Framework for Soil Health as Natural Capital that Generates Ecosystem Services

Urs Kreuter
Richard Teague
Kristie Maczko

Ecosystem Science and Management, Texas A&M University, College Station, Texas, USA
Sustainable Rangeland Roundtable, University of Wyoming, Laramie, Wyoming, USA

Introduction

- ***Nature doesn't care!*** Nature responds to external biophysical and anthropogenic forces.
- ***We care about nature*** because it provides benefits (goods & services) that affect our wellbeing.
- ***We manage ecosystems*** not because they need to be managed but to ensure these benefits persist.
- ***Millennium Ecosystem Assessment*** was the first comprehensive effort to link delivery of ecosystem services with human wellbeing!

Soil Health

- ***Soil health*** (or soil quality) refers to "the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans." (NRCS)
- This emphasizes the importance of managing soils so they are ***sustainable for future generations***.
- Soil contains diverse organisms that perform functions required to produce many ***ecosystem goods and services***.

https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health

Why is Soil Health Important

- ***Soil Health*** is a core element of ***Soil Security***
- ***Soil Security*** linked to six global challenges via seven soil functions:
  - (1) biomass production; (2) storing, filtering & transforming of nutrients, substances & water; (3) biodiversity pool; (4) physical & cultural environment; (5) source of raw materials; (6) acting as a carbon pool; (7) archive of geological & cultural heritage

Koch et al., 2013

Dimensions of Soil Security

1. Capability (potential functionality)
2. ***Condition (current state [health])***
3. Capital (stock of biophysical resources)
4. Connectivity (stewardship)
5. Codification (policy and regulation)

McBratney et al. 2013

Natural Capital

- ***Capital***
  - Productive capacity of a system (stock of assets)
- ***Dividends***
  - Benefits flowing from a system's productive assets

Biophysical element

Natural capital (biophys. infrastructure)
➔ *ecosystem goods and services*

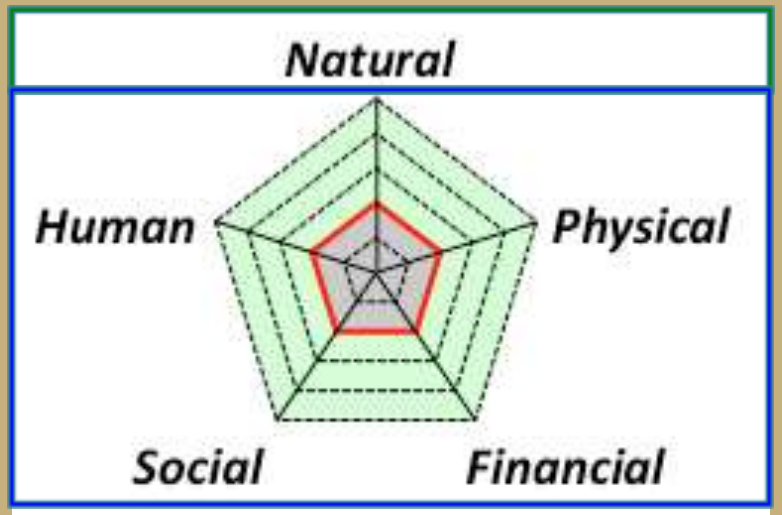
Social (anthropogenic) elements

Physical capital (infrastructure)
➔ economic production capacity

Financial capital (assets)
➔ financial dividends

Human capital (education/health)
➔ well-being and adaptability

Social capital (networks/institutions)
➔ community functionality



Five capitals of sustainable livelihoods

Ecosystem Services from Soils

Soil-based ecosystem services are the *benefits derived from Soil Infrastructure*.

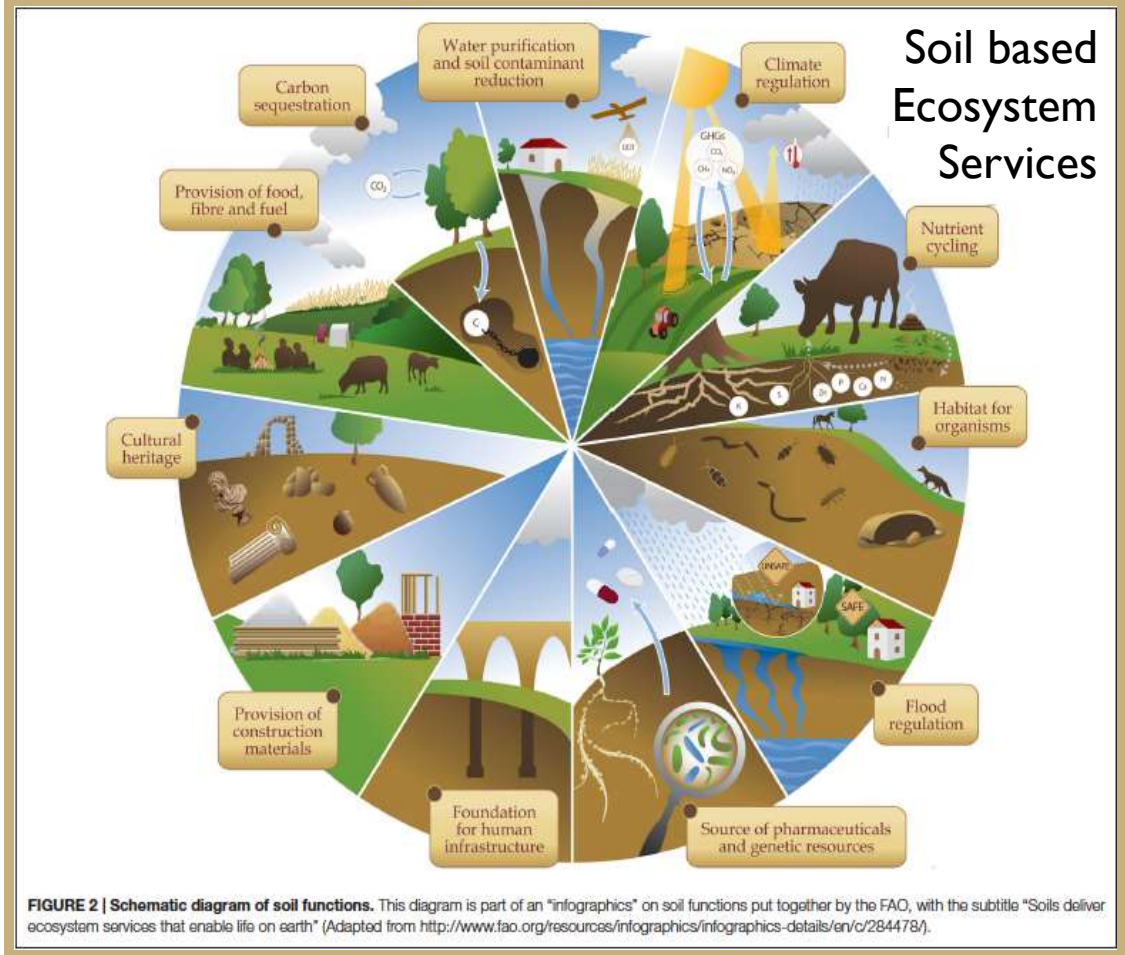


FIGURE 2 | Schematic diagram of soil functions. This diagram is part of an "infographics" on soil functions put together by the FAO, with the subtitle "Soils deliver ecosystem services that enable life on earth" (Adapted from http://www.fao.org/resources/infographics/infographics-details/en/c/284478/).

- *Provisioning*
  - Food, fiber, fuel
  - Raw materials
  - Genetic resources
  - Physical support
- *Regulating*
  - Carbon sequestration
  - Climate regulation
  - Water filtration
  - Flood mitigation
  - Pest/disease control
  - Habitat maintenance
  - Waste assimilation
- *Cultural*
  - Artifact repository
- *Supporting*
  - Nutrient cycling

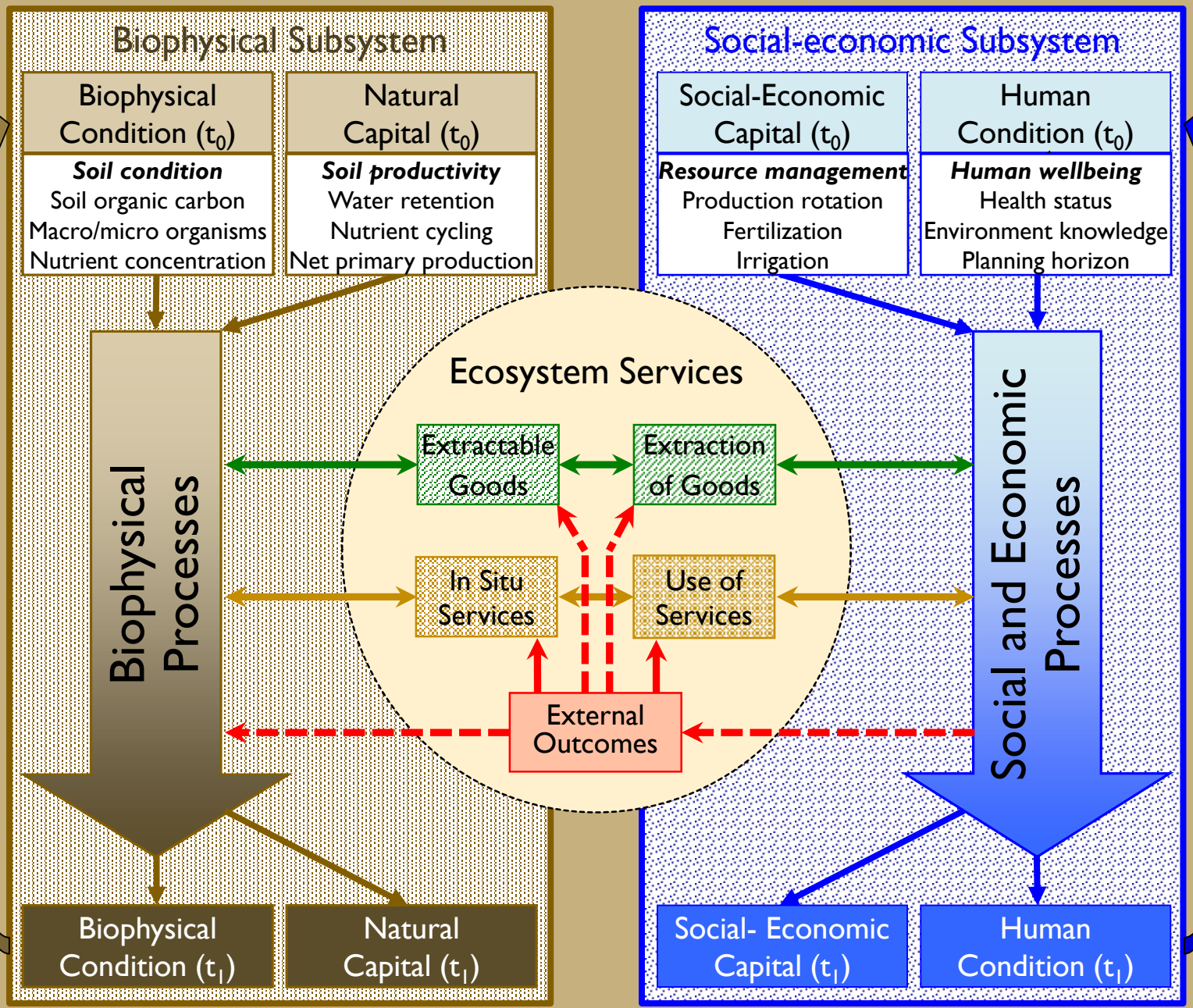
Evaluation Challenges

- Evaluating nature (soil health) is hindered by:
  - Complex multi-scale interactions between biophysical and socioeconomic factors that affect ecosystem functionality (Nicholson et al., 2009);
  - Scale and focus of most land use decision-making discourages comprehensive assessment of tradeoffs resulting from development (Allred et al. 2015);
  - Knowledge of processes affecting natural resources is hindered by inconsistent use of concepts and terms to describe complex social-ecological systems (Ostrom 2009).

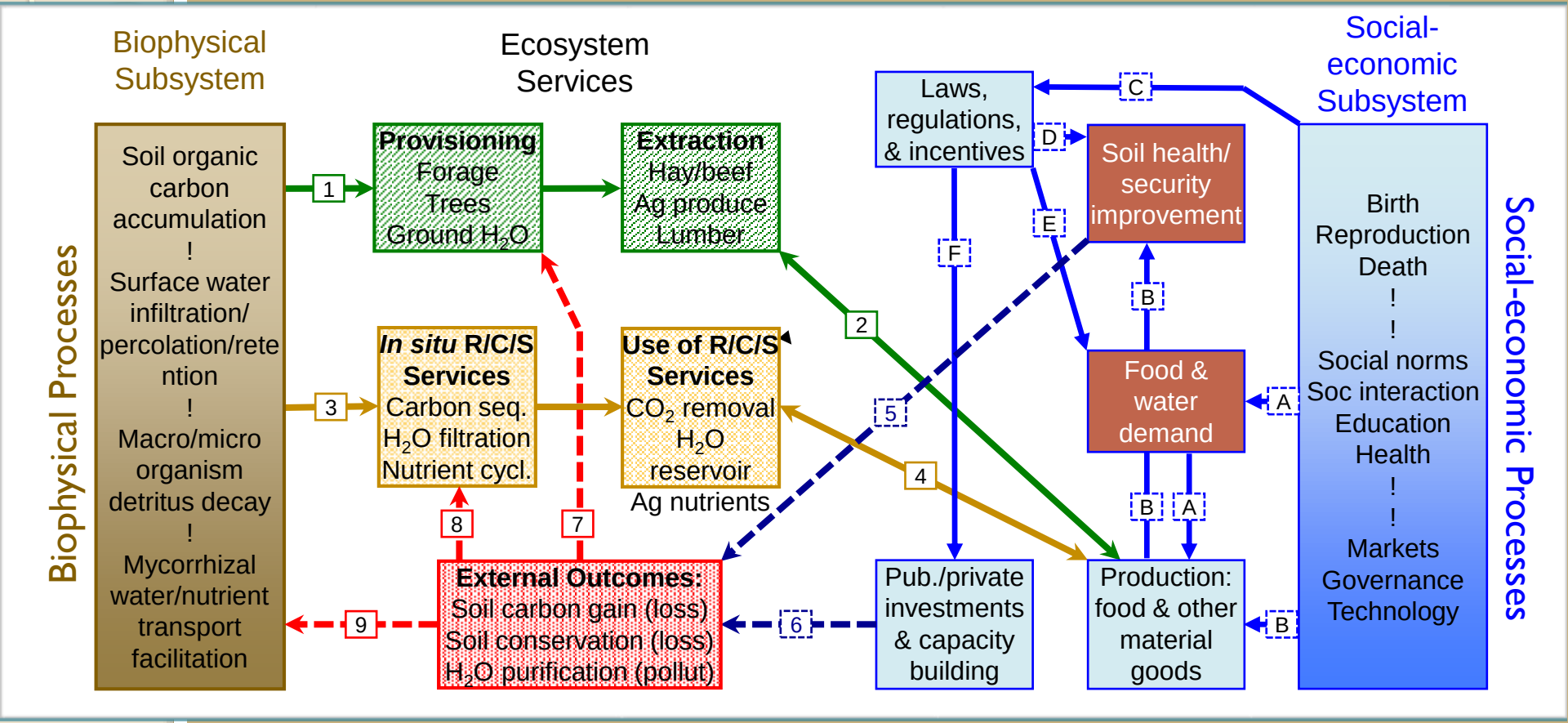
Social-Ecological Systems Framework

- Systems with interacting/interdependent biophysical (ecological sub-system) and social-economic (social subsystem) components
- Sustainable Rangeland Roundtable (SRR) developed Integrated Social, Economic & Ecological Conceptual (ISEEC) framework to disentangle complexity of interactions affecting delivery and use of ecosystem services on rangelands (Fox et al., 2009).
- ISEEC provides useful tool for systematically identifying interactions affecting integrity of rangelands used for energy production and indicators to monitor and evaluate these effects (Kreuter et al., 2012, 2016).

ISEEC Framework



ISEEC Applied to Soil Health



1 = Provision extractable resources
2 = Extraction/use of provisions for production

3 = In situ delivery of R/C/S services
4 = In place use of eco-services for production of material goods

5 = Policy feedback on soil health
6 = Investment/cap building feedback

7 = Direct effects on provision/use of extractable resources
8 = Direct effects on delivery/use of R/C/S services
9 = Feedback – biophysics processes

A = social drivers – food/water demand
B = social drivers – production/effects on soil
C = social drivers – laws/regulations
D = regulatory effects – soil security
E = regulatory effects – food/water use
F = regulatory effects – investments/capacity

Need for Linking Indicators

- Because people value things differently, we need to present audience-specific information.
- Because we seek to motivate people, we must measure things that are meaningful to people.
- A subset of biophysical and socio-economic indicators that clearly and directly matter to land managers and policy makers as well as other stakeholders are needed.

Focusing on Sustainability

- Sustainable Rangeland Roundtable (2001–present)
- 5 Criteria; 64 indicators (27 core indicators):
  - Biophysical criteria:
    - I: Soil & water conservation (10)
    - II: Conservation & maintenance of plant & animal resources (10)
    - III: Maintenance of productive capacity (6)
  - Social and economic criteria:
    - IV: Social & economic sustainability (28)
    - V: Legal, institutional, & economic framework for conservation/ sustainable management (10)

Indicators to Monitor "Forward" Links

Linkage*	Description	Indicator**
1	Plant resources	[12] Spatial extent of vegetation communities [14] Fragmentation of plant communities [21] Above ground plant biomass
2	Plant resource extraction (food production)	[24] Number of domestic livestock produced [25] Presence and density of wildlife functional groups on rangeland. [27] Value of forage harvested by livestock [28] Value of production of non-livestock products (crops) [32] Return on investment in livestock, wildlife, water, biofuel, etc.
3	Soil services	***[??] Phospholipid derived fatty acids*** ***[??] Haney soil health test*** [01] Extent of significantly diminished organic matter &/or high C:N ratio [02] Extent of changes in soil aggregate stability [03] Microbial activity in soils (microbe/fungi ratio) [04] Extent of significant change in extent of bare ground [05] Extent of accelerated soil erosion by water or wind
4	Soil services utilization	***[??] Soil carbon for carbon credits*** ***[??] Soil moisture holding capacity*** *[32] Return on investment in non-extractive benefits (soil health, etc.)* [33] Area of land under conservation ownership

* Numbers in the first column indicate the corresponding link in ISEEC applied framework for soil health.

** Indicators for monitoring sustainability of rangeland ecosystems identified by SRR with (number in brackets represent the SRR indicator number) (source: Maczko et al., 2008).

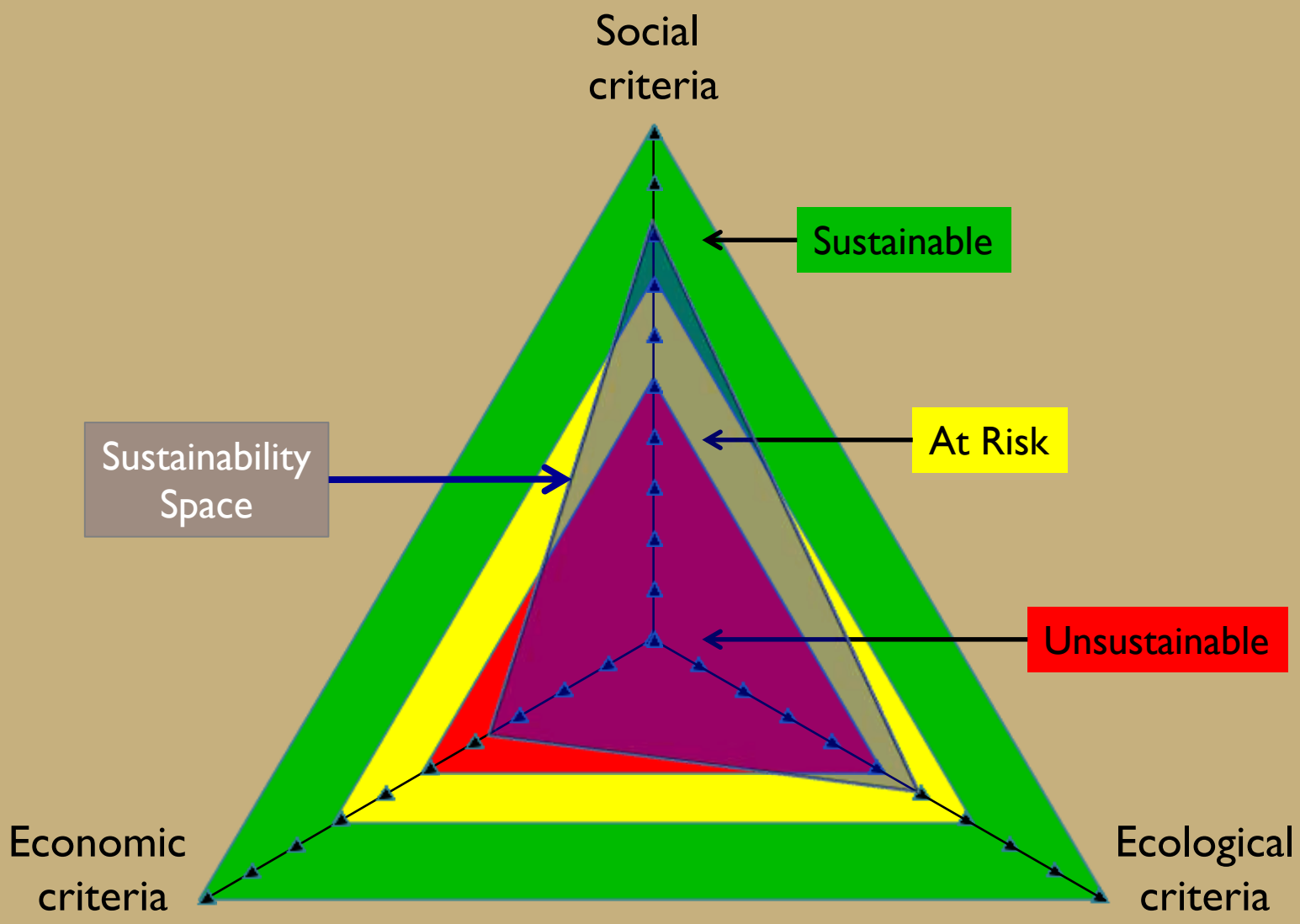
Indicators to Monitor "Feedbacks"

Linkage*	Description	Indicator**
5	Soil health policy effects	***[??] Laws, regulations and programs aimed at enhancing soil health/security*** [56] Extent to which government agencies/NGOs affect conservation management [57] Extent to which economic policies support conservation/management of soils
6	Public/private investment and capacity building	[33] Area of land under conservation ownership [59] Professional education/technical assistance support [60] Conservation management support [63] Resources for monitoring soil condition [64] Conservation/management research/development support
7, 8, 9	Effects on provision of ecosystem goods/services and on biophysical processes	***[??] Soil carbon for carbon credits*** ***[??] Soil moisture holding capacity*** ***[??] Phospholipid derived fatty acids*** ***[??] Haney soil health test*** [01] Extent of significantly diminished organic matter &/or high C:N ratio [02] Extent of changes in soil aggregate stability [03] Microbial activity in soils (microbe/fungi ratio) [04] Extent of significant change in extent of bare ground [05] Extent of accelerated soil erosion by water or wind [12] Spatial extent of vegetation communities [14] Fragmentation of plant communities [21] Above ground plant biomass

* Numbers in the first column indicate the corresponding link in ISEEC Applied Figure.

** Indicators for monitoring sustainability of rangeland ecosystems identified by SRR with (number in brackets represent the SRR indicator number) (source: Maczko et al., 2008)

Soil Health Sustainability Triangle



Conclusion

- Systematic and comprehensive assessment of alternative land uses on soil health and ecosystems services derived from "healthy" soils is critical and needs a coordinated and integrated approach.
- Conceptual integrative frameworks, like ISSEC, provide a useful tool to facilitate impact evaluations of alternative land uses on social-ecological systems links that affect the delivery and use of ecosystem services.
- Standardized indictors are needed to monitor the cumulative effects of alternative land uses on key linkages in soil-dependent social-ecological systems.
- Current knowledge gaps call for integrated research.

References

- Allred, B.W., et al. 2015. Ecosystem services lost to oil and gas in North America. Science 348, 401-402.
- Fox, W.E., et al. 2009. An integrated social, economic, and ecologic conceptual framework for considering rangeland sustainability. Society and Natural Resources 22, 593-606.
- Koch, A., McBratney, A.B., Adams, M., Field, D.J., Hill, R., Lal, R., Abbott, L., Angers, D., Baldock, J., Barbier, E., Bird, M., Bouma, J., Chenu, C., Crawford, J., Flora, C.B., Goulding, K., Grunwald, S., Jastrow, J., Lehmann, J., Lorenz, K., Minansy, B., Morgan, C., O'Donnell, A. , Parton, W., Rice, C.W., Wall, D.H., Whitehead, D., Young, I., Zimmermann, M. 2014. Soil security: solving the global soil crisis. Glob. Policy J. 4:4.
- McBratney, A.B., Field, D.J., Koch, A. 2013. The dimensions of soil security. Geoderma. 213:203-213.
- Kreuter, U.P., et al. 2012. Framework for comparing ecosystem impacts of developing unconventional energy resources on western US rangelands. Rangeland Ecology and Management 65, 433-443
- Kreuter, U.P., et al. 2016. State of knowledge about energy development impacts on North American rangelands: An integrative approach. J. Environmental Management. 180, 1-9.
- Maczko, K., Hidinger, L. (Eds.). 2008. Sustainable rangelands: Ecosystem goods and services. Sustainable Rangelands Roundtable, Colorado State University. Ft. Collins, CO. Available at: http://sustainable.rangelands.org/pdf/Ecosystem_Goods_Services.pdf
- Nicholson, E., et al. 2009. Priority research for ecosystem services in a changing world. J. Applied Ecology 46, 1139-1144.
- Ostrom, E. 2009. A general framework for analyzing sustainability of social-ecological systems. Science 325, 419e422.


Thank you
Questions?

Soil ES and Valuation Methods