



Food and Agriculture  
Organization of the  
United Nations

PHASE 1

Country Guidelines and  
Technical Specifications for

# Global Soil Nutrient and Nutrient Budget Maps

# GSNmap





# **Country Guidelines on Digital Soil Mapping**

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Food and Agriculture Organization of the United Nations  
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## **Way forward**

This technical manual provided step-by-step guidance on how to generate nutrient maps by means of quantile regression forest models within a digital soil mapping framework. The array of maps produced belongs to the first implementation phase of the GSNmap initiative and provides urgently needed data on nutrient stocks and soil properties that govern nutrient availability. Policymakers will be able to use this data to derive conclusions on where to concentrate efforts to improve soil and land management to strengthen agrifood systems. The second phase of the GSNmap will make use of the first phase data products to derive nutrient budget maps. Therefore, additional datasets will be used for calculating input and output terms of nutrient stocks. The methodology is currently under development by the GSNmap working group. The technical documentation towards implementing the second phase will be made available in mid 2023.

### **10.1 Frequent asked questions and Troubleshooting answers**

To be developed soon...

## 10.2 Issues in the GSNmap Technical Manual

Please, report any issue in the GSNmap Technical Manual in its issues GitHub page <https://github.com/FAO-GSP/GSNmap-TM/issues>.

## 10.3 Get help

- Check the issues GitHub page <https://github.com/FAO-GSP/GSNmap-TM/issues>
- Issues with R packages: search for solutions in <https://stackoverflow.com/>
- `caret` package <https://topepo.github.io/caret/>
- `terra` package <https://rspatial.org/terra/pkg/1-introduction.html>
- `tidyverse` package <https://r4ds.had.co.nz/>
- `sf` package <https://r-spatial.github.io/sf/>

If these links do not help you, contact us including the following text:

*I am [FULL NAME], responsible for producing the GSNmap of [COUNTRY].*

`marcos.angelini@fao.org`

# **Annex I: Compendium of R scripts**

Placeholder

**Script 0: Introduction to R**

**Script 2: Data preparation**

**Scripts 3: Download environmental covariates**

**Script 4: Modelling, validation and prediction using soil data with coordinates**

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Placeholder

# **Annex IV: Quality assurance and quality control**

The following protocol was devised to provide National Experts with a step-by-step guideline to perform a Quality Assurance (QA) and Quality Control (QC) of the 10 GSNmap first phase products.

The following protocol does not provide any guidance in terms of uncertainty estimation and validation. For more details and information on the estimation of uncertainties and potential map validation strategies please refer to Chapter 8.4.

Quality assurance and quality control consist of activities to ensure the quality of a particular result. Quality control is a reactive process that focuses on identifying defects and errors while quality assurance is a proactive approach aimed at preventing defects and errors. In the context of digital soil mapping, both processes are often interlinked. A QA is interlinked with a QC when it identifies defects and the QA remodels the process to eliminate the defects and prevent them from recurring (Chapman, 2005)(Figure10.1).

Each step in the following protocol should be considered in order to detect and eliminate errors, address data inaccuracies and assess the output completeness.

## **Step 1: Completeness of layers**

The following Table ??tab:products) gives an overview of all the GSNmap products in alphabetical order. Each product should include the ISO 3166-1



Figure 10.1: Quality assurance and quality control.

alpha-3 country code as uppercase letters in its name. For instance, in the case of Turkiye, ISO\_GSNmap\_Ntot\_Map030 should be changed to TUR\_GSNmap\_Ntot\_Map030.

All 10 soil property and soil nutrient maps with their corresponding 10 uncertainty layers must be georeferenced TIF (.tif) files.

Data product overview.

Product

Filename

Major nutrients (3 files)

Total Nitrogen map

ISO\_GSNmap\_Ntot\_Map030.tif

Available Phosphorus map

ISO\_GSNmap\_Pav\_Map030.tif

Total Potassium map

ISO\_GSNmap\_Ktot\_Map030.tif

Associated soil properties (7 files)

Cation exchange capacity map

ISO\_GSNmap\_CEC\_Map030.tif

Soil pH map

ISO\_GSNmap\_pH\_Map030.tif

Soil clay map

ISO\_GSNmap\_Clay\_Map030.tif

Soil silt map

ISO\_GSNmap\_Silt\_Map030.tif

Soil sand map

ISO\_GSNmap\_Sand\_Map030.tif

Soil organic carbon map

ISO\_GSNmap\_SOC\_Map030.tif

Soil bulk density map

ISO\_GSNmap\_BD\_Map030.tif

Uncertainty maps (10 files)

Total Nitrogen uncertainty map

ISO\_GSNmap\_Ntot\_UncertaintyMap030.tif

Available Phosphorus uncertainty map

ISO\_GSNmap\_Pav\_UncertaintyMap030.tif

Total Potassium uncertainty map

ISO\_GSNmap\_Ktot\_UncertaintyMap030.tif

Cation exchange capacity uncertainty map

ISO\_GSNmap\_CEC\_UncertaintyMap030.tif

Soil pH uncertainty map

ISO\_GSNmap\_pH\_UncertaintyMap030.tif

Soil clay uncertainty map  
ISO\_GSNmap\_Clay\_UncertaintyMap030.tif  
Soil silt uncertainty map  
ISO\_GSNmap\_Silt\_UncertaintyMap030.tif  
Soil sand uncertainty map  
ISO\_GSNmap\_Sand\_UncertaintyMap030.tif  
Soil organic carbon uncertainty map  
ISO\_GSNmap\_SOC\_UncertaintyMap030.tif  
Soil bulk density uncertainty map  
ISO\_GSNmap\_BD\_UncertaintyMap030.tif

## **Step 2: Check the projection and resolution of all data products**

Open the products in QGIS or any other preferred GIS platform. Check that the projection of all products is EPSG:4326 - WGS 84 (Layer properties). Check that the spatial resolution (pixel size) (Layer properties) is equal to ~0.002246 degrees ; 250 m x 250 m at the equator.

## **Step 3: Check the extent**

Visualize the 20 products in QGIS or any preferred GIS platform. Load a land-use layer to visually assess that the simulations were done exclusively on croplands.

## **Step 4: Check the units, ranges, and outliers**

In the following section possible value ranges for each product category (except available potassium) are presented. It is important to note that the provided

ranges represent a gross approximation of the extremes within which the values should fall in. Results that fall outside these ranges need to be carefully evaluated based on local expertise and available literature.

The provided ranges can be compared in QGIS, R, or any preferred platform. Descriptive layer statistics can be viewed in QGIS under Layer Properties.

The following table (Table 10.2) presents ranges of possible values for 9 of the 10 mandatory GSNmap products. The ranges were calculated based on the distribution of the soil profile data within the World Soil Information Service (WoSIS), specifically the WoSIS snapshot 2019 (Batjes, N. H. *et al.* 2020). It is important to note that the data was not filtered for croplands and that the ranges were extracted from soil profiles sampled globally from a wide array of land covers and land uses.

Possible soil property and soil nutrient values based on the distribution of the values within the World Soil Information Service (WoSIS), specifically the WoSIS snapshot 2019.

Soil property

property\_id

Unit

Min

1st Quartile

Median

3st Quartile

Max

n

Total N

n\_0\_30

ppm

0.0

400.0

700.0

1500.0

84000.0

216362

P Bray I

p\_0\_30

ppm

0.0

1.6

5.0

16.0

150.0

40486

P Mehlich 3

p\_0\_30

ppm

0.0

1.6

6.1

22.0

149.4

7242

P Olsen

p\_0\_30

ppm

0.0

0.7

2.0  
4.3  
141.0  
8434  
CEC  
cec\_0\_30  
cmol(c)/kg  
0.1  
7.5  
14.0  
23.0  
140.0  
295688  
pH (water)  
ph\_0\_30  
/  
1.5  
5.2  
6.2  
7.5  
12.3  
613322  
Clay  
clay\_0\_30  
%  
0.0

11.1  
21.9  
35.3  
100.0  
590368  
Silt  
silt\_0\_30  
%  
0.0  
15.0  
30.0  
47.6  
100.0  
558233  
Sand  
sand\_0\_30  
%  
0.0  
15.0  
36.0  
60.2  
100.0  
482334

Soil Organic Carbon

soc\_0\_30  
%

0.0  
2.0  
5.1  
14.0  
99.4  
471301  
Bulk density  
bd\_0\_30  
g/cm3  
0.0  
1.3  
1.4  
1.7  
2.6  
116756  
Available K  
k\_0\_30  
ppm  
NA  
NA  
NA  
NA  
NA  
NA

## QA/QC Script

The following script automates the for Steps described in the previous sections. It is important to note that the script's main objective is to provide a fast alternative to check the output layers and that it does not replace the need to visually assess the final maps based on expert knowledge.

```
#-----
#  
# QA/QC  
# Soil Property Mapping  
#  
# GSP-Secretariat  
# Contact: Isabel.Luotto@fao.org  
#           Marcos.Angelini@fao.org  
#-----  
  
#Empty environment and cache  
rm(list = ls())  
gc()  
  
# Content of this script =====  
# 0 - Set working directory and packages  
# 1 - Step 1: Completeness of layers  
# 2 - Step 2: Check the projection and resolution of all data products  
# 3 - Step 3: Check the extent  
# 4 - Step 4: Check the units, ranges, and outliers  
#  
# 5 - Export QA/QC report  
#-----  
  
# 0 - Set working directory, soil attribute, and packages =====  
  
# Working directory  
wd <- 'C:/Users/hp/Documents/GitHub/GSNmap-TM/Digital-Soil-Mapping'  
#wd <- 'C:/Users/luottoi/Documents/GitHub/GSNmap-TM/Digital-Soil-Mapping'  
setwd(wd)
```

```

# Define country of interes through 3-digit ISO code
ISO = 'ISO'

#load packages
library(terra)
library(readxl)

# Load reference values
dt <- read_xlsx("C:/Users/luottoi/Documents/GitHub/GSNmap-TM/tables/wosis_dist.xlsx")
dt <- dt[!(dt$`Soil property` %in% c( "P Bray I","P Olsen" )),]

# In case old naming system was used
dt$old_prop_ids <- c('Ntot', 'Pav', 'CEC','pH', 'Clay', 'Silt', 'Sand', 'SOC', 'E

## Set potential ranges for Available K in ppm

dt[dt$property_id=='k_0_30','Min'] <- 0
dt[dt$property_id=='k_0_30','Max'] <- 150
# 1 - Step 1: Completeness of layers -----
#Check number of layers

## Specify number of soil property maps generated (not including the uncertainty

## Check if all layers were correctly generated (including uncertainty layers)
# and if the correct ISO code and soil property ids were included in the files no
files <- list.files(pattern= '.tif', full.names = T)
names <- list.files( pattern= '.tif', full.names = F)
names <- sub('.tif', '', names)

# Switch depending on the naming system (i.e. files have e.g. Pav instead of p_0_
#Step1 <-data.frame(property_id =dt$property_id)
Step1 <-data.frame(property_id =dt$old_prop_ids) #old naming system

Step1$Names <- 'Rename layer'
Step1$Uncertainty <- 'Missing'

```

```

for (i in unique(Step1$property_id)){

  t11 <- TRUE %in% grepl(paste0('SD_GSNmap_',i), files)|grepl(paste0('sd_',i), fi
  t12 <- TRUE %in% grepl(paste0(ISO,'_GSNmap_',i), files)|grepl(paste0('mean_',i)

  t13 <- TRUE %in% grepl(ISO, files)

  Step1[Step1$property_id ==i, 'Names'] <- ifelse(t12[[1]] ==T & t13[[1]] ==T, 'C
  Step1[Step1$property_id ==i, 'Uncertainty'] <- ifelse(t11[[1]] ==T , 'Generated

}

# 2 - Step 2: Check the projection and resolution of all data products -----
r <- rast(files)
names(r) <- names
# Check projection (WGS 84)
(Step21=crs(r, describe=TRUE)$name =='WGS 84')

# Check resolution (250 m)
(Step22=round(res(r)[[1]], 5) == 0.00225)

# 3 - Step 3: Check the extent -----
# Check if the layers were masked with a cropland mask

mask <- rast('mask/mask.tif')
mask <- project(mask, r[[1]])

t <- r[[1]]
t <- ifel(!is.na(t),1, NA)

t3 <- sum(values(t, na.rm=T))-sum(values(mask, na.rm=T))

(Step3= t3 <=10)

# 4 - Step 4: Check the units, ranges, and outliers -----

```

```

Step4 <- data.frame(property_id=Step1$property_id)
#Step4 <- data.frame(property_id =dt$property_id)
Step4$in_range <- 'Values not in range'

for (i in unique(Step4$property_id)){
  t41 <-min(values(r[[grep1(paste0('mean_',i), names(r))|grep1(paste0(ISO,'_GSNma
  t42 <-max(values(r[[grep1(paste0('mean_',i), names(r))|grep1(paste0(ISO,'_GSNma

  Step4[Step4$property_id ==i, 'in_range'] <- ifelse(t41[[1]] ==T & t42[[1]] ==T,
}

# 5 - Export QA/QC report -----
report <- merge(Step4, Step1, by=c('property_id'))

report$projection <- ifelse(Step21, 'WGS 84', 'Reproject layer')
report$resolution <- ifelse(Step21, '250 m', 'Resample layer')
report$extent <- ifelse(Step3, 'Croplands', 'Mask out layer')

report

write.csv(report, paste0('QA_QC_', ISO, '.csv'))

```

# References



The Global Soil Partnership (GSP) is a globally recognized mechanism established in 2012. Our mission is to position soils in the Global Agenda through collective action. Our key objectives are to promote Sustainable Soil Management (SSM) and improve soil governance to guarantee healthy and productive soils, and support the provision of essential ecosystem services towards food security and improved nutrition, climate change adaptation and mitigation, and sustainable development.



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