Food and Agriculture Organization of the United Nations

The Global Soil Organic Carbon Sequestration Potential Map

(GSOCseq)

Isabel Luotto
Guillermo Peralta

GLOBAL SOIL PARTNERSHIP

The Global Soil Partnership (GSP)

Was established in December 2012 with the main aim of:

1. creating a mechanism to foster strong partnerships and collaboration to place soils on the global agenda;
2. promoting Sustainable Soil Management (SSM);
3. improving the governance of soils.

Find out more about the GSP and its many activities and projects here: http://www.fao.org/global-soil-partnership/en/

The Global Soil Partnership (GSP) in numbers:

10 years of GSP!

8 regional partnerships, over **370** partners worldwide

160 focal points appointed directly by UN’s Food and Agriculture Organization FAO member countries

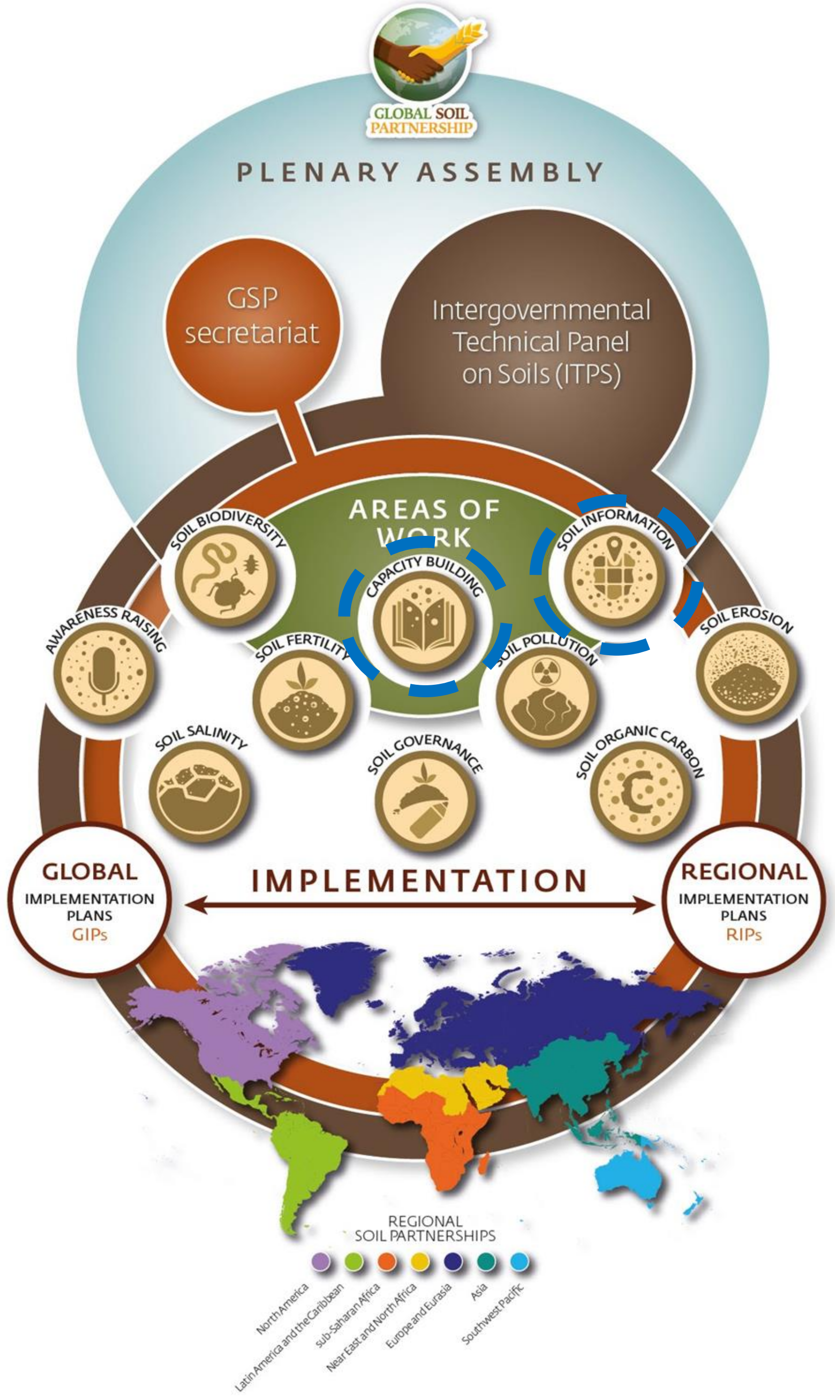
7 International Networks

Check out the main **achievements of the GSP** in this 10 year timeline!

https://www.fao.org/3/cc0212en/cc0212en.pdf

As well as the GSP Brochure!

https://www.fao.org/documents/card/en/c/cc0921en


GLOBAL SOIL PARTNERSHIP
PLENARY ASSEMBLY
GSP secretariat
Intergovernmental Technical Panel on Soils (ITPS)
AREAS OF WORK
SOIL BIODIVERSITY
CAPACITY BUILDING
SOIL INFORMATION
AWARENESS RAISING
SOIL FERTILITY
SOIL POLLUTION
SOIL EROSION
SOIL SALINITY
SOIL GOVERNANCE
SOIL ORGANIC CARBON
GLOBAL
IMPLEMENTATION PLANS
GIPs
IMPLEMENTATION
REGIONAL
IMPLEMENTATION PLANS
RIPs
REGIONAL SOIL PARTNERSHIPS
North America
Latin America and the Caribbean
sub-Saharan Africa
Near East and North Africa
Europe and Eurasia
Asia
Southwest Pacific

GSP - area of work:
Soil Data and Information

INSII
INTERNATIONAL NETWORK OF SOIL INFORMATION INSTITUTIONS

Soil Data is essential for…

- Global challenges, e.g. Earth-System **Models**
- National and regional data-driven **policy-making**
- Field operations, e.g. to optimize **fertilizer** and **pesticide applications**

However…

Soil Data is…

- **Not harmonized**
- **Not updated** regularly
- **Fragmented** among and within Institutions

GSP - area of work:
Soil Data and Information

Global Data Products	System Development	Capacity Development	Capacity Development	Publications
4	7	60	1200+	12
36 Map Layers	National Soil Information Systems (TCP)	Training Workshops	National Experts	Key Publications
Country Driven	Digital Transformation	DSM, Product Oriented	Large Expert Network	Technical, Scientific

Capacity Development

Capacity Development

1200+

National Experts

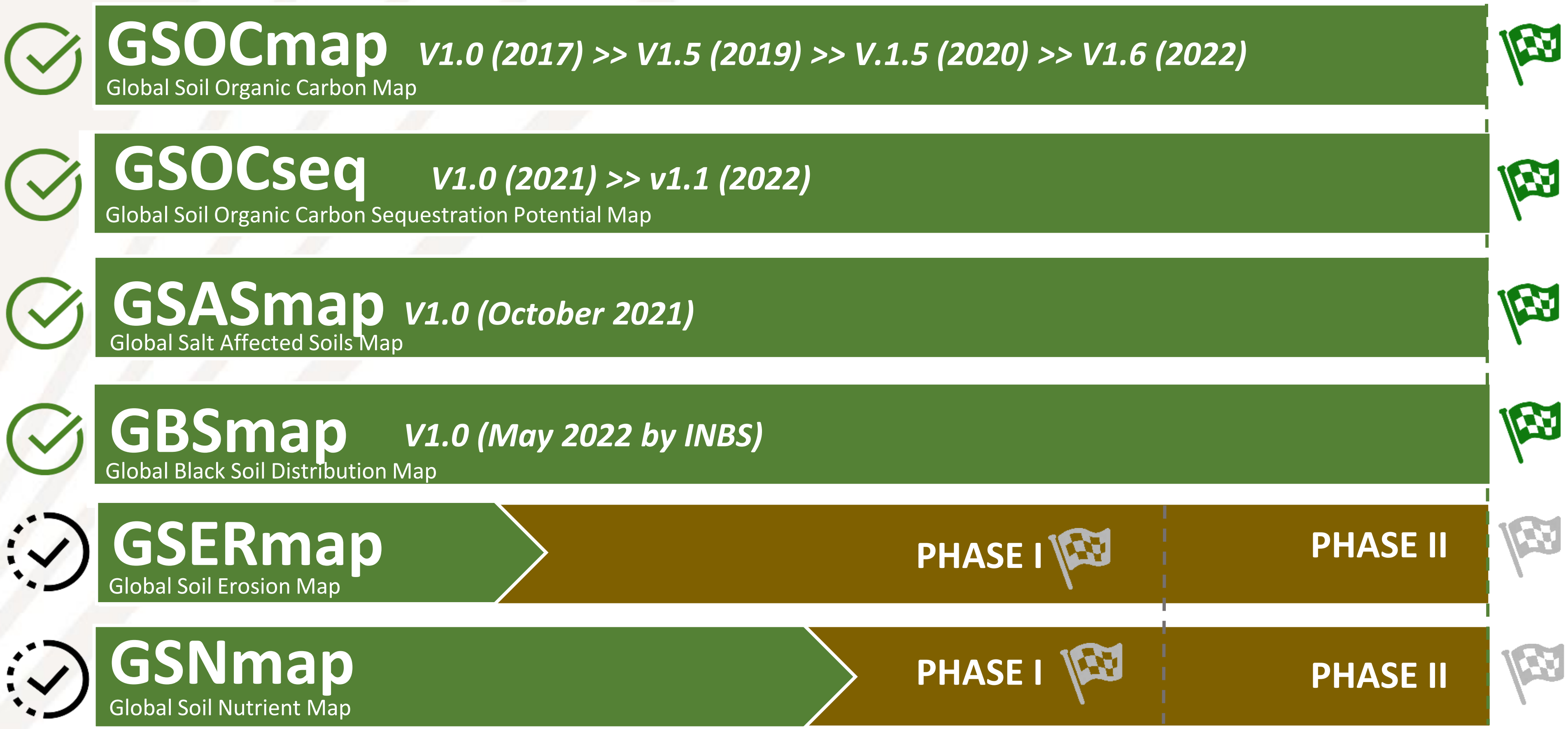
60+

Training Workshops

140+ Countries
All GSP Regions

GloSIS: Country-driven Global Data Products

Of the countries, by the countries, for the countries!



Why **GSOC**seq?

Following FAO members request, Global Soil Partnership (GSP) has started the GSOCseq initiative to:

1. **Set** attainable and evidence based **national targets for carbon sequestration;**

2. **Identify areas** that have high SOC sequestration **for SSM projects**

3. **Enhance National capacities** on sustainable soil management, soil data management, digital soil mapping and modelling; as inputs for NDCs and reporting

The GSOCseq approach for reporting CSCs in GHGI

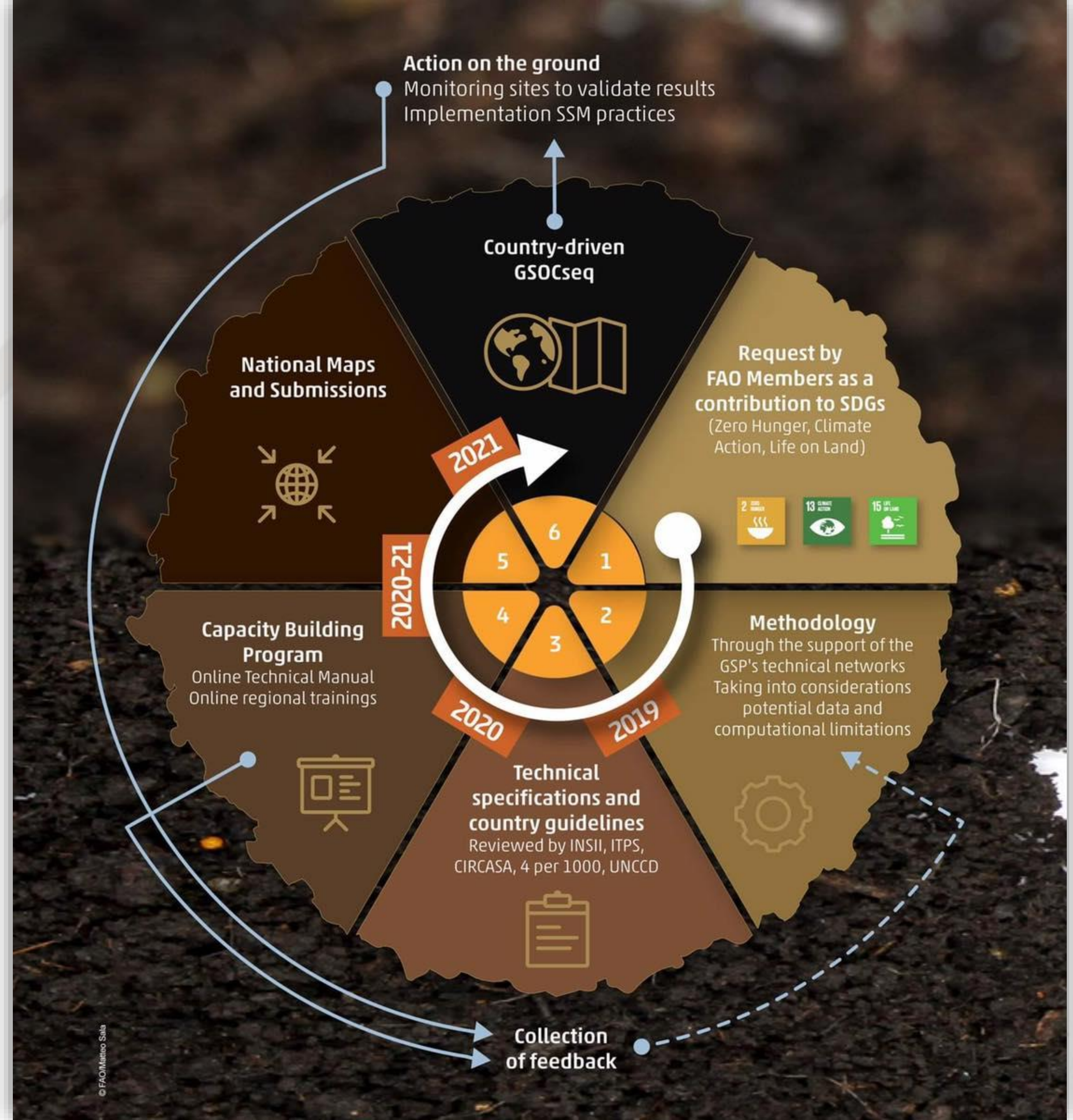
- It's important to understand what the GSOCseq approach allows you to report on
  - ✓ CO_2 emission/removals in non-waterlogged* mineral soils in croplands and grasslands
  - ✓ CO_2 emissions/removals in paddy field soils* (Shirato & Yokozawa, 2005)

- However, the current GSOCseq has the following limitations:
  - ✕ It does not replace the need for ground data as well as the Tier 1 approach (*the results should be validated with local measurements and compared to the results following the Tier 1 approach*)
  - ✕ Further parametrization might be needed (e.g. SOC dynamics in Vulcanic soils)
  - ✕ It cannot report CO_2 emissions/removals for forests
  - ✕ It does not take into account CH_4, NO_2 emissions

- Why take part in the GSOCseq initiative?
  - ↱ If properly parametrized and complemented superior to Tier 1 – local spatially explicit data
  - ↱ Thw GSP offers capacity development in GIS, mapping and modeling
  - ↱ Scenario-based modeling and mapping for data-driven policy-making

GSOCseq

A country driven process



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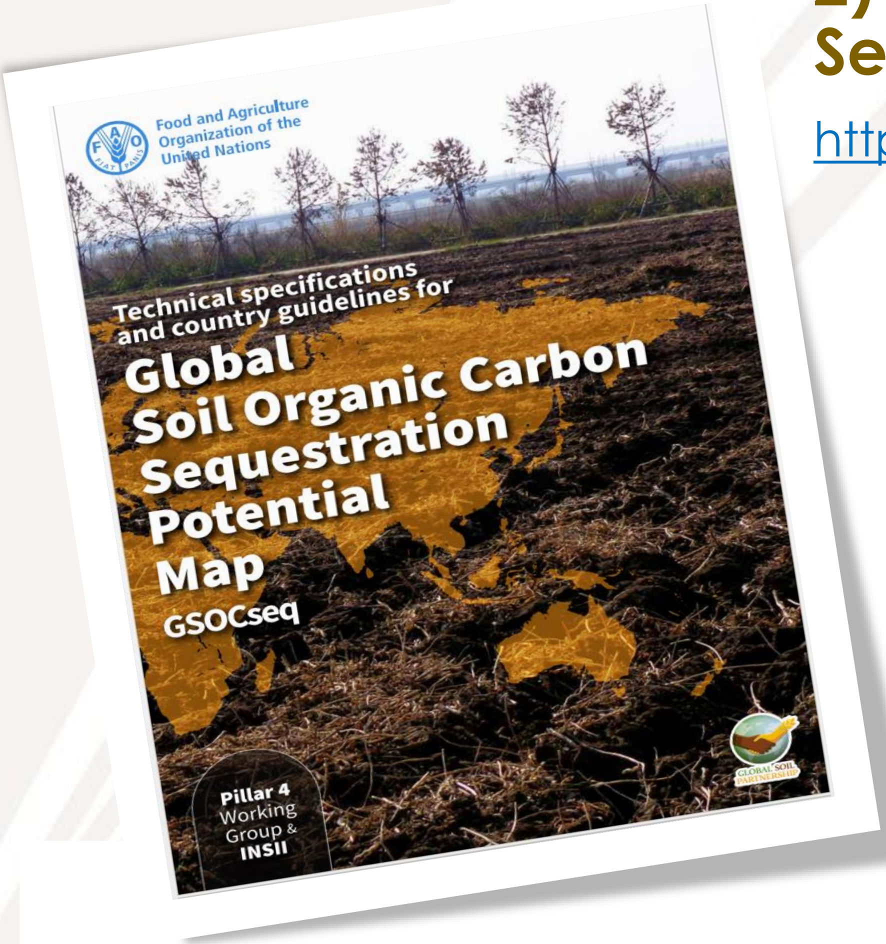
The GSOCseq approach



1) Technical Specifications and Country guidelines

http://www.fao.org/documents/card/es/c/cb0353en/

2) Technical Manual Global Soil Organic Carbon Sequestration Potential Map GSOCseq

https://www.fao.org/documents/card/en/c/cb2642en/

Contributors and reviewers

Professor Pete Smith – University of Aberdeen

INSII - International Network of Soil Information Institutions

ITPS - Intergovernmental Technical Panel on Soils

4per1000 SCT - 4 per 1000 Scientific and Technical Committee

CIRCASA - (Coordination of International Research Cooperation on Soil Carbon Sequestration in Agriculture)

UNCCD-SPI - The UNCCD Science-Policy Interface

The Global Soil Organic Carbon Sequestration Potential Map

GSOCseq

Methodology

- Based on the **process-based model RothC**
- **3 SSM scenarios and 1 business as usual**
- Uncertainty based on the uncertainties of the input data

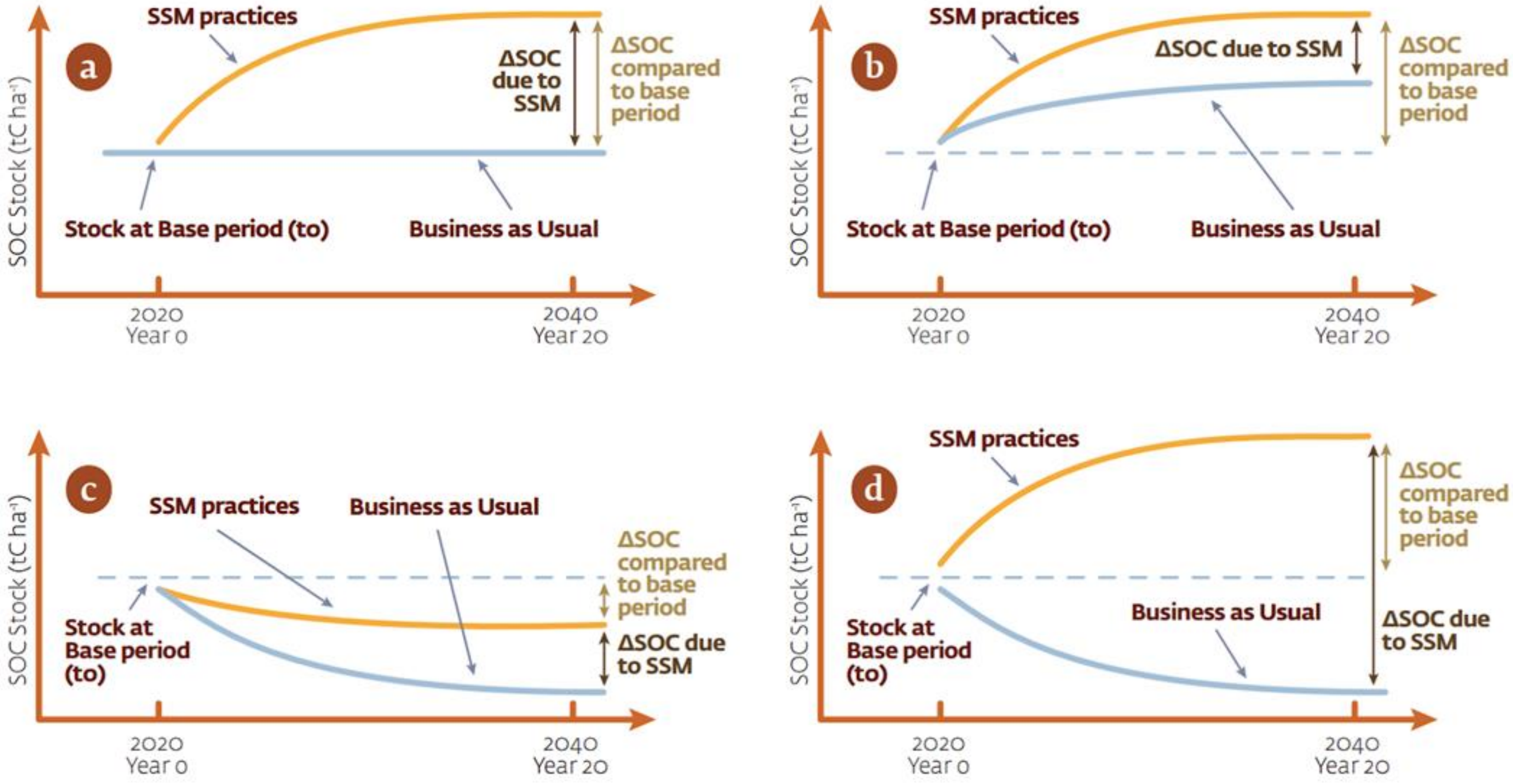
Extent

- **Agriculturally managed lands** where SSM can be implemented
- **20 years** into the furute (t0=2020, t=2020)
- **1 km resolution**

Process

- **Country-driven** (global map based on national submissions)
- Launched in 2021, continously updated following a **Versoning system**

Absolute and relative SOC sequestration

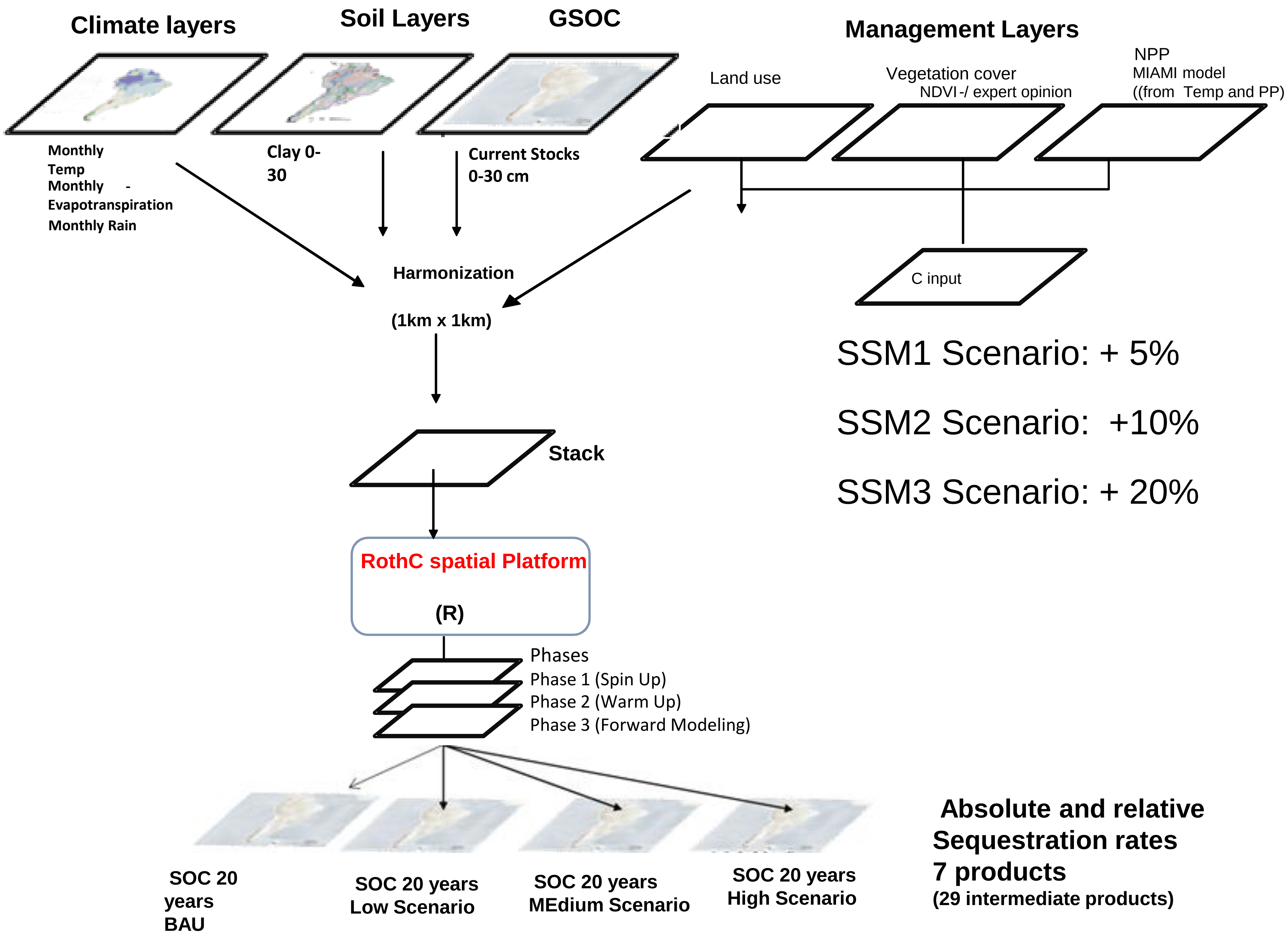


SOC sequestration (Difference) = Δ SOC in 20 years

Annual Sequestration rate = Δ SOC / 20 years

Absolute sequestration rate = (Final SOC SSM 2040– Initial SOC 2020)/ 20 years

Relative Sequestration rate= (Final SOC SSM 2040– Final SOC BAU 2040)/ 20 years



Climate layers
Soil Layers
GSOC
Management Layers
Land use
Vegetation cover
NDVI -/ expert opinion
NPP
MIAMI model
((from Temp and PP)
Monthly
Temp
Monthly -
Evapotranspiration
Monthly Rain
Clay 0-
30
Current Stocks
0-30 cm
C input
Harmonization
(1km x 1km)
SSM1 Scenario: + 5%
SSM2 Scenario: +10%
SSM3 Scenario: + 20%
Stack
RothC spatial Platform
(R)
Phases
Phase 1 (Spin Up)
Phase 2 (Warm Up)
Phase 3 (Forward Modeling)
Absolute and relative
Sequestration rates
7 products
(29 intermediate products)
SOC 20
years
BAU
SOC 20 years
Low Scenario
SOC 20 years
MEdium Scenario
SOC 20 years
High Scenario

Why RothC as standard model?

- **Standard method** among countries (DayCent, Century, ICBM, YASSO,DAISY,AMG, CLM5, etc)
  - Fewer **data requirements**; data relatively easy to obtain;
  - It has been applied across several ecosystems, climate conditions, soils and land use classes;
  - Successfully applied at **national, regional and global scales**; e.g. Smith et al. (2005), Smith et al. (2007), Gottschalk et al. (2012), Wiesmeier et al. (2014), Farina et al. (2017), Mondini et al. (2018), Morais et al.(2019);
  - It (or its modified/derived version) has been used to estimate carbon dioxide emissions and removals in different **national GHG inventories as a Tier 3 approach**; Smith et al. (2020): Australia (as part of the FullCam model, Japan (modified RothC), Switzerland, and UK (CARBINE, RothC).

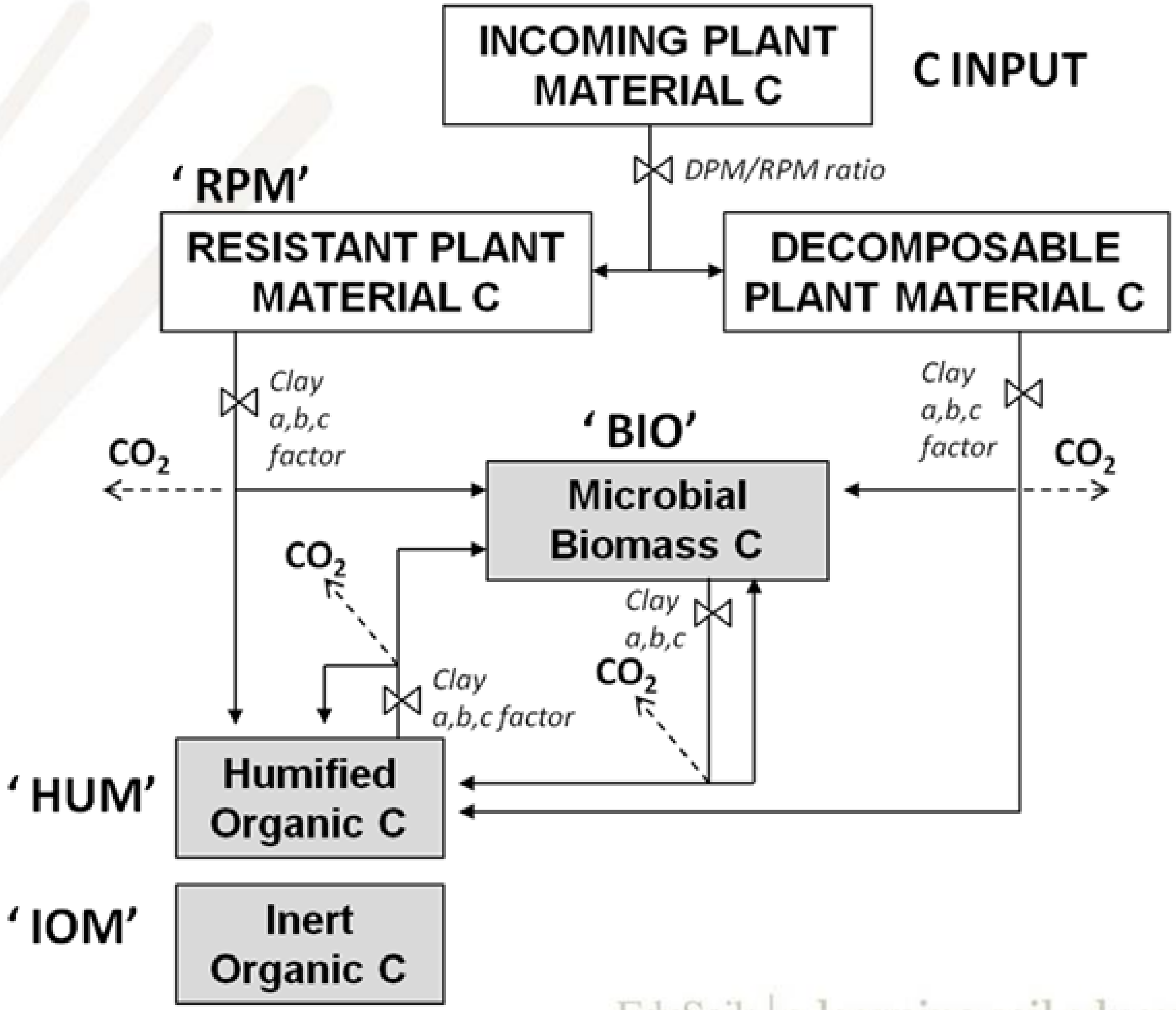
RothC Data requirements

Climate	Soil	Management
		

Climate Data	Soil Data	Land Use- Management Data
1. Monthly rainfall(mm) 2. Average monthly mean air temperature (ºC) 3. Monthly open pan evaporation (mm)/evapotranspiration (mm) Penman-Monteith	1. Total initial 0-30cm SOC stocks (t C ha^{-1}) 2. Initial C stocks of the different pools (t C ha^{-1}): DPM, RPM, BIO, HUM, IOM 3. Clay content (%) at simulation depth.	1. Land cover/use 2. Vegetation cover (binary: bare vs. vegetated) 3. DPM/RPM ratio, an estimate of the decomposability of the incoming plant material 4. Irrigation (to be added to rainfall amounts)* 5. Monthly Carbon inputs from plant residues (aboveground + belowground), (t C ha-1)* 6. Monthly Carbon inputs from organic fertilizers and grazing animals' excretion (t C ha-1)*

2. Country driven Approach

RothC



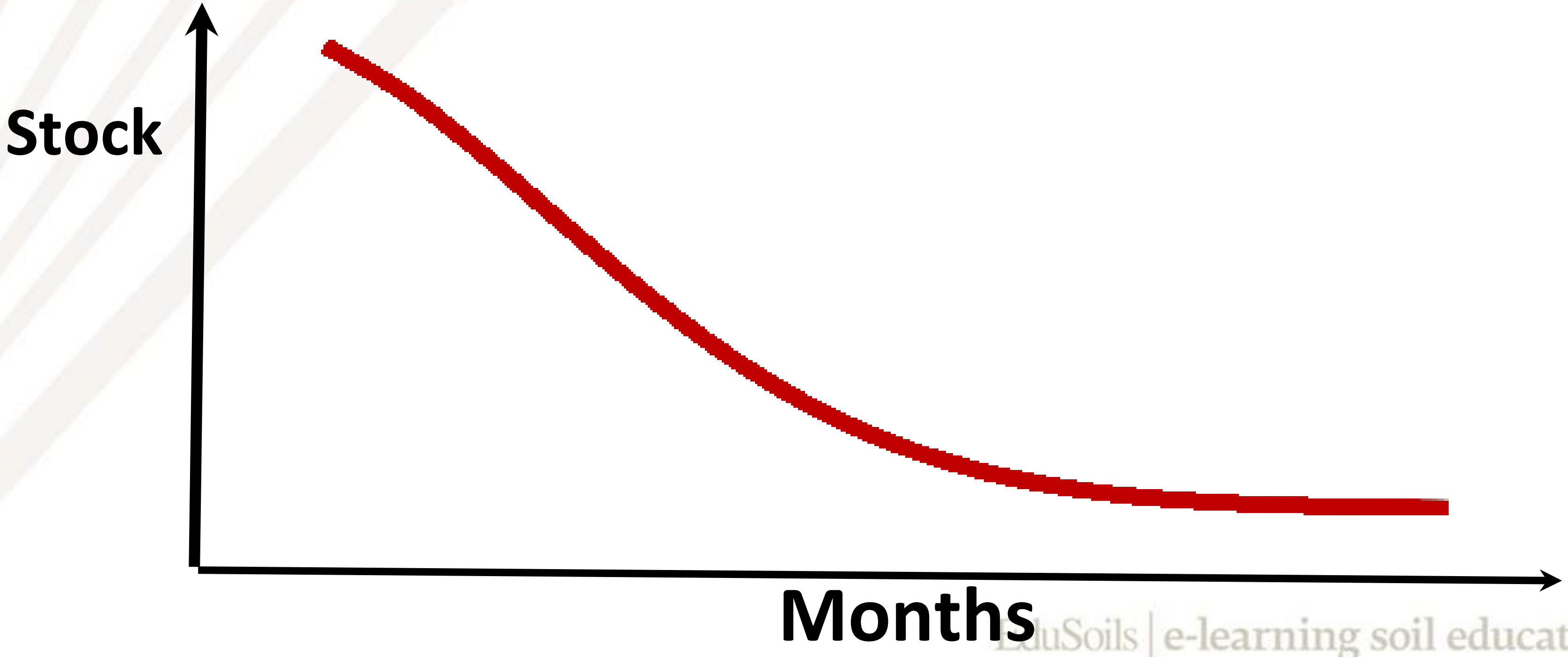
SOC dynamics in RothC

The amount of SOC of each pool (Y) decomposes following an **exponential decay function**:

$$Y \cdot e^{-kt}$$

k = annual decomposition constant

t = time, months 1/12 (0,083)



Decomposition rates

Constants (*k*), *in years^{-1}, different for each pool:*

- DPM (decomposable plant mat): **10.0** .... 0.1 years (turnover time)
- RPM (resistant plant material): **0.3**   ......3.3 years
- BIO (microbial biomass): **0.66**   .... 1.5 years
- HUM (Humified organic C) : **0.02** .... 50 years
- IOM (Inert) .....0.000000 .... ɑ

SOC dynamics in RothC

… These **k** are affected by different factors:

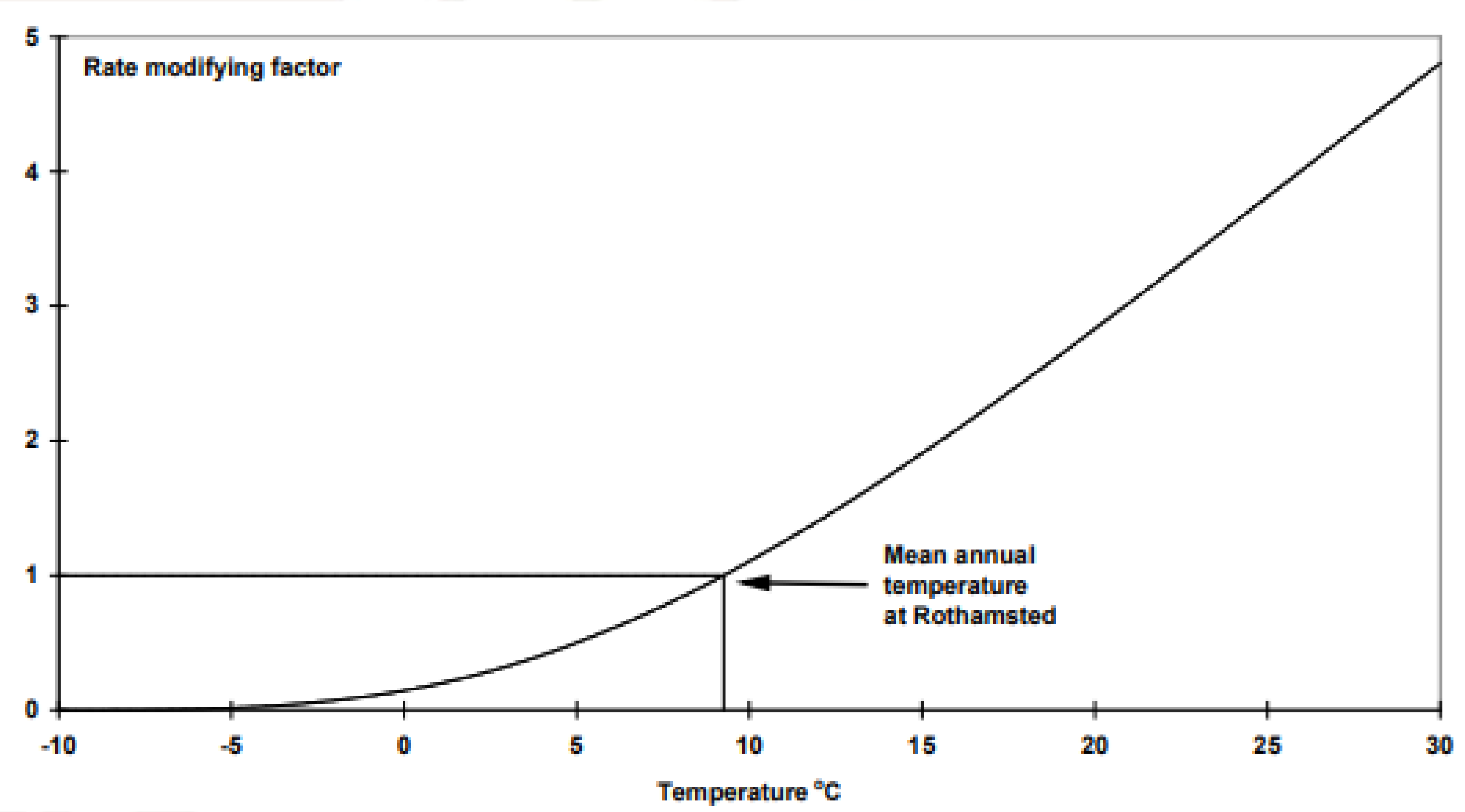
$$Y \, . \, e^{-kt} \Rightarrow Y \, . \, e^{-k.\,a.b.c.\,t}$$

a= temperature factor

b= soil moisture factor

c= soil cover factor

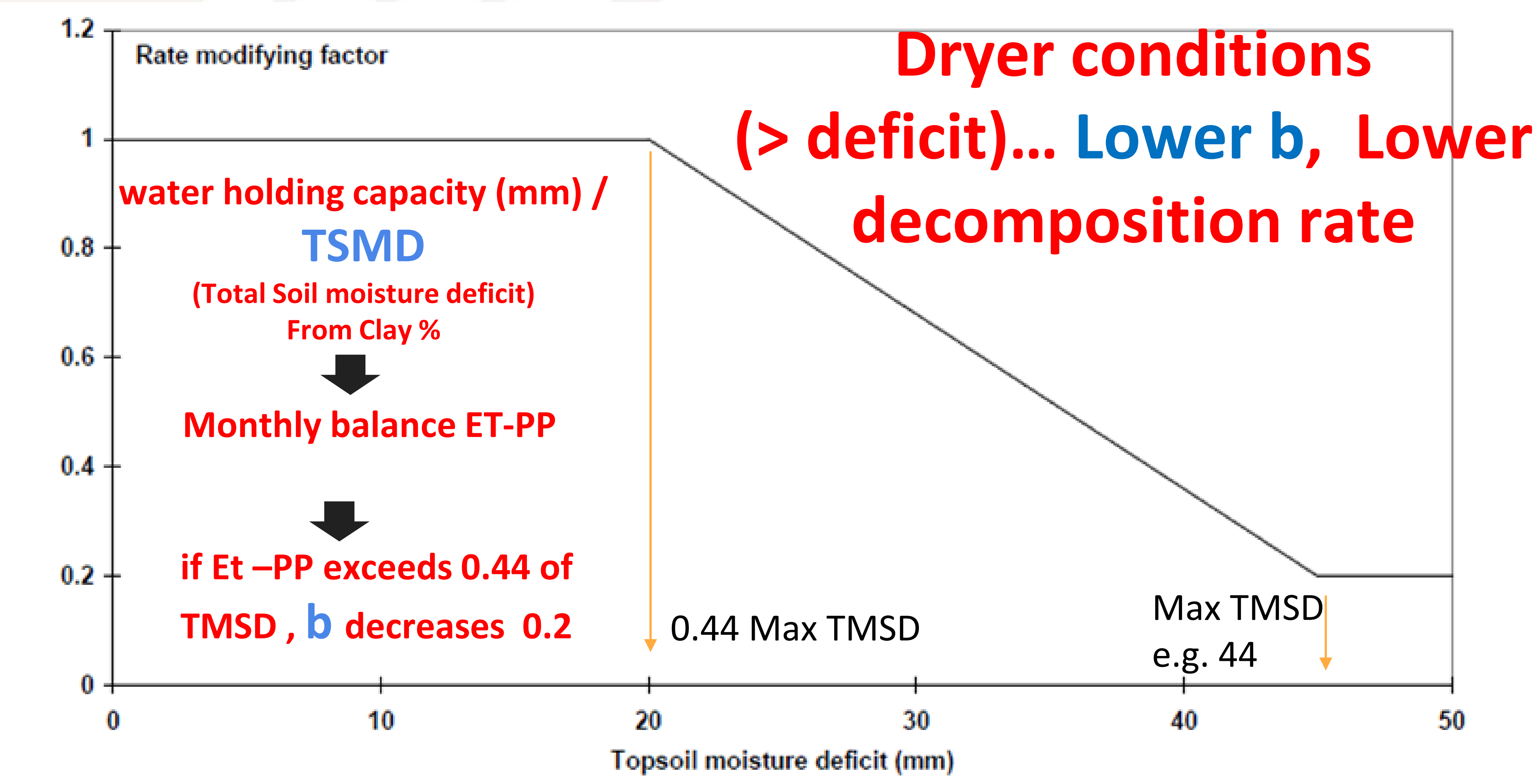
Temperature factor (a)



> Temperature,
> decomposition rate

From: K. Coleman & D.S. Jenkinson, 2014

Soil moisture factor (b)



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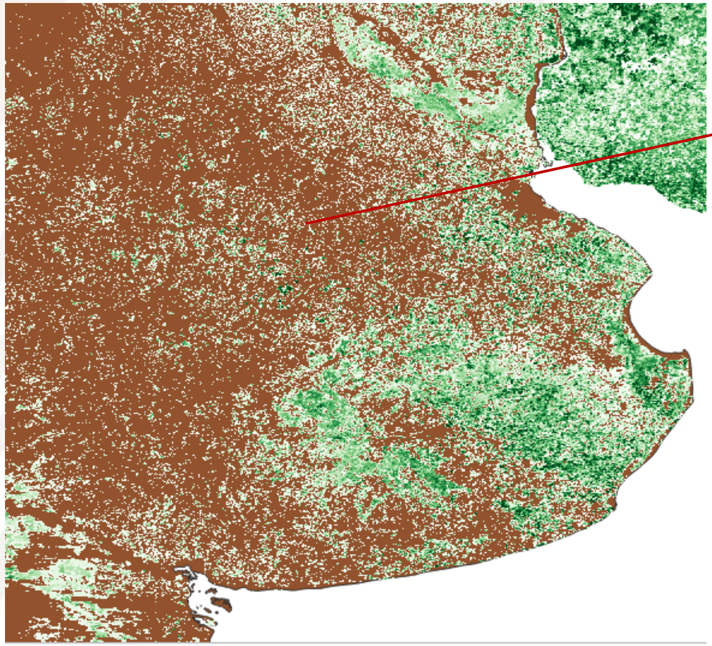
Soil/vegetation cover factor (c)

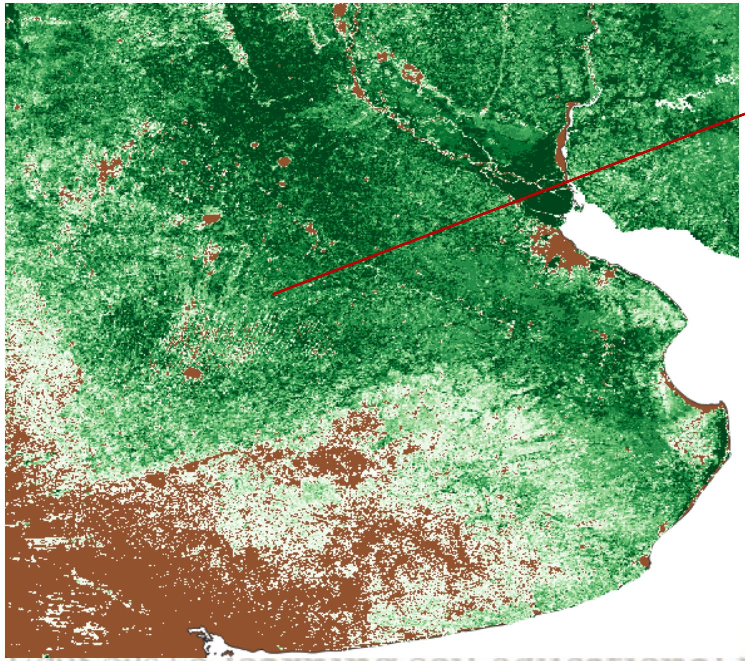
If soil is vegetated $c=0.6$

If soil is bare $c=1.0$

If Vegetated, Lower "c" Lower decomposition rate

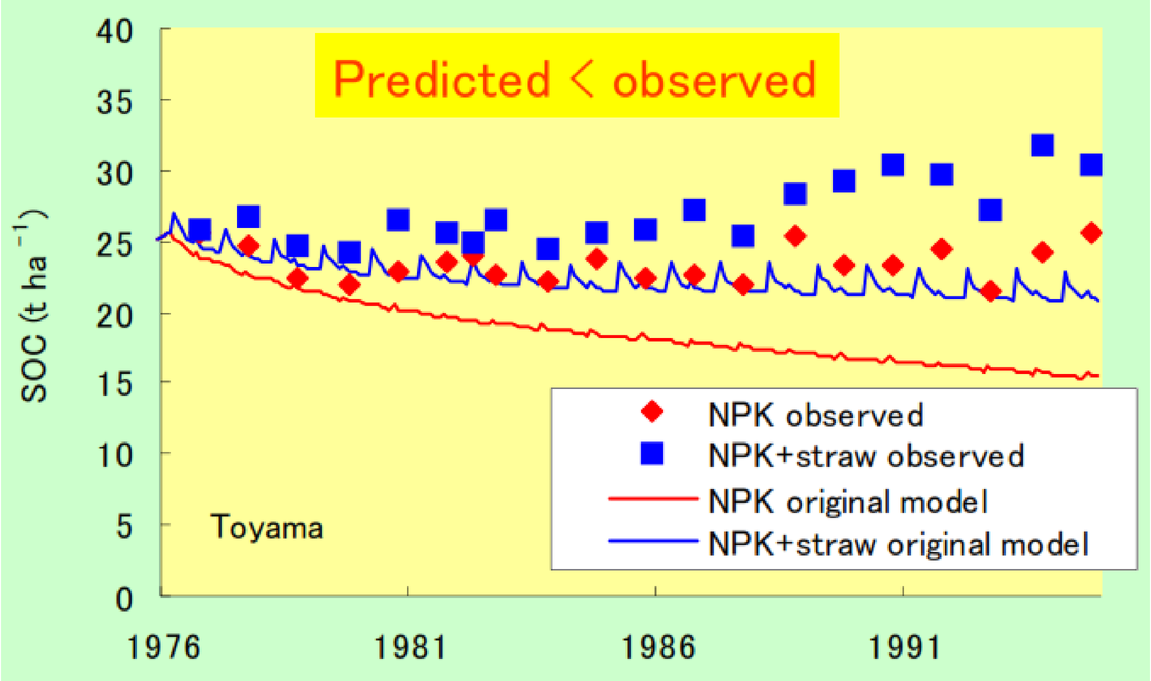


July
No crops
Bare;
c=1.0



January
Growing crops veg.;
c=0.6

Example RothC Japan – Paddy Rice - watterlogged soils



The model underestimated SOC, as expected (slower decomposition because of anaerobic condition)

From:Yirato y Yagasaki. NIAES

(Shirato & Yokozawa, 2005)

Modifying factor for paddy rice

0.6 x k months no flooded rice

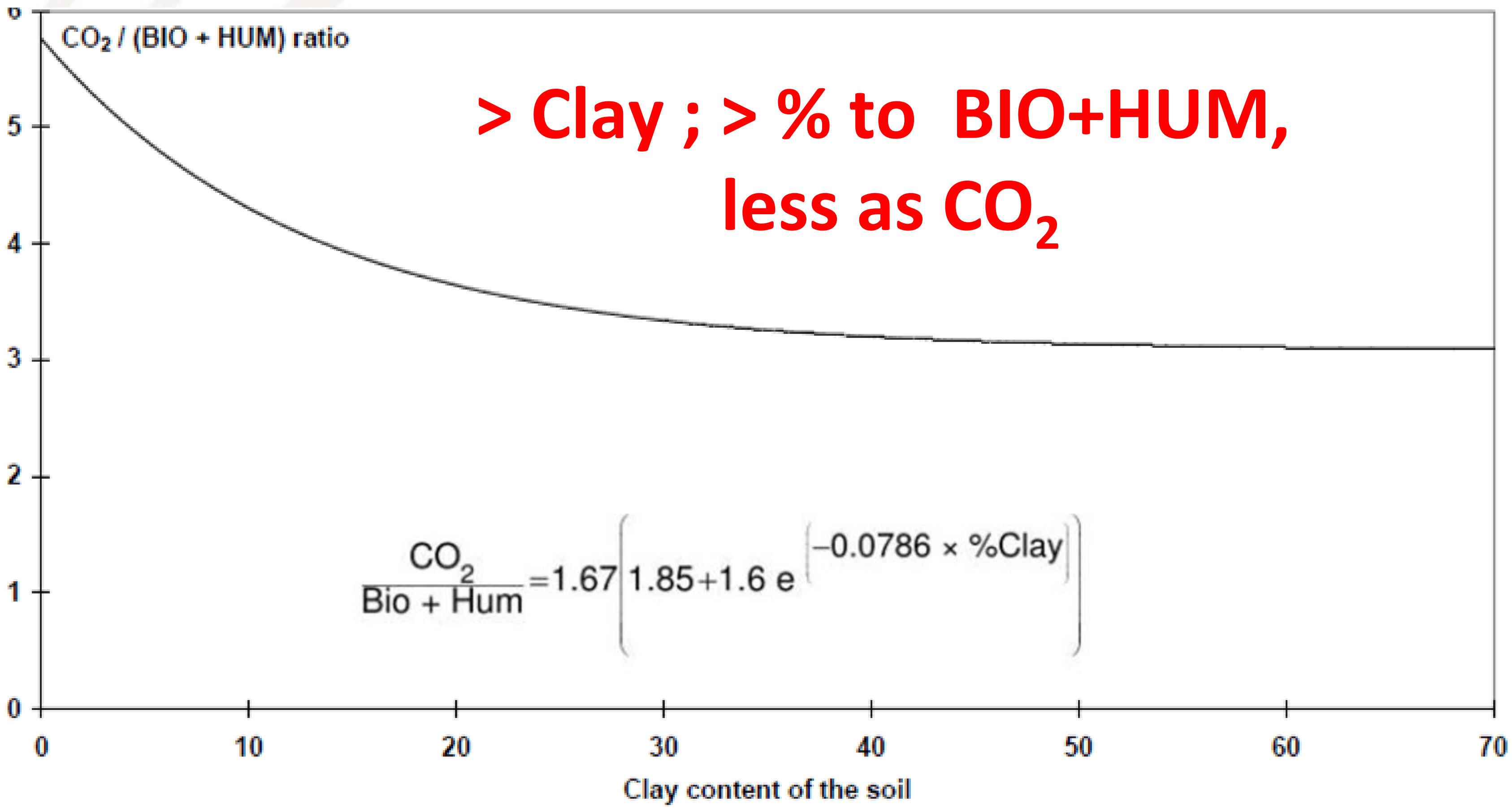
0.2 x k with flooded Rice

Paddy rice modifying factor GSOCseq= 0.4 x k

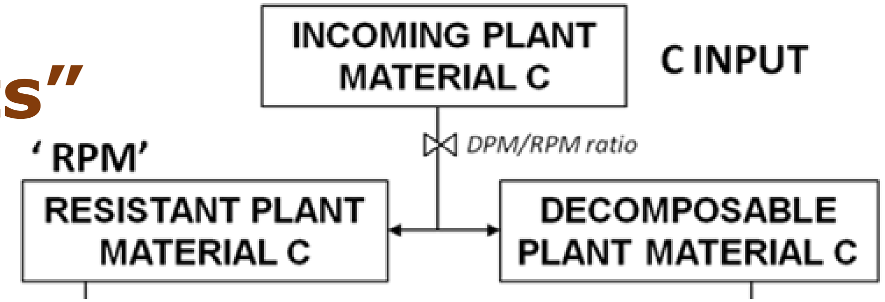
Soil texture

Clay% … affects the proportion of C from each pool that is released as **CO_2** or to **Soil organic carbon pools**

- From that… **46 % goes to BIO**; **54% goes to HUM**



DPM/RPM… "Decomposability of C inputs" C inputs split between DPM and RPM



Default values…

- Crops and improved pastures…

DPM/RPM = 1.44 (59% is DPM, 41% is RPM)

- Grasslands, shrublands/savannas

DPM/RPM = 0.67 (41% is DPM; 59% is RPM)

Tree crops

variable…DPM/RPM = 1.44; 0.67; 0.35

(Morais et al 2019;Farina et al 2017)

- Forests (deciduous, tropical)…

DPM/RPM =0.25 (20% is DPM y 80% is RPM)

- Manure…

DPM/RPM =1 (49% is DPM; 49% is RPM ; 2%HUM)

- Depends on Land Use
- Can be modified

RothC – Soil R

Sierra et al., 2012; 2014

Geosci. Model Dev., 5, 1045–1060, 2012
www.geosci-model-dev.net/5/1045/2012/
doi:10.5194/gmd-5-1045-2012

Geoscientific Model Development

Models of soil organic matter decomposition: the SOILR package, version 1.0

C. A. Sierra, M. Müller, and S. E. Trumbore
Max Planck Institute for Biogeochemistry, Hans-Knöll-Str. 10, 07745 Jena, Germany
Correspondence to: C. A. Sierra (csierra@bgc-jena.mpg.de)

Received: 29 March 2012 – Published in Geosci. Model Dev. Discuss.: 2 May 2012
Revised: 2 August 2012 – Accepted: 4 August 2012 – Published: 24 August 2012

https://www.geosci-model-dev.net/5/1045/2012/gmd-5-1045-2012.pdf

Soil R site:

https://www.bgc-jena.mpg.de/TEE/software/soilr/

- SoilR- simplified version of RothC – Higher speed, adapted to simulate multiple objects (e.g. 1 km x 1 km)
- Transparent, R language, can be modified
- Open Software (R)
- SoilR, already integrates othes SOC models (e.g. ICBM, Century)…to perform model ensemble approach

Spatial Version RothC Soil-R

- GSP: We provide a tool based in R language using Soil R – RothC functions

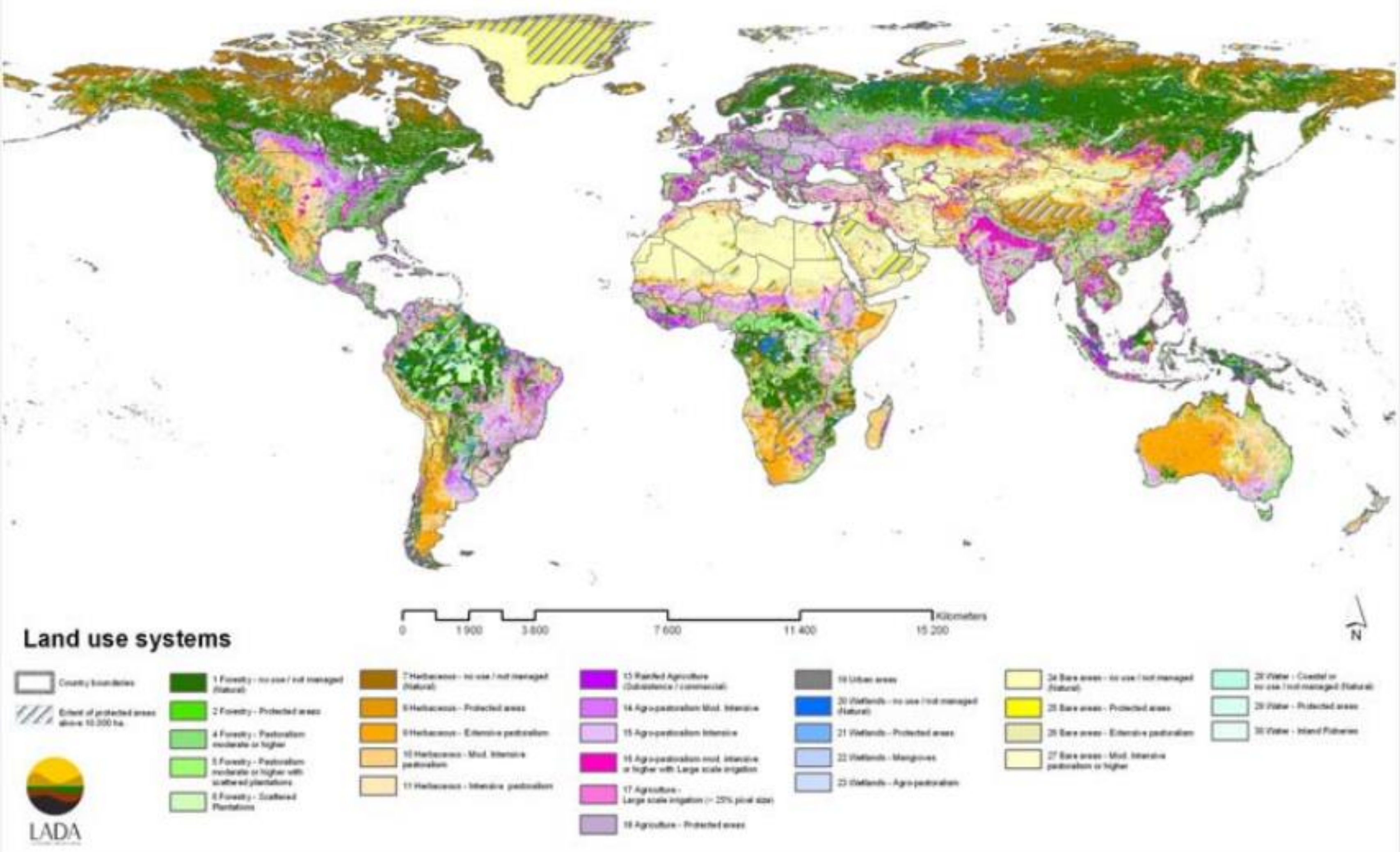
- Each country can improve and modify the tool, develop their own tool (using Roth C to generate the standard products in a first stage)

- **Countries are encouraged to provide additional (´non-standard´) sequestration maps, using modifications/adaptations, alternative approaches, other models**

How to harmonize and model thousands of different practices, often combined? …Specially with limited data

SSM?

Land use systems of the world



… First stage…

Practices that increase C inputs

3 scenarios:

- **+5% increase Ci**
- **+10% increase Ci**
- **+20% increase Ci**

Conservative ranges…may be high for other systems

based on Smith, 2004; Wiesmeier et al., 2016

ing soil educational platform

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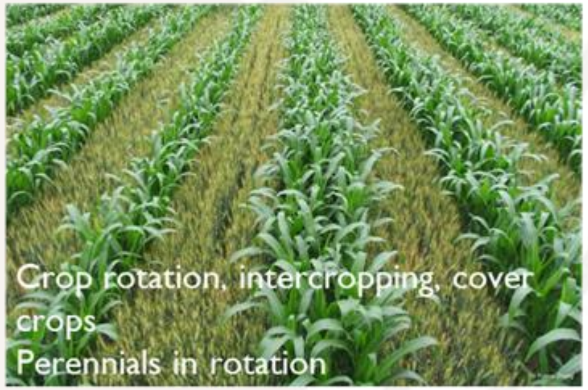
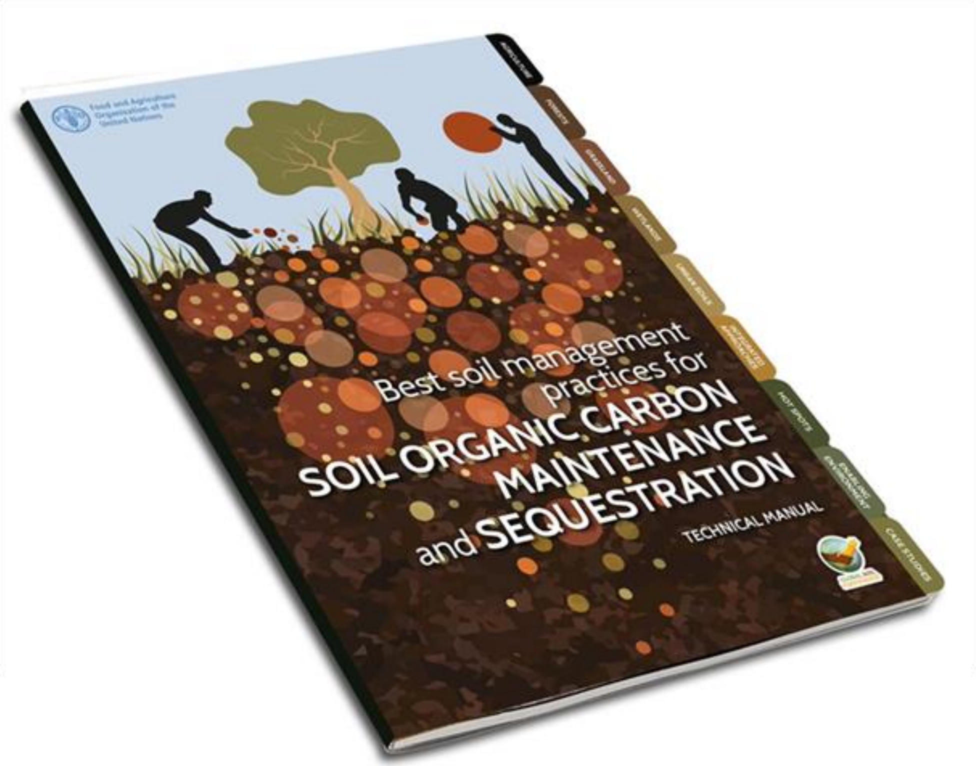
SSM practices



"Technical manual of recommended management practices for SOC maintenance and Sequestration"

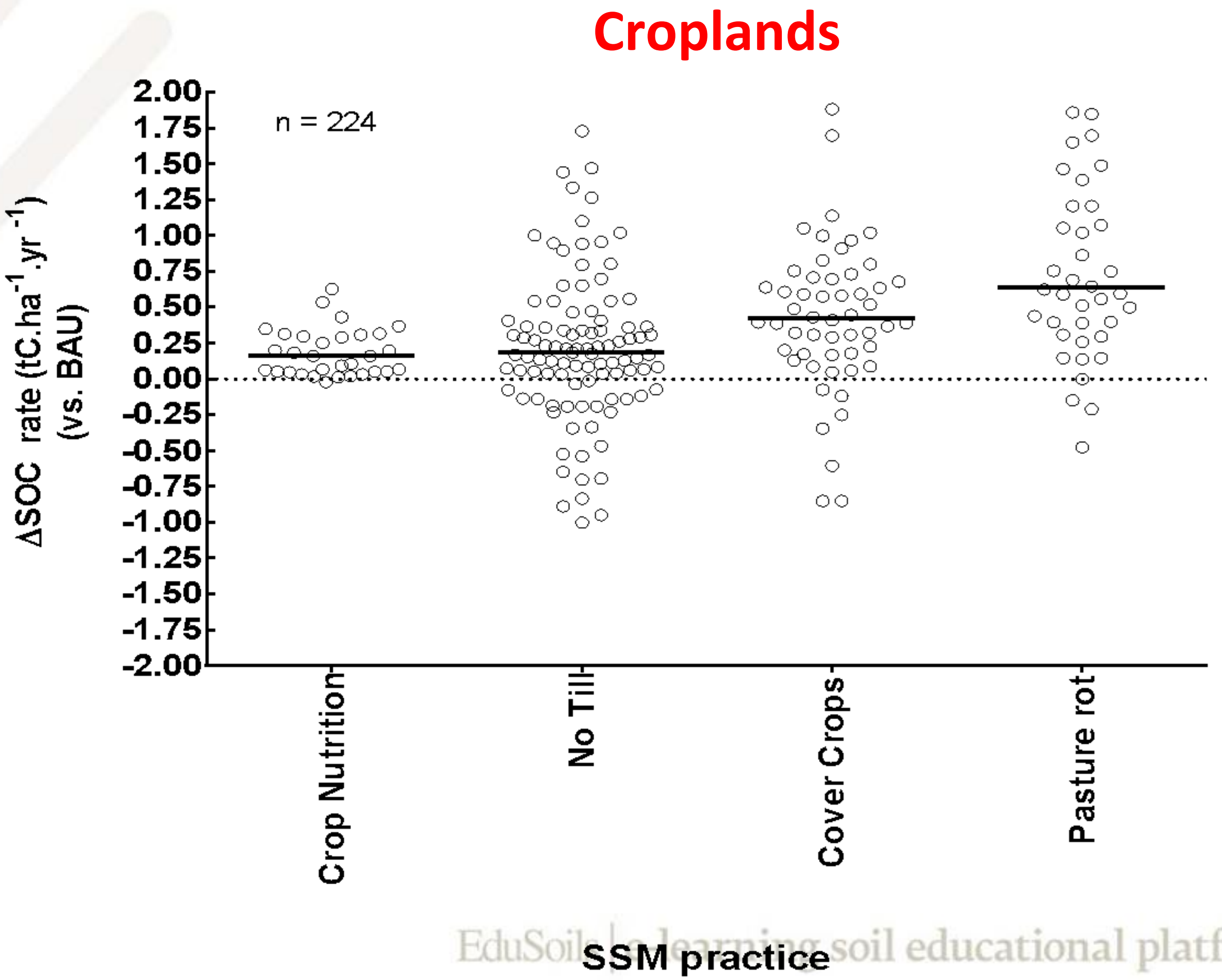


..and many other practices around the world…

Local adjustment of scenarios and % increase in C inputs

E.g.

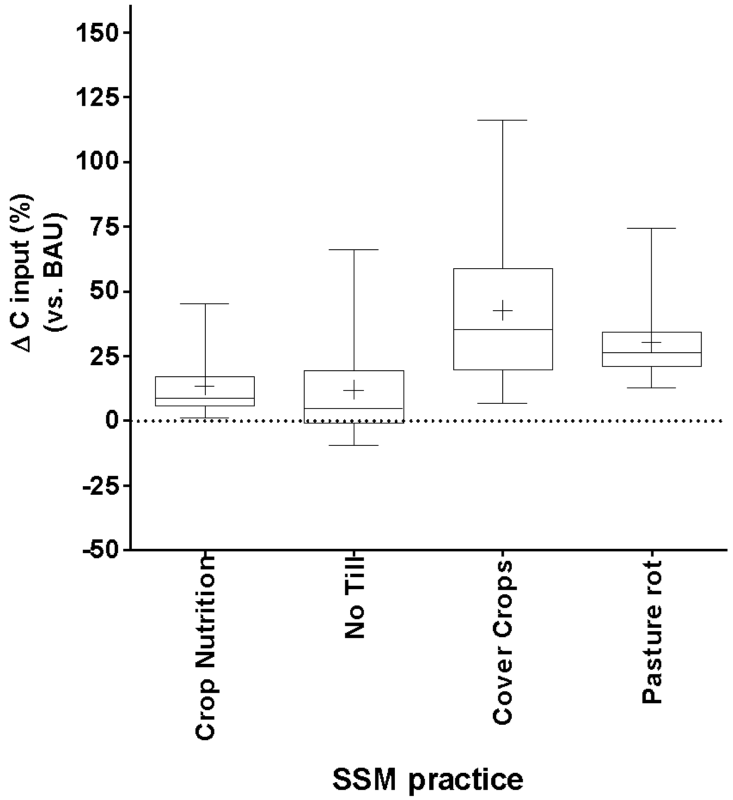
Ad hoc Meta-analysis from local studies



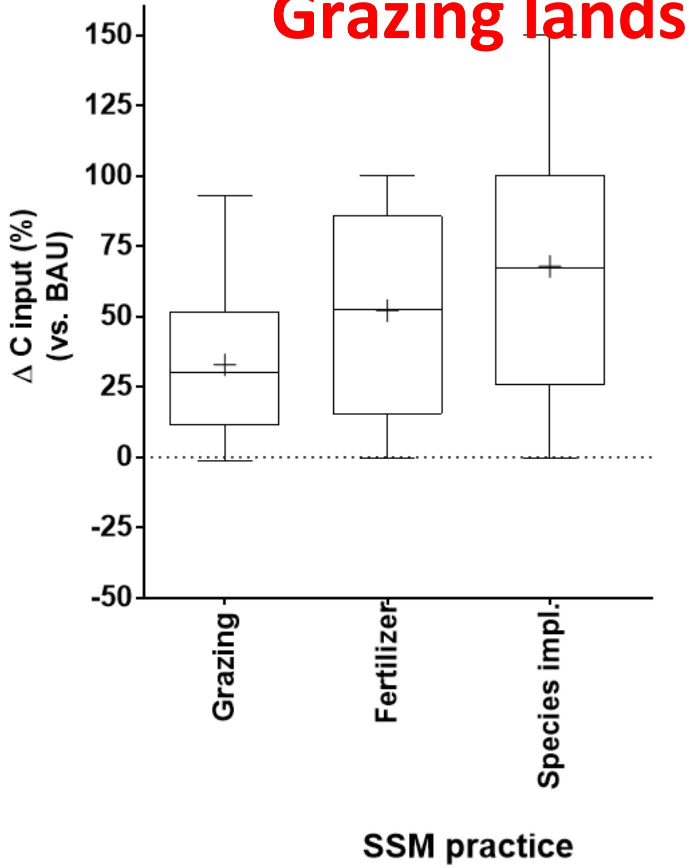
Local adjustment of scenarios and % increase in C inputs

E.g. **Ad hoc Meta-analysis from local studies**

Croplands

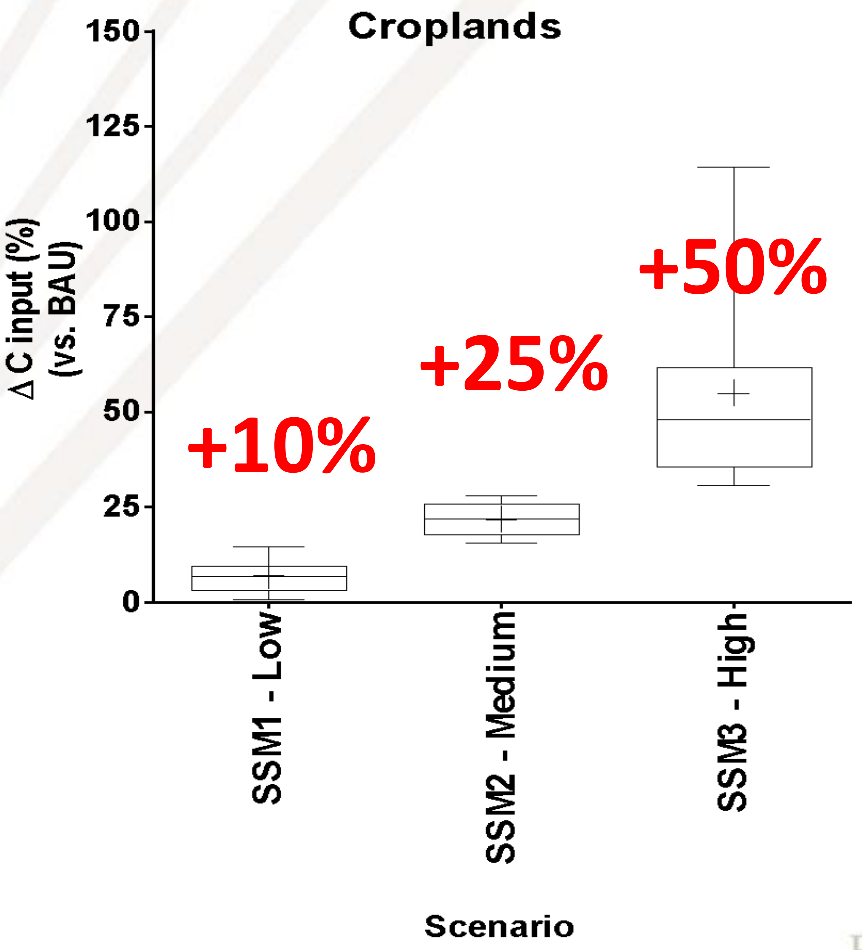


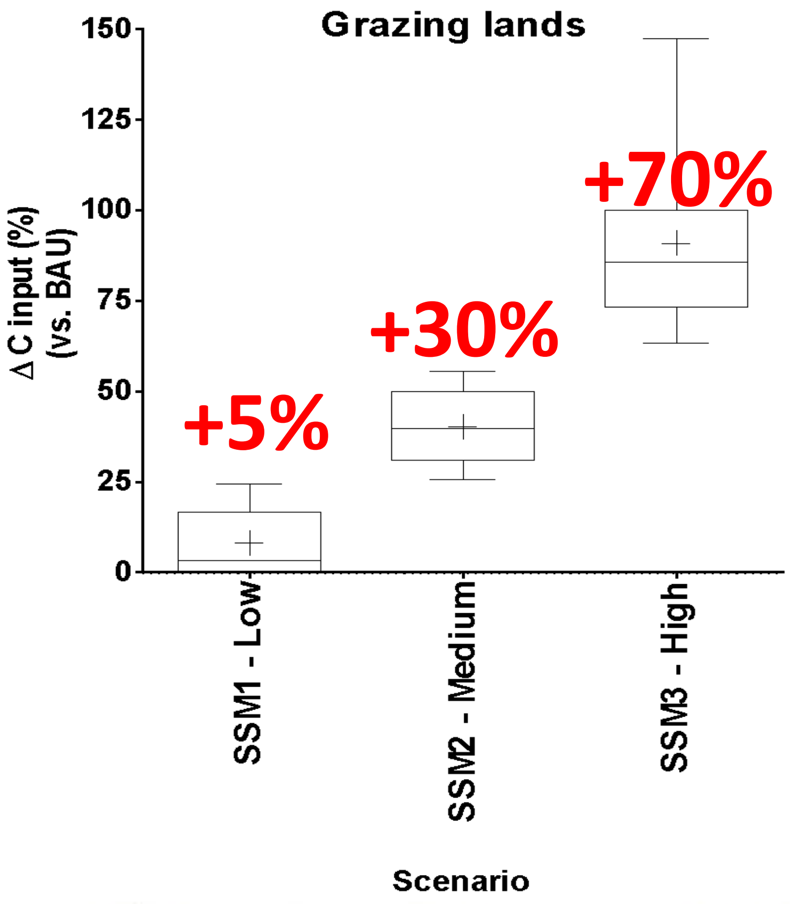
Grazing lands



Local adjustment of scenarios and % increase in C inputs

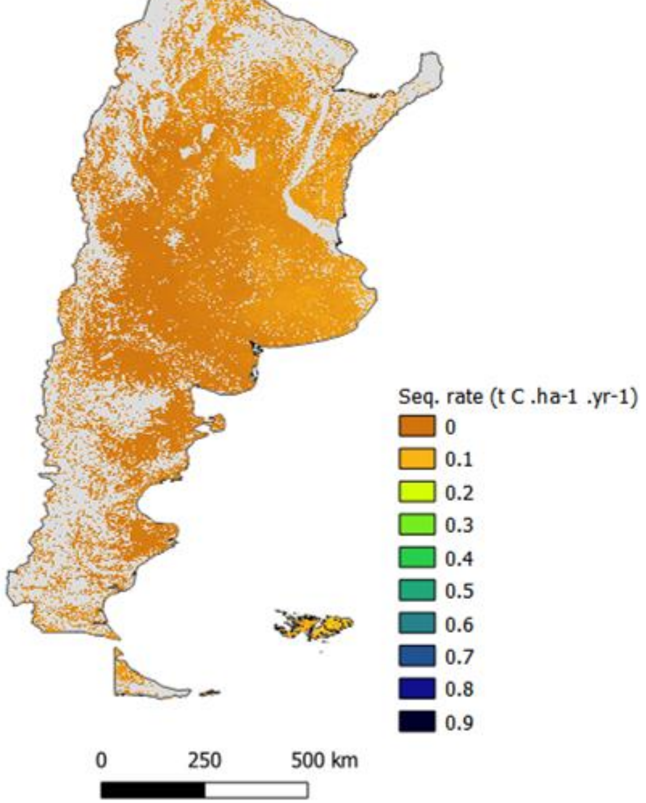
E.g.



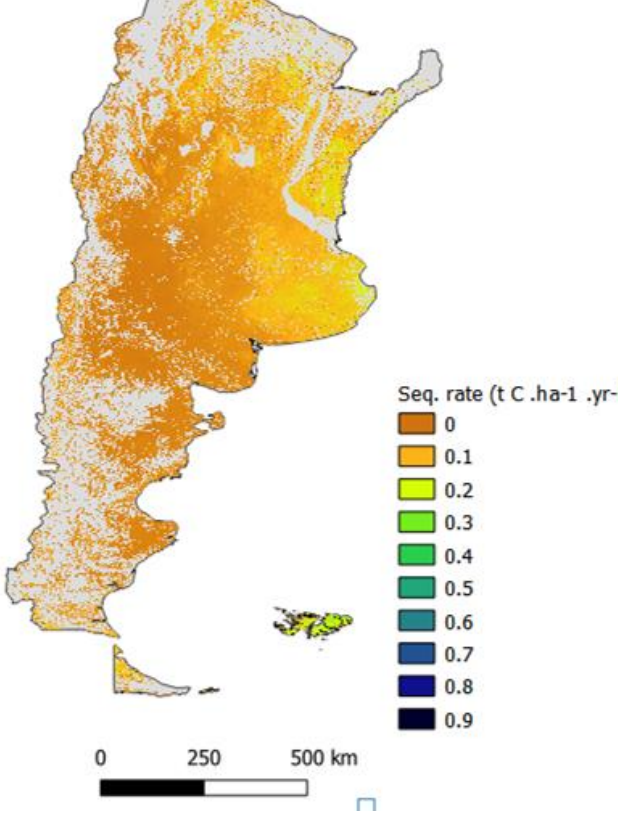


Standard Products

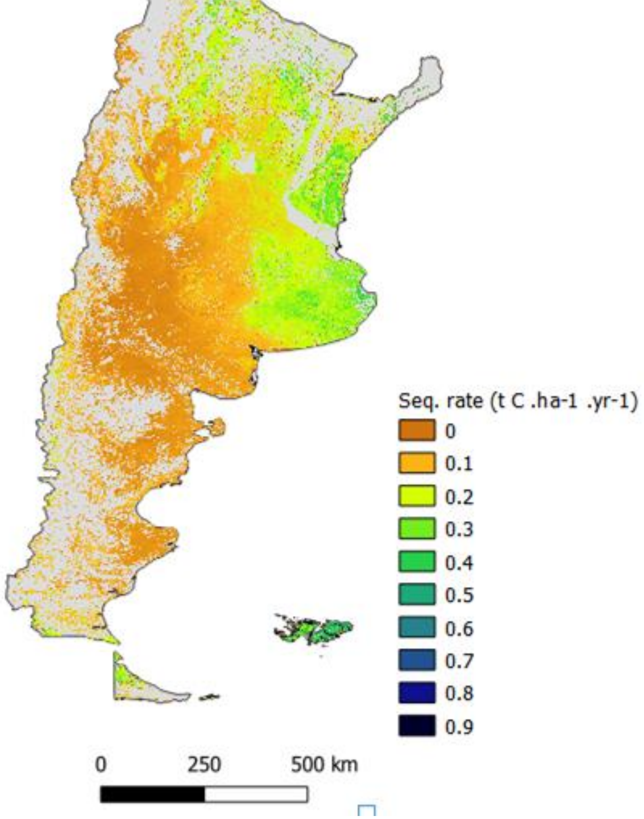
Low (+5%)



Medium (+10%)



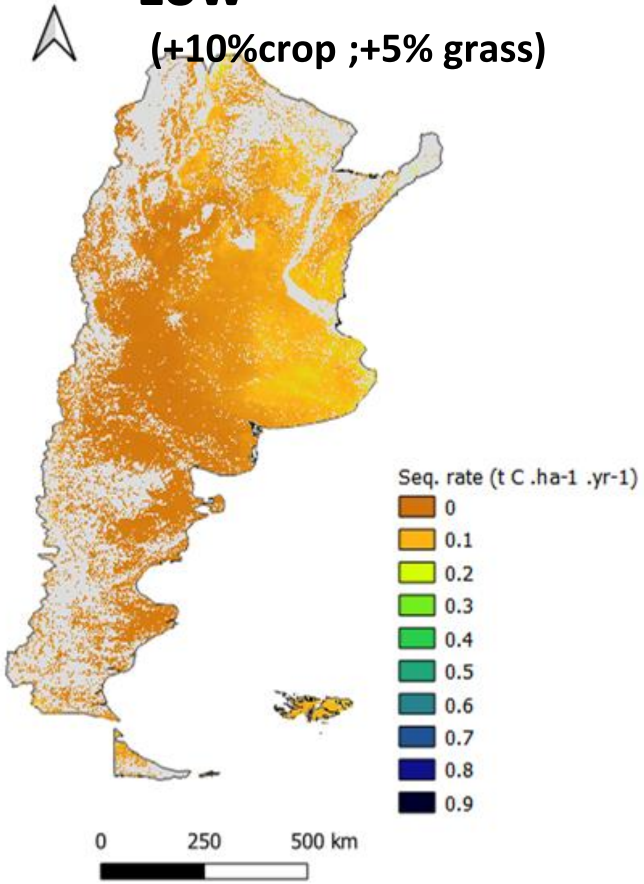
High (+20%)



Non-Standard Products Using modified coefficients

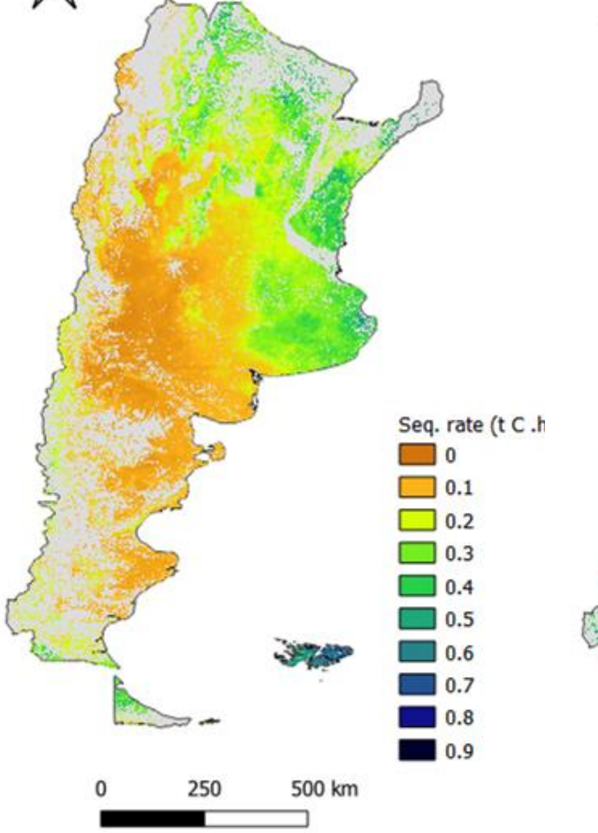
Low

(+10%crop ;+5% grass)



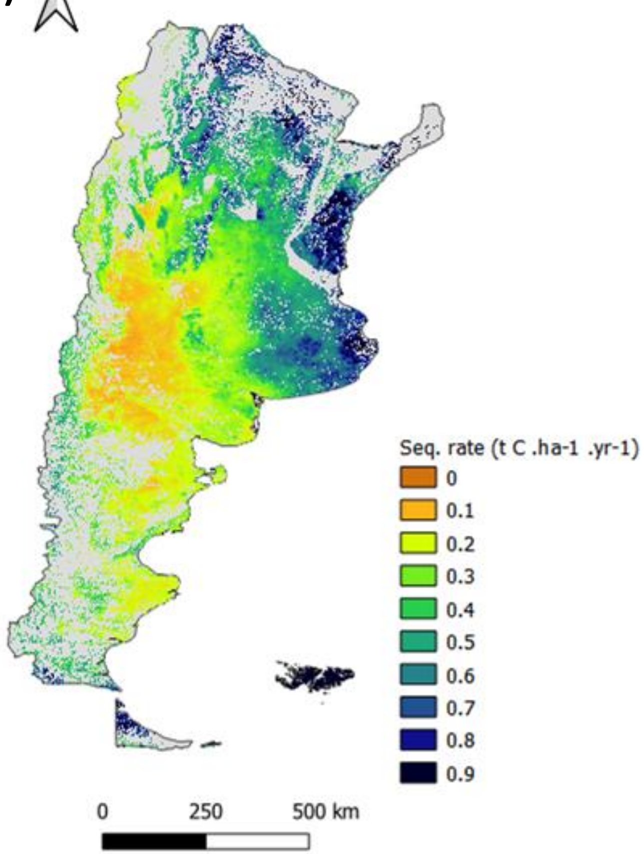
Medium

(+25% crop ;+30% grass)

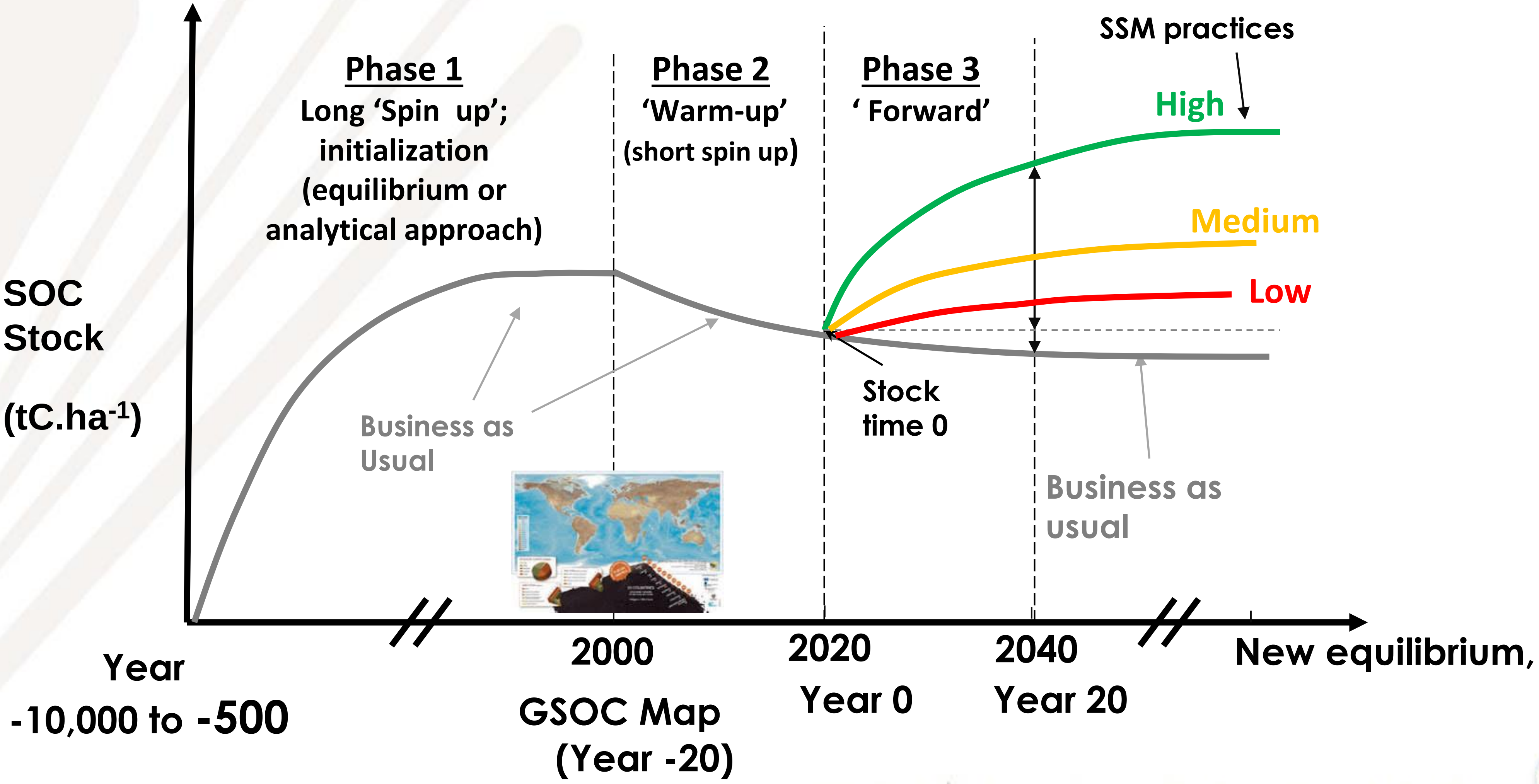


High

(+50%crop ;+70% grass)

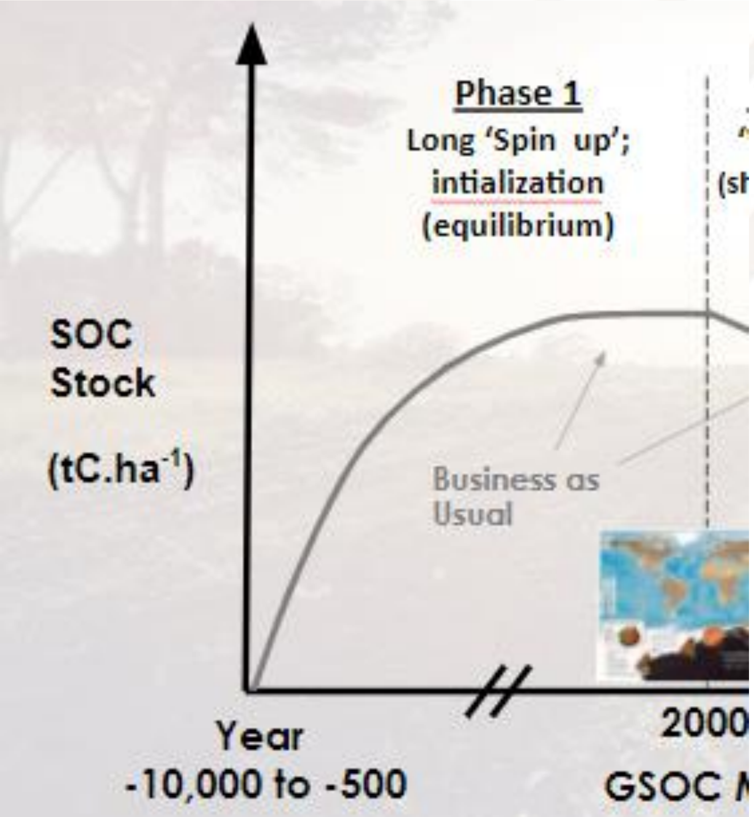


For each 1km x 1km pixel:



Approach based on Smith et al 2006; 2008; Gottschalk et al. 2012

Phase 1 . Spin up



Initialization phase

Required to:

- **obtain C stocks of different pools (BIO, HUM, DPM, RPM, etc)**
- **Estimate baseline C-inputs (C inputs required to reach GSOC stocks) (referred as Ceq)**

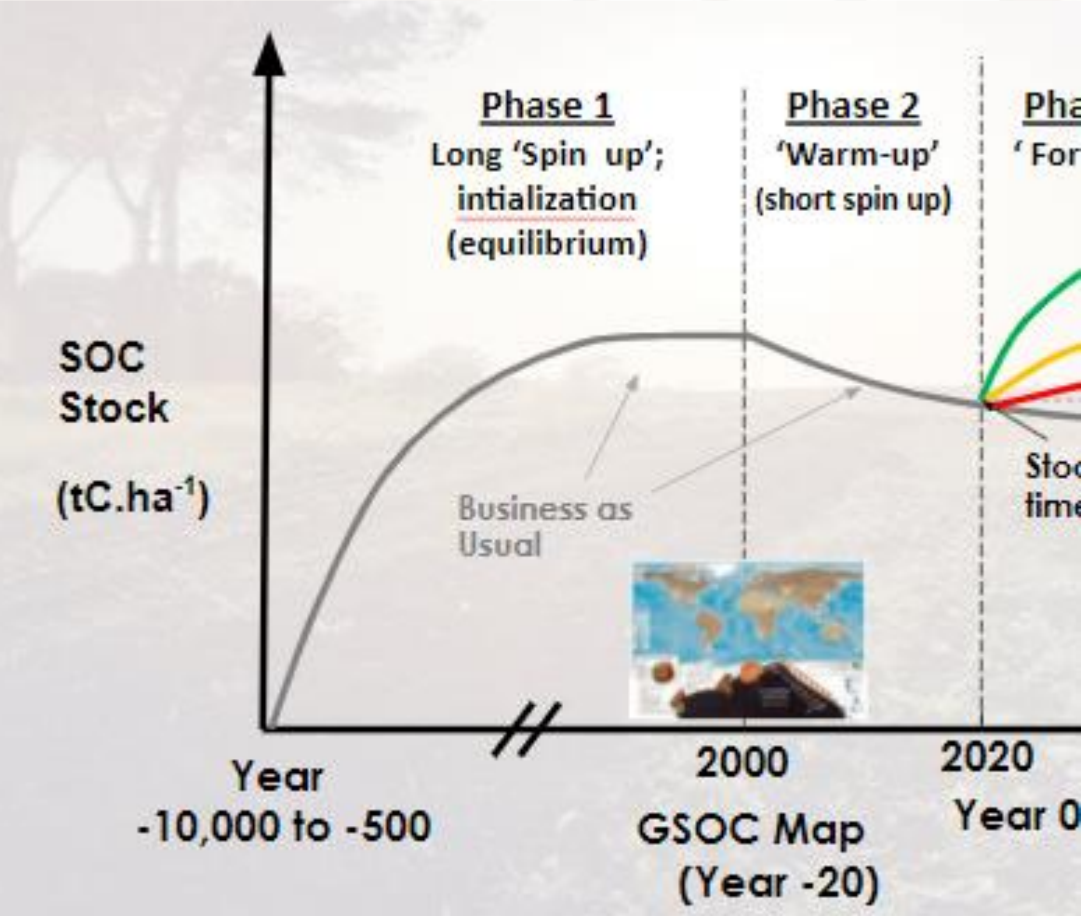
Ceq = C inputs under business as usual/baseline

Procedure:

Model is run for a long time span (e.g. 500 years) using historic climate (1980-2000)… first using a fixed C input (1 t)… C inputs are adjusted until SOC stock = GSOC map:

- $C_{eq}=C_i\times[(C_{meas}-IOM)/(C_{sim}-IOM)]$

Phase 2 . Warm up – Short Spin up (18-20 years)



Required to:

- Adjust climate variation between 2000-2020
- Harmonize major time differences in GSOC map FAO (generated soil profiles 1960-2000s)... current
- Adjust Land use changes 2000-2020
- Adjust over or under estimation in C stocks of a specific pool (E.g. High DPM)
- Not necessary if current SOC stocks = GSOC

Procedure:

- The model is run for 18-20 years using monthly climate data, year to year (2001-2020)
- Annual C inputs are corrected according to annual changes in NPP

Phase 2 . Warm up – Short Spin up (Cont.)

- Annual NPP to adjust year to year C inputs
- NPP by MIAMI Model (Lieth, 1972; Gottschalk et al., 2012)
- Other preferred NPP sources/models can be used

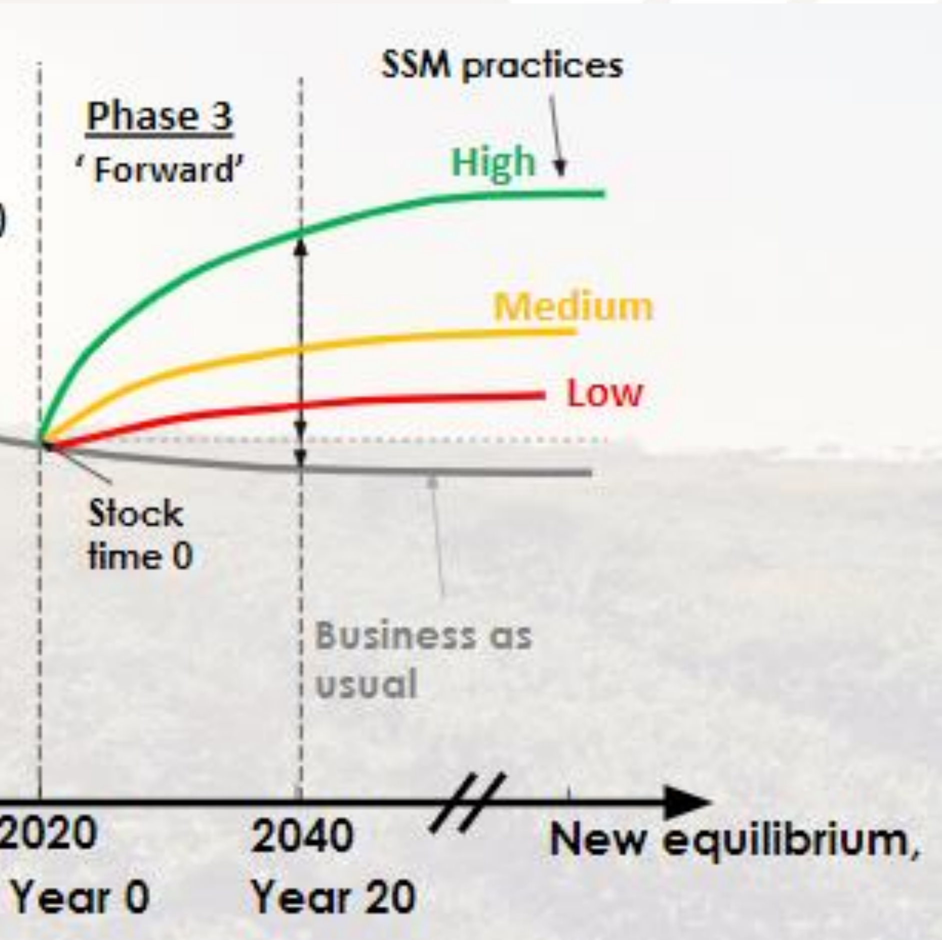
NPP can be adjusted for Land Use changes (Schulze et al 2010)

$NPPt_{forests} = NPP_{MIAMI} \times 0.88$

$NPPt_{grasslands} = NPP_{MIAMI} \times 0.72$

$NPPt_{croplands} = NPP_{MIAMI} \times 0.53$

Phase 3 . Forward run (2020 – 2040)



Required to:

- Obtain SOC stocks in different SSM scenarios after 20 years
- Estimate SOC sequestration rates

Procedure:

- Model is run for 20 years using average climate 2000-2020
- (Future versions include climate change… decide scenarios)
- **The 4 scenarios are run:**
  - **BAU**
  - **SSM1 ('Low increase') (+ 5% in C)**
  - **SSM 2 ('Medium increase') : (+10%)**
  - **SSM 3 ('High increase'): (+20%)**

Validation and uncertainties

Difficulties

- Validate changes that did not happen yet?
- Complex methods (e.g. Montecarlo) require multiple simulations (computational time)
- Data availability, uncertainty in input layers

- **We require to estimate uncertainties with limited computational and data resources**

General Uncertainties

$$U (\%) = 100 * (UL\ CI – LL\ CI) / (2 * SOCav)$$

UL = upper limit of the 95% confidence interval of the estimated SOC at the end of the simulation (in t $C.ha^{-1}$),
LL= lower limit of the 95% confidence interval of the estimated SOC at the end of the simulation (in t $C.ha^{-1}$); a

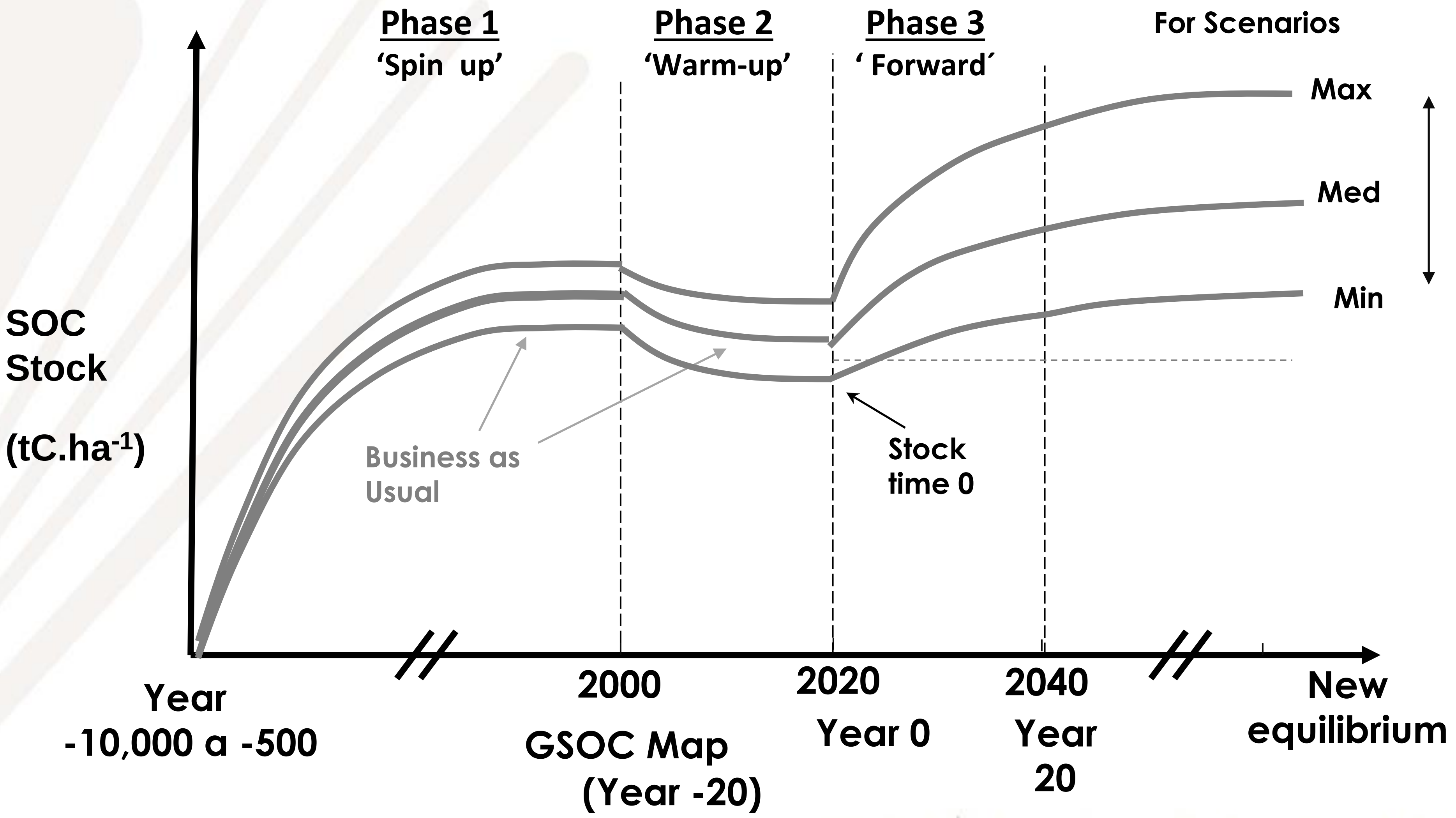
SOCav = the average of the estimated SOC at the end of the simulation (t $C.ha^{-1}$)

VCS 2012

SOC max/UL = Model (SOC FAO max, Ci max, Temp min, Pp max, Clay max)

SOC min/LL = Model (SOC FAO min, Ci min, Temp max, Pp min, Clay min)

General Uncertainties



Uncertainties

If information on uncertainty of layer for each pixel 1 km x 1km (SOC FAO, PP, Clay, Temp, etc):

P min = Xp – 1.96 x SEp

P max = Xp +1.96 x SEp

And run model changing Input Layers (using Pmin, y PmAx)

If NO information on the uncertainties of each layer , use general variation (> % uncertainties…)

General uncertainties of main parameters affecting SOC dynamics. Derived from Gottschalk et al. (2007) and Hastings et al. (2010).

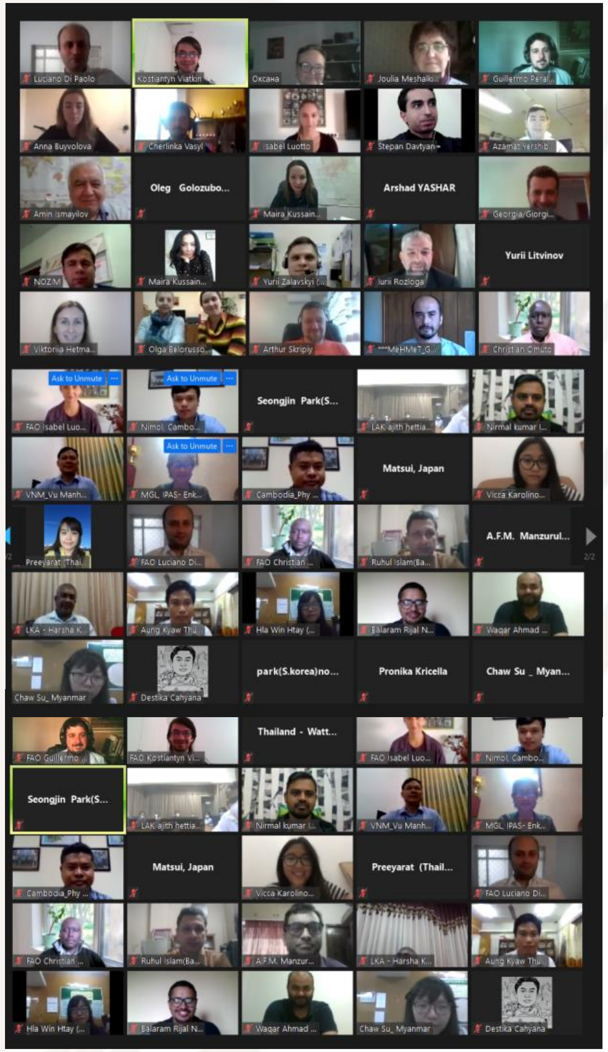
Parameter	**Uncertainty in the input**	Minimum value	Maximum value
Temperature	**± 2 %**	Monthly Temp * 0.98	Monthly Temp * 1.02
Precipitation	**± 5 %**	Monthly PP * 0.95	Monthly PP * 1.05
Clay content	**± 10 %**	Clay * 0.90	Clay * 1.10
FAO SOC	**± 20 %**	SOC FAO *0.8	SOC FAO * 1.2
C input increase in SSM scenario	**± 15 %**	C eq * (SSM1 % increase - 15%)	C eq * (SSM % increase + 15%)

Limitations

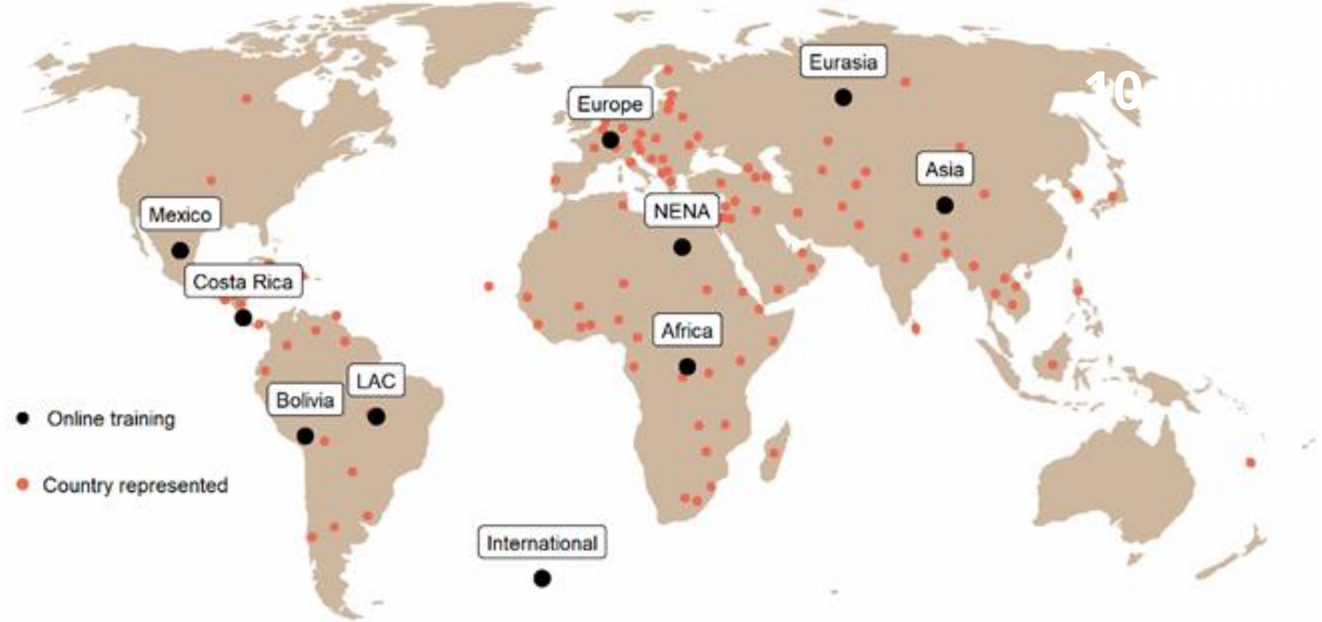
- Models= simplifications of reality
- No universal models
- Erosion, Clay type? soil nutrients effects?
- pH? Bases?
- aridic soils? Sodic soils? Salt affected?
- red-ox potential; waterlogging, anaerobiosis; organic soils?
- micro and meso fauna effects?
- Soil structure ? Soil compaction?
- Among others!!!!

... But we need an initial step...

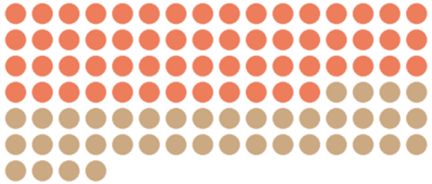
Results: Capacity development



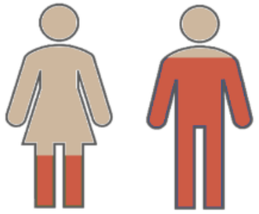
10 online trainings



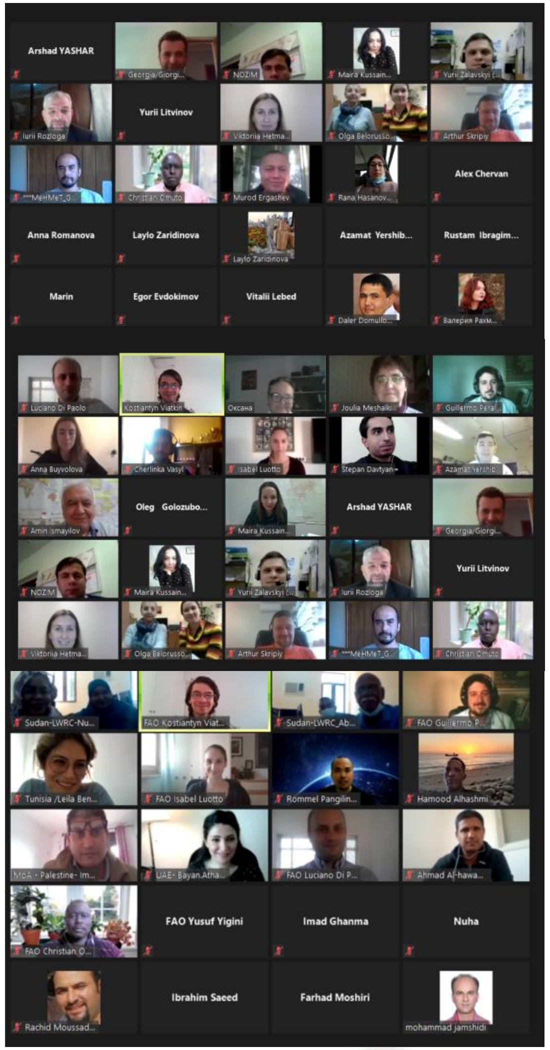
119 countries



433 participants



27 % | 73 %

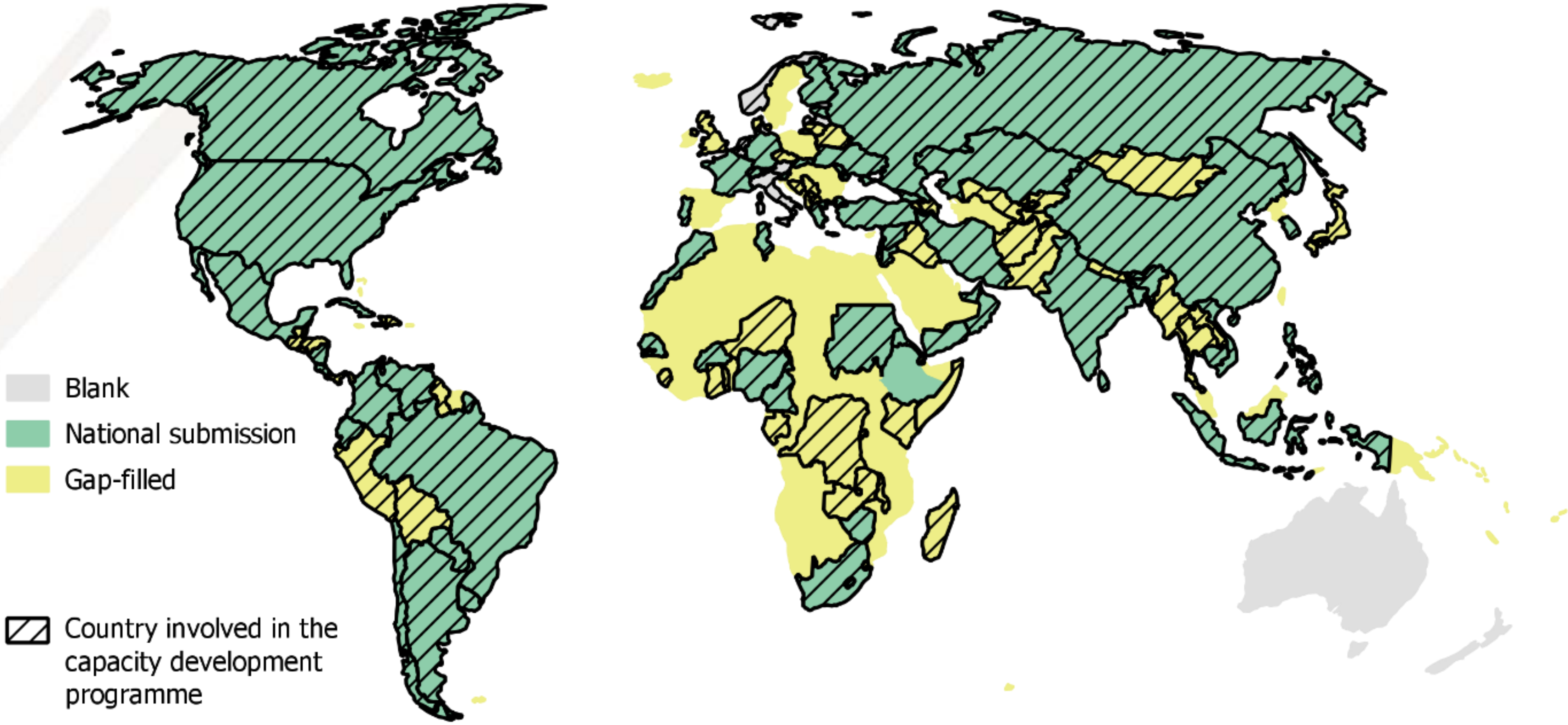


EduSoils | e-learning soil educational platform

GLOBAL SOIL PARTNERSHIP

GSOCseq in numbers

- GSOCseq v1.1 launched in 2021
- 10 Online Regional Trainings
  - over 430 national experts reached
  - 119 Countries reached
- Currently provides data for 90 % of the agricultural land area



GSOCseq

http://54.229.242.119/GloSIS/

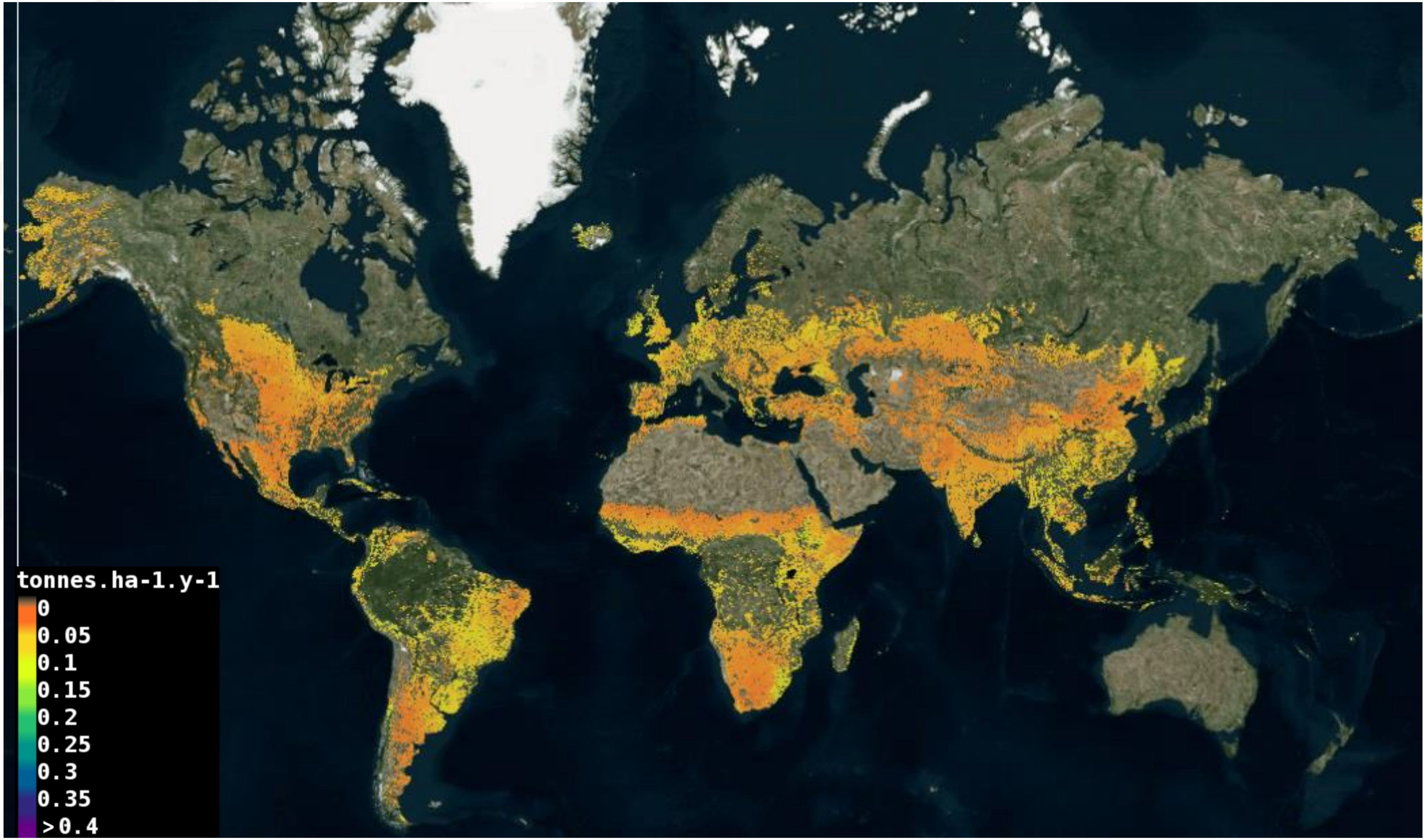
Relative sequestration rates tonnes.ha-1.y-1

SSM1 >> SSM3

GSOCseq v1.1

- SOC sequestration (tC/ha/yr) SSM 1-3
- Agricultural lands (croplands + grazing lands)
- 20-year period
- Depth: 0-30 cm
- 1 x 1 km resolution

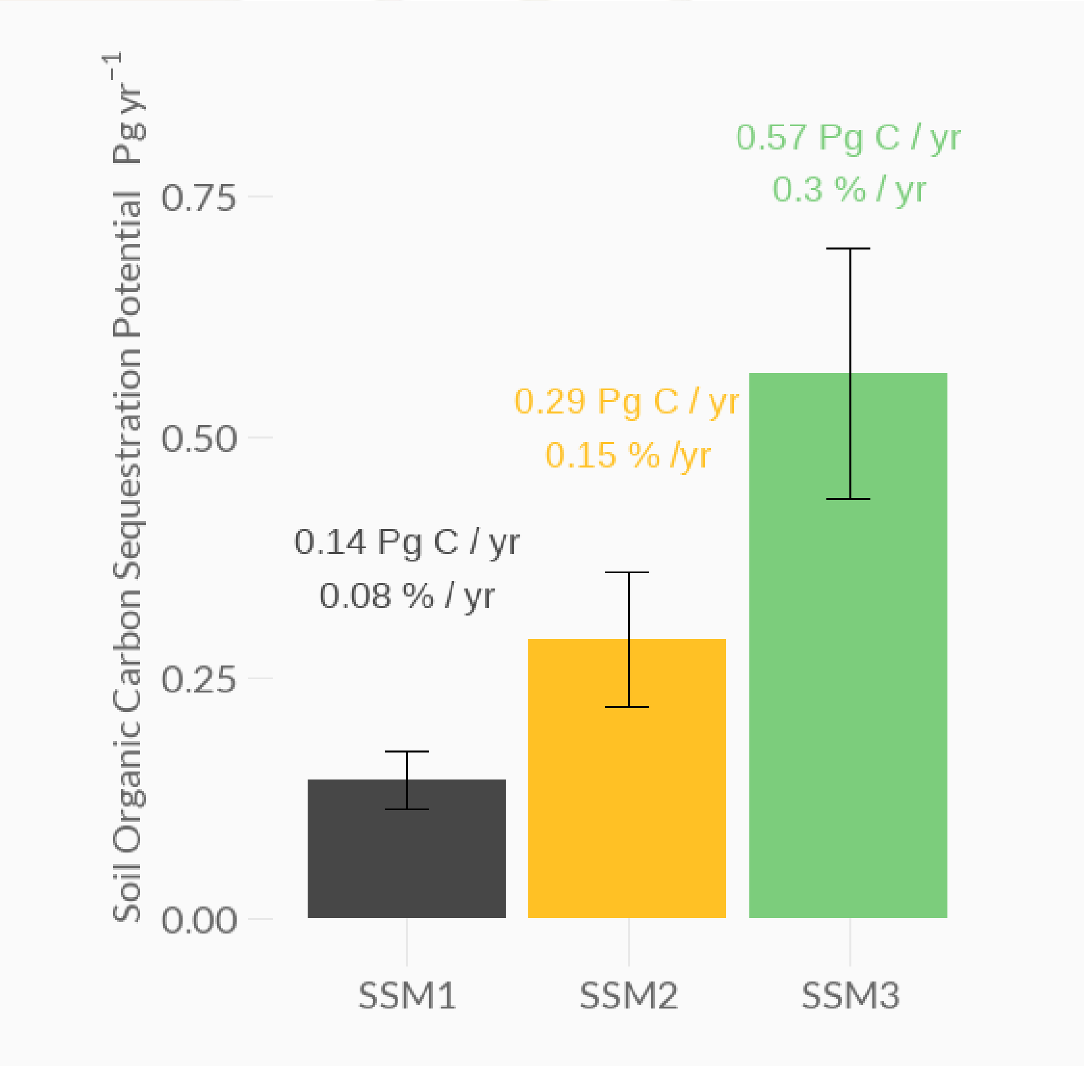
Continuously being updated!



GSOCseq v1.0.0 Uncertainties (%)

First results - Annual SOC sequestration*

*Excluding blank countries

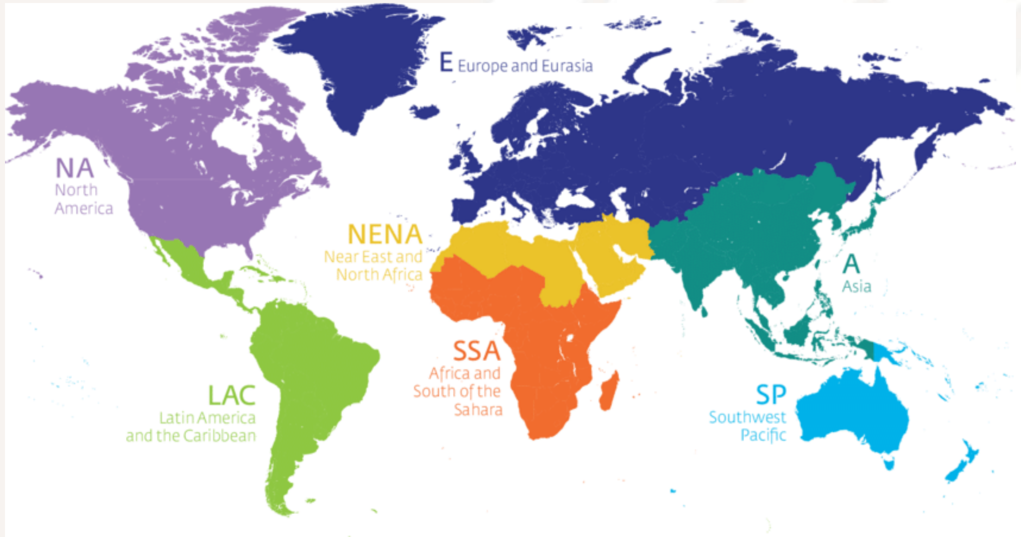


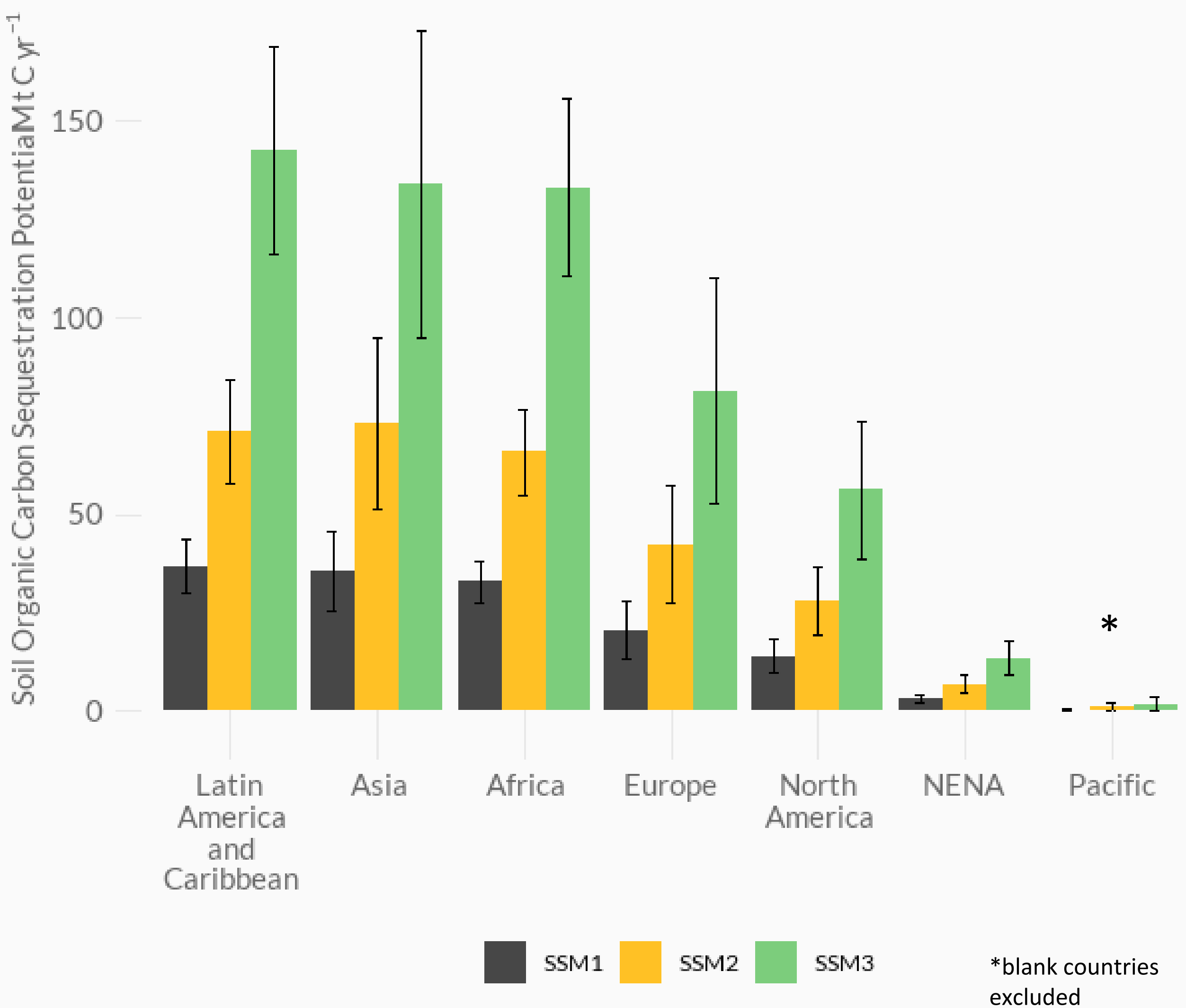
Previous estimates

Source	Seq.rate Pg C.year^{-1}
Paustian et al (2004)	**0.44 - 0.88**
Smith et al (2008)	**0.44 - 1.15**
Sommer and Bossio (2014) (croplands+grasslands)	**0.37 - 0.74**
Batjes et al (2019)	**0.32 - 1.01**
Lal et al (2018) (croplands+grasslands/shrublands)	**0.48 – 1.93**
Fuss et al (2018)	**0.54 – 1.36**

Potential uses - statistics

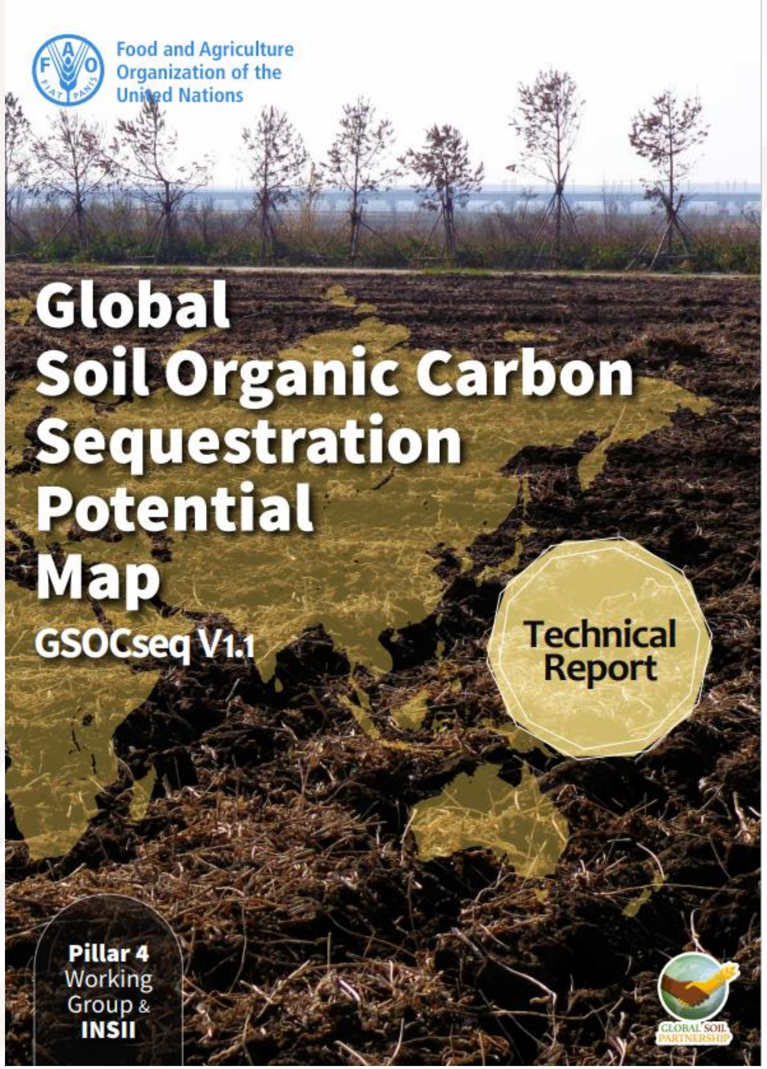
Which **climates**, **land uses**, **regions**, **countries** have greater SOC sequestration potential?





*blank countries excluded

GSOCseq v1.1 Technical Report



- To be periodically updated as more national maps are delivered
- Next year GSOCseq v1.2 and GSOCseq Technical Report v1.2

Summary. Inputs for the 3 Phases

Input data requirements				
Data	**Variables**	**Time series**	**Units**	**Type**
Climatic data	Monthly air temperature	1980-2000; 2001-2020 (or until last year available)	°C	Raster
	Monthly evapotranspiration (Penman-Monteith)	1980-2000; 2001-2020 (or until last year available)	mm	Raster
	Monthly precipitation + irrigation	1980-2000; 2001-2020 (or until last year available)	mm	Raster
Soil data	Topsoil clay content (0-30 cm)	-	%	Raster
	Current Soil organic carbon stocks (0-30 cm)	Latest version of national FAO-GSOC map	$tC\ ha^{-1}$	Raster
Land use/cover	Predominant land use/cover, re-classified into: Minimum: 4 default classes required by model: agricultural crops, grassland/shrubland/savannas ; forests; others Optimum: 11 classes defined in the FAO Global Land Cover - SHARE (GLC-SHARE)	Minimum: representative 2000-2020 (or last year available) Optimum: annual land use 2000 to 2020	1-11	Raster
	Monthly vegetation cover. Obtained from national statistics/local expert knowledge; or derived from NDVI or spectral indexes (see section 3.3.4)	Minimum: average 2015- 2020 (or last year available period) Optimum: monthly soil cover 2000 to 2020	0-1	Raster

What's next? GSOCseq v2

- The country-driven approach has allowed us to create a global network of national experts
- A dedicated GSOCseq Working Group was established
- Based on the implementation of the GSOCseq we were able to identify global needs and priorities to improve the data product

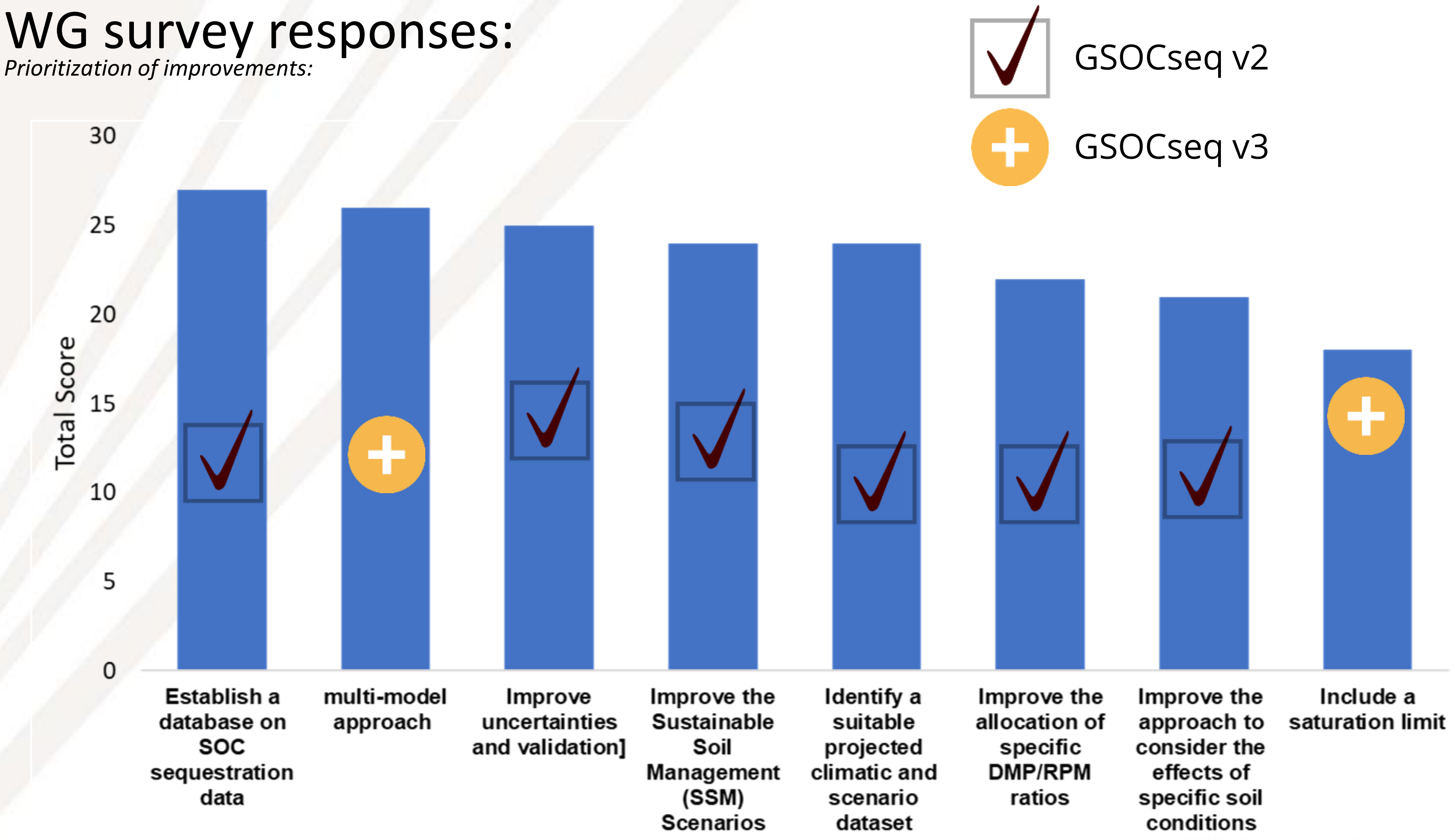
What’s next? GSOCseq v2

- The GSOCseq WG was the first thematic WG created under INSII
- Its objective are:
  - Support the development of a way forward for the future versions of the GSOCseq:
    - Short-term improvements (GSOCseq v1.x): Provide technical guidance for the improvement of the current scripts and routines to generate a national GSOCseq product
    - Long-term improvements (GSOCseq v2.0): Provide technical guidance to select and prioritize potential improvements of the methodology (e.g. inclusion of climate change scenarios, country-specific scenarios)
  - Support the drafting of relevant publications
- 2 meetings so far:
- 1st Meeting of the GSOCseq Working Group (February 18 2022)
- 2nd Meeting of the GSOCseq Working Group (April 28 2022)
- If you would like to join: Isabel.Luotto@fao.org

What’s next? GSOCseq v2

WG survey responses:

Prioritization of improvements:



What’s next? GSOCseq v2

- Improvement of the scripts:
  - From 16 distinct scripts (based on single steps) down to 9
  - Streamlined Input Data - GEE and R through the package rgee
  - Identification of a suitable climatic projection (downscaled future climate data from worldclim)
- Currently being implemented:
- Improvement of the SSM scenarios based on practices
  - A database of practices and their effect on SOC was compiled from the **Recarbonizing global soils - A technical manual of recommended management practices**
- A RECSOIL data collection app and database is currently being developed
- Improvement of the uncertainty assessment by incorporating the approach using the analytical Taylor Francis approach (Martin et al., 2021)
- Improved DPM/RPM ratio allocation (grasslands)

Thank you for your attention

GLOBAL SOIL PARTNERSHIP

INSII INTERNATIONAL NETWORK OF SOIL INFORMATION INSTITUTIONS

itps INTERGOVERNMENTAL TECHNICAL PANEL ON SOILS

Special thanks to

- University of Aberdeen; Thünen-Institut
- 4p1000 SC, CIRCASA, UNCCD
- National SOCseq teams and all experts contributing to the process
- GSOCseq Working Group

DISCUSSION

"Errors using inadequate data are much less than those using no data at all"

Charles Babbage, English Polymath

Food and Agriculture Organization of the United Nations

EduSoils

Setting up a Monitoring, Reporting and Verification (MRV) system for soil organic carbon in agricultural lands:

RECSOIL Protocols

Guillermo Peralta – FAO GSP

GLOBAL SOIL PARTNERSHIP

Why an MRV ?

- **SOC** stocks and other soil properties usually show a **high spatial variability**

- **Changes** in **SOC** stocks and other soil health indicators **cannot be easily measured**

Smith et al., 2021 (Global Change Biology)

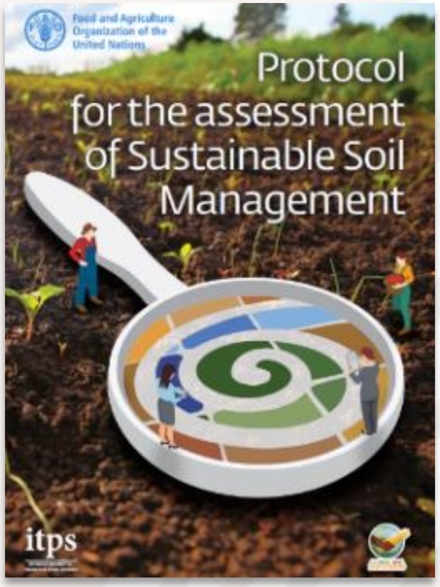
- Absence of harmonized **measurement / monitoring, reporting and verification (MRV) platforms** …a **key barrier** to implementing programs to increase SOC at large scale.
- Urgent need! Without such platforms, **investments could be considered risky.**

But also…

- Multiple MRV Protocols (at least 20; public/private sector), vary from one carbon offset program to another
- Many of them complex, extremely costly to implement
- Need for a "common language" between different projects from different countries, but flexible enough to adapt to local conditions.

Since 2017 FAO - ITPS – GSP … development of MRV Protocols and Platforms

SSM Protocol

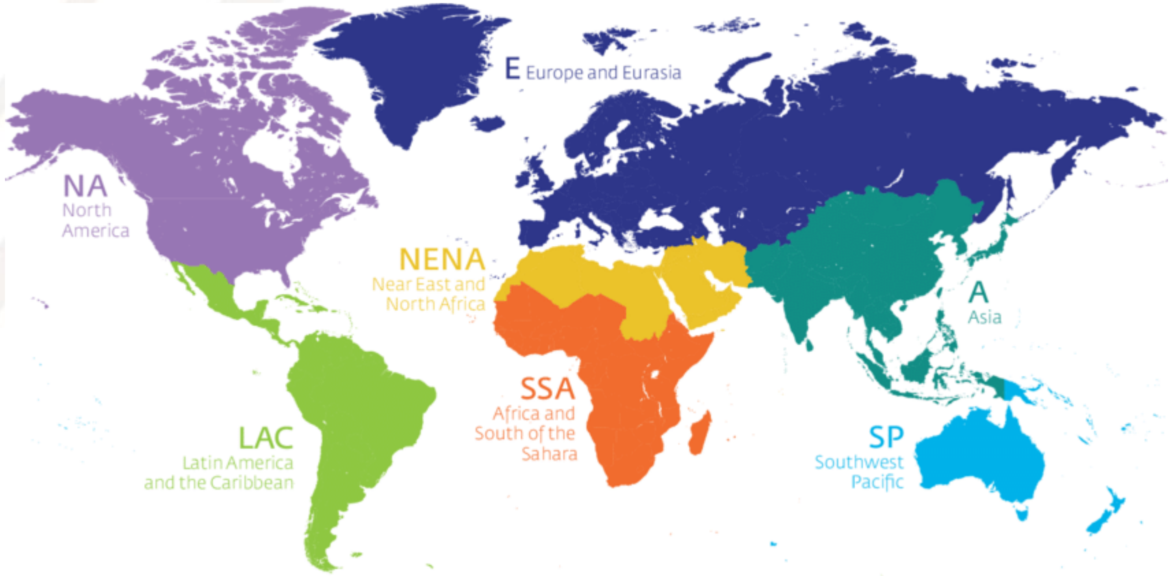


RECSOIL Green Path

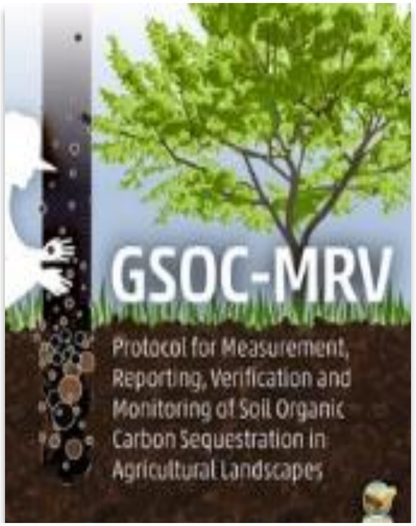
Focus:

✓ **Soil health and Ecosystem services (SOC as an indicator)**

+ 200 experts from all regions in the world



GSOC MRV Protocol



RECSOIL Carbon Path

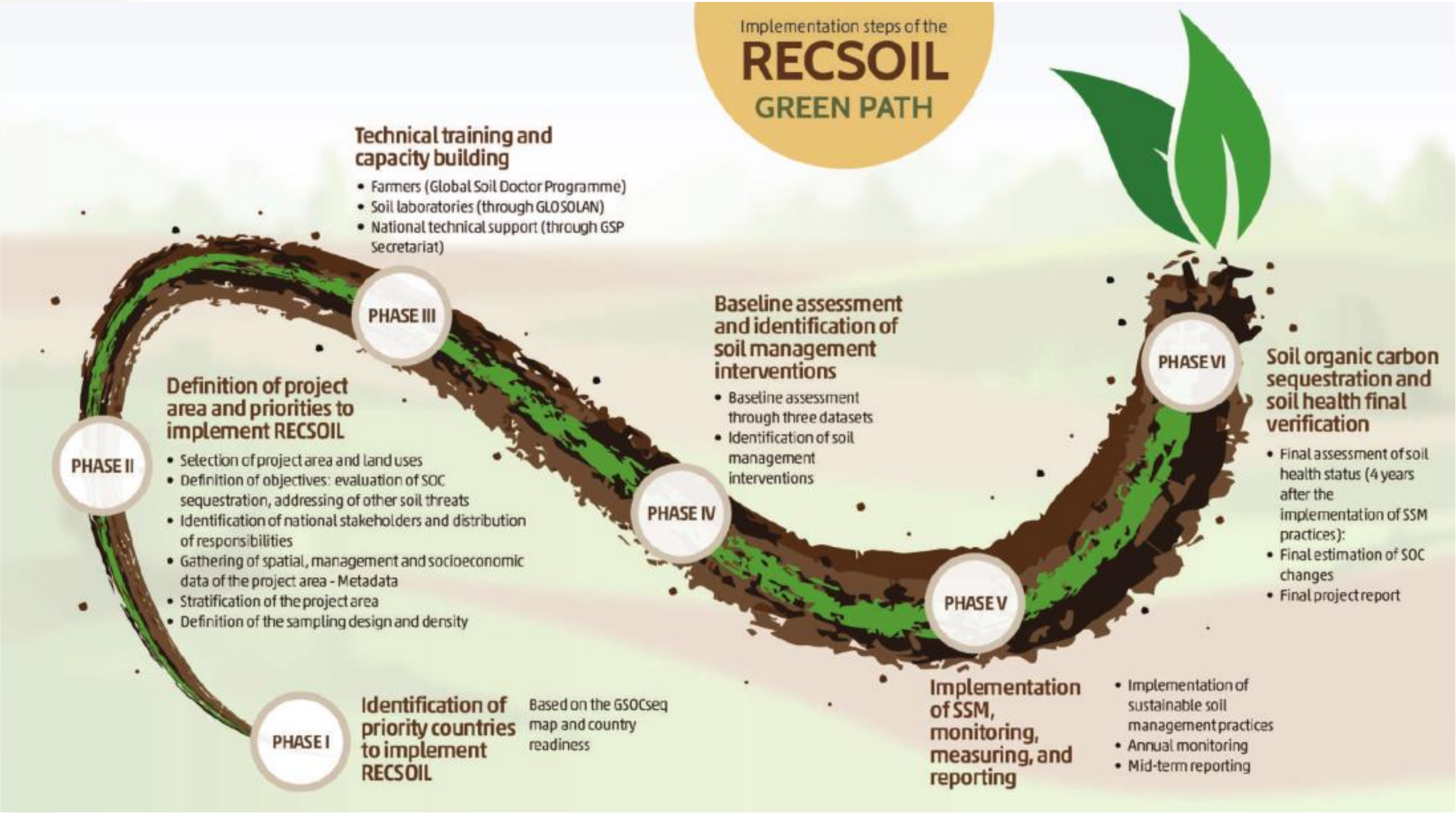
Focus:

✓ **Carbon credits**

(Through MRV of SOC sequestration and GHG reductions)

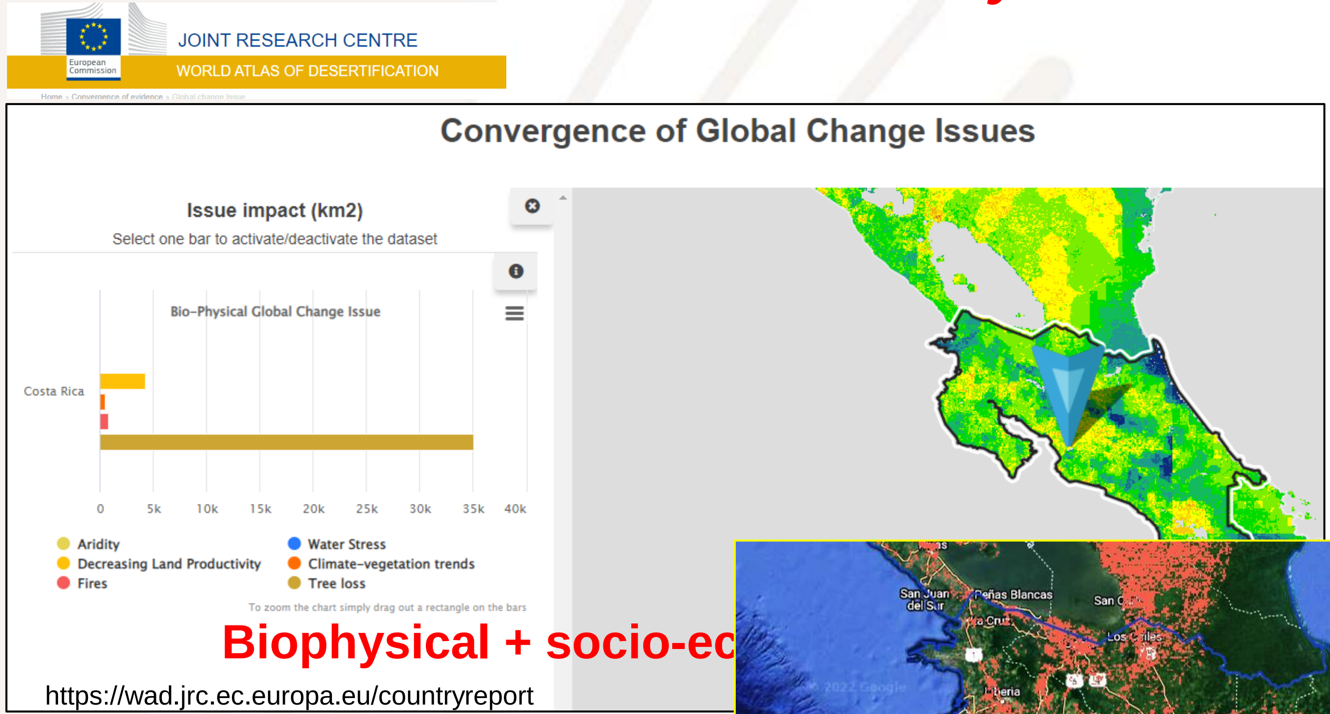
GLOBAL SOIL PARTNERSHIP

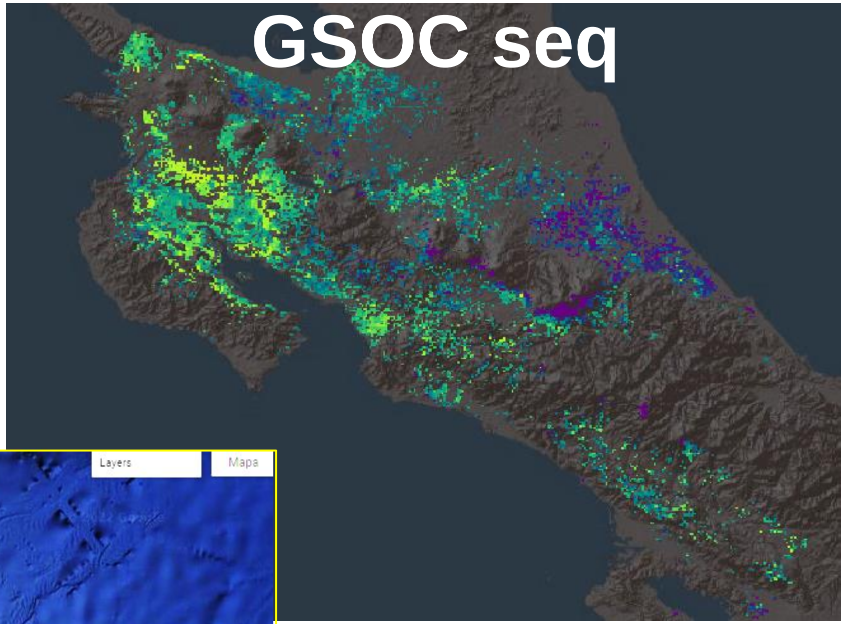
RECSOIL Green Path –SSM Protocol - Key Steps



RECSOIL Green Path –SSM Protocol - Key Steps

Identification of Priority areas and Definition of Project Areas





Earth Engine Apps

Select Issues

- ☑N deficit
- ☑N surplus
- ☑Aridity
- ☑Built
- ☑Fires
- ☑GNI
- ☑Livestock exess
- ☑LPD
- ☑Neg. Veg. Trend
- ☑Population
- ☑Pop. change
- ☑Forest loss
- ☑Water Stress

Identification of "**HOTSPOTS**" with greater convergence of issues + Greater Sequestration Potential

ng soil educational platform

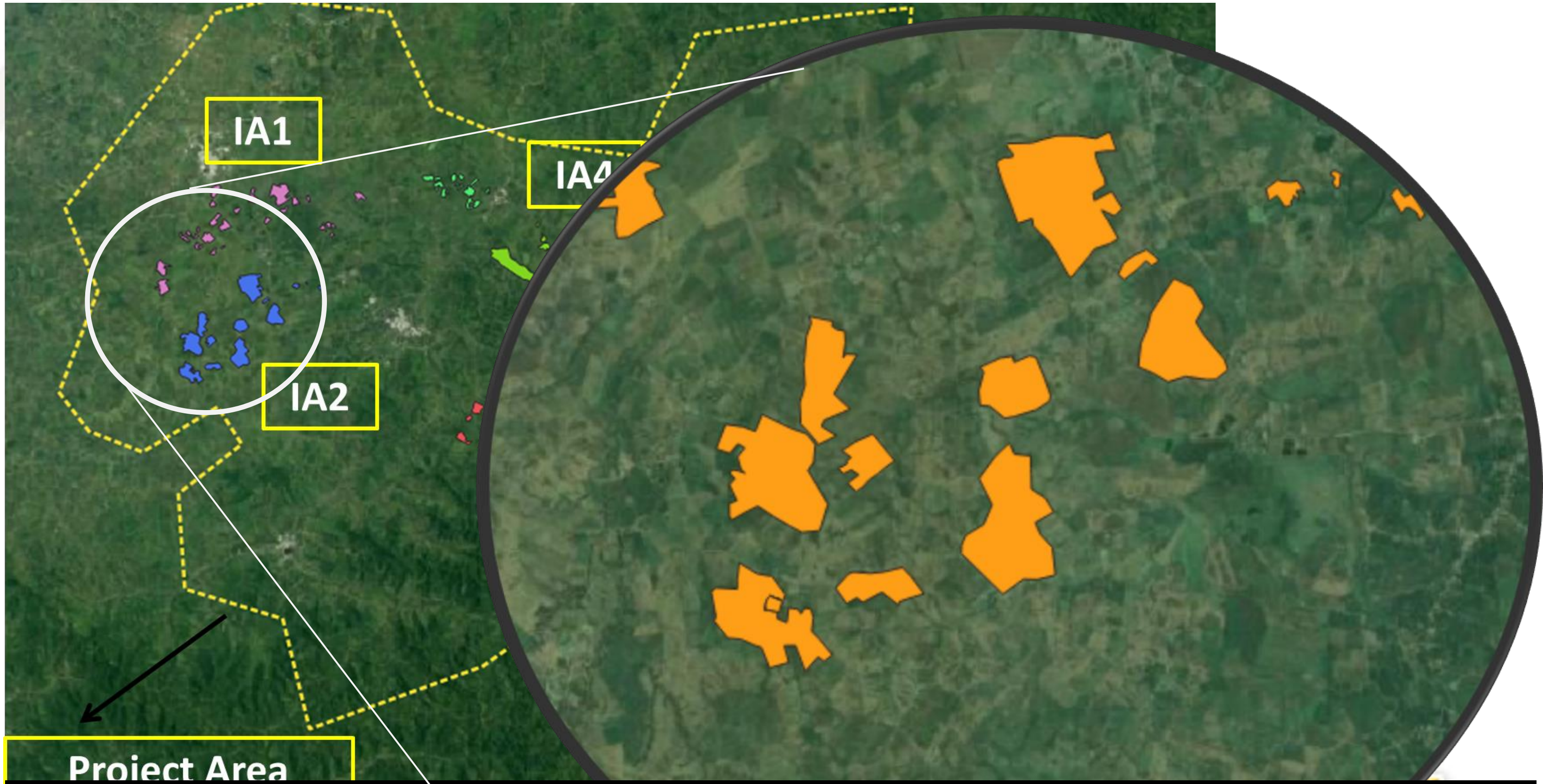
GLOBAL SOIL PARTNERSHIP

… Once the Total Area of the Project has been identified …Identification of **Intervention Areas (IAs)**

- Represent the **specific areas** where similar sustainable soil management (**SSM**) practices will be **implemented**; where **SOC changes and GHG emissions will be estimated**
- same agro-ecological zone, with similar land use and farming system

1 IA = 1 Field/ Ranch / Farm

Contiguous IA



One IA = multiple Fields / Ranches / Farms / Paddocks with similar systems, within the same agro-ecological region. Non-contiguous IAs

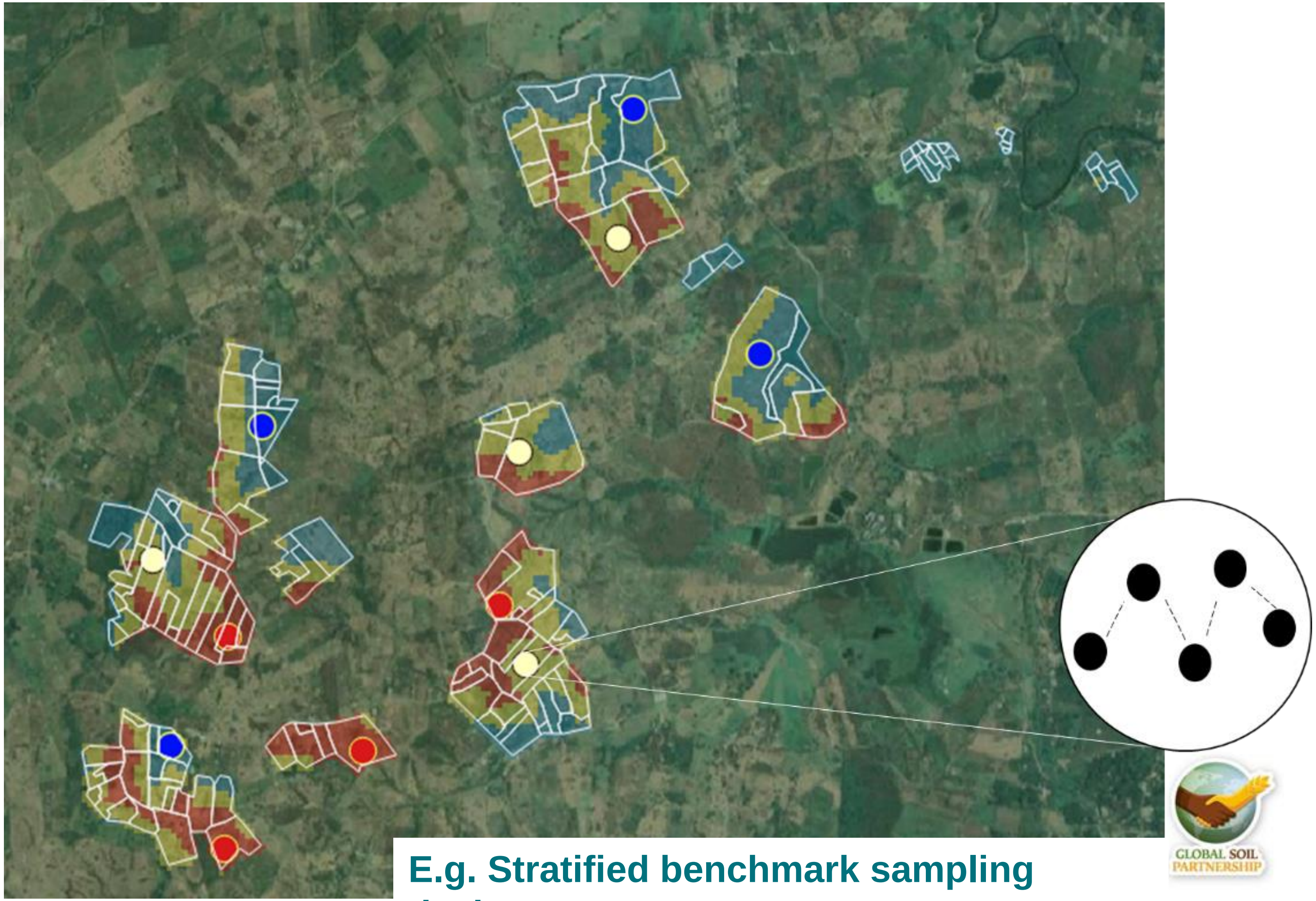
RECSOIL Green Path –SSM Protocol - Key Steps

Definition of Project Areas, Intervention Areas, Strata – Assessment Units

IAs are then
Divided into Strata – Assessment
Units (AUs)

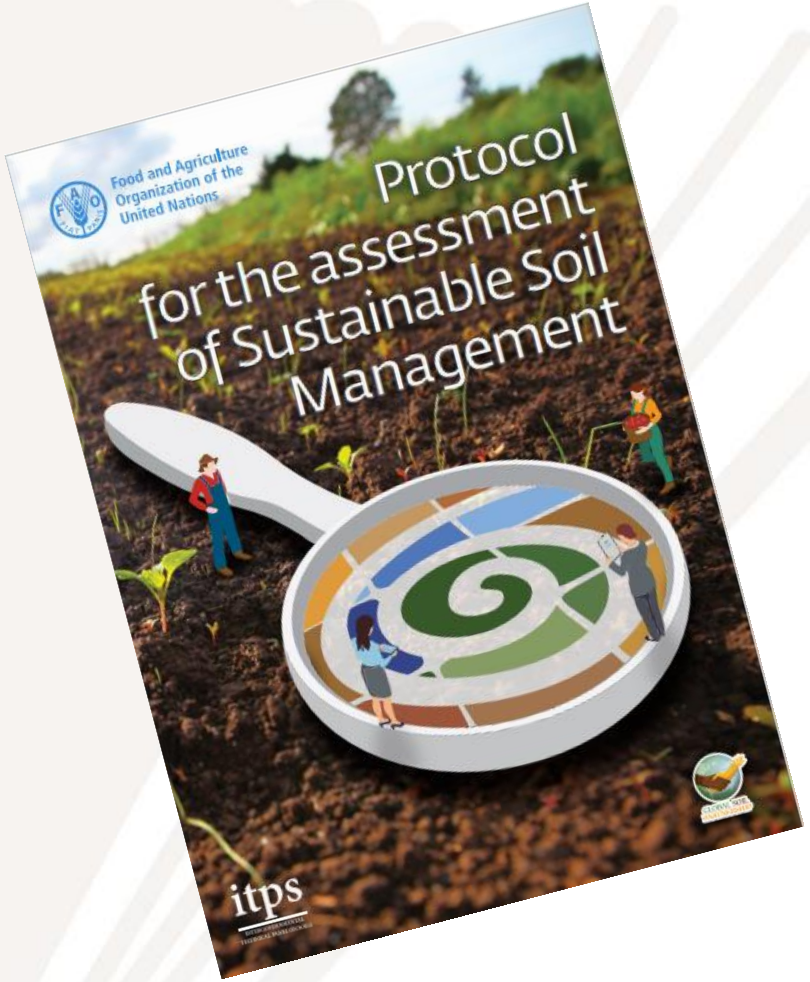
An AU or stratum represents a land area being relatively homogenous in terms of biophysical features, including:

- climate,
- soil type, topography (e.g. slope position), hydrology,
- **historic land use and management, among other factors**



E.g. Stratified benchmark sampling design

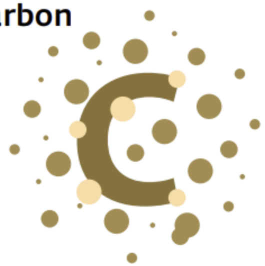
RECSOIL Green Path –SSM Protocol - Monitoring Phase



https://www.fao.org/fileadmin/user_upload/ /GSP/SSM/SSM_Protocol_EN_006.pdf

SSM Protocol - Based on the assessment of :

- **4 key indicators (common to all RECSOIL projects)**
- **Visual Soil Health Assessment** (VSA)
- and a set of **additional indicators** to assess soil health (physical, chemical and biological indicators)

Soil productivity 	Agricultural productivity or biomass in dry matter (t ha^{-1} $year^{-1}$)	**Soil physical properties** 	Bulk density (kg dm^{-3}) In some cases, bulk density can be complemented by available water capacity, or other relevant soil physical properties *(See additional indicators)*
Soil organic carbon 	Organic carbon (%)	**Soil biological activity** 	Soil respiration rate (gCO_2 m^{-2} d^{-1}) Ideally combined with at least one other biological indicator *(See soil biological activity p. 4 and 5)*

Being updated!!!

RECSOIL Green Path –SSM Protocol - Monitoring

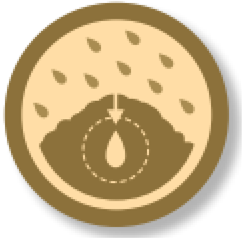
Additional Indicators –

(depending on the main threats to soil health)

Soil Nutrients
(P, N, K, etc)

Soil salinity
(EC- Electrical conductivity)

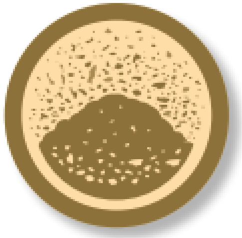
Acidity – Alkalinity
Soil pH



Available water capacity
(FC-PWP)

Water infiltration

Soil penetration resistance



Erosion
(USLE, erosion pins, Gerlacht boxes, etc)

Biological activity
(Enzimatic activity, microbial biomass, etc.)

Diversity
(e.g. pitfall traps, etc)

Soil pollution
(concentration, trace elements, pesticides, etc)



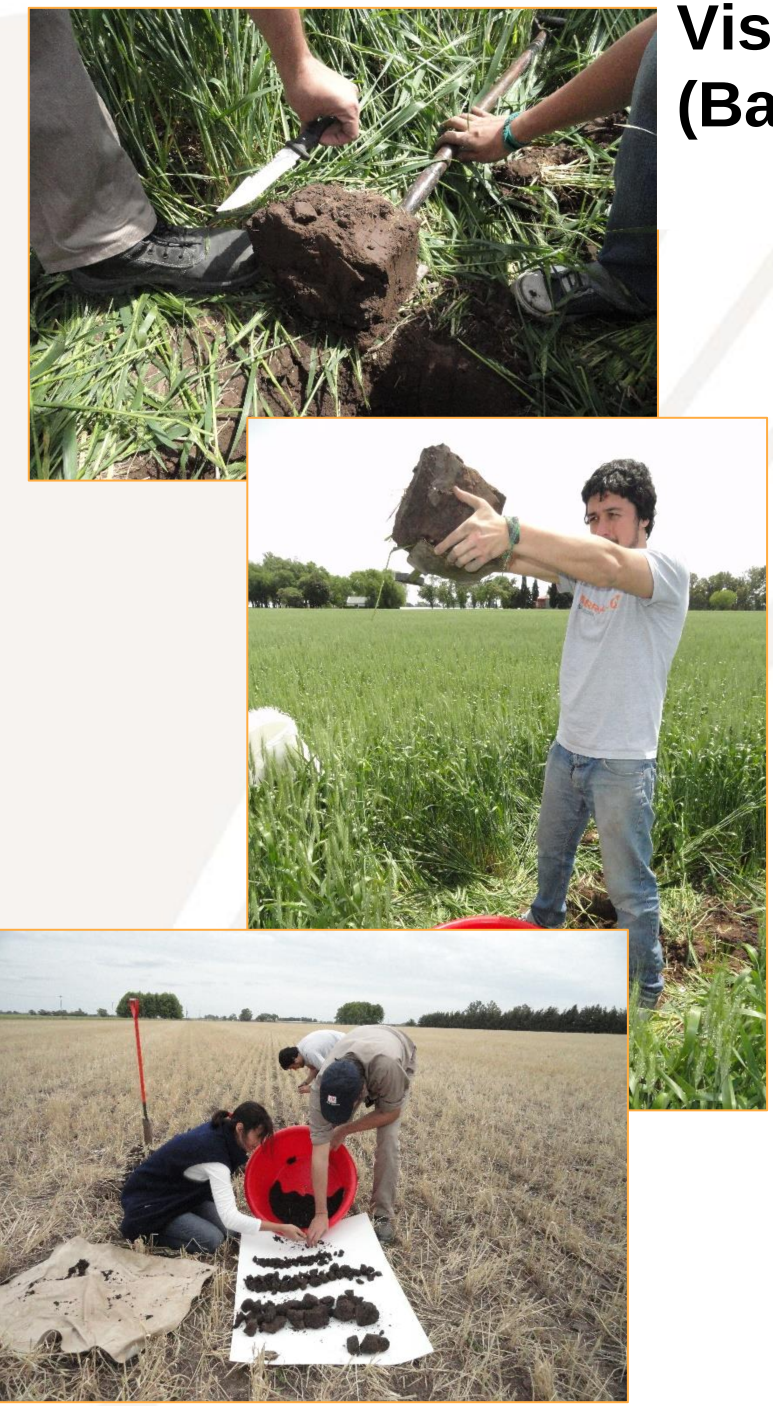


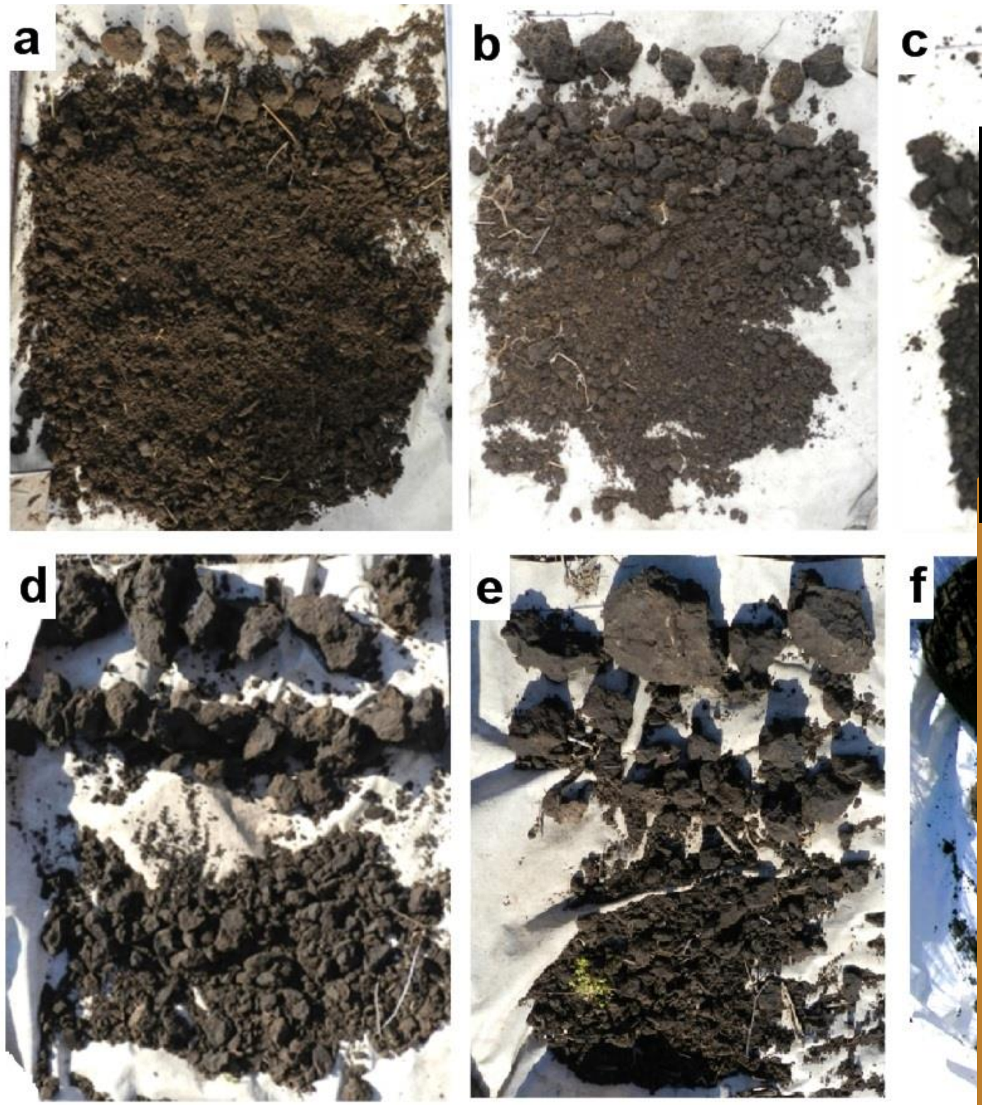

Promoting sustainable soil management for all

ALIANZA MUNDIAL POR EL SUELO

E.g. Soil Health assessment No till Argentina

Visual Soil Health assessment – (quali – quantititative) (Based on Shepherd 2008 – FAO Guidelines)





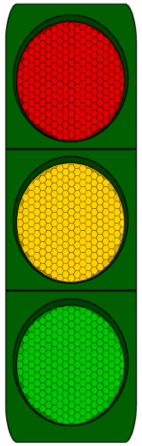
VSA of indicators such as:

Soil structure

Soil Porosity

Soil Color and mottles

Growth of roots, fauna presence etc



Poor condition

Moderate condition

Good condition

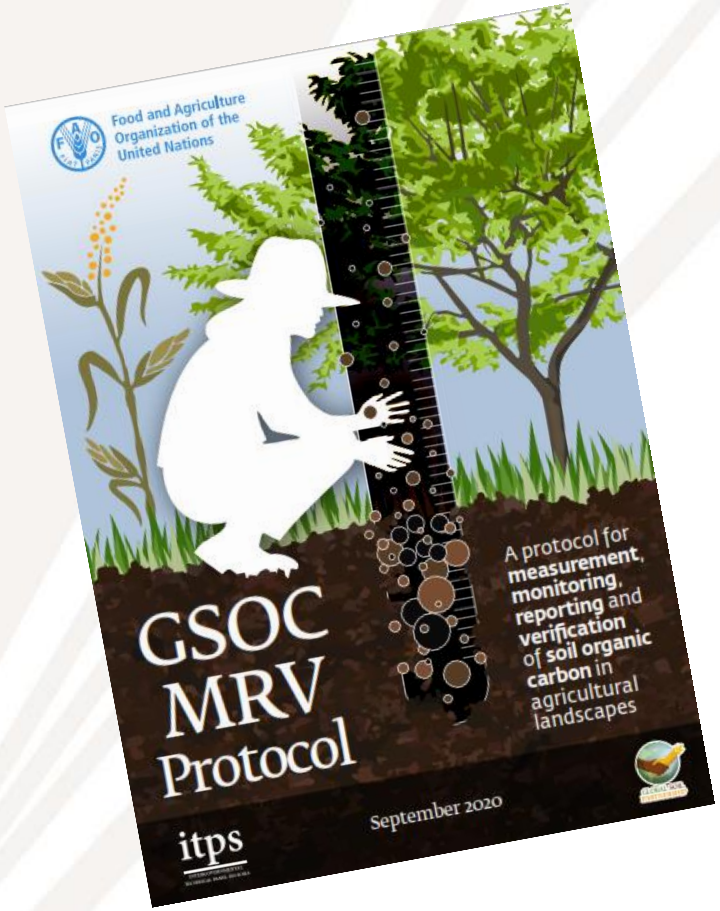
RECSOIL Green Path –SSM Protocol - Monitoring

- Countries have started to introduce their additional indicators.
- Costa Rica RECSOIL Pilot

Example. Grassland CR pilot:
- Vegetation cover %
- % Living Fences
- % Area Improved Pastures ,
- Applied compost (0=none; 1=5 t/ha; 2=5-10 t ha; 3=>10 t/ha)
- And other specific indicators!

2. GSOC MRV Protocol -Carbon Path

Objective: provide standard methodologies for the monitoring, reporting and verification **SOC stock changes** and **GHG emissions/removals** from agricultural projects.



Key aspects of GSOC MRV

- Only applicable to certain lands and activities
- Minimum of **8 years to be applied**.
- General methodology:
  - Soil **Measurements** : SOC, BD, Particulate Organic Carbon POC (optional) baseline, and every 4 years
  - + SOC **Modeling** (bi-annual)
  - + GHG **estimates** (IPCC, 2019 GL) (bi-annual)
  - periodic auditable reports.

https://www.fao.org/3/cb0509en/cb0509en.pdf

Applicability conditions: Eligible Lands GSOC MRV

In order to avoid potential damage to biodiversity-rich lands, this protocol is only applicable if practices are not implemented on these conditions:

a) wetlands and peatlands, or lands that have been subject to the drainage of a wetland/peatland during a baseline period (past 10 years) or other baseline periods determined by obligations under national and international legislation;

b) b) organic soils, Histosols, or soils having a histic or folic horizon (FAO, 2015);

c) c) current native forest lands, or lands that have been native forest lands and were converted to grasslands or croplands, at any point during a baseline period (at least past 10 years), or other baseline periods determined by obligations under national and international legislation;

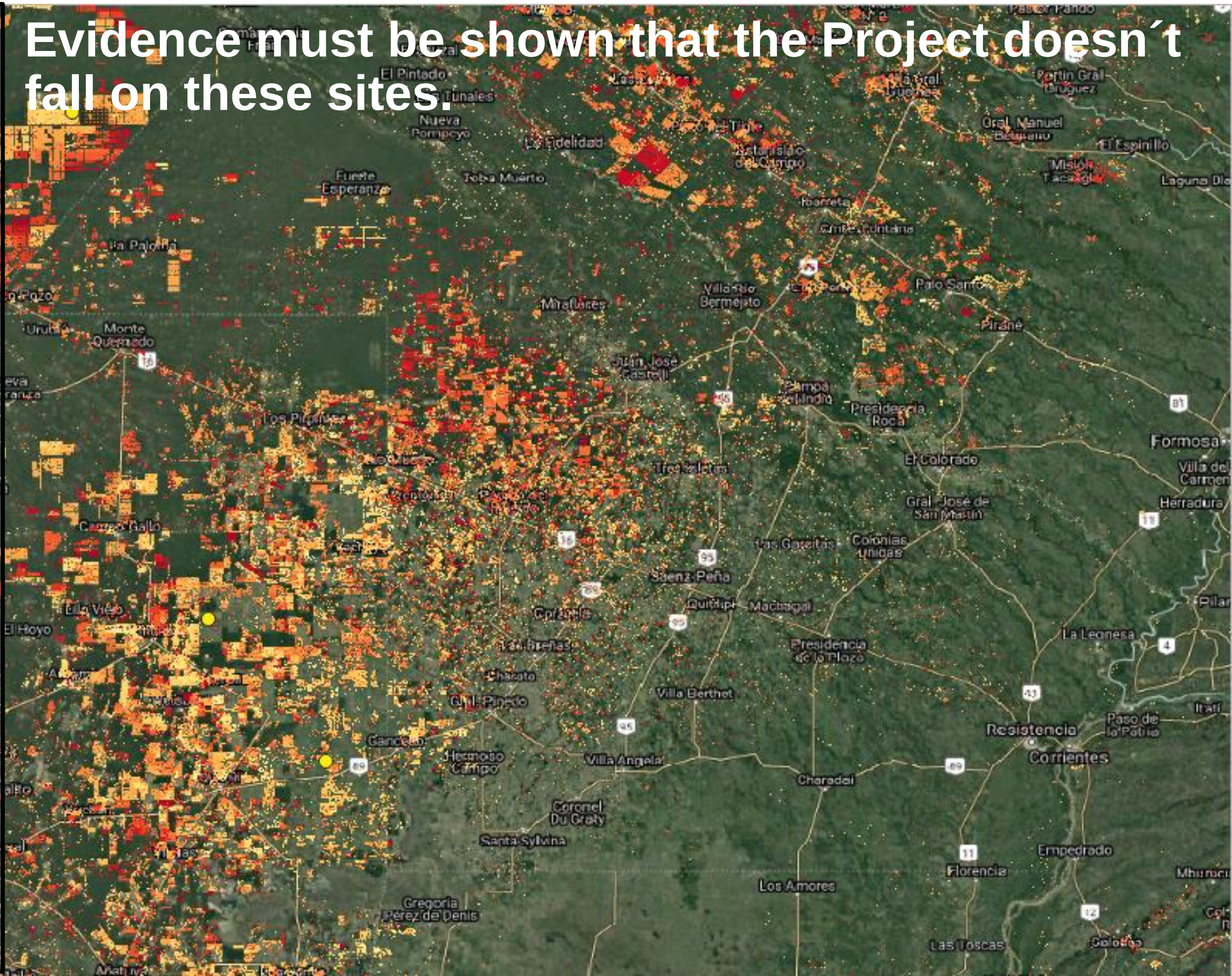
Applicability conditions: Elegible Lands GSOC MRV

Recently Deforested Areas

Example Global Forest Change Database

Global Forest Change Database v1.8 (2000-2020), downloadable from Google Earth Engine at a 30 m resolution. This datasets includes forest loss during the study period, defined as a stand-replacement disturbance (a change from a forest to non-forest state); Tree canopy cover for year 2000, defined as canopy closure for all vegetation taller than 5m in height; and the year of gross forest cover loss event. Potapov et al. (2020).

Evidence must be shown that the Project doesn´t fall on these sites.



Carbon Path - GSOC MRV Protocol

Monitoring: Soil sampling

What to Measure?

- Total SOC (%)
- Bulk density (t / m3)
- Particulate Organic Carbon (POC, optional)

→

- C stocks (t C / ha)

Adjusted by Equivalent Soil Mass (ESM)

- How to Measure?

- SOC %
- POC %

\+

- Bulk density

or

- SOC + Bulk density (soil mass)

With soil augers which do not disturb the sample and with a diameter > 3.5-4 cm

Carbon Path - GSOC MRV Protocol

Monitoring: Soil sampling

Sampling Depth?

- **Minimum: 0-30 cm**
- optimal: up to 100 cm
- Recommended: 0-10 cm + 10-30 cm

Or Adaptations (e.g. to provide samples for additional indicators)

E.g. 0-20 cm + 20-40 cm (+40-60 cm)

Frequency?

- Baseline (time= 0) Mandatory
- 2 years (optional; POC)
- 4 years (mandatory)

Carbon Path - GSOC MRV Protocol
Monitoring: Laboratory analysis

GLOSOLAN SOPs (Standard operating Procedures) (FAO, 2019)

Recommended option:
- **Dry combustion (Dumas)**

  - Autoanalyzer for C.
  - Analytical balance, ±0.0001 g, to weigh samples and reference materials.
  - Milling system that meets the requirements of the autoanalyzer manufacturer.

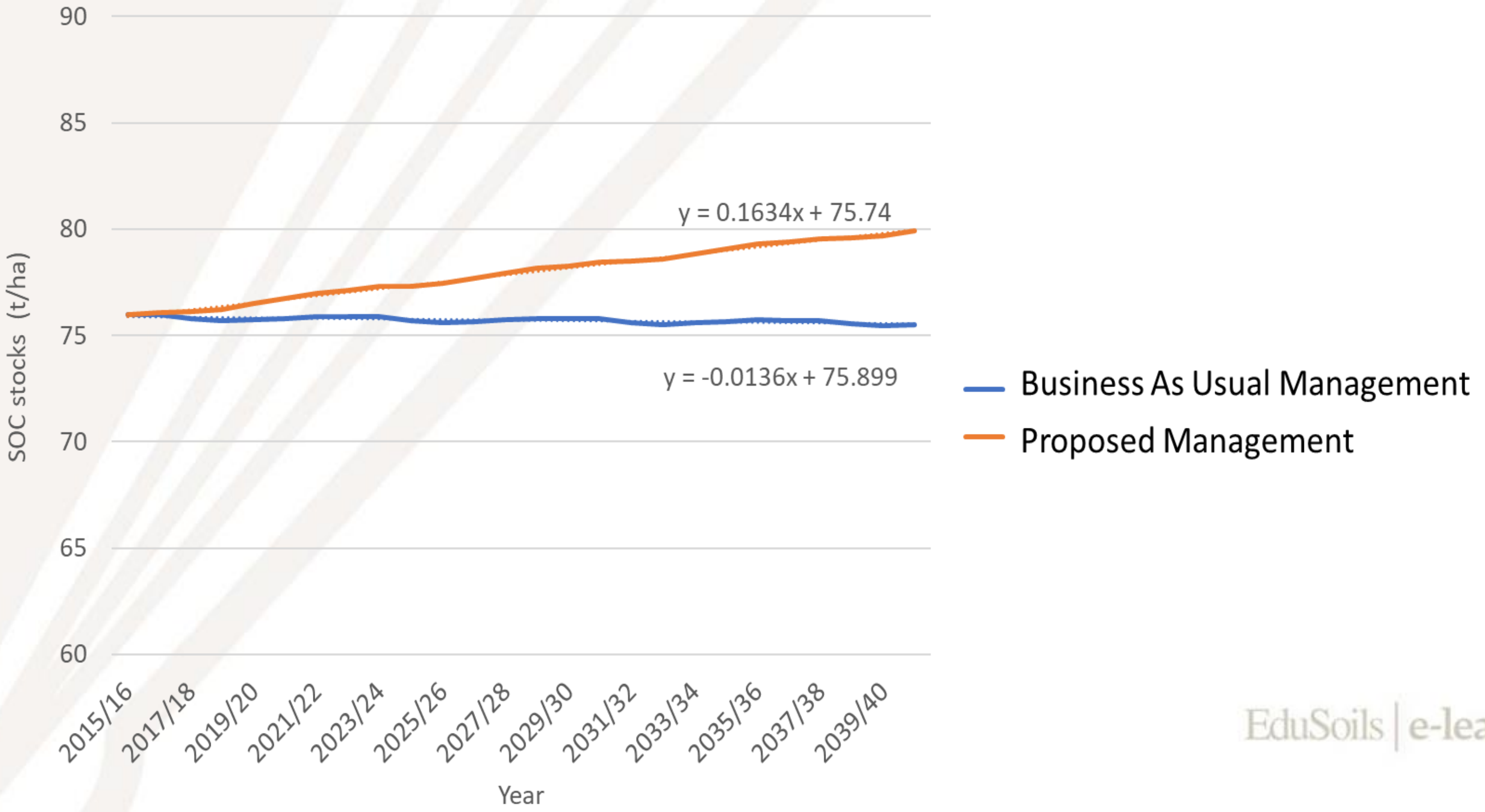
Alternative options :
- **Wet oxidation** (Walkley and Black, 1934)
- **Spectroscopy** (Evidence shall be attached)

- **POC Particulate Organic Carbon** (Cambardella and Elliot, 1993): 2 mm and 53 µm sieves.

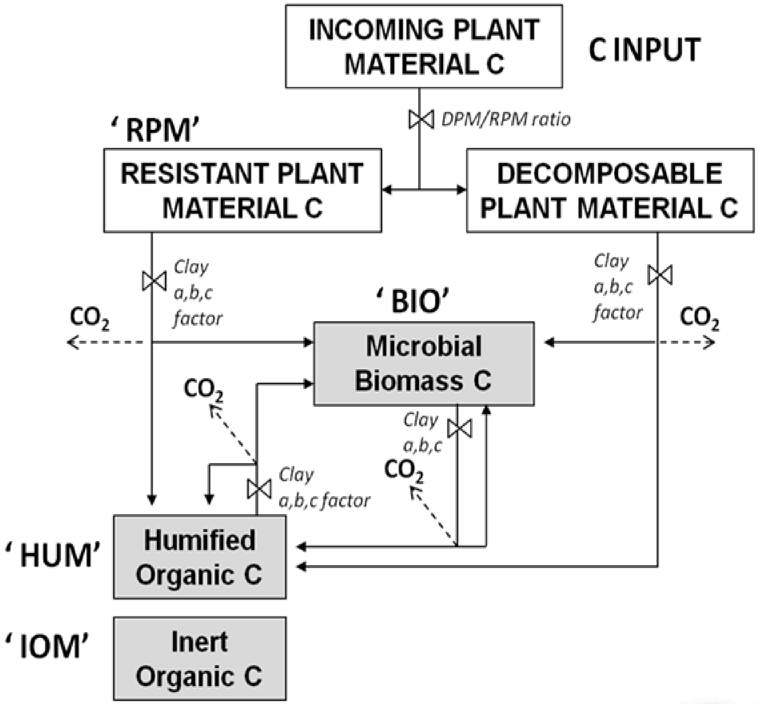
Carbon Path - GSOC MRV Protocol

Monitoring: SOC projections using SOC simulation models

20-year projection for BAU and Project



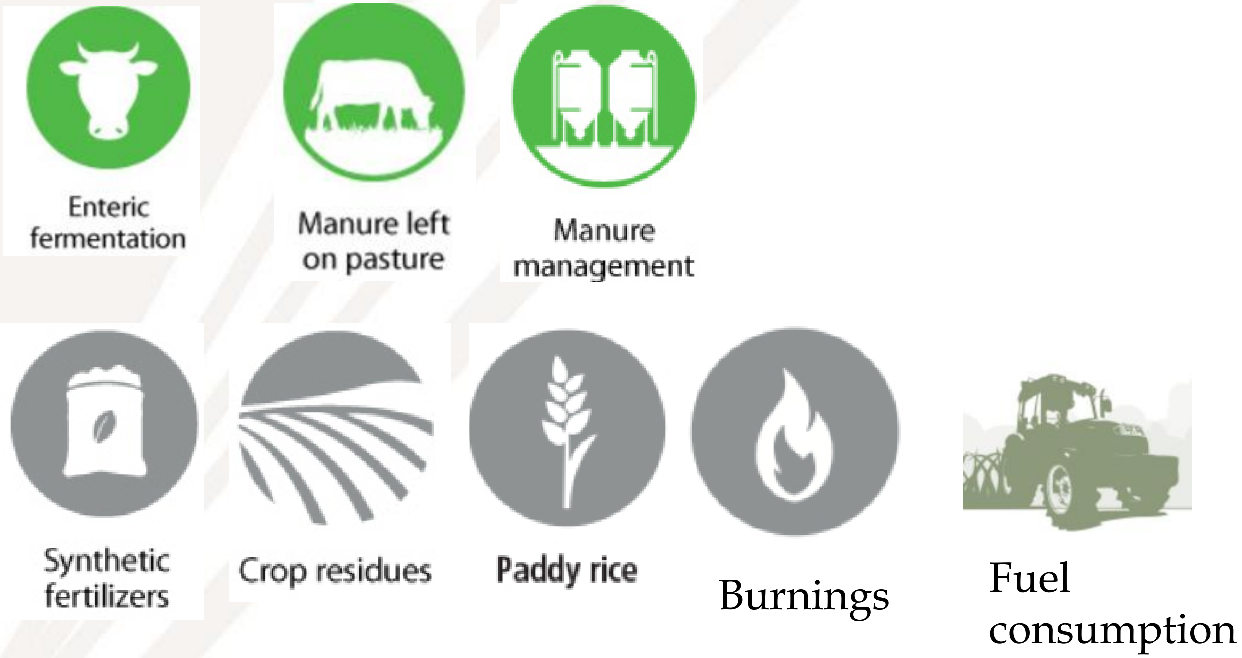
Models – No specific model recommended… but Guide using RothC Model is provided

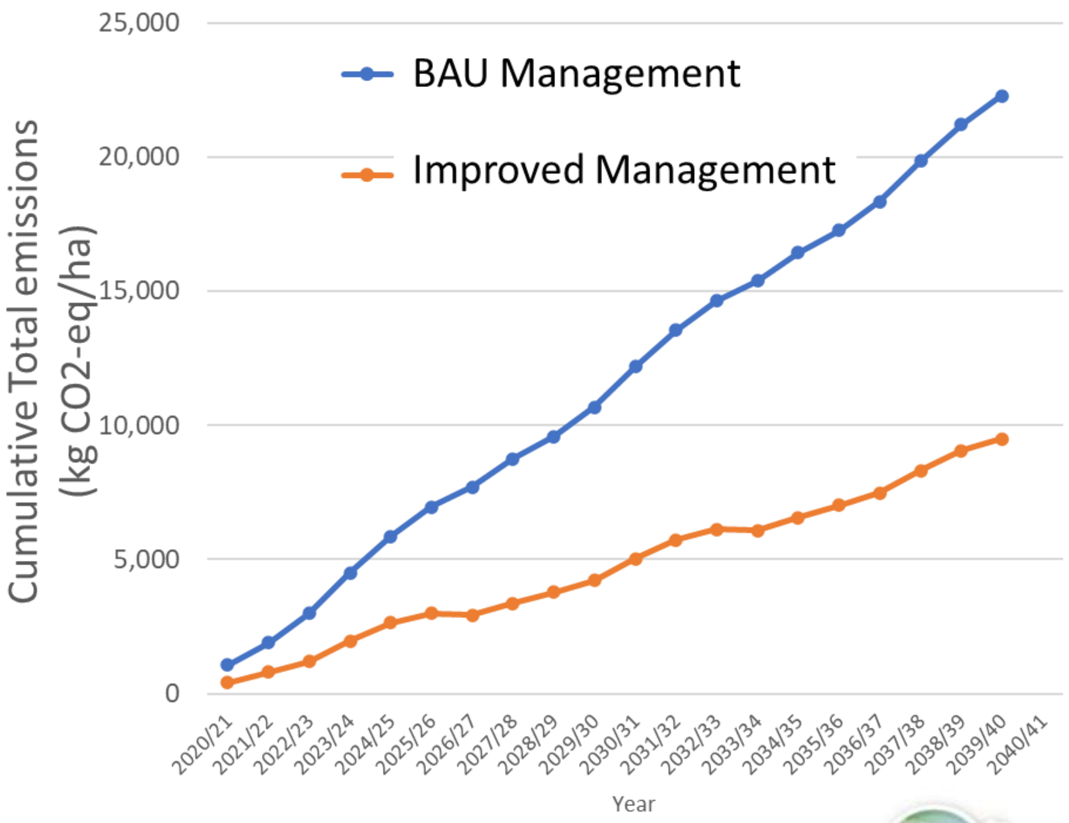


Carbon Path - GSOC MRV Protocol

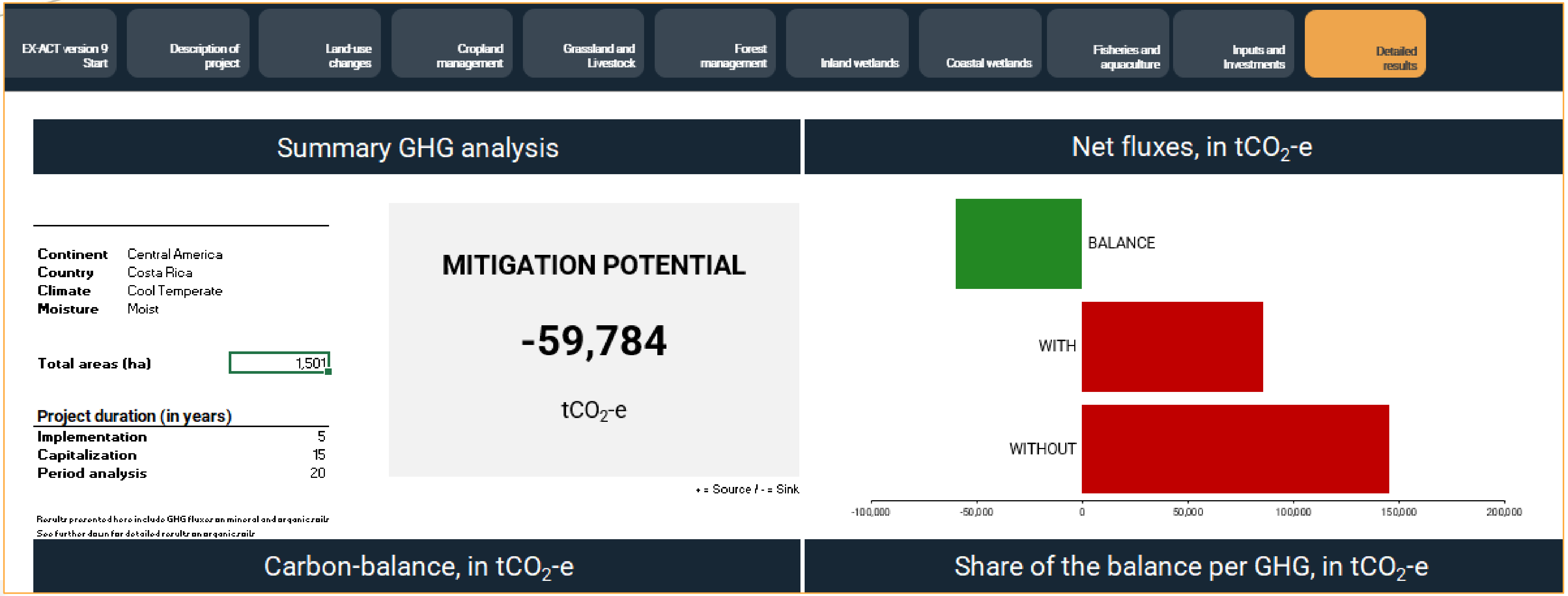
Monitoring: GHG projections using simulation models

- Ej. GHG emissions (IPCC 2019):
- CO_2; CH_4; N_2O, (using EXACT or peer reviewed tool)





GHG emissions balance - (E.g. EXACT)



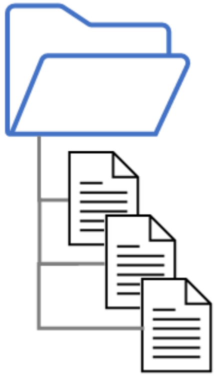
https://www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act/en/

In both Protocols …

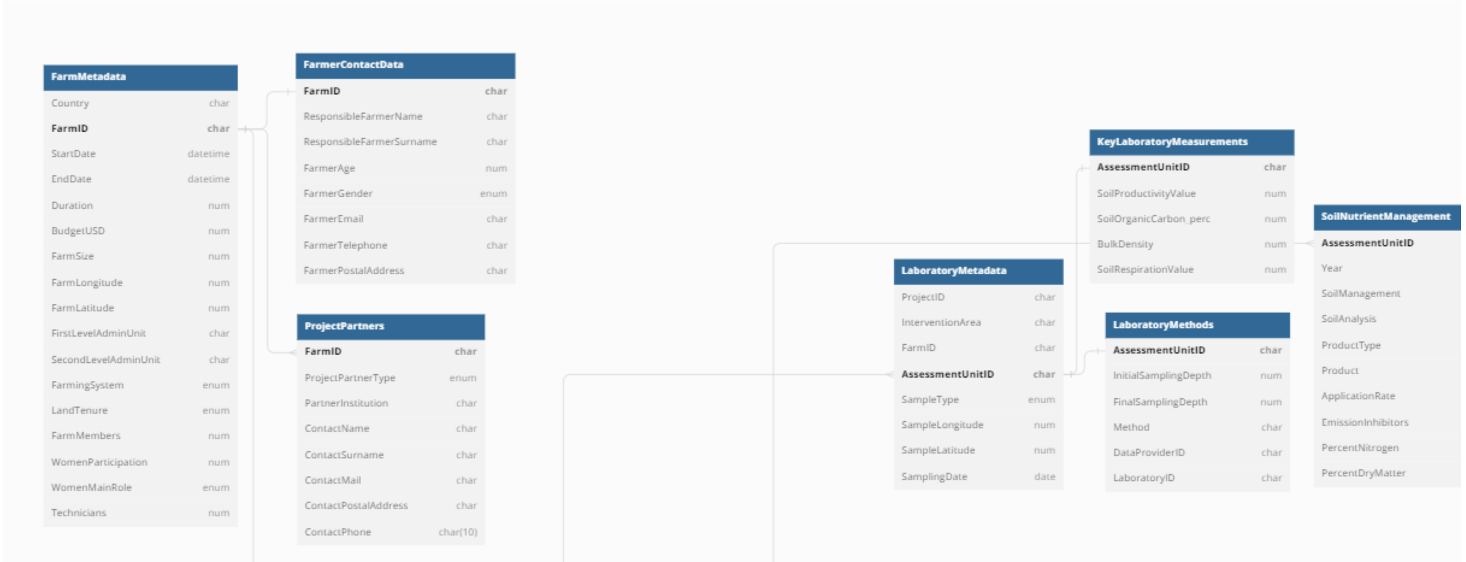
Collecting and Managing Field Activity Data

(e.g. crops, yields, fertilzier dose, livestock heads, etc)

- Key to characterize business as usual and Intervention/Project scenarios
- Key to model SOC changes and GHG emissions
- Key for monitoring process (to verify projected activities and deviations)



Database for all **RECSOIL** Projects
...under construction

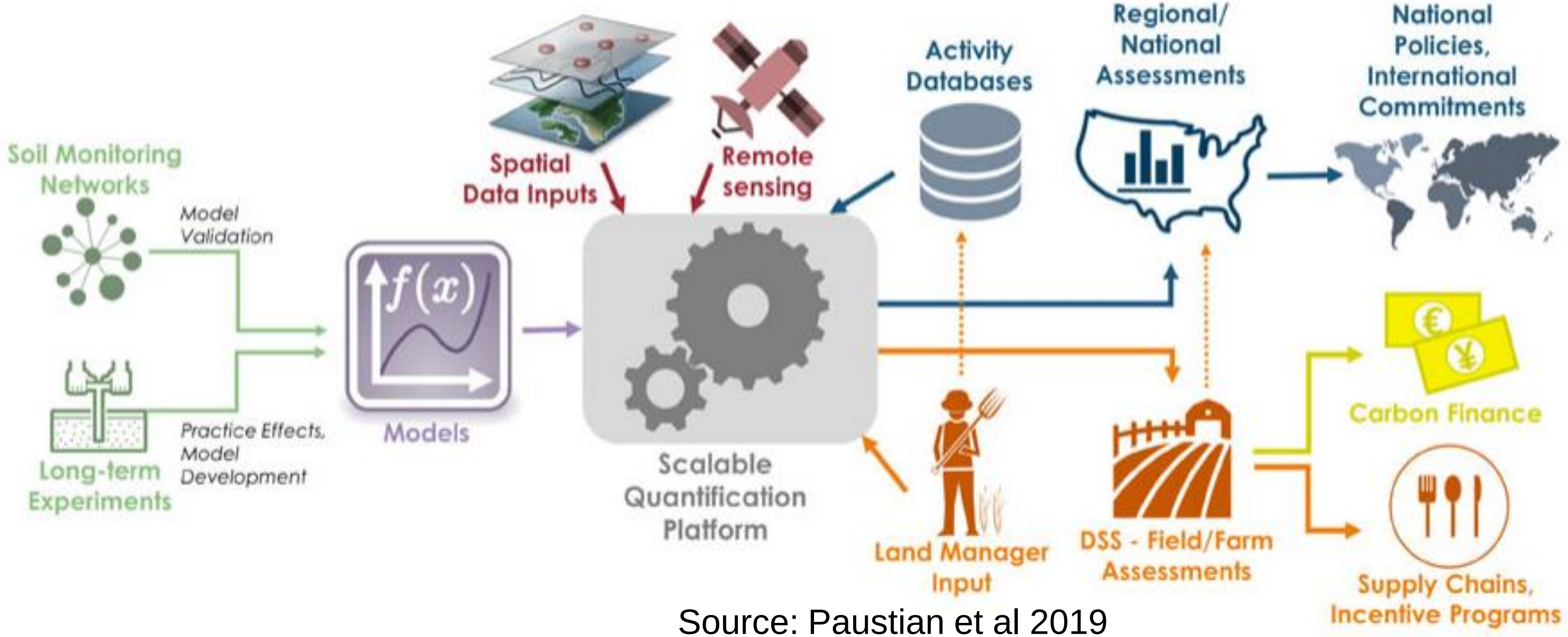


In both cases ...

Field Activity Data and SOC ground data generated in Projects → **National GHG inventories**

E.g. Data from Georeferenced sampling sites – Benchmark sites:

- Change in SOC stocks could be used to:
  - ground-truth SOC changes estimated by the Tier 1, Tier 2 or Tier 3 model projections over time.
  - Calibrate and evaluate models in different regions; derive tier 2 local EF
- Current SOC stocks could be used to update and improve SOC maps (key input for Tier 2-3 estimates of emissions from SOC changes)
- Ground-truthing activity data



Source: Paustian et al 2019

RECSOIL Protocols

- Developed through an extensive research, consultation and inclusive process, involving scientists, policy makers, FAO Members, and international and intergovernmental panels
- Scientifically **robust** yet **flexible** protocols
- General Framework – Possibility to adapt specificities to local conditions
- Will generate results which can contribute to National GHG inventories

Way forward:

- Currently working on Pilots and Implementation Manuals
- Update - Improvement of the Protocols … "Living documents" : improved as there are more users worldwide, and more and better data is generated

Food and Agriculture Organization of the United Nations

Training Workshop for Reporting Soil Carbon Stock Change in National Greenhouse Gas Inventories

1st December 2022

Thank you

EduSoils

GLOBAL SOIL PARTNERSHIP