The Criticality Concept and Its Application to Develop Indicators for Assessing Sustainability of Agricultural and Livelihood Systems

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Outline

• Motivation
• Methodology of metal criticality determination
  – Application to metals
  – Further applications
• Sketching a methodology of nutrient criticality determination at farm level
Motivation

- Indicators of sustainability of agricultural livelihood systems
  - Problem-oriented (e.g., soil nutrient balances)
  - Solution-oriented (e.g., resilience)

- What about indicators considering both problems and related solutions?
Problem-oriented indicators

• E.g., soil fertility management

• Typical indicators
  – Soil nutrient balance
  – Return to labor

• Very quantitative

• Do not indicate what should be done to alleviate problem
Solution-oriented indicators

- E.g., socio-ecological resilience of farming systems at different scales

- Typical indicators
  - Social network structure (self organization)
  - Financial capital (buffer capacity)
  - Functional and response diversity (buffer capacity)

- Very qualitative, hard to operationalize, so far little focus on “shocks” (=problems)

- Deliver entry points for action!
Methodology of metal criticality determination

- How critical is a metal...
  - To corporations?
  - To a national economy?
  - To the globe?

  - Link between problem and solution
  - Useful tool for studies of resource sustainability

- Multi-dimensional indicators
  - Supply risk
  - Vulnerability to supply restriction
  - Environmental implications

- Fairly popular concept, both in science and practice
  - E.g., General Electric and Rhenium in jet turbines
Different existing methodologies to assess criticality

- **Yale criticality methodology**
  - Supply risk, vulnerability to supply restriction, environmental implications

- **EU criticality methodology**
  - Supply risk, economic importance
Supply risk & vulnerability to supply restriction

Each indicator rated on a scale from 0 (low SR/VSR) to 100 (high SR/VSR)
Metal criticality results (global)

Further applications

• Water

• Gravel
Approach for development of criticality components

- Yale criticality methodology as starting point
  - Supply risk (SR)
  - Vulnerability to supply restriction (VSR)
  - Environmental implications

- Scales
  - Smallholder farms
  - Village
  - Region

- Adaptation of indicators needed to reflect smallholder farms context
  - Smallholder farms are not corporations
  - Soil nutrients are not substitutable
  - Nutrients fulfill other functions than crop growth support
  - Mine (soil) is within smallholder farms
Conceptualization of smallholder farms

Mineral fertilizers

Soil stock

Organic fertilizers
Components and candidate indicators of supply risk

- Pedological
  - Depletion time (= Nutrient soil stock/nutrient soil balance) ➔ Material flow analysis

- Technological
  - Plowing

- Nutrient uptake (metabolism-specific)
  - Uptake mechanisms

- Agrobiogenetical (crop-specific)
  - Plant conversion efficiency
Candidate indicator of pedological supply risk: Depletion time

Translation onto a 0-100% scale?
Components and candidate indicators of **resilience** to supply restriction

- **Buffer capacity**
  - Human capital for internal innovation in the face of nutrient supply restriction
  - Labor

- **Self-organization**
  - Social networks (informing nutrient exchange possibilities)
  - Reliance on own nutrients $\rightarrow$ Material flow analysis

- **Capacity for training**
  - Access to training
Candidate indicator of self-organization: reliance on own nutrients
Environmental implications

• Environmental impacts of mineral fertilizer consumption
  – Greenhouse gas emissions
  – Cumulative energy demand
  – Cumulative water demand
  – Total environmental impacts
• Environmental impacts of fertilizer application
  – Eutrophication
  – Soil salinization
  – ...
Conclusions

• Yale criticality methodology as starting point, but...

• Important adaptations
  – Closed loop as low supply-risk smallholder farm
  – Mine is within the farm
  – Resilience instead of vulnerability
Discussion points

- Relevance/validity?
- Robustness?
- Important components or indicators missing?
- Links between criticality and sustainable intensification?