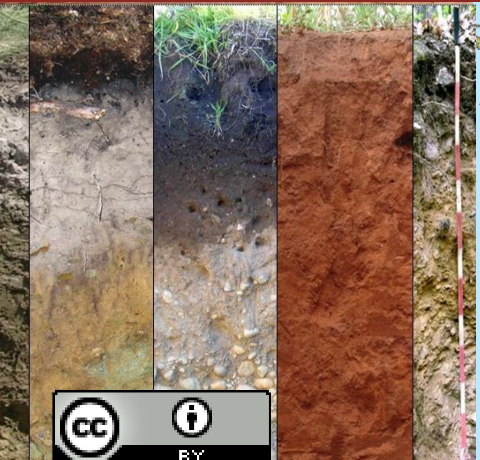
ISRIC
World Soil Information

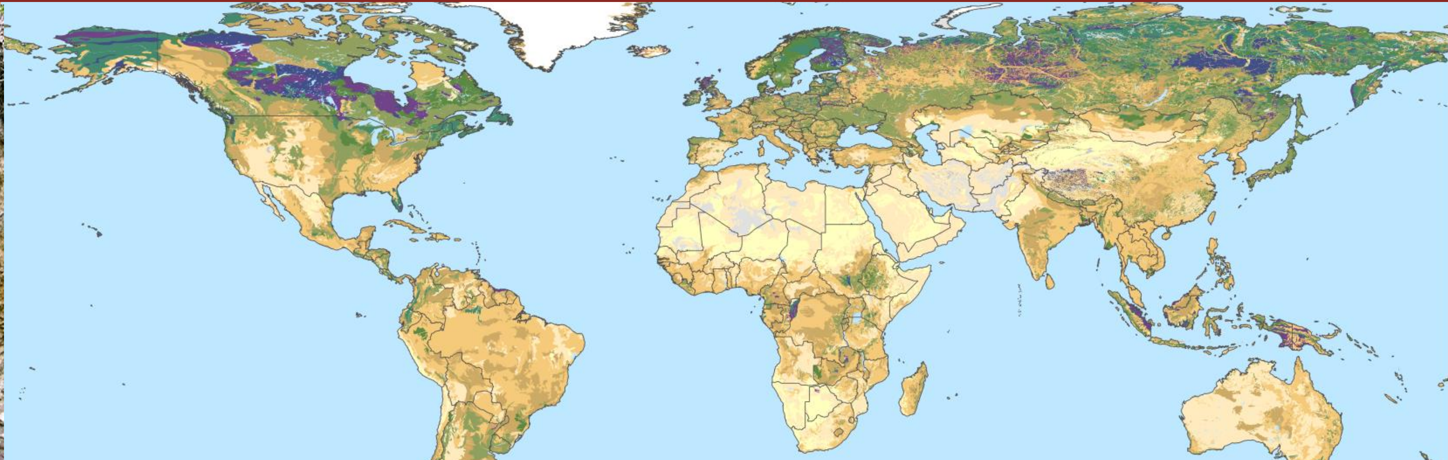
Benefits of soil carbon - an overview

Niels H. Batjes

GSP Soil organic carbon mapping training
(6-23 June 2017, Wageningen)

GLOBAL SOIL PARTNERSHIP





Structure of presentation

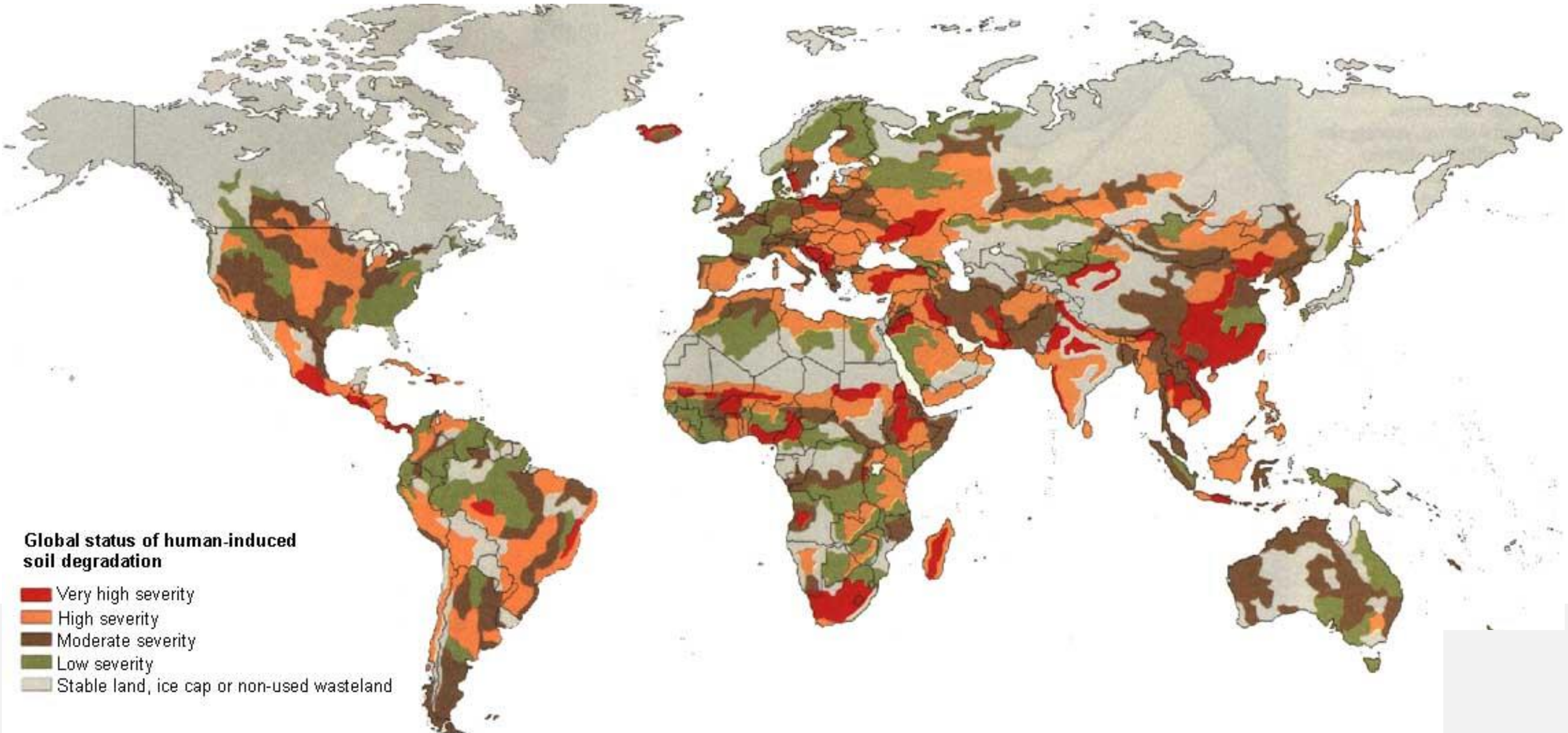
- Introductory lecture (~ 45 min):
  - Background
  - Soil organic matter and soil functions
  - Global distribution of soil organic carbon
  - Restoring SOM with improved management
- Hands-on computer exercise (~ 45 min):
  - Simple Assessment CBP tools

"Strictly speaking, any aspect of 'soil C' that could lead to a benefit of some sort for an individual or society should actually be considered as a 'Soil Organic Matter' benefit"

(Feller et al. 2015, SCOPE Benefits of Soil Carbon)

Background (1)

- Soils provide ecosystem services essential for human-well being
- Within the next 2 decades the global demand for food is projected to increase by 50%, demand for water by 35-60%, and demand for energy by 45% (UNEP 2012)
- Yet, the world's soils are under increasing pressure



Background (2)

- Soil is a non-renewable natural resource on a human-life scale
- Once degraded, soils lose their capacity to support ecosystem functions
- Many of these functions are related to the beneficial properties of soil organic
- Depleted SOM stocks can be restored to some degree through judicious Sustainable Land Management

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Background (3)

- Managing soils to obtain multipe economic, societal and environmental benefits requires integrated policies and incentives aimed at maintaining and enhacing SOM
- Different approaches and tools are required for reliable and verifiable estimates of changes in soil and biomass C at scales ranging from the individual plot to (supra) national level

Soil Carbon Benefits

SOIL ORGANIC MATTER AND SOIL FUNCTIONS

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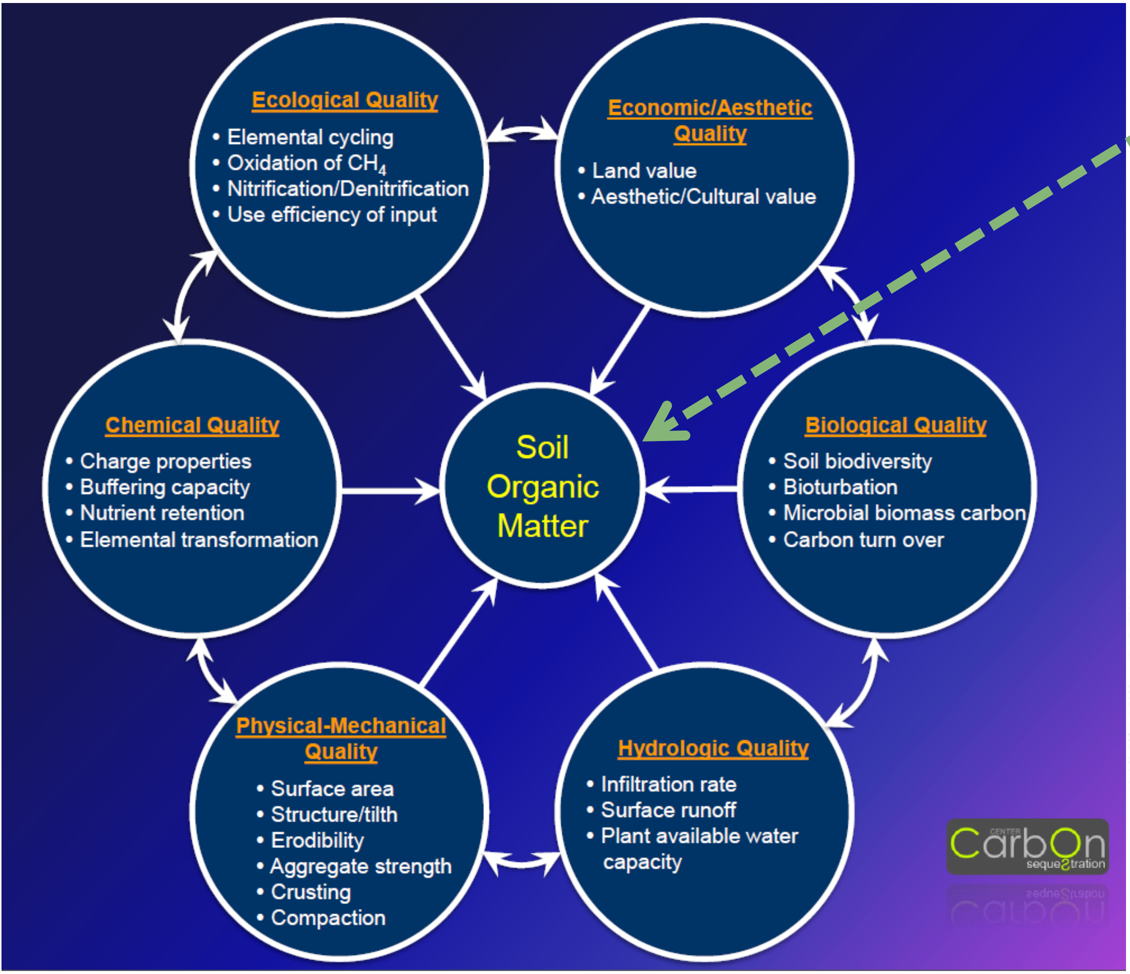
Why study changes in SOM?

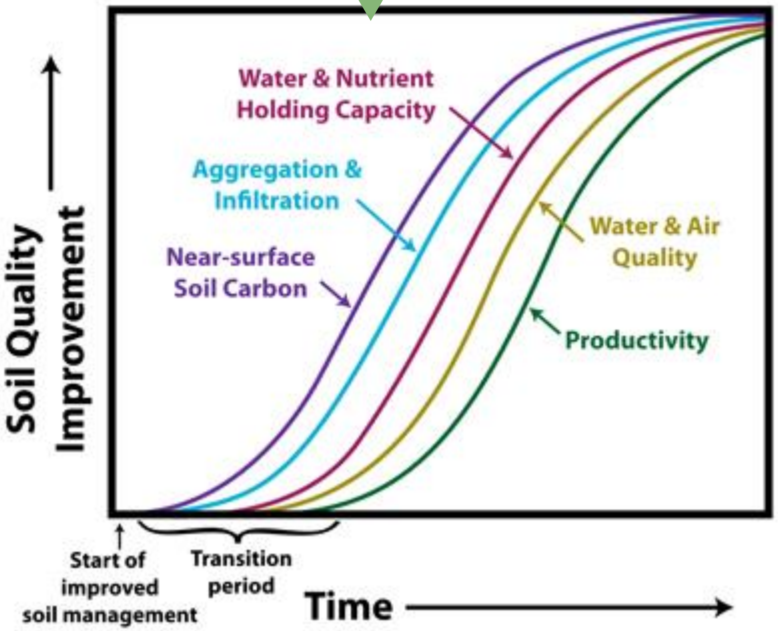
- *Traditional reasons*
  - Soil processes
  - Focus on agriculture, crop production (soil fertility)
  - Mainly plough layer
  - Field level, seasonal scale

- *New needs*
  - Focus on environment and ecosystem services
  - Offsetting GHG emissions / Carbon trading
  - Soil profile to greater depth
  - Project-scale
  - Need to understand long-term trends
  - Inform the UN conventions etc.

Favourable properties of SOM

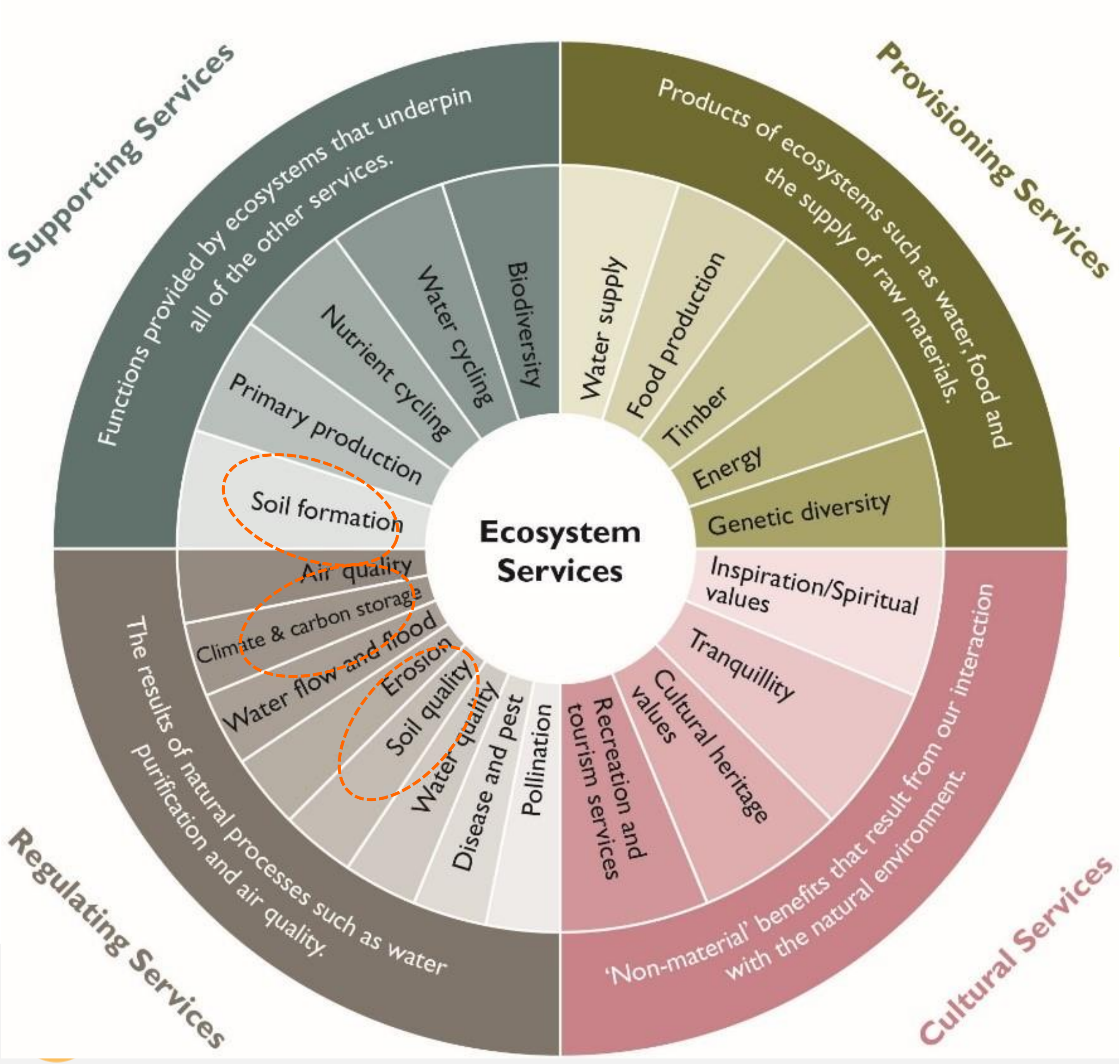


Ecosystem services: "benefits people obtain from ecosystems" MEA (2005)



Credit: NRCS

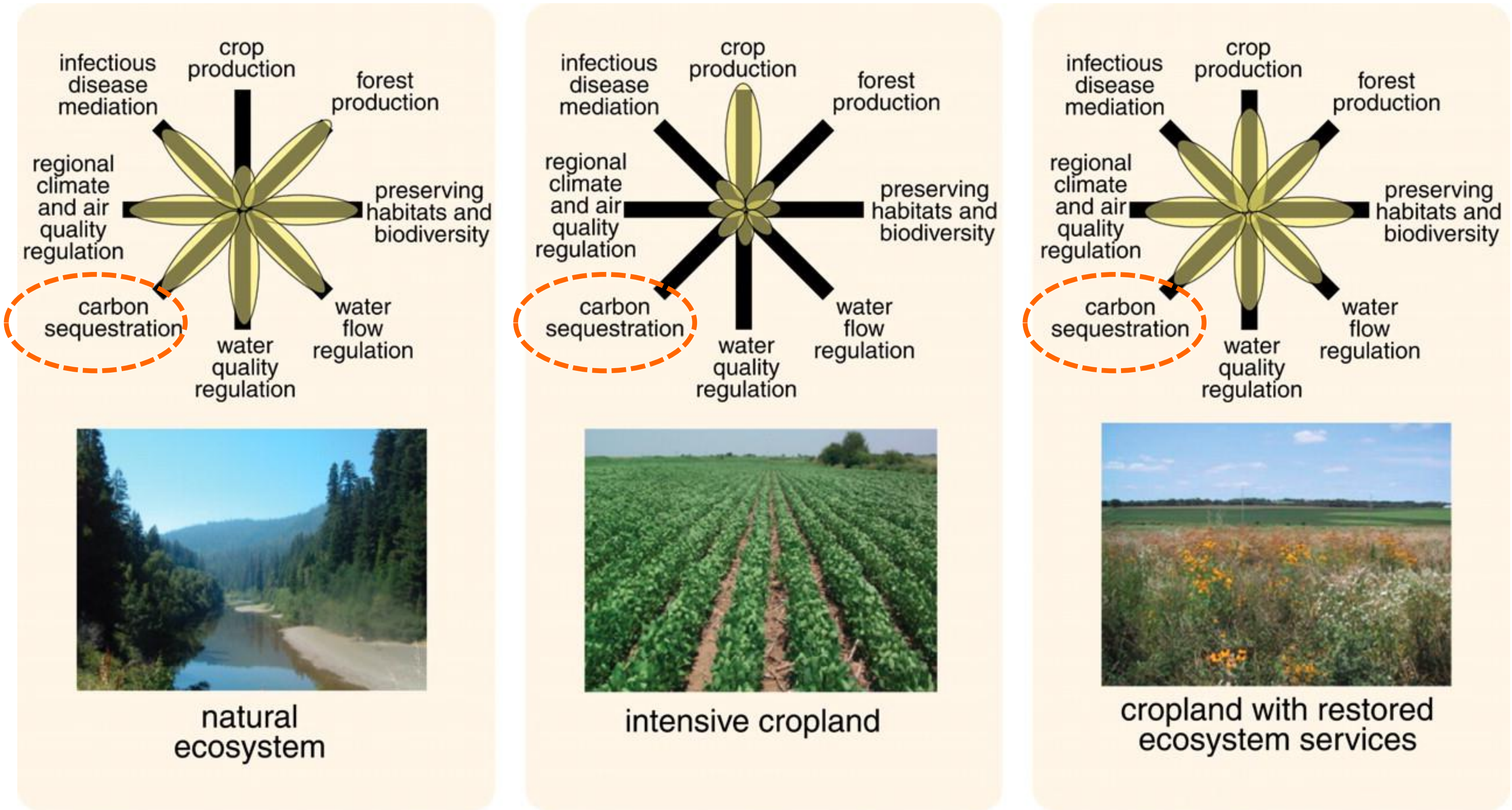
SOM: a major determinant of the quantity and quality of many ecosystem services



Ecosystem services: benefits people obtain from ecosystems (MEA 2005)

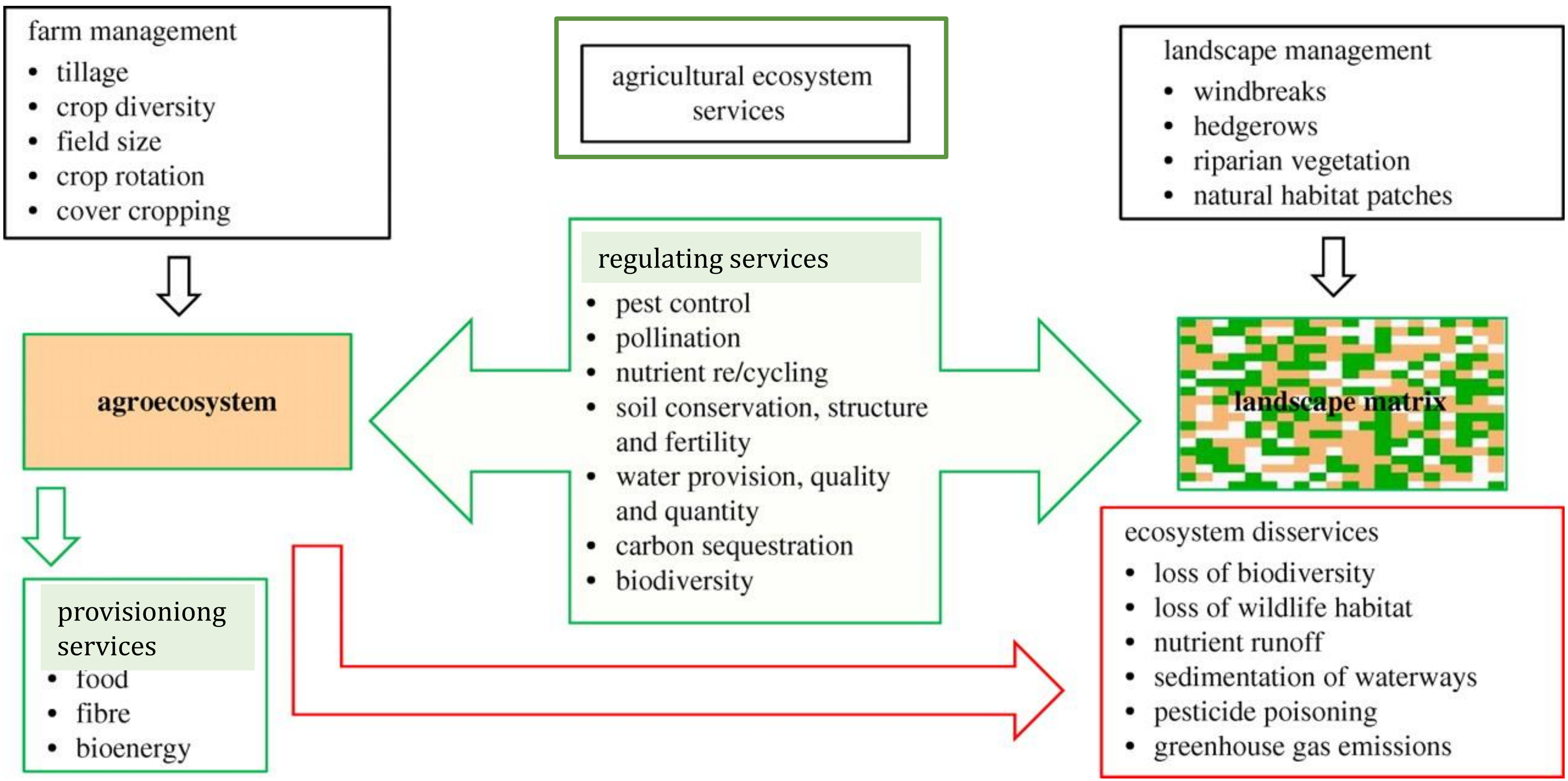
Slide credit

Comparing land use and trade-offs of ecosystem services



Jonathan A. Foley et al. Science 2005;309:570-574

Ecosystems services and agriculture: trade offs and synergies



Ecosystem services have a clear connection with soil functions

1) food and fibre (*provisioning* service)
2) fresh water by its filtering action (*provisioning* and *regulating* service)
3) biodiversity (s*upporting* service)
4) physical and cultural environment for human activities (*cultural* service)
5) raw materials (*provisioning* service)
6) pool for carbon (*regulating* service)
7) archive expressing our geological and archeological heritage (*cultural* service)

EU Soil Protection Strategy (2006)

The Directive establishes a framework for the protection of soil, its sustainable use and the preservation of soil functions:

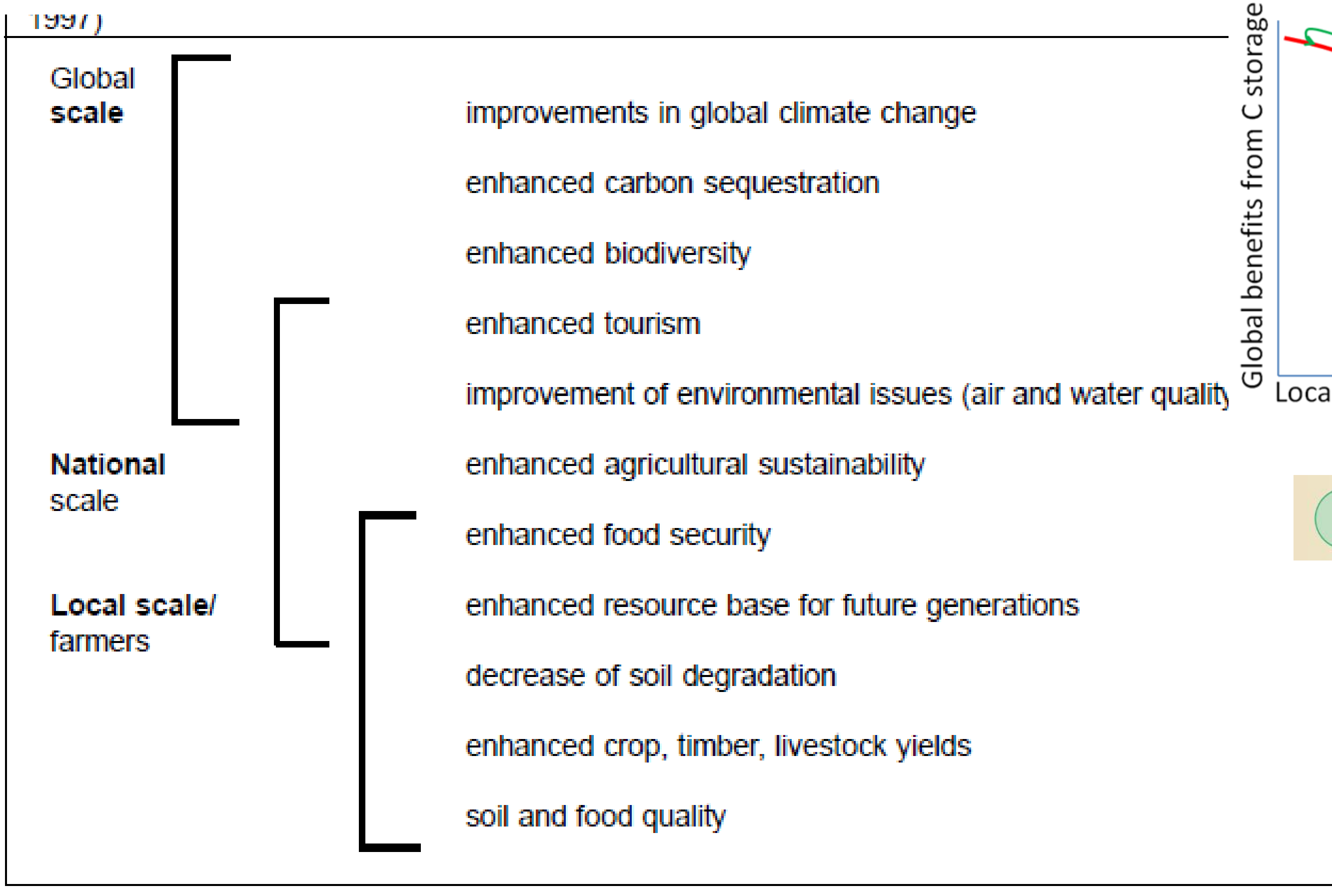
(a) *Biomass production, including in agriculture and forestry;*
(b) *Storing, filtering and transforming nutrients, substances and water;*
(c) *Biodiversity pool, such as habitats, species and genes;*
(d) *Physical and cultural environment for humans and human activities;*
(e) *Source of raw materials;*
(f) *Acting as carbon pool;*
(g) *Archive of geological and archaeological heritage.*

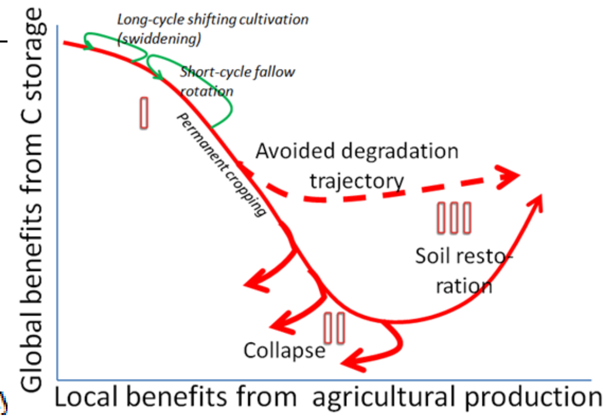
Bouma et al. (2014)

Need to maintain or increase SOC content

Maintaining SOC storage at an equilibrium or increasing SOC content towards the optimal level for the local environment can contribute to achieving the SDGs; also UNFCCC, UNCCD, and Paris Agreement

Principal benefits of SOM management at various spatial and temporal scales





Van Noordwijk et al. (2015)

Benefits of Soil Carbon
An International Rapid Assessment Project

'In the absence of policy interventions, it will be rational for individual farmers in tropical countries to manage their soil carbon at socially sub-optimal levels since soil carbon is part of the national and world natural capital'

Izac 1997

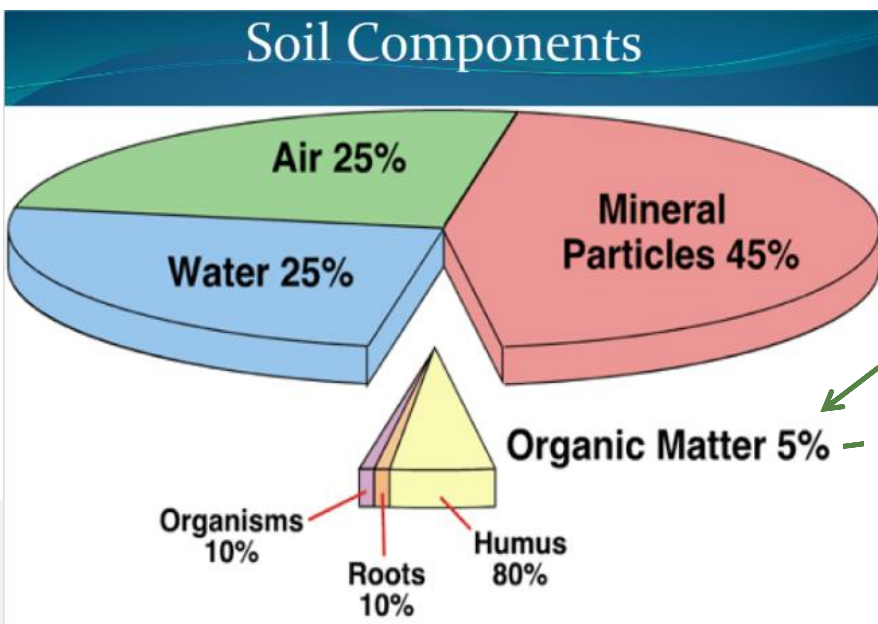
Soil Carbon Benefits

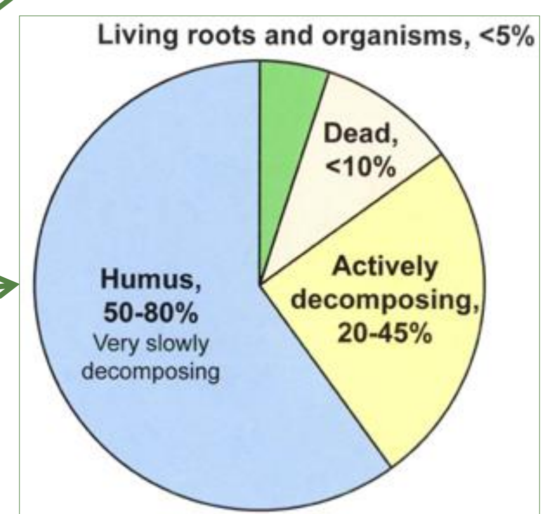
GLOBAL DISTRIBUTION OF SOC

Definition of SOM and SOC

- Soil organic matter: “the organic fraction of the soil exclusive of undecayed plant and animal residues” (SSSA 1997)
- Humus, is more commonly used when referring to the well-decomposed organic materials (humic substances)

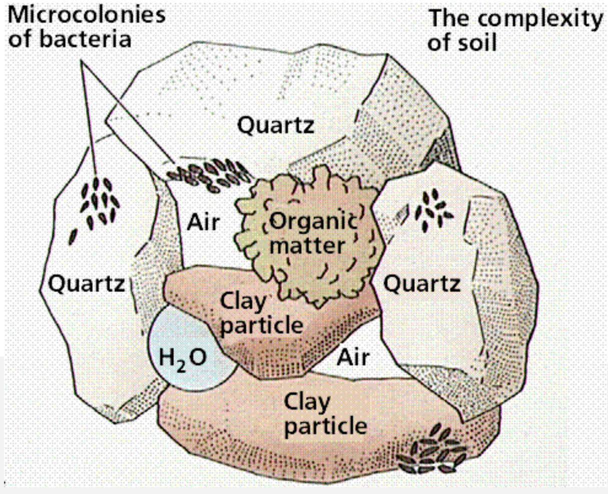
SOM% = SOC% x 1.724%
(Van Bemmelen factor; the actual range in nature is large, about 0.2-3.0)



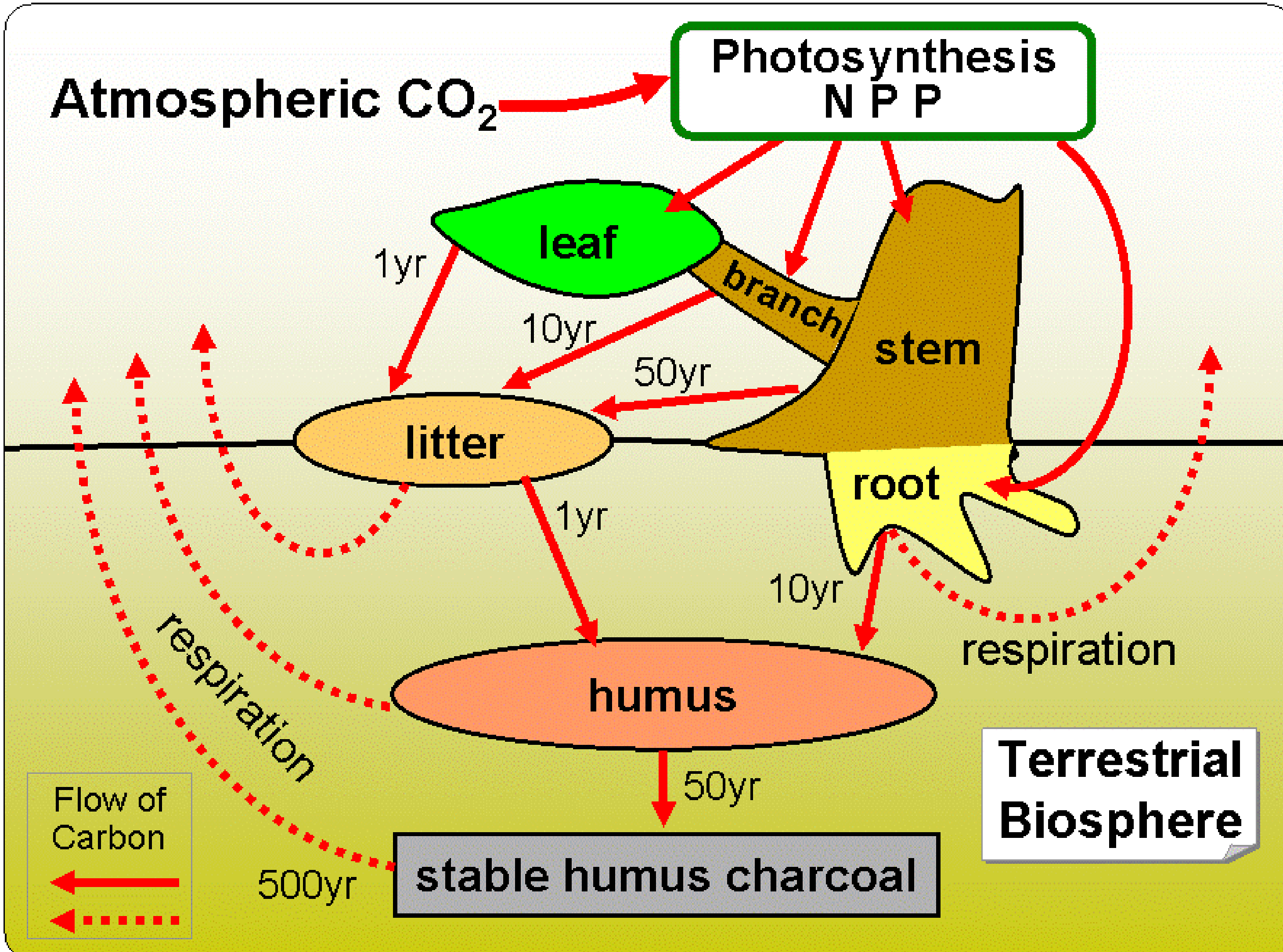


Total Soil C *versus* SOC

- Total Soil C= Soil Organic Carbon + Soil Inorganic Carbon (TotC = SOC + SIC)
- SIC is most common in soils of semiarid and arid regions (e.g., Calcisols; calcic and calcaric qualifiers in WRB)
- Lab analyses: SOM generally includes only those organic materials that accompany soil particles < 2 mm sieve (Nelson and Sommers, 1982) ; many differences in analysis methods!

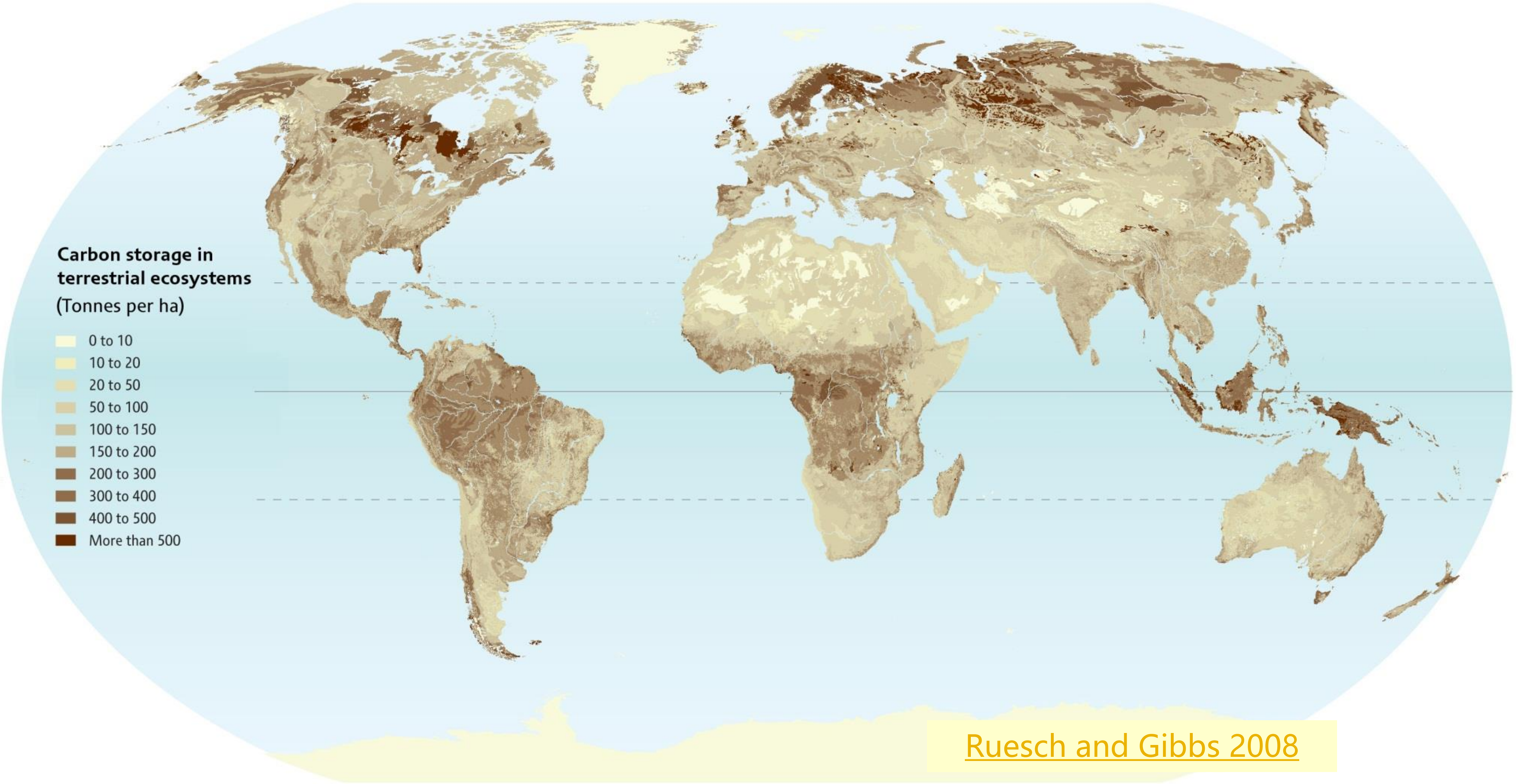


Carbon flow in agro-ecosystems



http://ww.mri-jma.go.jp/Project

Carbon stocks in biomass and soil



Ruesch and Gibbs 2008

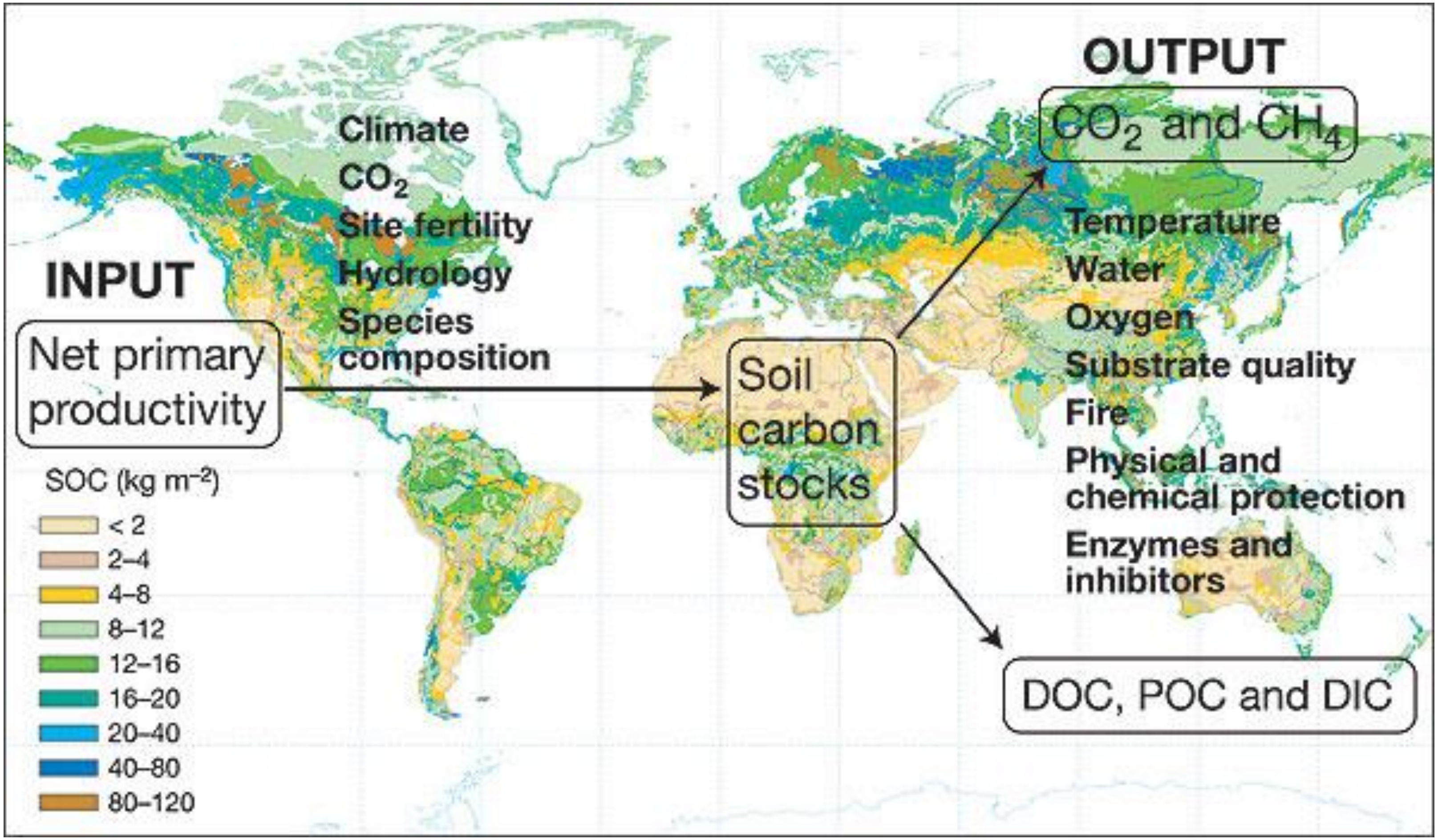
Carbon in natural ecosystems

	Vegetation growth	Vegetation decomposition	C Source or Sink	Current C storage (t C / ha)	Where majority of C is stored	Main threat(s) for potential C emission
Tundra	Slow	Slow	Sink	Approx. 258	Permafrost	Rising temperatures
Boreal Forest	Slow	Slow	Sink	Soil: 116–434; Vegetation: 61–93	Soil	Fires, logging, mining
Temperate Forest	Fast	Fast	Sink	156–320	Biomass above- and below-ground	Historic losses high but largely ceased
Temperate grassland	Intermediate	Slow	Likely sink	Soil: 133; Vegetation: 8	Soil	Historic losses high but largely ceased
Desert and dry shrublands	Slow	Slow	Sink (but uncertain)	Desert soil: 14–102; Dryland soil: < 266; Vegetation: 2–30	Soil	Land degradation
Savannas and tropical grasslands	Fast	Fast	Sink	Soil: < 174; Vegetation: < 88	Soil	Fire with subsequent conversion to pasture or grazing land
Tropical forests	Fast	Fast	Sink	Soil: 94–191; Vegetation: 170–250	Aboveground vegetation	Deforestation and forest degradation
Peatlands	Slow	Slow	Sink	1450	Soil	Drainage, conversion, fire

Overall there is more C in soil than in biomass

Grid Arendal

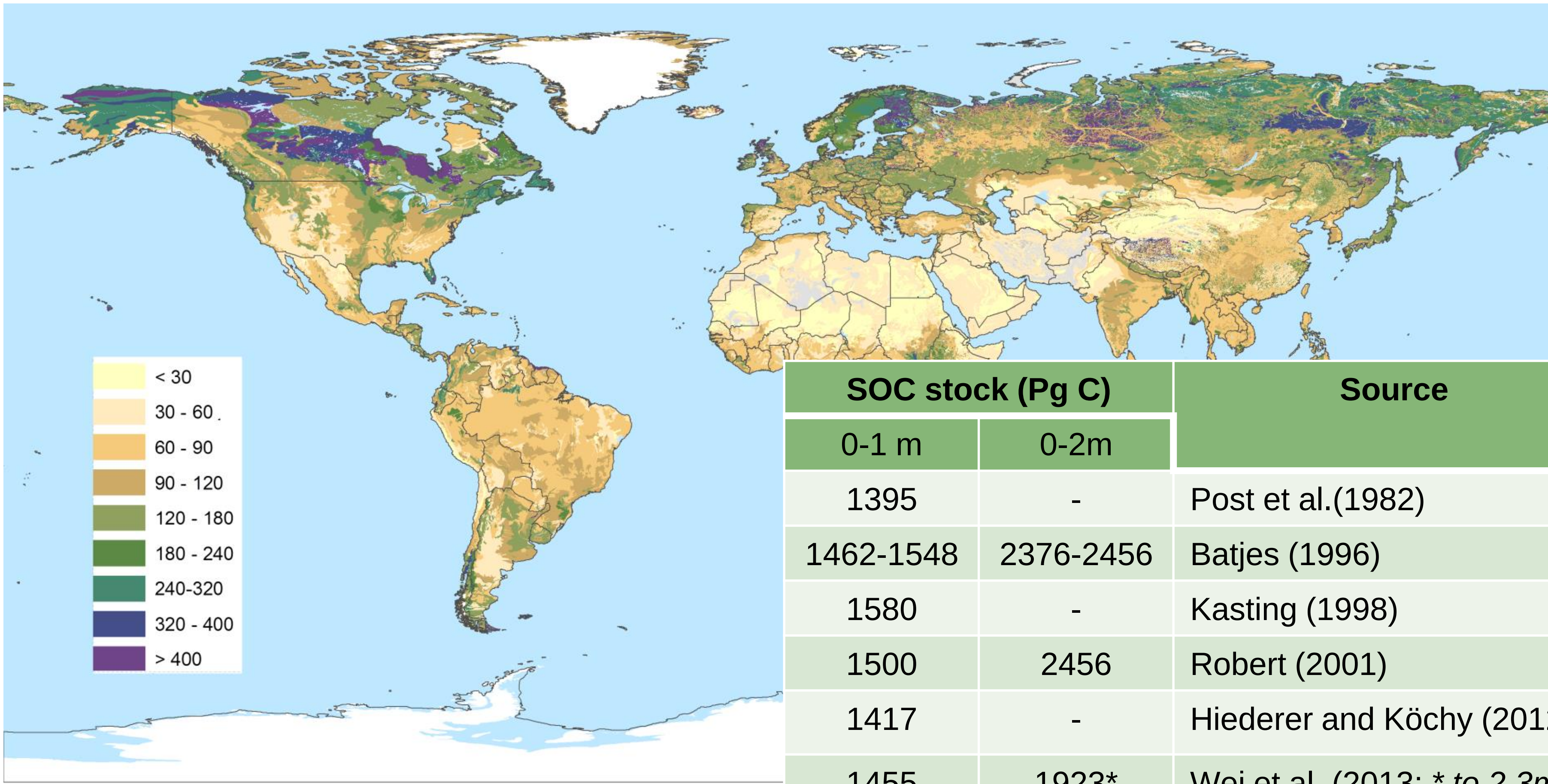
Factors that regulate SOC stocks



Drivers of change: Policy, Climate, Pollution, Land use

Davidson and Jannsens (2006)

Global distribution of SOC stocks



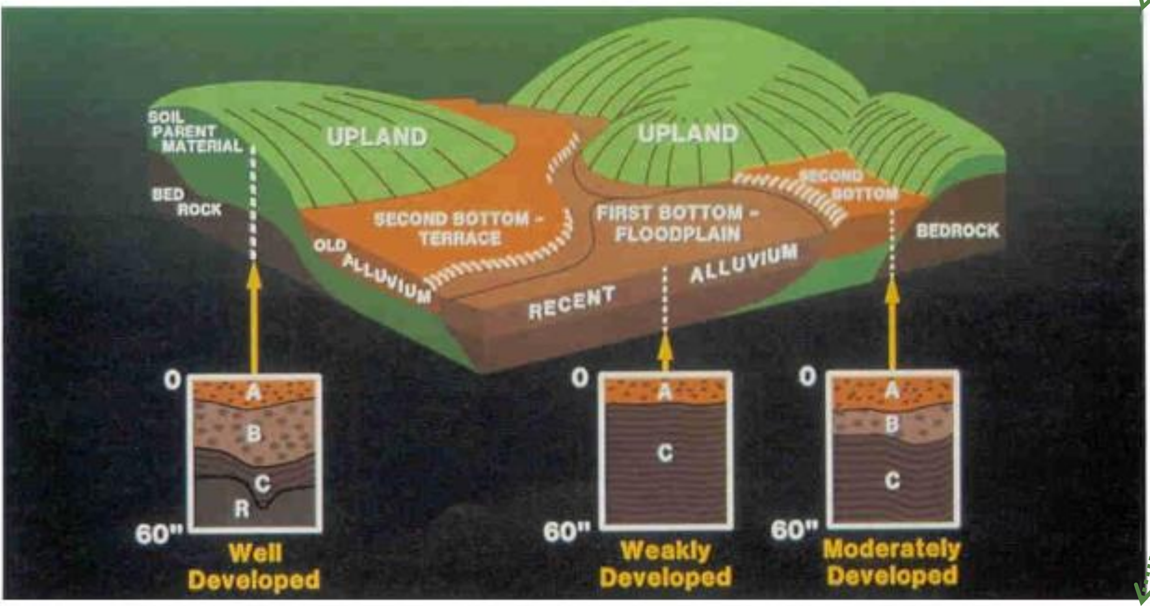
* Mg C per ha to 1 m depth (Batjes 2016)

SOC stock (Pg C)		Source
0-1 m	0-2m	
1395	-	Post et al.(1982)
1462-1548	2376-2456	Batjes (1996)
1580	-	Kasting (1998)
1500	2456	Robert (2001)
1417	-	Hiederer and Köchy (2012)
1455	1923*	Wei et al. (2013; * *to 2.3m*)
1408±154	2060±217	Batjes (2016)

"Although the estimates for global SOC stocks tend to converge, the regional patterns can differ widely between maps"

How much C can a given soil type store?

- Determined by many factors such as rainfall, temperature, vegetation/land use and soil type
- Some of these factors are:
  - determined by the climate
  - fixed characteristics of the soil
  - influenced by management practices



Soil forming factors:

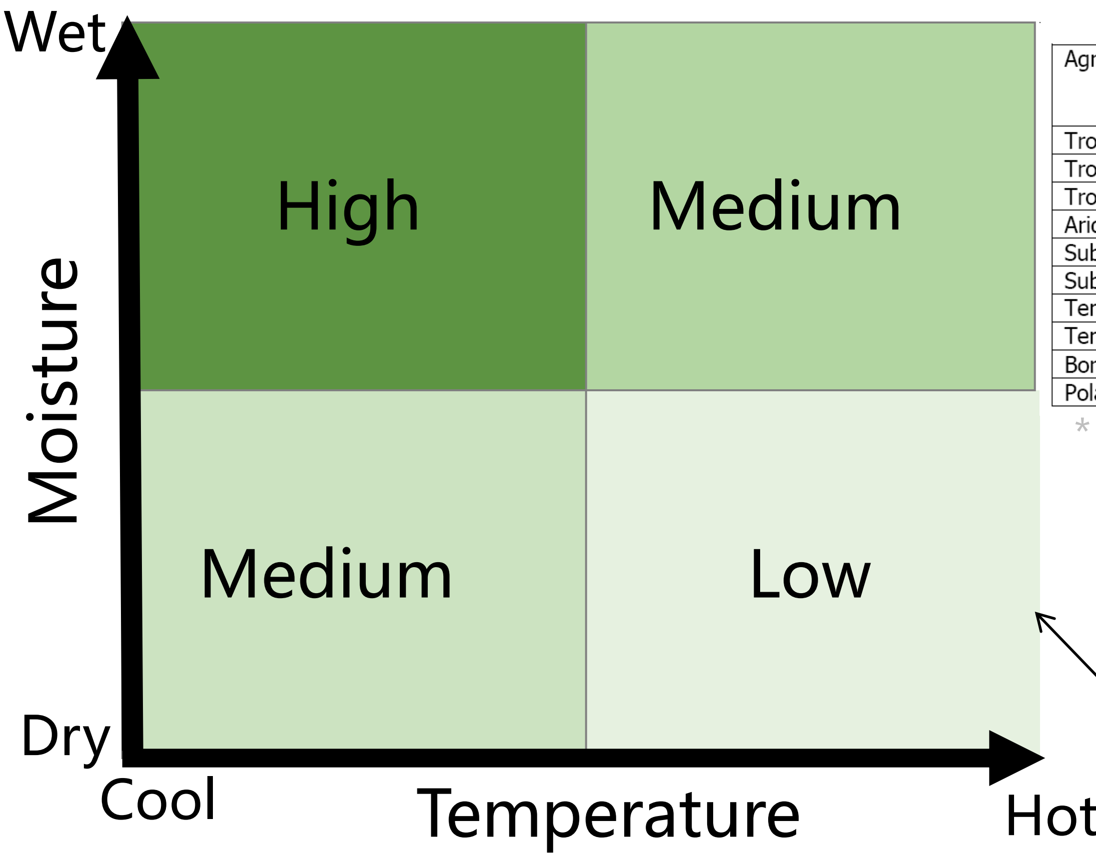
s = f(cl, o, r, p, t, …)

where:

- *s* - soil properties
- *cl* - regional climate
- *o* - potential biota/man
- *r* - topography
- *p* - parent material
- *t* - time

(Jenny 1941)

Potential for SOC sequestration varies with climate

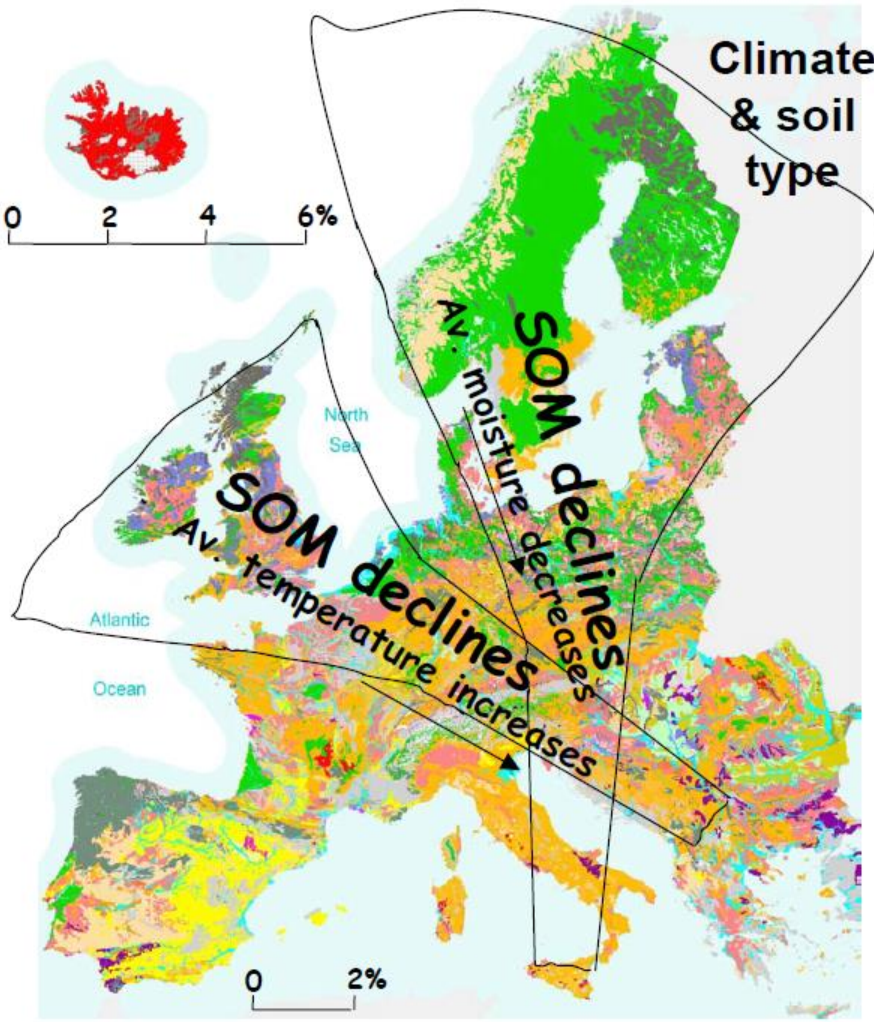


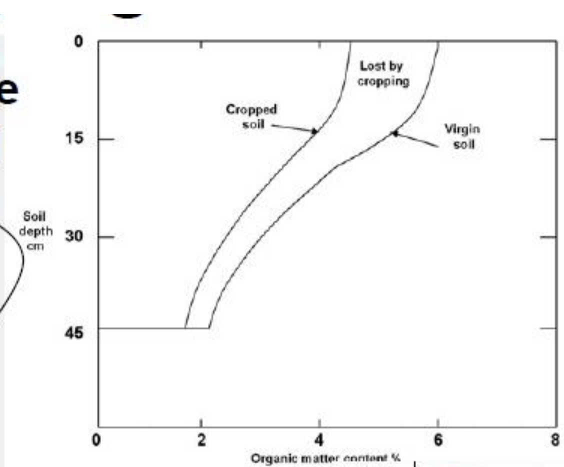
Agro-ecological Zone	Spatially-weighted SOC stocks (Pg C to 1 m depth)	Mean SOC content (kg C m^{-2} to 1 m depth)
Tropics, warm humid	176-183	10.0-10.4
Tropics, seasonally dry	121-128	7.0-7.3
Tropics, cool	55-60	8.4-8.9
Arid	91-100	3.7-4.1
Subtropics, with summer rains	64-68	8.6-9.1
Subtropics, with winter rains	37-41	7.2-8.0
Temperate, oceanic	39-44	11.7-12.9
Temperate, continental	233-243	10.8-11.3
Boreal	477-496	23.1-24.0
Polar and Alpine (excl. Land ice)	166-189	20.6-23.2

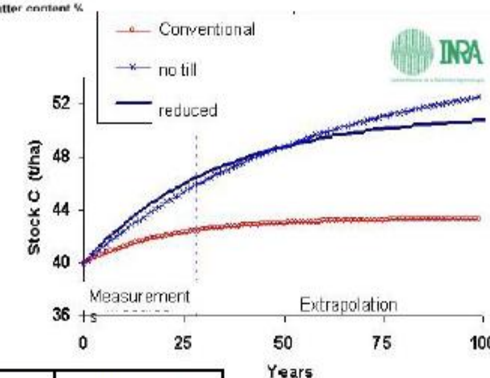
* Large uncertainties remain

'Higher C-costs may be incurred in (degraded) areas where natural processes do not effectively favour SOC sequestration'

Factors affecting soil organic matter







Texture Class	Topsoil OM (%)	Subsoil OM (%)
Sands	0.80	0.50
Clay loams	1.30	0.55
Clays	1.45	0.65

Soil texture
Soil mineralogy
Soil drainage…

Jones et al. (2004)

Mean SOC content by FAO soil unit

- Large uncertainties are associated with estimates of mean SOC content of a soil taxonomic unit
- Coefficients of variation often > 65%

Table 2 Mean organic carbon contents for four depth intervals by FAO–UNESCO soil units/kg m^{-2}

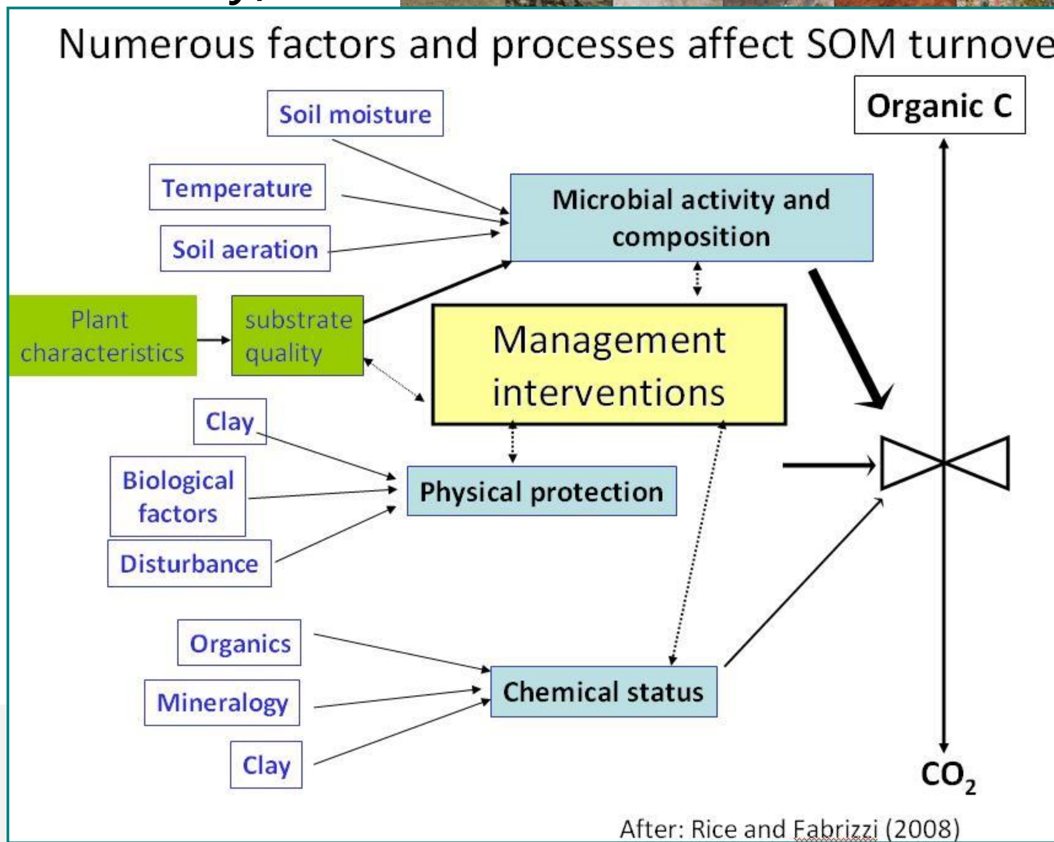
Soil unit	0–30 cm			0–50 cm			0–100 cm			0–200 cm		
	Mean	CV	*n*	Mean	CV	*n*	Mean	CV	*n*	Mean	CV	*n*
Acrisols	5.1	83	309	6.7	84	302	9.4	82	269	10.4	113	56
Ferric	3.7	65	122	4.8	59	120	6.7	49	104	6.8	49	23
Gleyic	6.2	97	19	7.9	96	18	9.0	60	16	11.5	—	1
Humic	10.6	54	71	14.1	57	70	20.3	57	63	29.3	64	15
Orthic	3.7	52	63	5.0	46	60	7.1	43	55	7.3	40	12
Plinthic	5.1	64	34	6.8	63	34	9.2	59	31	6.5	82	5
Cambisols	5.0	91	531	6.9	82	481	9.6	77	332	15.7	92	36
Chromic	4.4	62	30	6.0	62	30	8.2	58	18	15.8	—	1
Dystric	7.6	82	85	9.5	73	82	12.5	47	59	19.5	43	7
Eutric	4.4	97	124	6.3	68	99	8.8	63	68	12.0	50	6
Ferralic	4.2	51	44	5.5	50	43	7.3	49	35	10.9	40	8
Gleyic	5.2	67	47	6.8	61	45	9.0	60	26	19.5	45	3
Humic	11.6	59	45	16.1	60	42	21.1	68	31	45.6	66	4
Calcic	3.0	89	100	4.3	78	90	7.1	70	67	11.5	37	7
Vertic	4.6	59	42	6.4	55	36	9.5	53	[illegible]	[illegible]	[illegible]	0
Gelic	6.6	56	14	9.7	55	14	12.4	80	[illegible]	[illegible]	[illegible]	0

Batjes (1996)

Summarizing

For given climate/soil stratum, the possible *magnitude* and *rate* of SOC sequestration depend on:

- Reference and baseline level
- Antecedent SOC pool (land use history)
- Soil type:
  - depth of soil
  - clay content & mineralogy
  - internal drainage/aeration
  - soil nutrient status (N,P,K,...)
- Land use management
- Socio-economic conditions and incentives
- Policy



After: Rice and Fabrizzi (2008)

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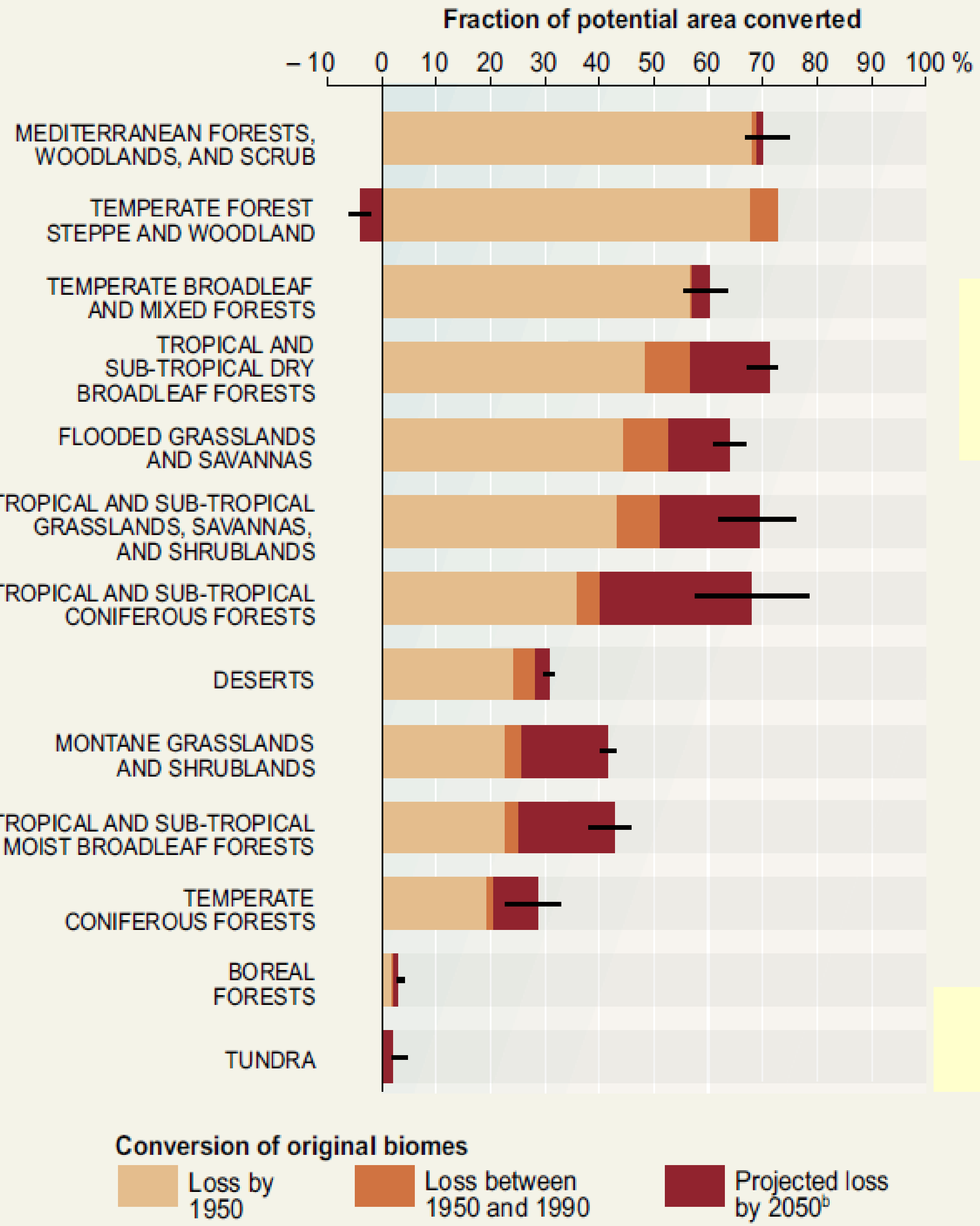
Soil Carbon Benefits

RESTORING SOM WITH IMPROVED MANAGEMENT



Most of the conversion of these biomes is to cultivated systems

SOC losses (Lal et al. 2011)

Historic: 320 Pg C

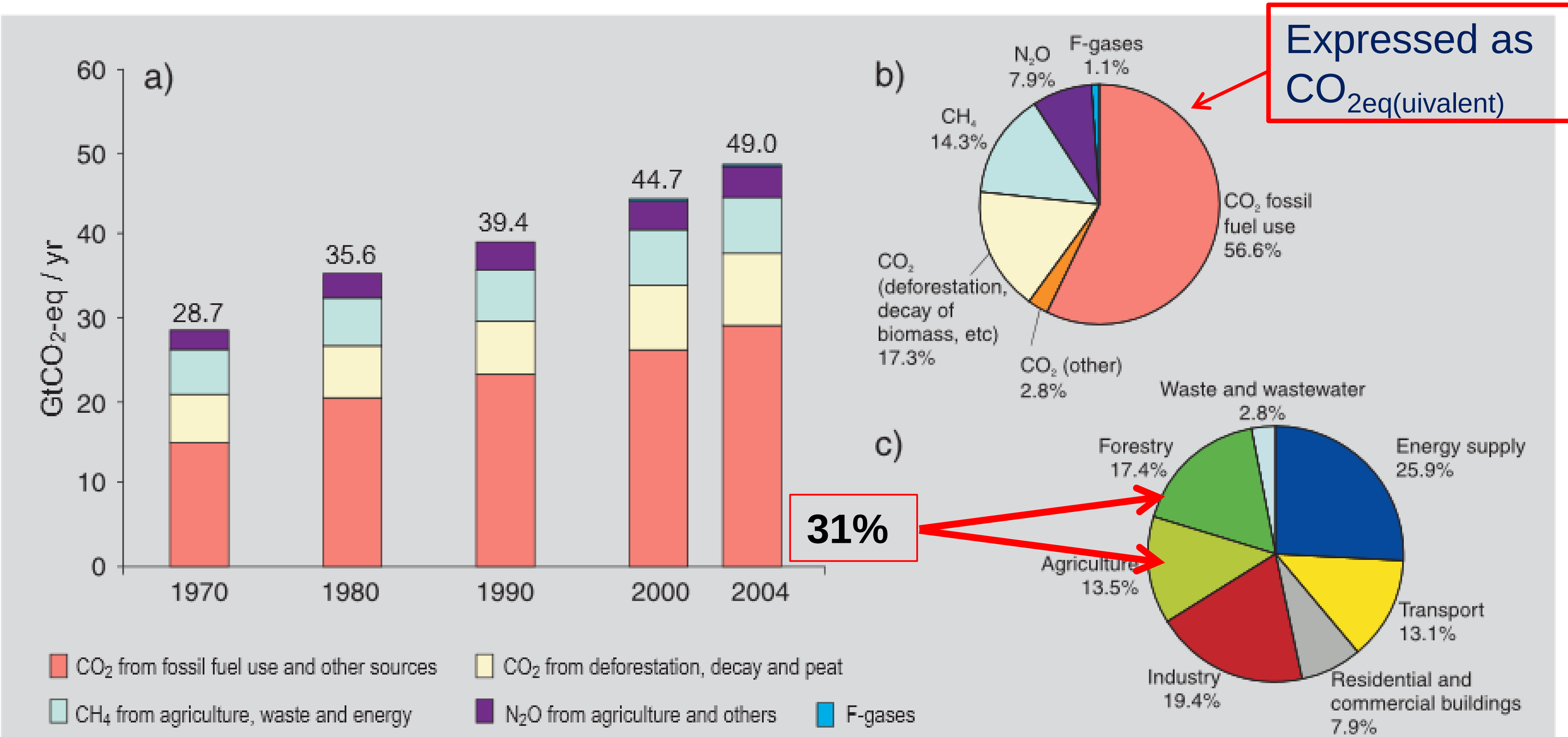
Since 1750: 156 Pg C

2010-2030: 30 Pg C

Current rate: ~1.1 Pg C yr^{-1}

Millenium Ecosystem Assessment (2005)

Global anthropogenic GHG emissions



a) Global annual emissions of anthropogenic GHGs from 1970 to 2004
b) Share of different anthropogenic GHGs in total emissions for 2004
c) Share of different sectors in total anthr. GHG emissions in 2004 (Forestry includes deforestation)

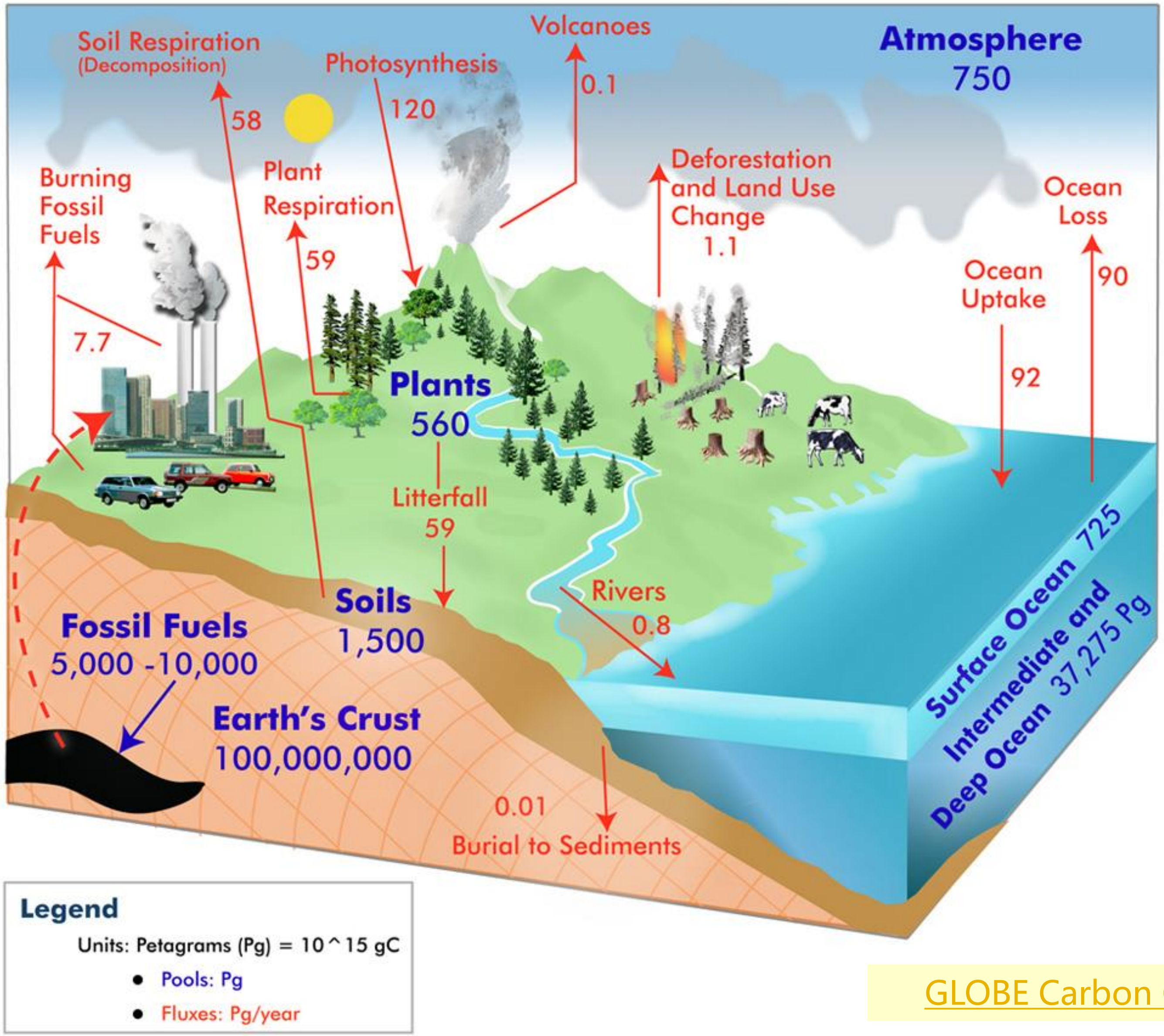
IPCC (2007)

What is a CO_{2eq}?

- Based on Global Warming Potential (GWP)
- A relative measure of how much heat a greenhouse gas traps in the atmosphere
- Compares the amount of heat trapped by a certain mass of a given gas to the amount of heat trapped by a similar mass of carbon dioxide
- Calculated over a specific time interval
- IPCC SAR considers a 100 yr period (GWP: CO_2= 1 ; CH_4= 21 ; N_2O= 310)

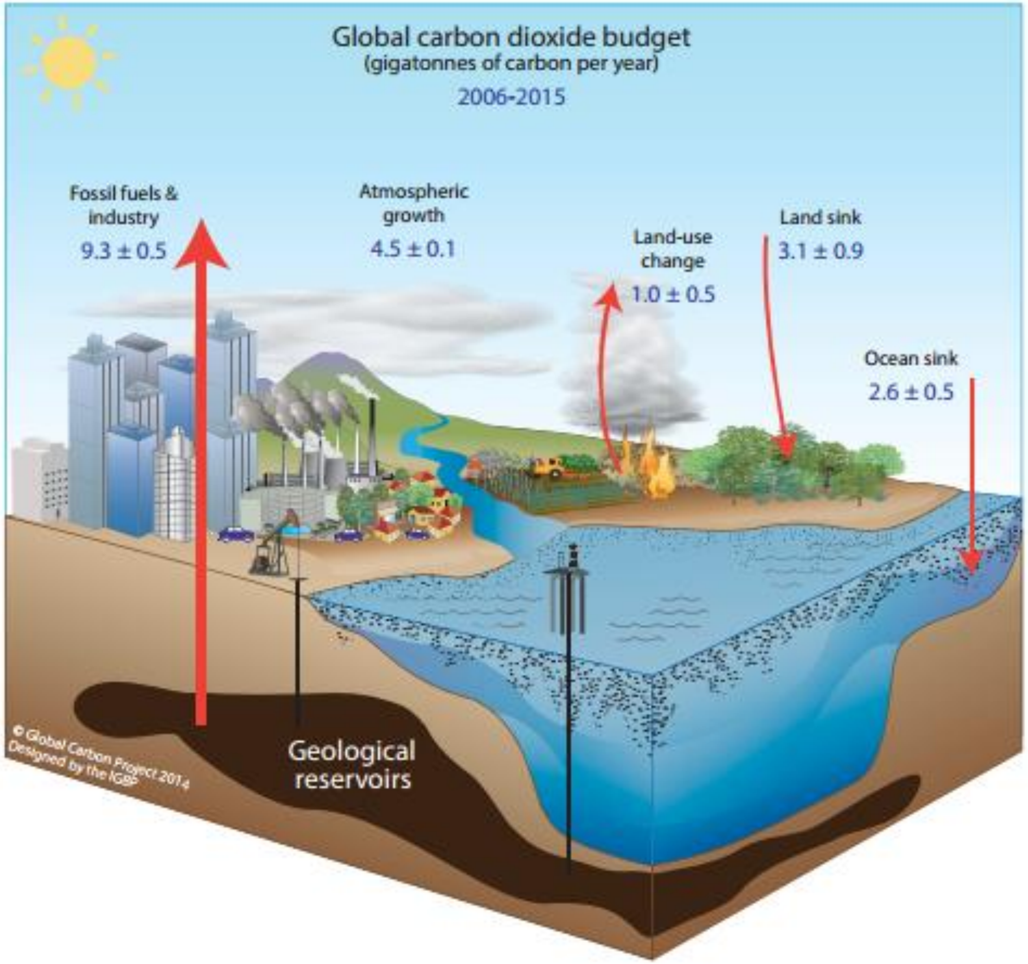
Industrial Designation or Common Name (years)	Chemical Formula	Lifetime (years)	RadiativeEfficiency (W m^{-2} ppb^{-1})	Global Warming Potential for Given Time Horizon SAR[‡] (100-yr)	20-yr	100-yr	500-yr
Carbon dioxide	CO_2	*See below*[a]	[b]*$1.4x10^{-5}$*	*1*	*1*	*1*	*1*
Methane[c]	CH_4	*12*[c]	*$3.7x10^{-4}$*	*21*	*72*	*25*	*7.6*
Nitrous oxide	N_2O	*114*	*$3.03x10^{-3}$*	*310*	*289*	*298*	*153*

Global carbon cycle



GLOBE Carbon Cycle Project (2010)

Overall perturbation of the global carbon cycle by anthropogenic activities



Gt C yr^{-1}

Le Quéré et al. (2016)

Decadal mean in main components of anthropogenic CO_2 budget

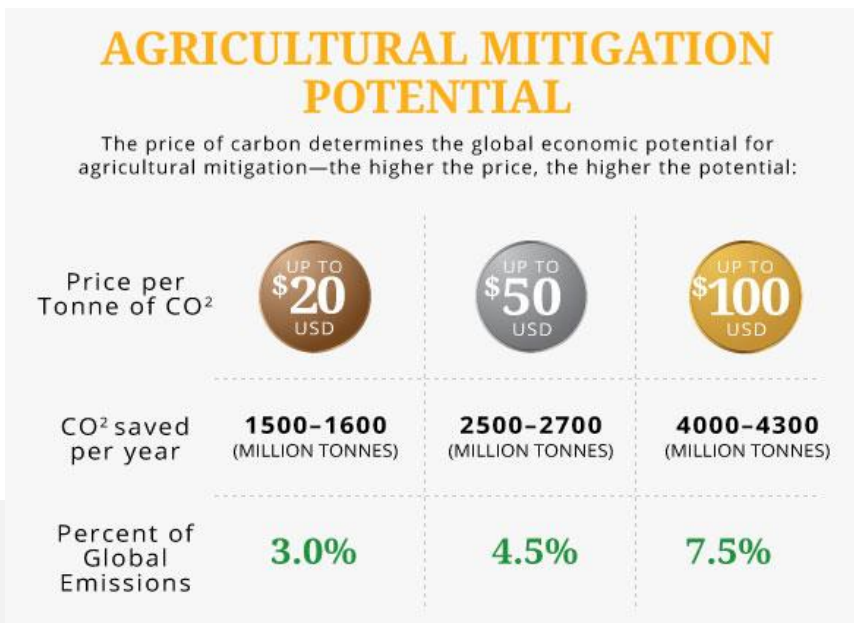
	Mean ($GtC\,yr^{-1}$)					
	1960–1969	1970–1979	1980–1989	1990–1999	2000–2009	2006–2015
Emissions						
Fossil fuels and industry (E_{FF})	3.1 ± 0.2	4.7 ± 0.2	5.5 ± 0.3	6.3 ± 0.3	8.0 ± 0.4	9.3 ± 0.5
Land-use-change emissions (E_{LUC})	1.5 ± 0.5	1.3 ± 0.5	1.4 ± 0.5	1.6 ± 0.5	1.0 ± 0.5	1.0 ± 0.5
Partitioning						
Growth rate in atmospheric CO_2 concentration (G_{ATM})	1.7 ± 0.1	2.8 ± 0.1	3.4 ± 0.1	3.1 ± 0.1	4.0 ± 0.1	4.5 ± 0.1
Ocean sink (S_{OCEAN})	1.2 ± 0.5	1.5 ± 0.5	1.9 ± 0.5	2.2 ± 0.5	2.3 ± 0.5	2.6 ± 0.5
Residual terrestrial sink (S_{LAND})	1.7 ± 0.7	1.7 ± 0.8	1.6 ± 0.8	2.6 ± 0.8	2.6 ± 0.8	3.1 ± 0.9

Gt C yr-1 (Le Quéré et al. 2016)

$$S_{LAND} = E_{FF} + E_{LUC} - (G_{ATM} + S_{OCEAN}).$$

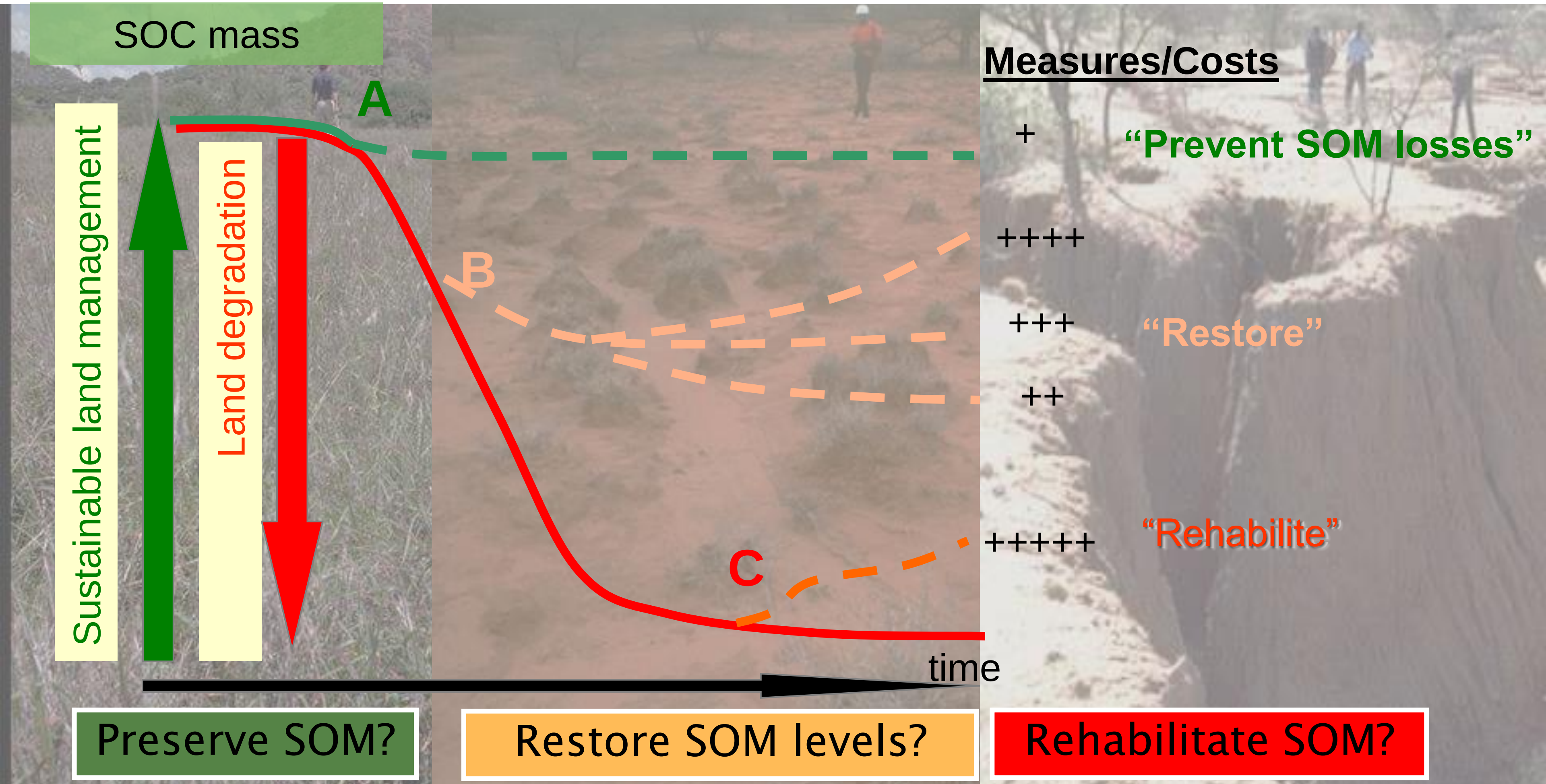
Estimated mitigation potential

- Human-induced increase in atmospheric GHG concentrations, some 49 Pg CO_{2eq} yr^{-1}
- About 1/3 comes from changes in land use, hence important technological potential for mitigation
- Some 90% of this potential can be achieved by enhanced C sequestration through improved land and water management*



* Smith et al. (2007), UNFCCC (2008)

‘It is easier and probably cheaper to preserve th to restore SOM’



+: Socially/financially/politically more demanding types of interventions, and ti be needed to bring back SOC towards their original levels

After: HP L

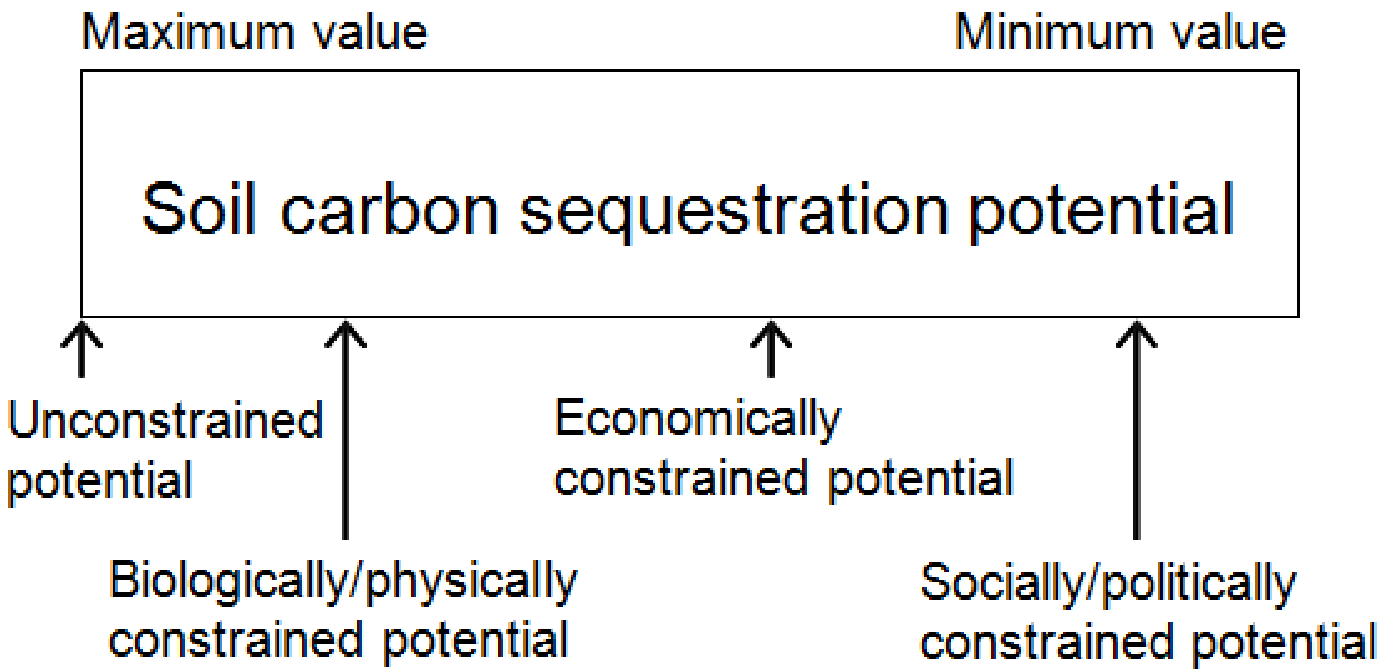
Restoring depleted SOM

- Mainly achievable through SLM interventions : involves managing soils for multiple economic, societal and environmental benefits

- Total (technological) potential of C sequestration in world soils is estimated at 0.4 to 1.2 Gt C yr^{-1} *

- Management practices that also improve food security and profitability are most likely to be adopted

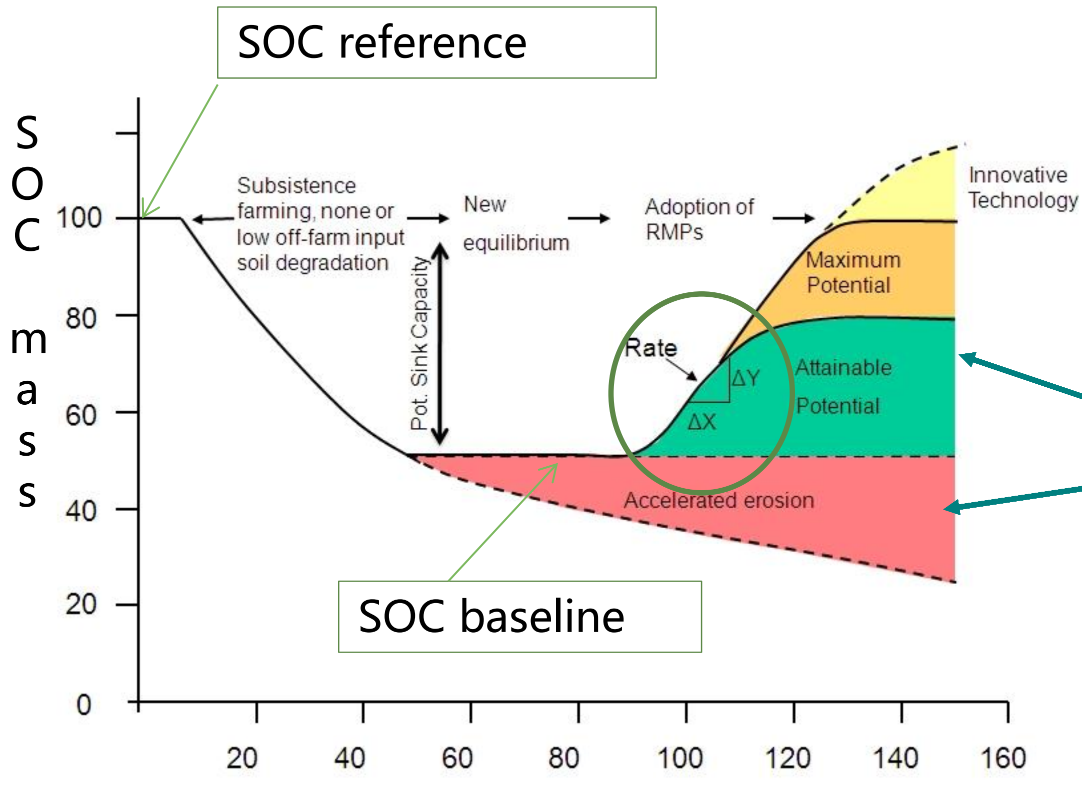
Constraints on agricultural C sequestration



"The maximum feasible C sequestration potential at any given location will seldom be realized due to a series of biological, physical, social, and political constraints"

Sanderman et al. 2010

Changes in SOC mass with land use change



After: Lal, 2004

Judicious SLM interventions can improve SOC mass

SOC dynamics:

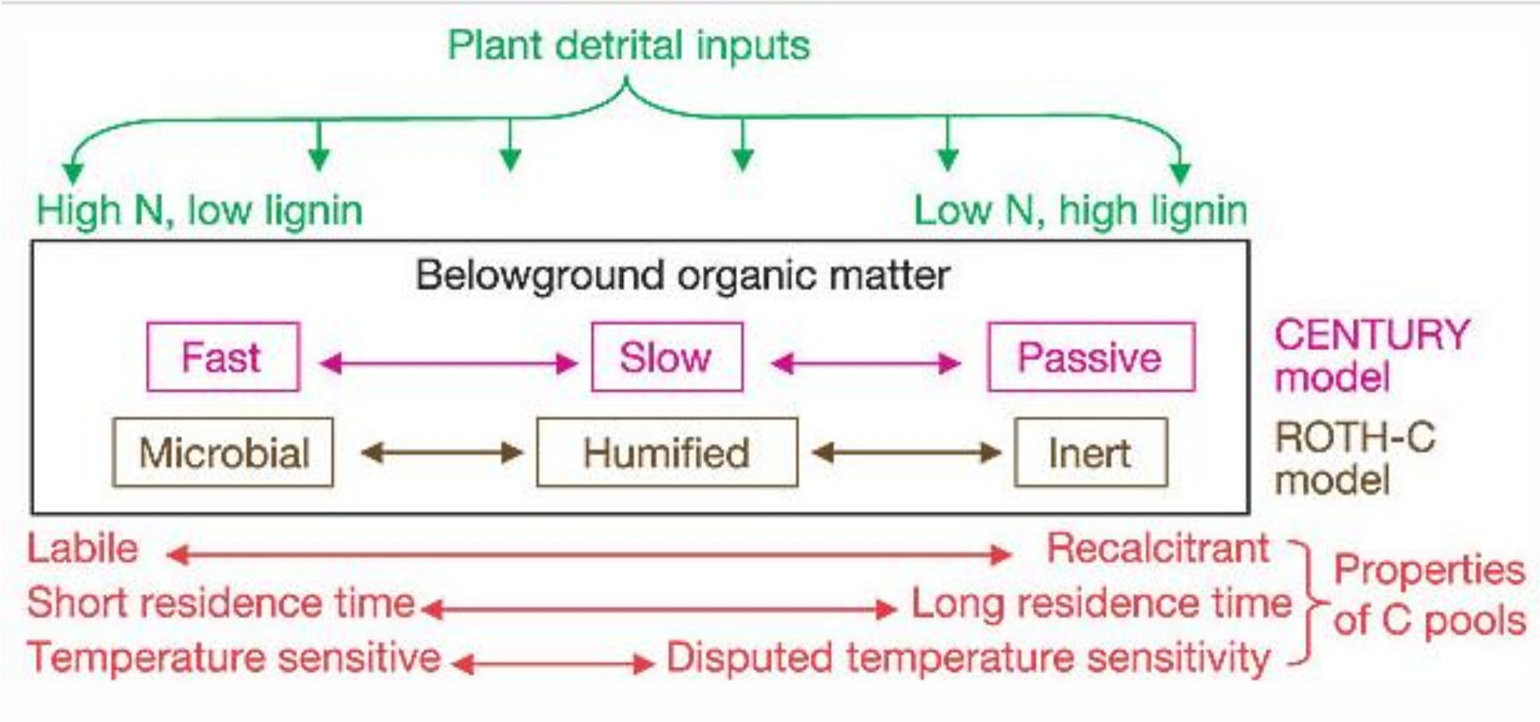
C Sequestration : $C_{input} > C_{output}$

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

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

Describing SOC dynamics

- Often functionally described using models that explicitly consider pools differing in residence times (Davidson and Jannsens 2006)



- "SOM/SOC should be considered as a continuum of organic material in all stages of transformation and decomposition or stabilization" (Lehmans and Kleber 2015)

Mean residence time

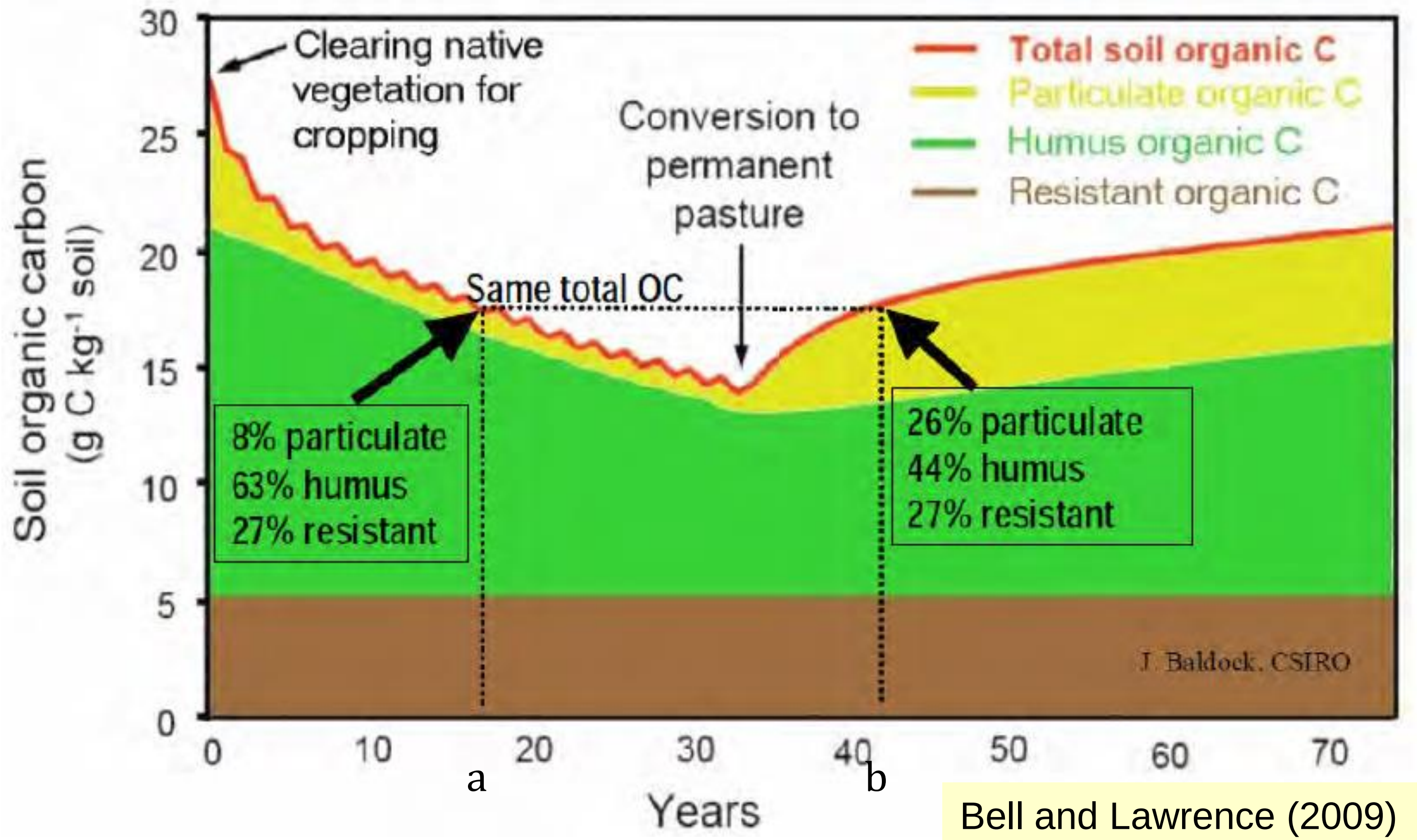
- Average MRT ~ 30-50 yr
- SOC reservoir is quite responsive to perturbance /management over timescales of decennia

Type of organic matter	Proportion of total OM (%)	Turnover time (yr)	C-pool
Microbial biomass	2-5	0.1-0.4	labile
Litter	-	1-3	rapid
Particulate OM	18-40	5-20	moderate
Light fraction	10-30	1-15	moderate
Inter-microaggregate [a)]	20-35	5-50	moderate to slow
Intra-microaggregate [b)]			
Physically sequestered	20-40	50-1000	passive
Chemically sequestered	20-40	1000-3000	passive

a) Within macro-aggregates but external to micro-aggregates, including particulate, light fraction, and microbial C.
b) Within micro-aggregates, including sequestered light fraction and microbially derived C.

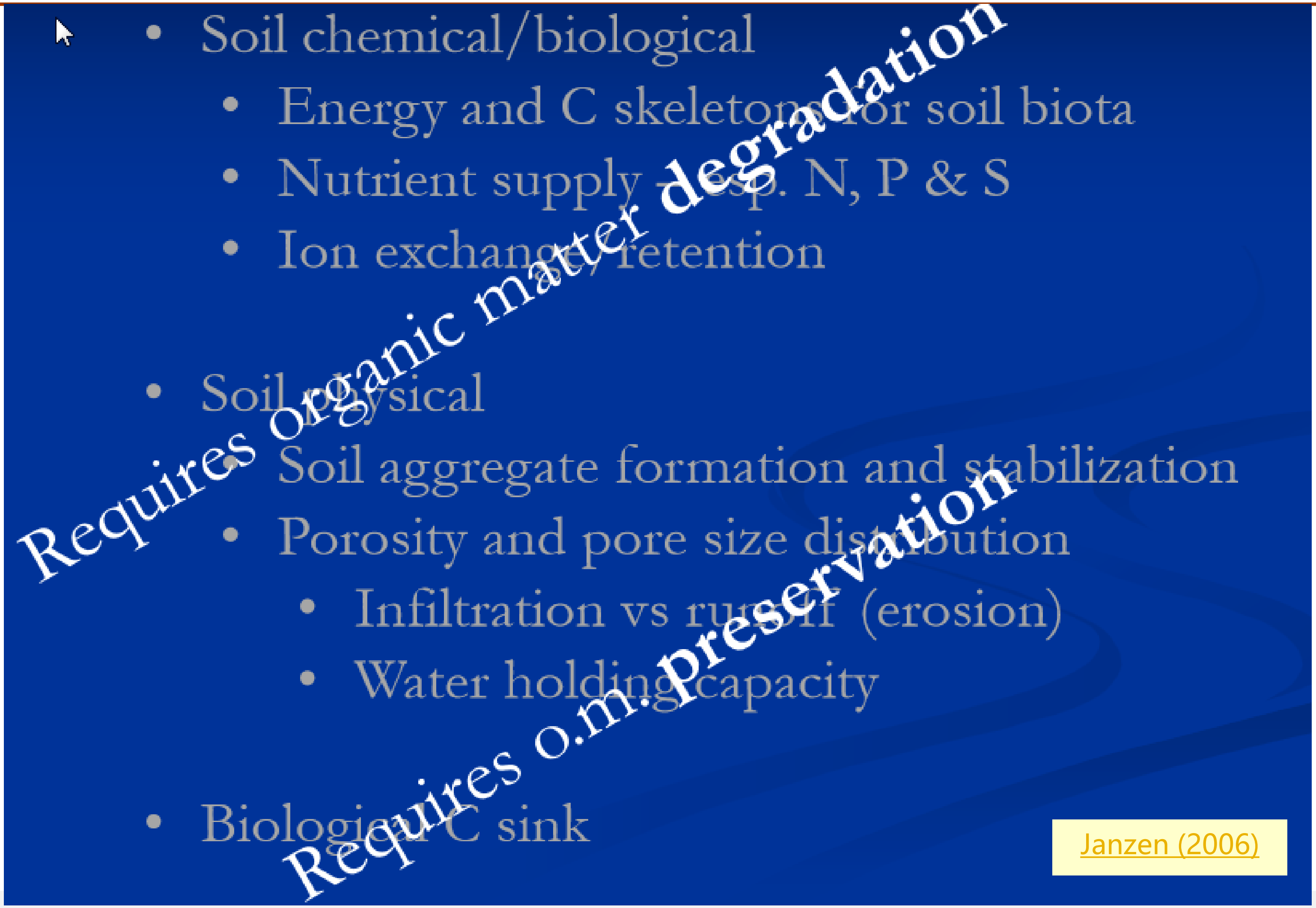
Jastrow and Miller 1997

Permanence of changes in SOC pools



Bell and Lawrence (2009)

The so-called 'Soil C dilemma': Shall we hoard it or use it?

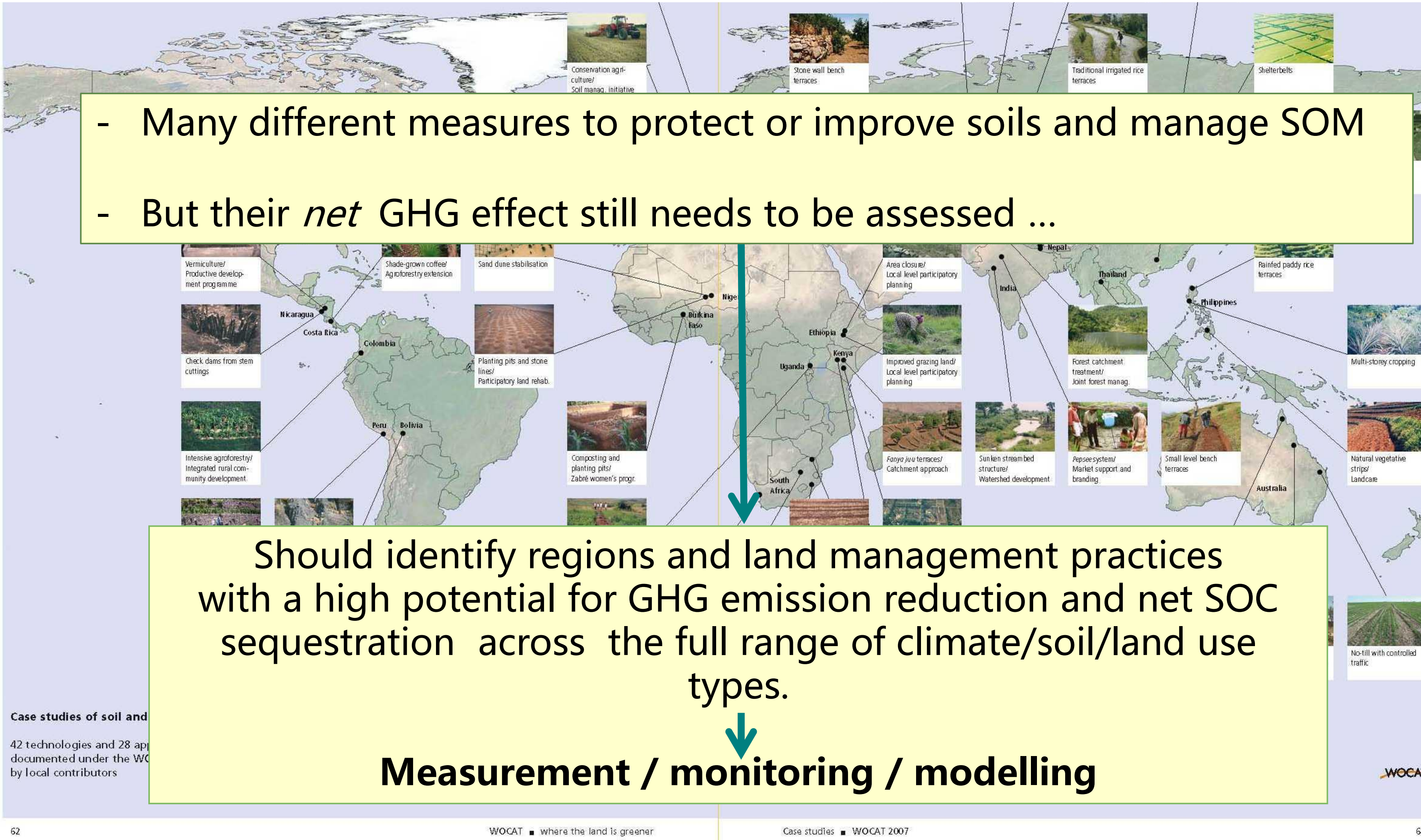


Soil management affects SOM levels

Often much scope for improvement …

Farmers are key and need support …

Recommended Management Practices (RMP)



- Many different measures to protect or improve soils and manage SOM
- But their *net* GHG effect still needs to be assessed …

Should identify regions and land management practices with a high potential for GHG emission reduction and net SOC sequestration across the full range of climate/soil/land use types.

↓

Measurement / monitoring / modelling

Priority agro-ecosystems for C sequestration in world soils, with examples of recommended technological options

Carbon sequestration in world soils

Croplands
- No-till farming
- Mulching
- Cover cropping
- Integrated nutrient management (compost, manure)
- Complex rotations
- No residue burning
- Biochar and other ammendments
- Perennial grains

Paludiculture

Agroforestry

Peat lands
- Rewetting
- Regulating water table
- Establishing native species
- Cultivating biomass

Grasslands/grazing lands
- Controlled grazing
- Low stocking rate
- Improved pasture species
- Water conservation
- Fire management

Nature conservancy

Silvo-pastoral systems
Agro-silvo-pastoral systems

Degraded lands
- Afforestation
- Vegetative barriers
- Water conservation
- Soil fertility enhancement
- pH management
- salinity management

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SOWAL-FAO (2009)

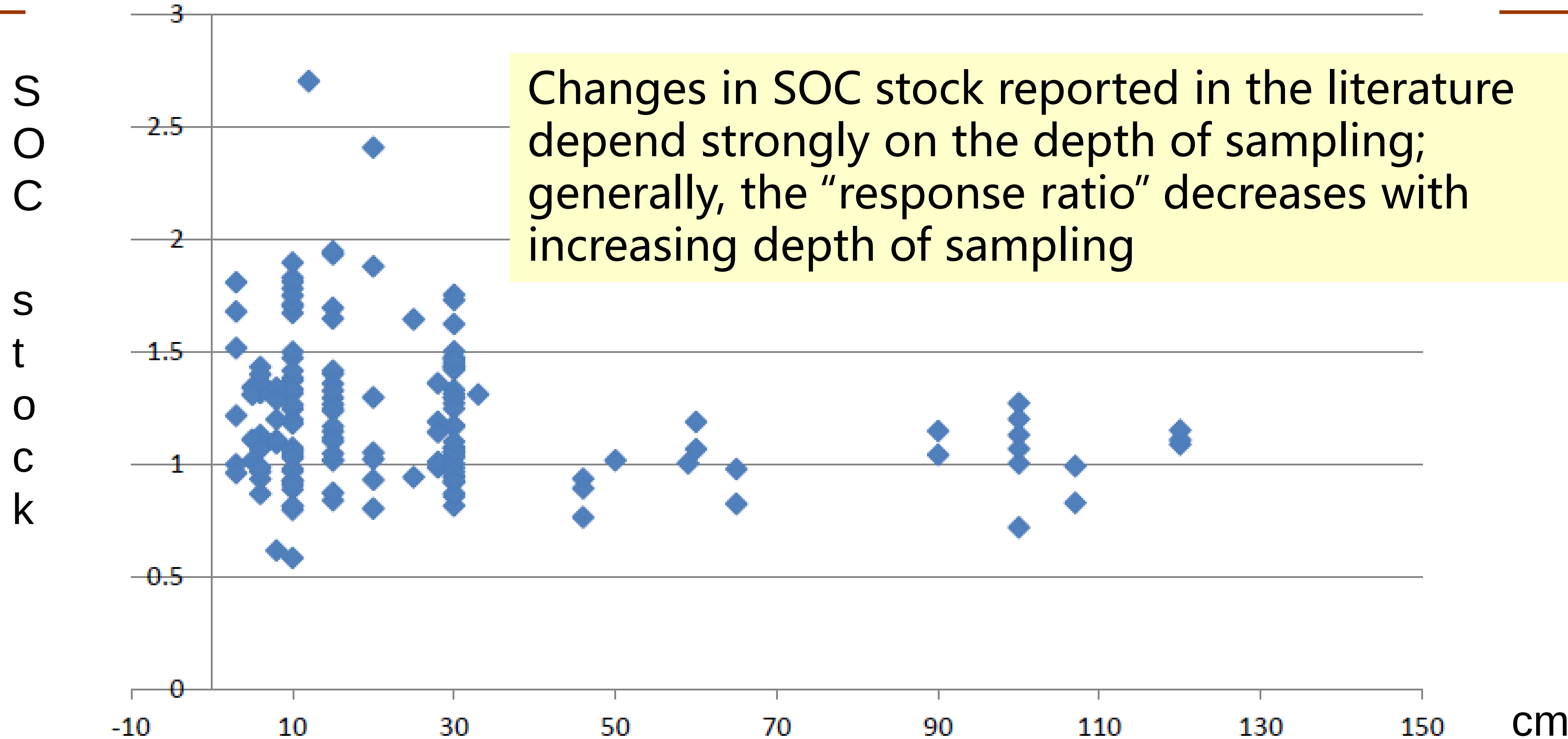
Some C sequestration rates

Recommended practices	C sequestration potential (Mg C ha^{-1} yr^{-1})
Conservation tillage	0.10-0.40
Winter cover crop	0.05-0.20
Soil fertility management	0.05-0.10
Elimination of summer fallow	0.05-0.20
Forages based rotation	0.05-0.20
Use of improved varieties	0.05-0.10
Organic amendments	0.20-0.30
Water table management/irrigation	0.05-0.10
Lawn & Turf	0.5-1.0
Minesoil reclamation	0.5-1.0

Lal et al., 1998

** Such estimates may vary widely between studies …*

Effects of depth of sampling ...



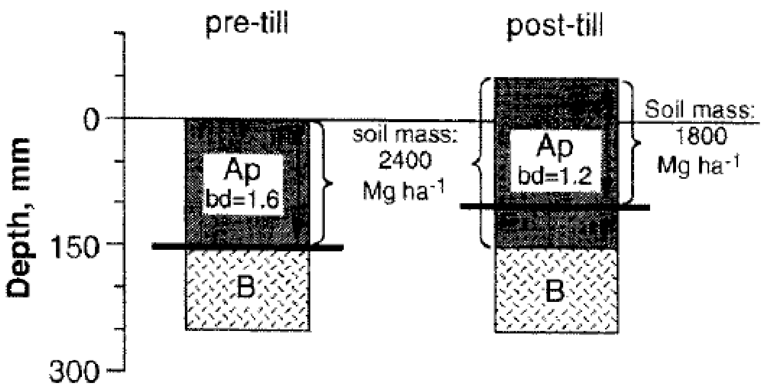
Changes in SOC stock reported in the literature depend strongly on the depth of sampling; generally, the “response ratio” decreases with increasing depth of sampling

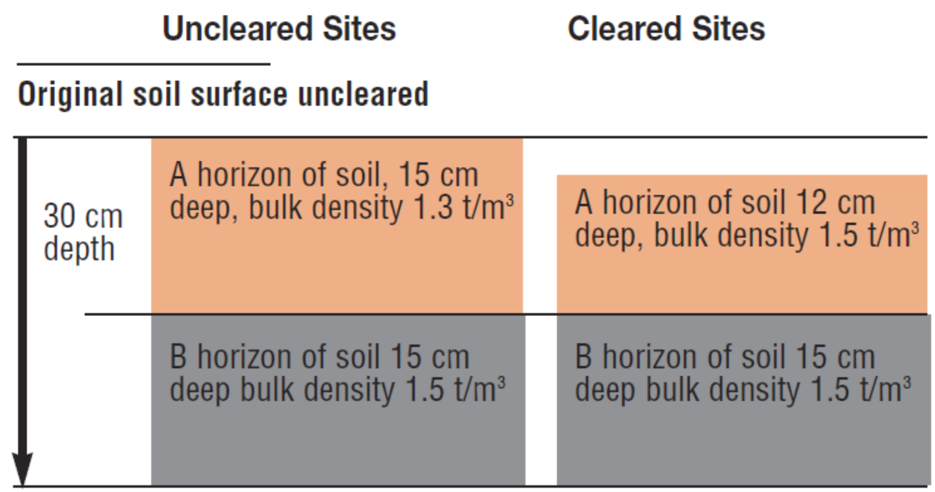
Depth-integrated SOC stock in alternatively managed or converted grassland *versus* traditionally managed grassland against depth of sampling

Govers et al. 2012

Should consider equivalent soil mass …

Impacts of management on SOC storage will be mis-interpreted if changes in BD are not accounted for.





Note that the depth of the original 30 cm of soil in the uncleared site is now equivalent in mass to about 27 cm of soil in the cleared site.

* Examples assumes concentration remains constant at 2% or 20 kg C Mg^{-1} soil ’
(Ellert and Bettany 1995)

Effects of possible disturbances

- Climate change: warming increases respiration rates, SOC ↘
- Warming and atmospheric CO_2: stimulate plant growth, SOC ↗
- Disturbance by tillage: increases respiration rates, SOC ↘
- Harvesting: reduces input, SOC ↘
- Land use change: SOC ↘ or SOC ↗

For recent discussions, see: Davidson and Jannsens (2006), Smith (2012), Lu et al. (2013), Luo et al. (2016), Levèvre er al. (2017)

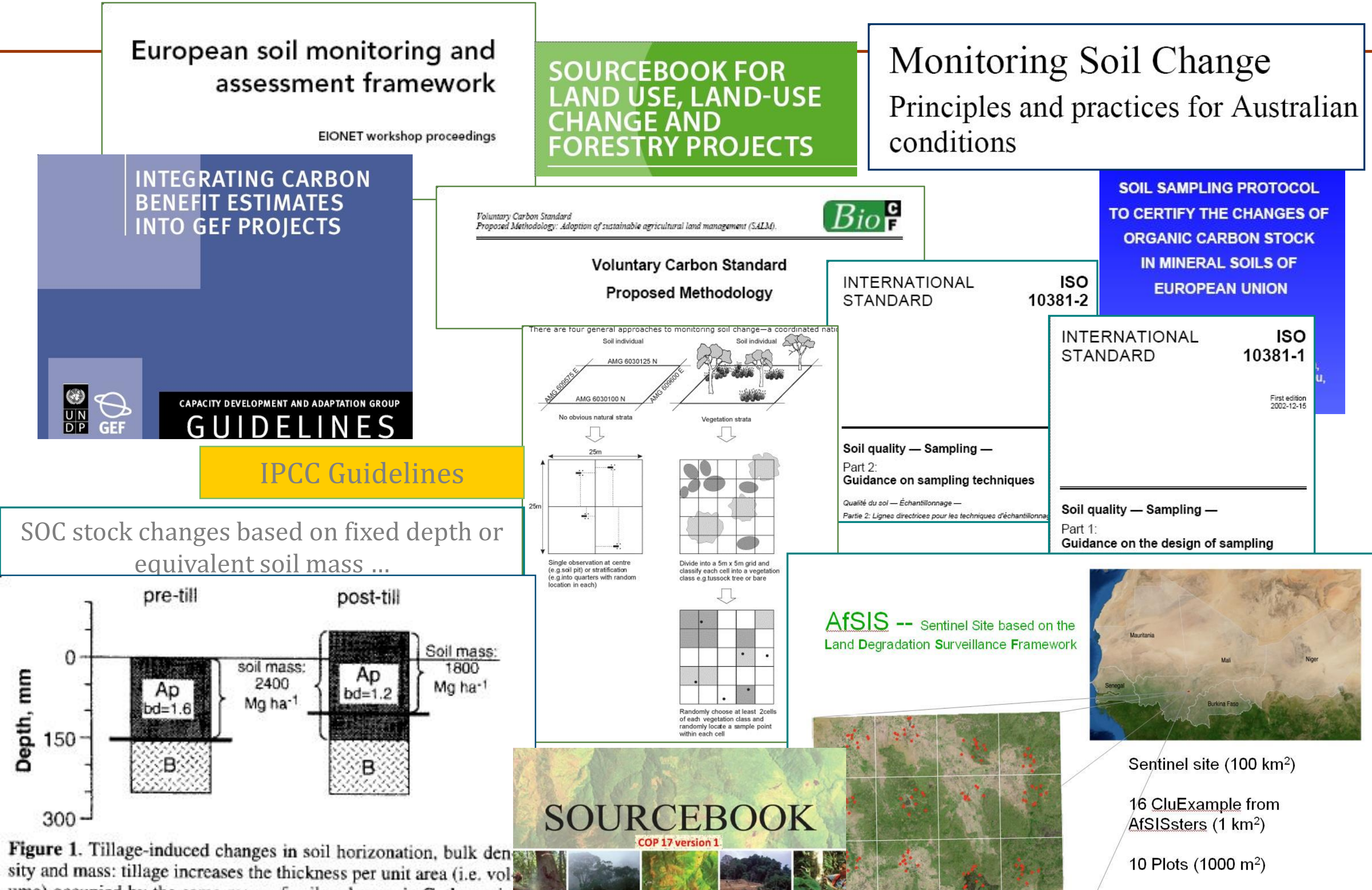
Part I - Concluding remarks

- Response time of SOC to Δ(management) = decades
- Sequestration rates possible under alternative management systems may be lower than proposed in earlier studies
- Possible gains for a given soil/climate type are finite (in capacity and time)
- Must consider *net* carbon gains (full GHG accounting)
- Soil C sequestration can buy 'us time' until the alternatives to fossil fuel take effect
- Should focus on *co-benefits*: job creation, increased soil quality; improved water retention ; increased yields ; biodiversity preservation …

Part II - Hands-on computer exercise

Excercise with Simple Assessment CBP tools (Kakamega, Kenya)

Many different procedures/protocols …



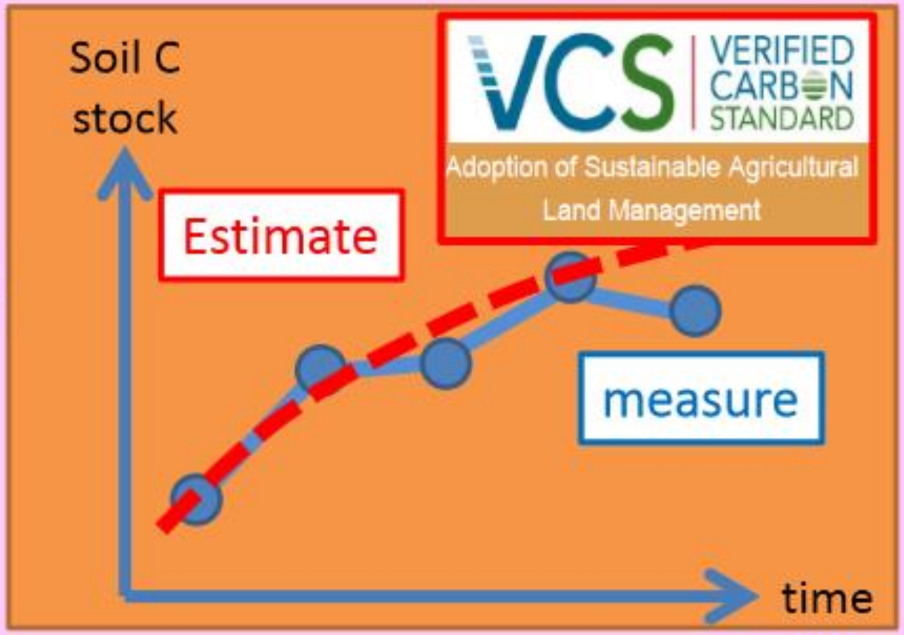
Projects can have different MRV needs

Market based on adoption of sequestering practices or management options

Adoption of a practice that stores/preserves carbon

Market based on the impact/result of the practice / management options

Estimated results | **Verified result**

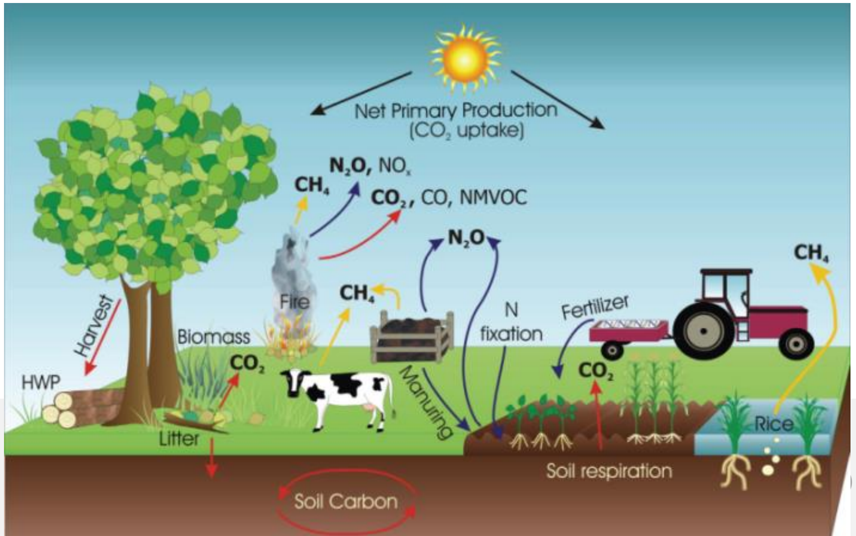


Bernoux 2013

Background CBP tools

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

- CBP project developed 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



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Features of CBP modelling system

Developed to land use carbon project developers in selecting *methods that combine livelihood benefits with climate change mitigation benefits:*

- On-line
- User friendly
- Applicable at any stage of a project
- Can be used for different types of projects with different amounts of data
- Spatially explicit output
- Reporting in a standard format

CBP toolkit advisor

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.

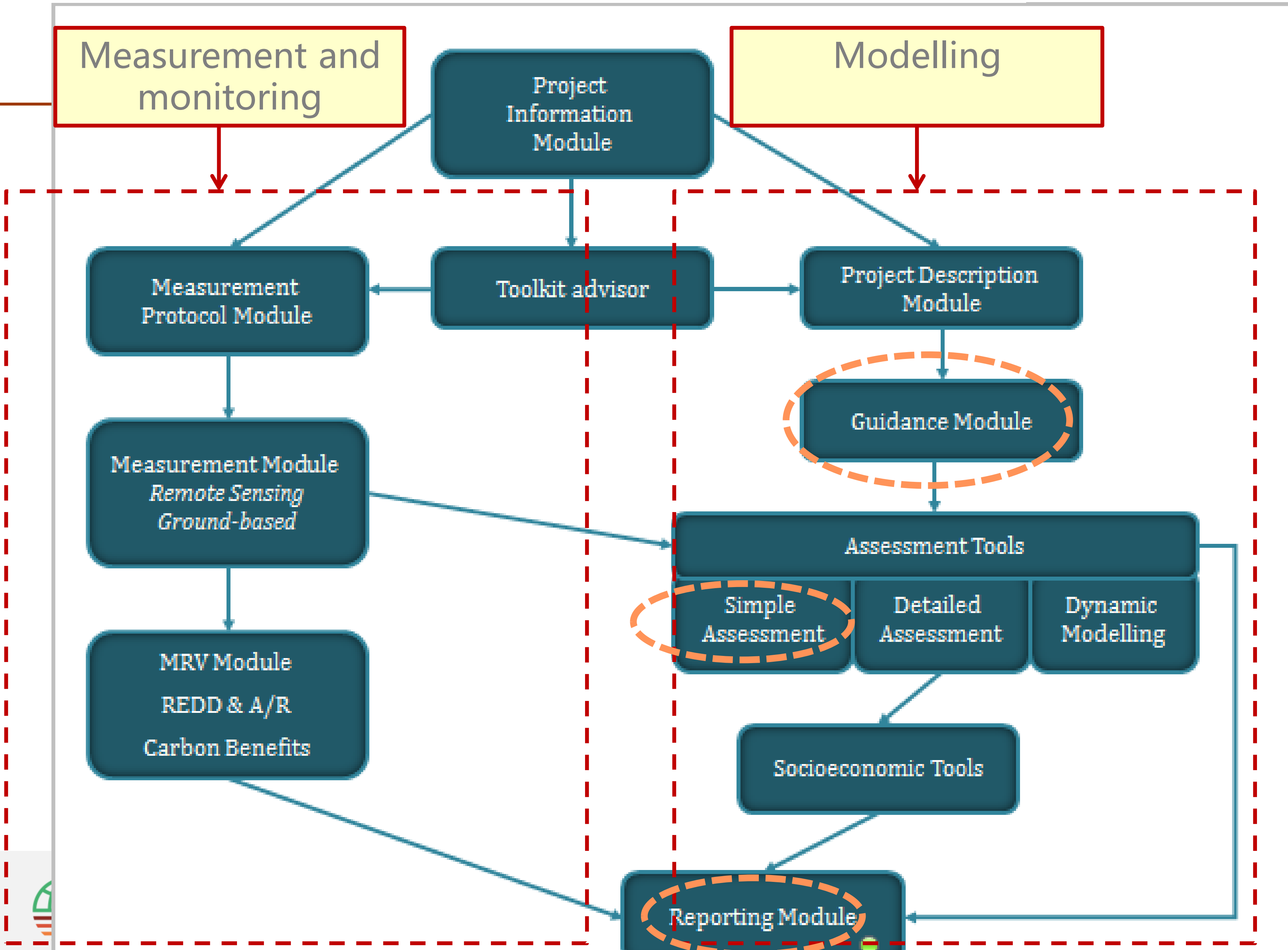
Detailed Assessment of the impact projects have on carbon stocks and greenhouse gas emissions. Requires information on land use changes and/or livestock production in the project area plus can utilize local and project specific field measurements and other local datasets. Suitable for detailed reporting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

Concept behind the CBP toolset



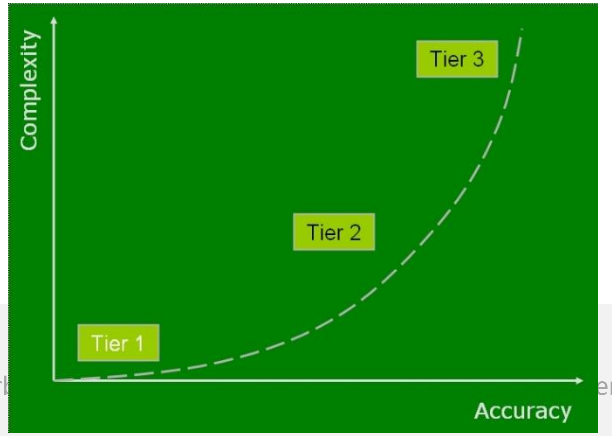
Differences in methodological complexity and data needs

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

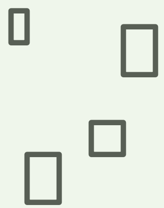
Source: http://www.gofc-gold.uni-jena.de/redd/, p.73

CBP Assessment Tools:
- **Simple Assessment** (Tier I)
- Detailed Assessment (Tier II)
- Dynamic Modelling (Tier III)

data needs



Main principle: Stratify project areas



Project Boundaries

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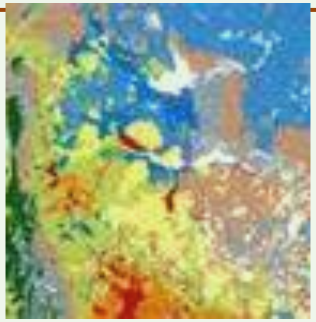

Soils

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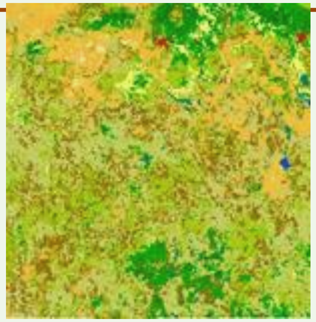
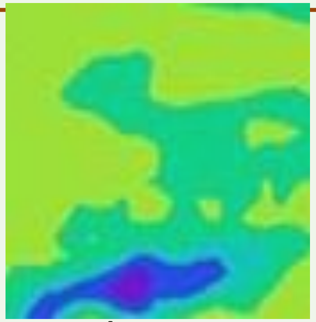


LULC

+

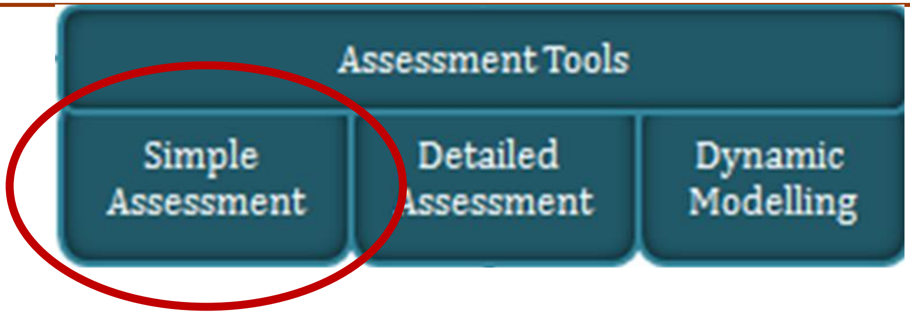


Climate

Area	Soil	LULC	Climate
50000 ha	Ferralsols→LAC	Forest land to Cropland	Tropical moist
76 ha	Histosols→ORG	Wetland remaining Wetland	Tropical moist
2300 ha	Fluvisols →WET	Cropland to Agoforestry	Tropical moist
…	…	…	…

CBP tools/models

Simple Assessment



- 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 (*ex-ante* and *ex-post*)
- Uses standard information on greenhouse gas emission rates
- Uses default IPCC climate and soil classes

Simple Assessment

(IPCC Tier-I inventory approach)

SOC changes in mineral soils (IPCC 2006):

$$\Delta SOC = \sum_{h=1}^{H} \left(SOC_t(h) - SOC_{t-20}(h) \right)$$

$$SOC(h) = SOC_{REF} * (F_{LU} * F_{MG} * F_I) * A$$

- SOC_{REF} – reference carbon stock (for climate-soil stratum)
- Stock change factors:
  - F_{LU} – base factor (land use)
  - F_{MG} – tillage factor (management system)
  - F_I – input factor (inputs of organic matter)
- A – land area (for given stratum)

Getting started …

- Download course materials: http://www.isric.org/documents/document-type/training-material-gsoc-mapping-cbp-tools

- Register at *: http://cbp-web1.nrel.colostate.edu

* *CBP tool is best used with Firefox, Chrome or Safari*

"Irrespective of the climate debate, soil quality and its organic matter content must be restored, enhanced and improved"

www.isric.org

Acknowledgements: This presentation draws on materials derived from many sources which, to the extent possible, have been acknowledged using URLs to the original studies/materials.