Food and Agriculture Organization of the United Nations

# INSOILFER Working Group Meetings

27-29 November 2023

## The importance of soil monitoring and connection to mapping


**Luis Rodríguez-Lado, PhD**

**Global Soil Nutrient and Soil Nutrient Budget Maps (GSNmap)**
Soil Information and Data Team
GSP-Secretariat
Land and Water Division


Insoilfer
International Network on Soil Fertility and Fertilizers

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# GSNmap

## Global Soil Nutrient and Nutrient Budget Maps

## GSOIL4N

- Develop **country-driven global soil nutrient and nutrient budget maps.**
- **Map and monitor soil fertility** in a broader perspective by also considering the physical, chemical, and biological soil properties.
- Support countries with capacity development for conducting **soil nutrient budget maps** and n**ational soil information and monitoring systems**.
- Advocate for a **global approach** to facilitate the collation and availability of soil fertility data and information.
- Adopt a **holistic approach** that considers all aspects of soil nutrient inputs and outputs.

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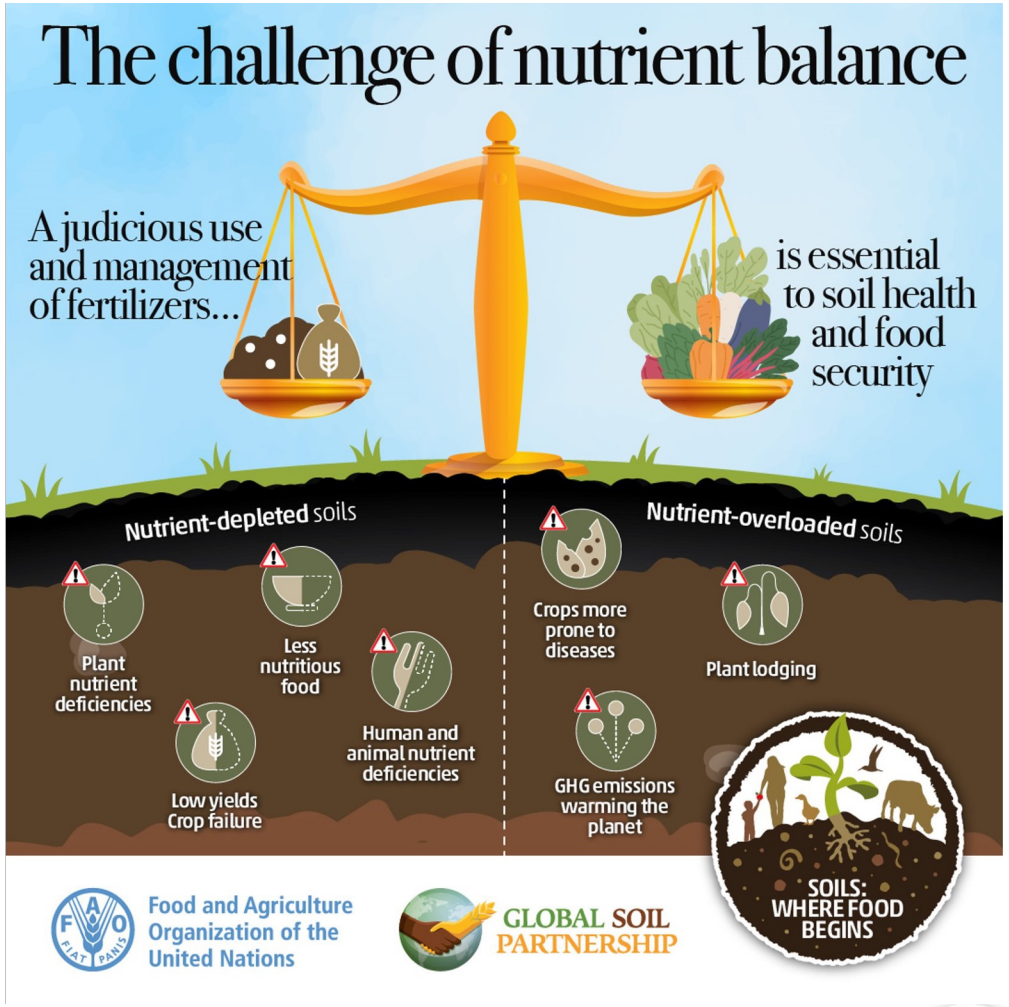
# GSNmap

## Global Soil Nutrient and Nutrient Budget Maps

- **Global Soil Nutrient and Nutrient Budget Maps** (**GSNmap**) is a initiative of INSII and the GSP with the intent of developing current state maps of nutrients (NPK) and their budgets.
- Based on **country-driven** approach
- **Phase I**: maps of soil nutrient and soil fertility properties
- **Phase II**: NPK budget maps

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# GSNmap

## Global Soil Nutrient and Nutrient Budget Maps

### Methodology

- **Phase I: Digital Soil Mapping** based on a machine learning algorithm (Quantile Regression Forest)
- **Phase II: N, P, K nutrient budgets**

### Development

- **Country-driven** (global map based on national submissions)
- Updated following a **Versioning system**

### Extent

- Scale: **National (Croplands)**
- Depth: **0-30 cm**
- Resolution: **250 x 250 m**

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# GSNmap

## Global Soil Nutrient and Nutrient Budget Maps

**Mandatory products**

- **total N**
- **available P**
- **available K**
- *CEC*
- *pH*
- *clay, silt, and sand*
- *soil organic carbon*
- *bulk density*

# GSNmap

## Country-driven mapping

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**GSP Members request for GSNmap**

**Two-phase initiative**

**Phase I: Nutrient maps (current status)**

**Phase II: Nutrient budget maps**

### Methodology

Definition of a methodology through the support of the GSP's technical networks,

International Network on Soil Information Institutions (INSII),

Working groups and the ITPS

### Technical specifications and country guidelines

Publication and divulgation to define a standardized approach

### Capacity Building Program

Online Technical Manual

Online regional training & follow-up one to one technical sessions with National Experts

### National Submission

Quality assessment and quality check of the submitted maps

31 August 2023

**GSNmap Products**

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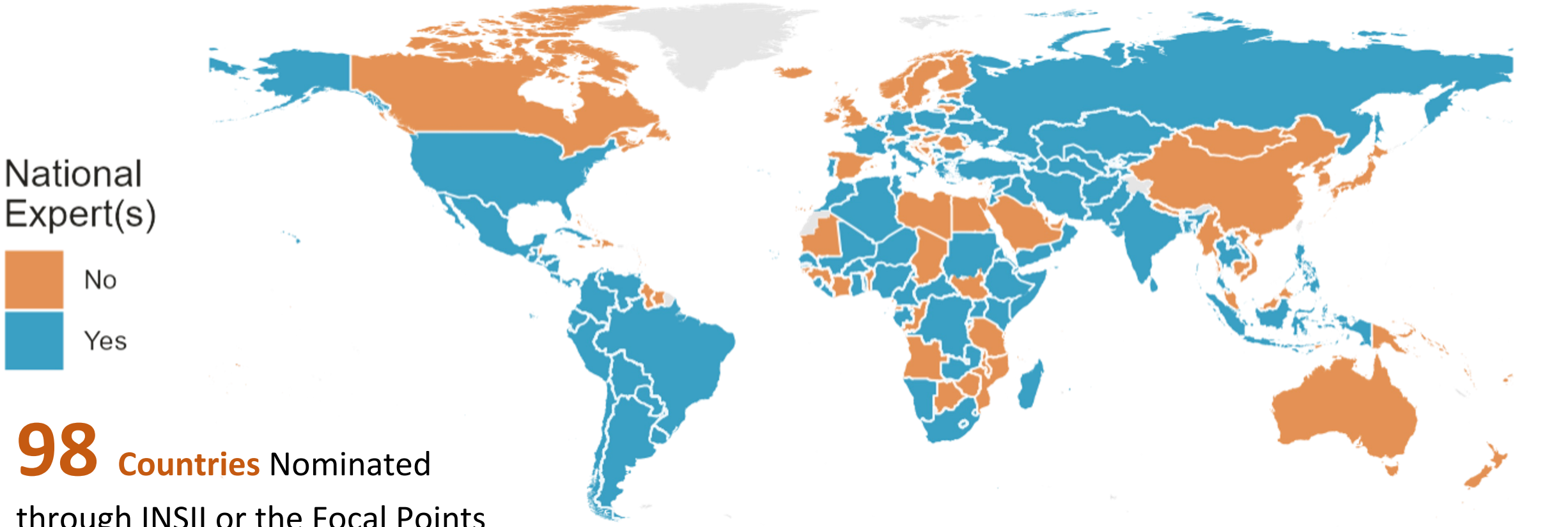
# GSNmap

## COUNTRY ENGAGEMENT




**98** **Countries** Nominated

through INSII or the Focal Points one or more national experts to be in charge of the GSNmap exercise.

Source: United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations, modified by the authors. Notes: Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

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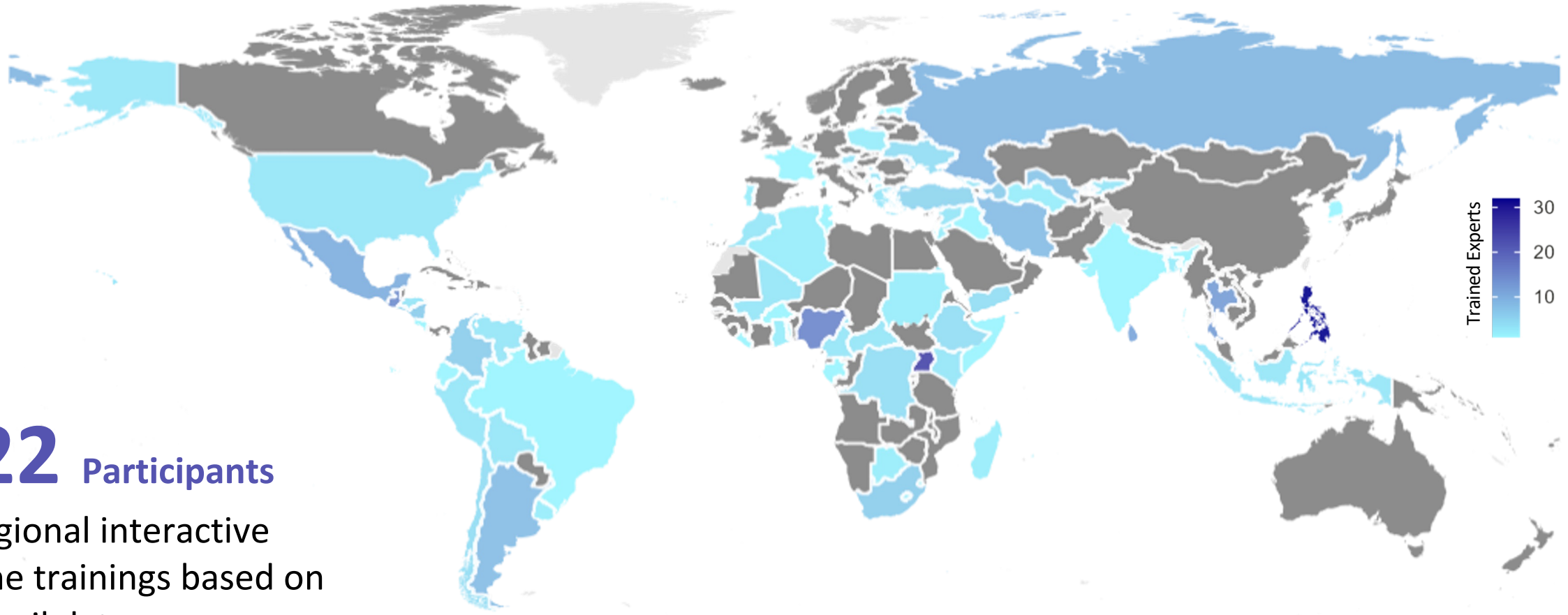
# GSNmap

## CAPACITY DEVELOPMENT




**322** **Participants**

**6** Regional interactive online trainings based on real soil data

Source: United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations, modified by the authors. Notes: Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

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# GSNmap Phase I

## world coverage

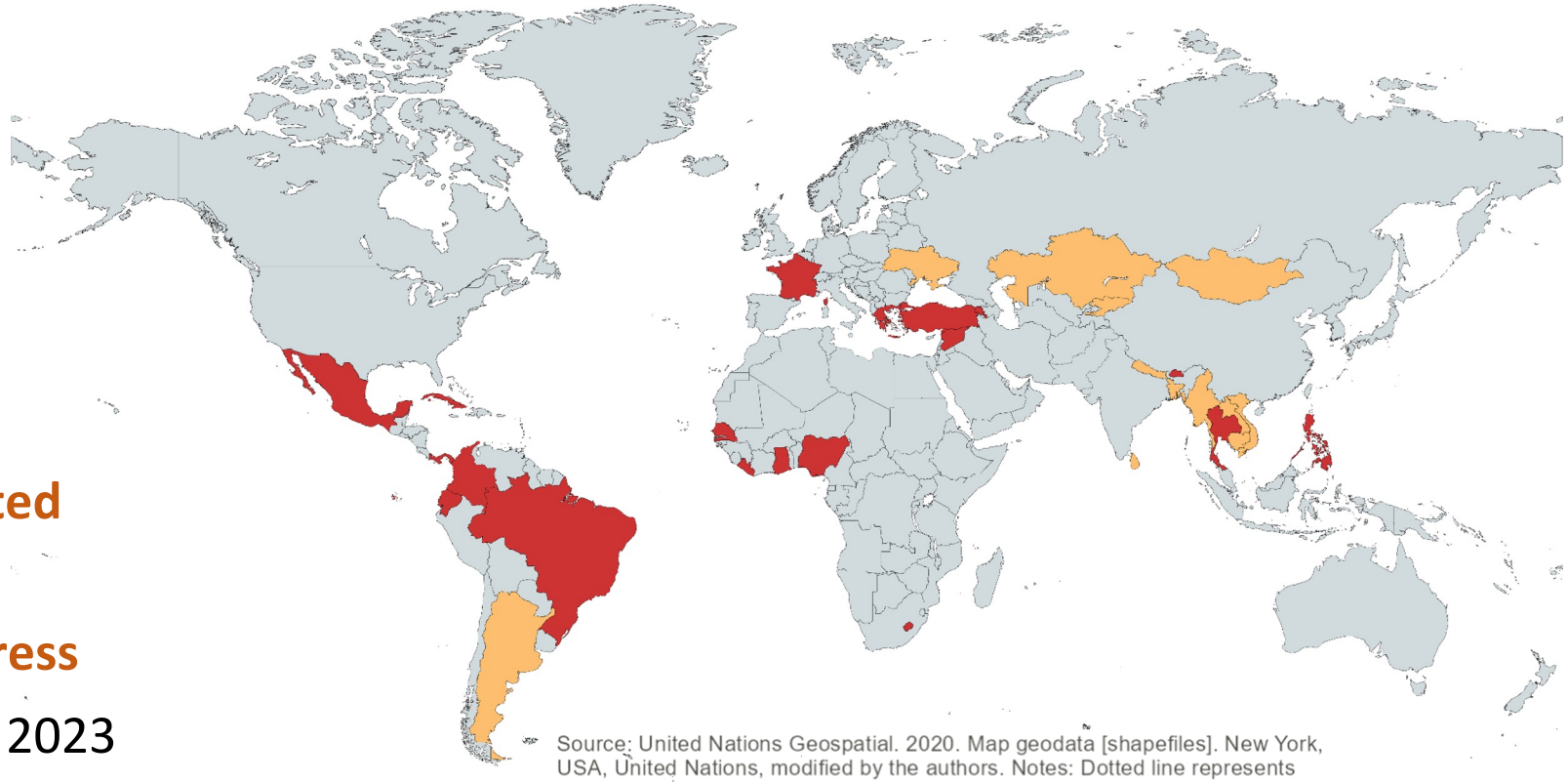
Submitted

In progress

**19** **Countries submitted**

**13** **Countries in progress**

First deadline: 31 August 2023



Source: United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations, modified by the authors. Notes: Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

Created with mapchart.net

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# GSNmap Phase I

gap-filling

## GSNmap version 1.0:

EXTENDED

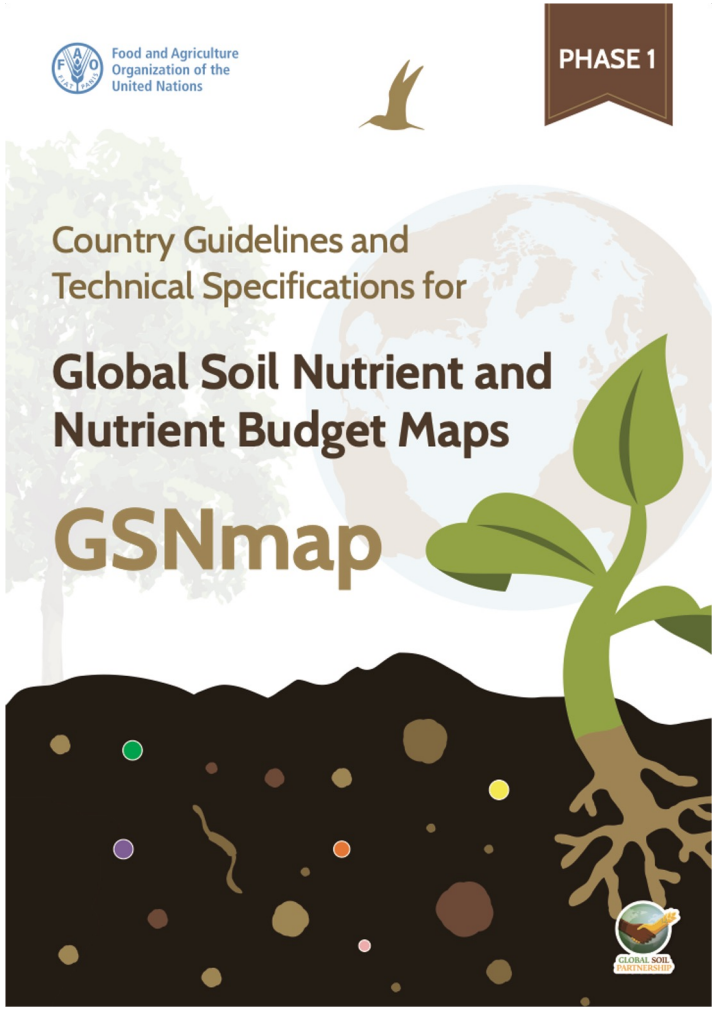
**Step 1**: National Submissions (deadline **August 31st, 2023**)

**Step 2**: Countries that did not submit on time.

- **Gap-filling** using a top-down approach with the methodology and covariates described on the Country Guidelines document (GSP-Secretariat).

- Leave the country **blank**.

**Launch**: 12th GSP Plenary Assembly 2024 (June)



# GSNmap Phase I

gap-filling

Gap-filling is the process of estimating missing or incomplete country data within a raster map.

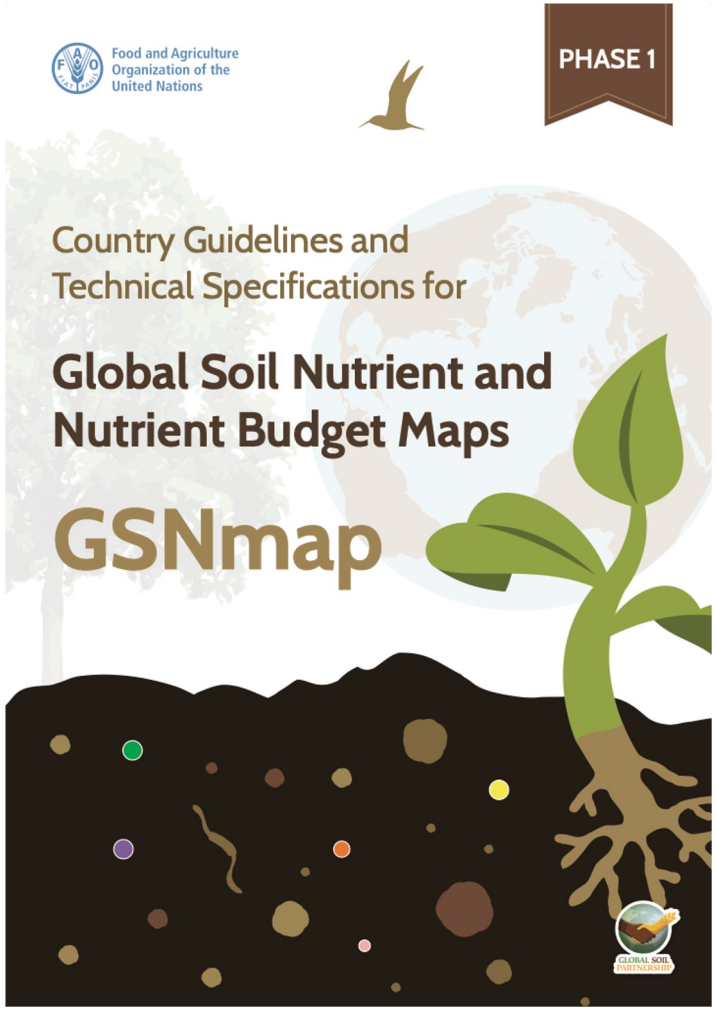
The selection of the Gap-filling method depends on data characteristics.

Common approaches for gap-filling:

i. Data Completion

ii. Interpolation

iii. Machine Learning Approaches



# Data Completion

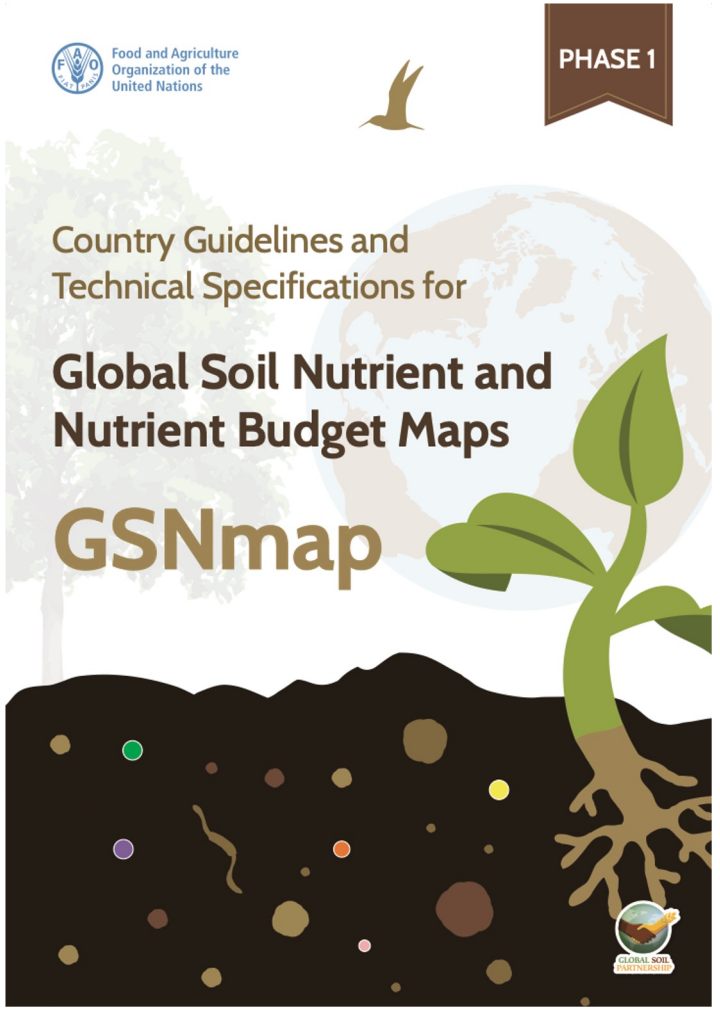
## Integrating existing raster data products to fill gaps in GSNmap.

**PROS**

- Fast and straightforward method utilizing already existing maps.

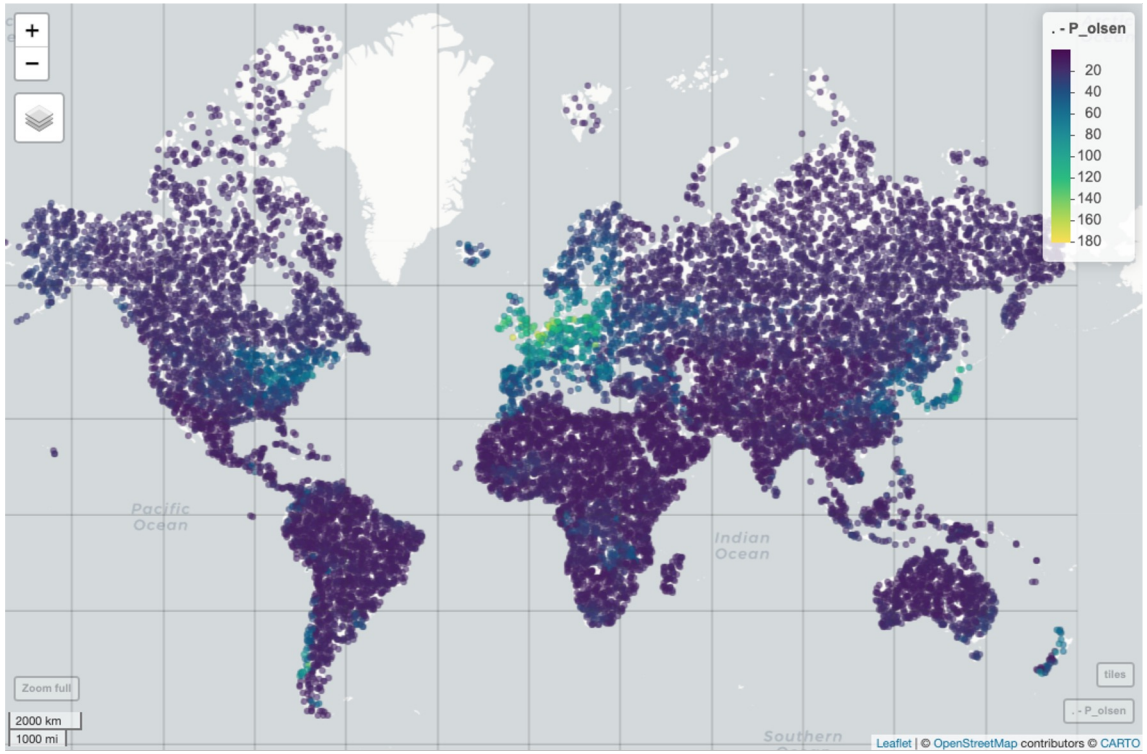
**CONS**

- Accuracy.
- Not visually consistent, with noticeable differences among adjacent areas.



# Estimation by Machine Learning

- DATA
  - point databases
  - raster maps
  - both




RASTER DATA EXTRACTION : Random sampling within tiles. In this case, we extracted 1000 point values randomly at tiles of 30 degrees from the raster predictions of Olsen phosphorus from McDowell et al. (2023).

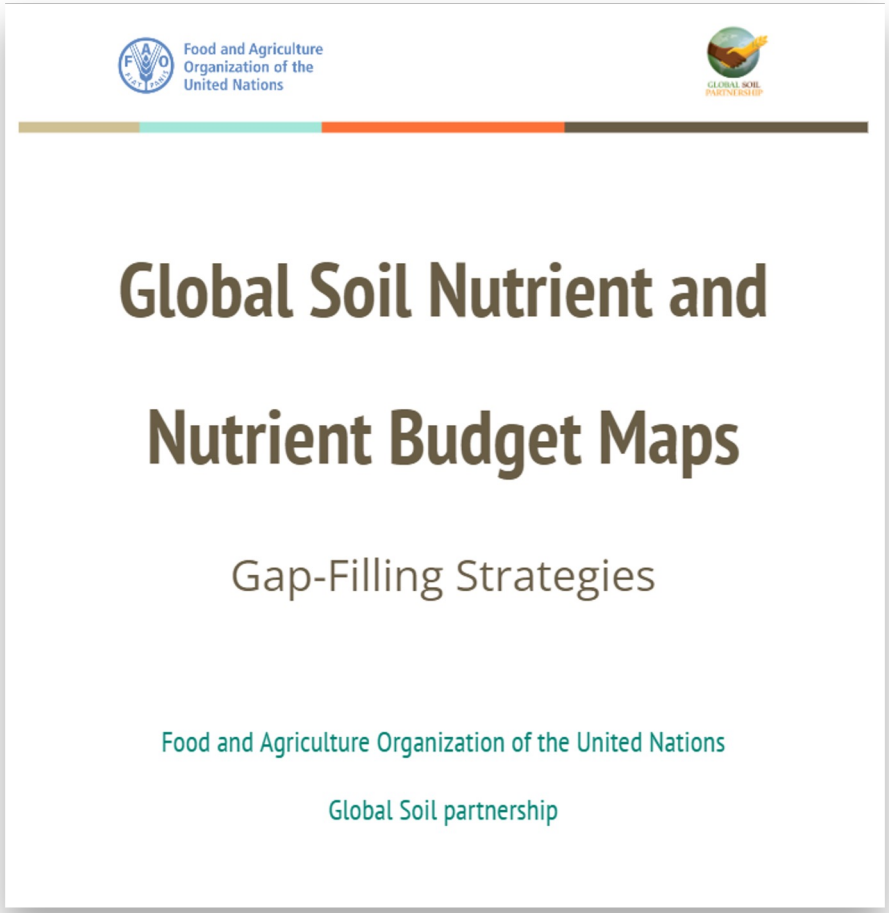
https://github.com/FAO-GSP/GSNmap-Gap-Filling/tree/main

# GSNmap Phase I

## gap-filling strategies

Link to the document

| Nutrient | Data Type | Source |
|---|---|---|
| PHOSPHORUS | Vector Data | Batjes et al. (2017) |
| | | Batjes et al. (2020) |
| | | Brazilian Repository of Soil Data |
| | | Hou, E. (2017) |
| | | Hou et al. (2018) |
| | | Lu, Chaoqun; Tian, Hanqin (2016) |
| | | Jones et al. (2020). LUCAS 2015 Topsoil Database |
| | | McDowell et al. (2023) |
| | | NEON (2022) |
| | | WoSIS Database |
| | | He. X., et al (2021) |
| | | Pavinato et al. (2021) |
| PHOSPHORUS | Raster Data | McDowell et al. (2023) |
| | | Poggio, L., et al (2021) |
| | | He. X., et al (2021) |
| | | Yang et al. (2014) |
| | | Alewell et al. (2020) |



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INSOILFER
Working Group Meetings
27-29
November
2023
GSNmap - Phase II
Mapping Nutrient Budgets
Insoilfer
International Network on
Soil Fertility and Fertilizers
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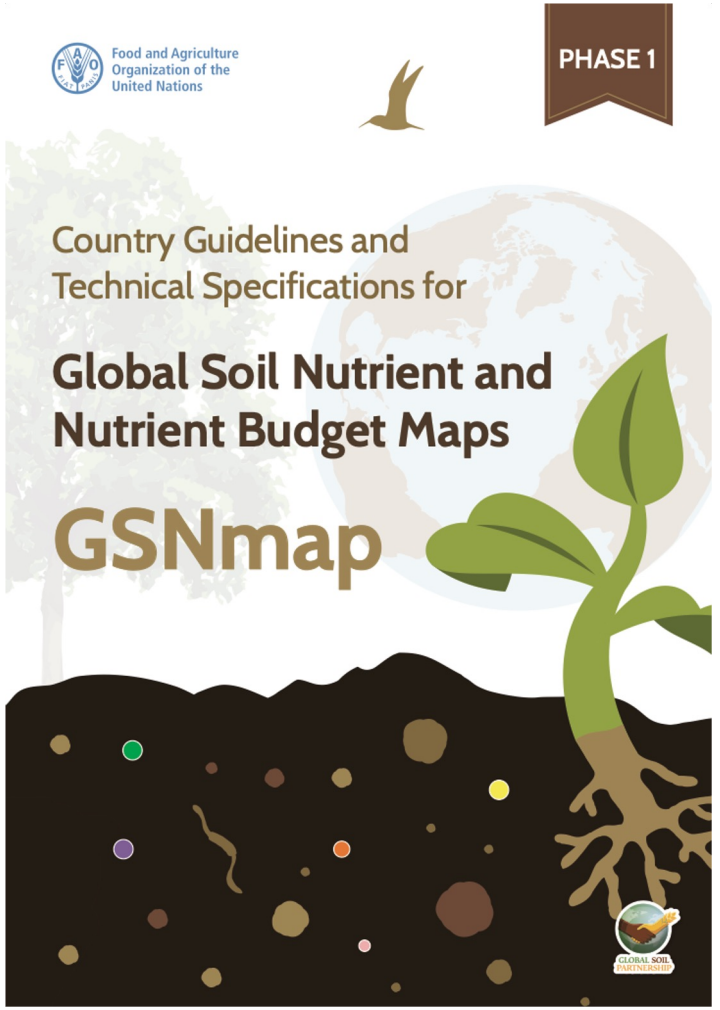
# Rationale

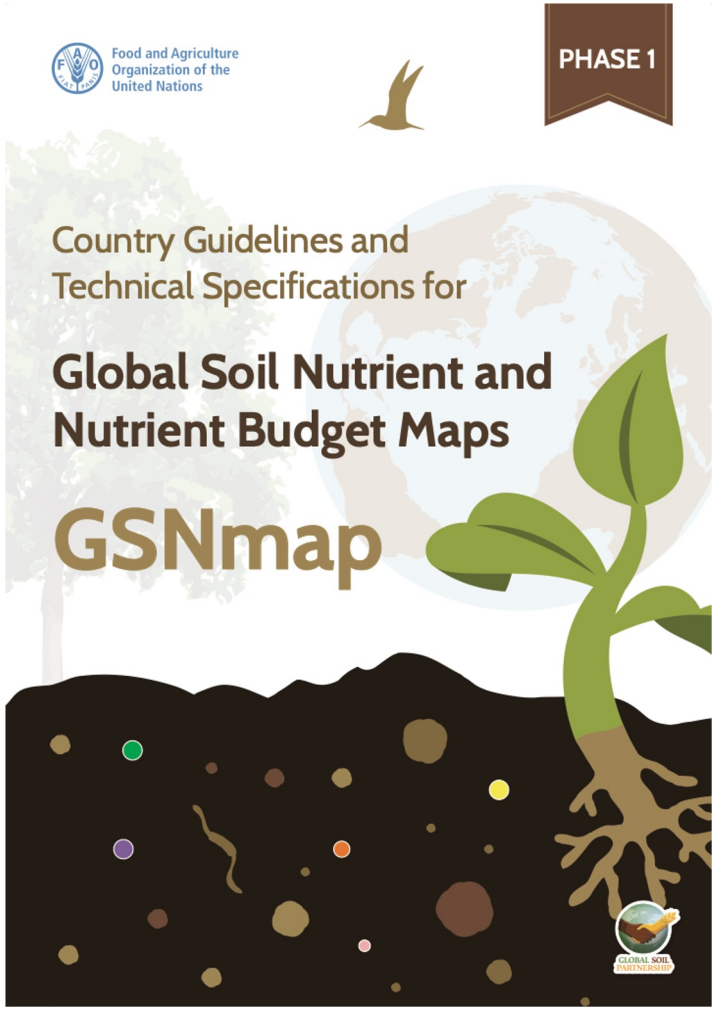
- Data from nutrient dynamics on a global scale, is aggregated at national scale and on a yearly basis (FAOSTAT, IFA, IFRI ).

- This data lacks the detail to reflect subnational spatial variations and the actual status of soil nutrients.



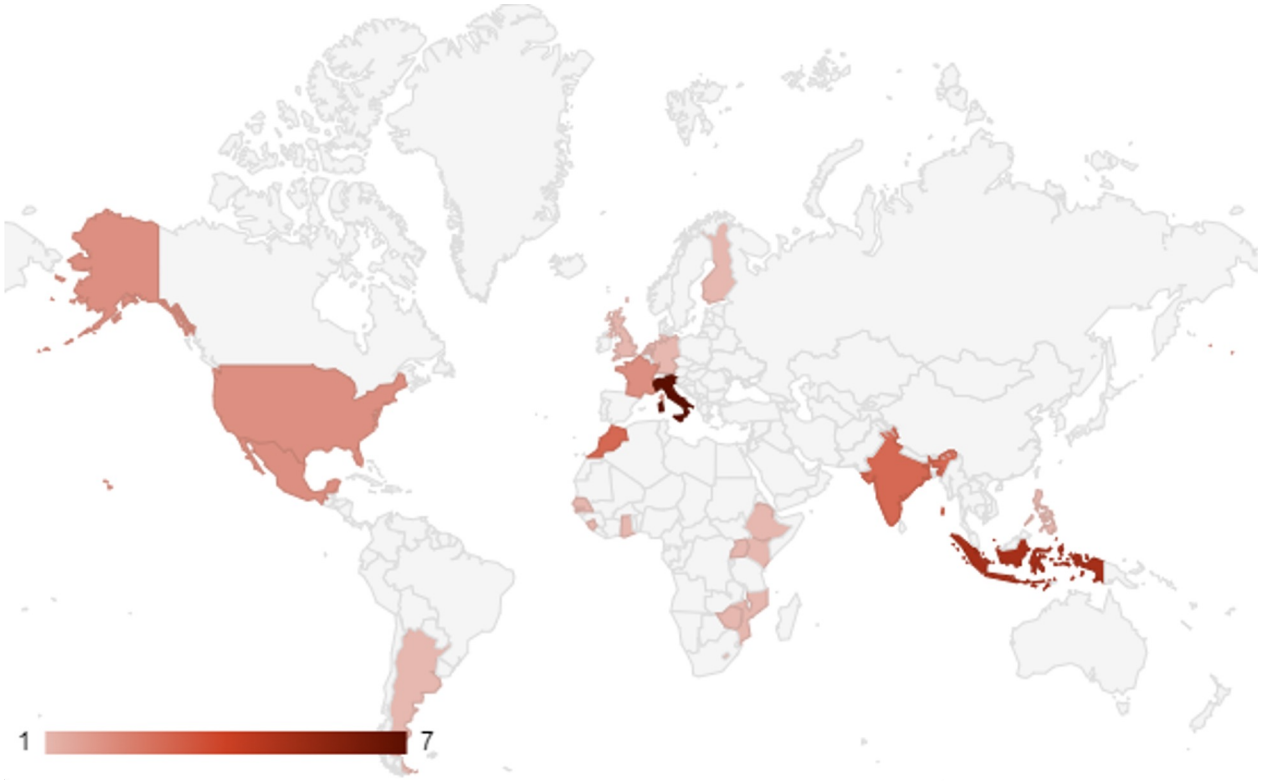
# Objective

- Improve the global soil nutrient budgets by incorporating assessments of soil nutrient stocks and the impact of erosion and leaching under a country-driven approach.



**24** Experts on Soil Nutrition

**2** Meetings for discussing methodologies to produce national maps, get insight and recommendations




Source: United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations, modified by the authors. Notes: Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

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# GSNmap Phase II

## GSNmap Working Group

### Agenda

| | | |
|---|---|---|
| 1. | Opening and Tour de Table | 14:00 - 14:15 |
| 2. | GSNmap: Progress and challenges (15 min) | 14:15 - 14:30 |
| 3. | GSNmap Phase I: top-down gap-filling strategy (15 min) | 14:30 - 14:45 |
| | *Q&A* | 14:45 - 15:00 |
| 4. | GSNmap Phase II: mapping soil nutrient budgets (30 min) | 15:00 - 15:30 |
| | *Open discussion* | 15:30 - 16:00 |

Food and Agriculture Organization of the United Nations

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LINK

**Global Soil Nutrient and Nutrient Budget Maps**

GSNmap - Phase II

DRAFT

Food and Agriculture Organization of the United Nations

Global Soil partnership

Minutes of the 2nd meeting

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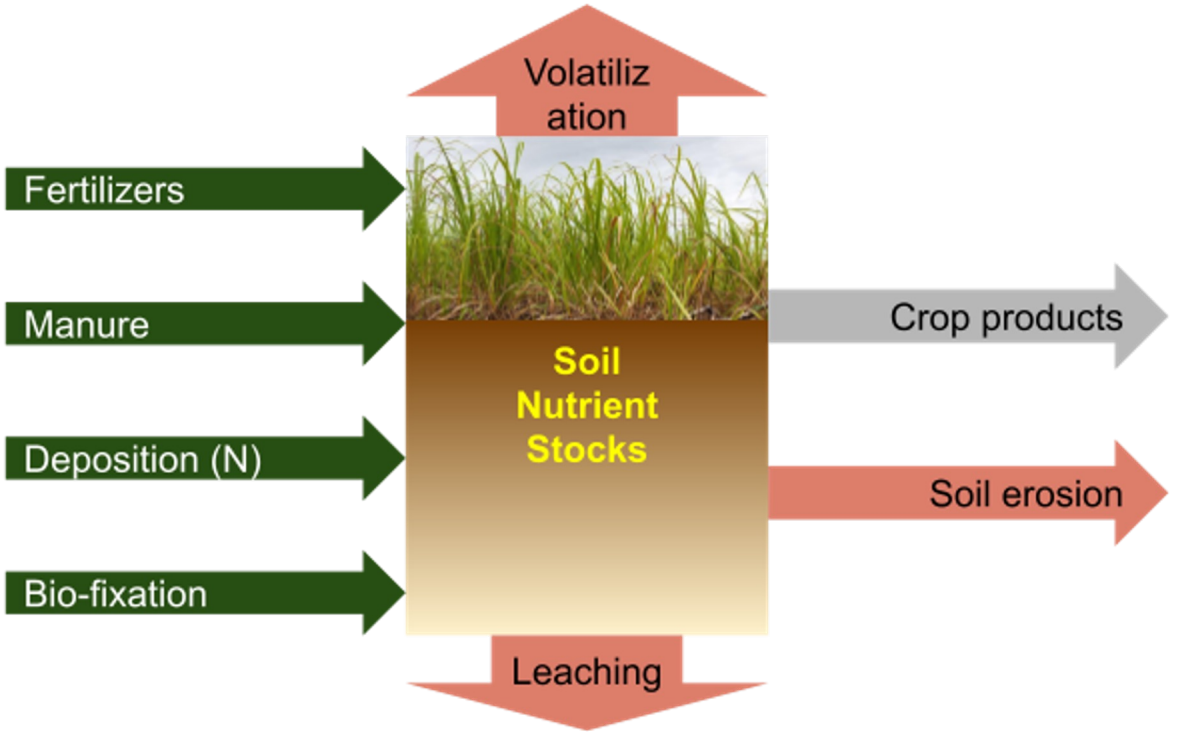
- Zhang et al., 2021
- FAOSTAT, 2022
- Lesschen et al., 2007

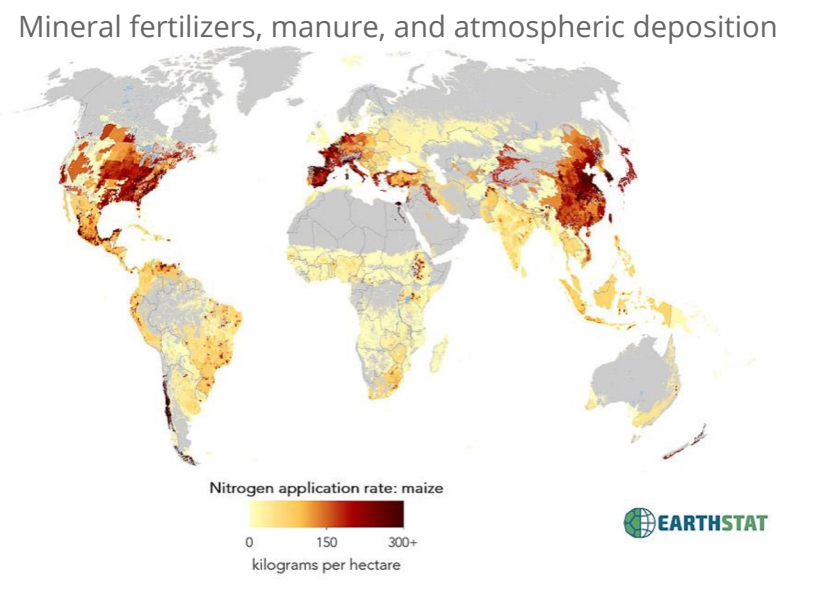



$$SNB_y = \sum_{i=1}^{n}\left(SF_{i,y} + MAS_{i,y} + ND_{i,y} + BF_{i,y}\right) - \sum_{i=1}^{n}\left(CR_{i,y} + NL_{i,y} + NLO_{i,y} + ER_{i,y}\right) \qquad (Eq.1)$$

# GSNmap Phase II

## Input: Synthetic Fertilizer (crop type)

| Input/Output | Tier One (Default Datasets) | Tier Two (National Datasets) |
|---|---|---|
| **Synthetic Fertilisers (SF)** | Mueller et al., 2012. Nutrient Application for Major Crops (EarthSTAT)<br><br>Lu et al. 2017. Global nitrogen and phosphorus fertilizer use in agriculture. | - Fertilisers by Nutrient (FAOSTAT https://www.fao.org/faostat/en/#data/RFN) at subnational level |



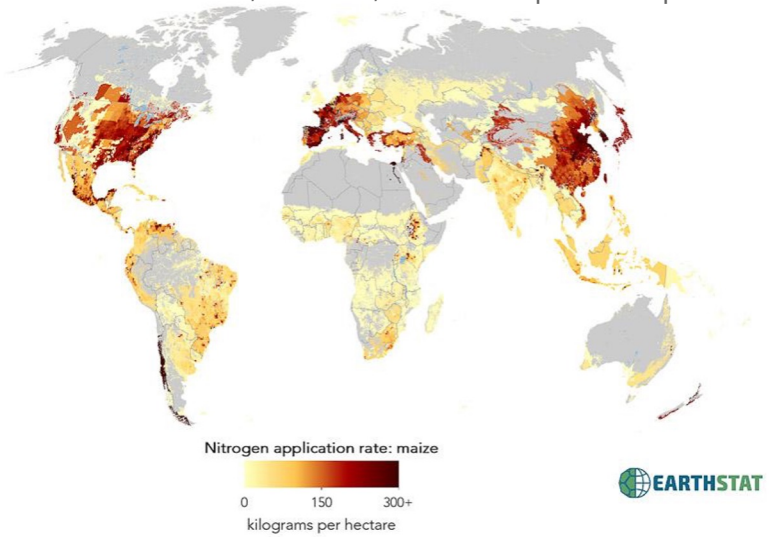

http://www.earthstat.org/nutrient-application-major-crops/

# GSNmap Phase II

## Input: Manure Applied to Soils

| Input/Output | Tier One (Default Datasets) | Tier Two (National Datasets) |
|---|---|---|
| **Manure Applied to Soils (MAS)** | West, et al., 2014. Nutrient Application for Major Crops (EarthSTAT)<br><br>Zhang, B et al. 2017. Global manure nitrogen production and application in cropland | - Livestock Manure (FAOSTAT https://www.fao.org/faostat/en/#data/EMN) at subnational level |

Mineral fertilizers, manure, and atmospheric deposition



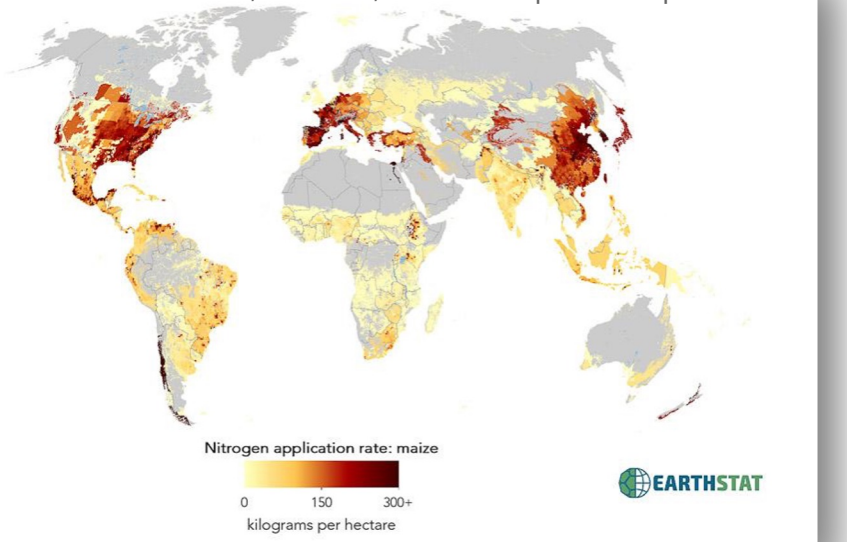

http://www.earthstat.org/nutrient-application-major-crops/

# GSNmap Phase II

## Input: Nitrogen Deposition

| Input/Output | Tier One (Default Datasets) | Tier Two (National Datasets) |
|---|---|---|
| **Nitrogen Deposition (ND)** | West, et al., 2014. Nutrient Application for Major Crops (EarthSTAT) | - Cropland Nutrient Budget (FAOSTAT https://www.fao.org/faostat/en/#data/ESB) at subnational level |

Mineral fertilizers, manure, and atmospheric deposition



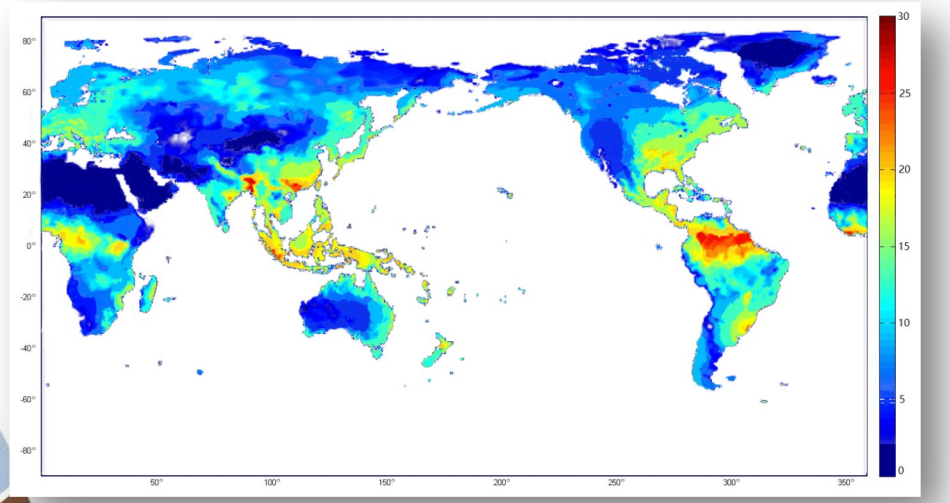

http://www.earthstat.org/nutrient-application-major-crops/

# GSNmap Phase II

## Input: Nitrogen Deposition

| Input/Output | Tier One (Default Datasets) | Tier Two (National Datasets) |
|---|---|---|
| **Biological Fixation (BNF)** | Yu, T. and Zhuang, Q. 2020. Modelling biological nitrogen fixation in global natural terrestrial ecosystems. | - Cropland Nutrient Budget (FAOSTAT https://www.fao.org/faostat/en/#data/ESB) at subnational level |

Simulated spatial distribution of BNF rates (kg $N_2$ $ha^{-1}$ $yr^{-1}$)



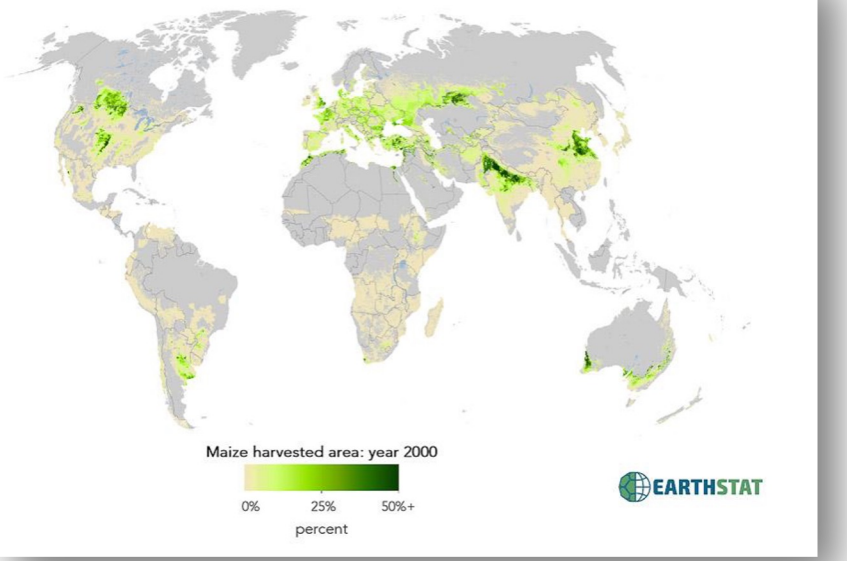

https://bg.copernicus.org/articles/17/3643/2020/

# GSNmap Phase II

## Output: Crop Removal

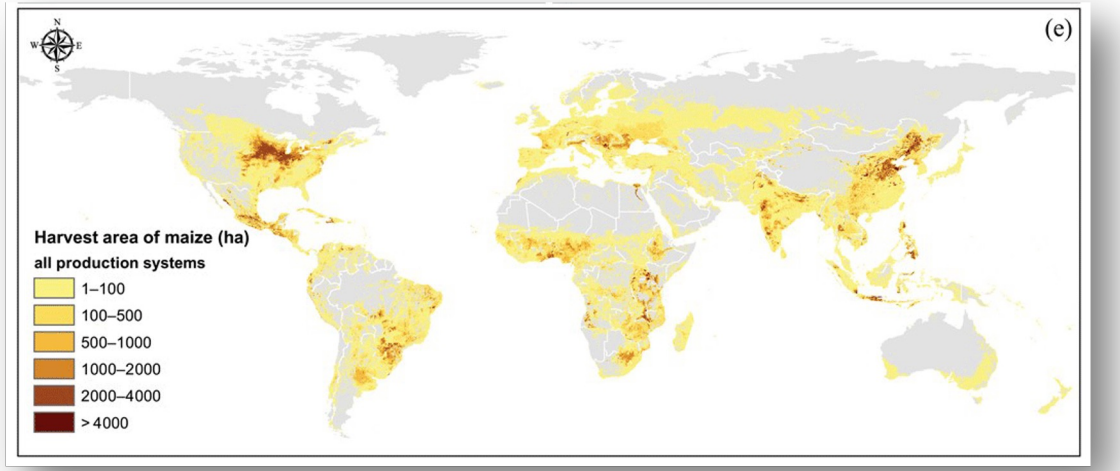
| Input/Output | Tier One (Default Datasets) | Tier Two (National Datasets) |
|---|---|---|
| **Crop Removal (CR)** | Monfreda et al. 2008. Harvested Area and Yield for 175 Crops (EarthSTAT)<br><br>SMAP IFPRI V4 (Yu et al., 2020) | Subnational information |

Harvested Area and Yield for 175 Crops year 2000




http://www.earthstat.org/harvested-area-yield-175-crops/

Harvested-area maps for maize in all farming systems (Yu et al., 2020)

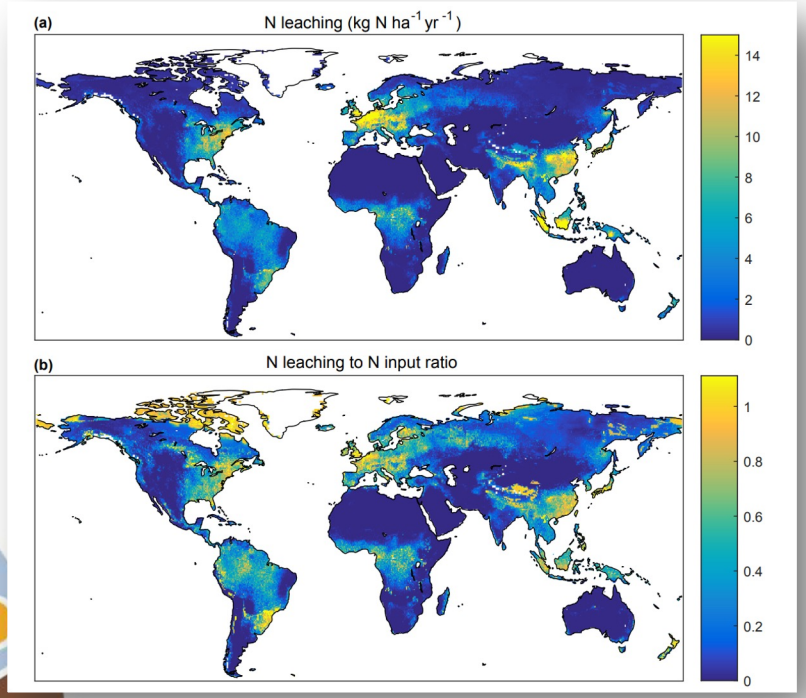



https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/PRFF8V

# GSNmap Phase II

## Output: Nitrogen Leaching

| Input/Output | Tier One (Default Datasets) | Tier Two (National Datasets) |
|---|---|---|
| **Nitrogen Leaching (NL)** | Braakhekke et al., 2017. Nitrogen leaching from natural ecosystems under global change | Lesschen et al., 2007 |




$$L_N\ (kg\ N/ha/year) = 0.0463 + 0.0037 * (P\ /\ (C - L)) * (FN + D - NOM - U)$$

$$L_K\ (kg\ K/ha/year) = 6.87 + 0.0117 * P + 0.173 * FK - 0.265 * CEC$$

where:

- $L_N$ and $L_K$ = N leaching and K leaching, respectively
- $P$ = precipitation (mm/year)
- $C$ = clay (%)
- $L$ = layer thickness (m) [rooting depth]
- $FN$ = mineral and organic fertilizer nitrogen (kg N/ha/year)
- $D$ = decomposition rate of organic matter (1.6% per year)
- $NOM$ = amount of nitrogen in soil organic matter (kg N/ha)
- $U$ = uptake by crop (kg N/ha/year)
- $FK$ = mineral and organic fertilizer potassium (kg K/ha/year)
- $CEC$ = cation exchange capacity (cmol/kg)

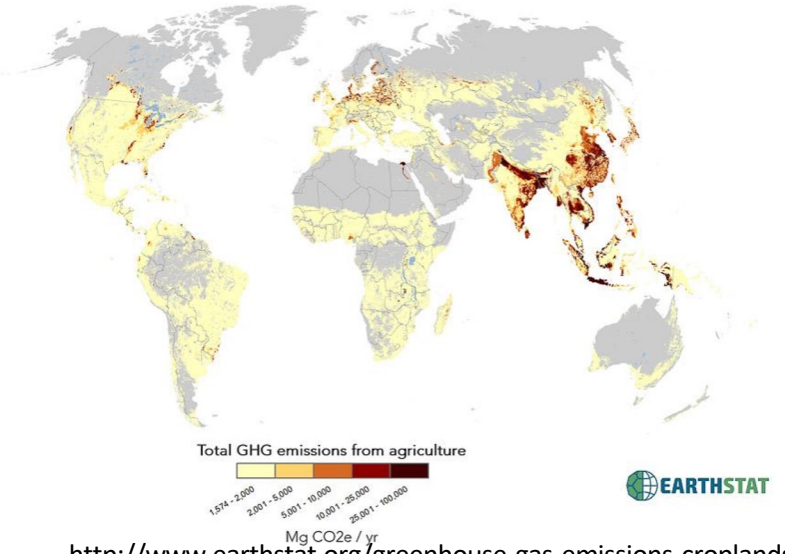
https://esd.copernicus.org/articles/8/1121/2017/esd-8-1121-2017.pdf
https://easy.dans.knaw.nl/ui/datasets/id/easy-dataset:75687

# GSNmap Phase II

## Output: Nitrogen Loss

| Input/Output | Tier One (Default Datasets) | Tier Two (National Datasets) |
|---|---|---|
| **Nitrogen Loss (denitrification + volatilization) (NLO)** | Carlson et al. 2016. Greenhouse gas emissions intensity of global croplands (EarthSTAT) | NLO (Kg N ha yr-1) = 0.025 + 0.000855 P (mm) + 0.13 F (inputs mineral + organic kg N ha yr) + 0.117 SOC (%) (Lesschen et al., 2007) |

Greenhouse Gas Emissions on Croplands

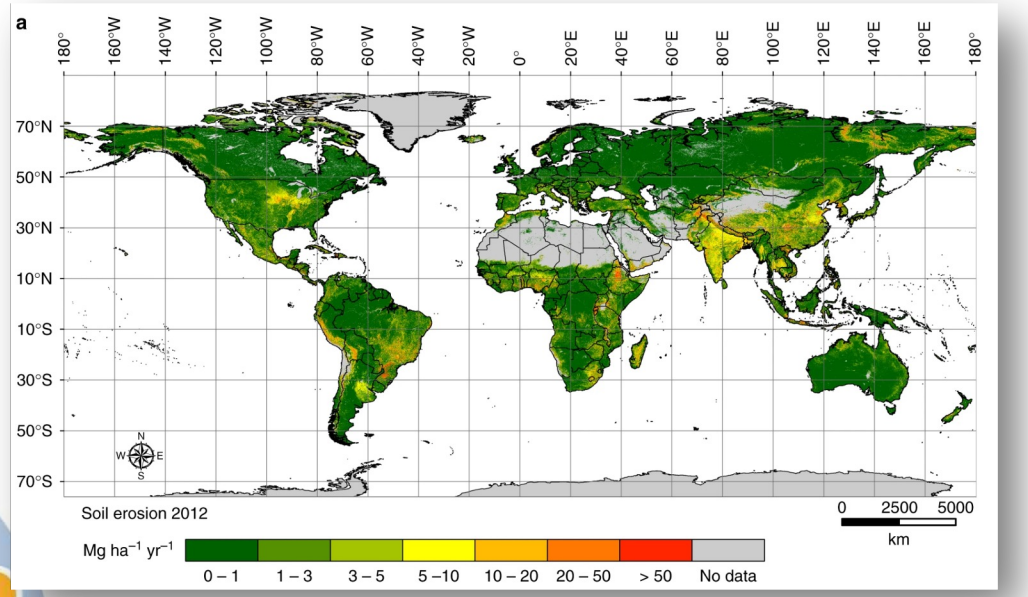



http://www.earthstat.org/greenhouse-gas-emissions-croplands/

# GSNmap Phase II

## Output: Erosion

| Input/Output | Tier One (Default Datasets) | Tier Two (National Datasets) |
|---|---|---|
| **Erosion (ER)** | Borrelli et al 2017. JSR Global Soil Erosion | National Soil Erosion Map |




+

Soil nutrient stock from Phase I

https://esdac.jrc.ec.europa.eu/content/global-soil-erosion#tabs-0-description=0

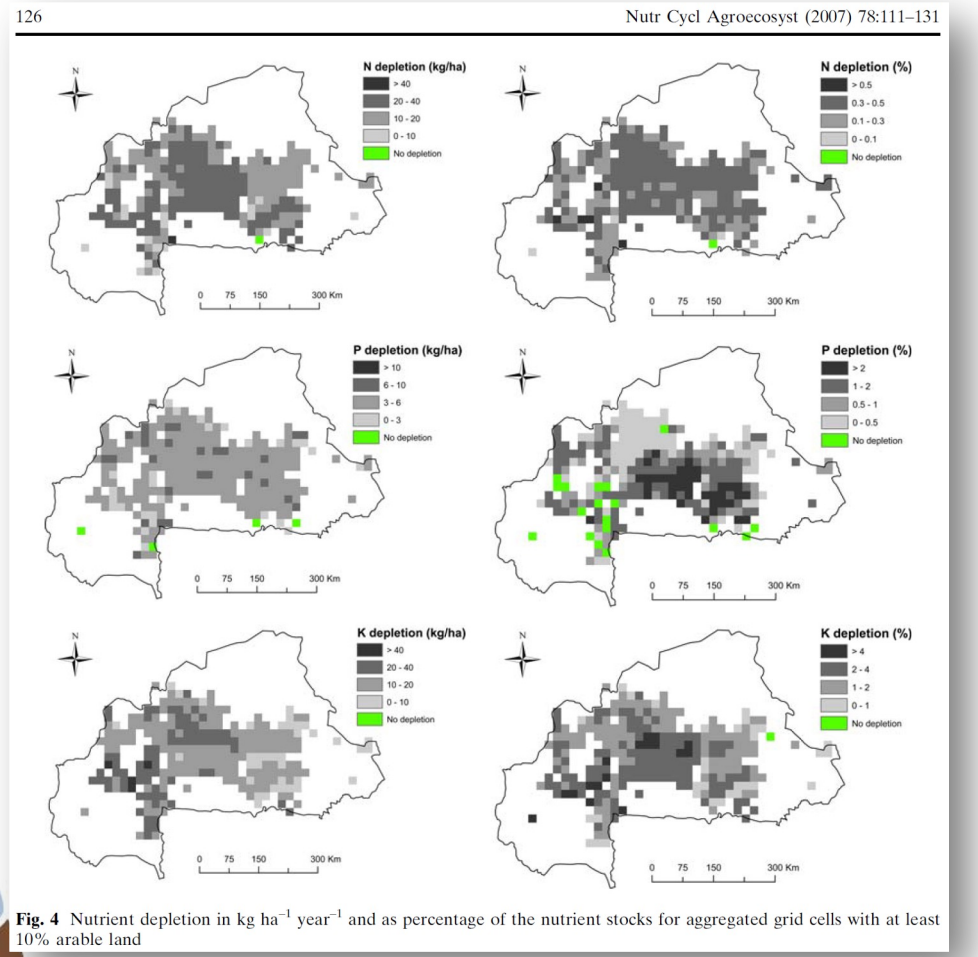
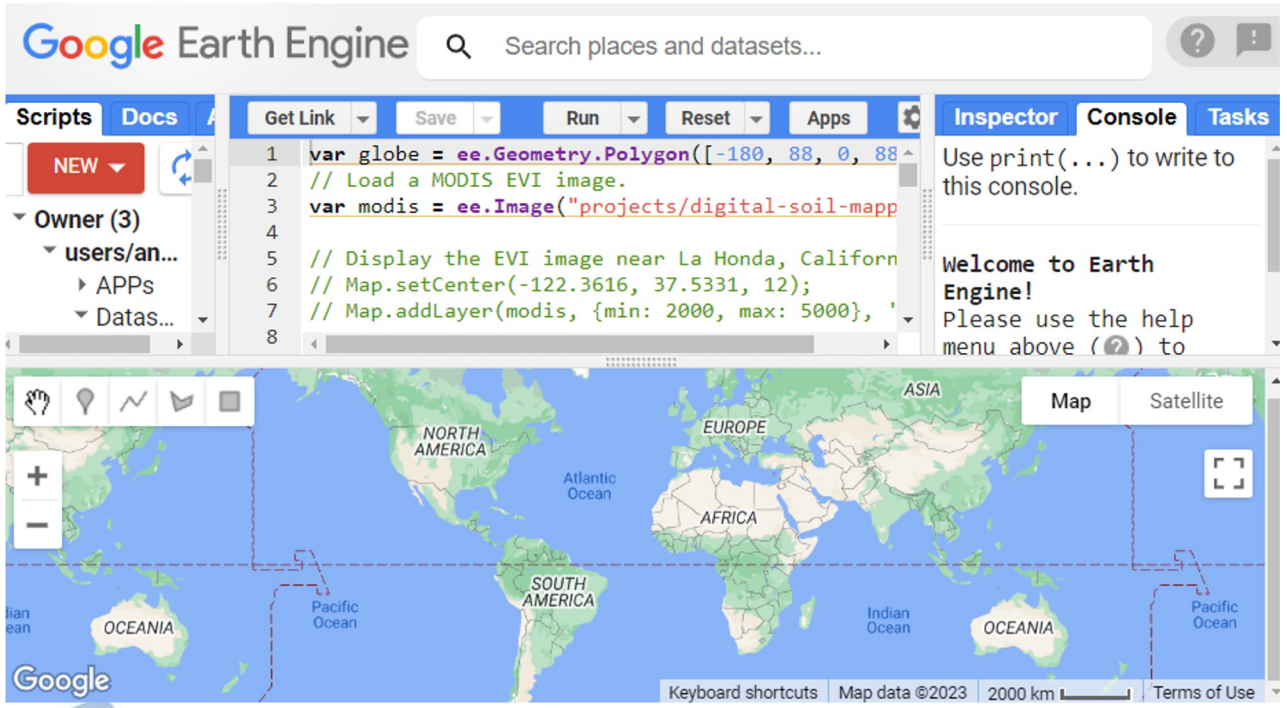



**Fig. 4** Nutrient depletion in kg ha$^{-1}$ year$^{-1}$ and as percentage of the nutrient stocks for aggregated grid cells with at least 10% arable land

# Expected Results

- Nutrient stocks estimated during Phase I might be included as an input factor to estimate nutrient loss by soil erosion, and to the ratio between nutrient depletion with regard to nutrient stock
- While this will only be a (static) picture, not on a yearly basis, it can be taken as a baseline to measure the risk of soil degradation

Lesschen et al., 2007




- GEE script with global defaults and GSNmap layers from Phase I (Tier 1)
- Countries can upload assets (layers) for the other global parameters if available at national level (Tier 2)
- A country could request to be blank in the final map, to submit all standard layers (Tier 1), or to improve the estimation of any of the input layers (Tier 2).

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# GSNmap Phase II

Follow-Up

1. Technical specifications and country guidelines to be finalised and sent to INSII on the first half 2024.
2. INSII will review and approve it.
3. Kick-off second phase during the second half 2024.

**Luca Montanarella**
*INSII Chairperson*

Food and Agriculture Organization of the United Nations

27-29 November 2023

# Thanks for your attention

Yusuf

Isabel

Newton

Luis

Marcos

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