Measuring, monitoring and modelling soil organic carbon
- an overview -

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ISRIC World Soil Information

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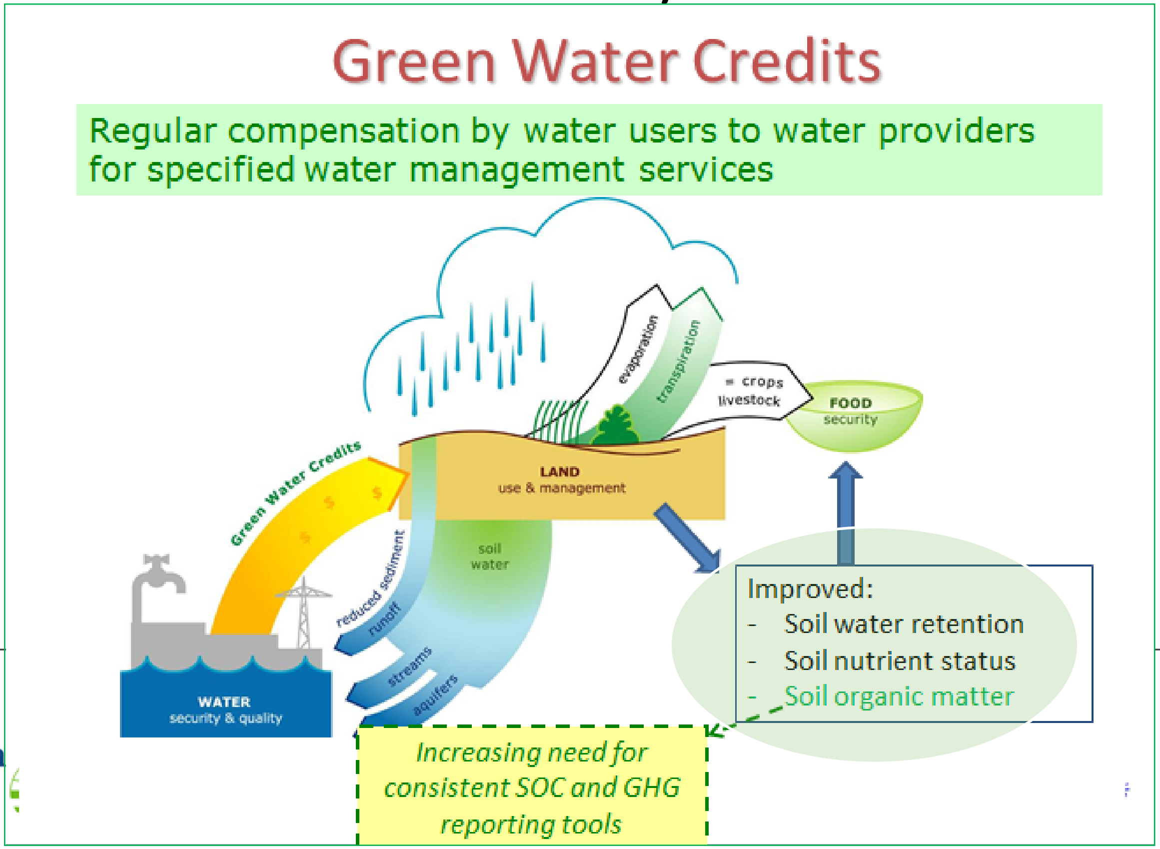
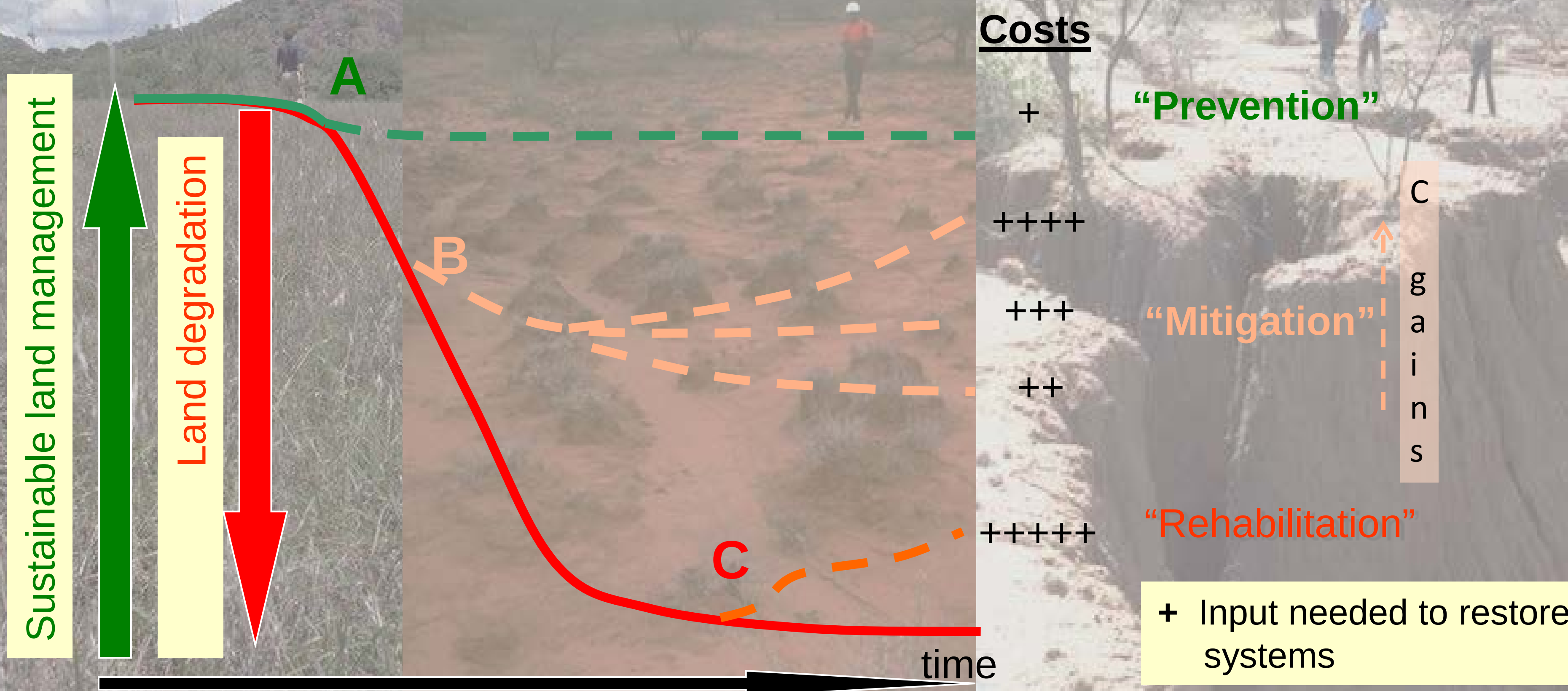
Projects can have different MRV needs

- Climate change mitigation: strict C and GHG reporting needs (e.g., CDM, REDD^{+} ...)
- SLM projects → generate co-benefits: food security, human livelihood/well-being, resilience and biodiversity

http:/greenwatercredits.net/



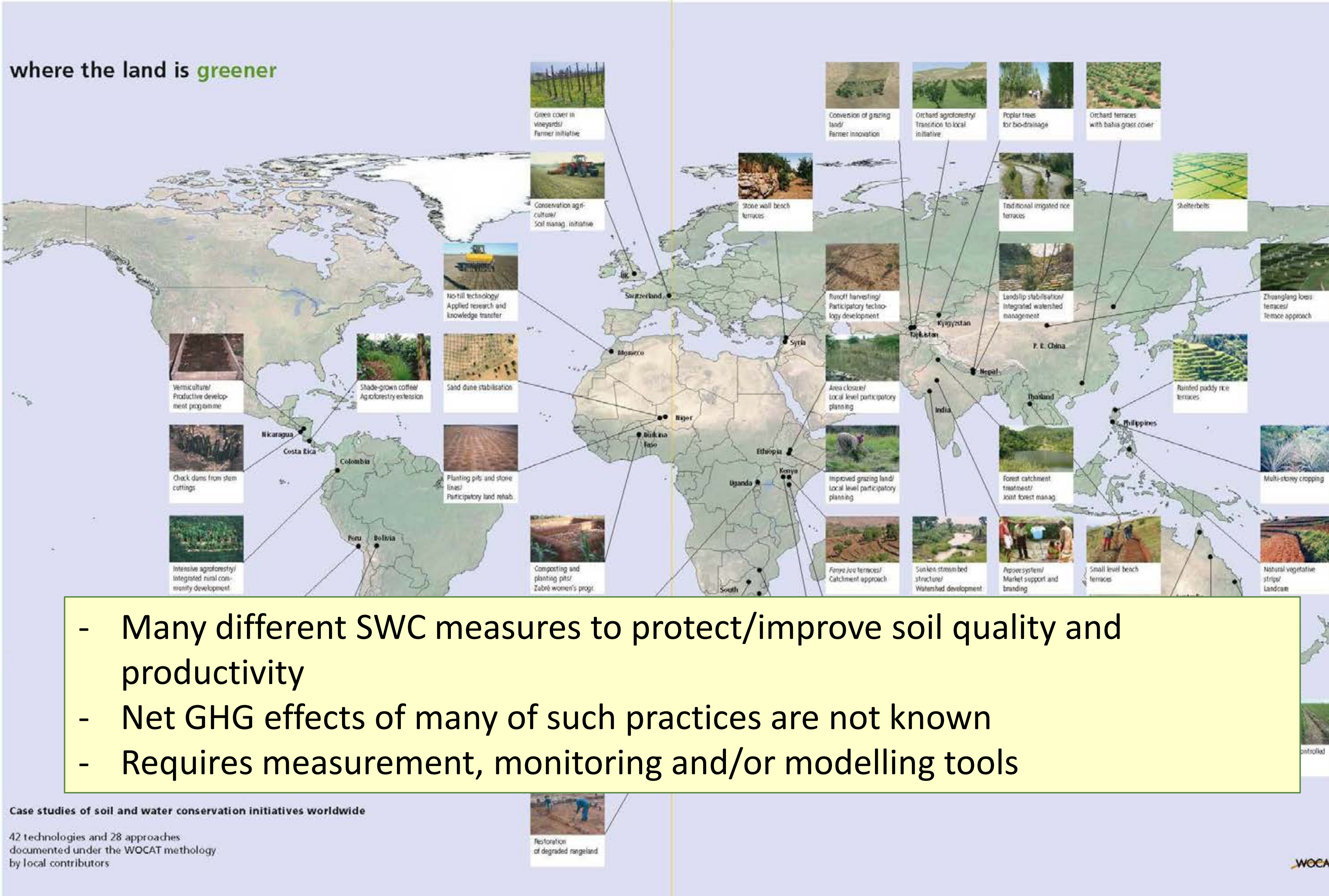
Various options, with varying costs ...



- *Evaluate socio-economic implications of alternative management options*
- *Consider impacts on human livelihood*

Prevention? Mitigation? Rehabilitation?

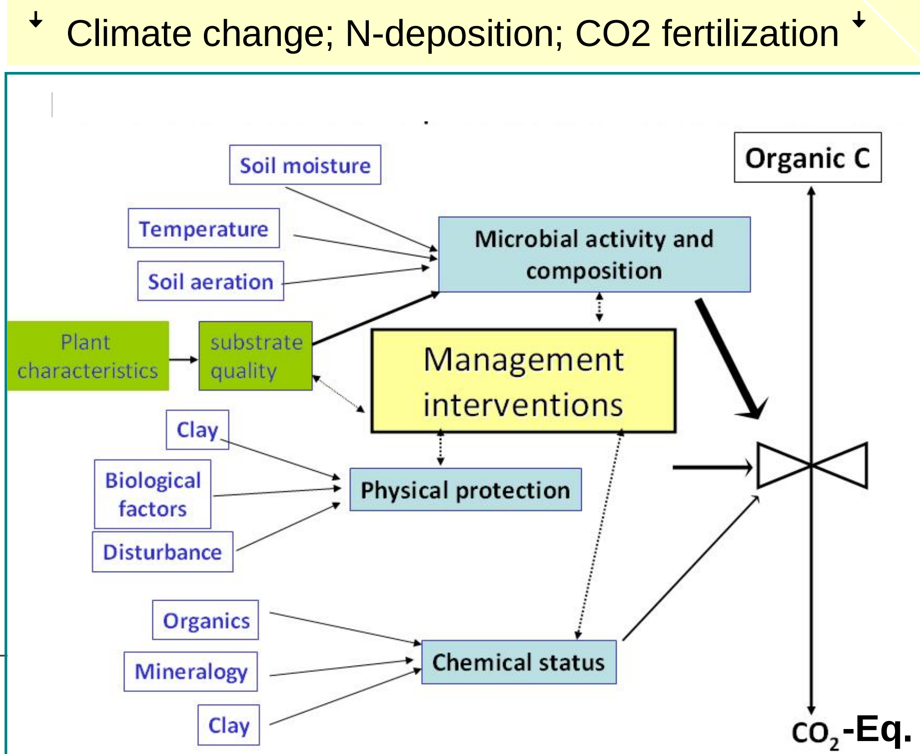
After: HP Liniger/WOCAT



- Many different SWC measures to protect/improve soil quality and productivity
- Net GHG effects of many of such practices are not known
- Requires measurement, monitoring and/or modelling tools

Numerous factors and processes affect SOM turnover

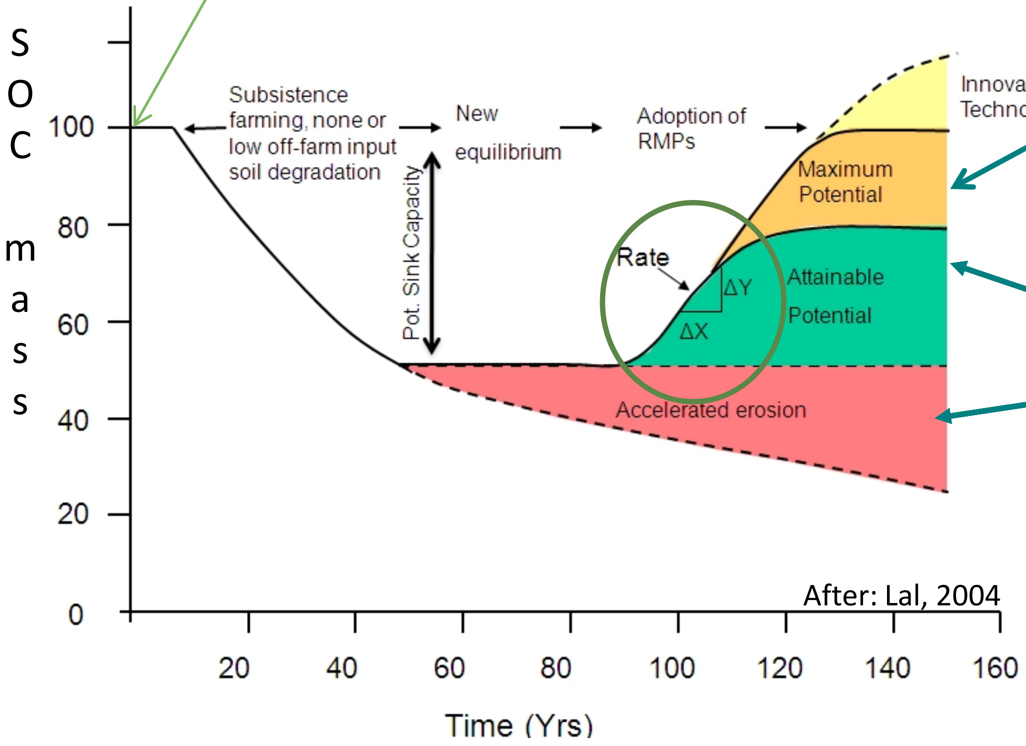
- Climate
- Land use history (antecedent SOC pool)
- Land use management
- Soil type:
  - depth of soil
  - clay content & mineralogy
  - internal drainage/aeration
  - soil nutrient status (N, P, K)
- Socio-economic conditions, incentives



After: Rice and Fabrizzi (2008)

Changes in SOC mass

SOC baseline



Judicious SLM interventions can improve SOC mass

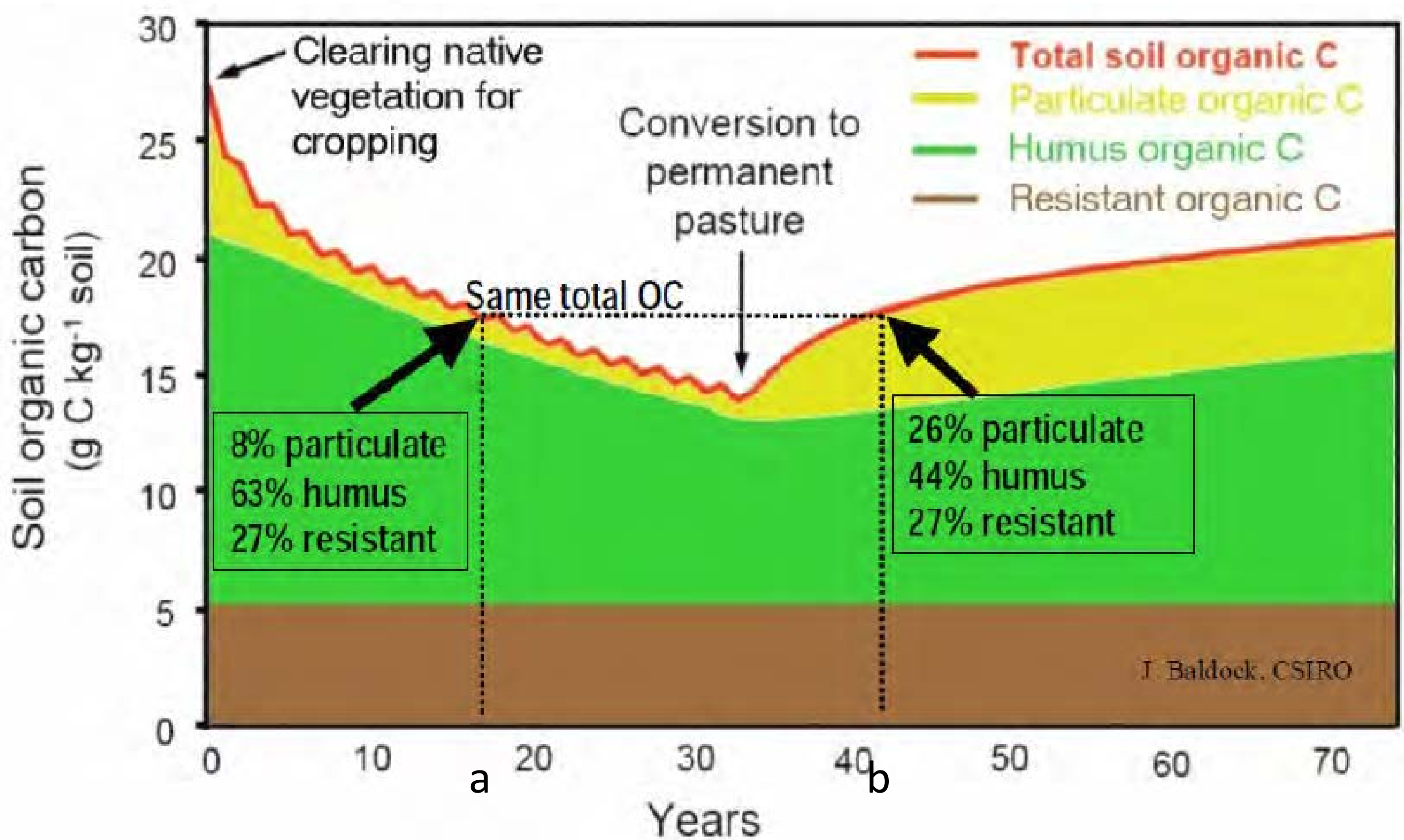
SOC dynamics:

C Sequestration : $C_{input} > C_{output}$

C Depletion : $C_{input} < C_{output}$

Well-designed field sampling can help quantifying how SOC dynamics change upon changes in land use management climate, and atmospheric CO_2 concentration

Changes in SOC pools



Schematic example of SOC mass and pool changes under changing land use
(Source: Bell and Lawrence 2009)

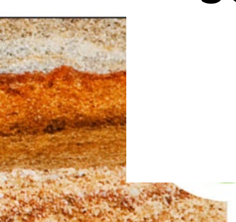
Measuring SOC changes

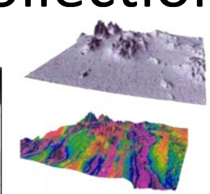
- Compared with C in biomass, SOC changes must be monitored over longer periods
- Changes in SOC are small compared to the large mass present in a given soil
- Changes can be difficult to measure even within a given stratum, considering the inherent variation
- Many replicates needed for each stratum to ensure that SOC changes can be detected consistently (known accuracy, within defined permissible error) across complex landscapes

Measurement methods

- Standard methods of soil analysis are often too expensive to provide the bulk of data for continuous monitoring

- New proximal sensing techniques offer perspectives for rapid and cost-effective measurements:
  - Vis-NIR, MIR reflectance spectrometry
  - Inelastic neutron scattering (up to 30 cm depth)
  - Laser-induced breakdown spectroscopy (LIBS)
  - Gamma-ray-spectroscopy (SOC, bulk density)
- Airborne imaging spectroscopy for SOC (‘bare soils’)
- Still require calibration against “standard methods” of soil analysis (need for reference collections)





Measurement methods

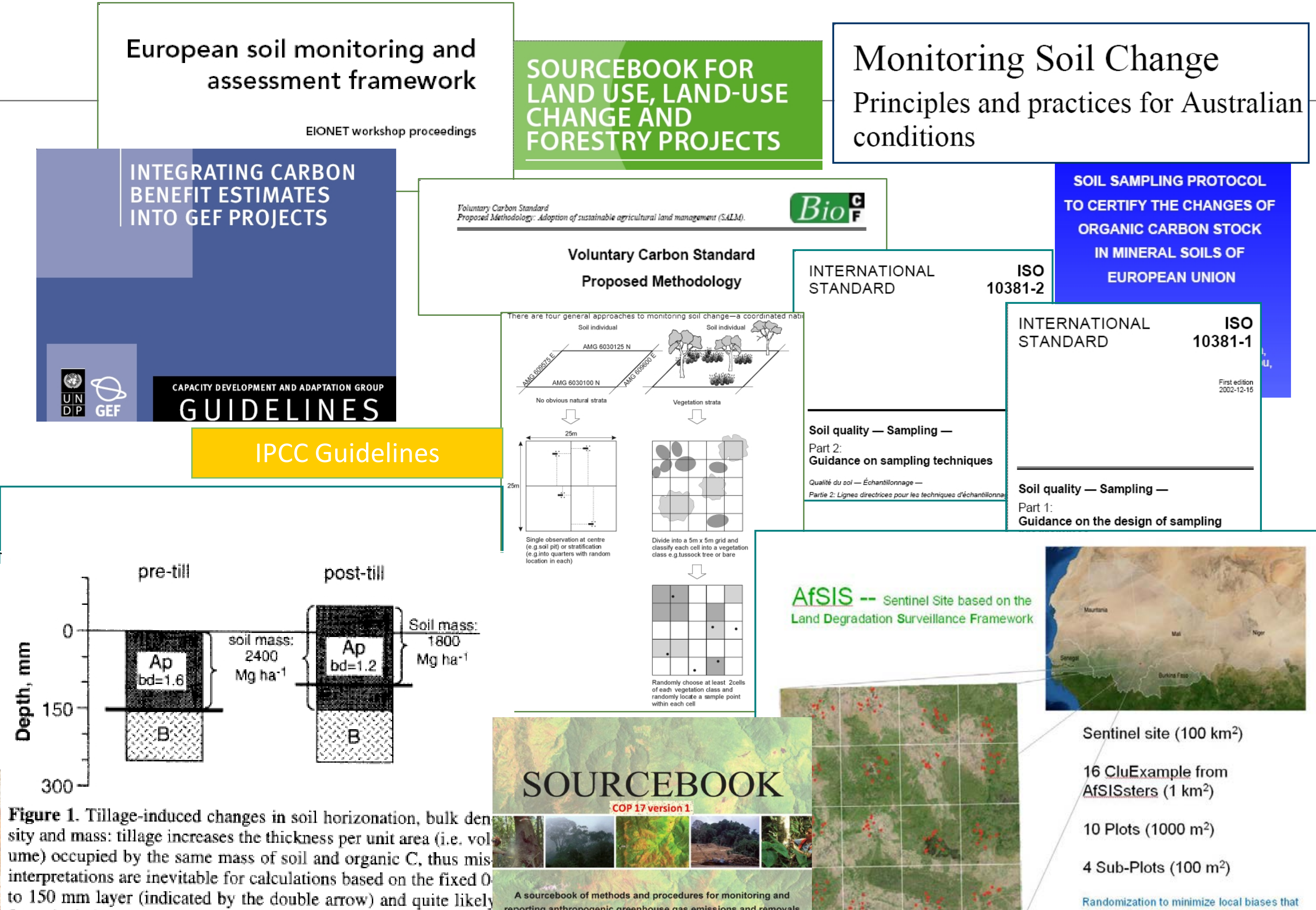
- Remote sensing provides a.o. improved estimates of area/land cover changes, crop LAI and phenology thereby increasing the accuracy of SOC change predictions
- Operational RS assessment of SOC stocks is not yet possible (TCG, 2010)

- New RS techniques may permit routine monitoring of changes in selected chemical and physical soil properties (to a limited depth)
- The accuracy and precision of such methods is improving as more experience is gained

Monitoring changes

- Relationships between environmental & management factors and SOC dynamics can be studied using:
  - Experimental field-trials
  - Chronosequence studies
  - Monitoring networks
- Soil monitoring networks can provide:
  - Direct changes of SOC stocks through repeated measurements at geo-located sites/points
  - Data to parametrise and test biophysical models at plot scale
  - Point observations that represent the variation in climate/soil/land use management at national scale, allowing for upscaling
- Most SMNs are in the planning or early stages (*PLOS* 2011:247-259; JRC-IES 2011)

Many different procedures and protocols are used …



GEF expressed needs (CBP 2009)

- Standard measurement protocol applicable to all projects involving interventions in natural resources management in a wide range of climate zones, landscapes, and soil types

- Modelling tools that are scientifically rigorous and cost-effective to establish the net carbon benefits of SLM interventions in terms of protected or enhanced carbon stocks and reduced GHG emissions

CBP online toolset

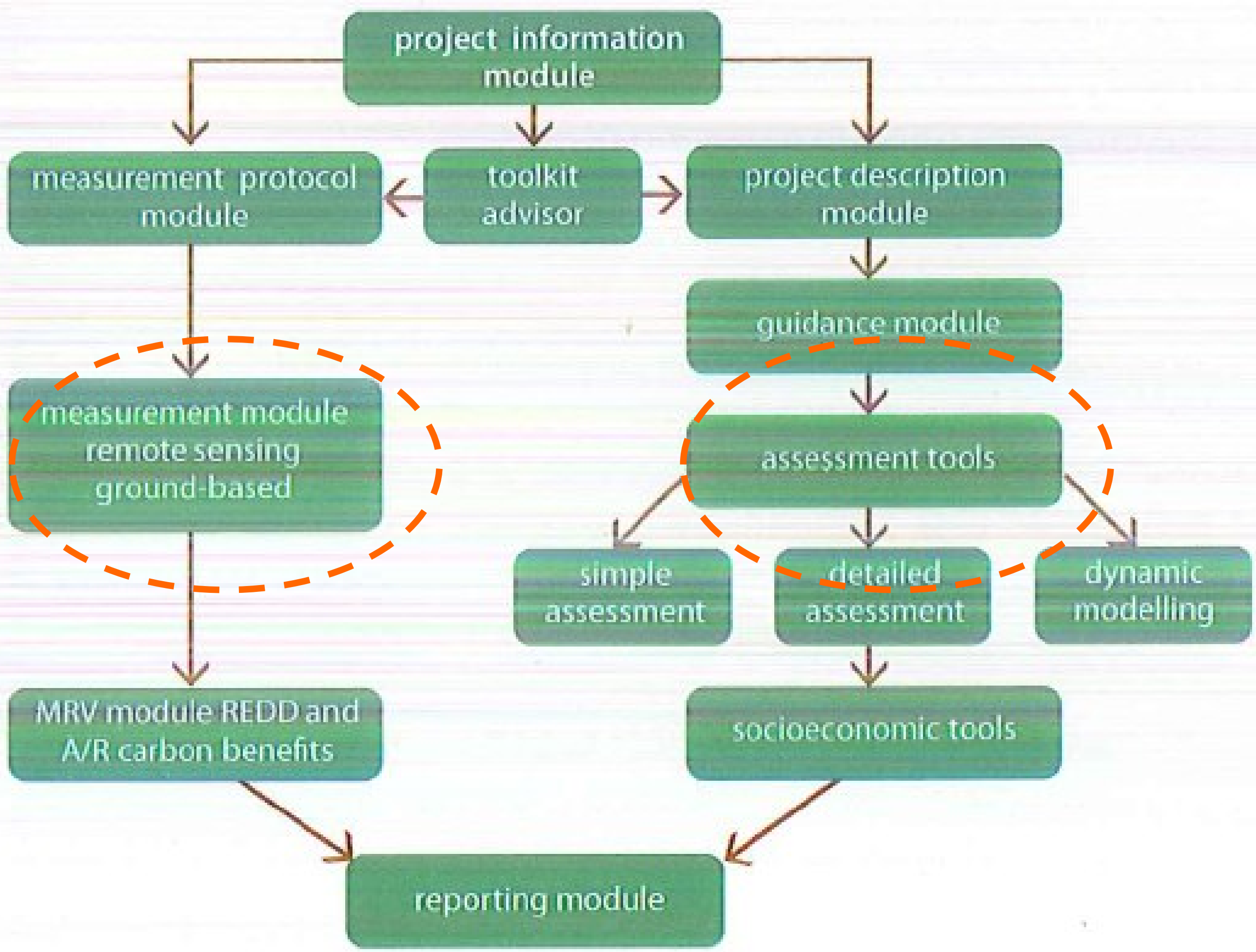


Figure 6: The concept behind the Carbon Benefits Project online toolset.
Source: CBP (2012)

Select Modelling or Measurement Tools

Simple Assessment of the impact of a project on carbon stock and greenhouse gas emissions. Requires information on land use changes and/or livestock production in the project area. Suitable for a quick assessment at any stage including proposals. Uses standard information on greenhouse gas emission rates.

Detailed Assessment of the impact projects have on carbon stocks and greenhouse gas emissions. Requires information on land use changes and/or livestock production in the project area plus can utilize local and project specific field measurements and other local datasets. Suitable for detailed reporting in projects with a reasonable focus on climate change mitigation.

Dynamic Modelling utilizes the Century Model to assess soil and biomass carbon stock changes. For users with a scientific background who wish to model carbon stock changes in projects with a carbon focus.

Direct Measurement provides a general protocol and specific methodologies for field, laboratory and remote sensing measurements of carbon stocks and greenhouse gases. Requires extensive field measurements and remote sensing analysis to measure carbon stocks in soil and biomass and monitor their changes over time in the project area. Displays project spatial information in an online information system to manage measurement data in carbon and greenhouse gas projects. Project indicators display a results framework of social, biodiversity and environmental indicators of carbon and greenhouse gas benefits in the project area. The data derived from measurements can be used directly for reporting changes in the carbon and greenhouse gas balance or the measurement data may be used as inputs for CBP modelling assessments.

Project Planning Tools provide supporting information for project managers during the development phase of landscape carbon and other sustainable land management projects. The information provided is useful for making decisions on which trees to plant based on a large database of agroforestry trees, to estimate the economic benefits that can be expected from participating in the carbon markets by planting trees and support in setting up project boundaries using available maps.

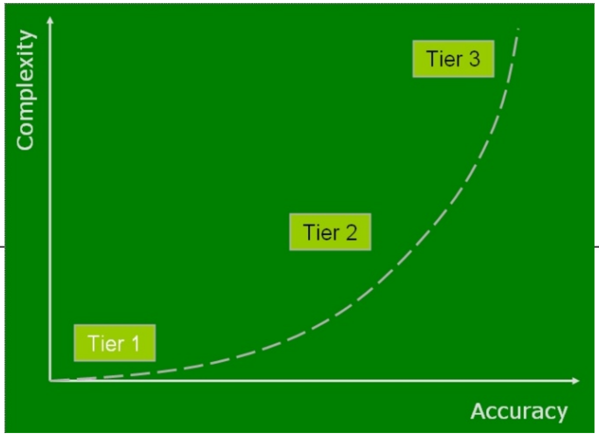
http://www.unep.org/ClimateChange/carbon-benefits/cbp_pim

Differences in methodological complexity & data needs

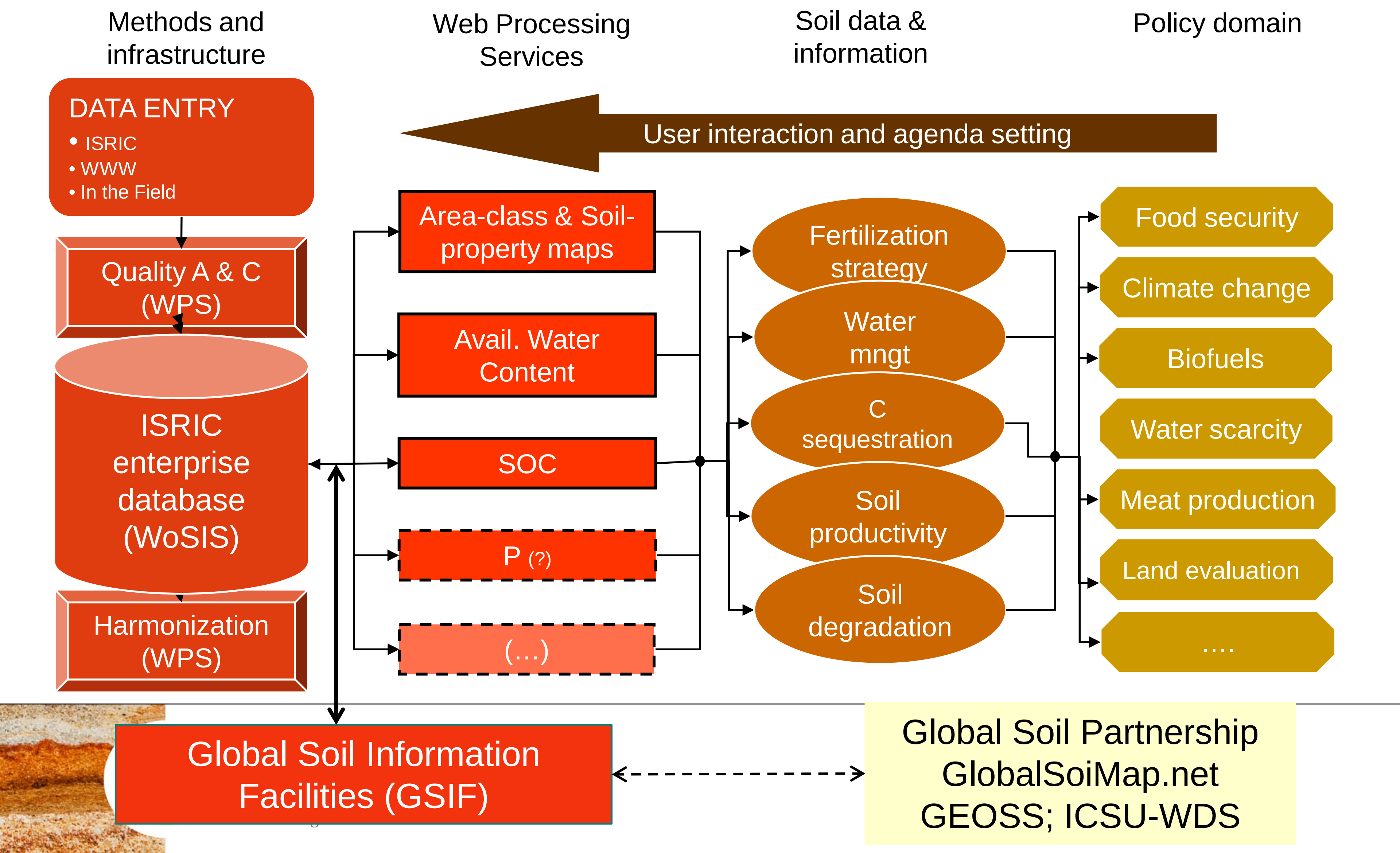
Soil carbon pool	Tier 1	Tier 2	Tier 3
Organic carbon in mineral soil	Default reference C stocks and stock change factors from IPCC	Country-specific data on reference C stocks & stock change factors	Validated model complemented by measures, or direct measures of stock change through monitoring networks
Organic carbon in organic soil	Default emission factor from IPCC	Country-specific data on emission factors	Validated model complemented by measures, or direct measures of stock change

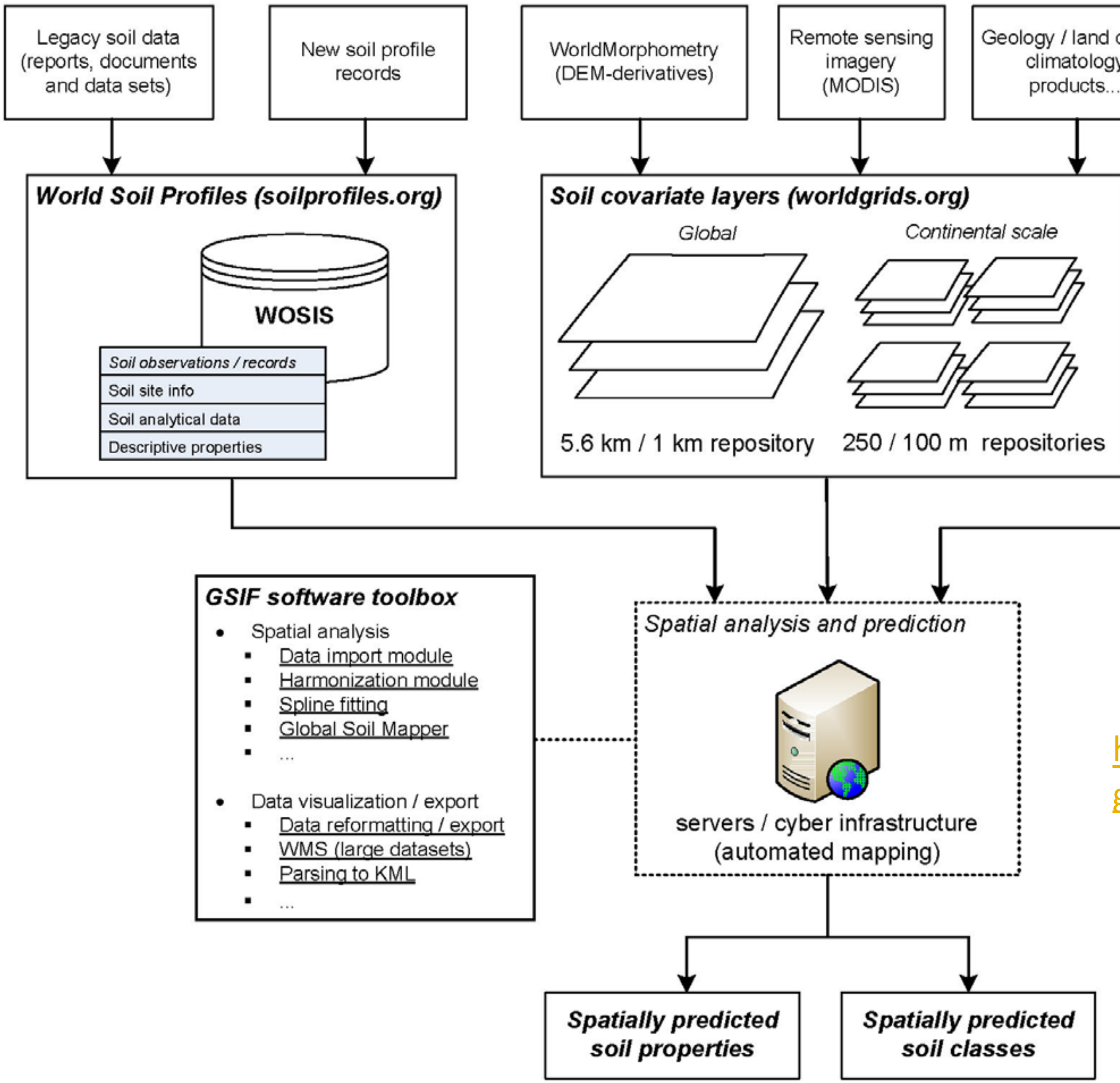
http://www.gofc-gold.uni-jena.de/redd/

data needs



Linking soil information to policy



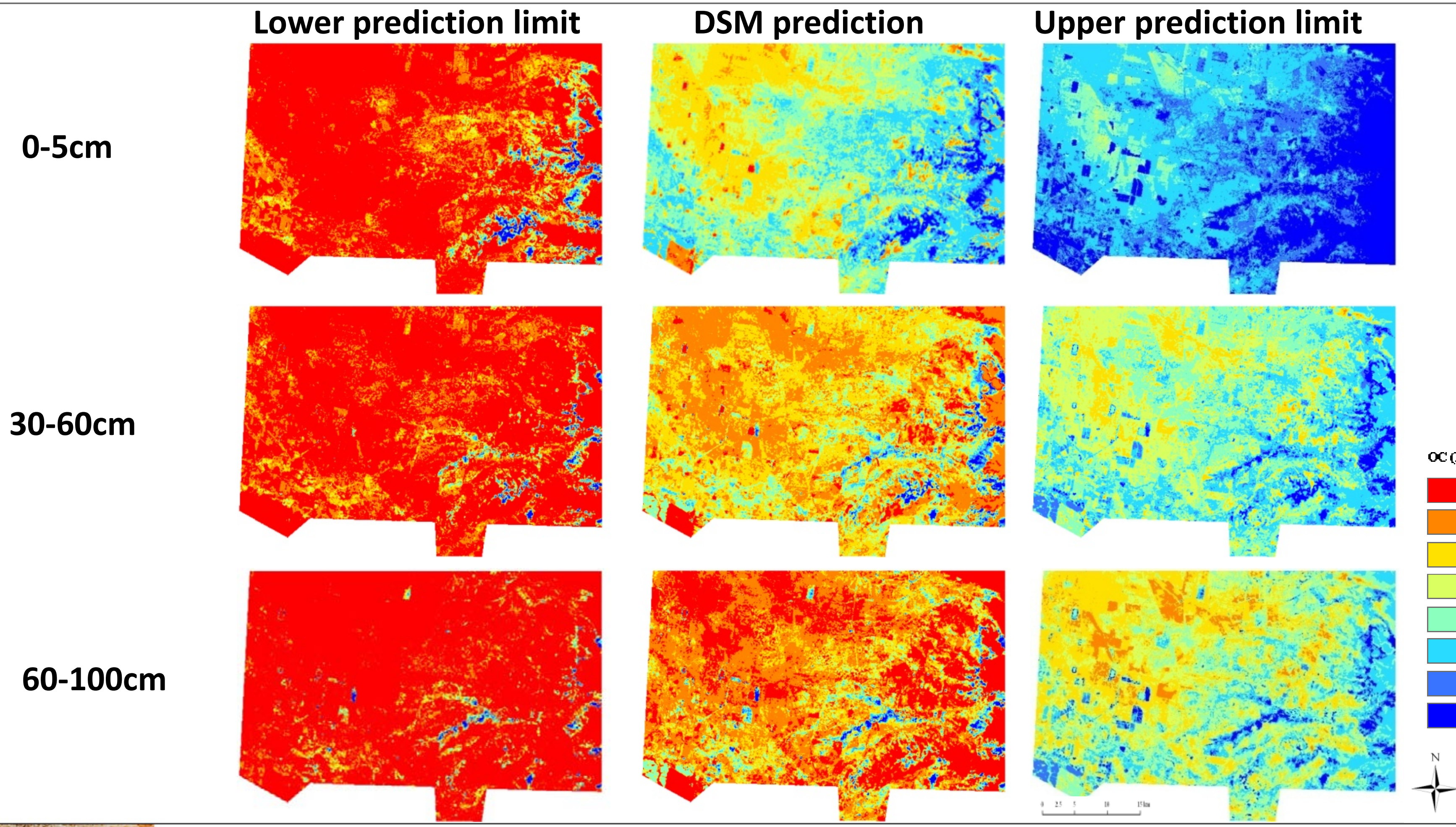


http://www.isric.org/projects/global-soil-information-facilities-gsif

(Under development)

- Global Soil Partnership
- GlobalSoilMap.net
- GEOSS
- ICSU-WDS

Derived soil property maps (SOC)



Slide Credit: Alex McBratney

Concluding remarks

- SLM and SOC management require an integrated, landscape scale approach
- Cost-effective techniques to measure all C pools (and GHGs) to reduce need for “traditional” laboratory analyses
- Long-term support for national scale MRV systems
- Model development plus validation across varying agro-ecosystems
- Global, spatial data infrastructure with driving variables and tools--at relevant scales; ideally open-access
- Capacity building

Think globally – Act locally

We can do this – through collaboration and sharing of information

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