Research Seminars

System Analyses for Sustainable Agricultural Production and Livelihoods of Smallholders: Complementary Approaches and Case studies in Southwestern Burkina Faso

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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
  - Van den Bosch, H., De Jager, A., & Vlaming, J. (1998). Monitoring nutrient flows and economic performance in African farming systems (NUTMON): II. Tool development. *Agriculture, Ecosystems & Environment, 71*(1–3), 49-62.
- 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
  - Cabell, J. F., & Oelofse, M. (2012). An Indicator Framework for Assessing Agroecosystem Resilience. Ecology and Society, 17(1).
  - Ifejika Speranza, C., Wiesmann, U., & Rist, S. (2014). An indicator framework for assessing livelihood resilience in the context of social–ecological dynamics. Global Environmental Change, 28, 109-119.
- 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!

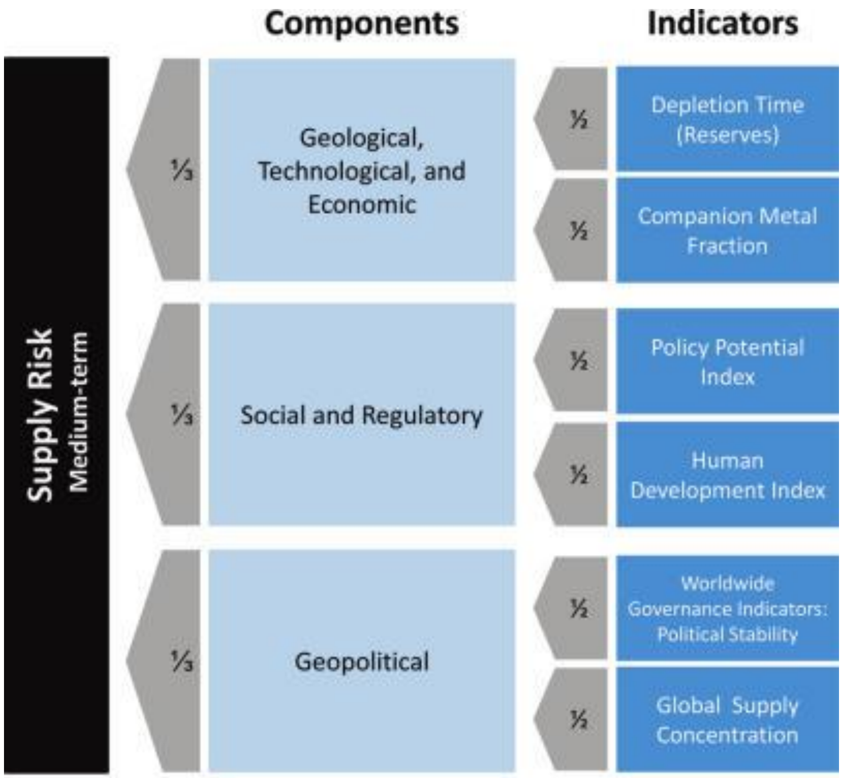
Methodology of metal criticality determination

- 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

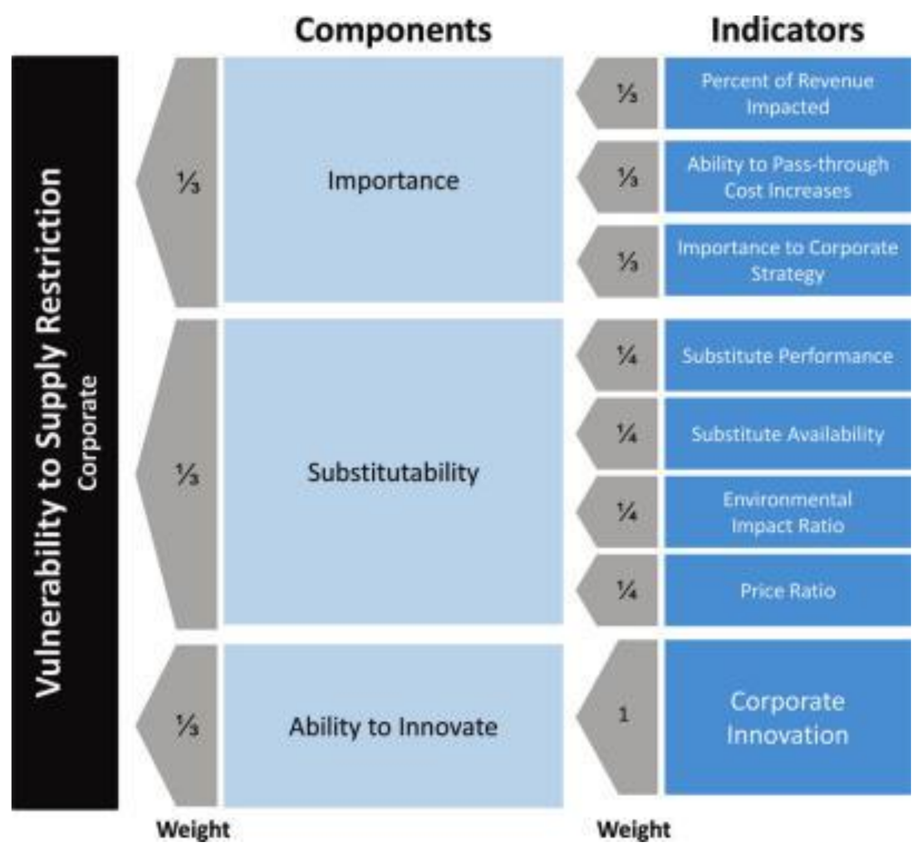
Different existing methodologies to assess criticality

- Yale criticality methodology
  - Supply risk, vulnerability to supply restriction, environmental implications
  - Graedel, T. E., Barr, R., Chandler, C., Chase, T., Choi, J., Christoffersen, L., Friedlander, E., Henly, C., Jun, C., Nassar, N. T., Schechner, D., Warren, S., Yang, M.-y., & Zhu, C. (2012). Methodology of metal criticality determination. *Environmental Science & Technology, 46*(2), 1063-1070.
- EU criticality methodology
  - Supply risk, economic importance
  - European Commission. (2014). Report on critical raw materials for the EU. Report of the Ad-hoc Working Group on defining critical raw materials. Brussels: European Commission's DG Enterprise and Industry.

Supply risk & vulnerability to supply restriction



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



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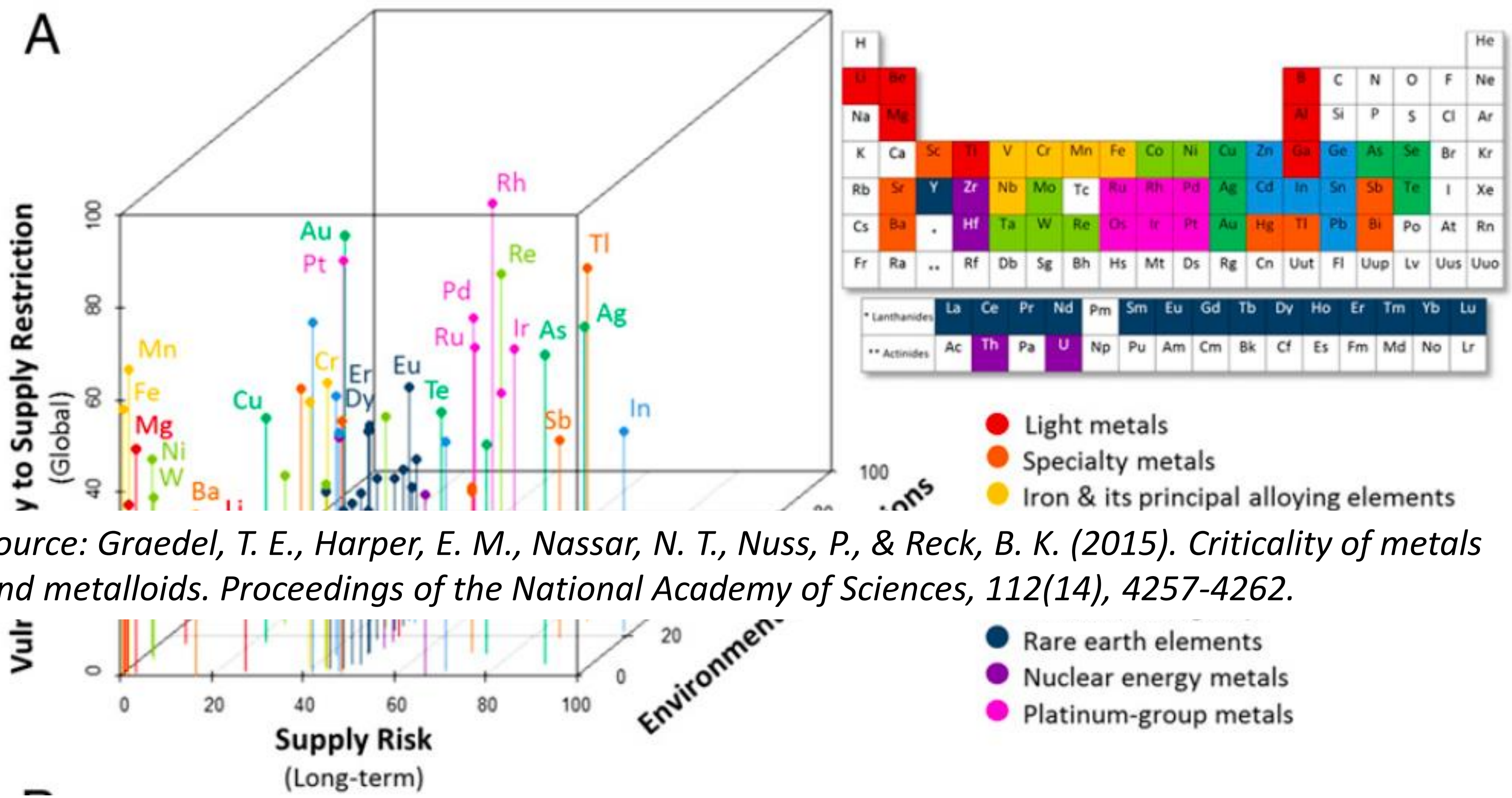
Metal criticality results (global)



Source: Graedel, T. E., Harper, E. M., Nassar, N. T., Nuss, P., & Reck, B. K. (2015). Criticality of metals and metalloids. Proceedings of the National Academy of Sciences, 112(14), 4257-4262.

Further applications

- Water
  - Sonderegger, T., Pfister, S., & Hellweg, S. (2015). Criticality of Water: Aligning Water and Mineral Resources Assessment. Environmental Science & Technology, 49(20), 12315-12323.
- Gravel
  - Ioannidou, D., Meylan, G., Sonnemann, G., & Habert, G. (in review). Is gravel becoming scarce? Evaluating the local criticality of construction aggregates. Resources, Conservation & Recycling.

Approach for development of criticality components

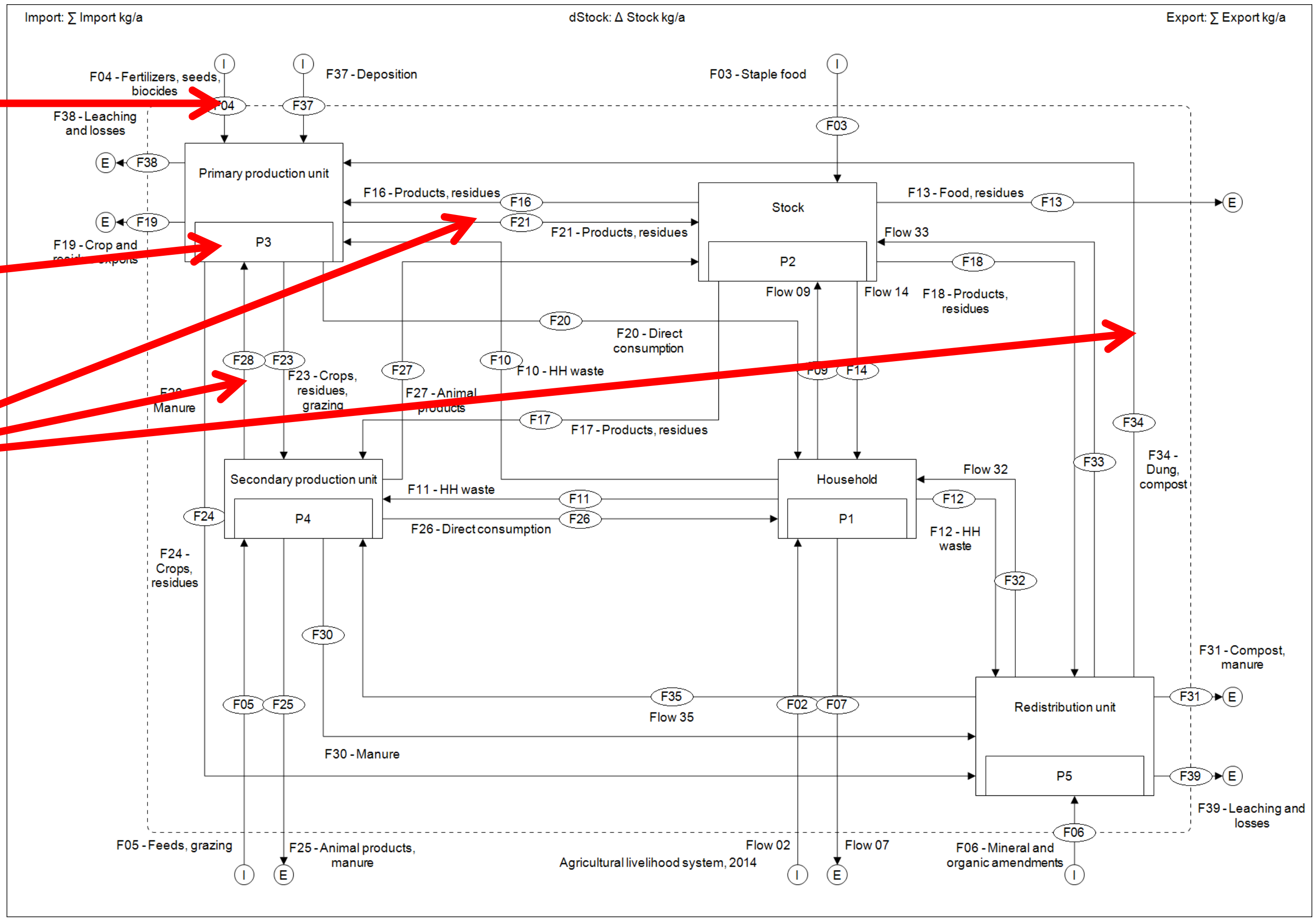
- Yale criticality methodology as starting point
  - Supply risk (SR)
  - Vulnerability to supply restriction (VSR)
  - Environmental implications
- Scales
  - **Smalholder farms**
  - Village
  - Region
- Adaptation of indicators needed to reflect smallholder farms context
  - Smallholder farms are not corporations
  - Soil nutrients are not substitutable
  - Nutrients fulfill other functions than crop growth support
  - Mine (soil) is within smallhjolder farms

Conceptualization of smallholder farms

Mineral fertilzers

Soil stock

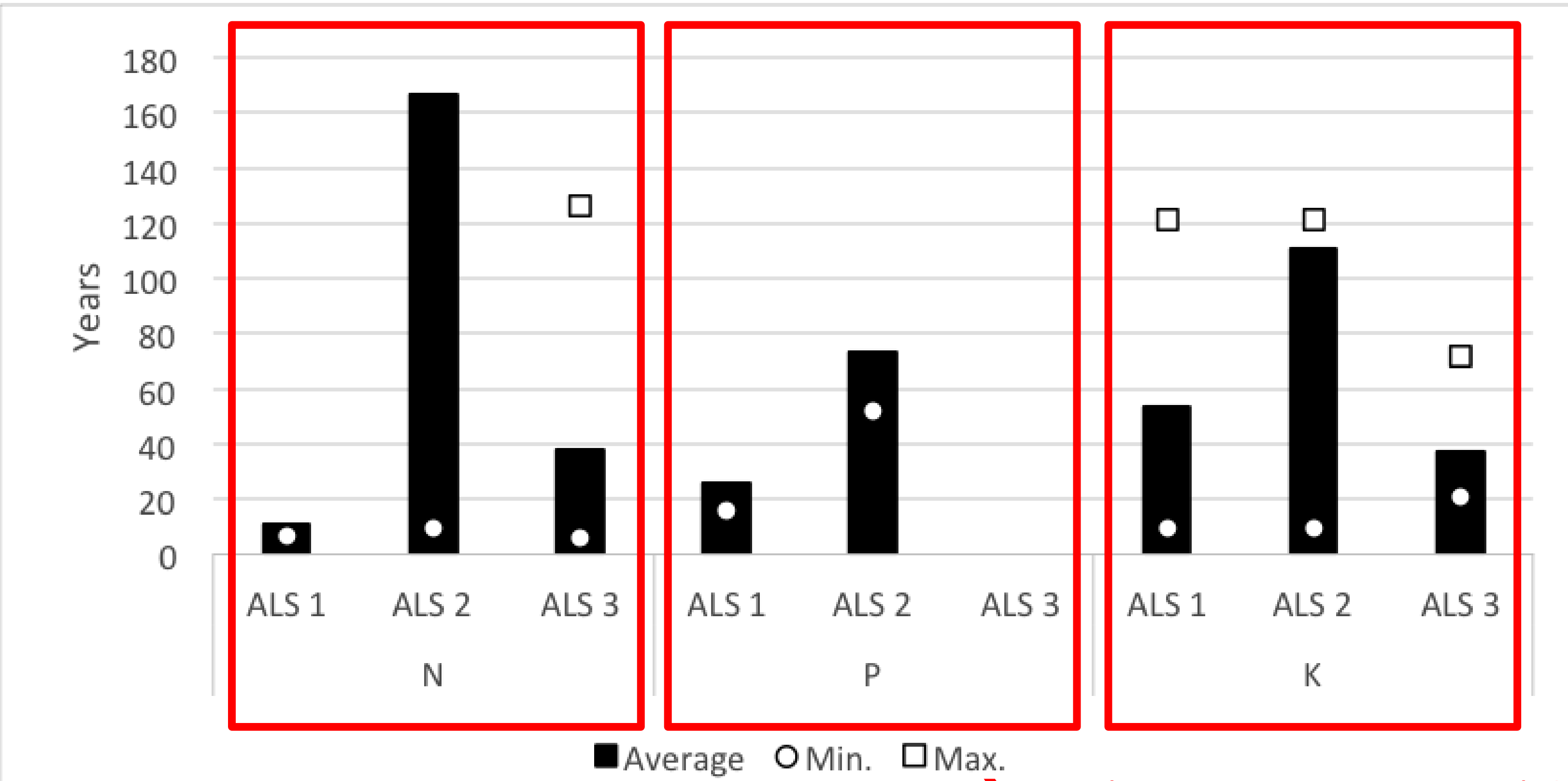
Organic fertilizers



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?*

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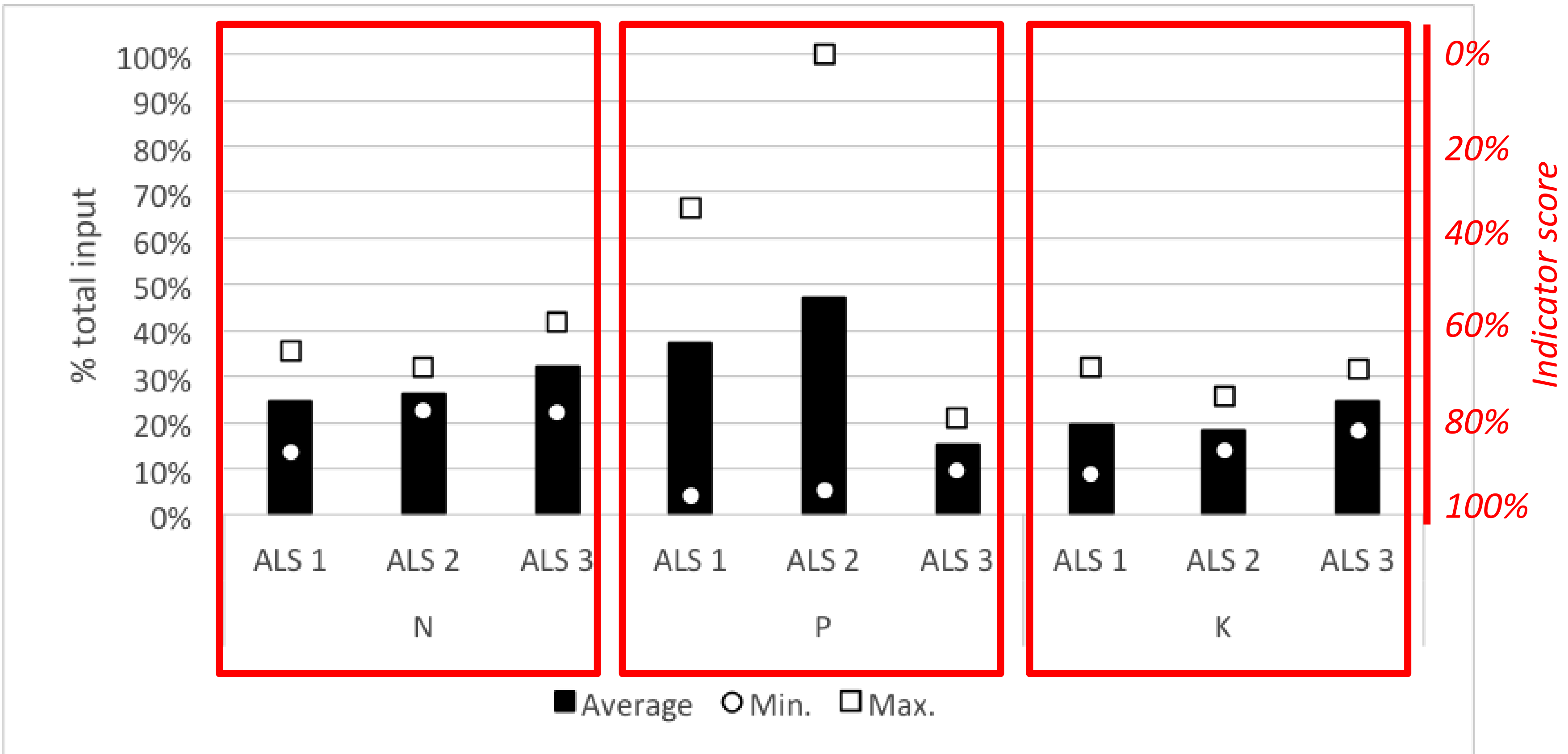
Components and candidate indicators of **resilience** to supply restriction

- 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 ➔ Material flow analysis
- Capacity for training
  - Access to training

Candidate indicator of self-organization: reliance on own nutrients



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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?