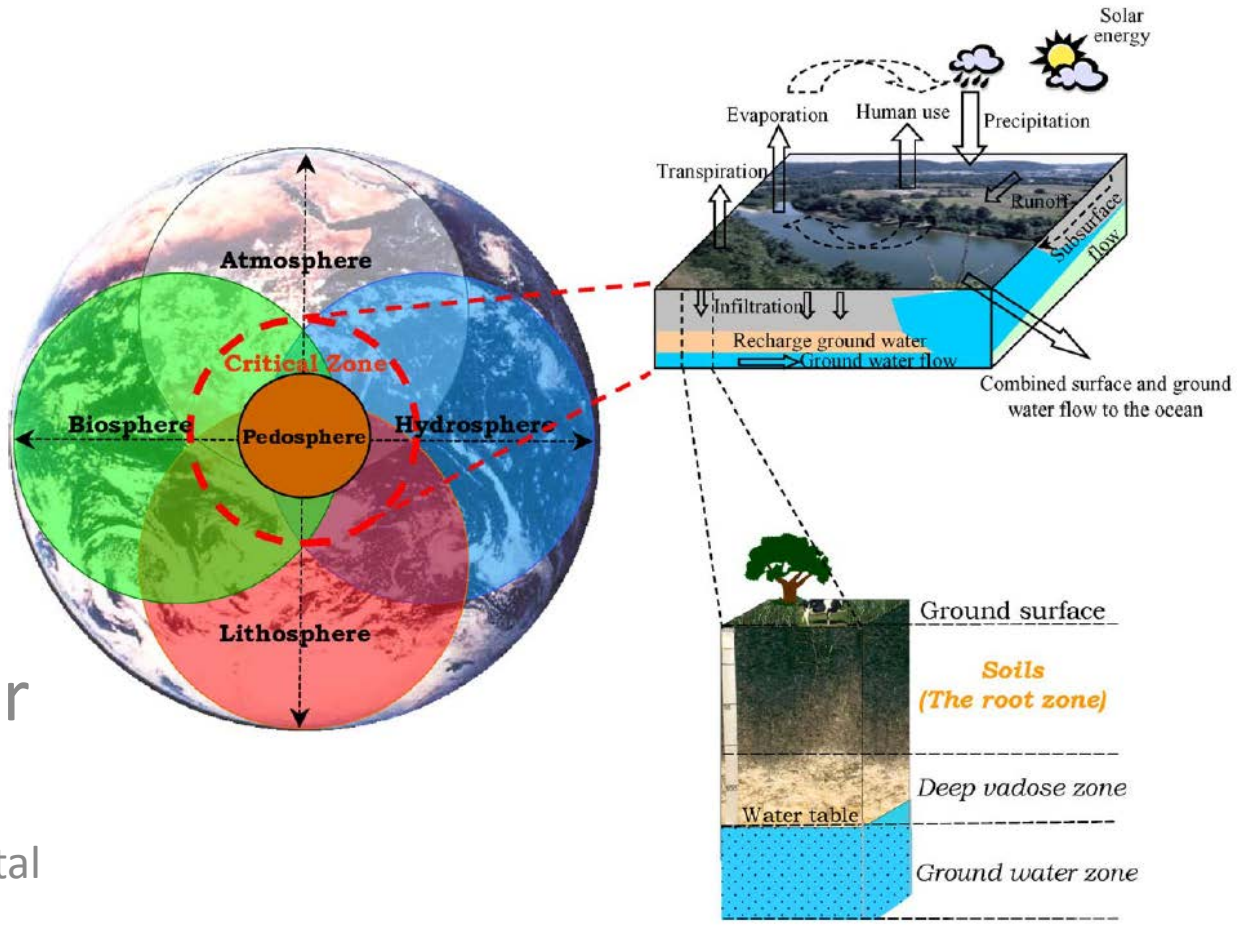
Soil Health and Sustainable Agriculture; Considering the Critical Zone

L.P. Wilding, H. Lin / Geoderma 131 (2006) 257–274 259



Michelle Wander
University of Illinois
Department of Natural Resources and Environmental Sciences
mwander@illinois.edu

Dynamic Soil Properties: Critical Indicators of Sustainability

Trust but Verify

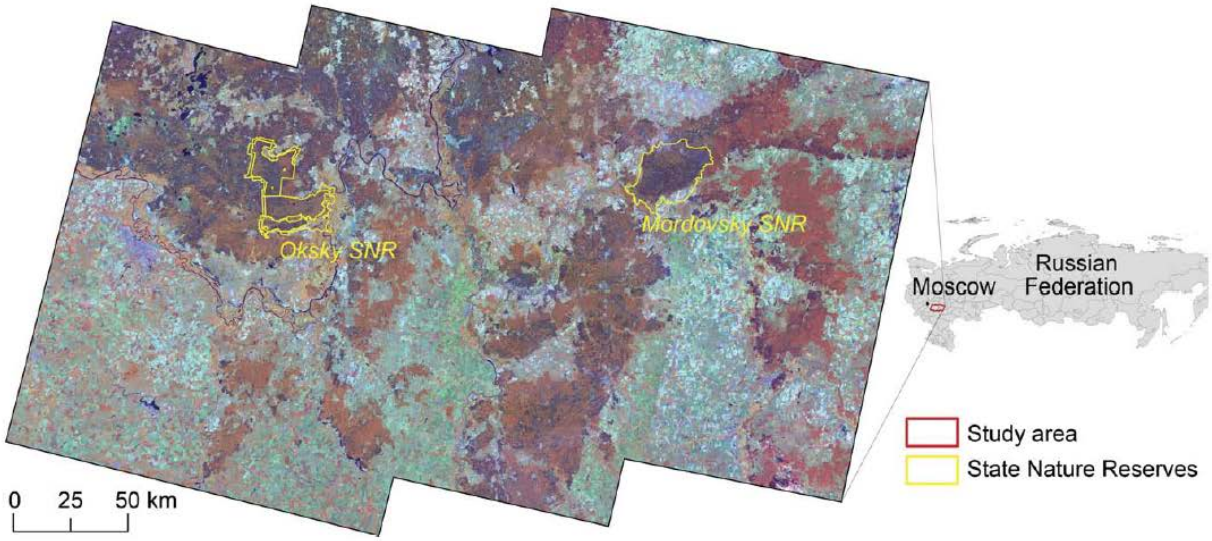


Fig. 1. Study area in European Russia with Oksky and Mordovsky State Nature Reserves (Landsat footprints path/row (acquisition date): 176/22 (2007-05-31), 175/22 (2000-05-28), and 174/22 (2007-08-21), in band combination 4/5/3, i.e., false color). Photosynthetically active vegetation is shown in reddish colors (e.g., different forest types or cultivated agricultural land).

Landsat-based mapping of post-Soviet land-use change to assess the effectiveness of the Oksky and Mordovsky protected areas in European Russia

Anika Sieber [a,*], Tobias Kuemmerle [a,b], Alexander V. Prishchepov [c], Kelly J. Wendland [d], Matthias Baumann [e], Volker C. Radeloff [e], Leonid M. Baskin [f], Patrick Hostert [a]

Pedometrics and the Soil Survey

Pedometrics, which is the application of probability and statistics to soils has potential to complement conventional soil surveys for use in precision agriculture and precision conservation.

Sustainable Ag History in US

RODALE

1940s-present

1989

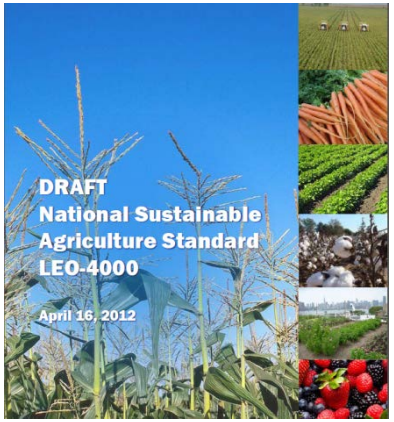
SARE
Sustainable Agriculture
Research & Education

1985

1962

USDA
ORGANIC

1995



2012

Third party certifiers

Private or public organizations that use scientific theories, tests, and data as well as technical artifacts to independently verify production and product quality and safety claims. They are usually distinguished by their claimed independence from both buyer and seller.

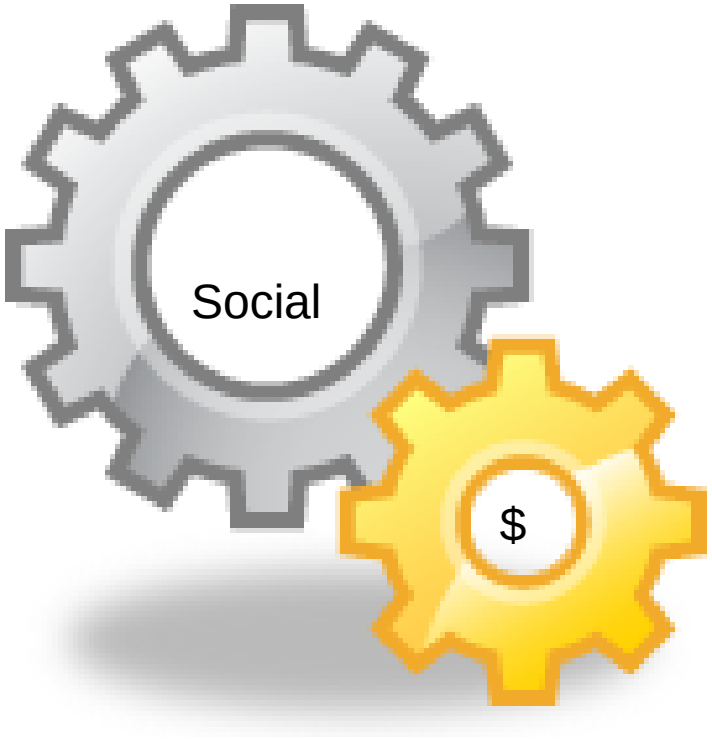
Social Movements placing a variety of demands on industry for **credence goods (services)** such as environmental and worker protection, food quality, and minimized pesticide residues.

Under these conditions, many governments and firms look to third party certifiers because they are responsive and have great flexibility.

TPCs appeal to **'technoscientific'** values such as independence, objectivity, consistency, competence, transparency, and effectiveness in an effort both to increase trust and public consent as well as limit liability.

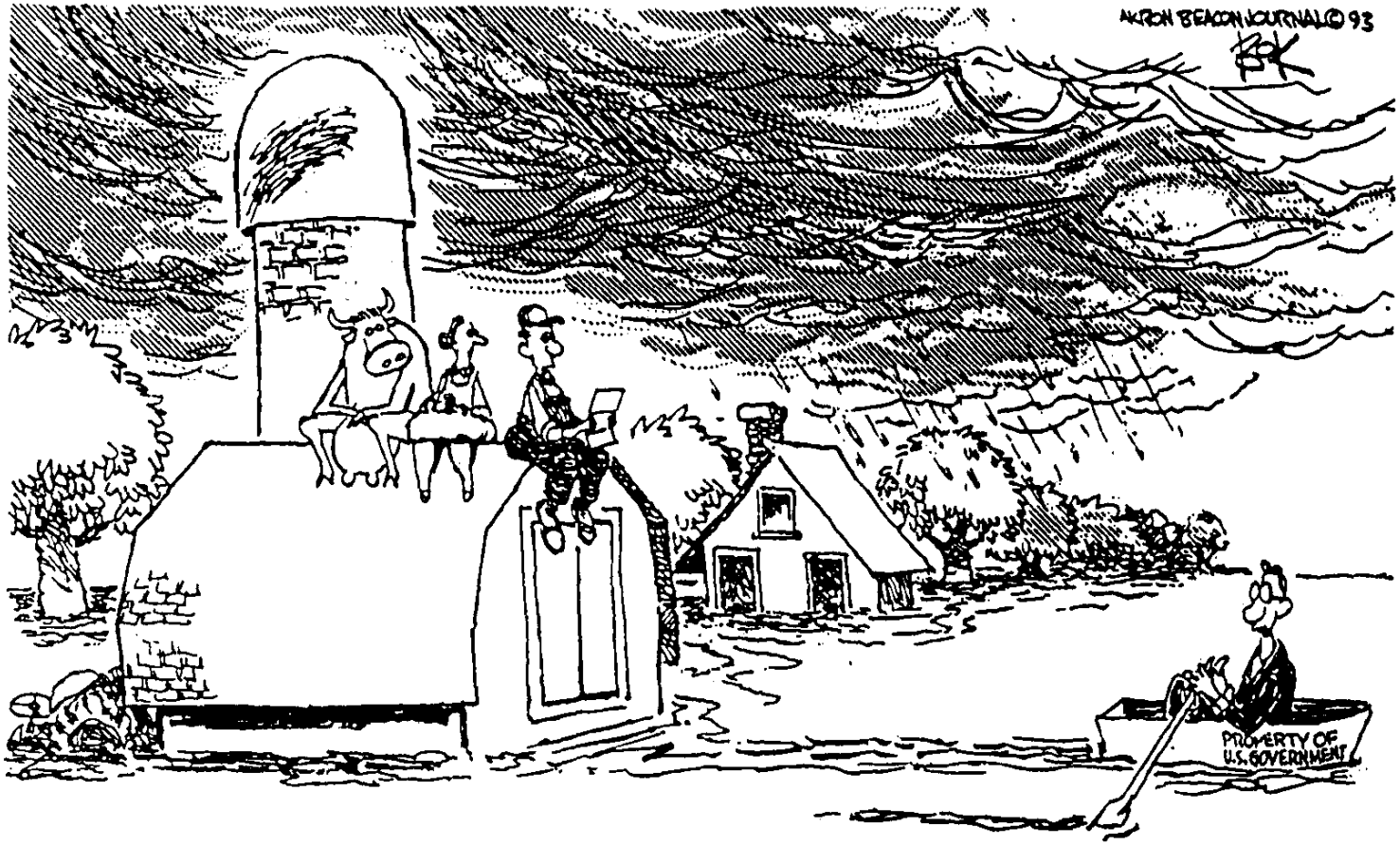
Standards and Sustainability

Voluntary
Brands
Certification
Federal programs
Regulatory
Cap and trade
Federal regulations



Frameworks, Indicators and Application

Role of Government?



BOK, 1993; REPRINTED WITH PERMISSION FROM THE AKRON BEACON JOURNAL

"LOOKS LIKE A DISASTER RELIEF CHECK, CROP LOSS COMPENSATION, AND A FINE FOR DISTURBING A WET LAND."

Available online at www.sciencedirect.com

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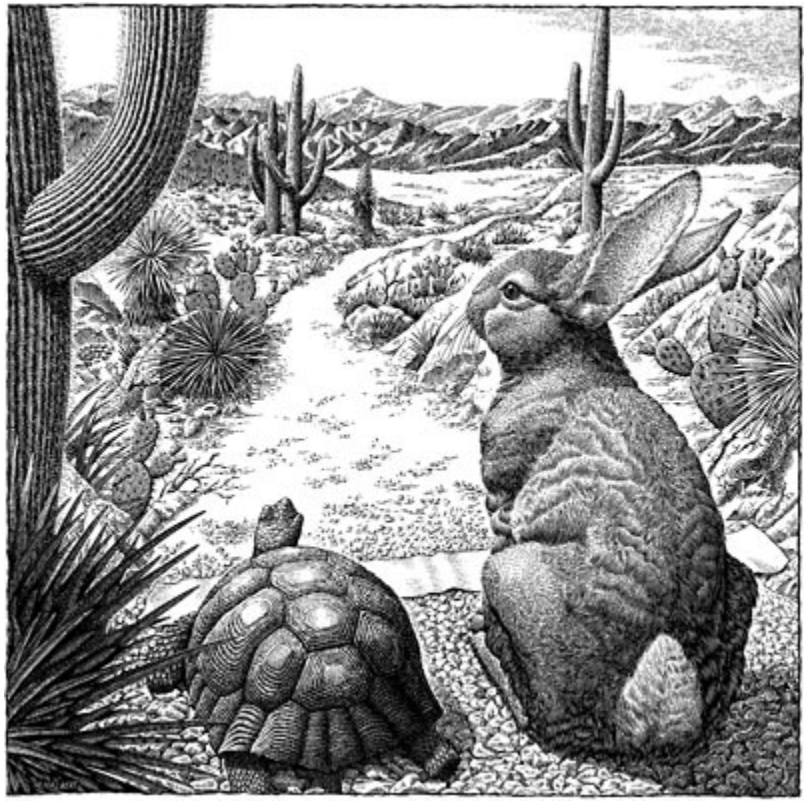
Current Opinion in Environmental Sustainability

Global governance of soil resources as a necessary condition for sustainable development

Luca Montanarella[1] and Ronald Vargas[2]



It is go time

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NATURE | CORRESPONDENCE

Global soil week: Put soil security on the global agenda

Andrea Koch, Alex McBratney & Rattan Lal

Affiliations | **Corresponding author**

Nature **492**, 186 (13 December 2012) | doi:10.1038/492186d

Published online 12 December 2012

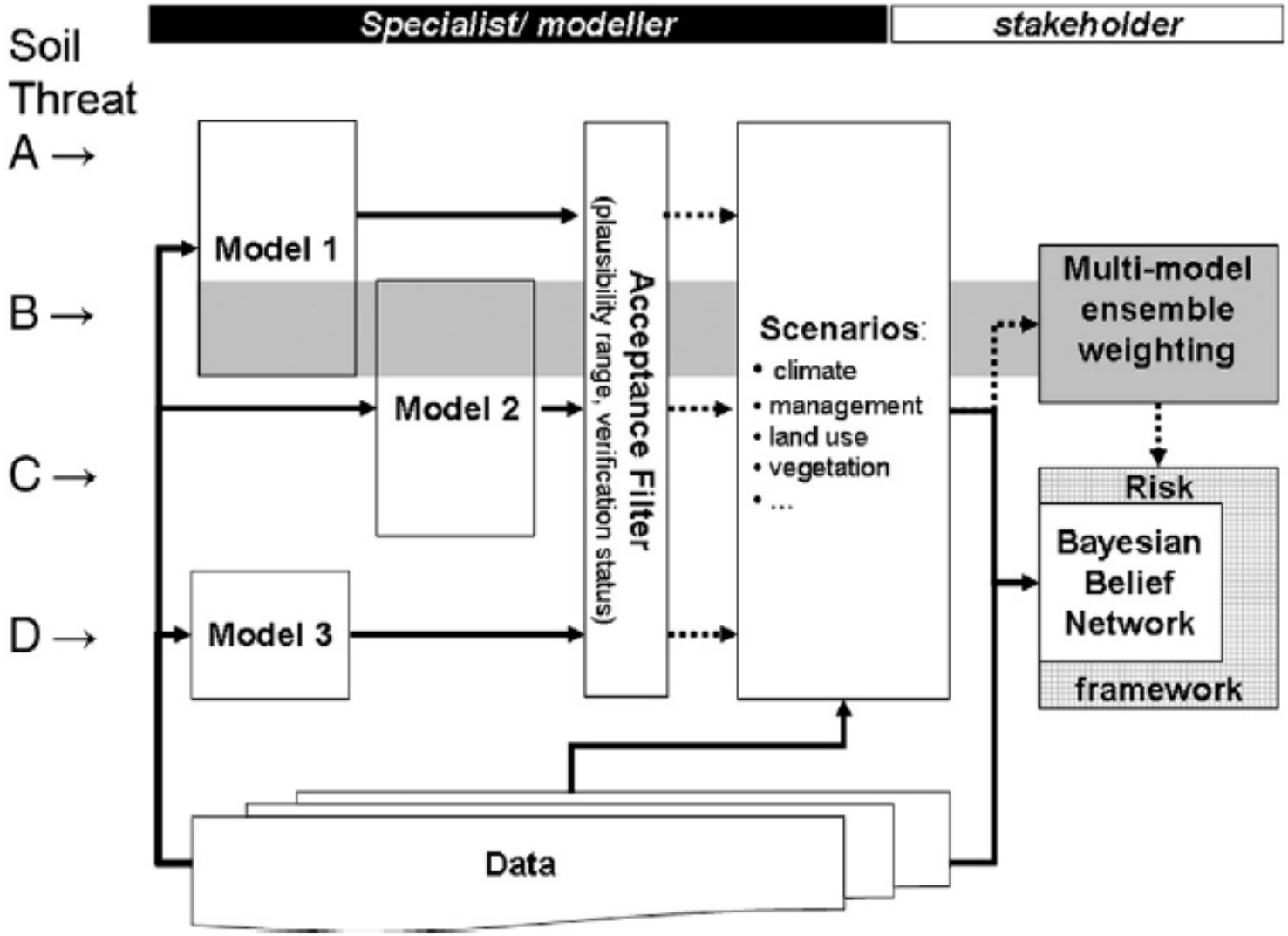
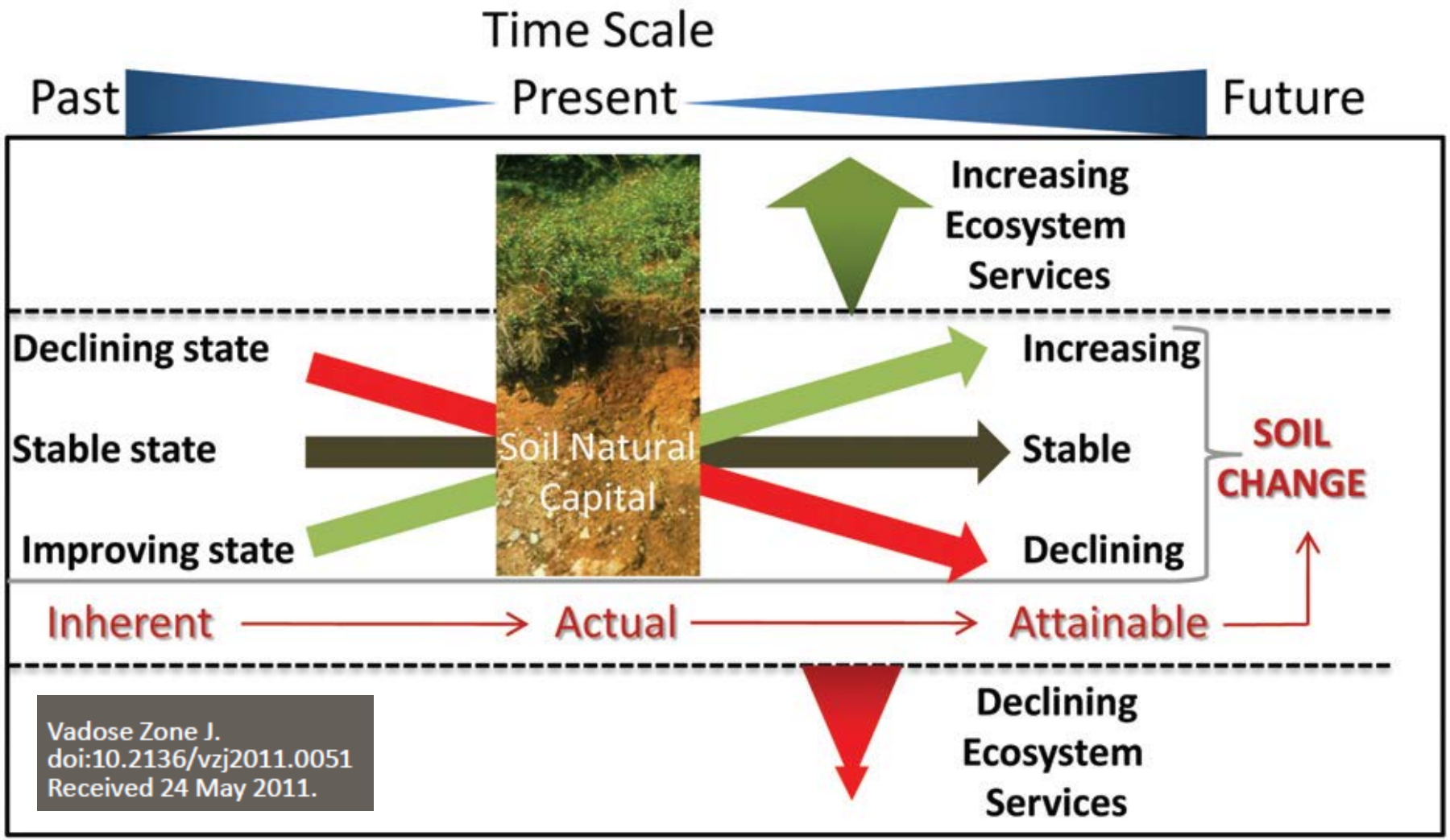


Fig. 3. Options to use uncertain models for digital soil assessment in an EU-soil threat context.

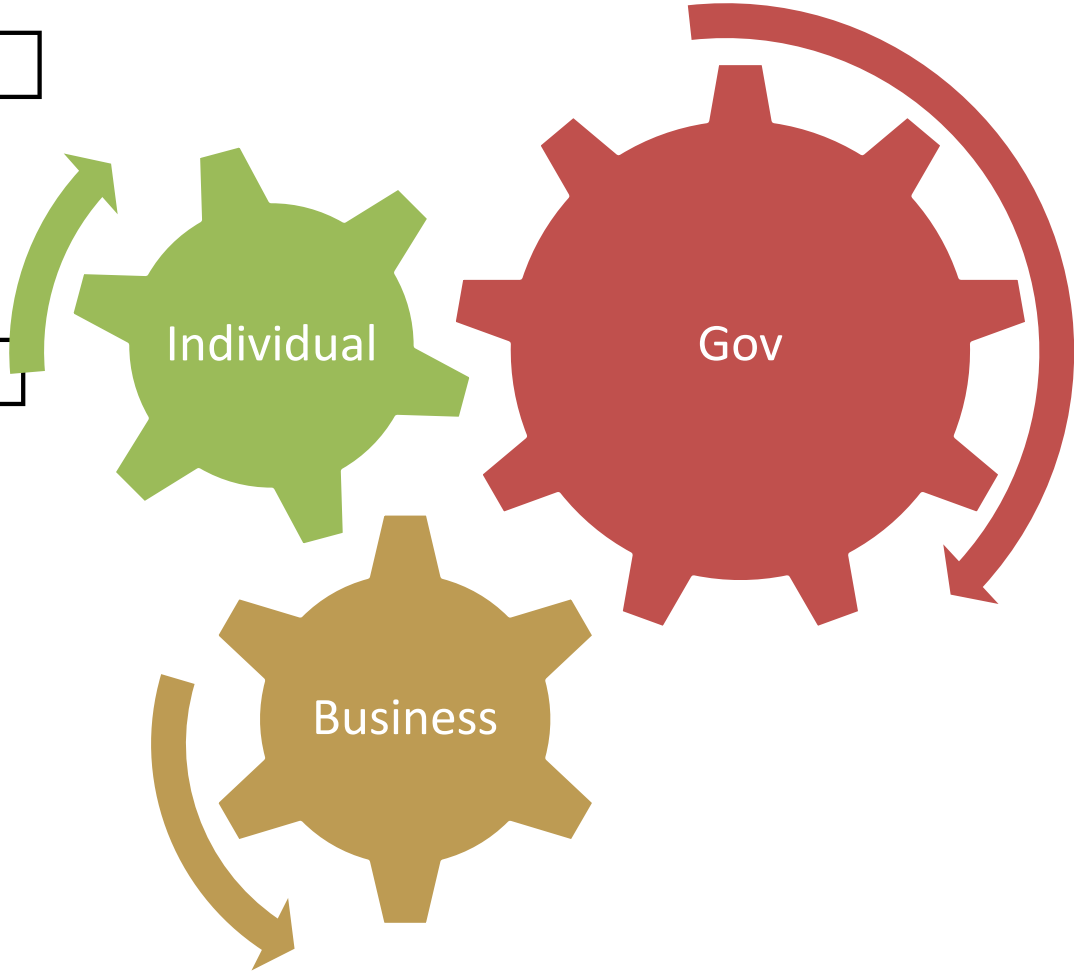
Soils as a Dynamic System



Robinson et al.

Need integrative geospatial monitoring and measurement approaches

- [illegible]
- [illegible]



Sustainable agriculture standard would

- Define what constitutes sustainable agriculture in the US,
- Establish a new sustainable food market,
- Potentially could cause significant economic, social, and environmental transformations.

National Sustainable Agriculture Std

1.1 Description of the standard

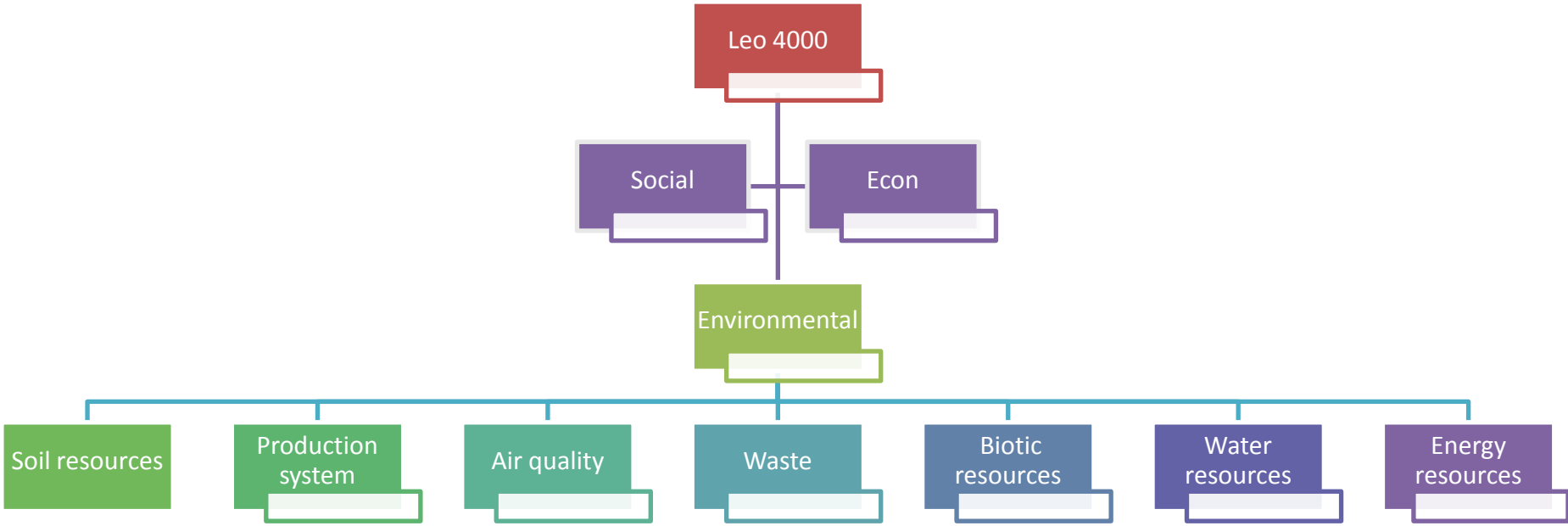
- Delineates outcome-oriented environmental, social and economic criteria and indicators for assessing the sustainability of a given farm or ranch operation;
- Provides a framework for demonstrating continual improvement towards fulfilling sustainability goals appropriate to the specific operation; and
- Identifies multiple levels of achievement or tiers of sustainability that can be communicated to customers or used for assessing progress internally.

1.2 Scope of the standard

- **This standard currently addresses the production of plants. In the future it is expected that the standard may be expanded to address animal production as well.**

1.3 Description of the format of the standard

- **The standard is structured with the following components:**
  - Principles
    - » The Principles identify over arching objectives for sustainable agriculture
  - Criteria
    - » The Criteria identify key areas of or achievement in sustainable agriculture
  - Indicators
    - » The Indicators identify measurable components of achievement for each Criteria
  - Performance levels
    - » The performance levels identify measurable levels of performance under each indicator
  - Tiers
    - » The tiers indicate the overall level of performance by a producer using the standard.



Soil Resource Indicators	PLS
Soil Resources Description	4
Soil Erosion	7
Soil Structure and Tilth	10
Soil Organic Matter (SOM)	13
Soil Biological Activity	8
Soil Degradation (other than Erosion)	14
Soil Nutrients	7

Keystone Field to Market

www.fieldtomarket.org/fieldprint-calculator/

keystone sustainable ag std

Most Visited | Getting Started | Suggested Sites | Web Slice Gallery | Blackboard Learn | Blackboard Learn | Web of Knowledge [v.... | Main Menu

Field to Market

Home | Fieldprint Calculator | National Report | From the Field | Resources | News | About Us

Welcome to the Fieldprint Calculator - a tool to help you analyze how your decisions relate to sustainability.

The Fieldprint Calculator is a free online tool for growers to voluntarily and securely analyze how their management choices impact natural resources and operational efficiency. To try out the Fieldprint Calculator, follow the steps below or login now. Or, you can learn more by exploring our frequently asked questions. Field to Market continues to learn about the relationships between agricultural practices and sustainability outcomes. Updates to the Calculator will be made to continue incorporating the best available information about these impacts.

Step 1 - Login

The calculator lets you login using one of the following two options: 1) register and create an account to keep your data secure and confidentially saved for future sessions, or 2) login as a guest user to test the Calculator without saving any data. No matter which option you choose, your personal information, production information, and individual results are for your use only and are not shared with any third party unless you specifically agree to a data-sharing option. For more information, read our Privacy Policy. For more information, read our Privacy Policy.

Step 2 - Enter Field Information

In the Start Tab, you will locate your specific field and enter basic information about your soils, crops, and management practices. The Calculator allows you to outline the specific field on a map, which automatically determines the acreage for your field as well as other characteristics such as soil and climate data. All of this foundational information will be used to calculate your Fieldprint for a variety of indicators on the following tabs.

Step 3 - Test Scenarios

On the Land Use, Soil Conservation, Soil Carbon, Irrigation Water Use, Energy Use, and Greenhouse Gas Emissions Tabs, use the bars on the right-hand side to compare your results to county, state, and national averages. You can also test new scenarios by changing the management practice information entered in the Start Tab.

Step 4 - View your Fieldprint

View the FieldPrint for your base scenario on the Summary Tab and print a report of the findings.

Step 5 - Analyze your Economics

Standards for Sustainable Agriculture

View the SAN Sta
Sustainable Sourc Policy
Palm Oil Statement

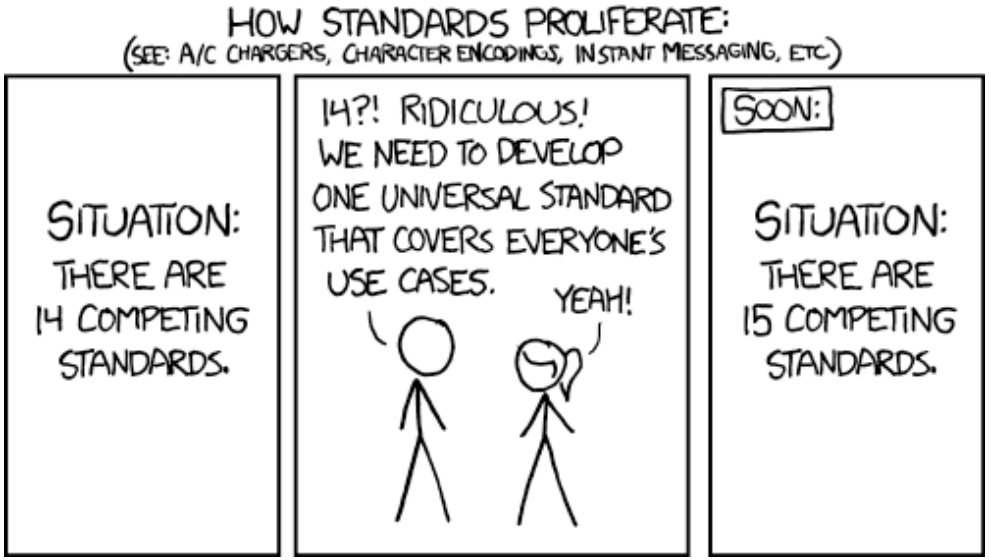
Rainforest Alliance Certified farms have met rigorous social and environmental standards set by the Sustainable Agriculture Network (SAN). For complete information about the standards, please visit the SAN website.

The SAN, the oldest and largest coalition of NGOs striving to improve commodity production in the tropics, develops criteria for responsible farm management. The standards developed by the SAN Secretariat comply with the Code of Good Practice for Setting Social and Environmental Standards of the International Social and Environmental Accreditation and Labeling (ISEAL) Alliance. The ISEAL Alli an association of leading voluntary international standard-setting and conformity assessment organizations that focu social and environmental issues. ISEAL Alliance members collaborate to build international recognition and legitima their programs. This collaboration represents a significant global movement to promote the interests of workers, communities and the environment in world trade.

Through the collaboration of ISEAL members, certification processes are continually improved. For Rainforest Allian Certified farms, the certification body Sustainable Farm Certification, International certifies farms that comply with S standards. Inspection bodies, typically local NGOs, are authorized by Sustainable Farm Certification, International t provide audit services for farmers and agricultural companies in their respective countries. Inspection bodies also offe knowledge and experience to help continually refine and develop Sustainable Agriculture standards.

Indicators- 'You get what you measure'

- Can make the 'invisible' visible
- Can be expensive to collect
- Can be used by individuals, companies, governments



Public Trust & Data

3 – Numerical estimate pedigree matrix for qualitative assessment of data uncertainty (adopted from Costanza et

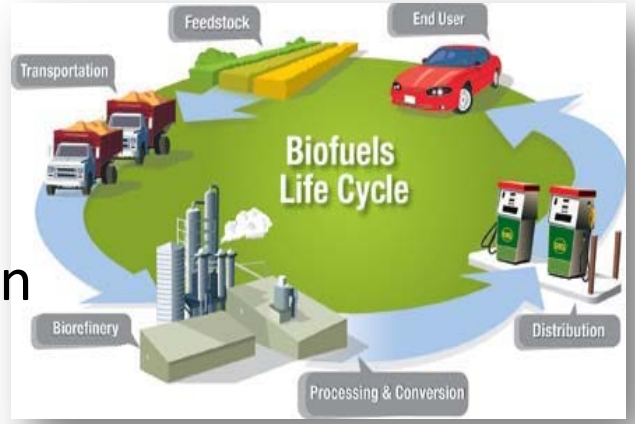
Theoretical, quality of model	Empirical, quality of data	Social, degree of accepta
Established theory	Experimental data	Total
Many validation tests	Statistically valid samples	All but cranks
Causal mechanisms understood	Controlled experiments	
Theoretical model	Historical/field data	High
Few validation tests	Some direct measurements	All but rebels
Causal mechanisms hypothesized	Uncontrolled experiments	
Computational mode	Calculated data	Medium
Engineering approximation	Indirect measurements	Competing schools
Causal mechanisms approximated	Handbook estimates	
Statistical processing	Educated guesses	Low
Simple correlations	Very indirect approximations	Embryonic field
No causal mechanisms	"Rule of thumb" estimates	
Definitions/assertions	Pure guesses	None

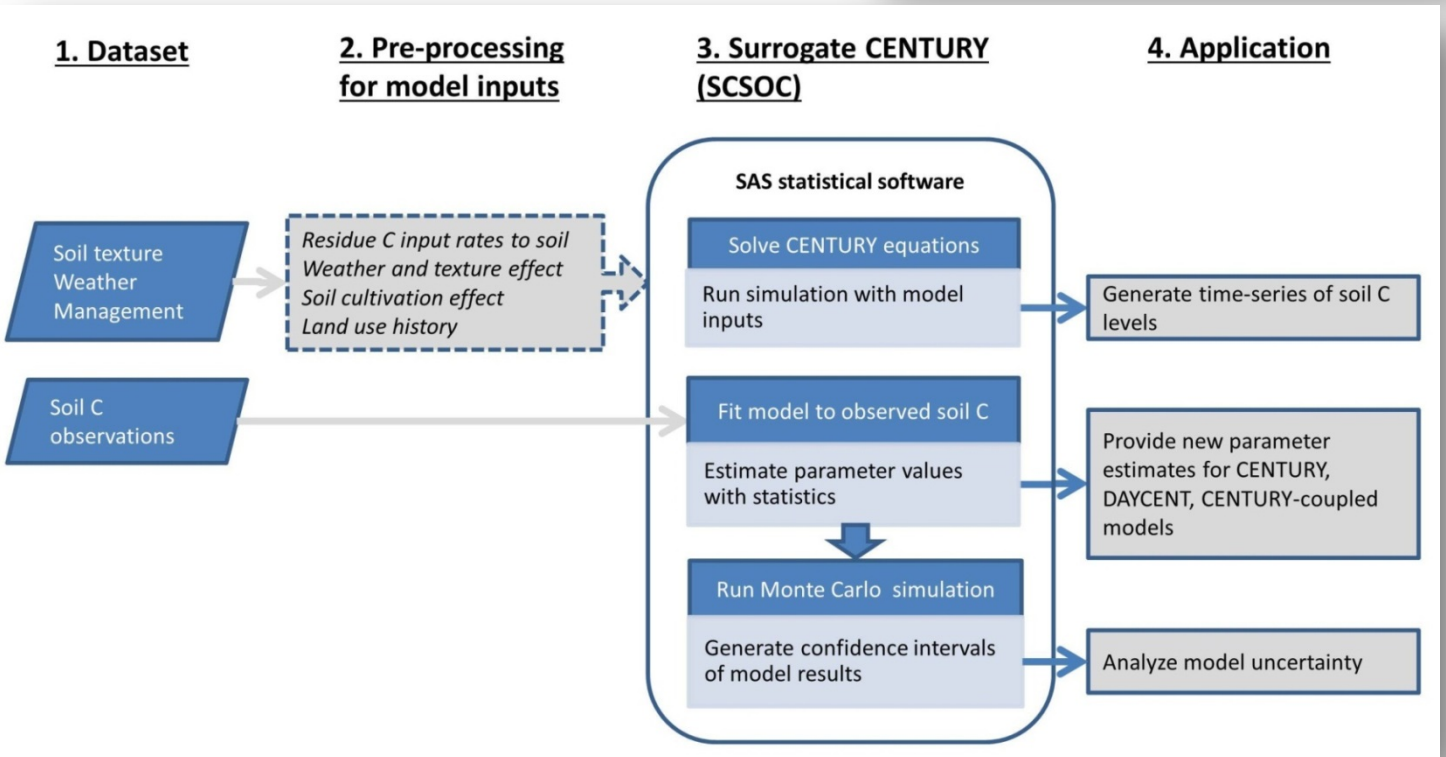
A new method for assessing the sustainability of land-use systems (I): Identifying the relevant issues

ECOLOGICAL ECONOMICS 68 (2009) 1275–1287

Direct Soil C Emissions Factors for Biofuels

The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model used to compute emissions for transportation fuels based on LCA

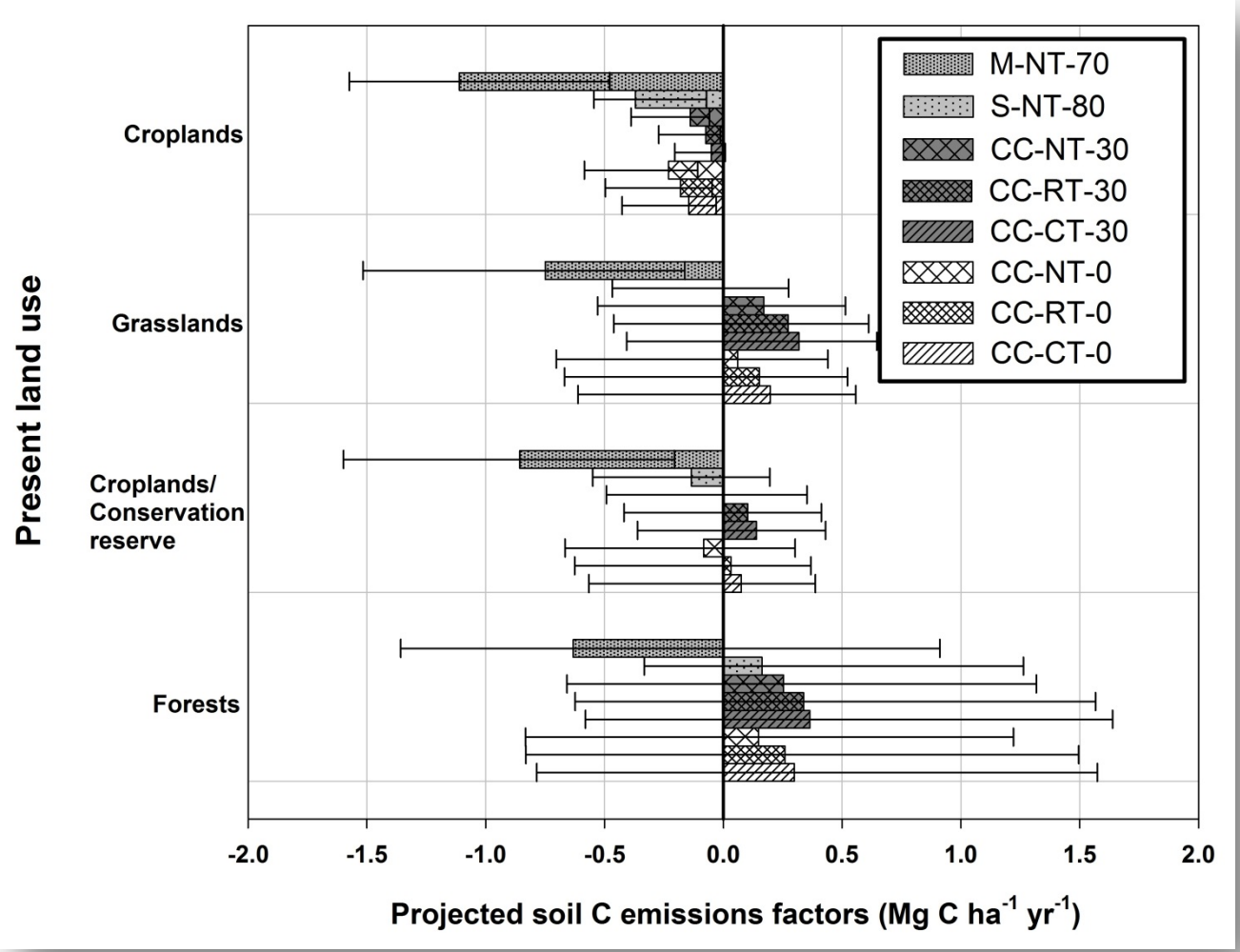




Land Use Change Scenarios

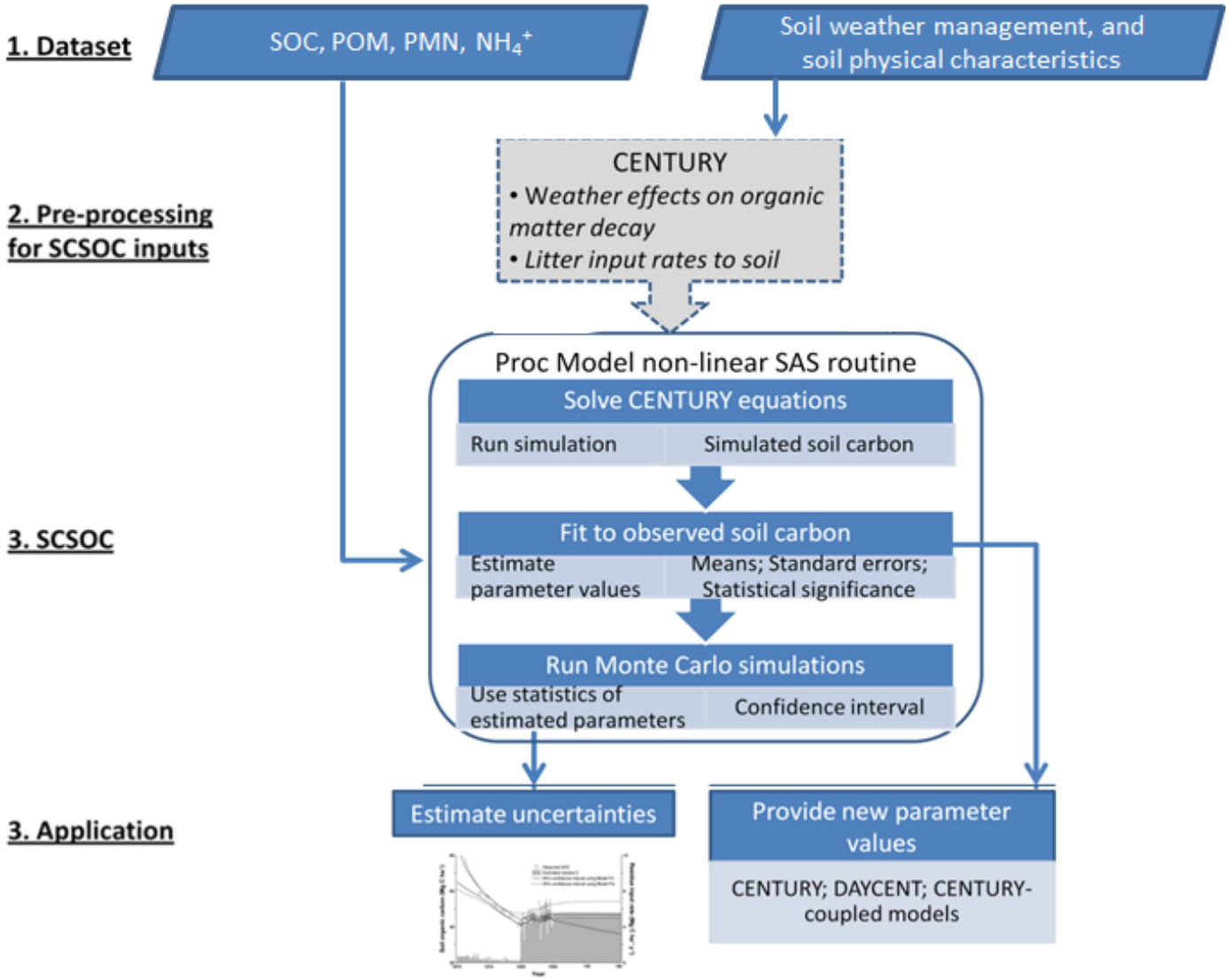
Scenario	Pristine	Early	Modern	Land use change		Stover or biomass harvest (%)
	(prior 1880)	(1881-1950)	(1951-2010)	(2011-2040)		
1	Grasslands	Croplands	Croplands	Corn-corn	Conventional tillage	0
2						30
3					Reduced tillage	0
4						30
5					No tillage	0
6						30
7				Switchgrass	No tillage	80
8				Miscanthus	No tillage	70
	Forest	Grasslands Forests	Grasslands Forests Conservation reserve			

Comparison of soil C emissions factors under different biofuel production pathways in 40 states



Kwon et al. 2013

Calibration with Dynamic Soil Properties (Indicators)



Bottom-up digital soil mapping. I. Soil layer classes

Geoderma 163 (2011) 38–44

Nathan P. Odgers [a,b,*], Alex. B. McBratney [a], Budiman Minasny [a]

[a] Faculty of Agriculture, Food and Natural Resources, McMillan Building A05, The University of Sydney, Sydney, New South Wales 2006, Australia
[b] Geospatial Research Unit, Division of Plant and Soil Sciences, West Virginia University. 3040 University Avenue, Suite 3037, Morgantown, West Virginia 26505, United State

Numerical classification of soil profile data using distance metrics

F. Carré [a,*], M. Jacobson [b]

Geoderma 148 (2009) 336–345

[a] European Commission, DG Joint Research Centre, Institute of Environment and Sustainability, Land Management and Natural Hazards Unit, TP 280, 21020 Ispra
[b] via Leopardi, 1, 21020 Ranco (VA), Italy

Disaggregation of legacy soil data using area to point kriging for mapping soil organic carbon at the regional scale

Ruth Kerry [a,b,*], Pierre Goovaerts [c], Barry G. Rawlins [d], Ben P. Marchant [e]

Geoderma 170 (2012) 347–358

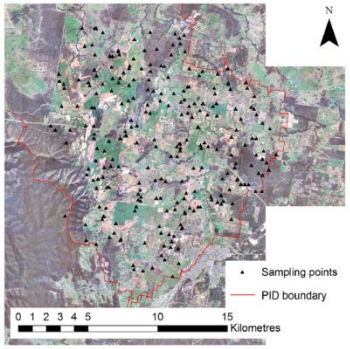


Fig. 2. Location of sampled profiles.

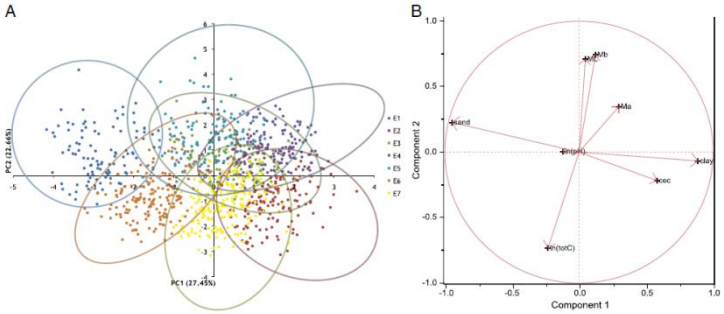
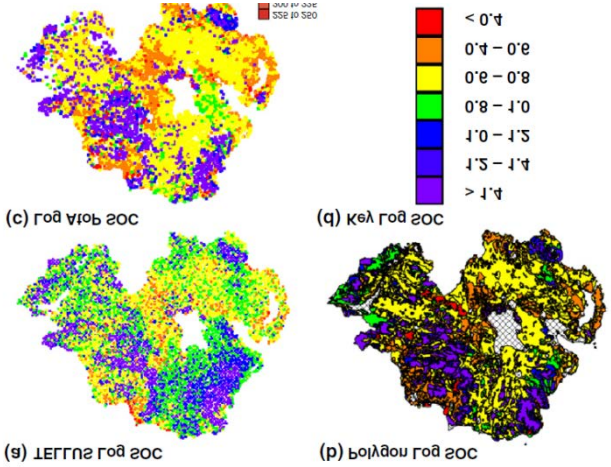


Fig. 5. (A) Biplot showing distribution of the observed soil layers on the first two principal components, coloured by the E layer class to which they had the maximum membership; (B) Loadings biplot showing contribution of the input data to the first two principal components.



Indicators and functional taxonomy?

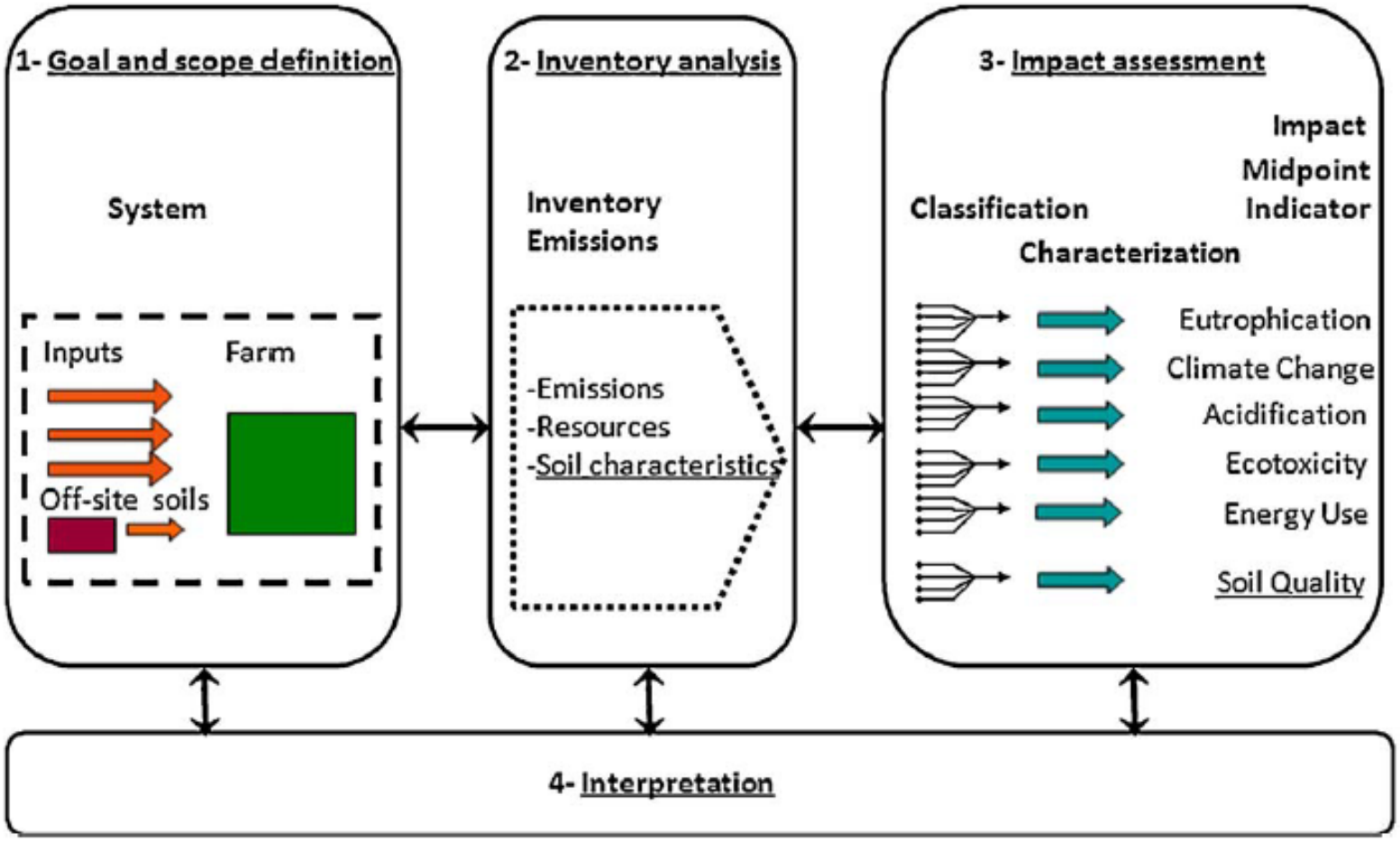


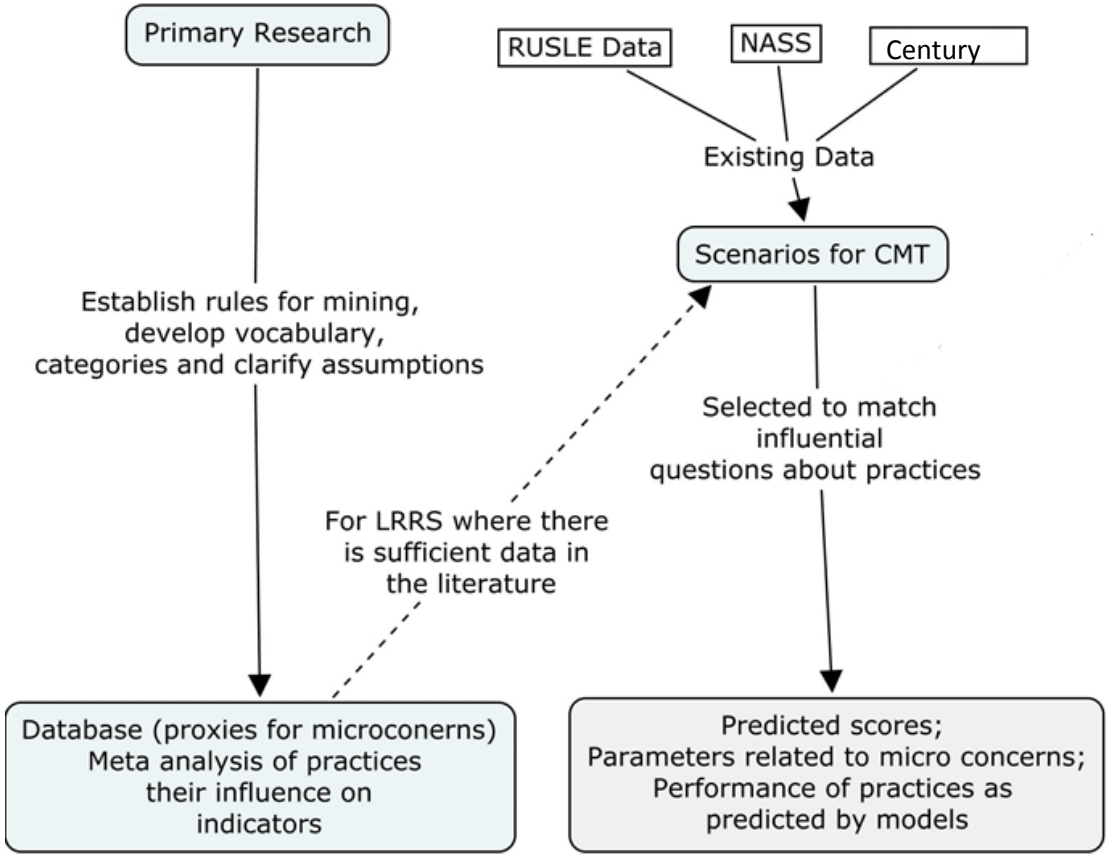
Fig. 1. Phases of Life Cycle As ng impacts on soil quality.

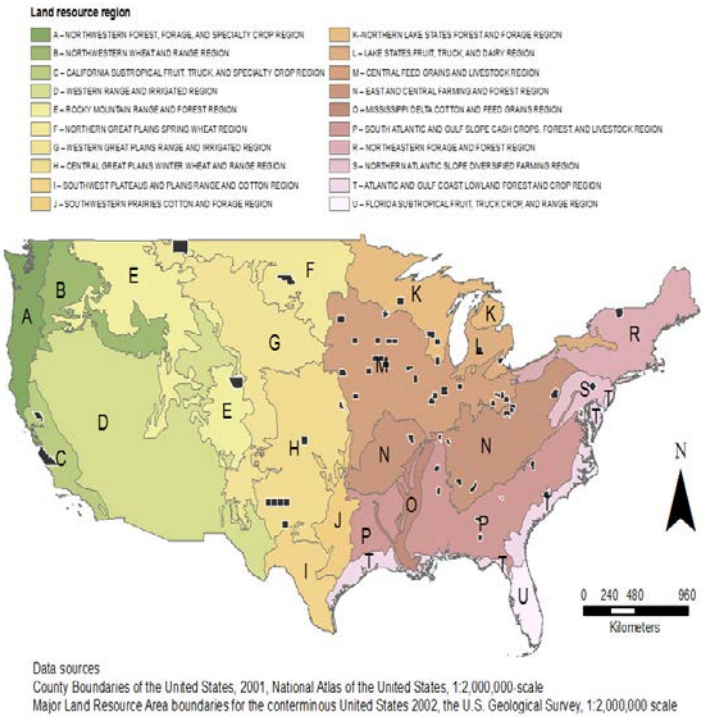
Ecological Indicators 18 (2012) 434–442

Conservation Measurement Tool

- **Soil erosion**
  - Sheet, rill, wind irrigation
  - ephemeral, gully
  - Stream bank, shoreline
  - road banks, construction sites
- **Soil quality**
  - organic matter depletion
  - Organic matter oxidation
  - salinity, other contaminations
  - nutrient cycling
  - compaction
- **Water quantity**
  - excess water
  - insufficient water
  - inefficient use of irrigation water
- **Water quality**
  - Sediment
  - Nutrients
  - Pesticides
  - Pathogens
  - salinity
- **Air quality**
  - airborne soil particulates
  - greenhouse and ozone gases
  - chemical spray drift
  - Odors
- **Plants**
  - diversity, health, vigor
  - declining populations
- **Animal**
  - domestic livestock cover, food, and water
  - terrestrial wildlife cover, food, connectivity, and water
  - declining populations
- **Energy**
  - energy conservation

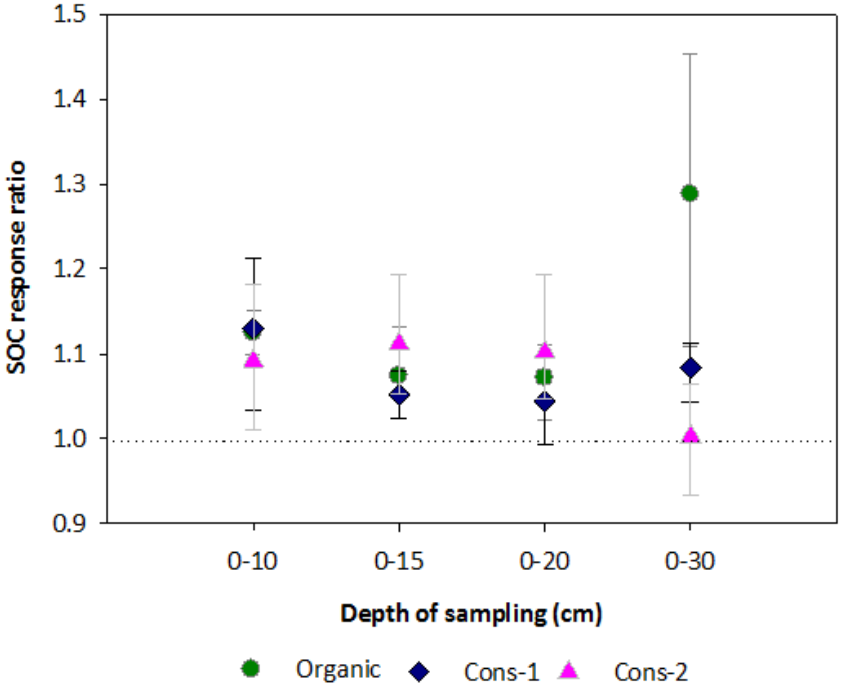
Need for Validation

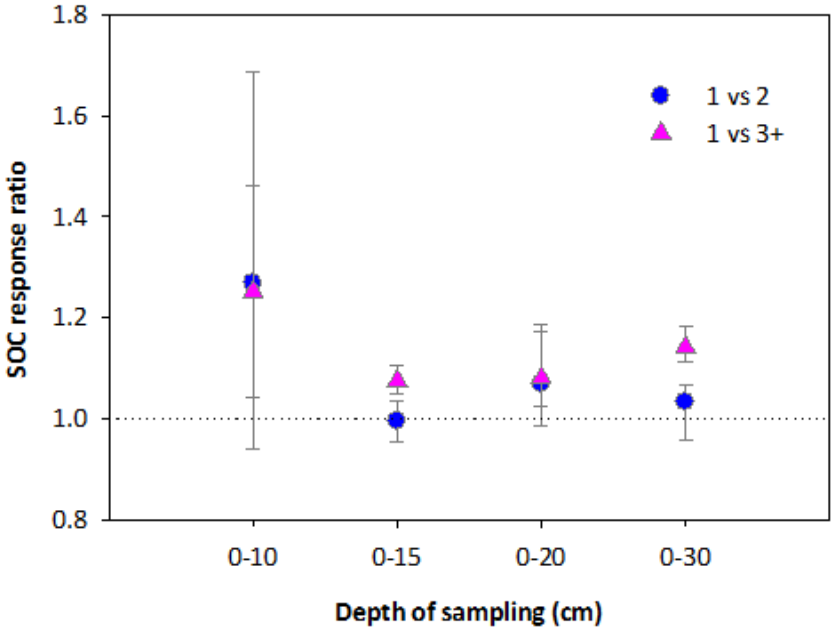




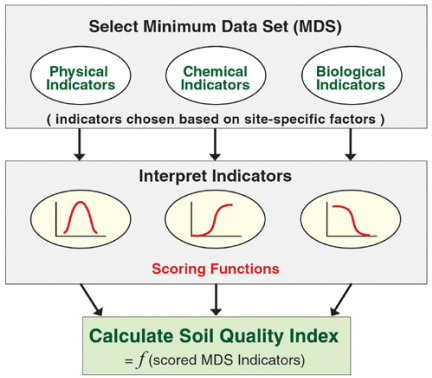
Conservation Measurement Tool sub scores for farming systems compared in meta-analysis.

Selected management practices	Cropping System			Rotation Length	
	Organic	Cons-1	Cons-2	2-year	≥3-year
	Score SOM Micro Concern				
Frequency harvested low residue crops	0	0	0	0	0
Frequency harvested high residue crops	3	3	3	3	3
Frequency of cover crops	5	-	-	-	5
Diversity within rotation (# of species)	5	-	-	-	5
Frequency of hay fallow	5	-	-	-	-
Spring tillage	-4	-4	-	-	-
Conservation tillage	0	0	-	-	-
No tillage with low residue	-	-	3	-	-
No tillage with high residue	-	-	5	-	-
Strip cropping	-	3	-	-	-
Residue management practices	4	4	4	-	-
Covered alleyways	3	-	-	-	-
Grassed waterways	0	0	0	-	-
Contour buffer strips	2	2	-	-	-
Application of fertilizers or manure	2	2	2	-	-
Manure or compost application	5	-	-	-	-
Total	30	10	17	3	13


1.5
1.4
1.3
1.2
1.1
1.0
0.9
SOC response ratio
0-10
0-15
0-20
0-30
Depth of sampling (cm)
Organic
Cons-1
Cons-2


1.8
1.6
1.4
1.2
1.0
0.8
SOC response ratio
1 vs 2
1 vs 3+
0-10
0-15
0-20
0-30
Depth of sampling (cm)

Soil Management Assessment Framework



SOIL SCI. SOC. AM. J., VOL. 68, NOVEMBER–DECEMBER 2004

ised for interpretatio ... icity (AWC) (g g^{-1}), bulk density (D_b) (S m^{-1}), microbial bio ... ralizable N (PMN) (mg kg^{-1}), sodium P) (mg kg^{-1}), and total organic C (TOC) (%), and the case study's minimum data set in which each indicator is found.

Indicator	Scoring Algorithm†	Fixed Parameters‡	Site-specific factors§	Selected site-specific factor references	Case study MDS¶
AGG	IF AGG > 50 AND [$y = a + b \times \cos(c \times AGG - d) < 1$], THEN $y = 1$ ELSE $y = a + b \times \cos(c \times AGG - d)$	$a = -0.8$, $b = 1.799$, $c = 0.0196$	$d = f$(iOM#, texture††, Fe_2O_3‡‡)	USDA (1966); Jastrow (1996)	NRI, IA
AWC	IF region = arid, THEN $y = (a \times b + c \times AWC^d)/(b + AWC^d)$, ELSE $y = a + b \times \cos(c \times AWC + d)$	$a = 0.0114$; $c = 1.088$; $d = 2.182$ $a = 0.477$; $b = 0.527$; $c = 6.878$	region§§, $b = f$(texture, iOM); $d = f$(texture)	Seybold et al. (1998); Gregory et al. (2000)	GA
D_b	IF texture > 35% clay, THEN $y = a - b \times \exp(-c \times D_b^d)$, ELSE $y = a - b \times \exp(-c \times D_b^d)$	$a = 0.994$ $a = 0.994$	$b, c, d = f$(texture, mineralogy¶¶); $b, c, d = f$(texture)	Grossman et al. (2001a, 2001b)	IA, GA
EC	IF EC ≤ 0.3, THEN $y = EC \times 3.33$, IF 0.3 < EC < T, THEN $y = 1$ IF EC ≥ T, THEN $y = a + b \times EC$	$a = 1 - bT$	T## $= f$(method†††, crop‡‡‡, texture); $b = f(T)$	Smith and Doran (1996); Maas (1990)	CA
MBC	$y = a/[1 + b \times \exp(-c \times MBC)]$	$a = 1.0$; $b = 40.478$	$c = f$(iOM, texture, season§§§)	Franzluebbers et al. (1996); Sparling (1997)	NRI, IA, GA
pH	$y = a \times \exp[-(pH - b)^2/(2 \times c^2)]$	$a = 1.0$	$b, c = f$(crop)	Whittaker (1959)	NRI, IA, CA, GA
PMN	$y = a/[1 + b \times \exp(-c \times PMN)]$	$a = 1$; $b = 50.1$;	$c = f$(iOM, texture, climate¶¶¶)	Franzluebbers (1998); Jones et al. (1982)	NRI, IA
SAR	IF EC ≤ 0.2, THEN $y = 1/[a + b\,(SAR^c)]$; IF 0.2 < EC ≤ 0.55, THEN $y = a + b \times SAR + c \times SAR^2 + d \times SAR^3 + e \times SAR^4 + f \times SAR^5 + g \times SAR^6$; IF EC > 0.55, THEN $y = a + b \times SAR + c \times SAR^2 + d \times SAR^3 + e \times SAR^4$	$a = 4.06$; $b = 0.79$; $c = 3.05$ $a = 0.8$; $b = 0.013$; $c = -0.07$; $d = 0.03$; $e = -0.005$; $f = 5.5 \times 10^{-4}$; $g = -2.1 \times 10^{-5}$ $a = 1.0$; $b = -0.07$; $c = 0.012$; $d = -6.8 \times 10^{-4}$; $e = -2.39 \times 10^{-5}$	EC EC EC	Hanson and Grattan (1992)	CA
Test P	IF $P \le$ max(for crop and method), THEN $y = (a \times b + c \times P^d)/(b + P^d)$; IF $P >$ max(for slope and method), THEN $y = a - b \exp(-c \times P^d)$, ELSE $y = 1$	$a = 9.26 \times 10^6$; $c = 1.0$; $d = 3.06$ $a = 1$; $b = 4.5$; $d = -2$	$b = f$(crop, TOC, texture, method†††) $c = f$(slope###, TOC, texture, method)	Havlin et al. (1999) Sharpley et al. (2003)	NRI, CA, GA
TOC	$y = a/[1 + b \times \exp(-c \times TOC)]$	$a = 1$; $b = 50.1$	$c = f$(iOM, texture, climate)	USDA (1966); Needelman et al. (1999)	NRI, IA, CA, GA

† Scoring algorithms transform data according to performance of soil function, where the indicator abbreviation is the observed measure (x) and y is the indicator score. Other variables in these algorithms are defined as either fixed parameters or site-specific factors in adjacent columns.
‡ Variables in the scoring algorithms that do not change.
§ Variables in the scoring algorithms that are site-dependent and, therefore, change as a function of site characteristics, such as soil type or climate.
¶ Listing of case studies that include the designated indicator in their mimimum data set (MDS).
# iOM = inherent organic matter levels grouped by soil suborder (USDA-NRCS, 1998; C. Seybold, personal communication, 2001).
†† Texture = soil texture grouped into five classes (Quisenberry et al., 1993).
‡‡ Fe_2O_3 = class includes ultic subgroup and Ultisols (USDA-NRCS, 1998).
§§ Region = major land resource areas grouped into arid versus non-arid or northern versus southern (USDA-SCS, 1981; Bailey, 1995).
¶¶ Clay mineralogy grouped as smectitic, glassy and other (USDA-NRCS, 1998).
T = crop- and EC method-dependent threshold level for EC beyond which yield reductions are expected to occur (Smith and Doran, 1996).
††† Method = the methodology used for the specified assay (Smith and Doran, 1996 [for EC]; Wolf and Baker, 1985 [for test P]).
‡‡‡ Crop = requirements for the current crop or, for EC, minimum threshold crop among all crops in a rotation (Smith and Doran, 1996; Maynard, 1997).
§§§ Season = expected seasonal changes as affected by climate (USDA-SCS, 1981; Bailey, 1995).
¶¶¶ Climate = major land resource areas classed by average annual precipitation and degree days above freezing (USDA-SCS, 1981; Bailey, 1995).
Slope P = slope classes for assessing P transport factors.

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Looking to the Literature

Table 7. Reference values for indicators of soil organic matter found in the organic literature.

Soil property	Management	(No. of sites)	Median	Concentration (Min–Max)	Citations
$g\,kg^{-1}$ SOC ($g\,C\,kg^{-1}$ soil)	Organic Conventional	13 14	16.7 16.2	10.0–28.0 9.0–26.0	Drinkwater et al.[4]; Marriott and Wander[7]; Khan et al.[44]; Delate and Cambardella[51]; Wander et al.[61]; Teasdale et al.[66]; Wander et al.[67]; Wander and Bollero[83]; Needelman et al.[84]; Poudel et al.[85]; Maughan et al.[86]; Varvel and Wilhelm[87].
TN ($g\,N\,kg^{-1}$ soil)	Organic Conventional	9 13	1.5 1.2	0.9–2.4 0.9–1.9	Drinkwater et al.[4]; Marriott and Wander[7]; Khan et al.[44]; Delate and Cambardella,[51]; Wander et al.[61]; Teasdale et al.[66]; Wander et al.[67]; Wander and Bollero[83]; Needelman et al.[84]; Poudel et al.[85]; Maughan et al.[86]
POM-C ($g\,C\,kg^{-1}$ soil)	Organic Conventional	7 7	2.9 2.2	2.0–5.8 1.8–2.5	Marriott and Wander[7]; Wander et al.[67]; Maughan et al.[86]; Mirsky et al.[88]; Coulter et al.[89]; Hernandez-Ramirez et al.[90]
POM-N ($g\,N\,kg^{-1}$ soil)	Organic Conventional	2 5	0.2 0.1	0.2–0.2 0.1–0.2	Marriott and Wander[7]; Maughan et al.[86]; Coulter et al.[89]; Hernandez-Ramirez et al.[90]
POM C:N ratio	Organic Conventional	2 5	19.0 18.0	15.0–23.0 15.0–18.0	Marriott and Wander[7]; Maughan et al.[86]; Coulter et al.[89]; Hernandez-Ramirez et al.[90]
FDA (μg FDA g^{-1} dry soil h^{-1})	Organic Conventional	4 5	23.0 20.0	18.0–66.0 12.0–149.0	Drinkwater et al.[4]; Workneh and van Bruggen[91]; van Bruggen[92]; Mendes et al.[93]; Darby et al.[94]
IL-N (mg NH_4-N kg^{-1} soil)	Organic Conventional	2 18	334.0 224.0	165.0–503.0 98.0–465.0	Marriott and Wander[7]; Khan et al.[44]; Spargo et al.[64]; Wander et al.[67]; Ruffo et al.[95]
PMN (mg NH_4-N kg^{-1} soil $week^{-1}$)	Organic Conventional	8 10	6.4 4.7	4.5–29.4 4.3–22.0	Drinkwater et al.[4]; Needelman et al.[84]; Clark et al.[96]; Liebig and Doran[97]; Idowu et al.[98]

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Points I'd Like to Make

- There is immediate need for site and system specific data and interpretation delivered through trusted frameworks
- We can not let perfection get in the way of the good
- Indicators of soil quality are and will increasingly be used to assess sustainability
- Soil Survey of DSPs would be of tremendous value