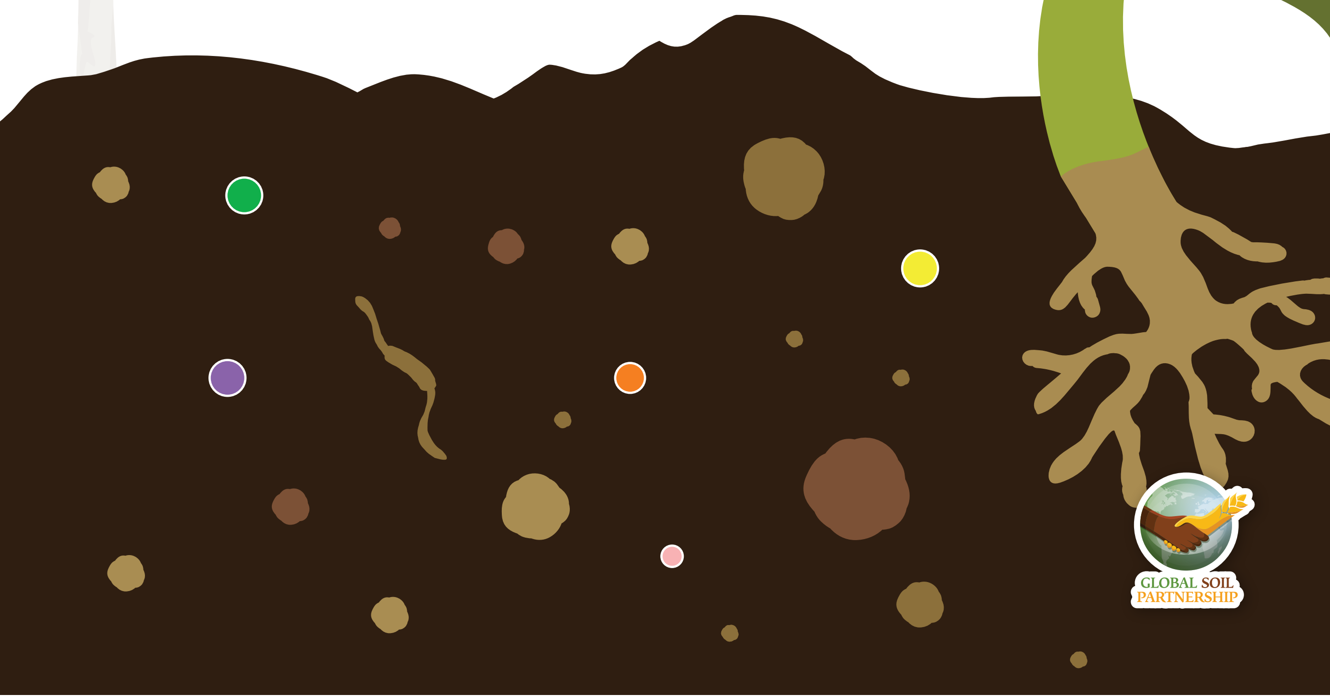
Food and Agriculture
Organization of the
United Nations

PHASE 1

Country Guidelines and
Technical Specifications for

Global Soil Nutrient and Nutrient Budget Maps

GSNmap



GLOBAL SOIL PARTNERSHIP

Country Guidelines on Digital Soil Mapping

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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

Annex III: Mapping without point coordinates

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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.tiff

Available Phosphorus map

ISO_GSNmap_Pav_Map030.tiff

Total Potassium map

ISO_GSNmap_Ktot_Map030.tiff

Associated soil properties (7 files)

Cation exchange capacity map

ISO_GSNmap_CEC_Map030.tiff

Soil pH map

ISO_GSNmap_pH_Map030.tiff

Soil clay map

ISO_GSNmap_Clay_Map030.tiff

Soil silt map

ISO_GSNmap_Silt_Map030.tiff

Soil sand map

ISO_GSNmap_Sand_Map030.tiff

Soil organic carbon map

ISO_GSNmap_SOC_Map030.tiff

Soil bulk density map

ISO_GSNmap_BD_Map030.tiff

Uncertainty maps (10 files)

Total Nitrogen uncertainty map

ISO_GSNmap_Ntot_UncertaintyMap030.tiff

Available Phosphorus uncertainty map

ISO_GSNmap_Pav_UncertaintyMap030.tiff

Total Potassium uncertainty map

ISO_GSNmap_Ktot_UncertaintyMap030.tiff

Cation exchange capacity uncertainty map

ISO_GSNmap_CEC_UncertaintyMap030.tiff

Soil pH uncertainty map

ISO_GSNmap_pH_UncertaintyMap030.tiff

Soil clay uncertainty map

ISO_GSNmap_Clay_UncertaintyMap030.tiff

Soil silt uncertainty map

ISO_GSNmap_Silt_UncertaintyMap030.tiff

Soil sand uncertainty map

ISO_GSNmap_Sand_UncertaintyMap030.tiff

Soil organic carbon uncertainty map

ISO_GSNmap_SOC_UncertaintyMap030.tiff

Soil bulk density uncertainty map

ISO_GSNmap_BD_UncertaintyMap030.tiff

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 throuhg 3-digit ISO code
ISO ='ISO'

#load packages
library(terra)
library(readxl)

# Load reference values
dt <- read_xlsx("../tables/wosis_dist.xlsx")
dt <- dt[!(dt$`Soil property` %in%c( "P Bray I","P Olsen" )),]

## 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 na
files <- list.files('02-Outputs/maps/', pattern= '.tif', full.names = T)
names <- list.files('02-Outputs/maps/', pattern= '.tif', full.names = F)
names <- sub('.tif', '', names)

Step1 <-data.frame(property_id =dt$property_id)
Step1$Names <- 'Rename layer'
Step1$Uncertainty <- 'Missing'

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

  t11 <- TRUE %in% grepl(paste0('sd_',i), files)
  t12 <- TRUE %in% grepl(paste0('mean_',i), files)
  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('01-Data/covs/mask.tif')
mask <- project(mask, r[[1]])

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

(Step3= sum(values(mask -t, na.rm=T)) <=10)



# 4 - Step 4: Check the units, ranges, and outliers ----------------------------
Step4 <- data.frame(property_id =dt$property_id)
Step4$in_range <- 'Values not in range'

for (i in unique(dt$property_id)){
t41 <-min(values(r[[grepl(paste0('mean_',i), names(r))]],na.rm=T)) >=dt[dt$proper
t42 <-max(values(r[[grepl(paste0('mean_',i), names(r))]],na.rm=T)) <=dt[dt$proper

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

}
```

```r
# 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('National Report/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.

Australian Government

Department of Agriculture, Water and the Environment

AFACI

Asian Food & Agriculture Cooperation Initiative

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Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Rural Development Administration

CC1717EN/1/09.22