How valuable is the soil resource? How can we measure it? How can we communicate its value to the public?

ISRIC Spring School 2018

David G Rossiter

Guest Researcher, ISRIC – World Soil Information

Adjunct Associate Professor, Section of Soil & Crop Sciences, Cornell University (USA)

Visiting Professor, Nanjing Normal University (PRC)

01-June-2018

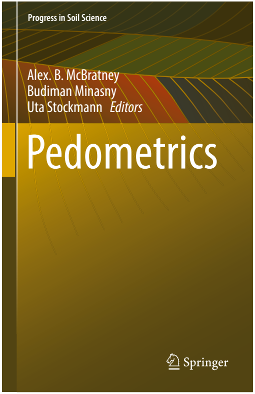
Outline

1. Concepts of Value
2. Valuation
3. Land evaluation
4. Ecosystem Approach
5. Communicating value

Reference

Rossiter, D. G., Hewitt, A. E., & Dominati, E. J. (2018). *Pedometric Valuation of the Soil Resource*. In *Pedometrics* (pp. 521–546). Springer
`https://doi.org/10.1007/978-3-319-63439-5_17`

Alan Hewitt: Manaaki Whenua – Landcare Research, New Zealand
Estelle Dominati: AgResearch Grasslands, Palmerston North, New Zealand



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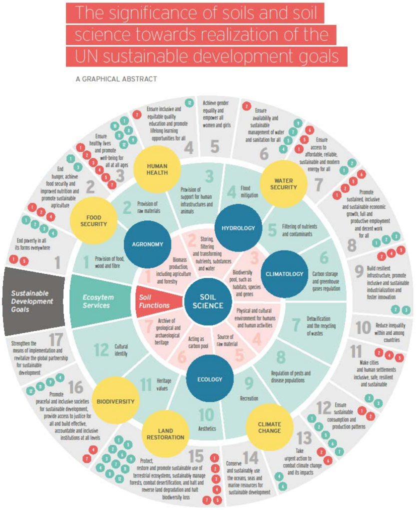
Concepts of "Value"

"Nowadays people know the price of everything and the value of nothing"

Oscar Wilde

– *The Picture of Dorian Gray, 1890*

Soils in the Sustainable Development Goals



FORUM paper: The significance of soils and soil science towards realization of the UN sustainable development goals (SDGs)
Keesstra, S.D., Bouma, J., Wallinga, J., Tittonell, P., Smith, P., Cerdà A., Montanarella, L., Quinton, J., Pachepsky, Y., van der Putten, W.H, Bardgett, R.D, Moolenaar, S., Mol, G., Fresco, L.O.

Definitions of "Value"

- "quality of an object that permits **measurability** and therefore **comparability**"
- "worth, desirability, utility, [and] qualities on which these depend" (OED) – worth **to whom**? and **for what**?
  - explicitly **anthropocentric** – we are the ones doing the valuing
- "Value" measured by some common means of exchange (i.e., money) or a more abstract measure?

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Valuation

[W]hen you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind.

William Thompson (Lord Kelvin)

– Lecture to the Institution of Civil Engineers, 3 May 1883

Tafí del Valle, Tucumán, Argentina

Economic contexts

neo-classical "free"-market supply/demand, everything valued by willingness to pay; actors maximize utility

- often semi-controlled, guided by limitations on, or supplements to, market forces
- i.e., regulations, subsidies

command, planned values are set according to whole-society values, what things "should" cost to maximize overall social benefit (e.g., ex-Soviet Union)

ecological attempts to acccount for inter-dependence of natural ecosystems and human activity

Valuation

- Attempt to “value” the soil in terms that can be related to **monetary value**
- Explicitly **neo-classical economics** viewpoint
- Useful for **equitable taxation** (e.g., German *bonitierung* system) . . .
- Useful for **equitable land exchange**, e.g., consolidation . . .
- . . . within a neo-classical economic framework (free exchange)

Valuation indices

- Ratio value 0 . . . 100 or similar
- No attempt to value in money terms
  - Important: the **relative** valuation must be seen as **fair**, for e.g., taxation
- Combines a set of **indicators** (land characteristics) relevant for the use value
  - soil properties, climate indices, infrastructure availability . . .
- Only relevant for stable situations (no land degradation, common set of uses)

Storie index

Storie, R. E. (1978). *The Storie Index soil rating revised* (Special publication No. 3203). University of California, Division of Agricultural Sciences.

Riquier, J. (1974). *A summary of parametric methods of soil and land evaluation*. In Approaches to land classification, Soils Bulletin 22. Rome: FAO.

Weighted average, multiplicative, geometric:

$$S = \sum_{i=1}^{q} \mathrm{LC}_i \cdot w_i \quad \text{where} \sum_{i=1}^{q} w_i = 1 \qquad (2a)$$

$$S = \prod_{i=1}^{q} \mathrm{LC}_i \qquad (2b)$$

$$S = \sqrt[q]{\prod_{i=1}^{q} \mathrm{LC}_i} \qquad (2c)$$

Storie Index Soil Rating

R. Earl Storie is Professor Emeritus, Soils and Plant Nutrition and former Soil Technologist in the Experiment Station, Berkeley.

The Storie Index

This method of soil rating, known as the Storie Index, is based on soil characteristics that govern the land's potential utilization and productive capacity. It is independent of other physical or economic factors that might determine the desirability of growing certain plants in a given location.

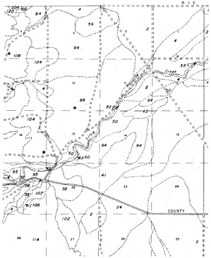
Essentially the present revision sets up a new factor C to evaluate slope; the original factor **C** is now designated as factor **X.**

Percentage values are assigned to the characteristics of the soil itself, including the soil profile (factor **A);** the texture of the surface soil (factor B); the slope (factor C); and conditions of the soil exclusive of profile, surface texture, and slope—for example, drainage, alkali content, nutrient level, erosion, and microrelief (factor **X).** The most favorable or ideal conditions with respect to each factor are rated **at 100** per cent. The percentage values or ratings for the four factors are then multiplied, the result being the Storie Index rating of the soil.

The characteristics of the **soil** profile (factor **A)** are essentially the features of the subsurface layers. For California purposes the soils have been divided into nine profile groups.* For example, soils that are deep and readily pervious to roots and water (listed in profile group I in the soil-rating chart) are rated at 100 per cent. Profiles with dense clay subsoils (listed in profile group IV on the soil-rating chart) are rated lower. Primary or residual soils (listed in profile groups VII, VIII, and IX) are rated in accordance with the depth to bedrock.

Next, the soils are rated on the basis of the texture **of** the surface soils (designated as factor **B).** Medium-textured soils, such as the loams and the silt loams, are rated highest; the extremes in texture, such as sands and clays, lower.

Rating of the slope of the land is considered in factor **C.** Nearly level or gently sloping land is rated at 100 per cent. **As** the slope increases, the rating for this factor decreases. **As** shown in the soil-rating chart, single letters are used to indicate simple slopes, and double letters to indicate compound slopes. The per-cent slope expresses the number of feet rise or fall for 100 feet horizontal distance.



Conditions exclusive of profile, soil texture, and slope are considered in factor **X** on the soil-rating chart. These conditions consist of drainage, alkali or salt content, general nutrient level, acidity, erosion, and microrelief (surface regularity). If two or more conditions exist that are listed under factor **X,** the ratings for each are treated independently; that is, they are multiplied in order to secure the factor X rating.

* Storie, **R.** Earl, and Walter **W.** Weir, ***Manual*** *for Identifying and Classifying California* **Soil** *Series,* 1948, with Supplement, **1958.** Published by Associated Students' Store, Univ. **of** Calif., Berkeley.

Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

REVISED DECEMBER **1978**

SPECIAL PUBLICATION 3203

SOIL-RATING CHART

(Storie Soil Index rating= factor A x factor B x factor C x factor X)

FACTOR A—Rating on character of Physical profile

	per cent
I. Soils on recent alluvial fans. flood plains. or other secondary deposits having undeveloped profiles	100
x-shallow phases (on consolidated material). 2 feet deep	50–60
x-shallow phases (on consolidated material). 3 feet deep	70
g-extremelygravelly subsoils	80–95
s-stratified clay subsoils	80–95
II. Soils on young alluvial fans. flood plains. or other secondary deposits having slightly developed profiles	95–100
x-shallow phases (on consolidated material). 2 feet deep	50–60
x-shallow phases (on consolidated material). 3 feet deep	70
g-extremely gravelly subsoils	80–95
s-stratified clay subsoils	80–95
III. Soils on older alluvial fans. alluvial plains. or terraces having moderately developed profiles (moderately dense subsoils)	80–95
x-shallow phases (on consolidated material). 2 feet deep	40–60
x-shallow phases (on consolidated material). 3 feet deep	60–70
g-extremely gravelly subsoils	60–90
IV. Soils on older plains or terraces having strongly developed profiles (dense clay subsoils)	40-80
V. Soils on older plains or terraces having hardpan subsoil layers	
at less than 1 foot	5–20
at 1 to 2 feet	20–30
at 2 to 3 feet	30-40
at 3 to 4 feet	40–50
at 4 to 6 feet	50–80
VI. Soils on older terraces and upland areas having dense clay subsoils resting on moderately consolidated or consolidated material	40–80
VII. Soils on upland areas underlain by hard igneous bedrock	
at less than 1 foot	10–30
at 1 to 2 feet	30–50
at 2 to 3 feet	50–70
at 3 to 4 feet	70–80
at 4 to 6 feet	80–100
at more than 6 feet	100
VIII. Soils on upland areas underlain by consolidated sedimentary rocks	
at less than 1 foot	10–30
at 1 to 2 feet	30–50
at 2 to 3 feet	50–70
at 3 to 4 feet	70–80
at 4 to 6 feet	80–100
at more than 6 feet	100
IX. Soils on upland areas underlain by softly consolidated material	
at less than 1 foot	20-40
at 1 to 2 feet	40–60
at 2 to 3 feet	60–80
at 3 to 4 feet	80–90
at 4 to 6 feet	90–100
at more than 6 feet	100

FACTOR B---Rating on basis of surface texture

	per cent
Medium-textured:	
fine sandy loam	100
loam	100
silt loam	100
sandy loam	95
silty clay loam, calcareous	95
silty clay loam. noncalcareous	90
clay loam. calcareous	95
clay loam. noncalcareous	85—90
Heavy or fine-textured:	
silty clay. highly calcareous	70—90
silty clay. noncalcareous	60—70
clay. highly calcareous	70—80
clay. noncalcareous	50—70
Light or coarse-textured:	
coarse sandy loam	90
loamy sand	80
very fine sand	80
fine sand	65
sand	60
coarse sand	*30-60*

Rating the Soil for a Tract of Land

The index for each soil type in the tract is calculated separately, and then *a* rating for the entire tract is obtained by weighing each soil index according to the proportion of the acreage of that soil in the tract. As an example, using the soil map on the back page the rating of the tract is determined as follows:

1. Index for the area Yl-A (Yolo loam, nearly level): This is a recent alluvial soil, deep, smooth, well drained.

	Rating in per cent
Factor **A:** Yolo series, profile group **I**	100
Factor B: loam texture	**100**
Factor C: slope A, nearly level	100
Factor **X:** no other modifying factors	**100**

Indexrating=100%x100%x100%x100%=100%

2. Index for Ac-BB (Antioch clay loam, undulating): This is a claypan terrace soil with undulating topography.

	Rating in per cent
Factor **A:** Antioch series, profile group **IV**	**60**
Factor B: clay loam texture	85
Factor C: undulating topography	95
Factor **X:** no other modifying factors	100

Index rating = **60%** x 85% *x* 95% *x* 100%=48%

3. Index for Acl-CC (Altamont clay loam, rolling): This is *a* brown upland soil from shale parent material; redrock at a depth of 3 feet. Rolling topography, moderate sheet erosion, with occasional gullies.

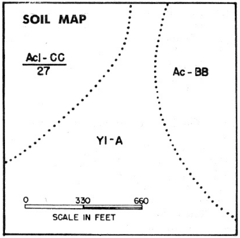
	Rating in per cent
Factor **A:** Altamont series, profile group VIII	70
Factor B: clay loam texture	85
Factor C: rolling topography	90
Factor **X:** moderate sheet erosion with shallow gullies	70

Index rating = 70% x 85% *x* 90% x 70% = 37%.

4. The index for the entire tract shown on the map may then be calculated according to the acreage **of** each soil, as follows:

	Index		Acreage		
Yolo loam	100	*x*	10	=	1,000
Antioch clay loam	48	*x*	5	=	240
Altamont clay loam	37	*x*	5	=	185
			20		1,425

Index rating for the tract $= \frac{1{,}425}{20} = 71\%$.



MAP SYMBOL	SOILS	ACREAGE	INDEX
Yl-A	YOLO LOAM	10	100
Ac-BB	ANTIOCH CLAY LOAM	5	48
Acl-CC 27	ALTAMONT CLAY LOAM	5	37

THIS LEAFLET is a revision of the soil-rating chart published originally by the author in Bulletin 556, *An Index for Rating the Agricultural Value of Soils,* **1933,** and later **in** the revised edition **of 1937,**

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Bogor-Cibodas highway, W Java

Land evaluation

- FAO 1976 "Framework"[1]; replaces earlier approaches, e.g. Land Capability Classification, USBR Suitability for Irrigation
- "the process of **assessment of land performance** when [the land is] used for **specified purposes** [Land Utilization Types (LUT)]".
- Matches Land Use Requirements (LUR) of the LUT with Land Qualities (LQ) of the land
- The LQ are quantified based on indicator Land Characteristics (LC) with some model (expert, simulation, statistical)
- Lower values of LQ can match with **higher inputs** or **lower outputs** $\rightarrow$ **economic value**

[1] `http://www.fao.org/docrep/x5310e/x5310e00.HTM`

Economic land evaluation I

1. Select representative LUTs that are **feasible** in a given **socioeconomic-political context**.
2. Describe these by their land use requirements (LUR), together with the financial effects of less-than-optimum LUR (lower yields, higher production costs, or longer time to product).
3. Build a model to evaluate the level of output(s) from each LUT, based on levels of the LUR.
4. Build models to evaluate each LUR from measurable land characteristics (LC).
5. Describe the LC of each land area to be evaluated, the land mapping unit (LMU).
6. For each LUT, apply its LUR models to each LMU.

Economic land evaluation II

7. For each LUT, combine the results of the LUR models in the LUT model.
8. Compute the financial balance for each LMU and LUT.
9. Compute financial indicators for each LMU, combining all the LUT results.

Rossiter, D. G. (1995). *Economic land evaluation: why and how*. **Soil Use & Management**, 11(3), 132–140.
`https://doi.org/10.1111/j.1475-2743.1995.tb00511.x`

Problem

- Problem: disaggregating effect of **soil** vs. **other resources** (e.g., climate)
- Problem: Including **externalities**: these can be costed even if the land user is not directly penalized
- Main problem: **medium-term** at best (Net Present Value)

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南京栖霞山 QiXia Mountain, Nanjing, Jiangsu (PRC)

Ecosystem approach: value as contributions to well-being

Natural capital "stocks of natural assets [e.g., soil] . . . that yield a flow of valuable **ecosystem goods or services** into the **future**"

Soil stocks soils viewed as natural capital

Ecosystem services "the direct and indirect contributions of ecosystems to **human well-being**"

- so, determine how soils contribute to these services, and value these
- **Not so easy!**

Ecosystem services

Dominati (2010) conceptual framework for placing **soils** into the context of **wider ecosystems** and **human well-being**

1. soil as a form of **natural capital stocks**;
2. the processes of **formation, maintenance, and degradation** of this natural capital;
3. the **external drivers** affecting these processes and thereby natural capital;
4. the **provisioning, regulating, and cultural ecosystem** services flowing from natural capital stocks **under a use**;
5. the **human needs fulfilled** by these ecosystem services.

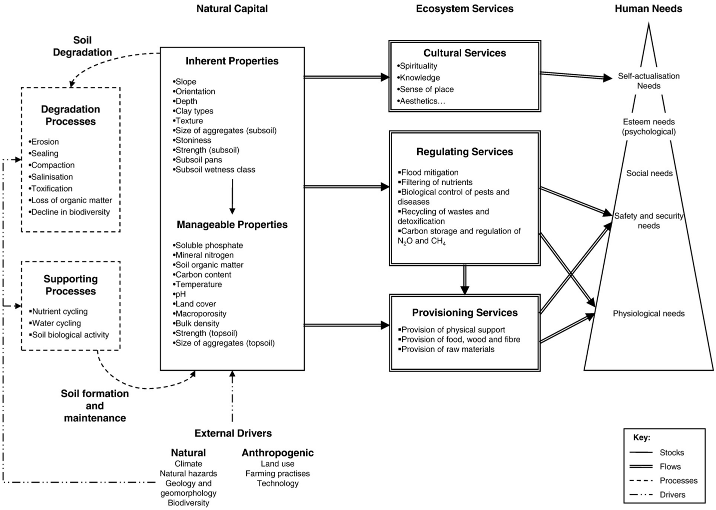


Fig. 2. Framework for the provision of ecosystem services from soil natural capital.

E. Dominati et al. / Ecological Economics 69 (2010) 1858–1868

Valuing ecosystem services

Baveye (2015)[2]:

> *"very little progress has been made to date on the monetization of soil services.*
> *"This may be due to the fact that it is not straightforward to assign a price to features or processes . . ."*
>
> *"The challenge for soil scientists is either to find ways to* **monetize soil services** *meaningfully. . . ". . . or to demonstrate convincingly . . . that there are alternative paths that can be followed to* **preserve soils without necessarily putting price tags on their services**.

[2] Baveye, P. C. (2015). Grand challenges in the research on soil processes. Soil Processes, 3, 10. https://doi.org/10.3389/fenvs.2015.00010

Fundamental problems with ecosystem service valuation

- Markets[3] by definition are **set by the present-day population**.
- In so far as they value the **future**, this can be included, with a suitable **discount rate**.
- Humans can only understand **relatively short-term outcomes**, which is why net present value methods work well for **short-term planning** and **(modestly) delayed gratification**.
- A full monetary valuation of the soil resource in terms of its ecosystem services is **impossible**, in the sense that **the future is inherently unknowable**.

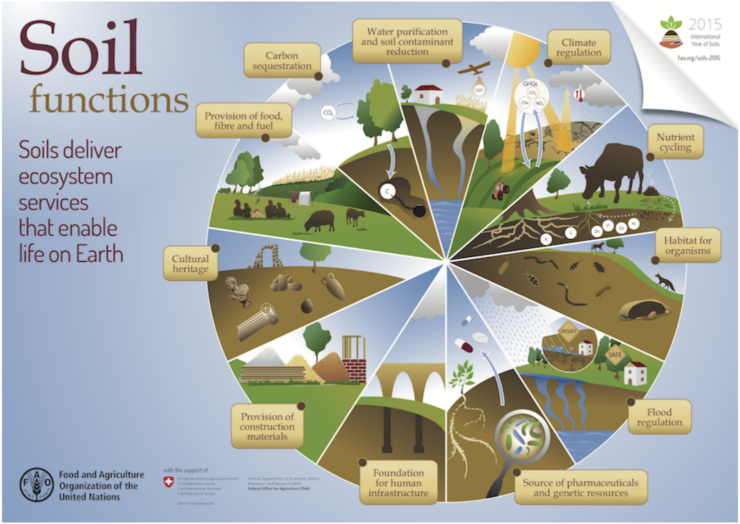
[3] including virtual markets revealed by hedonic pricing, contingent valuation, or other indirect neoclassical methods

Toward a pedometric valuation of the soil resource based on ecosystem services

- Select a set of feasible LUT (can be scenarios) **in the context**
- Determine the ecosystem services to be evaluated
- Model the services in terms of **soil functions** (see next)
  - process models, empirical-statistical models, expert judgement
- **Rate** each service provided 0 . . . 100 based on the model
- Present as a "spider diagram"
- This is then input to **multi-criteria** evaluation or valuation

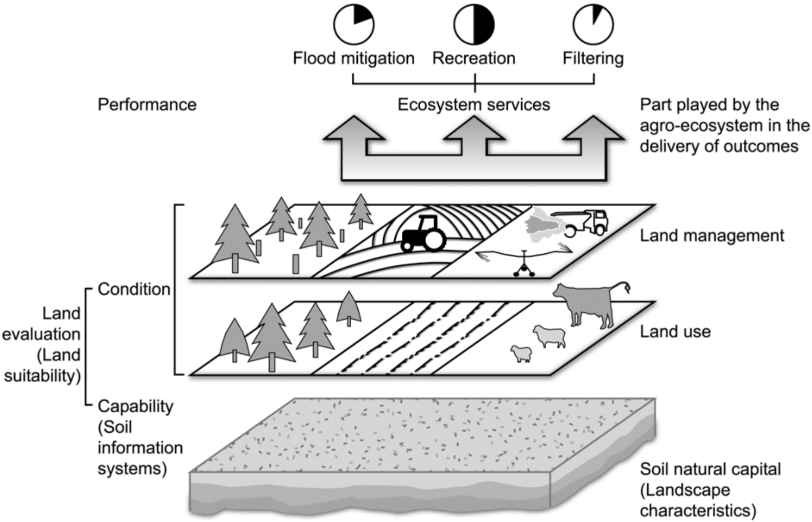
Soil functions

- How the soil acts in the environment
- **Functions** are how the soil provides **services**

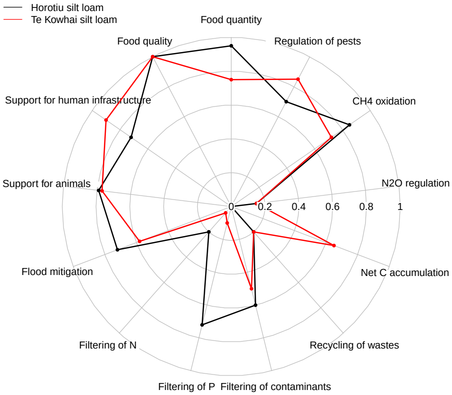


http:
//www.fao.org/resources/infographics/infographics-details/en/c/284478/

From soil to functions to services



Multi-criteria evaluation of ecosystem services



One LUT, two soils

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Communication value of soil to the public

- Current (public) understanding of soil “value”: land price, agricultural production
  - generally not separating “soil” from “land” (climate, location, infrastructure . . .)
- A few cases where other services are (somewhat) known: e.g., NY City water supply regulating function
- “Alarmist” approach – “all is lost!”


New York City's
Water Supply System
Catskill/Delaware
Watersheds
Croton
Watershed
Schoharie
Reservoir
Cannonsville
Reservoir
Pepacton
Reservoir
Ashokan
Reservoir
Neversink
Reservoir
Rondout
Reservoir
West Branch
Reservoir
New Croton
Reservoir
Kensico
Reservoir
Delaware
River
Hudson
River
Catskill Aqueduct
Delaware Aqueduct
West Delaware Aqueduct
East Delaware Aqueduct
PENNSYLVANIA
NEW YORK
NEW JERSEY
CONNECTICUT
MASSACHUSETTS
Albany
Oneonta
Kingston
Poughkeepsie
White Plains
Bronx
Manhattan
Queens
Brooklyn
Staten
Island
New York
Bay
Long Island Sound
Atlantic Ocean
25 Miles (from City Hall)
50 Miles
75 Miles
100 Miles
125 Miles
DEP
Catskill / Delaware Watershed Area
Croton Watershed Area
Rivers and Reservoirs
Catskill Aqueduct and Tunnels
Croton Aqueduct
Delaware Aqueduct and Tunnels
County Borders
State Borders
www.ci.nyc.ny.us/dep

Alarmist reporting

Soil

Third of Earth's soil is acutely degraded due to agriculture

Fertile soil is being lost at rate of 24bn tonnes a year through intensive farming as demand for food increases, says UN-backed study

Jonathan Watts

Tue 12 Sep 2017 13.18 EDT

5,974 421

▲ Soil erosion in Maasai heartlands, Tanzania, is due to climate change and land management decisions. Photograph: Carey Marks/Plymouth University

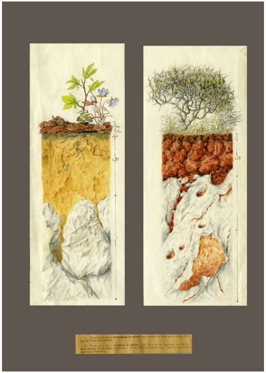
A third of the planet's land is severely degraded and fertile soil is being lost at the rate of 24bn tonnes a year, according to a new United Nations-backed study that calls for a shift away from destructively intensive agriculture.

Ecosystem Principles Approach

Jobstvogt, N., Townsend, M., Witte, U., & Hanley, N. (2014). *How can we identify and communicate the ecological value of deep-sea ecosystem services?* **Plos One**, 9(7), e100646. `https://doi.org/10.1371/journal.pone.0100646`

- Present the valuation in terms of **general ecosystem principles** that (it is hoped) are **easily understandable**
- e.g., "[f]lora and fauna that filter food or nutrients from the water column and maintain a sedimentary lifestyle have a stabilizing effect on the [marine] sediment."
    - then (semi-)quantify (in words) how well this service is provided in each specific case
- For soils, something like: "deep, well-aerated soils with good structure let rainwater infiltrate and pass at moderate speed through to groundwater."

Emotional (not alarmist) approach – beauty and pedodiversity



Kubiëna, W. L. (1954). *Atlas of soil profiles*. London: Thomas Murby

Conclusion

- It is inherently impossible to value soil, in the neo-classical economic framework, in the long term
- For short-term strictly monetary valuation, disentangle soils from other factors of land value
- The **ecosystem sevices** approach provides a relative multi-criteria assessment of soils under land uses
- Communication with the public should emphasize ecosystem services and soil functions that provide these