Food and Agriculture Organization
of the United Nations


# AFGHANISTAN SOIL INFORMATION SYSTEM (AfSIS)

July 2019

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| SDGs: | 15 LIFE ON LAND |
| Countries: | Islamic Republic of Afghanistan |
| Project Codes: | TCP/AFG/3601 |
| FAO Contribution: | USD 497 000 |
| Duration: | 1 April 2016 – 31 March 2019 |
| Contact Info: | FAO Representation in Afghanistan<br>FAO-AF@fao.org |


### Implementing Partner

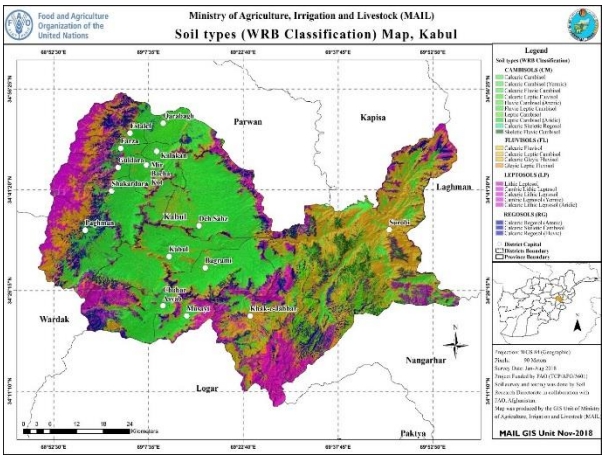
Ministry of Agriculture, Irrigation and Livestock (MAIL).

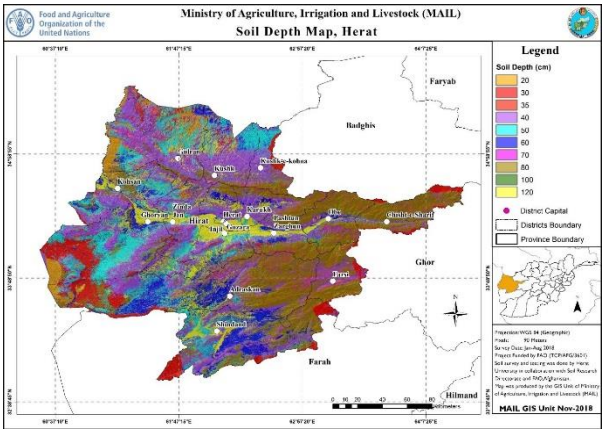
### Beneficiaries

Key decision-makers, including Ministry of Water and Power, Ministry of Urban Development Affairs, Ministry of Mines, academic institutions, local authorities, water communities and catchment management authorities, the private sector, civil society organizations and farmer associations.

### Country Programming Framework

CPF No 4: Support to better natural resource management – Outcome 4.1: Enhanced capacity to improve sustainable environmental management, including in terms of policy-making capacity and information management, and ensure rehabilitation of the natural resource base.




## Background

Over 80 percent of Afghanistan's population lives in rural areas, where the main income comes from agricultural production. On-farm management practices are often highly extensive, putting the country's soils under intense pressure and causing various types of degradation. Available data on Afghanistan's soils are limited and earlier soil surveys have lacked a systematic approach and standardized methods. Sustainable soil management requires systematic soil data collection through field surveys and the continuous monitoring of soil properties organized into an appropriate data base and soil information system (SIS). The creation of such a system, providing accurate and up-to-date soil information, is thus a high priority, as it will enable sustainable land management at farm level and assist in the efficient monitoring of land degradation processes.

Once in place, the Afghanistan Soil Information System (AfSIS) will contain data and information relating to the spatial variability of soil types and soil properties integrated with such natural co-variables as climate, vegetation, geology, relief conditions, hydrology and hydrography. It can be continuously upgraded and extended with new information from the field and will serve as a reference centre for storing all valuable soil data.

The aim of the project was to identify, collect, evaluate, synchronize and systematize existing soil and non-soil data into a geodatabase integrating the various data sets. The data stored will enable the application of digital soil mapping (DSM) tools and models for the prediction of spatial distribution of soil properties, the identification of possible threats and pressures, risk assessment and the implementation of measures to mitigate soil degradation processes. The project would also strengthen the technical capacities of the country's soil science community in the conduct of systematic and standardized field and laboratory soil properties analyses.

## Impact

The project has contributed to the implementation of sound policies, strategies and actions related to sustainable soil management as a necessary step towards the sustainable development of the country. The use of AfSIS will also assist decision-makers in their actions towards climate change impact mitigation and adaptation, and, in particular, will aid the future soil monitoring system of the country, ensuring sustainable agricultural land management in Afghanistan over the medium to long term for increased agricultural production and rural development.

## Achievement of results

The project successfully mapped 2 000 000 ha of land, exceeding its target by 500 000 ha, and equipped eight soil laboratories to conduct soil surveys and analyse soil samples. A permanent soil geodatabase was established at the Agriculture Statistic Directorate, MAIL, which can be used to update soil mapping and manage future soil survey and analysis data. One national soil type map and nine provincial soil type maps were developed. The project also conducted a complementary soil survey in 26 districts of the nine selected provinces, after which laboratory analysis was conducted on 4 300 soil samples. With regard to capacity development, 38 technical staff from the Soil Research Directorate, MAIL and five national universities received training in soil survey, analysis and soil mapping. Digital soil maps were also developed at regional and national level to cover selected physical and chemical properties, plant nutrients, soil types, soil fertility status, soil suitability to different crops soil erosion and carbon stocks.

Eight soil laboratories of MAIL and national universities were fully or partially equipped by the AfSIS project. Two soil laboratories, (Balkh and Kandahar PAIL soil laboratories), which had no soil analysis practices prior to receiving support from the project were also equipped and their technicians trained in the delivered items. This has enabled them to analyse soil pH, salinity, organic matter, organic carbon, calcium carbonate, texture, bulk density, plant macro nutrients (total and available nitrogen, phosphorus, potassium, sulphur and calcium), sodium, water-holding capacity and cation exchange capacity. The staff members of the remaining six soil laboratories were also trained and provided with equipment based on their needs and requests. The equipment provided included soil laboratory analysis reagents, glassware and other non-expendable items, spectrophotometer, flame photometer, Kjeldhal nitrogen analysers and centrifuges.

In addition, all eight soil laboratories received complete field soil survey kits, and their technical staff was trained to pursue future soil surveys to the required technical standards.

## Implementation of work plan

All project activities were based on the work plan and major modifications were not necessary, although the inclusion of value-added activities such as a soil catalogue and soil atlas required a no-cost extension of three months. In order to reflect changes in allocation, one budget revision was made and approved.

## Follow-up for government attention

The project conducted soil surveys on 2 000 000 ha of land. This is insufficient to represent soil specifications for the entire country and it is recommended that soil resources be mapped throughout Afghanistan.

Eight soil laboratories were equipped during the project. However, they need to be provided with further equipment, including Atomic Absorption Spectroscopy (AAS) machines for micronutrient analysis. In addition, eight soil laboratories are insufficient for a country as large as Afghanistan. More soil laboratories are needed to carry out continuous soil analysis on a sustainable basis and provide recommendations for proper agronomic practices.

In order to keep AfSIS updated and gather comprehensive soil information in the future another soil survey project should be designed and funding should be sought from an international donor. This should be implemented as soon as possible.

## Sustainability

### 1. Capacity development

Relevant staff in Afghanistan now has the capacity to work together to enrich AfSIS through soil surveys, soil laboratory analysis and, to some extent, soil mapping. The new policy and strategy of the Agriculture Research Institute of Afghanistan will focus on soil resource data management under the platform of the Soil Research Directorate.

### 2. Gender equality

In Afghanistan, men and women are involved in land, agriculture and livestock management, and access to land and livestock resource information can enable both to choose better agriculture practices. The SIS set up by the project provides information for sustainable land management, agricultural productivity and quality, and food security at household level and thus contributes to the livelihoods of both men and women.

Both men and women staff were trained in soil survey and laboratory analysis, and were part of the project lifecycle.

### 3. Environmental sustainability

The project provided essential soil information and identified threats to agriculture and the environment, e.g. soil erosion, salinity, alkalinity, soil and nutrient loss and land degradation. It has thus contributed to sustaining the environment, natural resources and agriculture management.

### 4. Human Rights-based Approach (HRBA) – in particular Right to Food and Decent Work

Project formulation was in full compliance with the HRBA as all project stakeholders were recognized as key actors at all project stages. Beneficiaries in all regions understood their role not only as implementers but also as owners of the project, which was fully supported by the stakeholders.

The project developed capacity and equipped all stakeholders based on their needs. It also hired local labour in each region, which had a positive impact on field work.

### 5. Technological sustainability

One criterion adopted by the project was to procure equipment and instruments appropriate to the context of Afghanistan, and to provide intensive training in their use in the eight soil laboratories. All items and developed systems are now fully functional and are being used by beneficiaries effectively. The approach adopted by the project can be used elsewhere in Afghanistan to produce the requisite soil maps.

The project trained technical staff from five local universities and four soil laboratories. The trained staff can now contribute successfully to upcoming national-level soil survey and analysis projects. Stakeholders who received training and took part in the project can also conduct soil surveys without technical assistance, while soil laboratory technical staff can pursue laboratory analysis of those parameters covered by the project. Technical assistance is still required in soil mapping.

### 6. Economic sustainability

The project procured equipment and instruments appropriate to the context of Afghanistan and each beneficiary received training in their use. Beneficiaries also received intensive training in the use of developed online applications that can easily be used in the future.

The human resources of MAIL were dedicated to this project during soil survey, laboratory analysis and soil mapping activities. Five local universities also participated in these activities and the bilateral assistance made the project both successful and economically viable.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## Documents and outreach products

- Soil Survey Manual. Christian Thine Omuto. August 2017. 48 pp.
- Afghanistan Soil Catalogue. Hameedullah Ahmadzai and Christian Thine Omuto. FAO Afghanistan, Kabul, Afghanistan. 20 April 2019. 236 pp.
- Afghanistan Soil Atlas. Hameedullah Ahmadzai and Christian Thine Omuto. FAO Afghanistan, Kabul, Afghanistan. 20 April 2019. 235 pp.
- Project Progress Reports.
- Soil Database. Agriculture Statistic and Information Management Directorate. http://180.94.71.228:8080
- Soil Survey online form in Open Data Kit (ODK) Application.
- Soil Laboratory Analysis Log.
- Soil Survey Field Maps.
- Soil Type Maps.
- Soil Properties Maps.
- Soil Nutrients Maps.
- Soil Carbon Stock Maps.
- Soil Erosion Maps.
- Soil Fertility Status Maps.
- Soil Suitability Maps to Different Crops.


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## Achievement of results - Logical framework

| Expected Impact | Ensure sustainable agricultural land management in Afghanistan over the medium to long term for increased agricultural production and rural development | |
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| Outcome | A Digital Soil Information System of Afghanistan is used for sustainable management of soil resources and counterparts have improved capacities for systematic soil survey and soil monitoring | |
| | Indicator | Mapped area in digital format.<br>Soil laboratories capable of performing soil surveys. |
| | Baseline | 0<br>1 |
| | End Target | 1 500 000 ha of land mapped<br>Five soil laboratories equipped |
| | Comments and follow-up action to be taken | 2 000 000 ha of land were mapped.<br>Eight laboratories were equipped and can now conduct soil surveys and analyse various parameters of soil samples. However, 2 000 000 ha of land cannot represent soil specifications nationwide and there is a need to map soil resources throughout the country.<br>The eight soil laboratories equipped by the project need to be fully equipped and provided with AAS machines for micronutrient analysis. In addition, eight soil laboratories are insufficient to conduct continuous soil analysis on a sustainable basis for the entire country and to provide recommendations for proper agronomic practices. |

| Output 1 | Setting up AfSIS geodatabase and Geographic Information System (GIS) Web portal | | |
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| | Indicators | Target | Achieved |
| | Number of geodatabase developed | 1 | Yes |
| Baseline | 0 | | |
| Comments | A permanent soil geodatabase was established in the database department of the Agriculture Statistic Directorate, MAIL. This can be used to update soil mapping, and for future soil survey and analysis data management.<br>The database was developed and all data correctly synchronized. | | |
| Activity 1.1 | Kick-off meeting and setting-up of National Steering Committee | | |
| | Achieved | Yes | |
| | Comments | The committee consisted of soil professors of five national universities and Soil Research Directorate staff. These were among the implementing partners. | |
| Activity 1.2 | Procurement, installation and testing of AfSIS infrastructure | | |
| | Achieved | Yes | |
| | Comments | Tablets were procured and provided to soil surveyors after being loaded with designated mobile applications: ODK (for pre-arranged survey questioners), QGIS (for navigation and field mapping) and World Reference Base for Soils (WRB) application (for soil classification). The applications were used by each field soil surveyor to carry out digital soil survey. | |
| Activity 1.3 | Collection, evaluation and harmonization of soil legacy data | | |
| | Achieved | Yes | |
| | Comments | Soil legacy data were collected from various sources and organized in a newly developed database. | |
| Activity 1.4 | Collection, preparation and storing of environmental variables (geology, climate, land cover types, soil, etc.) | | |
| | Achieved | Yes | |
| | Comments | Environmental variables data were collected and used during digital soil mapping. | |
| Activity 1.5 | Digitalization and storing of available historical soil legacy data and newly collected soil data | | |
| | Achieved | Yes | |
| | Comments | Soil legacy data and newly collected data were digitalized and stored in soil database. | |
| Activity 1.6 | Collection, evaluation and harmonization of soil legacy data | | |
| | Achieved | Yes | |
| | Comments | Soil legacy data were collected from various sources and organized in newly developed database. | |

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| **Activity 1.7** | Design of AfSIS geodatabase structure | |
| | Achieved | Yes |
| | Comments | The soil database was designed and developed, and all studied and soil legacy data synchronized into the database. The soil database/Web site is online for public use. The database was developed by the Agriculture Statistic and Information Management Directorate, which is responsible for its maintenance. |
| **Activity 1.8** | Development of tailor-made application for the Web portal | |
| | Achieved | No |
| | Comments | Development of tailor-made application for the Web portal. The Afghanistan Agriculture Information Portal (AAIP) was developed under TCP/AFG/3501 in 2016 and its ownership handed over to MAIL. The portal was further improved by MIS unit of MAIL with the support of GCP/AFG/087/EC to develop the Integrated Agricultural Portal, which is under re-construction at present. |
| **Activity 1.9** | Selection of services and publishing of AfSIS via Web-based GIS portal | |
| | Achieved | Yes |
| | Comments | The maps were developed and published on GIS Web portal of MAIL. |

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| **Output 2** | Preparation of National Soil Map | | |
| | Indicators | Target | Achieved |
| | Number of soil type maps produced | 9 | Yes |
| **Baseline** | 0 | | |
| **Comments** | Nine provincial soil type maps and one national soil type map were developed.<br>All 34 provinces need to be mapped. | | |

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| **Activity 2.1** | Collection, harmonization and storing of available topographic datasets (topographic maps, orthophotographs, satellite images, digital elevation models [DEM], etc.) | |
| | Achieved | Yes |
| | Comments | Satellite images, DEM, topographic maps, orthophotographs were collected from various sources, used for soil mapping during project implementation, harmonized and stored for future use. |
| **Activity 2.2** | Selection of appropriate methods and approaches in preparation of Digital Soil Map | |
| | Achieved | Yes |
| | Comments | The following software was used during digital soil mapping: ArcGIS and QGIS for GIS interoperability; ILWIS for multivariate statistics; R for mapping statistics and simulations; SAGA for geomorphology. |
| **Activity 2.3** | Validation of the estimated soil types spatial distribution | |
| | Achieved | Yes |
| | Comments | All maps were developed according to DSM techniques (Random Forest and Regression Kriging) and holdout cross-validation. All maps have accompanied uncertainty maps. |
| **Activity 2.4** | Development of codification system for soil mapping units and harmonization of national soil classification with WRB | |
| | Achieved | Yes |
| | Comments | Raster-based soil maps were produced and classified according to WRB system. |
| **Activity 2.5** | Overlapping of digital soil map with topographic data set | |
| | Achieved | No |
| | Comments | Soil maps were developed at national and provincial level. Provincial maps were for the nine sampled provinces while national maps were aggregations from provincial maps. There were no clear topographic maps to align with soil maps. |
| **Activity 2.6** | Preparation of digital soil maps in particular scale as a digital map sheets | |
| | Achieved | Yes |
| | Comments | The provincial soil maps were developed at 90-m spatial resolution and the national maps at 250-m spatial resolution. |

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| **Output 3** | Implementation of a complementary soil survey on preselected areas | | |
| | Indicators | Target | Achieved |
| | Number of ha of land surveyed | 1 500 000 ha of land surveyed | Yes |
| **Baseline** | 0 | | |
| **Comments** | 2 000 000 ha in 25 districts of nine provinces were surveyed.<br>The entire country needs to be surveyed in the follow-up project. | | |

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| **Activity 3.1** | Development of a work plan and methodology for complementary soil survey | |
| | Achieved | Yes |
| | Comments | A work plan was prepared with implementing partners for soil survey, laboratory analysis and methodologies. |
| **Activity 3.2** | Soil survey on preselected areas and elaboration of preliminary soil maps | |
| | Achieved | Yes |
| | Comments | The soil survey was completed in 25 districts of nine preselected provinces. Prep-maps were developed for each province and soil surveyors used these during field surveys. |
| **Activity 3.3** | Laboratory analysis of collected soil samples | |
| | Achieved | Yes |
| | Comments | A total of 4 300 soil samples was analysed in the soil laboratories. Different soil analysis parameters (soil texture, bulk density, water holding capacity, pH, salinity [EC], calcium carbonate, organic carbon and matter, nitrogen, phosphorus, potassium, sulphur, zinc, manganese, copper and boron) were considered.<br>There is a need to provide further facilities to soil laboratories to enable them to perform other chemical properties analyses. |
| **Activity 3.4** | Conversion of newly collected soil survey data into suitable digital format | |
| | Achieved | Yes |
| | Comments | The soil data were collected via digital format (online form in ODK) and submitted to a developed database. |

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| **Output 4** | Capacity development for soil survey and digital soil mapping | | |
| | Indicators | Target | Achieved |
| | Number of technical staff trained and skilled | 38 technical staff | Yes |
| **Baseline** | 0 | | |
| **Comments** | 38 technical staff members of Soil Research Directorate, GIS department of MAIL and five national universities were trained in soil survey, analysis and soil mapping.<br>The capacity developed is insufficient for Afghanistan. More university and soil laboratory technical staff need to be trained to contribute to national-level soil survey and laboratory analysis. | | |

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| **Activity 4.1** | Strengthening of technical capacitates of soil laboratories | |
| | Achieved | Yes |
| | Comments | The project conducted training courses for soil laboratory technicians in soil analysis and instrument applications. Two under-equipped and -staffed soil laboratories (Kandahar and Balkh) were provided with equipment and intensive training to analyse soil texture, bulk density, pH, salinity (EC), calcium carbonate, organic carbon, nitrogen, potassium, phosphorus, sulphur, calcium, sodium and lithium through standard instrument and procedure. Six other laboratories were also equipped and supported. Altogether, the project equipped eight soil laboratories and enhanced their technical capacity. However, these eight laboratories cannot meet the need to analyse soil samples sustainably. They need more items/instruments to be able to analyse all required analysis parameters. |
| **Activity 4.2** | Upgrading the existing information technology (IT) and software capacities within GIS laboratory of MAIL to meet AfSIS requirements | |
| | Achieved | No |
| | Comments | The existing IT infrastructure and existing software were adequate and no major contribution was required. |
| **Activity 4.3** | Preparation of training material and implementation of training sessions for soil survey and laboratory analysis, for national staff | |
| | Achieved | Yes |
| | Comments | Soil survey manuals were prepared and shared with field surveyors. Soil surveyors and laboratory technicians received training and on-the-job coaching. |
| **Activity 4.4** | Intensive training of national staff in data base management (SQL) and GIS software solutions | |
| | Achieved | Yes |
| | Comments | Training in database management and GIS software was given to GIS department staff and fresh graduates during the project life |
| **Activity 4.5** | Training of national staff on digital soil mapping techniques | |
| | Achieved | Yes |
| | Comments | GIS department staff of MAIL was trained in digital soil mapping techniques. |

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| **Output 5** | Digital soil property maps and soil suitability applications | | |
| | Indicators | Target | Achieved |
| | Number of digital soil properties maps developed.<br>Number of plant nutrients in soil maps produced.<br>Number of soil suitability application maps developed.<br>Number of soil erosion maps developed.<br>Number of Afghanistan carbon stock map developed. | Six properties maps for nine provinces and some major properties for national level.<br>Three plant nutrients provincial maps.<br>One erosion map for nine provinces as well as at national level.<br>One Afghanistan carbon stock map. | Yes |
| **Baseline** | 0 | | |
| **Comments** | Eight physical and chemical properties (soil texture, bulk density, water-holding capacity, pH, salinity [EC], calcium carbonate, organic matter and CEC) maps were developed for nine targeted provinces and some (pH, salinity and texture) maps for overall national level generated.<br>Nine maps of plant nutrients available in the soil (nitrogen, potassium, phosphorus, sulphur, zinc, copper, boron, manganese and iron) were developed for targeted nine provinces.<br>Soil erosion maps for targeted nine provinces and one at national level were developed.<br>Afghanistan carbon stock map was developed and shared with Global Soil Partnership for inclusion in global carbon stock map.<br>Soil maps of this type should be developed for each province, with higher resolution at national level.<br>National soil suitability maps for different crops have been developed. | | |
| **Activity 5.1** | Selection of most suitable approaches, tools, and methodology for DSM | | |
| | Achieved | Yes | |
| | Comments | The following software was used for DSM: ArcGIS and QGIS for GIS interoperability, ILWIS for multivariate statistics, R for mapping statistics and simulations, and SAGA for geomorphology. | |
| **Activity 5.2** | Selection and harmonization of environmental variables on national level for DSM | | |
| | Achieved | Yes | |
| | Comments | Soil mapping variables used were: 1:200 k land cover types map; remote sensing images for NDVI and cover types from Sentinel 2; 1:250 k geology map from the Government, new and updated national boundaries map; climate date (snow fall, rainfall, and temperature) from the Government; and 90-m SRTM elevation map downloaded from United States Geological Survey Web site. These variables were corrected and harmonized with standardized legacy soil data. | |
| **Activity 5.3** | Development of digital soil mapping of functional/property maps | | |
| | Achieved | Yes | |
| | Comments | Eight physical and chemical properties (soil texture, bulk density, water holding capacity, pH, salinity [EC], calcium carbonate, organic matter and CEC) maps were developed for nine targeted provinces.<br>Three soil major properties (pH, salinity and texture) maps were generated at national level. | |
| **Activity 5.4** | Validation of predicted soil property maps with exact field measurement data | | |
| | Achieved | Yes | |
| | Comments | All soil maps were validated by means of holdout cross-validation approaches using the data from the database | |
| **Activity 5.5** | Development of applications such as soil erosion and soil suitability assessment | | |
| | Achieved | Yes | |
| | Comments | Soil erosion/loss map was developed for all nine provinces and one at national level.<br>Soil suitability maps of different crops were developed for national level generally. | |
| **Activity 5.6** | Preparation of meta data for all produced GIS layers and DSM products | | |
| | Achieved | Yes | |
| | Comments | All developed maps have metafiles detailing map properties, methods used, input data sources and uncertainty. | |

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