Estimating CSC from soils: Indonesia Experience

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Acknowledgement

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- **SOC content variation**
- **SOC mapping**
- **SOC temporal change & land management**
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- **Potential solutions**

Why should SOC map be available?

- Indicator of soil health
- Indicator of soil fertility
- Indicator of land suitability

- Critical issue in climate change, land degradation, food security,
- Important in sustainable land management

SOC CONTENT

Soil color is first estimate of soil organic carbon (SOC) content

Black color : high soil organic carbon

Further detail: soil laboratory analysis, using different methodologies (Loss of Ignition, etc)

Its said that tropical soils low in SOC, is not it?

Average of SOC content of Peat Soils

Peat soil are high in SOC

Province	Sapric		Hemic		Fibric	
	OC (%)	n	OC (%)	n	OC(%)	n
Kalbar	51,89	22	55,58	25	57,11	80
Kalsel	46,62	24	47,37	57	49,60	103
Kalteng	54,07	41	45,15	143	48,78	133
Jambi	48,99	269	50,23	271	51,47	221
Aceh	td		56,22	364	57,31	152
Riau	50,14	48	54,49	159	54,65	100
Sumatera & Kalimantan	49	415	52	1025	53	790
Papua*	28.27		30.53		35,92	
Sumatera*	44,95		48,00		53,31	
Kalimantan*	33,53		36,24		42,63	

Source: Mulyani et al. (2013); *Wahyunto et al (2004)

Note: always consider C/N ratio when considering SOC in peat soil.

Still need organic fertilizer in peat soils

Average of SOC content of Mineral Soils (0-30 cm)

SOC unit in %

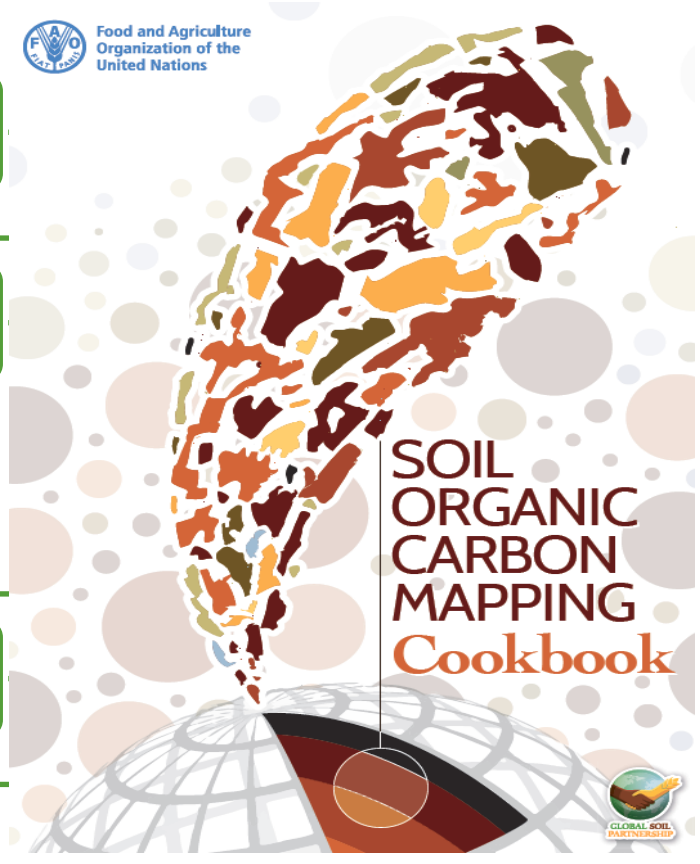
suborder	N	Mean	Min	Max	Variance	Median
Aqualfs	6	0.63	0.18	1.20	0.15	0.69
Aquents	7	2.52	0.75	4.14	1.78	2.48
Aquepts	55	2.20	0.18	7.00	2.85	1.67
Aquerts	24	1.02	0.19	1.79	0.23	1.07
Aquods	4	4.25	1.41	7.66	9.44	3.96
Aquolls	2	0.82	0.38	1.26	0.39	0.82
Aquox	1	1.08	1.08	1.08		1.08
Aquults	3	1.62	0.85	2.63	0.83	1.39
Fluvents	3	0.92	0.49	1.22	0.15	1.05
Humults	7	3.49	0.97	9.85	8.71	2.48
Orthents	28	1.51	0.12	3.91	0.82	1.37
Orthods	3	1.59	0.31	2.45	1.28	2.01
Psamments	4	1.13	0.94	1.55	0.08	1.01
Udalfs	19	2.15	0.57	7.86	3.18	1.42
Udands	21	4.04	0.51	10.89	8.98	3.38
Udepts	132	1.58	0.12	8.55	1.83	1.12
Uderts	3	2.95	1.56	3.71	1.45	3.57
Udolls	12	1.80	0.89	3.10	0.39	1.97
Udox	10	1.75	0.60	2.84	0.49	1.78
Udults	100	1.48	0.14	6.47	2.16	0.92
Ustalfs	22	1.55	0.08	5.03	1.49	1.04
Ustands	2	1.83	0.98	2.67	1.43	1.83
Ustepts	61	1.40	0.14	4.25	0.78	1.22
Usterts	28	1.57	0.29	3.12	0.61	1.28
Ustolls	32	1.90	0.35	4.15	1.08	2.05
Ustults	1	1.75	1.75	1.75		1.75
Vitrands	3	1.60	1.03	1.93	0.25	1.85

SOC Mapping

- **To identify SOC distribution over landscape**
- **Issues in mapping:**
  - **spatial pattern**
  - **values of mapping unit**
  - **uncertainty**
  - **representation: grid or polygon**
  - **scale**
- **Approach/Method/procedure**

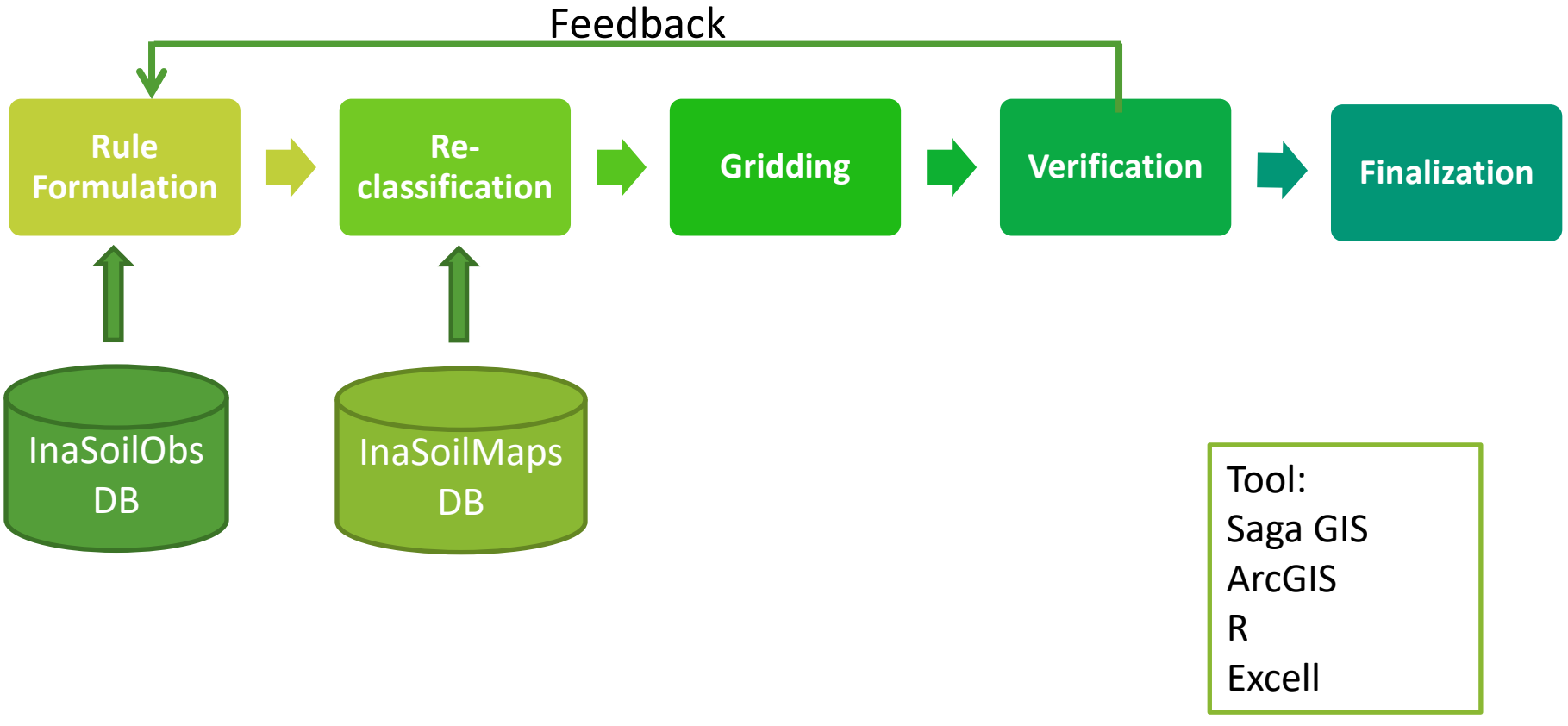
APPROACH

- Utilize legacy soil data
- Geomatching
  - average SOC per mapping unit
  - work on soil legend
  - dominan soil grup
- SOC Mapping Cookbook

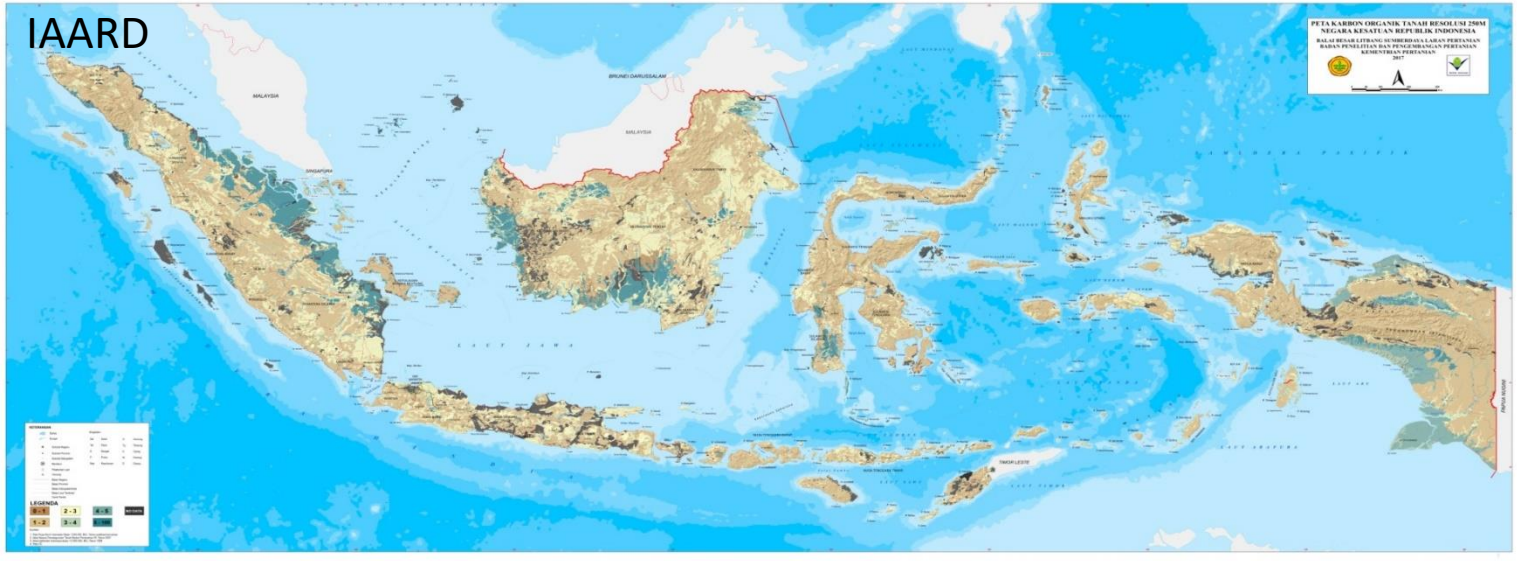


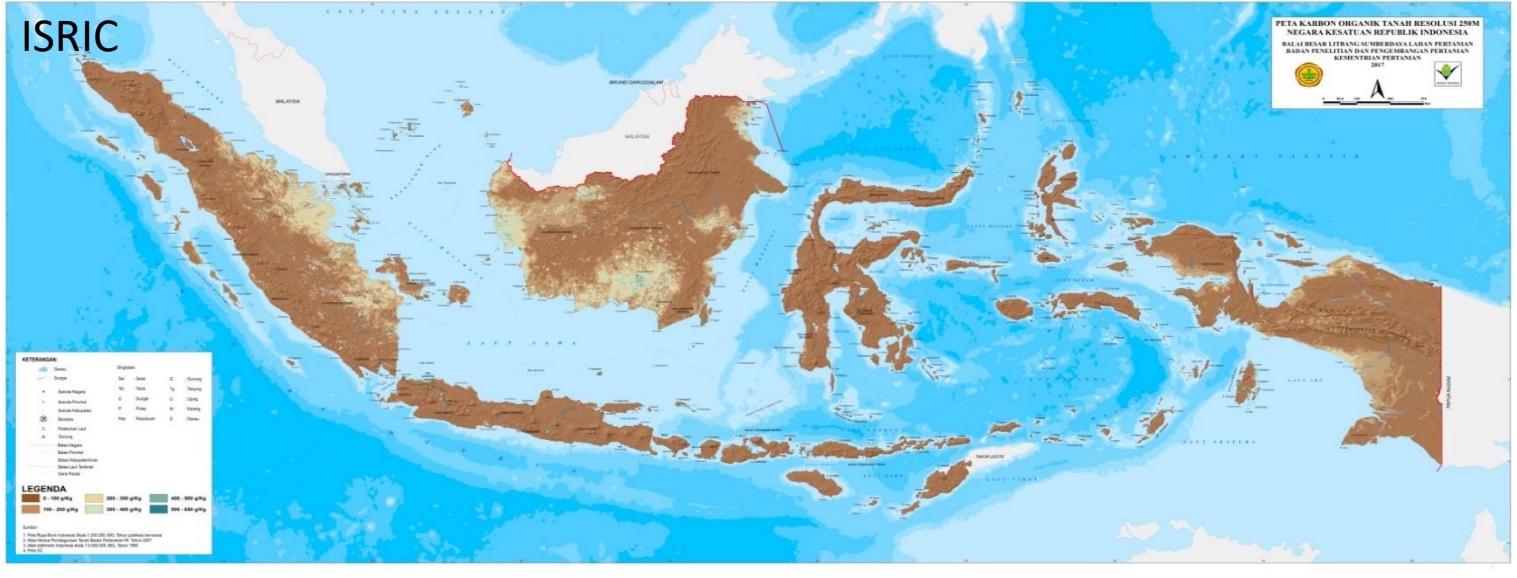
1. Sulaeman Y, Minasny B, McBratney AB, Sarwani M, Sutandi A. 2013. Harmonizing legacy soil data for digital soil mapping in Indonesia. Geoderma 192:77-85..
2. Lettens S, van Orshoven J, van Wesemel B, Muys B. 2004. Soil organic and inorganic carbon content of landcape units in Belgium for 1950-1970. Soil use and management 20:40-47

MAPPING STEPS



Tool:
Saga GIS
ArcGIS
R
Excell





SOC Maps

Created by national experts

More up to date data support

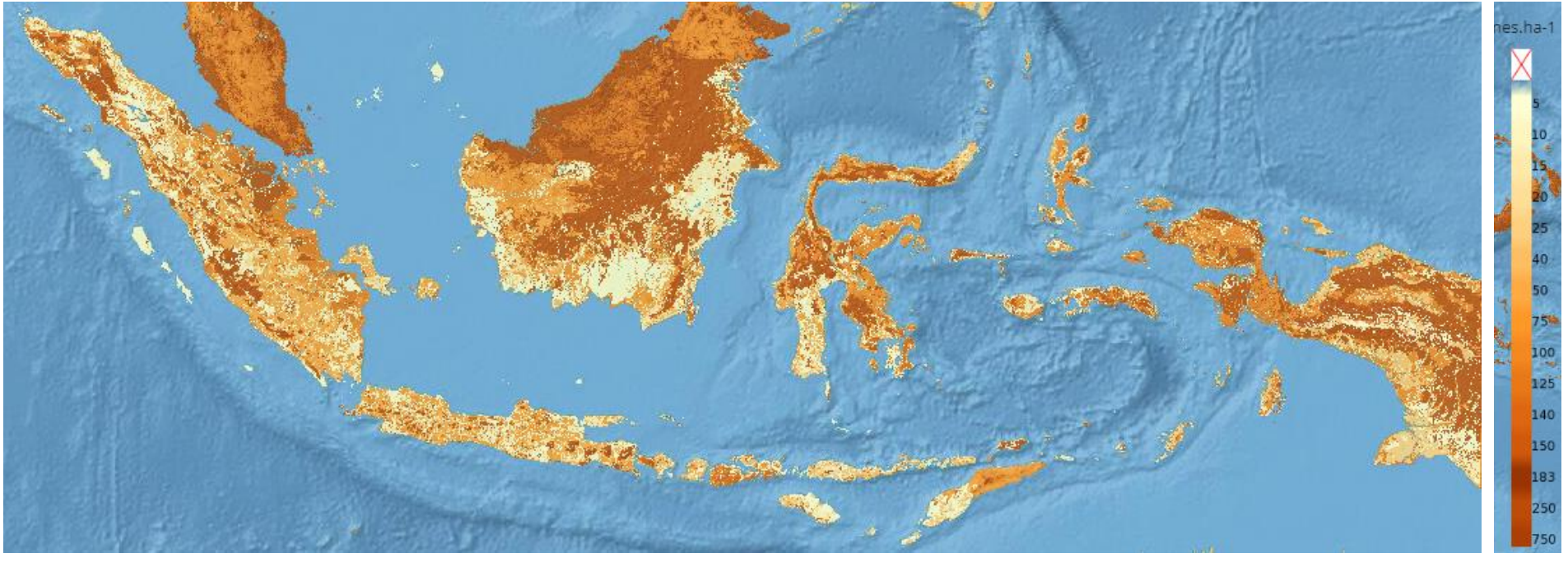
Could be updated by national experts

Created by Non-national experts/external institution

Limited data support

National expert can not do modification directly

Global soil organic carbon stock (ton ha^{-1}) of mineral soils



http://54.229.242.119/GSOCmap/

First map, national coverage, GSP Spec, 250m grid

One product of Global Soil Partnership

TEMPORAL CHANGE

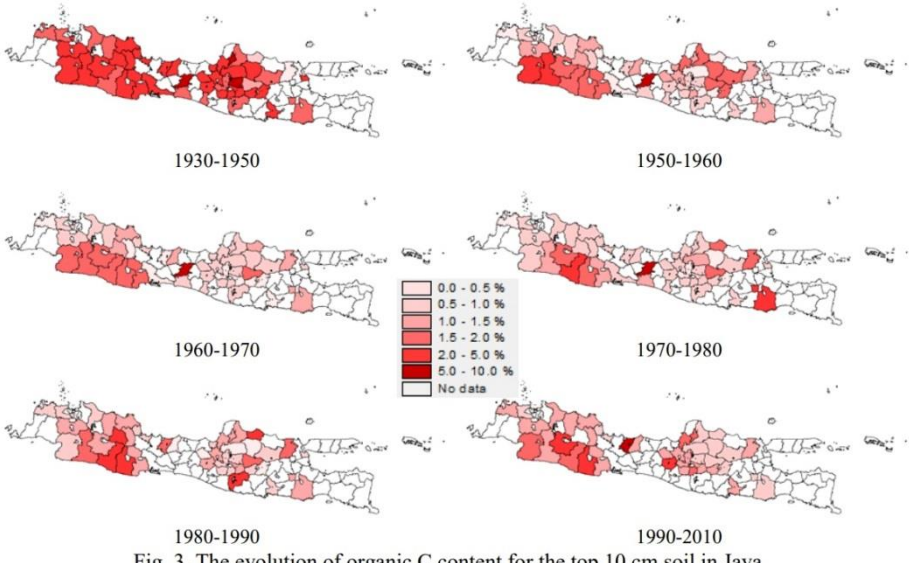


Fig. 3. The evolution of organic C content for the top 10 cm soil in Java

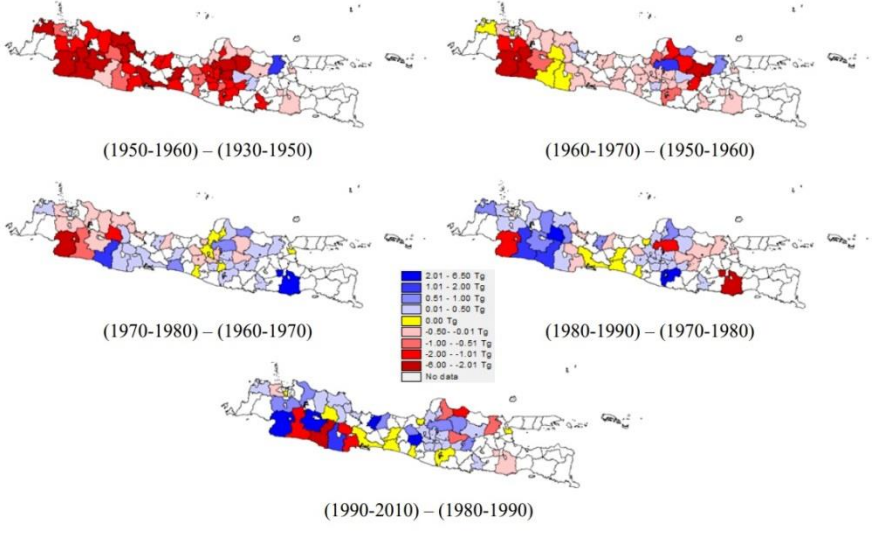


Fig.4. The changes in C stock over successive period for the top 10 cm soil in Java

Source: Sulaeman et al. 2010

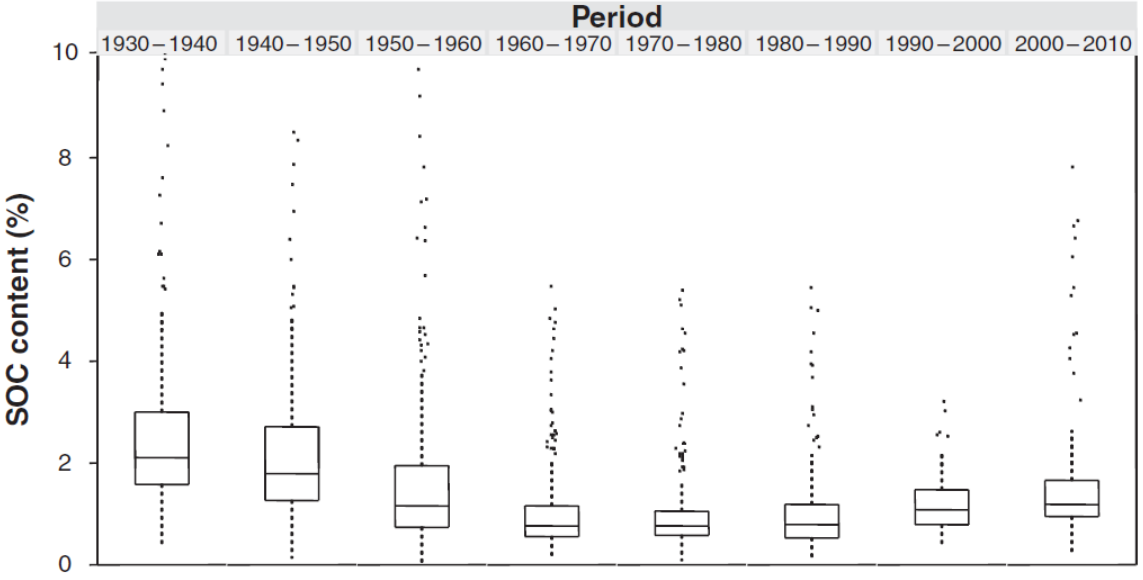


Table 1 Soil organic carbon (SOC) content and carbon stock for topsoil in Java, grouped by decades

Period	*n*	Median C content ($g\,100\,g^{-1}$)	Median C stock (0–10 cm) ($kg\,m^{-2}$)
1930–1940	282	2.11	2.04
1940–1950	183	1.79	1.84
1950–1960	437	1.15	1.14
1960–1970	434	0.76	0.73
1970–1980	223	0.75	0.70
1980–1990	209	0.79	0.80
1990–2000	77	1.08	1.09
2000–2010	157	1.18	1.21

Fig. 2 Box plot of soil organic carbon (SOC) content for the surface soils in Java over time. The ends of the box are the 25th and 75th quantiles. The line across the middle of the box is the median value.

Source: Minasny et al. 2010

Improved soil management,
Improved SOC content

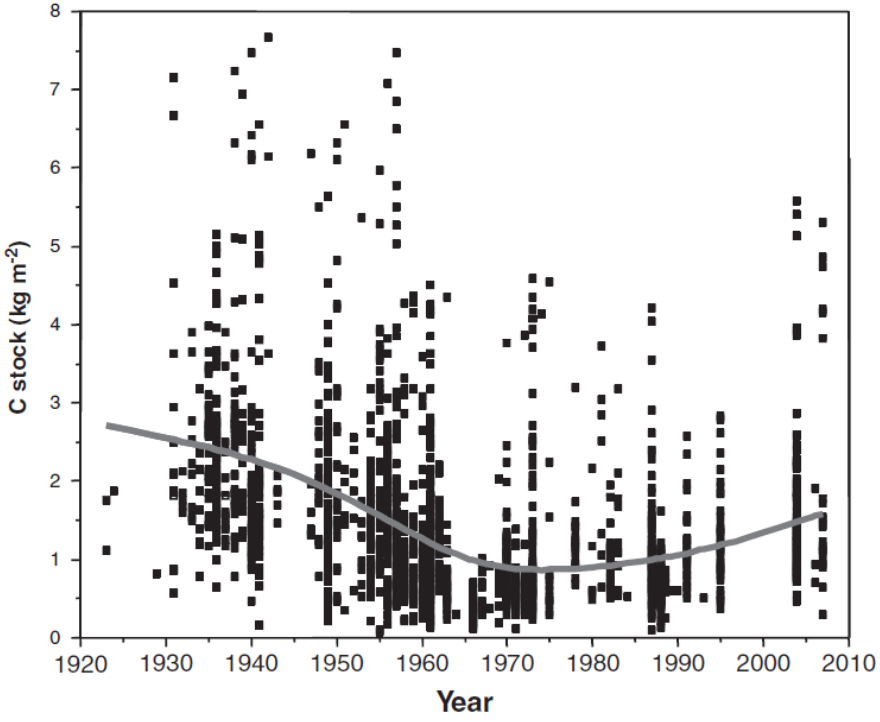


Fig. 5 A smoothing spline fitted to the soil organic carbon stock at 0–10 cm with time.

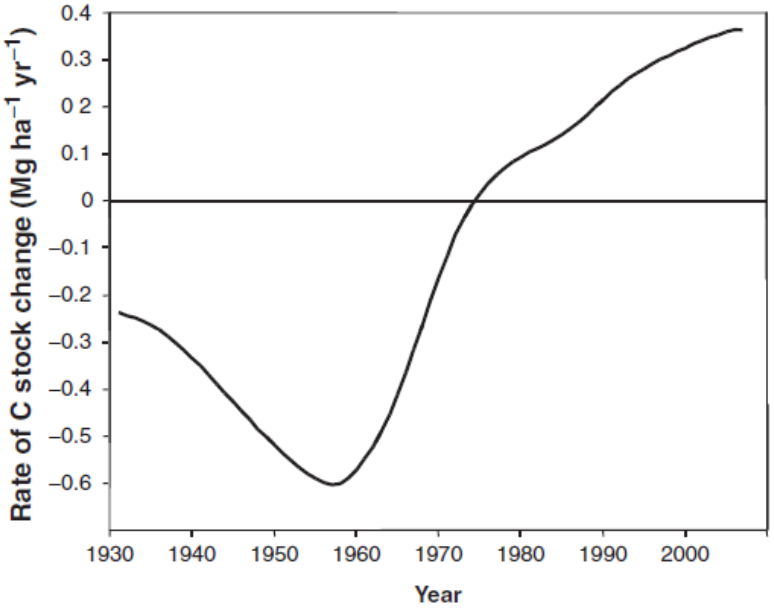


Fig. 6 The rate of change of soil organic carbon stock (Mg ha^{-1} yr^{-1}) for 0–10 cm over time in Java.

Source: Minasny et al. 2010

"Rapid conversion of natural vegetation to agricultural farms in the 1930s resulted the decline of SOC content from 2% to 0.75% in 1960. However agricultural practices
have started to accumulate soil C since 1975. This suggests that human influence can be more important than environmental factors, and soil C sequestration is a real possibility in the tropics and worldwide" (Minasny et al 2010

Black Soils

Soils, that is

- **black in color**
- **high SOC (>0.6% in tropic)**
- **Thick (>25 cm**

Include: deep Mollisols, several Vertisols, several Andisols

At Initial stage: Mollisols only

Where? Characteristics? Threat?

Mapping procedure

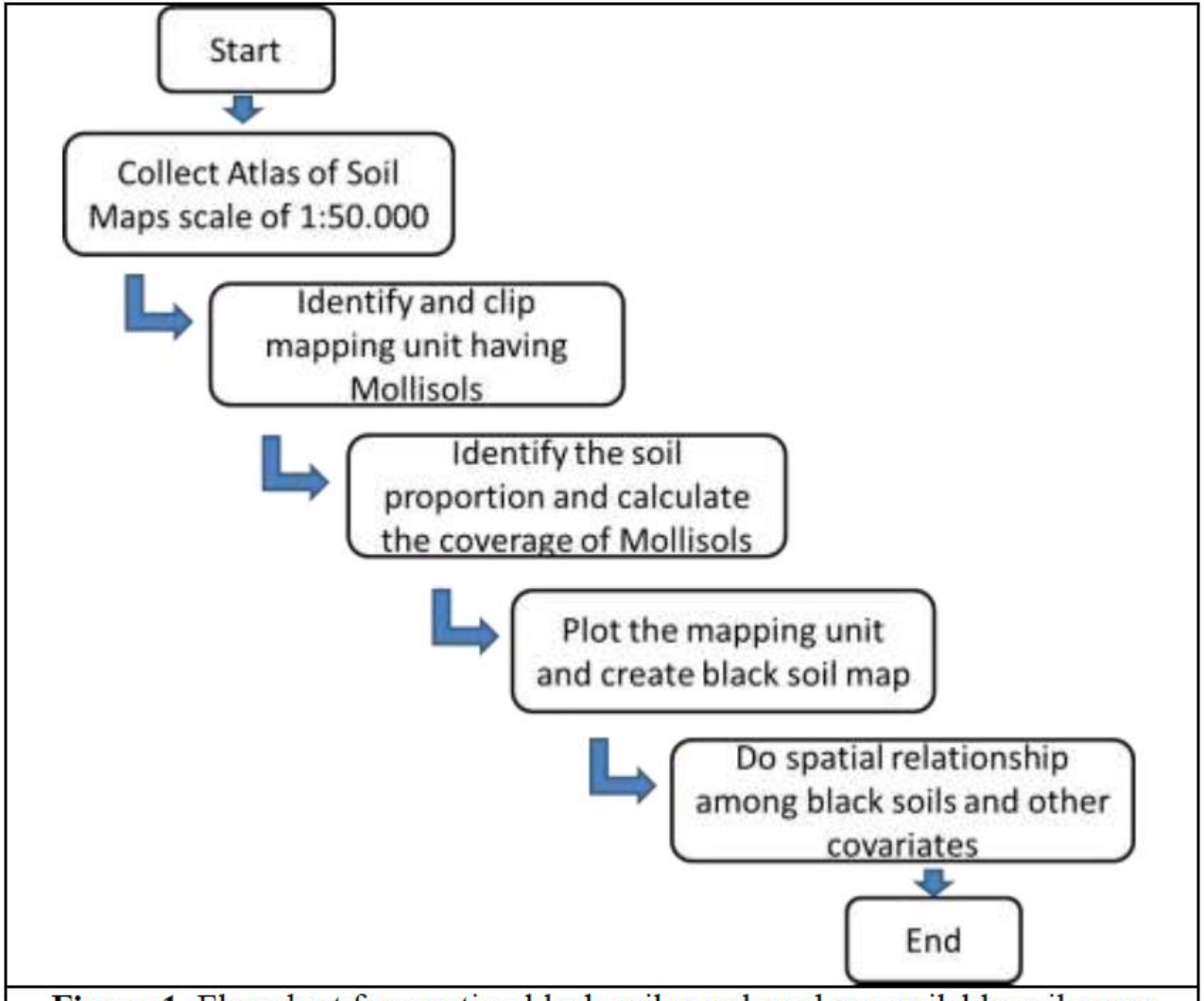
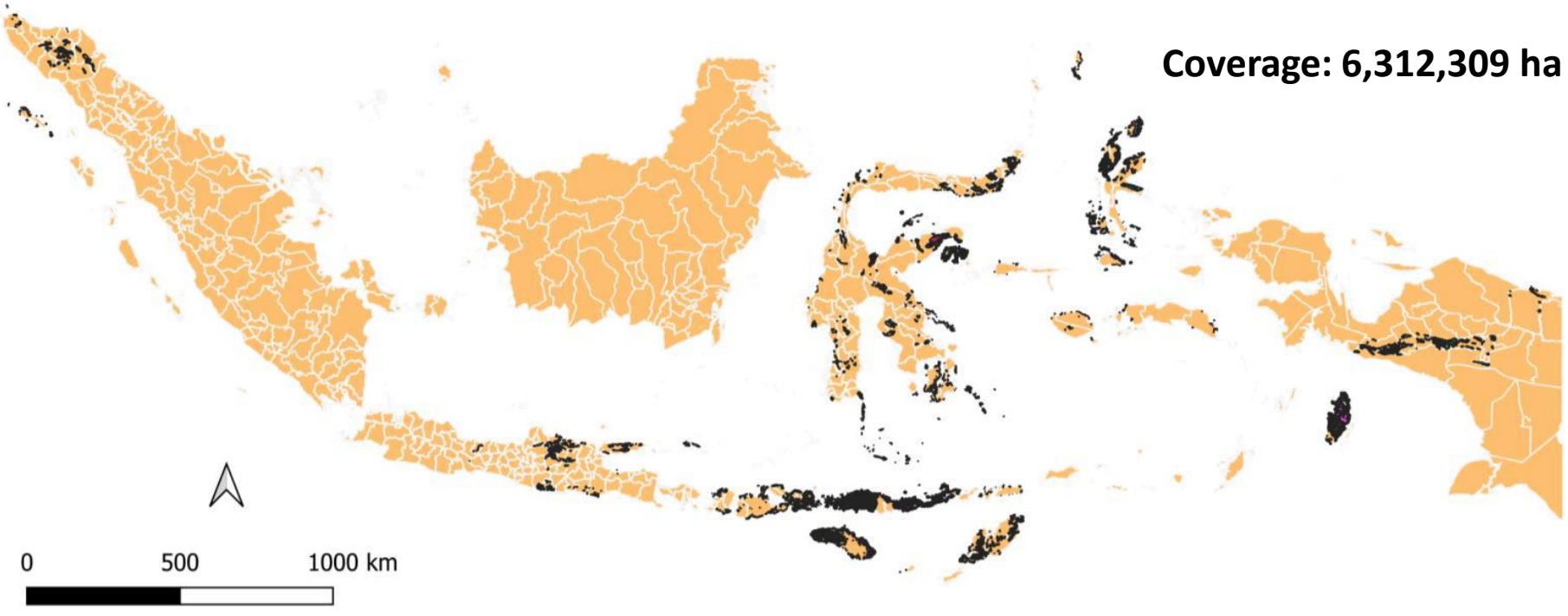


Figure 1. Flowchart for creating black soil map based on available soil maps

Source: Sulaeman et al. 2022



SOC content

Ricefield: **0.6 –2.7 %**
Dryland Ag: 0.62 –8.2 %
Single garden: 0.72 –3.75 %
Mixed garden: 0.6 –3.4 %
Savanah: 0.7 –2.2 %
Forest: 0.78 –5.32 %
Shrubs and bush: 0.7 –5.6 %

Source: Sulaeman et al. 2022

Threat to black soils

- Soil erosion—*loosing soil*
  - *Soil erosion remove fertile top soil, leave low fertile soil behind, need more inputs, reduce yield*
- Nutrient mining
  - *cropping without fertilizer application, mining available nutrient, reduce growth and yield*
- Landuse change—
  - *decrease OM inputs, SOC depletion,*

Best practise to maintain and increase SOC content (examples)

- Conservation agriculture
  - Minimum mechanical soil disturbance, Permanent soil organic cover (by crop residue, cover crop), Crop rotation/diversification
- Environmental friendly, rice farming (irrigated, wetland)
  - rice straw utilization, chemical fertilizer reduction, manuring, superior varieties, moisture/water management,
- Zero burning in land preparation
  - land & peat fire reduction, prevent SOC loss, soil biodiversity loss
- Manure/Organic fertilizer application
  - Priming soils, improve soil and chemical properties
- Liming on acid soils
  - Liming on acid soils (mineral, peat soil) increase nutrient availability and reduce toxic Al. Fe, good growth and yield
- Crop-cattle integration
- Soil erosion control/soil conservation measure

Challenges

- How to update existing maps (similar scale)
- How to detailing maps (to support practical issues)
- How to include more parties (inclusive approach in development)

Potential solutions

- Collate more observation data
  - Collaboration with other Institutes/Universities
  - Clear protocol of data utilization: for research and education only
- Secure old, historical soil and site data for monitoring and change detection
- Update and downscaling existing SOC, BS maps
- Capacity building to map, analysis, visualise with current advance technology (R, GEE, Python)

Thank You