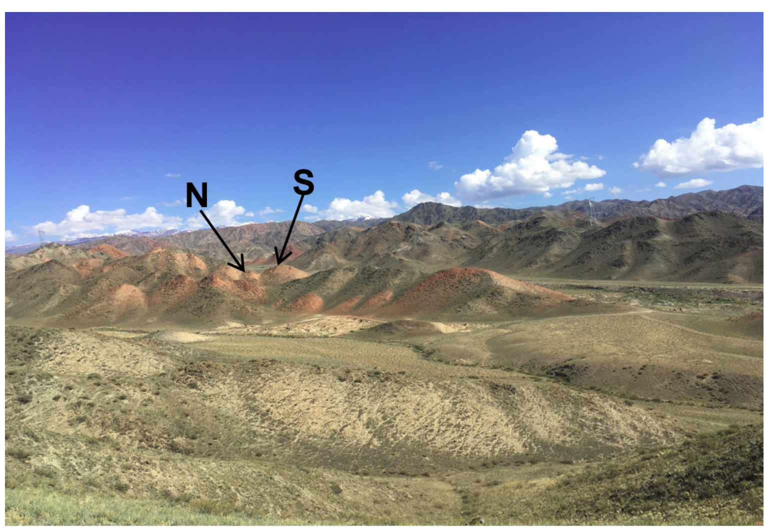


Figure 8: Sampling points on the north and south slopes on a hilly grassland site

For the **field survey**, a north-facing pit of about 40 cm deep, 100 cm long, and 30 cm wide was excavated at the representative point (Figure 9). On slopes, the profile wall was aligned downhill.

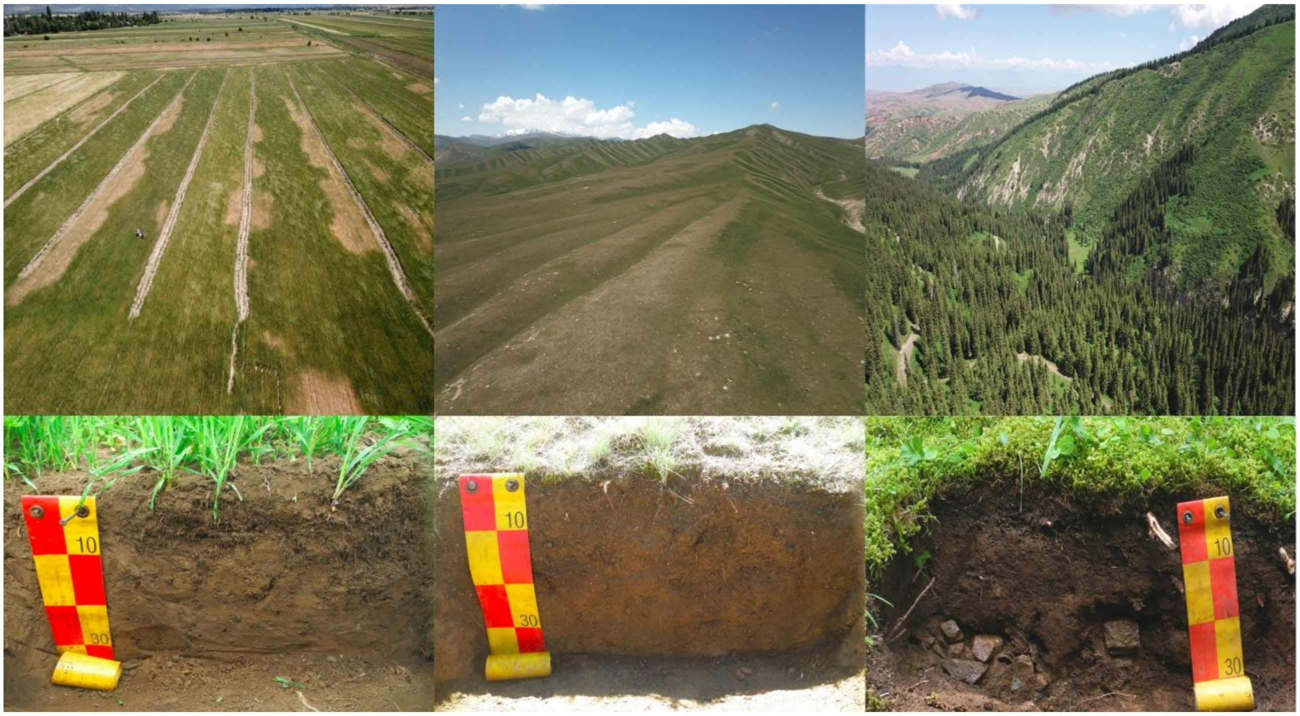


Figure 9: Soil pits in different land-cover classes (from left to right): cropland, grassland, tree-covered area

A short site survey was carried out, which recorded relevant information such as coordinates, elevation, relief information, land cover, and land use (Appendix B, Table 10).

Sampling included five composite samples, three core samples, and, in some cases, one "spade sample". A well homogenized composite sample was taken from the upper 30 cm layer for analysis of SOC content, texture, and pH. To capture the fine-scale heterogeneity of the SOC content, mixed samples were taken from around the central soil pit in all cardinal and intercardinal directions at 10 m from the centre (Figure 10) using an Edelmann drill (Appendix B, Figure 19). Opposite samples were mixed to form a composite sample. This resulted in four additional samples for SOC determination.

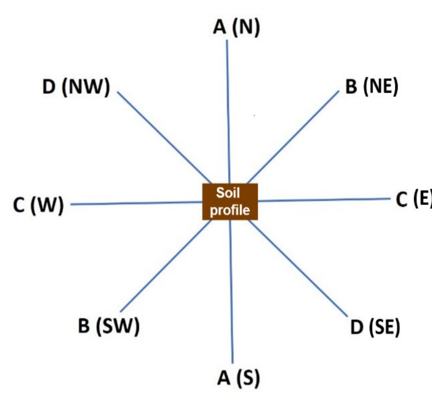


Figure 10: Sampling design

Cores were used to estimate and sample the coarse soil content as well as the $BD_{fine\ soil}$ (Appendix B, Figure 20). The procedure was carried out according to GAFA A2.8 (2009) and Jacobs et al. (2018) and was used to calculate the fine soil content. A differentiation from A to G was made depending on the proportions of coarse soil and grain sizes of the coarse soil (Table 3).

Table 3: Procedure for the determination of coarse soil and bulk density of the fine soil during field sampling (GAFA A2.8 2009; Jacobs et al. 2018, following Table 2-2)

Case	Coarse soil share	Grain size of the coarse soil	Number and volume of cores	Spade sample for measured value coarse soil fraction [mass %], ~5 kg	Estimated value when mapping for coarse soil fraction [%]
A	< 5 %	< 20 mm	3 x 100 cm³	–	–
B	< 5 %	> 20 mm	3 x 100 cm³	–	> 20 mm
C	> 5 %	< 63 mm	3 x 100 cm³	2 – 63 mm	–
D	> 5 %	> 63 mm	3 x 100 cm³	2 – 63 mm	> 63 mm
E	> 5 %	< 63 mm	only mini-core removal possible: 5 x 5 cm³	2 – 63 mm	–
F	> 5 %	> 63 mm	only mini-core removal possible: 5 x 5 cm³	2 – 63 mm	> 63 mm
G	> 5 %	-	estimate of BD according to Eckelmann et al. (2005)	-	> 2 mm

The method assumes that coarse soil fractions <5% with grain sizes <20 mm in 100 cm^3-cores can be included. Therefore, only three core samples were taken with a coarse soil content <5% (cases A and B). If coarse soil fractions >20 mm were present, a visual estimate was made on the profile wall (case B). If the coarse soil content was >5%, a spade sample weighing about five kilograms was taken in addition to three cores for coarse soil determination in the laboratory (cases C–F). If coarse soil fractions >63 mm were also present, they were recorded on the profile wall (cases D and F). The method allows the use of "mini cores" (5 cm³) in cases where a representative 100 cm³ sample could not be taken due to high coarse soil content (cases E and F). If it was not possible to use a stabbing cylinder, the BD and the coarse soil fraction >2 mm were visually estimated according to Eckelmann et al. (2005). Here, the $BD_{\text{fine soil}}$ was later calculated using a transfer function (case G). All $BD_{\text{fine soil}}$ samples were taken vertically at a depth between 10 and 20 cm.

MAIN FACTS: Field methods

- *As a first step, a representative sampling point was selected. The dominant (sub)class of land cover and the dominant topographic structures were identified.*
- *In flat areas, one point in the middle of the area was selected.*
- *In areas with a diameter >300 m where slopes dominated, one sampling point for each slope was chosen – one on a north- and one on a south-facing slope.*
- *A brief site survey was conducted at a prospecting pit (Appendix A, Table 10).*
- *Different samples were taken from the prospecting pit to determine the different laboratory parameters.*
  - *A mixed sample and three core samples were taken from the prospecting pit.*
  - *If coarse soil >5% was found, a "spade sample" was taken to determine the content.*
  - *In addition, mixed samples were taken in eight directions to capture the fine-scale heterogeneity of SOC.*

3.3 Laboratory methods

Table 4 shows the different types of samples and laboratory methods as well as the regulations used. SOC, pH, and texture analyses were performed by RPAS in Bishkek. $BD_{fine\ soil}$, coarse soil content, and root mass were determined partly by the Kyrgyz National Agrarian University (KNAU) and partly by the NGO Camp Alatoo in Bishkek.

SOC content was determined by wet ashing according to Tjurin, which is commonly used in Kyrgyz Republic (GOST 26213-91 1992). The pH and texture analyses were performed with mineral composite samples only.

For the analysis of $BD_{fine\ soil}$, coarse soil content, and root mass according to Jacobs et al. (2018) (modified according to GAFA A2.8 2009), samples were initially dried at 105 °C until the weight remained constant. All core samples were weighed and sieved with a 2 mm mesh. Soil adhering to stones was brushed off and the weight of the fine soil mass was determined. Coarse soil and root mass were separated and weighed. Spade samples were sieved with a 2 mm mesh and stones were then cleaned. Roots bigger than 2 mm were sorted out. Subsequently, fine soil, coarse soil, and root mass were weighed individually. The coarse mass (>2 mm) was sieved with a 6.3 mm mesh and the residue further sieved with a 63 mm mesh. Thus, the fractions 2–6.3 mm, 6.3–63 mm, and >63 mm could be determined.

Table 4: Overview of laboratory parameters, methods, and number of samples

Parameter	Unit	Sample type	Method	Norm	Total numbers of samples (n)
SOC content	%	Mixed sample	Wet incineration, double determination on air-dried and sieved samples (Tjurin)	GOST 26213-91 1992	366
pH	mol/L	Mixed sample	0.01 molar KCl solution, gas electrode with measuring error range <5%, double determination on air-dried and sieved samples	GOST 26423-85 2011	71
Texture	Mass-%	Mixed sample	Double determination on air-dried and sieved samples according to Kyrgyz grain size classification (Kachinsky)	GOST 12536-79 2008	71
Bulk density of the fine soil	g/cm³	Core ring	Core cylinder method, drying at 105 °C, repeated 3 times	GAFA 2009, Jacobs et al. 2018	213
Coarse soil content, root mass	Mass-%	Spade sample	Drying at 105 °C, sieving of the individual coarse soil fractions and roots, no repetition	GAFA 2009, Jacobs et al. 2018	43

MAIN FACTS: Laboratory methods

- *All laboratory analyses were done in Kyrgyzstan.*
- *Analyses of SOC, pH, and texture were carried out following Kyrgyz GOST standards.*
- *Analyses of bulk density of the fine soil, coarse soil content, and root mass were carried out according to the standards of "The Expert Committee Forest Analysis" 2009.*

3.4 Calculation of parameters

Appendix C shows all the formulae used for the calculation of the parameters fine soil stock and $BD_{\text{fine soil}}$.

3.5 Validating the method – selected results of statistical analyses

SOC_{stocks} of the representative units

The carbon stocks differ between representative units indicating that different combinations of the three input factors land cover, elevation, and climate (as precipitation) result in variable stocks (Figure 11 & Table 5). The lowest stocks are within grassland and cropland sites at low elevations; the highest in grasslands and tree-covered areas at high elevations.

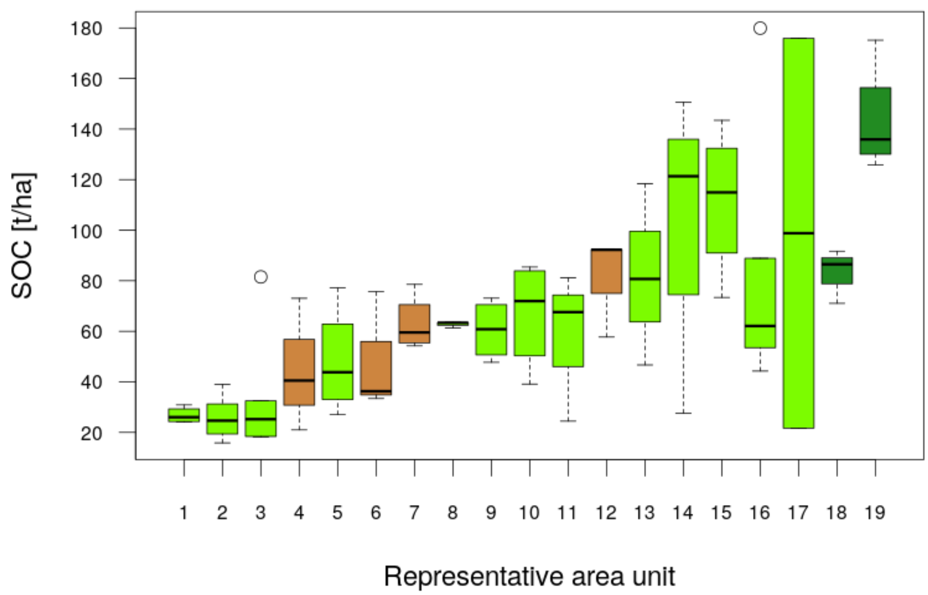


Figure 11: Organic carbon stocks of the representative units (cf. legend in Table 5) in tonnes per hectare, brown: "cropland", light green: "grassland", dark green: "tree-covered areas"

Table 5: Distribution of parameters within representative units (n = number of observations, $\bar{x}$= mean value, s = standard deviation)

No.	Land cover	Elevation [m]	Precipitation [mm/a]	n	SOC [%]		SOC_{stock} [t/ha]		$BD_{fine\ soil}$ [g/cm³]		pH		Clay [%]	
					$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
1	Grassland	1,000-1,500	300-600	4	0.78	0.55	26.77	3.18	1.17	0.09	8.34	0.09	10.18	1.11
2	Grassland	1,500-2,000	<300	5	0.80	0.34	26.02	9.29	1.26	0.10	8.43	0.26	8.34	3.18
3	Grassland	1,500-2,000	300-600	5	1.20	0.86	35.17	26.56	1.25	0.08	8.30	0.47	10.50	5.23
4	Cropland	1,000-1,500	300-600	3	1.67	1.17	44.85	26.29	1.27	0.16	8.22	0.17	17.29	2.26
5	Grassland	2,000-2,500	<300	4	1.72	0.34	47.94	21.37	1.15	0.05	8.48	0.36	11.38	6.11
6	Cropland	<1,000	300-600	3	1.75	1.54	48.43	23.60	1.30	0.18	8.11	0.08	18.12	7.31
7	Cropland	2,000-2,500	300-600	4	2.06	0.80	62.96	10.96	1.17	0.19	7.76	0.48	15.78	0.68
8	Grassland	2,500-3,000	300-600	3	2.19	0.27	62.74	1.20	1.08	0.09	8.20	0.16	18.16	4.30
9	Grassland	3,500-4,000	<300	4	2.50	0.44	60.61	11.91	0.91	0.08	8.31	0.17	18.17	2.71
10	Grassland	2,500-3,000	<300	4	2.83	1.39	67.10	21.48	0.96	0.24	8.10	0.40	17.73	4.47
11	Grassland	3,500-4,000	300-600	3	2.83	1.12	57.71	29.60	0.92	0.25	7.16	1.29	16.28	1.01
12	Cropland	1,500-2,000	300-600	3	3.52	0.88	80.80	19.99	1.32	0.01	8.21	0.08	17.43	3.04
13	Grassland	3,000-3,500	<300	3	3.54	2.08	81.92	35.87	0.89	0.12	8.29	0.07	21.82	2.74
14	Grassland	2,000-2,500	300-600	3	4.05	2.59	99.85	64.25	0.95	0.04	7.63	0.58	13.82	1.07
15	Grassland	3,000-3,500	300-600	4	4.09	1.38	111.67	29.32	0.94	0.09	8.16	0.22	20.79	2.77
16	Grassland	3,000-3,500	>600	5	4.16	3.31	85.72	55.22	0.94	0.18	5.79	0.43	19.42	6.93
17	Grassland	3,500-4,000	>600	2	5.28	5.41	98.79	109.05	0.89	0.22	6.36	0.04	13.75	5.13
18	Tree-covered areas	2,500-3,000	300-600	3	5.52	0.44	83.08	10.73	0.59	0.09	5.76	0.70	17.90	1.91
19	Tree-covered areas	2,000-2,500	300-600	4	7.96	2.41	143.21	21.87	0.66	0.13	6.52	0.87	12.27	6.09

SOC_{stocks} of the land cover, elevation, and precipitation classes

The SOC_{stocks} of tree-covered areas can be clearly differentiated from cropland and grassland areas (Figure 12) but there is no clear difference between cropland and grassland sites.

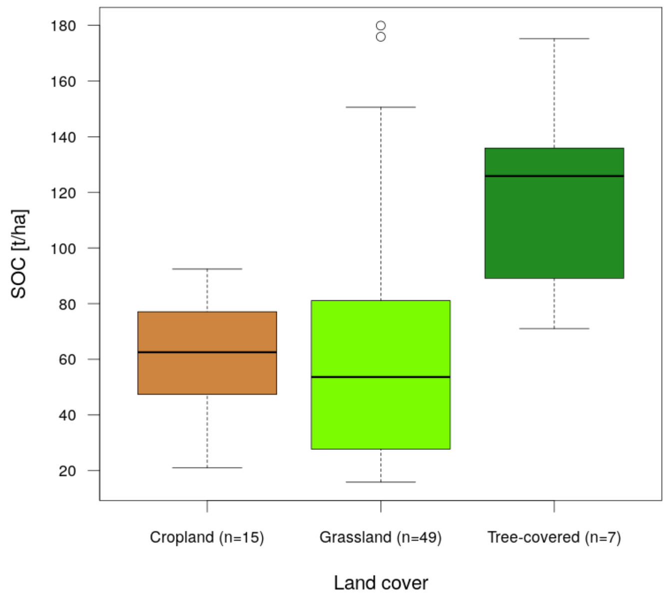


Figure 12: Relationship between land cover and soil organic carbon stocks in tonnes per hectare

The SOC_{stocks} of the elevation classes are similar and relatively low up to 2,000 m then increase for the upper four elevation bands, with a slight indication of a decline in the uppermost band (Figure 13).

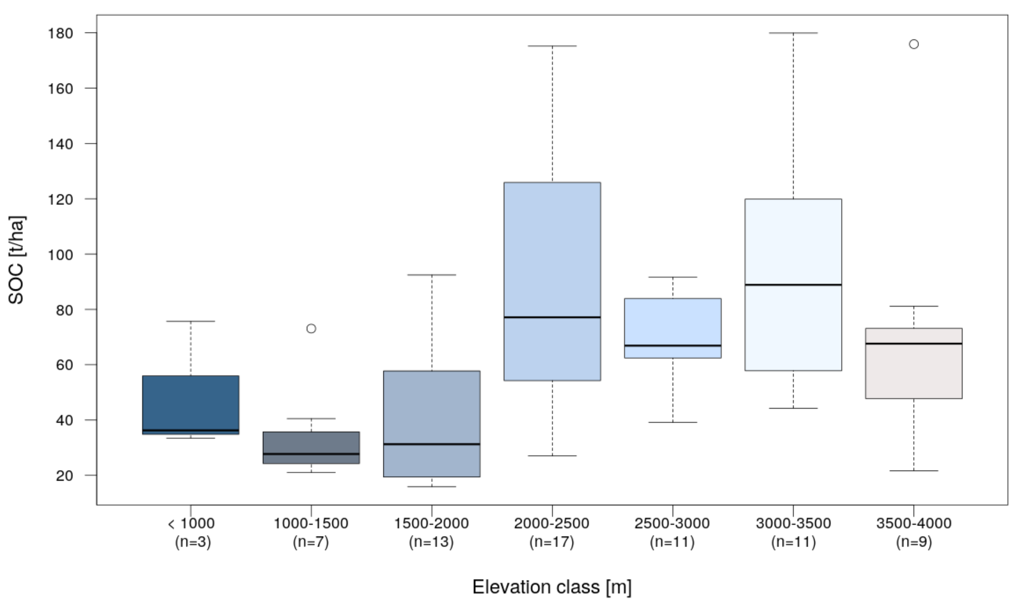


Figure 13: Relationship between elevation class and soil organic carbon stocks in tonnes per hectare

There is a trend of higher SOC_{stocks} values with increasing precipitation (Figure 14). Increasing the spatial resolution of the input data (1 km) and the number of classes could possibly lead to more specific results. In addition, only seven observations are included for the precipitation class >600 mm, thus hampering the comparison. Also, the precipitation range of 300–600 mm is the only one applicable to all three land-cover classes. Higher and lower amounts of precipitation are only recorded for grasslands. This possibly biases the interpretation of the effect of precipitation on SOC.

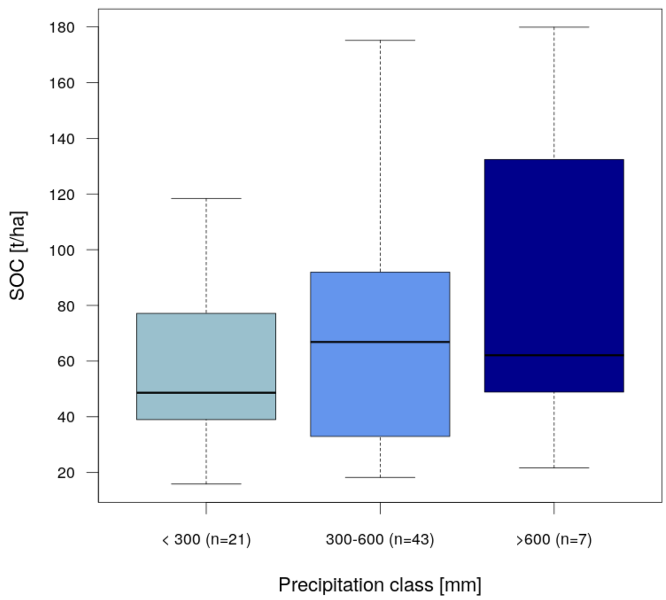


Figure 14: Relationship between precipitation class and soil organic carbon stocks in tonnes per hectare

Overall, the results show that all three parameters influence the variability of SOC_{stocks} in Kyrgyz Republic.

In the analysis of the other laboratory parameters, clay content shows a strong positive correlation with SOC content (Appendix D, Figure 21). An equally strong effect of clay on the distribution of SOC content has been described in the literature (see 2.3). However, at a nationwide scale, this factor could not be considered due to a lack of spatial digital data.

Consideration of $BD_{fine\ soil}$, coarse soil content, and root mass

When considering the relationship between $BD_{fine\ soil}$ and SOC, a distinction must be made between SOC content in percent and SOC_{stock}, as $BD_{fine\ soil}$ is used to calculate SOC_{stock}. The $BD_{fine\ soil}$ correlates strongly with the percentage SOC content (Figure 15). This is mainly due to the low density of humus.

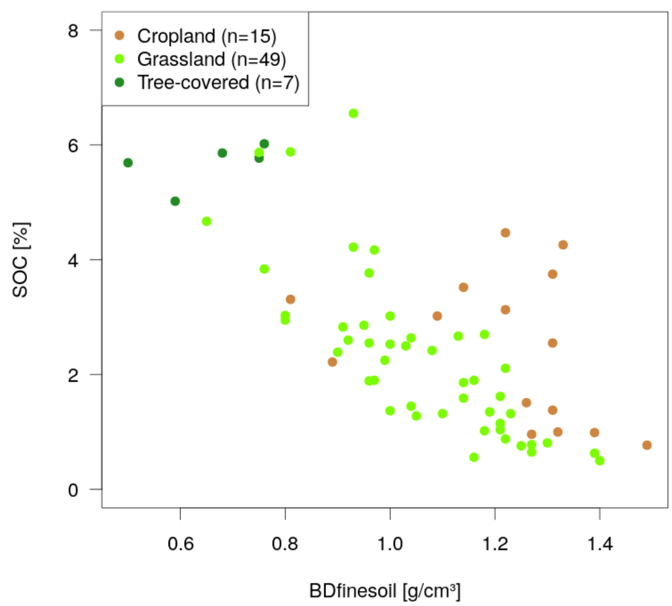


Figure 15: Relationship of soil organic carbon content [%] and bulk density of the fine soil [g/cm³]

When considering SOC_{stocks} in tonnes per hectare, however, lower $BD_{fine\ soil}$ also reduces the stocks. Some of the representative units have a high range of SOC_{stocks} compared to the percentage SOC content, with some of the grassland and tree-covered areas being particularly striking (Figure 16). In the grassland, this is due to the generally higher proportion of coarse soil and strongly varying $BD_{fine\ soil}$. The tree-covered areas show the highest percentages of SOC content of 5.52% to 7.96%. However, tree-covered sites have lower $BD_{fine\ soil}$ and sometimes higher root mass. Considering this, representative unit No. 18 has lower SOC_{stocks} than, for instance, some grassland sites (No. 14, 15 and 17).

Ignoring the $BD_{fine\ soil}$, root mass, and coarse soil content can therefore lead to a considerable overestimation of SOC_{stocks}. These findings correspond with the results of other studies (Rytter 2012; Throop et al. 2012; Mehler et al. 2014; Poeplau et al. 2017).

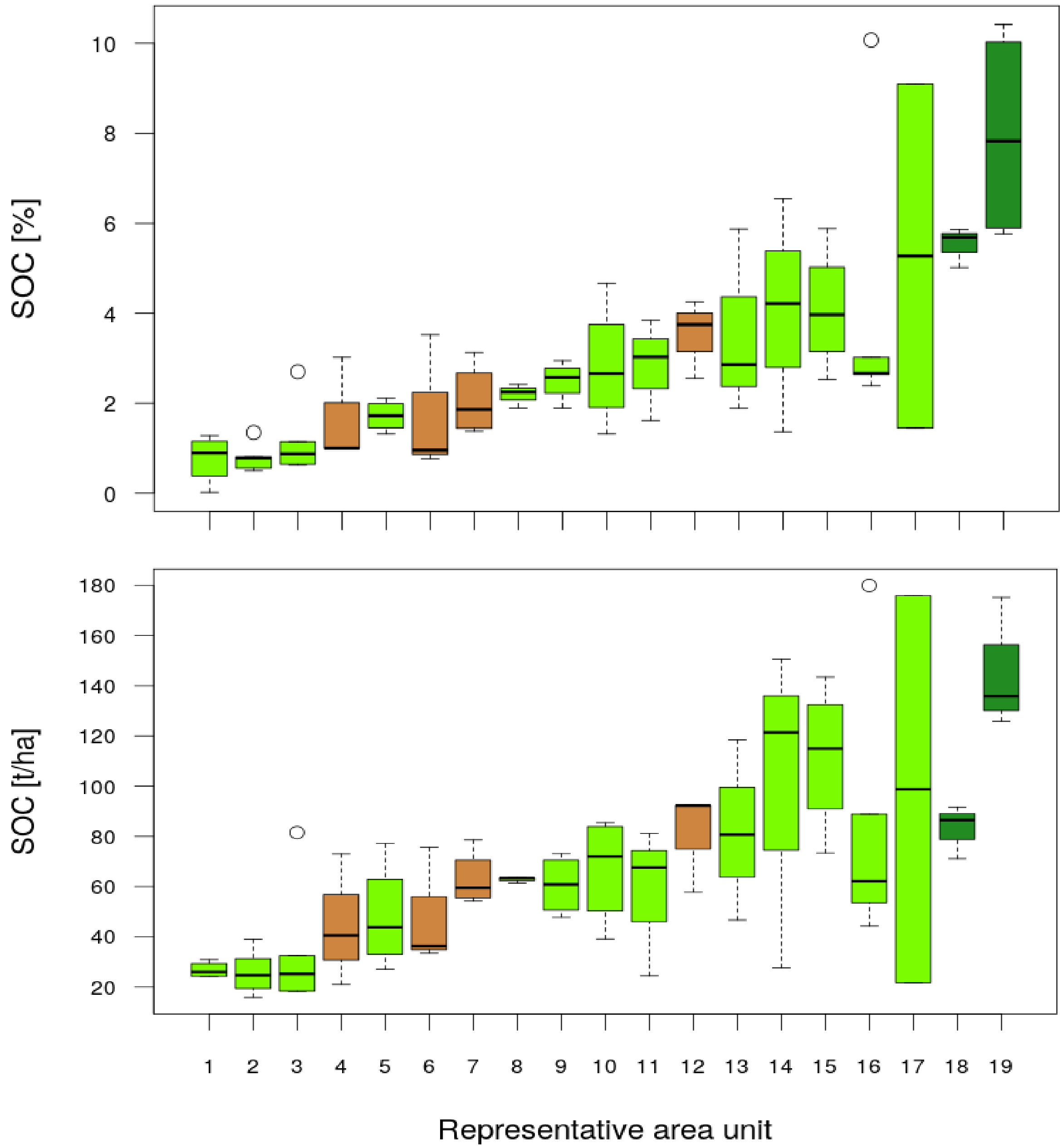


Figure 16: Comparison of organic carbon content as a percentage (above) and organic carbon stocks in tonnes per hectare (below) of the representative units (cf. legend in Table 5) as a percentage, brown: "cropland", light green: "grassland", dark green: "tree-covered areas"

Sampling points and small-scale variability

Cropland has a very low heterogeneity of vegetation cover and all sites are located on plains, which made representative sampling feasible. The grassland sites, on the other hand, often have highly heterogeneous vegetation cover and relief types, so that sampling on north- and south-exposed slopes was necessary (Appendix E, Figure 22) as is described in the literature (see 2.3). The representative sampling of the tree-covered sites was challenging due to many clearings and the uneven high mountain landscape. Multiple sampling at different exposures was not feasible because forests are very remote and slopes very steep. In addition, south-facing slopes are often without any vegetation cover. Within the class tree-covered areas only spruce forests were sampled. In Kyrgyz Republic, walnut forests also dominate, which are only partially distinguished as coniferous and deciduous forests in the UNCCD subclasses. However, they could not be sampled within the project due to the pandemic situation in 2020. The SOC_{stocks} of deciduous and coniferous forests can differ significantly. Therefore, future fieldwork should sample different forest types to gain additional information.

The high standard deviations and large ranges for the individual samples within the land-cover classes show the high in-field variability of the SOC content (Appendix E, Figure 23). Cropland sites have very small standard deviations because of topsoil homogenisation through management practises and low field variability. Grassland sites have a range of standard deviations, which increase with the level of SOC content. The variability of SOC content is due to the heterogeneity of grassland sites with respect to vegetation cover, coarse soil content, and relief. Slopes with low vegetation are affected by erosion and can therefore have very different SOC content in the topsoil. Tree-covered areas show the greatest fine-scale variability due to the very steep slopes and undulating relief surface.

In summary, land cover, elevation and precipitation reflect the heterogeneity of the Kyrgyz SOC_{stocks} very well. A strong relationship is found between clay content and SOC_{stocks}, but unfortunately, spatial data of the clay content of Kyrgyz soils are missing. In addition, differences in SOC_{stocks} between north- and south-facing slopes are found within the grassland sites. The representative sampling could be performed well for all land-cover categories except for tree-covered areas.

The consideration of fine-scale variability proved to be significant, since in some cases high standard deviations of SOC content within a single sampled field were found. Additionally, the consideration of $BD_{fine\ soil}$, coarse soil content, and root mass for the calculation of SOC_{stocks} turned out to be necessary for Kyrgyz Republic, because there are large differences between sampled areas. The developed method proved to be suitable to determine the typical Kyrgyz SOC_{stocks}.

MAIN FACTS: Validating the method – results of the statistical analyses

- *Among the factors influencing the representative units of SOC_{stocks}, land cover, elevation and precipitation are relevant.*
- *The procedure for finding a representative point within an area and for fine-scale sampling is appropriate.*
- *Sampling of $BD_{fine\ soil}$, coarse soil content, and root mass proved to be necessary for the determination of SOC_{stocks} in Kyrgyz soils.*
- *It would make sense to carry out further sampling of deciduous tree-covered areas, as this could not be done within the project due to the pandemic situation in 2020.*

3.6 Use of the baseline for reporting on soil organic carbon stock changes

To record changes in the SOC_{stocks}, a modified approach according to Tier 1 IPCC (method for the determination of national Greenhouse Gas Inventories) is proposed by the UNCCD (IPCC 2006, Table 2.3). Three types of change factors are differentiated (IPCC 2006; UNCCD 2018):

- Land use factor (FLU): Changes in SOC_{stocks} associated with land use
- Management factor (LMG): Change in SOC_{stocks} resulting from main management practices
- Input factor (FI): Changes in SOC_{stocks} resulting from different inputs of carbon into soil

There are no data of sufficiently high spatial resolution available for the management and the input factors. Therefore, the UNCCD only uses FLU, which can be determined by means of land-cover data (UNCCD 2018). FLU equals 1 if there is no change in land use, <1 if the SOC_{stocks} decreased due to adverse land-use changes, and >1 if land use improved (UNCCD 2018). Table 6 shows example values for FLUs as a function of different climatic conditions. The change factors are based, inter alia, on long-term field tests (UNCCD 2017). However, management measures are not taken into account, and for some climatic areas no values are available (UNCCD 2017).

Table 6: Land use factors (FLUs) for selected examples of changes in land cover (UNCCD 2018)

Change in land-cover class		Climate	Default FLU
Wetland	Any other class	All	0.04
Any other class	Other land	All	0.1
Any other class	Artificial surfaces	All	0.32
Tree-covered areas	Cropland	Temperate dry/Boreal dry	0.8
	Cropland	Temperate wet/Boreal moist/Boreal wet	0.69
	Cropland	Tropical dry	0.58
	Cropland	Tropical moist/wet	0.48
Grassland	Cropland	Temperate dry/Boreal dry	0.8
	Cropland	Temperate wet/Boreal moist/Boreal wet	0.69
	Cropland	Tropical dry	0.58
	Cropland	Tropical moist/wet	0.48
Other land, subclass Permanent snow & ice	Any other class	All applicable	0.7
Any other class	Other land, subclass Permanent snow & ice	All applicable	1
Water bodies	Any other class	All	1
Grassland	Forest	All	1
Forest	Grassland	All	1
Cropland	Tree-covered areas	Temperate dry/boreal dry	1.25
	Tree-covered areas	Temperate wet/Boreal moist/Boreal wet	1.45
	Tree-covered areas	Tropical dry	1.72
	Tree-covered areas	Tropical moist/wet	2.08
Cropland	Grassland	Temperate dry/Boreal dry	1.25
	Grassland	Temperate wet/Boreal moist/Boreal wet	1.45
	Grassland	Tropical dry	1.72
	Grassland	Tropical moist/wet	2.08
Any other class	Wetlands	All	2
Other land	Any other class	All	2
Artificial surfaces	Any other class	All	2

MAIN FACTS: Use of the baseline for reporting on SOC-stock changes to UNCCD

- *The UNCCD proposes to report on changes in the SOC on the basis of a Tier 1 IPCC approach that is used for the determination of Greenhouse Gas Inventories.*
- *The method is based on a land use factor (FLU) that describes changes of SOC_{stocks} associated with land-use changes.*
- *FLU equals 1 if there has been no change in land use, <1 if the SOC_{stocks} has decreased due to negative land-use change, and >1 if it has improved.*
- *Different FLUs correspond to different land-use changes (Table 6).*

Chapter 4. Institutional framework for assessment, monitoring, and reporting on soil organic carbon stock

4.1 Existing institutional environment and modes of ecological data provision and exchange in Kyrgyz Republic

Within the UNCCD framework, Kyrgyz Republic has formulated national goals in the area of LDN and has pledged to report on measures taken to implement the concept. Reliable and good quality data are key for achieving LDN targets. International experience shows that in the absence of such data, identifying areas of intervention as well as planning and monitoring actions are quite challenging. In Kyrgyz Republic, the first report on LDN prepared by LDN Working Group identified a serious gap in national carbon stock data and provided recommendations for the development of LDN assessment and monitoring presented in Chapter 2. The CARB-ASIA project builds on previous work and aims at developing a method for estimating organic carbon stocks in order to address the existing gap and improve LDN reporting. However, methodological developments alone will not guarantee success in achieving LDN objectives. Data obtained using the proposed method should be institutionalized, or in other words, the method should be officially approved at the national level. In addition, organizational gaps and problems must be addressed.

Most importantly, information management is not solely about data production and processing (i.e., technical infrastructure and data content), but also includes human, institutional, and organizational dimensions, which determine how the provision of data interacts with societies and institutions (Goldstein et al. 2018). From this perspective, information governance is multidimensional and different layers of functionality need to be considered to ensure implementation of the proposed method. To this end, the CARB-ASIA project has analysed the institutional environment for the assessment, monitoring, and reporting of soil organic carbon stock in particular, and on other LDN indicators in general, with the focus on three main and interdependent layers of information functionality: i) technical infrastructure, data, and format layer, ii) organizational layer, and iii) human layer.

In recent decades, as the number of multilateral agreements has increased, the demand for environmental information has also grown significantly. After an agreement is ratified, the relevant ministry under the Kyrgyz government is responsible for preparing a report on the implementation of international obligations. However, the institutional framework for assessing, monitoring, and reporting environmental indicators is still in the process of development and the capacity of state organizations in the field of environmental protection is limited to carry out a structured, comprehensible inventory of the required indicators (CAREC 2013). Although the focus of this manual is primarily on soil data, institutional analysis is based on a broader context of environmental and land data provision in the country. This identified key challenges and areas of expertise in existing national experiences in data production and use. The analysis thus aims to provide a basis for the necessary development within data management and reporting by identifying the main issues in the provision and use of information in Kyrgyz Republic, as well as by providing recommendations to improve national capacity to meet reporting obligations under the LDN system.

4.1.1 Current developments relevant for LDN monitoring and reporting

The following section provides an overview of the situation in Kyrgyz Republic with regard to current practices of land information provision necessary for LDN assessment, monitoring, and reporting, such as data collection, sharing, and use.

Technical infrastructure and the data and format layer

Since the collapse of the USSR, increasing external pressure from international actors (organizations, conventions, programmes, donor community, etc.) became a key factor in modernizing Kyrgyz Republic's environmental data and information collection system. Nevertheless, modes of data collection, exchange, and reporting highly rely on processes and organizational forms inherited from the Soviet past.

The main role in official data provision is assigned to the National Statistical Committee (NSC). Collection of data is traditionally organized in a centralized way according to the statistical standards issued by the NSC (i.e. statistical forms for data collection). District statistical offices are directly responsible for primary data collection. Statistical offices at a regional level compile all district databases and consolidate them into one database. Data processing is handled in regional and central computing departments of the NSC, where verification and validation of the received data takes place. Verification of data is performed by comparison with previous periods of data collection. Finally, the central NSC office publishes official statistical data on its website and in paper form. The NSC has quite strict regulations regarding data quality. This is why every statistical form for data collection must pass through a methodology council that approves its need and validity, that is, whether the form is really needed and if it assures the quality of collected data. Before any statistical form reaches the methodology council, respective ministries and agencies should approve it. This is also needed for crosschecking if any other institution already gathers this information so as to avoid double counting. It takes much time to develop such a form: on average, three to four years.

Until recently, the technical infrastructure for data collection and sharing was underdeveloped. A lot of information (in particular the data from the Soviet period) is still stored as hard copy, which affects the ability to share the information, and therefore its usability. As the data are mostly stored in archives and are not always available on the website of state bodies, the exchange of information between state bodies works mainly on formal written requests. The government recognizes the need to modernize the production and dissemination of information and is currently focusing on the national digitalization process. As a result, a state online inter-ministerial data exchange system (“Tunduk”) has been recently created. All state authorities are encouraged to use the system for information exchange. The system also serves as an information intermediary between public authorities and civil society.

A big step has recently been made towards the creation of an integrated system of environmental information (“Kerege”) – an online portal with an ecological database (managed by SAEPF, under the support of UNDP). First, an analysis of national data was conducted that allowed environmental indicators to be selected for preparing national reports on environmental protection and SDG indicators as well as for climate and national statistics. The next phase of the database development envisaged will include dynamic tables with the data for the last 10 years for each indicator and a planned annual update at the end of the year. The system will contain only official data from the NSC and governmental authorities. Open access to a wider public is planned as well. The “Kerege” system includes a total of 50 indicators, but it does not include soil or land data.

The trend related to digitalization processes covers many areas of activity, including creation of online soil and land databases (a so-called geoportal). The transition to shared informational systems is accompanied by many issues primarily related to the integration of different types of information, such as data format or standards for data sharing. This also applies to the possible integration of LDN data into such systems; potential problems and related recommendation will be discussed below.

Organizational layer

Since independence, the government of the Kyrgyz Republic has taken many important legislative initiatives affecting the agricultural sector: amendments to the Constitution of the Kyrgyz Republic in 1998, and the adoption of the Land Code in 1999. In the same year, the government adopted a number of other legislative acts, such as the Law of the Kyrgyz Republic on Environmental Protection, the Forest Code, and the Law on Peasant Farms. Later further laws were adopted: the Law on Agricultural Land Management (2000 and 2001), the Law on Mountain Regions (2002), the Water Code (2004), the Law on Cooperatives (2004), and the Law on Pastures (2009) (Anarbaev 2018).

However, the organizational structure of land monitoring in Kyrgyz Republic since its inception has been largely fragmented. Several different ministries and agencies perform the monitoring functions. The main executive agencies and departments responsible for the creation and implementation of national policy as well as for coordination of legislation and control of land management and protection have traditionally been the Ministry of Agriculture, Food Industry and Melioration of the Kyrgyz Republic (MAFIM), the State Institution "Cadastre", the Kyrgyz State Design Institute of Land Management (Kyrgyzgiprozem), which is engaged in the management of agricultural land, as well as the State Agency of Environmental Protection and Forestry under the Government of the Kyrgyz Republic (SAEPF), which is the coordinating agency for forest management (Figure 17). Until 2010, there used to be a united institutional structure for land management, which included several institutions dealing with land issues, such as Kyrgyzgiprozem, Land Cadastre, the State Office of Geodesy and Cartography, and others. However, these institutions were unbundled but in autumn 2019 they were merged again. Now all land-related issues are under one roof – a new State Agency on Land Resources (SALR) has been formed.

Despite these recent institutional changes, MAFIM remains a key actor responsible for designing the national policy with regard to agricultural land management and monitoring. The implementation and coordination functions have been passed on to SALR. SALR is based in the Cadastre Department and consists of the State Office of Geodesy and Cartography and Kyrgyzgiprozem. The Cadastre Department is responsible for property registration and keeps a record of land. One of the main tasks is to assure property rights for landowners. Land and property are not distinguishable in Kyrgyz Republic; land is a property *per se*. All property in the country is coded and mapped; the state is keeping record and defends owners' rights on land. The department is responsible for the national land registry, which was launched in 2014 by state decree. The aim is to obtain information on the quality and quantity of agricultural land since the last registry in 1994. The land inventory primarily collects information on administrative boundaries as well as on the type and condition of land. Soil observations are, however, not included in this inventory. According to the first LDN report, national land registry data can be used to determine the land cover indicator.

Kyrgyzgiprozem (i.e. RPAS) is responsible for soil observations and is a key agency in providing national data on carbon stocks for LDN assessment. In former Soviet times, Kyrgyzgiprozem had large departments that could monitor soil conditions across the whole country, but mainly concentrated on arable land, with a focus on assessing soil productivity to ensure stable yields. There used to be a department under

Kyrgyzgiprozem that conducted geobotanical observations for the monitoring of pasture vegetation and productivity. This geobotanical department was later renamed the pasture-monitoring department. The pasture-monitoring department continued geobotanical observations in a simplified form: selective data updates by following a specific method. As recommended by the LDN working group in the first report, this department can provide data on pasture productivity needed for computation of the land productivity indicator. There also used to be a land-planning department under Kyrgyzgiprozem, which was involved in crop planning for collective farms. After the collapse of the Soviet Union and the agrarian land reform, land planning at the national level was abolished since collective farms were divided into many small-plot farms. This also made it difficult to maintain crop rotation practices and anti-erosion measures. There are fragments of soil quality records for these lands, but there is still a need for a specific scale of observations (i.e. at the farm level). Observations of a bigger area may vary due to different approaches to land treatment, which means that there is no united systemic approach to improve soil quality in the country, and therefore no soil georeferenced data are available.

According to the Constitution of the Kyrgyz Republic all forests are under state ownership; most of them are managed by the State Agency for Environmental Protection and Forestry (SAEPF). Currently, the forest accounting system is being developed on two levels, which are independent and complementary actions: the National Forest Inventory (NFI) (see Chapter 2.2.1) and the Forest Management Inventory (see Chapter 2.2.2). The analysis of carbon stocks of Kyrgyz Republic was one of the major parts of the main report of NFI. However, the carbon stock estimate was used to calculate biomass rather than SOC in soils. For calculating carbon stocks, the IPCC guidelines were applied (IPCC 2006). The ongoing World Bank Project on Integrated Forest Ecosystem Management supports the Kyrgyz government in strengthening the institutional capacity for sustainable forest ecosystem management in the country as well as in building capacity for the establishment of a Forest Management Information System to be used in the forest management planning process by Forestry Departments at SAEPF, local and regional governments, local users, and user associations.

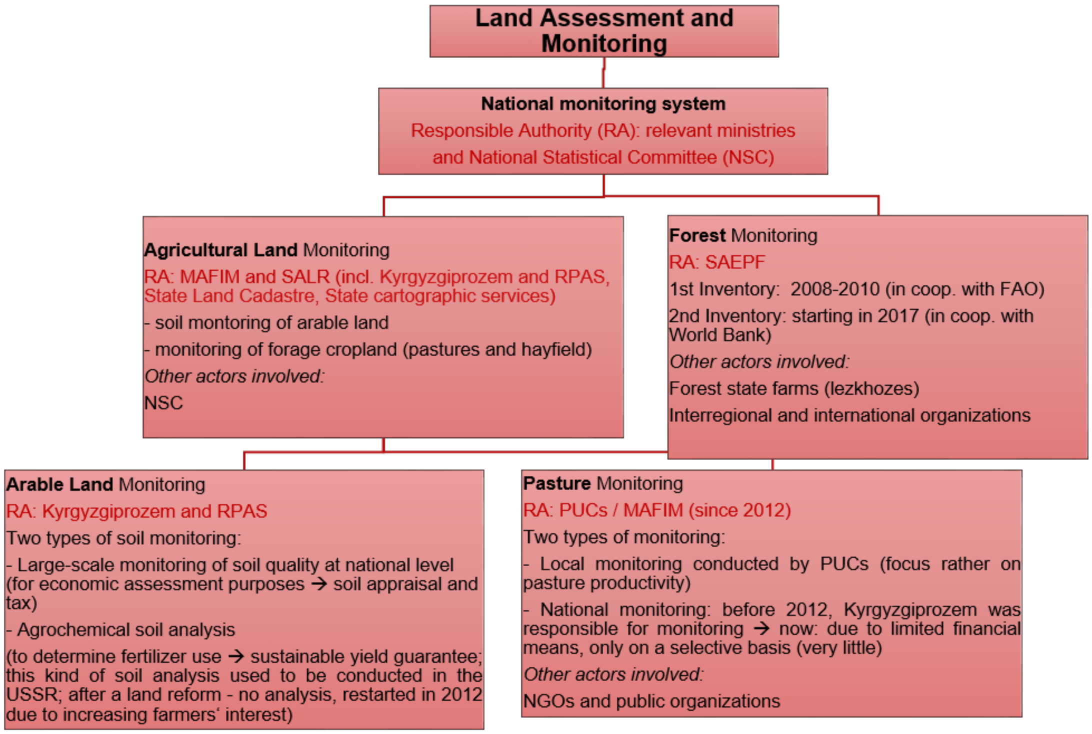


Figure 17: Current management of environmental data and information in Kyrgyz Republic (for arable land, pasture, and forest lands)

Over the past couple of years, several NGOs and public organizations in Kyrgyz Republic have shown interest in SOC data, also due to increasing international demand for this information (e.g. multilateral agreements, development projects). Universities and scientific organizations, such as Kyrgyz National Agrarian University and Kyrgyz Soil Science Association, acknowledge the importance and relevance of SOC monitoring. Universities conduct soil analyses in their own laboratories, but it is mainly done for scientific interest and very often the equipment and financial means are limited. Generally, data provided by NGOs or research centres do not physically cover the entire country in terms of sampling and can be used mainly for research or educational purposes: they are therefore accepted by the international community but cannot be recognized as official national data.

International organizations are likewise active in supporting improvements in information production and monitoring facilities. Thus, in recent years, UNDP and GIZ have focused on supporting the development of a national Monitoring, Reporting and Verification System in Kyrgyz Republic. Within this framework, UNDP and GIZ efforts have led to initial activities in supporting the preparation of the first LDN report. Moreover, with the project "Agenda 2030 monitoring", GIZ initiated creation of an automated system of data collection to avoid any data duplication or consolidation. This implies that the data are directly stored on central servers of the National Statistical Committee, which avoids paper-form filling and its collection by district statistical offices. However, only 10 forms have been automated and these forms for statistical data collection do not include soil data.

For any data to be officially used, the National Statistical Committee (NSC) should approve the method for data collection and processing. This is why the Statistical Committee plays a central role in the preparation of national reports. The NSC communicates all necessary data for important official reports and is therefore responsible for the data mentioned in national reports. The NSC is likewise the main national agency coordinating SDG monitoring: it collects information on SDG indicators from relevant state agencies. The three indicators used for LDN assessment are also recommended as sub-indicators for calculating the SDG indicator 15.3. In this case, the implementing agency is MAFIM.

A review of the existing organizational structure shows that there is no centralized data collection system that can meet the data needs for LDN assessment, monitoring, and reporting.

Human layer

The growing demand for environmental information and the need to develop national information management systems are leading to increased capacity-building activities. Training is organized on the basis of the state departments and agencies and often involves international experts in order to improve staff capacity to work with environmental data (in digital form). At present, one of the main catalysts for the organization of such training is the establishment of reporting processes on SDGs. Participation in international training and projects contributes to professional development of national staff.

4.1.2 Constraints, gaps, and related capacity needs

Despite the above-mentioned development processes in data collection and digitalization, the ability of the country to generate good data has several limitations (Gotgelf, *in preparation*). This section reviews the main constraints that lead to a lack of capacity to produce and use quality data in Kyrgyz Republic. These constraints should be taken into consideration and addressed in the run-up to the second LDN report in 2022.

Technical infrastructure, data, and format layer

At the first stage of data production, identification of what data to collect, generation of data, and their processing take place. In Kyrgyz Republic, economic issues are often prioritized over environmental concerns, and the limited capacity of government agencies to collect the necessary data, which is indeed extremely resource-intensive, leads to a lack of environmental information. Collection of land data is traditionally conducted manually on the ground, which is challenging in terms of countrywide coverage. In some cases, such as forest inventory or pasture monitoring, members of forest or pasture communities collect data themselves. Staff training is therefore important at this stage to assure the accuracy of data generation. Incidentally, there is a significant gap in the country in terms of data quality verification, especially with regard to environmental data: the data are scarce, and if available, they are not quite accurate.

Manually collected data are generally stored in paper form, which makes information sharing challenging and lowers data usability. Against the background of the current transition towards digitalization, switching to online data systems requires converting "paper" data to an online format, which comes with high costs since all data producers have to digitalize their data. Moreover, data in paper form is usually not well structured and it takes too much time to look for data in archives. If databases are not automatic (which is often the case), then there must be someone sending data, which is also tricky and costly in terms of time investments. Even where the data are digitalized, in most cases it still results in fragmented data storage because each institution stores data in its own databases. Especially in the regions, many local institutions are not even connected or do not have a stable internet connection. Data are stored on USB drives somewhere but not centrally; and then if someone leaves – and there is a constant rotation of heads and personnel – lots of knowledge is lost. Or someone is keeping the data on a private computer, which is also bad for institutional memory.

The technical infrastructure for land and environmental data collection and storage is still under development. Most statistical data are manually entered into an online database, using old software from the Soviet times. While there have been developments in the country towards the creation of integrated online data systems, many issues remain. First, such systems are very expensive, both in terms of set up and maintenance costs. Even if financial means are available and a system is created, its maintenance also requires human and financial support, which often results in extra workloads and responsibilities for existing staff due to the lack of financial means to hire IT expertise. This in turn leads to technical problems that arise while using such data systems and that cannot always be rapidly solved due to the lack of IT skills among regular staff. Second, rapid developments towards digitalization incentivize rapid reactions from the side of state authorities. Every authority tries to switch to a new digitalized format in order to be connected to online systems. They try to achieve this goal as soon as possible and in accordance with existing capacities and are therefore under pressure. This results in a problem of bringing all systems together since standards on data storage and formats are missing and there is a lack of cooperation on these issues. Every online inter-ministerial information exchange should be now operated via the online inter-ministerial data exchange system (called "Tunduk"), but the question of how to connect to this system remains unaddressed by many state authorities. Finally, connecting online databases, when data from various online sources should automatically flow into one system, also raises the question of data security and accessibility: the NSC has already been publishing its data online for years, but "technically" it does not correlate with the planned integrated system of ecological information.

The described issues are directly linked to another cornerstone in data management in Kyrgyz Republic – standardization. As shown above, there are no common regulations regarding data and storage formats for consolidating data from different sources. This leads to difficulties of a technical and statistical nature and has implications for information security and quality, data sharing, usability, and accessibility. In terms of data collection, there are defined methodologies and forms to collect statistical data, however, these rules remain on paper or are complicated to follow. In Kyrgyz Republic, it traditionally takes two to three years for each form to be optimized, which basically equals the process of a new standard development. While preparing the first LDN report, a big methodological gap in data relevance for land-cover indicators was identified, namely the difference in land-use categories between national and international systems. In Kyrgyz Republic, according to the law on the land fund, seven land-use categories are distinguished. An international land-use system identifies six land-use categories. Thus, a new system of land-use categories comparable to the international one is needed to comply with one of the major statistical laws – comparability is necessary, otherwise analysis becomes difficult. The NSC tried to address this issue and to make these two systems comparable, by adjusting national data to the international land-use system indicators. Likewise, in terms of carbon stock accounting, many initiatives are collecting data on organic carbon. However, these initiatives are more of an advisory nature. The collected data, method, and the way data are processed should be approved by NSC. It is also important that such a method not only facilitates single observations, but also allows further observations to be made at some point in time. Against this background, the recognition of the proposed method at the national level would be a crucial step towards standardizing carbon accounting.

The above-mentioned constraints have strong implications on the demand side of information provision. Lack of data on land-use indicators and soil quality as well as differences in data formats and infrastructure hinder data exchange and uptake for both decision making and preparing national communications. In the former case, it mainly results in a lack of evidence-based land use and land management practices. In the latter case, it leads to unsustainable reporting practices. Data are presented in different formats for different years and reporting on relevant issues changes by itself, making it difficult to find relevant data for further communications. For instance, during the national forest inventory, experts have received a lot of information on forests, but do not know how to manage these data or in which situations to use which information. Access to this information is a big challenge and there are no ways to use this information, for example, for reporting purposes.

Organizational layer

In addition to limitations on data functionality, it is important to consider limitations of organizational practices or stakeholder engagement with regard to data and information exchange. Getting high quality and reliable data is not usually an easy task, because if one needs information, one should make a written request, which is inconvenient. The main problem thus relates to poor coordination between the public authorities and within agencies. Although it seems simpler to exchange data when digitalizing the process, the problem remains that there is little motivation to exchange data. Much depends on informal internal procedures and interaction on a personal level. It is clear that people are not willing to share information with everyone, because knowledge is their capital. One does not want to share much information, because then somebody else could share it for her or his own purposes. It generates competition and refusal to cooperate between the parties involved. Thus, some official information providers are trying to prevent other sources of more disaggregated and accurate information (although demand for it is growing and some organizations do not have sufficient capacity due to the old infrastructure) as they are afraid of losing their niche of information monopolist.

Another important aspect is the lack of control over implementation issues: simply proposing an idea or a mechanism to solve a problem is not enough, it is necessary to monitor progress and move towards the result. As for international reporting, it is often regarded as a one-time event: since state agencies lack sufficient technical and human capacity, the development of reports is often delegated to external national or international experts. Thus, the group of experts established to prepare the first LDN report ceased to exist after the report was finalized. This seems unsustainable in terms of LDN implementation and leads to a problem that currently, in the run-up to the second LDN report, there is no coordination of efforts to implement the LDN at the national level, methodological gaps still exist, and therefore there are no reliable high-quality data on land quality for official reporting and policy development.

Human layer

Finally, human capacity plays a role in preventing or enabling certain processes. In the field of soil science, there is an acute shortage of soil specialists, especially in government bodies like Kyrgyzgiprozem, as such work is not attractive to young people and is poorly paid. Therefore, developing a new method for estimating carbon stocks in-house is a complex task; soil analysis in Kyrgyz Republic is very production-oriented and more scientific support is needed, especially in the development of new methods. Soil specialists at Kyrgyzgiprozem work routinely and have neither the capacity nor financial support to develop new methods. Similar reasons explain the gap in pasture monitoring. Currently, only the monitoring of arable land receives financial support from the state. In Kyrgyz Republic, there is more pasture than arable land

and pasture is most vulnerable to degradation but requires more financial resources for monitoring. The MAFIM pasture department has insufficient capacity (the major focus is put on working with Pasture User Committees (PUCs)) and has few trained staff to carry out pasture monitoring.

Lack of technical skills contribute significantly to the problem. For instance, most organizations lack IT skills, such as handling data in centralized databases with up-to-date software like SPSS or Excel, or programming skills to create and maintain that software. People are used to working with a paper-based system. Similarly, spatial data are rarely used, mainly because of a lack of skills, but also because of a lack of common standards in this area.

Much of the land degradation is due to lack of knowledge. In the case of arable land, there is a lack of knowledge about the role of soil quality in crop production, resulting in uncontrolled and indiscriminate use of fertilizers because of short-term and economy-oriented decision-making. The same happens in the case of pasture management. The 2009 pasture reform aimed at improving pasture conditions, however most projects focus on improving infrastructure and purchasing new equipment, rather than pasture conditions. At the higher government level, there is a lack of awareness and urgency in tackling land degradation. If this problem is not addressed now, inaction will have serious economic consequences in the future.

The constraints and gaps identified above lead to a reduction in the country's capacity to produce reliable data both to meet international reporting obligations on LDN and to make informed decisions. The way land information in particular and environmental information in general is produced in Kyrgyz Republic is supply-driven, limited to state ministries or agencies, and focused on bilateral approaches to information exchange. This results in a strong dependence on functional aspects of information provision, such as the development of statistical forms of data collection and the operation of online data systems. In our opinion, much attention has been paid to the supply side and to the interests of data producers, which means that the production of information is often limited to simple data collection, while specialist expertise in analysis is lacking to make it usable and accessible. On the user side, the focus is on government ministries and agencies as the main and, more importantly, official producers of information. The needs of other users of information (e.g., farmers, companies, universities, NGOs) are often neglected. Moreover, statistics on environmental indicators and on climate change are very new and appear to be challenging. For instance, in issues such as carbon stocks, data dynamics play a major role, but in Kyrgyz Republic, the statistics collected do not allow the tracking of changes as data collection has another purpose, namely, to know the static amount (in pure forms) of the object of interest.

MAIN FACTS: Assessing current capacity

- *Focusing on the supply side of information is an ineffective strategy to develop effective and sustainable reporting in Kyrgyzstan. This includes heavy reliance on functional aspects, i.e. the focus is on the technical infrastructure rather than on a suitable format of information provision and orientation towards its potential use. In addition, the lack of standards that could accompany the digitalization process leads to fragmentation of information systems with datasets that are not interchangeable and cannot be integrated with each other.*
- *Little attention has been paid to the future use of and demand for data. Institutional fragmentation and weak cooperation among governmental and non-governmental organizations also hamper effective information.*

4.2 Proposals to formalize the developed method and improve national capacity to meet LDN reporting obligations

4.2.1 The importance of formalizing the new method

In order to operationalize LDN, it is necessary to ensure a standardized approach to derive the sub-indicators and to promote capacity building for assessment, monitoring, and reporting at the national level (IAEG-SDGs 2016). The institutionalization of the proposed method would help address the first issue. The recognition of the proposed method for creating a baseline of the indicator SOC is a necessary and important step towards achieving LDN in Kyrgyz Republic. High quality and reliable data allow for setting realistic goals, which, in turn, provide clear direction for action. LDN offers numerous benefits that address national development priorities such as food security, poverty reduction, and climate change measures. Finally, LDN serves as a “lens” that helps focus on the multiple services that land provides, creating coherence among sustainable development policies (UNCCD 2017).

The proposed method is a scientifically based method adapted to international and LDN standards. The recognition of the data generated by the proposed method as official data facilitates monitoring and reporting to UNCCD, but also provides opportunities for coordinated monitoring and reporting to other international conventions and initiatives, such as UNFCCC, the Convention on Biological Diversity (CBD), and SDGs, as carbon is a universal reference for international reporting. Thus, the adoption and implementation of the method leads to the fulfilment of international requirements by the country.

Further, the implementation of the proposed method allows for the calculation of data primarily at the most detailed level - at Tier 3[2], thus ensuring higher data quality. According to the tiered approach recommended for the computation of the indicators, Tier 1 corresponds to the default method and relies on geospatial information and modelling, while Tier 3 is the most detailed method based on ground measurements. The state may benefit from such accurate data produced within the LDN assessment, as it can be used for various purposes. Thus, implementation of the proposed method is important for determining the dynamics of organic carbon in soils in Kyrgyz Republic, as such assessments have not been conducted for a long time (the last assessments were made about 40–50 years ago). These data could also be used for long-term monitoring of soils. Moreover, if data on soil organic carbon are available, they could already be used for training purposes with students and future specialists to help build knowledge for combating soil degradation.

These data are also essential for making informed decisions on land and agricultural planning at a regional or national level. In addition, they allow for the measurement of natural capital (the magnitude of change in the indicators) and ecosystem services, providing the opportunity to quantify and manage trade-offs between ecosystem services (UNCCD 2017). SOC data can also be used for economic valuation of land in the private sector, for example by demonstrating that sites with high SOC values are more productive.

While data collection is usually costly, the proposed method suggests an efficient approach: carbon stock assessment should only be done once to establish a baseline, against which changes will be communicated (monitoring). This is much more efficient than the establishment of permanent soil plots and their monitoring by instead investigating analogous relationships so as to estimate what will happen with SOC through the simpler recording of land use and intensity; it will then be unnecessary to take so many SOC

[2] A three-tiered process for data collection of LDN indicators (see Chapter 2.1.2)

samples across the country. Moreover, to determine nationwide carbon stock values, it is not necessary to physically cover the entire country in terms of soil sampling; instead, representative units can be analysed.

The proposed method for estimating soil carbon stocks focuses on generating data for national reporting and developing national and/or regional land degradation policies. However, there is also a need for data that can be used directly by land users to inform them of soil conditions for appropriate remediation measures.

MAIN FACTS: The importance of formalizing the new method

- *The proposed approach to record SOC_{stocks} is a scientifically sound method adapted to international standards. The adoption and implementation of the method allows the country to meet international (LDN) reporting requirements.*
- *The proposed method incorporates a cost-efficient approach to get accurate data on carbon stock assessment.*
- *Such reliable data are essential for informed decision-making at the regional or national level and can likewise be used to:*
- ➢ *determine the dynamics of organic carbon in soils in Kyrgyzstan;*
- ➢ *measure natural capital and ecosystem services, thus providing the opportunity to quantify and manage trade-offs between ecosystem services;*
- ➢ *conduct economic valuation of land in the private sector.*

4.2.2 Recommendations towards capacity development

This section addresses another important aspect of the operationalization of LDN – capacity building for assessment, monitoring, and reporting at the national level. Proposals to strengthen national capacities will also be distinguished according to the different layers of environmental data and information governance.

Technical infrastructure, data, and format layer

At the data management level, the analysis of the current potential of the national environmental information management system identified a number of problems, mainly a strong dependence on functional aspects such as technical infrastructure, rather than the correct format of information provision and focus on its potential use. In addition, the lack of standards that should accompany the digitalization process leads to fragmentation of information systems with datasets that are not interchangeable and cannot be integrated with each other. In this way, the issue of standardization appears to be central to almost all stages of information production, such as data collection, processing, dissemination, and use.

First, to obtain accurate data and benefit from such data (meaning the use of official data for various purposes), a standard must be strictly observed. As in the present work context, soil analysis involves a large number of standard procedures that need to be followed with high accuracy, step by step, in order to have reliable data that can be compared with other data, whether in other countries or within a single dataset. The proposed method takes into account the up-to-date requirements for the collection of SOC data, while considering the specific landscape of Kyrgyz Republic and the resulting dominant factors affecting SOC. Consideration was also given to existing national capacities (e.g. by following Kyrgyz standards for soil sample analysis) so that the method could be applied without external support. For other indicators relevant to LDN (land cover and land productivity), instead of choosing between several different approaches that exist for the computation of each indicator, a harmonization process leading to standardization is recommended wherever possible (UNCCD 2017). Formal recognition of the proposed SOC_{stocks} assessment method and agreement on the calculation of other LDN indicators is thus an important step in terms of standards compliance in the LDN reporting process.

Second, it is crucial to establish technical standards and an appropriate framework for the implementation of an LDN monitoring system based on a network of national and/or regional systems (UNCCD 2017). Common technical standards, in particular standards for data storage and format (e.g. disaggregation, open access, geospatial integration), should make it possible to (automatically) interconnect different online databases for more efficient information exchange (Keijzer and Klingebiel 2017). This is an important issue that must be taken into account when integrating SOC data and the established baseline for SOC records into existing digital shared information systems. In Kyrgyz Republic, there are plans for the newly established State Agency on Land Resources to create a digital database where all GIS data on land will be stored; this could be a suitable place to store SOC processed data, as well as becoming the main source of information on land cover and productivity in digital form. Additionally, raw and processed SOC data can be stored in Kyrgyzgiprozem as the main institution responsible for soil observations and integrated into the planned digital soil database. However, in such a case, the processed data should be readily accessible for use by other government departments and agencies. In any case, agreement must be reached on a common data format to increase their usability. For SOC data, it is important that the same data are collected and stored in the same way for each sample. Data must be stored in the same format (tables, notation, etc.) and in the same units (e.g. t/ha). This is particularly important for modelling: it is recommended to use standard software such as *R*[3] and *ArcGIS*. Georeferencing is essential.

Experts in the field suggest that storing data in centralized digital databases can improve the availability of data, for example by developing different layers of access (e.g. only for public authorities, land users, universities, NGOs). This will improve the exchange of information and lead to more efficient and faster decision-making on land use and planning issues. Moreover, in the case of automation systems, there is no dependence on one technical administrator to manage the data online, and data updates can be faster, which makes data analysis and data use more efficient. Potential problems related to coordination issues may still arise when reaching an agreement on a common data format, which requires time, funding, and making a political decision. The question of the format itself can be complex, depending on the availability of the digital data needed to assess and monitor land cover and land productivity, as well as the necessary human capacity and skills to handle georeferenced data.

Finally, at a more general level, in order to improve national reporting, a standardized process should be used to support the proactive part of administrative statistics, which would allow other data producers, not only the official statistical authorities, to submit data for official national reporting (Keijzer and Klingebiel

[3] R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

2017). This would mean that state departments and agencies collecting data for their own use should publish them, while the NSC could use these data for official statistics to avoid the double work that agencies and ministries do by completing the forms they receive from the NSC when collecting data for their own benefit and use. In addition, ideas should be developed on how information produced by non-state actors such as national universities or NGOs can also be verified and approved for use as official data.

Standardization of various aspects of data management is key to achieving data interoperability, which is an important feature of good quality data and is related to the possibility of easy reuse and processing in various applications, allowing different information systems to work together (JUDS 2016). Interoperability should be linked to both data collection and use and should be reflected in organizational practices and data management plans covering all parts of the information value chain. At the technical infrastructure level, the requirement that data be collected and stored in digitalized form and accessible through standardized formats in centralized online systems applies. At the data level, this reflects the need for standardized data collection and processing procedures. At the organizational level, this is about the effective allocation of responsibility for data collection, processing, analysis, and dissemination both within and across organizations (Morales and Orrell 2018). In Kyrgyz Republic, standardization of collection and processing of SOC data could be an important step in this direction.

In focusing on the information supply side, little attention is paid to the future use of data. In this vein, it is recommended to develop the capacity to deliver demand-driven data with particular attention to data users and future usability of data (Keijzer and Klingebiel 2017). In the case of LDN assessment, generation of data should not only be guided by the objective of complying with international reporting obligations (e.g. LDN or climate reporting), but also represent a visualization of the situation that should be available to national and regional authorities: the data obtained from the LDN assessment and its future monitoring provides evidence for land degradation policy development. UNCCD recommends viewing LDN assessment and future monitoring as a vehicle for learning as it provides i) opportunities for capacity building; ii) the basis to evaluate the decisions and interventions implemented and to plan future land management; and iii) the knowledge to inform adaptive management. Verification of monitoring results should also be a component of the learning process that will serve as a basis for adapting actions to achieve the LDN target (UNCCD 2017). Kyrgyz experts see the potential in the use of information generated by the Ministry of Agriculture for land resource assessment, crop structure planning, production forecasting, and food security. Proper storage and integration of LDN data into existing shared online systems should facilitate their use by decision makers at the national and/or regional levels for these purposes. In such a way, it should also be possible to use these data for the preparation of reports under other international conventions.

Achieving the desired changes with regard to interoperability and improved data usability depends largely on coordination. In situations where coordination is weak, information systems and data platforms often do not share common goals and lack the capacity to ensure synergy and coherence. The result is fragmented information systems with datasets that are not interoperable and which cannot be integrated with each other. This is a common problem that directly hinders the effective production and processing of data needed to achieve and monitor LDN (including other indicators, such as SDG indicators). Addressing this problem requires a coordinated approach and a set of common guidelines for all public authorities, which, from the beginning, should consider interoperability when it comes to purchasing IT solutions. This requires ensuring that data management and governance principles become integral components of organizational strategies (Morales and Orrell 2018). To achieve this, a coordinated approach and a set of common guidelines for all public authorities need to be developed by the government.

Table 7: Implications for change - Technical infrastructure, data, and format layer

Current capacity	Capacity development
Technical infrastructure, data, and format layer	
• heavy reliance on functional aspects of information provision, i.e. development and running of the data system	• focus on the right format of data production (i.e. unified format of data collection and storage, development of different layers of access, geospatial integration)
• focus on supply side of information provision	• focus on potential data users and impacts (e.g. the data obtained from the LDN assessment and its future monitoring provides evidence for land degradation policy development and can also be used for crop structure planning, production forecasting, and food security at national and regional levels)
• little focus on future data usability	
• low level of data interoperability due to outdated standards for data collection and storage	• improve data interoperability across the value chain of information by setting common technical standards to increase the possibility of more efficient reuse and processing of the same data in various applications, allowing different information systems to work together
• low data reliability and quality (high level of uncertainty) and weak processes of verification	• development of a verification process involving relevant stakeholders with various competences. Consider LDN monitoring as an instrument for learning (e.g. monitoring results can serve as a basis for adapting actions to achieve the LDN target)

Organizational layer

Setting the LDN target is not a stand-alone process: it provides opportunities for leverage and coordination across various ministries and sectors involved in land management. As a country-led process, the successful establishment and implementation of LDN targets depend on the highest level of political commitment and involvement of a wide range of sectors and stakeholders (UNCCD 2017). However, the current institutional environment in Kyrgyz Republic is fragmented and coordination between the public authorities and within agencies is weak. It is therefore proposed to focus on two main aspects to address the problems identified, i) distinguishing between the two organizational levels - “political” and “technical” and ii) various aspects of the LDN framework – its assessment, monitoring, and reporting.

First, it is essential to establish a permanent national working group on LDN in order to facilitate inter-ministerial and cross-sectoral cooperation. As the expert group established to prepare the first LDN report was dissolved after the report was finalized, the establishment of a new working group on a permanent basis would be a crucial step towards creating a coordination mechanism of integrated land use and management planning across scales and sectors to ensure stakeholder input to national and international decision making and reporting (UNCCD 2017). This group should include representatives of all responsible organizations involved in land-related issues, including Kyrgyz Academy of Sciences. This inter-ministerial group can be established at the initiative of MAFIM, which is the UNCCD focal point; however, in order to obtain a higher status and therefore ensure the integration of land degradation issues into the political agenda, national experts suggest forming it directly under the government of the Kyrgyz Republic. This may seem to be a complex task, but it is expected to be more effective than establishing a working group within one specific institution, which would limit its authority. Establishing such a group directly under the government could be an impetus in acting on land degradation. This will enable the emphasis to be placed on capacity building in ministries and sectors, as well as funding the necessary measures to achieve LDN.

The working group brings stakeholders together and serves as a platform for information exchange between representatives of all interested parties directly connected to land degradation processes and able to contribute to the achievement of LDN. To this end, the participation process should be enhanced (UNCCD 2017). There are currently many platforms for information exchange in Kyrgyz Republic, but most of them are rather informal in nature and are not institutionalized. The question remains how to formally initiate such platforms so that the various stakeholders can directly participate in the development of policies and processes related to LDN. If established under the government, the LDN working group could support and strengthen existing networks that operate in a way that is not linked to formal or official governance systems. This implies connecting existing exchange platforms at local and/or regional levels and linking them to broader governance systems at the national level. Furthermore, stakeholder involvement is essential for any LDN initiative to be effective. The Kyrgyz government (with the support of the suggested expert working group) need to develop outreach programmes to engage stakeholders in the co-production of knowledge and mutual learning at both the national and local levels, which could be accomplished through the establishment or leveraging of multi-stakeholder platforms at each relevant scale, with established links across scales as recommended by UNCCD (2017). Such multi-stakeholder platforms are important to guide LDN interventions using knowledge and engagement of local stakeholders. It is likewise important to validate the results of the LDN monitoring, which should be reviewed using national and local datasets and expert opinion to confirm the accuracy of monitoring data and the subsequent assessment of LDN status. Guidance is needed on how monitoring and verification can be conducted at the national level using a participatory approach through a multi-stakeholder platform that is linked to comparable platforms at the local level (for further detailed information please consult the UNCCD official Report of the Science-Policy Interface (UNCCD 2017)).

Given the diversity of land functions, a wide range of stakeholders and sectors should be actively involved in LDN process in Kyrgyz Republic (UNCCD 2016):

- Government agencies: agencies directly responsible for the development and implementation of land policies and plans at the national and subnational levels (e.g. MAFIM, SALR), as well as key ministries in environment/forestry, water, mining, energy, trade, economic development, and statistics, can become entry points for the implementation of the LDN agenda.
- Land users: stakeholders who make direct decisions on land management issues based on the type of land titles they hold. This diverse group includes small- and large-scale farmers, pasture and forest user communities, and private companies.
- Private service providers: those organizations who support land users and are indirectly involved in land management. This diverse group includes banks; seed, fertilizer, and machinery suppliers; energy and communications service providers; traders, producers, and chambers of commerce.

- Civil society organizations (NGOs): those who connect other stakeholders on land-related issues, working with local land users, their associations, and government agencies, such as Camp Alatoo, Kyrgyz Republic´s Community Development and Investment Agency (ARIS), and others.
- Development partners: multilateral and bilateral stakeholders who provide financial and technical support to those involved in land management.
- Science and national research institutes: those offering scientific advice on good land-use practices and related policy options, such as the Kyrgyz National Agrarian University, the Kyrgyz Soil Science Association, and the Kyrgyz Academy of Science.
- The NSC and all parts of national and subnational governments (e.g. District Agrarian Development Offices (DADOs)) play a crucial role when it comes to managing and verifying general aspects of data, statistics, and the overall data ecosystem.

The establishment of coordination mechanisms in the form of a single coordinating body directly under the Kyrgyz government, as well as in the form of multilateral platforms at the local, region, and national levels will facilitate the integration of LDN planning and implementation into existing land management processes, and improve the LDN reporting process, in which the Ministry of Agriculture will play a facilitating role as the focal point of the UNCCD and LDN.

Second, another aspect of a rather "technical" nature is the importance of assessment and monitoring of LDN in the country. Since the agrarian reform and until recent institutional changes, land assessment and monitoring appear to have been challenging and fragmented. It is therefore impossible to accurately assess changes, estimate the dynamics in due time, elaborate measures for land prevention and remediation, or provide control of the effectiveness of measures undertaken. At present, along with the recent creation of SALR, the idea of land consolidation is being revived, driven by an efficiency approach in economic terms. This process of establishing a new agency is already serving the purpose of focusing efforts and programmes aimed at improving land management and monitoring, and provides implicit recognition that a centralized system must be organized to better manage and evaluate data on land use and agriculture developments at the national level.

According to SALR's working plan, one of the priority developments is the creation of a fully functional land data infrastructure, that is all spatial land data stored in one geoportal, thus consolidating data from other state agencies that own any type of land data. Institutionally, this is now easier to achieve. On the basis of these developments, it is recommended that a centralized information system on land degradation issues for monitoring and evaluation of the LDN achievements is created (UNCCD 2016). This information system needs to be integrated into the planned geoportal and thus institutionalized within a permanent body, which will also facilitate inter-ministerial cooperation through the exchange of land data.

To make this possible, the recommendations outlined in the previous section should be followed. For example, it is important to agree on a standard for storing data formats, otherwise problems of consolidation and exchange of data between different agencies may arise. The information generated by this system must be accessible to all authorities that deal with land use. SALR is thus a key actor that should support MAFIM in generating information for LDN reporting and in facilitating inter-ministerial coordination on this issue. For this purpose, the processed SOC data should also be stored in this system. Spatial data required for land cover (perhaps derived from the European Space Agency's Climate Change Initiative Land Cover dataset[4]) and productivity (perhaps derived from the Joint Research Centre's Land Productivity Dynamics dataset[5]) estimations should also be stored in the geoportal and regularly updated. More centralized storage of all data in one place, necessary for LDN assessment and monitoring, is an effective way to organize its evaluation. Staff should be available to process these datasets and make the necessary calculations to estimate carbon stock changes based on land-use data. Otherwise, training of staff should be organized (e.g. if necessary, UNCCD can be requested to provide capacity-building support).

For the assessment of carbon stocks, the SOC record can be integrated into the current soil observations conducted by Kyrgyzgiprozem, which since 2019 is part of SALR. Then it would be possible to generate SOC data for arable land as a start. Potential constraints that may arise in this case are funding and staff capacity. Since the Republican Soil Agrochemical Station (RPAS) is the only state organization conducting soil analysis, it might not have sufficient capacity to collect SOC data. If this is the case, external services (e.g. Kyrgyz National Agrarian University) may conduct a SOC assessment, as it should be conducted only once, and then the state institute may take over the assessment of future carbon stock changes.

At present, there is no soil monitoring in forest and pasture areas. To estimate SOC stocks in forest areas, SOC assessments could be integrated into forest management inventories (FMI). This would also allow cost sharing for data provision. As this would require more time to collect data as well as additional laboratory analyses, this could be partially included in the forest inventory budget. Interviewed experts believe that FMI can benefit from integrating soil analysis into its structure, as SOC data can also be used to assess soil carbon sequestration potential in the context of climate change mitigation and the data can be used for climate reporting. In addition, soil data are important for planning forest-planting areas. Alternatively, SOC data collection in forest areas may be included in the carbon stock assessment assigned to an external agency. One of the main tasks to be addressed is the organization of pasture monitoring, which should be initiated by SALR. An important driving force for this would be the recognition of the serious state of pasture degradation and official support from the government. Kyrgyzgiprozem can take care of this, as it is already involved in monitoring pastures on the land surface and can combine both activities in the field. There are projects on pasture assessment running in the country and SOC assessments could be included in the data collection within these projects (e.g. FAO project on developing a global rangeland assessment method; but the method should be standardized in the future).

---

[4] http://maps.elie.ucl.ac.be/CCI/viewer/

[5] https://wad.jrc.ec.europa.eu/

Table 8: Development of the LDN framework in Kyrgyz Republic

<table>
<tr><th colspan="6">Possible organizational structure of LDN</th></tr>
<tr><th colspan="2"></th><th colspan="2">Assessment & Monitoring</th><th>Reporting</th><th>Implementation (achieving LDN)</th></tr>
<tr><td>„Political“ organizational level</td><td></td><td colspan="4">Establishment of a permanent LDN working group under the Government
(at the initiative of the Ministry of Agriculture)
• to foster inter-ministerial and cross-sectoral coordination (MAFIM, SALR (incl. Kyrgyzgiprozem and State Land Cadastre), SAEPF, NSC, Ministry of Finance, Academy of Science, KNAU, NGOs and public organizations)
• to enhance participation process through creation of a multi-stakeholder platform for information exchange between representatives of all interested parties
- to support and strengthen existing networks by organizing regular meetings
- to engage stakeholders in the co-production of knowledge and mutual learning
- to guide LDN interventions using knowledge and engagement of local stakeholders
- to validate the results of the LDN monitoring</td></tr>
<tr><td rowspan="4">„Technical“ organizational level</td><td>SOC indicator</td><td><u>Kyrgyzgiprozem (RPAS)</u>
• to collect and process soil data (SOC_{Stocks})</td><td rowspan="3">Online soil database
Establishment of a centralized information system (e.g. geoportal under SALR)
NSC data base
Forest management information system</td><td rowspan="3"><u>MAFIM</u>
• to assume responsibility for the fulfilment of reporting obligations as the focal point for UNCCD and LDN (supported by <u>SALR</u> in data production)</td><td rowspan="3"><u>MAFIM/SAEPF</u>
• to ensure informed decision making on land planning and agricultural development at national and regional levels
• to address national development priorities, such as food security, poverty reduction and climate change measures</td></tr>
<tr><td>Land cover indicator</td><td><u>State Land Cadastre/NSC/SAEPF</u>
• to collect and process land use data (based on national land registry and national forest inventories)</td></tr>
<tr><td>Land productivity indicator</td><td><u>Arable land – NSC</u>
• to collect and process data on national yields
<u>Pasture – Kyrgyzgiprozem</u>
• to collect and process geobotanical data
<u>Forest – SAEPF</u>
• to collect and process data based on forest management inventory</td></tr>
<tr><td></td><td colspan="4">NGOs, universities and research institutes, international organizations, etc.
• to contribute to and support LDN processes, using their knowledge and resource potential</td></tr>
</table>

As for the proposed responsibilities and tasks, there are several issues that need to be addressed. First, if the data are primarily produced in a georeferenced format, how will the NSC verify it? The NSC is usually responsible for the national data used in the preparation of international reports and relies on previous records that are available in an analogue format. This brings us back to the issue of the necessary standardization of environmental data collection and processing, especially with regard to data format issues. Second, a serious problem in the national environmental and land information systems is a lack of data validation. Third, how can NSC get involved and what role it should play in the processes of LDN assessment, monitoring, and reporting?

Last, but not least, the establishment of an official multi-stakeholder platform is relevant to addressing the issue of funding. It is expected that potential costs associated with LDN assessment, monitoring, and reporting activities will be mainly related to implementation of the SOC assessment and monitoring as well as coordination issues. Successful implementation of the LDN initiatives depends on effective mobilization of resources from all sources, starting from national budgets for data collection and reporting, external donors, and innovative sources of financing. The effective use of financial and human resources can be strengthened by seeking synergies among policies, commitments, and investments at both the global and national levels (UNCCD 2017).

Table 9: Implications for change - Organizational layer

Current capacity	Capacity development
Organizational layer	
• institutional fragmentation and weak cooperation between the authorities and non-governmental actors as well as within organizations	• strengthening cooperation across various ministries and sectors involved in land management (e.g. through establishment of a permanent LDN working group under the government, including civil society actors)
• lack of rules for data and information sharing	• adoption of a participatory approach through an organized multi-stakeholder platform (e.g. organizing regular meetings to bring together a wide range of stakeholders and sectors involved in LDN process)
	• establishment of a centralized land degradation monitoring and evaluation information system (e.g. geoportal under the SALR) and information policy development

Human layer

In addition to institutional capacity building, awareness-raising and communication play important roles in promoting support for the LDN process (Apasov 2020). LDN advocates raising awareness and communication about the cross-sectoral and multiple benefits of LDN measures, ensuring that key decision makers understand the innovative opportunities that LDN target setting can provide. In order to ensure sustainable and long-term awareness, information on ecosystem services, soil, and issues of environmental importance must be integrated into education on a large scale, starting at school.

At the level of LDN assessment, monitoring, and reporting, capacity building is a challenge in Kyrgyz Republic. International organizations that support capacity-building training and provide international expertise play a significant role in human resource capacity development of governmental ministries and agencies. National academic institutions and universities can also help strengthen human capacity by training and preparing specialists in environmental management, soil science, and computer science. Stakeholder engagement will facilitate the sharing of lessons learned and thus contribute to capacity building. Particular emphasis should be placed on building capacity within the relevant ministries and sectors. In this regard, multi-sectoral coordination will be essential as well as vertical coordination from the national level to sub-national and local governments and authorities (UNCCD 2017).

Kyrgyz experts believe that development of a mechanism to promote sustainable agricultural development in the country is important to create the basis for LDN implementation. Such a mechanism should include a programme aimed at raising awareness of the importance of soil for agriculture, including the development of infrastructure and laboratories for soil analysis. Society will also benefit from this, as less degraded land

and good soil means better food production and nutrition, and for the majority of the Kyrgyz population a guarantee of employment.

MAIN FACTS: Recommendations towards capacity development

- *To improve monitoring and reporting capacities at the national level, the following should be considered:*
- *We recommend focusing on the correct information production format, such as disaggregation, open access, and geospatial integration, as well as on possible data users and their impact.*
- *Data interoperability throughout the information value chain needs to be improved for potential reuse and processing of data in different applications, allowing different information systems to work together.*
- *The proactive part of administrative statistics should be supported, which would allow other data producers (e.g. universities, NGOs, land users), not just official statistical bodies, to provide official data.*
- *Coordination is key to achieving data interoperability. Therefore, it is important to strengthen cooperation between the various line ministries and sectors involved in land management by clearly defining rules and procedures for information exchange and use.*
- *Given the diversity of land functions, a wide range of stakeholders and sectors should be actively involved in LDN target setting and implementation. This can be achieved by creating a permanent LDN working group and involving representative of civil society.*
- *Considering LDN assessment and monitoring as a vehicle for learning is important as it provides capacity-building opportunities and a basis for testing hypotheses that underpin the counterbalancing decisions and the interventions implemented. Cooperation between German and Kyrgyz partners within the CARB-ASIA project is an important step in this process.*

Chapter 5. Conclusions and outlook

- The LDN reporting in Kyrgyz Republic is not yet well established but is making progress. The first national report revealed a number of limitations that Kyrgyz Republic has in meeting LDN international reporting requirements. These include unclear responsibilities and weak inter-ministerial coordination regarding land degradation issues as well as a lack of reliable, high-quality data on national SOC_{stocks} that could be used for both reporting and evidence-based decision making.
- The CARB-ASIA project has developed and tested a method for recording SOC_{stocks} that is suitable for LDN reporting. All national and global data available for Kyrgyz Republic were screened and tested for their suitability of estimating SOC_{stocks}. A specific survey design and sampling approach allowed for the incorporation of small-scale heterogeneity of SOC. The method is based on the following aspects:
  - With regard to SOC_{stocks}, representative units were determined, which show the correlation of SOC_{stocks} with the main land cover, elevation, and climate, based on available data.
  - Representative units were investigated and sampled in two field surveys. All units were sampled thrice, if possible, to increase statistical power. A total of 19 units were sampled covering 69 areas. As a result, the SOC survey was representative of more than 80% of the land area of Kyrgyz Republic.
- The results show that the method can predict $SOC_{stocks,}$ which is necessary for LDN reporting. Small-scale variability and the intensive sampling and analysis of the bulk density of fine soil, coarse soil, and root mass proved to be essential for a reliable recording of SOC_{stocks} in Kyrgyz soils. Land cover, elevation and precipitation were found to strongly affect SOC_{stocks} in Kyrgyz Republic. Surveys of forest areas, especially deciduous forest, are still underrepresented in the current sample size and should be carried out in future surveys.
- Kyrgyz Republic relies on a traditional approach of data provision, which is mainly supply-driven and includes bilateral approaches of information exchange. A new multidimensional approach is needed to promote more efficient data provision and their use for informed decision making in politics and land management as well as for national reporting. This approach should be based on appropriate methods of information acquisition accepted at the national level and should meet the international requirements, taking its potential impacts into account. The integration of a wide range of stakeholders and sectors that are actively involved in LDN target setting and implementation should also play a leading role. In anticipation of future reporting targets, additional capabilities should be planned, for example, for the preparation of the second LDN report in 2022 as well as national reporting on SDG indicators.
- Information management is not solely about data production and processing (infrastructure and data content), but also includes human, institutional, and organizational aspects – that is the societal and institutional dimensions of data provision. Land data and information governance are multidimensional, and consideration of the different factors of data functionality is recommended. A coordinated approach and a set of common guidelines for all participants involved in information creation, from the identification of what data are collected to their use for reporting and/or decision

making, are required along the entire value chain of information production. This would allow the principle of data interoperability to be integrated from the outset.

- The next step in implementing the proposed method is its official recognition at the national level. The Ministry of Agriculture, Food Industry and Melioration of the Kyrgyz Republic as the national focal point for UNCCD and LDN monitoring and reporting should lead the process of approval of the method. For instance, the method can be approved by the technical methodology department of the State Agency for Land Resources, which has been identified as playing a key role in the implementation processes of LDN. This step is essential to meet international reporting requirements as well as to get reliable data for informed decision making at the regional and national level.

5.2 Limitations of research

- The current Covid-19 situation may result in a shift of priorities in the country, so that environmental issues, such as land degradation would be neglected. That would be very unfortunate, as the question of food security in times of a crisis is particularly acute.
- Availability of high-resolution spatial digital data relevant for the estimation of SOC_{stocks}, such as land cover, is a major limitation.

5.3 Transferability of project results

- At present, all Central Asian countries face similar problems with regard to the collection, organization, storage, and sharing of land data in particular and environmental data in general. Major reasons for this problem are a lack of data, the absence of well-developed methodologies for data collection and evaluation, the incompatibility of national data with international standards, and the general lack of a permanent, well-functioning, multilateral assessment, monitoring, and reporting system as well as poor coordination of related processes. Due to the similar institutional structure of the Central Asian countries, we expect that our results and recommendations could be relevant to other countries in the region. Mountainous regions with comparable site ecology factors influencing SOC_{stocks}, such as Tajikistan, could adopt the method.
- Produced data can also be used for other climate reports, for example, IPCC in Kyrgyz Republic.
- The present work could be fruitful for current developments of the monitoring reporting verification (MRV) system as well. The results highlight key issues that are relevant beyond the LDN context and that need to be addressed to develop more reliable and effective information governance systems.

References

Adhikari, K.; Haremink, A.E.; Minasny, B.; Bou Kheir, R.; Greve, M.B.; Greve, M.H. 2014. Digital Mapping of Soil Organic Carbon Content and Stocks in Denmark. *PLoS One* 9(8): e105519, 1-13. doi: 10.1371/journal.pone.0105519.

Anarbaev, M. 2018. Soil Legislation and Policy in the Kyrgyz Republic on the Development of the Law "On Soil Fertility Protection of Agricultural Lands". In: Ginzky, H. et al. (eds.), International Yearbook of Soil Law and Policy 2017, https://doi.org/10.1007/978-3-319-68885-5_5.

Apasov R.T. 2020. Soil - a life resource. The article was published on June 17, 2020 in the national newspaper "Word of Kyrgyz Republic". To the World Day to Combat Desertification. Online: www.slovo.kg, last access: 08/10/2020.

Baibagyshov, E.; Walter, J.; Kasymov, U.; Zeitz, J. 2019. Measuring and Assessing Soil Organic Carbon to Archieve Land Degradation Neutrality in Kyrgyzstan. Proocedings. International Soil Congress 17-19 June 2019, Ankara, Turkey.

Bichsel, C.; Fokou, G.; Ibraimova, A.; Kasymov, U.; Steimann, B.; Thieme, S. 2010. Natural resource institutions in transformation: Tragedy and glory of the private. In: Hurni, H.; Wiesmann, U. with an international group of co-editors (eds.), Global Change and Sustainable Development: A Synthesis Regional Experiences From Research Partnerships. Bern, Switzerland: Geographica Bernensia, 255-269.

Blume, H.P.; Brümmer, G.Q.; Horn, R.; Kandeler, E.; Kögel-Knabner, I.; Kretzschmar, R.; Stahr, K.; Wilke, B.M. 2010. Scheffer/Schachtschabel. Lehrbuch der Bodenkunde. 16. Edition, Spektrum Akademischer Verlag Heidelberg.

Bloch, P. 2002. Kyrgyz Republic: Almost Done, What Next? *Problems of Post-Communism 49(1):* 61.

CAREC - The Regional Environmental Center for Central Asia. 2013. Towards Implementation of Shared Environmental Information System (SEIS) in Central Asia.

Crewett, W. 2012. Improving the Sustainability of Pasture Use in Kyrgyz Republic. The Impact of Pasture Governance Reforms on Livestock Migration. *Mountain Research and Development* 32(3): 267-274. doi: 10.1659/MRD-JOURNAL-D-11-00128.1.

Dai, W.; Huang, Y. 2006. Relation of soil organic matter concentration to climate and altitude in zonal soils of China. *Catena* 65 (1), 87–94. doi:10.1016/j.catena.2005.10.006.

De Brogniez, D.; Ballabio, C.; Stevens, A.; Jones, R.J.A.; Montanarella, L.; van Wesemael, B. 2015. A map of the topsoil organic carbon content of Europe generated by a generalized additive model. European Journal of Soil *Science* 66 (1): 1-14. doi: 10.1111/ejss.12193.

Dieleman, W.I.J.; Venter, M.; Ramachandra, A.; Krockenberger, A.K.; Bird, M.I. 2013. Soil carbon stocks vary predictably with altitude in tropical forests: Implications for soil carbon storage. *Geoderma* 204-205: 59-67. doi: 10.1016/j.geoderma.2013.04.005.

Doblas-Miranda, E.; Rovira, P.; Brotons, L.; Martínez-Vilalta, J.; Retana, J.; Pla, M.; Vayreda, R. 2013. Soil carbon stocks and their variability across the forests, shrublands and grasslands of peninsular Spain. *Biogeosciences* 10: 8353-8361. doi: 10.5194/bg-10-8353-2013.

Dorji, T.; Odeh, I.O.A.; Field, D.J. 2014. Vertical distribution of soil organic carbon density in relation to land use/cover, altitude and slope aspect in the Eastern Himalayas. *Land* 3, 1232–1250. doi: 10.3390/land3041232.

Eckelmann, W.; Sponagel, H.; Grottenthaler, W.; Hartmann, K.-J.; Hartwich, R.; Janetzko, P.; Joisten, H.; Kühn, D.; Sabel, K.-J.; Traidl, R.; Ad-hoc-Arbeitsgruppe Boden (eds.). 2005. Bodenkundliche Kartieranleitung. 5. Edition, Schweizerbart: Stuttgart.

esri. 2017. ArcGIS Desktop, Version 10.5.1. Online: http://www.esri.com/arcgis/about-arcgis, last access: 08/10/2020.

GAFA - Gutachterausschuss Forstliche Analytik (Hg.) 2009. Handbuch Forstliche Analytik. 4. edition. Online: https://www.bmel.de/SharedDocs/Downloads/Landwirtschaft/Wald-Jagd/Bodenzustandserhebung/Handbuch/HandbuchForstanalytikKomplett.pdf?__blob=publicationFile, last access: 08/10/2020.

Garcia-Pausa, J.; Casals, P.; Camarero, L.; Huguet, C.; Sebastià, M.-T.; Thompson, R.; Romanyà, J. 2007. Soil organic storage in mountain grasslands of the Pyrenees: effects of climate and topography. *Biogeochemistry* 82: 279-289. doi: 10.1007/s10533-007-9071-9.

Garten Jr., C.T.; Post, W.M.; Hanson, P.J.; Cooper, L.W. 1998. Forest soil carbon inventories and dynamics along an elevation gradient in the southern Appalachian Mountains. *Biogeochemistry* 45: 115-145.

Goldstein, E.; Gasser, U.; Budish, R. 2018. Data Commons Version 1.0: A framework to build toward AI for good: A roadmap for data from the 2018 AI for Good Summit. Cambridge, MA: Berkman Klein Center for Internet and Society, Harvard University.

Gotgelf, A. (*in preparation*). Assessing, monitoring and reporting on Land Degradation Neutrality: Social dilemmas in informational governance.

Gottschling, H. 2006. Die Naturräume des Biosphärenreservates Issyk-Kul in Kirgisistan. Eine landschaftsökologische Studie an Transekten. Greifswalder geographische Arbeiten. Institute for Geography and Geology of the Ernst-Moritz-Arndt-University Greifswald.

GOST 26423-85. 2011. Методы определения удельной электрической проводимости, pH и плотного остатка водной вытяжки – Soils. Methods for determination of specific electric conductivity, pH and solid residue of water extract. Moscow.

GOST 12536-79. 2008. Грунты. Методы лабораторного определения зернового (гранулометрического) и микроагрегатного состава – Soils. Methods of laboratory granulometric (grain size) and microaggregate distribution. Moscow.

GOST 26213-91. 1992. Методы определения органического вещества – Soils. Methods for determination of organic matter. Moscow.

Griffiths, R.P.; Madritch, M.D.; Swanson, A.K. 2009. The effects of topography on forest soil characteristic in the Oregon Cascade Mountains (USA): implications for the effects of climate change on soil properties. *Forest Ecology and Management* 257: 1-7. doi: 10.1016/j.foreco.2008.0 8.010.

IAEG-SDGs. 2016. Report of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators. Statistical Commission. UN Economic and Social Council.

IPCC. 2006. Guidelines for National Greenhouse Gas Inventories. Volume 4: Agriculture, Forestry and Other Land Use. Genf. Online: http://www.ipcc-nggip.iges.or.jp/public/2006gl/ vol4.html, last access: 08/10/2020.

Jacobs, A.; Flessa, H.; Don, A.; Heidkamp, A.; Prietz, R.; Dechow, R.; Gensior, A.; Poeplau, C.; Riggers, C.; Schneider, F.; Tiemeyer, B.; Vos, C.; Wittnebel, M.; Müller, T.; Säurich, A.; Fahrion-Nitschke, A.; Gebbert, S.; Hopfstock, R.; Jaconi, A.; Kolata, H.; Lorbeer, M.; Schröder, J.; Laggner, A.; Weiser, C.; Freibauer, A. 2018. Landwirtschaftlich genutzte Böden in Deutschland. Ergebnisse der Bodenzustandser-hebung. Thünen Report 64, Braunschweig. Online: https://literatur.thuenen.de/digbib_ex tern/dn060497.pdf, last access: 08/10/2020.

JUDS (Joined-Up Data Standards project). 2016. The frontiers of data interoperability for sustainable de-velopment. Available at: http://devinit.org/wp-content/uploads/2018/02/Thefrontiers-of-data-interoperabil-ity-for-sustainable-development.pdf

Keijzer, N.; Klingebiel, S. 2017. Realizing the Data Revolution for Sustainable Development: Towards Capacity Development 4.0. Discussion Paper No. 9. Partnership in Statistics for Development in the 21st Century.

Kerven, C.; Steinmann, B.; Ashley, L.; Dear, C.; Rahm, I. 2011. Pastoralism and Farming in Central Asia's Mountains: A Research Review. University of Central Asia, Mountain Societies Research Center. doi: 10.5167/uzh-52730.

Kyrgyz Republic. 2014. The National Action Plan (NAP) and the activity frameworks for implementing the UNCCD in the Kyrgyz Republic for 2015-2020. Developed in the framework of implementation of the Global Environment Facility-World Bank Project "Support to UNCCD NAP alignment and reporting process". TF012759. Bishkek.

Kyrgyz Republic. 2018. НАЦИОНАЛЬНЫЙ ОТЧЁТ ПО НЕЙТРАЛЬНОМУ БАЛАНСУ ДЕГРАДАЦИИ ЗЕМЛИ. LDN TSP Country Report. Online: https://knowledge.unccd.int/sites/default/files/ldn_targets/201811/Kyrgyz Republic%20LDN%20TSP%20Country%20Report.pdf, last access: 08/10/2020.

Lal, R. 2004. Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. *Science* 304: 1623-1627. doi: 10.1126/science.1097396.

Leifeld, J.; Zimmermann, M.; Fuhrer, J.; Conen, F. 2009. Storage and turnover of carbon in grassland soils along an elevation gradient in the Swiss Alps. *Global Change Biology* 15: 668-679. doi: 10.1111/j.1365-2486.2008.01782.x.

Ludi, E. 2003. Sustainable Pasture Management in Kyrgyz Republic and Tajikistan: Development Needs and Recommendations. *Mountain Research and Development*, 23(2): 119-123. doi: 10.1659/0276-4741(2003)023[0119:SPMIKA]2.0.CO;2.

Mehler, K.; Schöning, I.; Berli, M. 2014. The Importance of Rock Fragment Density for the Calculation of Soil Bulk Density and Soil Organic Carbon Stocks. *Soil Science Society of America Journal* 78(4): doi: 10.2136/sssaj2013.11.0480.

Morales, L.G.; Orrell, T. 2018. Data interoperability: a practitioner's guide to joining up data in the development sector.

Orr, B.J.; Cowie, A.L.; Castillo Sanchez, V.M.; Chasek, P.; Crossman, N.D.; Erlewein, A.; Louwagie, G.; Maron, M.; Metternicht, G.I.; Minelli, S.; Tengberg, A.E.; Walter, S.; Welton, S. 2017. Scientific Conceptual Framework for Land Degradation Neutrality. A Report of the Science-Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany.

Poeplau, C.; Vos, C.; Don, A. 2017. Soil organic carbon stocks are systematically overestimated by misuse of the parameters bulk density and rock fragment content. *Soil* 3: 61-66. doi:10.5194/soil-3- 61-2017.

Post, W.M.; Kwon, K.C. 2000. Soil carbon sequestration and land-use change: processes and potential. *Global Change Biology* 6(3): 317-327. doi: 10.1046/j.1365-2486.2000.00308.x.

Prietzel, J.; Christophel, D. 2014. Organic carbon stock in forest soils of the German Alps. *Geoderma* 221-222, 28–39. doi: 10.1016/j.geoderma.2014.01.021.

R Core Team. 2018. R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing.

Renger, M.; Kaupenhohann, M.; Wessolek, G. 2009. Bodenphysikalische Kennwerte und Berechnungsverfahren für die Praxis. Bodenökologie und Bodengenese 40, TU Berlin Selbstverlag, Berlin.

Rowell, D. L. 1994. Bodenkunde – Untersuchungsmethoden und ihre Anwendungen. Springer-Verlag, Heidelberg.

Rytter, R.-M. 2012. Stone and gravel contents of arable soils influence estimates of C and N stocks, *Catena* 95: 153-159. doi:10.1016/j.catena.2012.02.015.

Schimel, D.S.; Braswell, R.; Holland, E.A.; McKeown, R.; Ojima, D.S. 1994. Climatic, edaphic, and biotic controls over storage and turnover of carbon in soils. *Global Biogeochemical Cycles* 8(3): 279-293. doi:10.1029/94GB00993.

Simon, A.; Dhendup, K.; Rai, P.B.; Gratzer, G. 2018. Soil carbon stocks along elevational gradients in Eastern Himalayan mountain forests. *Geoderma Regional* 12: 28-38. doi: 10.1016/j.geodrs.2017.11.004.

Tashi, S.; Singh, B.; Keitel, C.; Adams, M. 2016. Soil carbon and nitrogen stocks in forests along an altitudinal gradient in the eastern Himalayas and a meta-analysis of global data. *Global Change Biology* 22 (6), 2255–2268. doi: 10.1111/gcb.13234.

Throop, H.-L.; Archer, S.R.; Monger, H.C.; Waltman, S. 2012. When bulk density methods matter: Implications for estimating soil organic carbon pools in rocky soils. *Journal of Arid Environments* 77: 66-71. doi:10.1016/j.jaridenv.2011.08.020.

UNCCD. 2015. Report of the Conference of the Parties on its twelfth session, held in Ankara from 12 to 23 October 2015. Part two: Actions taken by the Conference of the Parties at its twelfth session. UNCCD/COP(12)/20/Add. Bonn: United Nations Convention to Combat Desertification.

UNCCD. 2016. Achieving Land Degradation Neutrality at the country level Building blocks for LDN target setting. The Global Mechanism of the UNCCD.

UNCCD. 2017. Methodological note to set national voluntary Land Degradation Neutrality (LDN) targets using the UNCCD indicator framework. Global Support Programme Land Degradation Neutrality Target Setting Programme. Online: https://knowledge.unccd.int/sites/default/files/2018-08/LDN%20Methodological%20Note_02-06-2017%20ENG.pdf, last access: 08/10/2020.

UNCCD. 2018. Default data: methods and interpretation. A guidance document for the 2018 UNCCD reporting. UNCCD, Bonn. Online: https://prais.unccd.int/sites/default/files/helper_documents/3-DD_guidance_EN.pdf, last access: 08/10/2020.

UNCCD, CBD, FAO, STAP. 2016. Framework and Guiding Principles for a Land Degradation Indicator. To monitor and report on progress towards target 15.3 of the Sustainable Development Outcomes of the Expert Meeting., 2016. Goals, the strategic objectives of the Rio Conventions and other relevant targets and commitments. Washington DC. Online: https://www.unccd.int/sites/default/files/relevant-links/2017-01/Framework%20and%20Guiding%20Principles%20for%20a%20Land%20Degradation%20Indicator.pdf, last access: 08/10/2020.

UPAGES Report. 2016. "Utilisation and Protection of Agricultural Ecosystems in Central Asian High Mountains-Case Study Kyrgyz Alpine Pastures." Humboldt-Universität zu Berlin, Kyrgyz National Agricultural University.

Wang, S.; Wang, X.; Quyang, Z. 2012. Effects of land use, climate, topography and soil properties on regional soil organic carbon and total nitrogen in the Upstream Watershed of Miyun Reservoir, North China. *Journal of Environmental Sciences* 24(3): 387-395. doi: 10.1016/S1001-0742(11)60789-4.

Wiesmeier, M.; Barthold, F.; Blank, B.; Kögel-Knabner, I. 2011. Digital mapping of soil organic matter stocks using Random Forest modeling in a semi-arid steppe ecosystem. *Plant Soil* 340: 7-24. doi: 10.1007/s11104-010-0425-z.

Wolff, B.; Riek, B. 2006. Evaluierung von Verfahren zur Erfassung des Grobbodenanteils von Waldböden. Erarbeitung von Empfehlungen für die Anwendung dieser Verfahren im Rahmen der Bodenzustandserhebung im Wald. Final report. Forest + Soil Environmental Consultation GmbH on behalf of the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV).

Zhao, Y.; Ding, Y.; Hou, X.; Li, F.Y.; Han, W.; Yun, X. 2017. Effects of temperature and grazing on soil organic carbon storage in grasslands along the Eurasian steppe eastern transect. *PLoS ONE* 12(10): e0186980. doi: 10.1371/journal.pone.0186980.

Data:

Consortium for Spatial Information. 2019. SRTM 90m Digital Elevation Database. Data online: http://srtm.csi.cgiar.org/, last access: 08/10/2020.

Fick, S.E.; Hijmans, R.J. 2017. Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology*. Data online: http://worldclim.org/version2, last access: 08/10/2020.

UNCCD. 2018. Default data: methods and interpretation. A guidance document for the 2018 UNCCD reporting. UNCCD, Bonn. Online: https://prais.unccd.int/sites/default/files/helper_documents/3-DD_guidance_EN.pdf, last access: 08/10/2020.

Appendix

A. Sampling points

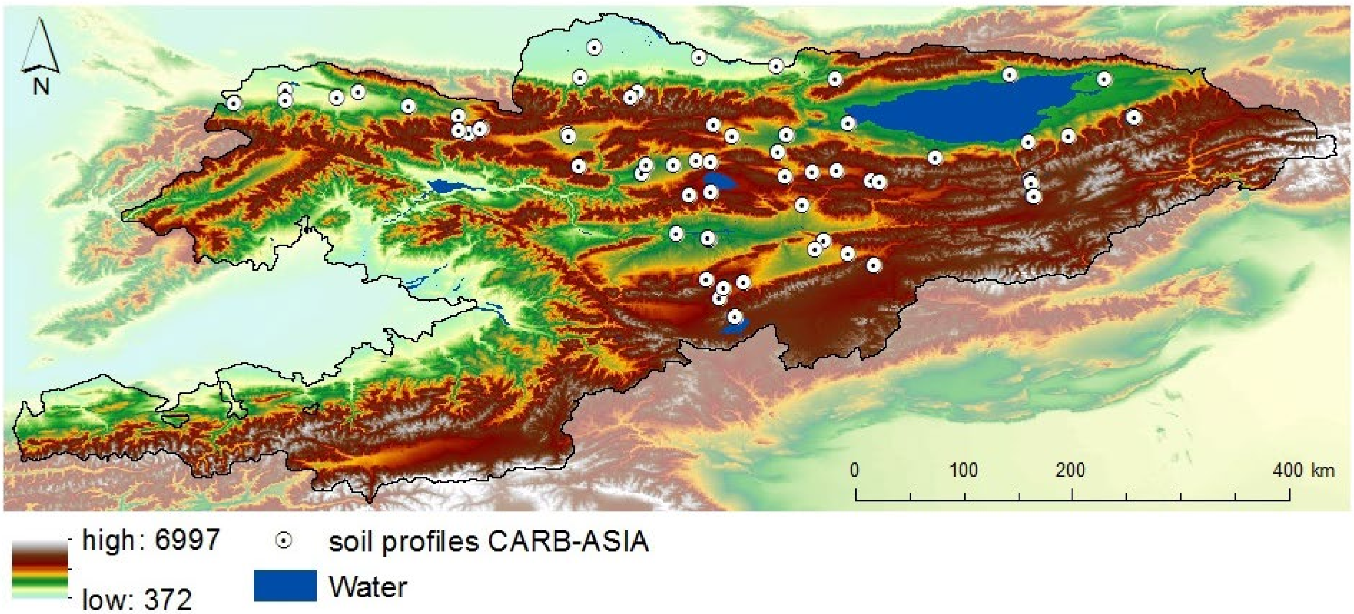


Figure 18: Soil profiles of the CARB-ASIA project

B. Profile recording sheet

Table 10: Profile record sheet used for CARB-ASIA

Site survey	
Profile number	
Representative unit [m^2]	
Elevation above sea level [m]	
Date	
Number of profiles per unit (north-facing slope=1, south-facing slope=2)	
Coordinates	
Slope	
Exposition	
Relief form type (*slope* or *plain*)	
Relief position (*central* or *peripheral location)*	
Weather (approximate last time of rainfall)	
Land-use	
Vegetation	
Estimate of the coarse soil content >63 mm in area (%*)	
Comments	
* if existing	

Figure 19: Use of an Edelmann drill

Figure 20: Core rings for the determination of the bulk density of the fine soil

C. Formulae for calculating the individual parameters

Bulk density of the fine soil

To calculate the $BD_{fine\ soil}$, two case distinctions had to be made according to Table 3 (Jacobs et al. 2018, modified according to GAFA A2.8 2009).

Cases A-D:

$$BD_{fine\ soil} = \frac{M_{SZ} - M_{GB-SZ} - M_{W-SZ}}{V_{SZ} - \frac{M_{GB-SZ}}{D_{GB}} - \frac{M_{W-SZ}}{D_W}} \quad (2)$$

$BD_{fine\ soil}$	Bulk density of the fine soil [g/cm³]
M_{SZ}	Mass of the soil sample taken by means of the core ring [g]
V_{SZ}	Volume of the core ring [cm³]
M_{GB-SZ}	Mass of the coarse soil in the soil sample taken with the core ring [g]
M_{W-SZ}	Mass of roots in the soil sample taken with the core ring [g]
D_{GB}	Density of the coarse soil [g/cm³] (=2.65 g/cm³)
D_W	Density of the roots [g/cm³] (Rowell 1994; 1.0 g/cm³)

Cases E and F were not used

Case G:

For case G a transfer function modified by the humus content according to Renger et al. (2009) was used (Jacobs et al. 2018). The uncertainty of the $BD_{fine\ soil}$ estimate increases with the humus content, therefore a humus factor is used in the formula for correction (Table 11).

Table 11: Humus factor for correction in the transfer function (Jacobs et al. 2018)

Humus content	1 – <6%	6 – 15%
Minimization of the $BD_{fine\ soil}$	0.04 g/cm³ per percent humus content	0.03 g/cm³ per percent humus content

$$BD_{fine\ soil} = BD - 0.005 * clay\ [\%] - 0.001 * silt\ [\%] - humusfactor \quad (3)$$

$BD_{fine\ soil}$	Bulk density of the fine soil [g/cm³]
BD	Bulk density by approximation according to Eckelmann et al. (2005)

Fine soil content

The formula for calculating the fine soil content must be adjusted according to the coarse soil proportions (case distinction, Table 3) (Jacobs et al. 2018, modified according to GAFA A2.8 2009).

Case A:

$$FBV = BD_{fine\ soil} * d * 100 * \left(1 - \frac{M_{GB-SZ}}{D_{GB} * V_{SZ}} + \frac{M_{W-SZ}}{D_{W-SZ} * V_{ges-SZ}}\right) \tag{4}$$

FBV	Fine soil content [t/ha]
$BD_{fine\ soil}$	Bulk density of the fine soil [g/cm³]
d	Thickness of the depth horizon [cm]
M_{GB-SZ}	Dry mass of the coarse soil (≥ 2 mm) in the core ring (SZ) [g]
D_{GB}	Density of the coarse soil [g/cm³] (=2.65 g/cm³)
V_{SZ}	Volume of the core ring [cm³]
M_{W-SZ}	Mass of roots in the soil sample taken with the core ring [g]
D_{W-SZ}	Density of the roots [g/cm³] (Rowell 1994; 1.0 g/cm³)

Case B:

$$FBV = BD_{fine\ soil} * d * 100 * \left(1 - \frac{0.66 * F_{GB>20}}{100} + \frac{M_{GB-SZ}}{D_{GB} * V_{SZ}} + \frac{M_{W-SZ}}{D_{W} * V_{ges-SZ}}\right) \tag{5}$$

FBV	Fine soil content [t/ha]
$BD_{fine\ soil}$	Bulk density of the fine soil [g/cm³]
d	Thickness of the depth step [cm]
$0.66 * F_{GB>20}$	Volume fraction of the coarse soil (>20 mm) according to the estimated value on the profile wall (in area %; conversion to volume % is done by the factor 0.66 in the formula (GAFA A 2.8 2009))
M_{GB-SZ}	Dry mass of the coarse soil (≥2 mm) in the core ring (SZ) [g]
D_{GB}	Density of the coarse soil [g/cm³] (=2.65 g/cm³)
V_{SZ}	Volume of the core ring [cm³]
M_{W-SZ}	Mass of roots in the soil sample taken with the core ring [g]
D_{W-SZ}	Density of the roots [g/cm³] (Rowell 1994; 1.0 g/cm³)

Case C and E:

$$FBV = BD_{fine\ soil} * d * 100 * \left(1 - \left(\frac{M_{GB-SP}}{D_{GB}} * \frac{BD_{fine\ soil}}{(M_{SP} - M_{GB2-63-SP} - M_{W-SP}) + BD_{fine\ soil} * \frac{M_{GB2-63-SP}}{D_{GB}}}\right)\right) \quad (6)$$

FBV	Fine soil content [t/ha]
$BD_{fine\ soil}$	Bulk density of the fine soil [g/cm³]
d	Thickness of the depth step [cm]
M_{GB-SP}	Dry mass of the coarse soil (≥2 mm) in the spade sample [g]
D_{GB}	Density of the coarse soil [g/cm³] (=2.65 g/cm³)
M_{SP}	Dried total mass of the spade sample [g]
$M_{GB2-63-SP}$	Dry mass of the coarse soil (2–63 mm)
M_{W-SP}	Dry mass of the roots in the spade sample [g]

Case D and F:

$$FBV = BD_{fine\ soil} * d * 100 * \left(1 - \frac{0.66 * F_{GB>62}}{100} - \left(\frac{M_{GB-SP}}{D_{GB}} * \frac{BD_{fine\ soil}}{(M_{SP} - M_{GB2-63-SP} - M_{W-SP}) + BD_{fine\ soil} * \frac{M_{GB2-63-SP}}{D_{GB}}}\right)\right) \quad (7)$$

FBV	Fine soil content [t/ha]
$BD_{fine\ soil}$	Bulk density of the fine soil [g/cm³]
d	Thickness of the depth step [cm]
$0.66 * F_{GB>63}$	Volume fraction of the coarse soil (>63 mm) according to the estimated value on the profile wall (in area %; conversion to volume % is done by the factor 0.66 in the formula (GAFA A 2.8 2009))
M_{GB-SP}	Dry mass of the coarse soil (≥2 mm) in the spade sample [g]
D_{GB}	Density of the coarse soil [g/cm³] (=2.65 g/cm³)
M_{SP}	Dried total mass of the spade sample [g]
$M_{GB2-6.3-SP}$	Dry mass of the coarse soil (2–6.3 mm) of the spade sample [g]
M_{W-SP}	Dry mass of the roots in the spade sample (g)
D_{W-SZ}	Dry mass of the roots (Rowell 1994; 1,0 g/cm³)

Case G:

$$FBV = BD_{finesoil} * d * (100 - 0.66 * F_{GB}) \tag{8}$$

FBV	Fine soil content [t/ha]
$BD_{fine\ soil}$	Bulk density of the fine soil [g/cm³]
d	Thickness of the depth step [cm]
0.66 * F_{GB}	Volume fraction of the coarse soil (≥2 mm) according to the estimated value on the profile wall (in area %; conversion to volume % is done by the factor 0.66 in the formula (GAFA A 2.8 2009))

Soil organic carbon stock

To calculate the SOC_{stocks}, the percentage SOC content was converted into mass content (g/kg) and then multiplied by the fine soil content (Wolff and Riek 2006; Jacobs et al. 2018).

$$SOC_{stock} = FBV * \mathrm{SOC} \tag{9}$$

SOC_{stocks}	Soil organic carbon stock [t/ha]
FBV	Fine soil content [t/ha]
SOC	Soil organic carbon content [g/kg]

D. Influencing factor clay

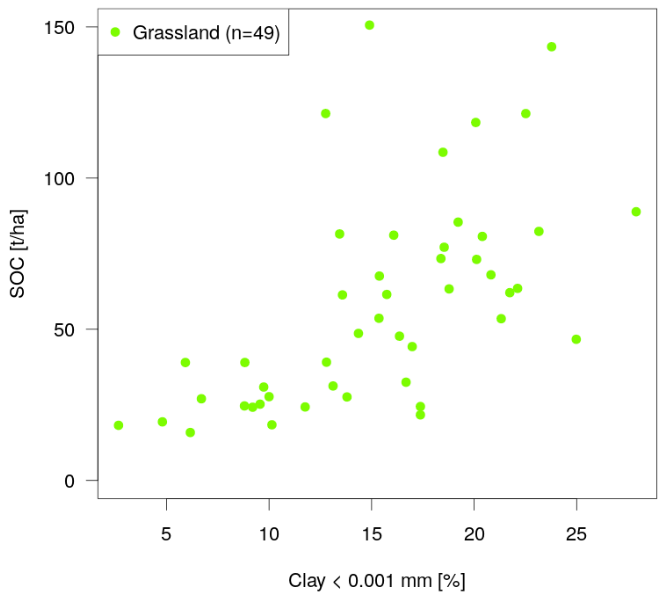


Figure 21: Relationship between percentage clay content and soil organic carbon stocks in tonnes per hectare for grassland sites

E. Small-scale variability

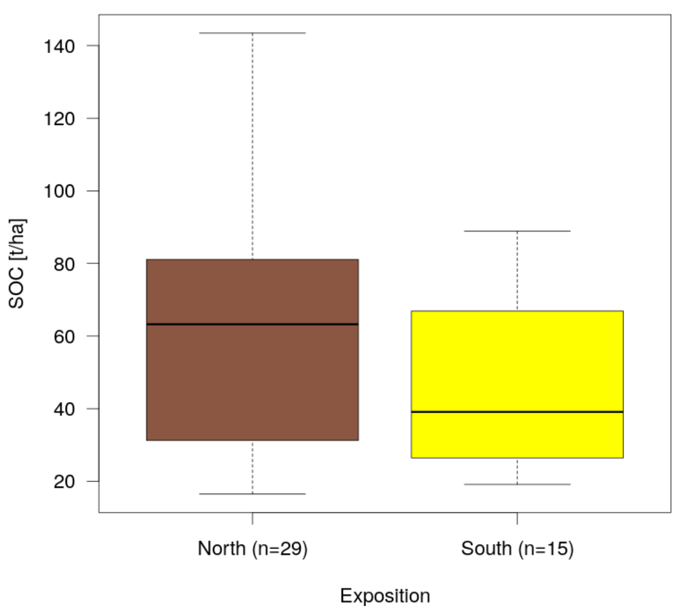


Figure 22: Relationship between exposition and soil organic carbon stock in tonnes per hectare for the land-cover class grassland

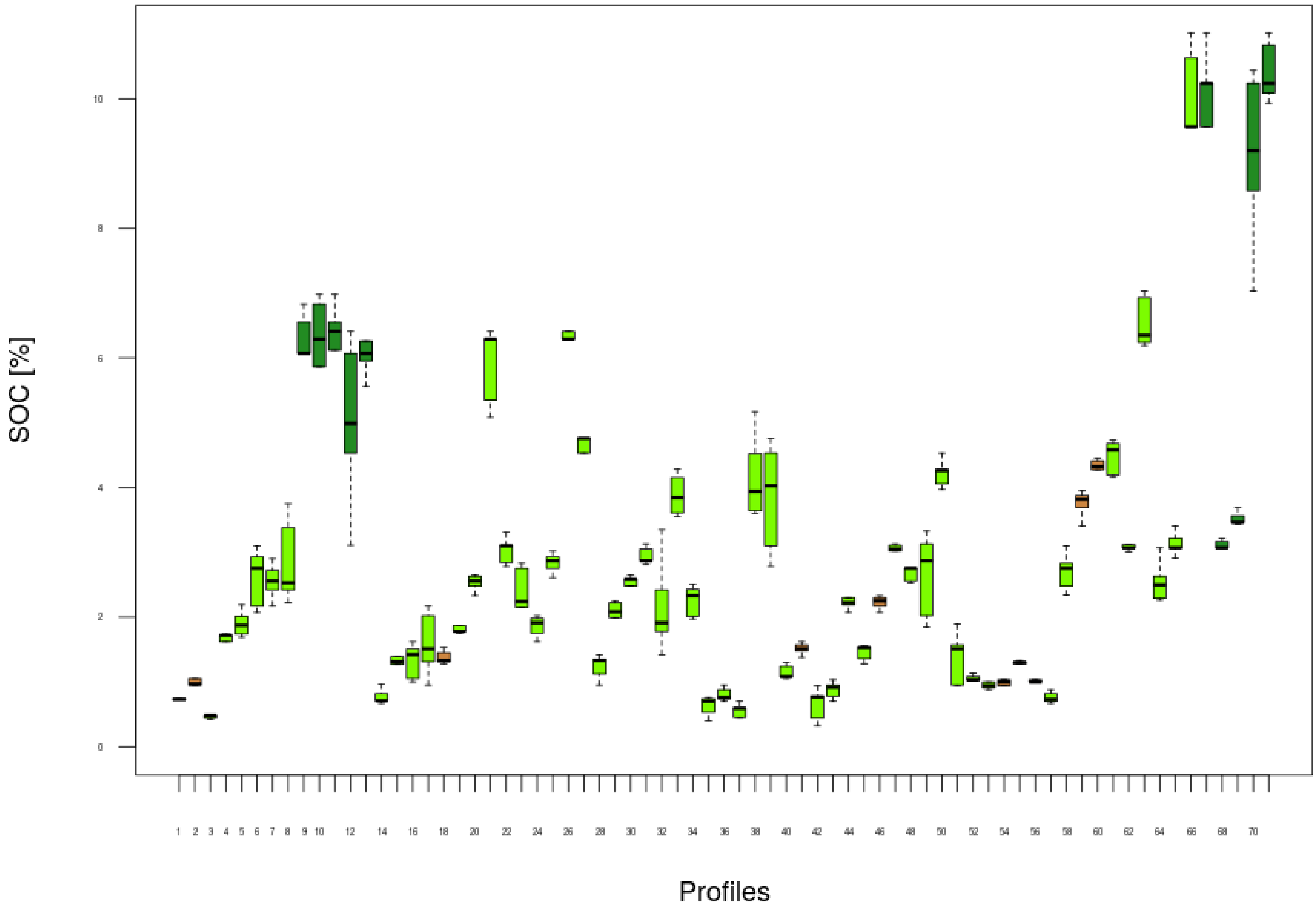


Figure 23: Small-scale variability of the percentage of organic carbon content of the sampling points

F. Selected individual parameters and their correlations

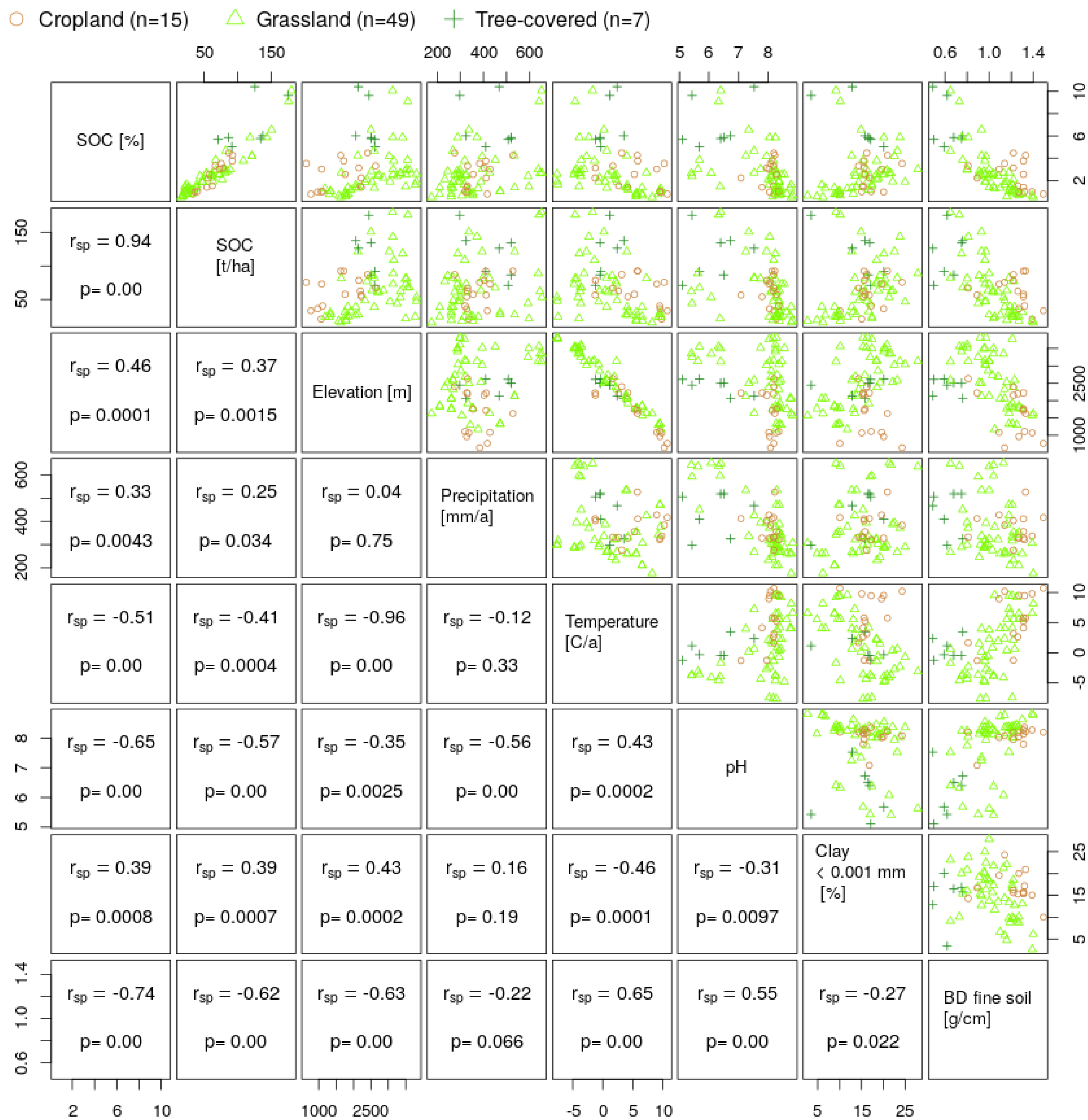


Figure 24: Relationships of the individual parameters to each other with specification of the correlation coefficient according to Spearman (r_{sp}) and the probability measure (p). (SOC= soil organic carbon, $BD_{fine\ soil}$ = bulk density of the fine soil)