RESEARCH PROGRAM ON
Dryland Systems

CGIAR

Food security and better livelihoods for rural dryland communities

Sustainable Intensification: Concept Revisited, Research Challenges, and New Methodologies from Modern Systems Science Perspective

Quang Bao Le
CRP Dryland Systems
Agricultural Livelihood Systems

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Forewords

- Share a product of my working stream on sustainable intensification (including eco-efficiency) started 3 years ago.
- Rather generic - not yet either specific to dryland context, or well-situated in CGIAR's SRF, etc.,
- Given my tries to express terminologies in new systems science, some specific terms may be unavoidably used

Sustainable intensification (SI) in recent literature

As goals (Garnet et al. 2013, Godfray and Garnett 2014)

- "Intensified" as increased food yield
- Improved environmental sustainability (natural resource bases/capital)
- Provide basis for improved human nutrition adequacy (quality foods, diverse diets)
- Pillar for rural economies and development

Premises

- Unavoidable given needs to feed growing population and huge land conversion "cost"
- Should not specify a priory whether conventional, high-tech, organic, or conservational agriculture
- Bio-physical and social contexts are important for looking at options

Sustainable intensification in recent literature

‘Intensification’ does not necessarily mean increasing of input that are the common thinking of many scientists, projects, programs.

Important missing still:
In goals

- System resilience
- Equity

In premises

- The law of nature: material and energy conservation, e.g. withdraw =< growth, or the essential role of natural capitals
- System constructs for SI?

A Dummy Choice Strategy: EITHER Sustainable Intensification, OR Security

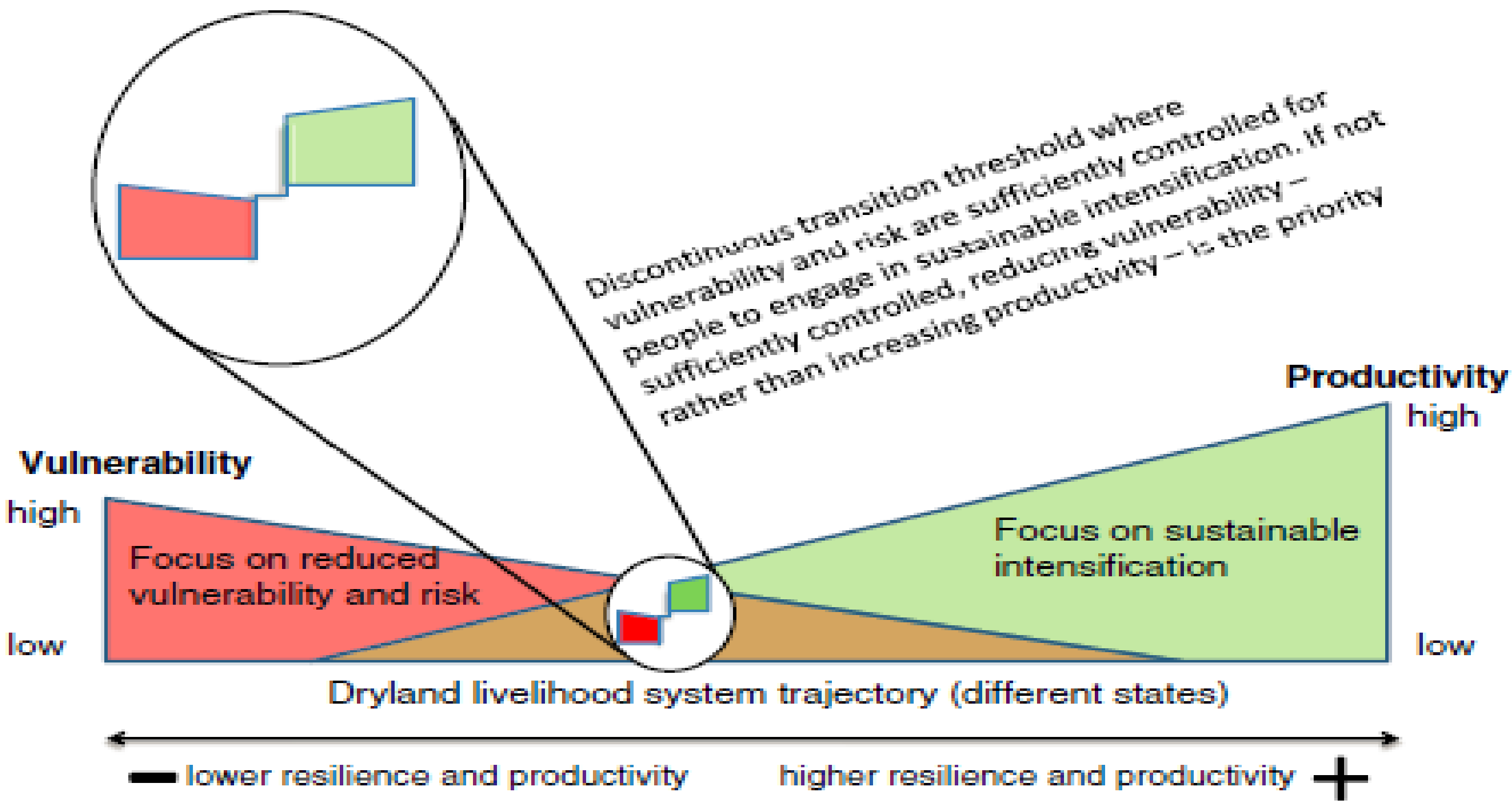


Fig. 1 Focus: reduced vulnerability and risk, or sustainable intensification

Source: Van Ginkel et al. (2013)

Is the assumption of "Vulnerability/Risk – Intensification Potential" continuum plausible?

- OLD, YET VALID FOREVER: higher investment, higher risk of loss.
  - In-/poor accessible and/or abrupt markets
  - Unexpected climate change
  - Unstable policies
- Vulnerability/risk would be important, or even much more in highly invested agriculture

Mekong Delta, Vietnam (2013-2015)

Critical mass adoption

Is the assumption of “Vulnerability/Risk – Intensification Potential” continuum plausible?

L.W. Robinson et al./Agricultural Systems 135 (2015) 133–140 135

- NOT allow for the possibility that some forms of intensification can increase vulnerability

- Moving along the continuum is NOT THE ONLY pathway out of poverty, i.e. security and intensification can accommodate each other.
  - Dryland: Intensification is NOT necessarily the inverse of extensity or diversification

- Scale/level-sensitive issue

F ... ise-
h ... itial.
In (B), reductions in vulnerability only result in increases in intensification once vulnerability has been reduced beyond a certain threshold.

Source: Robinson et al. (2015)

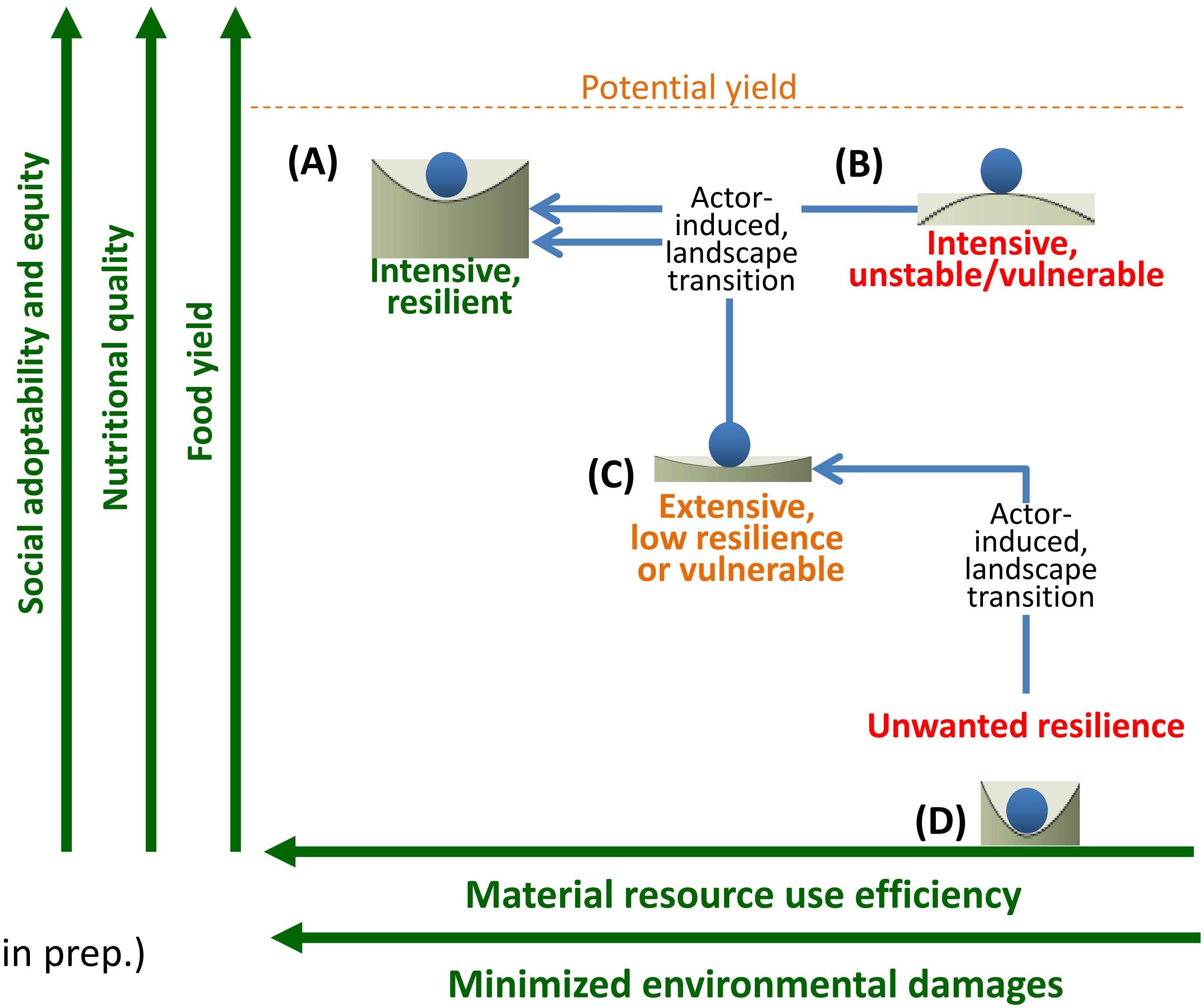
Revisited SI as goal from systems perspective

- Increased food yield AND nutrition quality
- Resilience of the intensified system to shocks or stresses **(X)**
- Improved efficiency in material resources uses, minimization of environmental impacts and social adoption **(X)**
  - Intensification = intensification of resource metabolism = metabolic intensification
- Social equity
- Multi-scale consideration required for all above **(X)**

Source: Le et al. (in prep.)

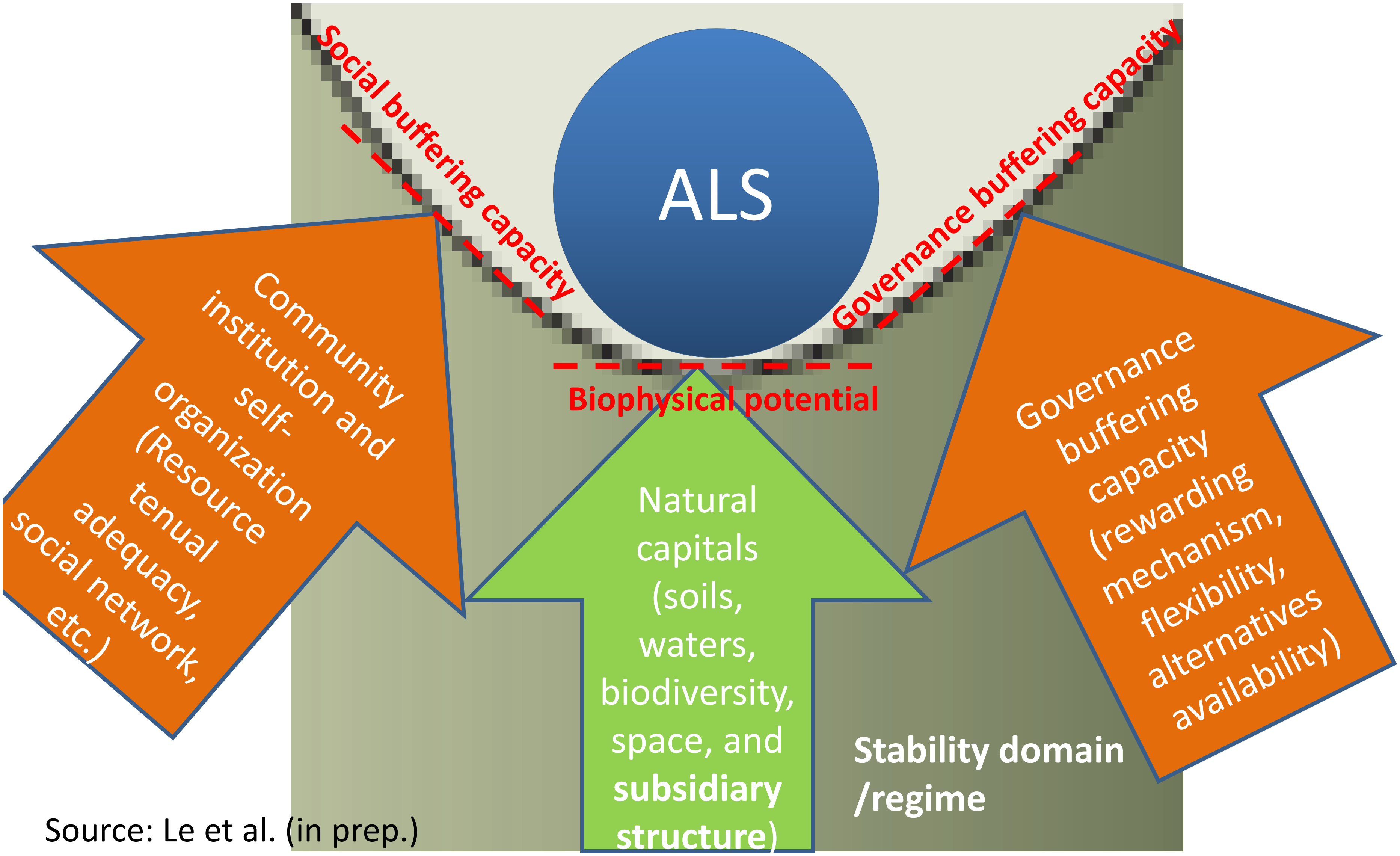
(X): will be elaborated in the next slides; others would be subjects of other talks by others

Resilience thinking: SI as a bouncing-forward, actor-driven transformation of agricultural livelihood systems toward improved stability regimes



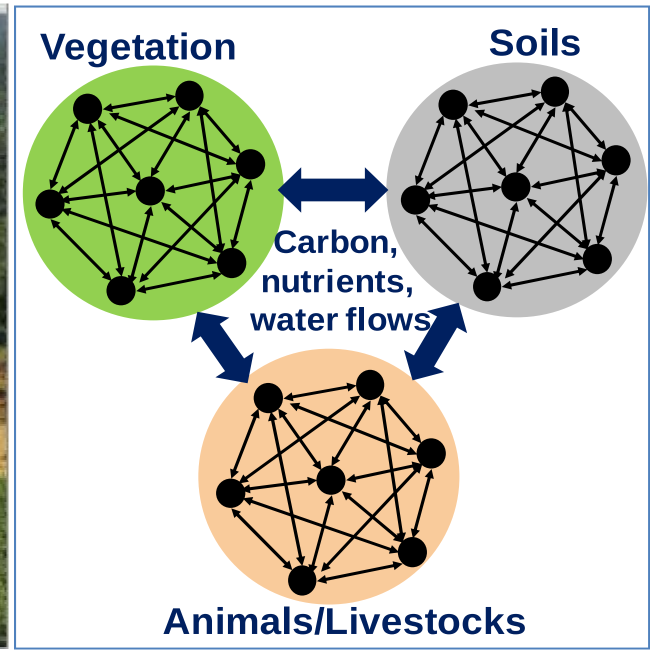
Source: Le et al. (in prep.)

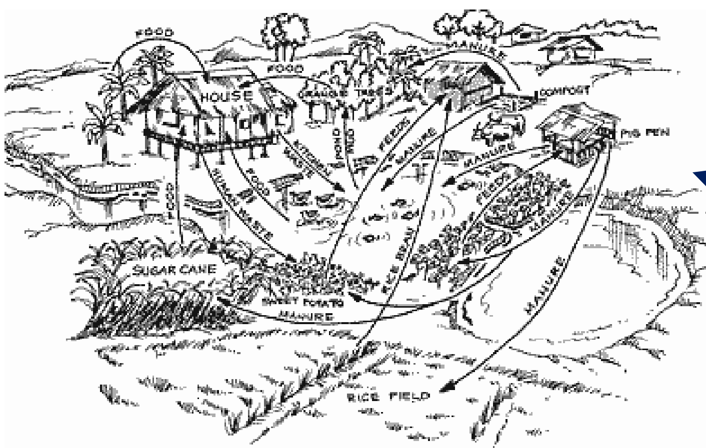
Factors determine, slowly transform stability domain/regime of ALS

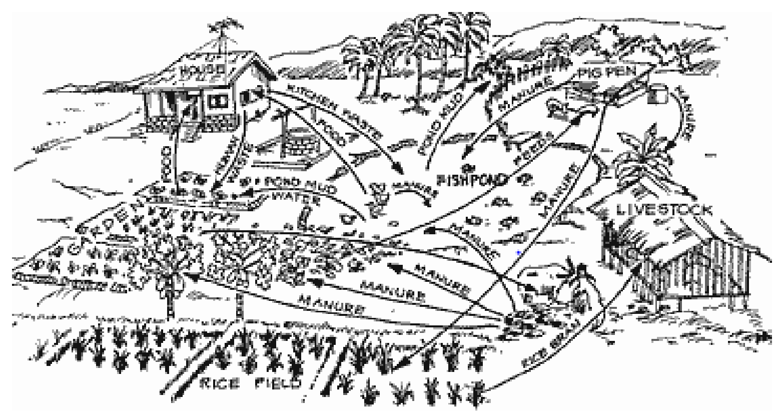


Source: Le et al. (in prep.)

Ecological integrity of farm systems and agrarian landscape



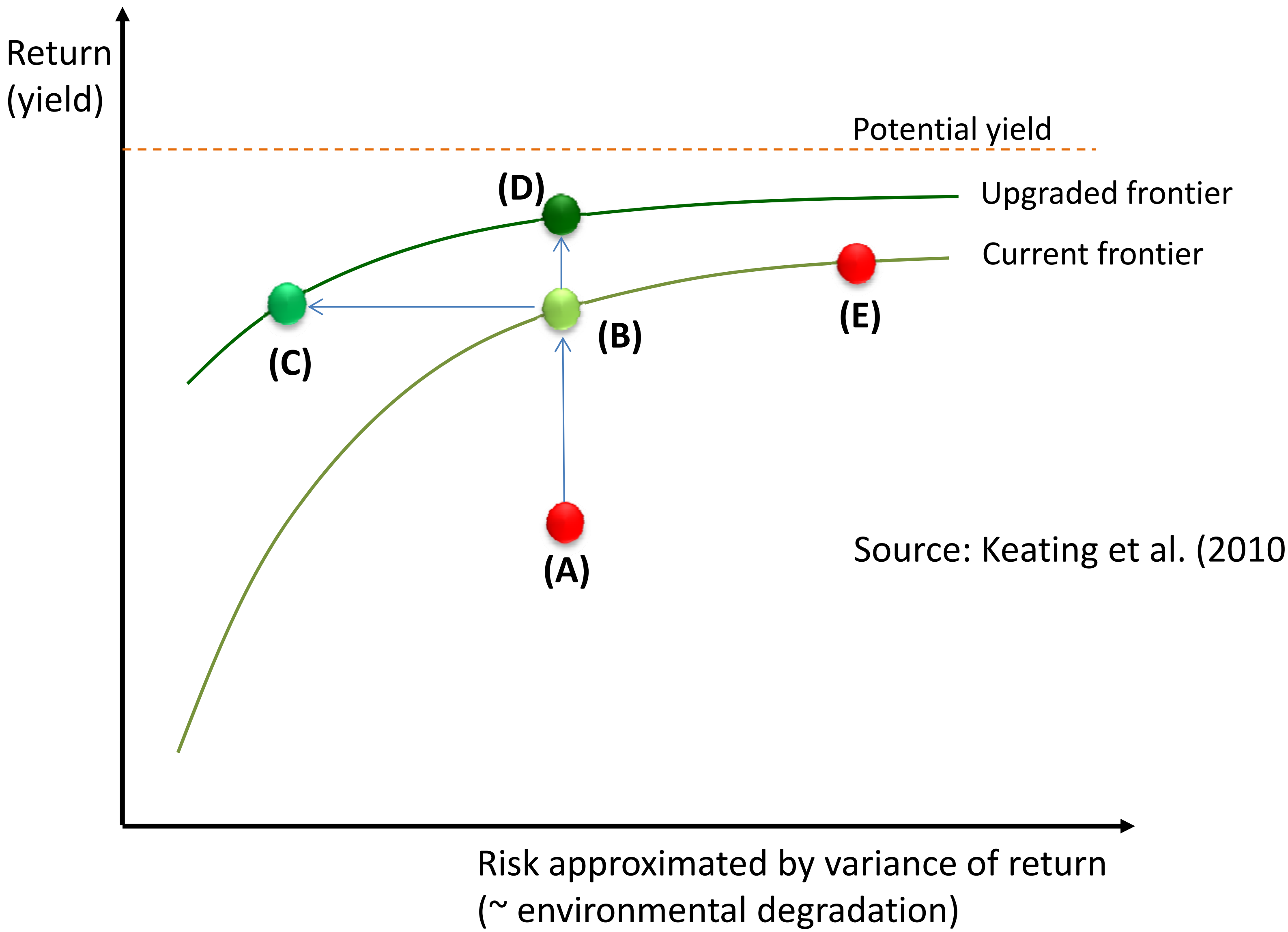




Integrity of upland farming system

Integrity of lowland farming system

Shift-up efficiency frontier as positive resilience (bouncing-forward) transitions



Efficiency frontier as a function of soil capital

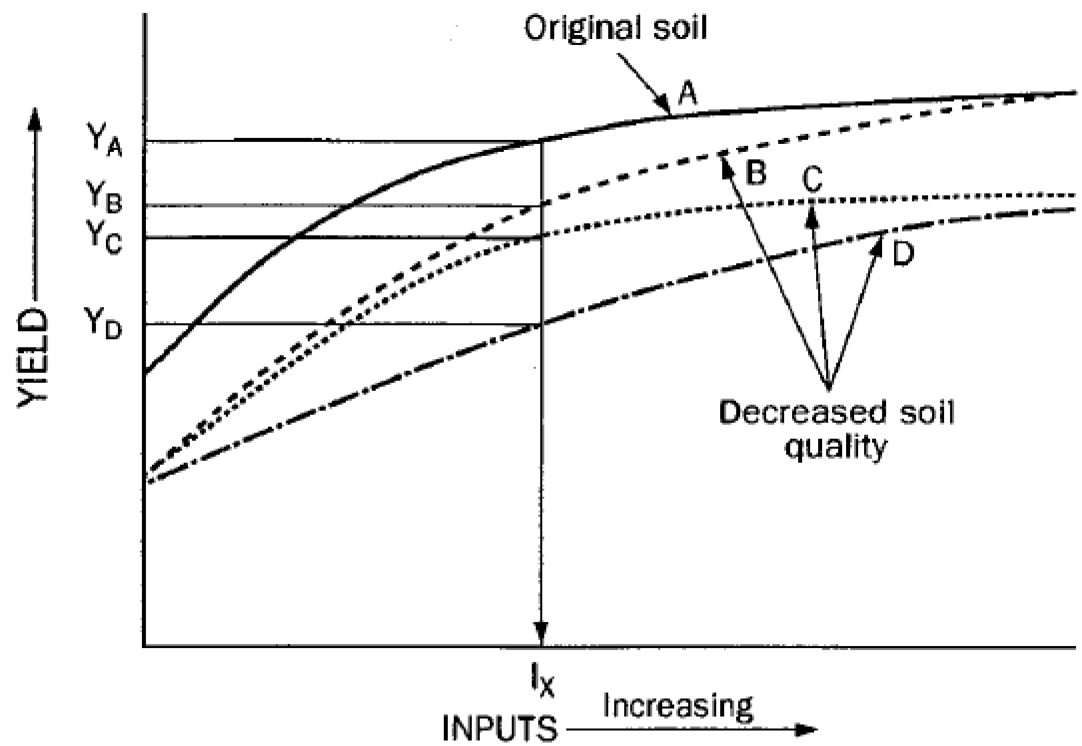
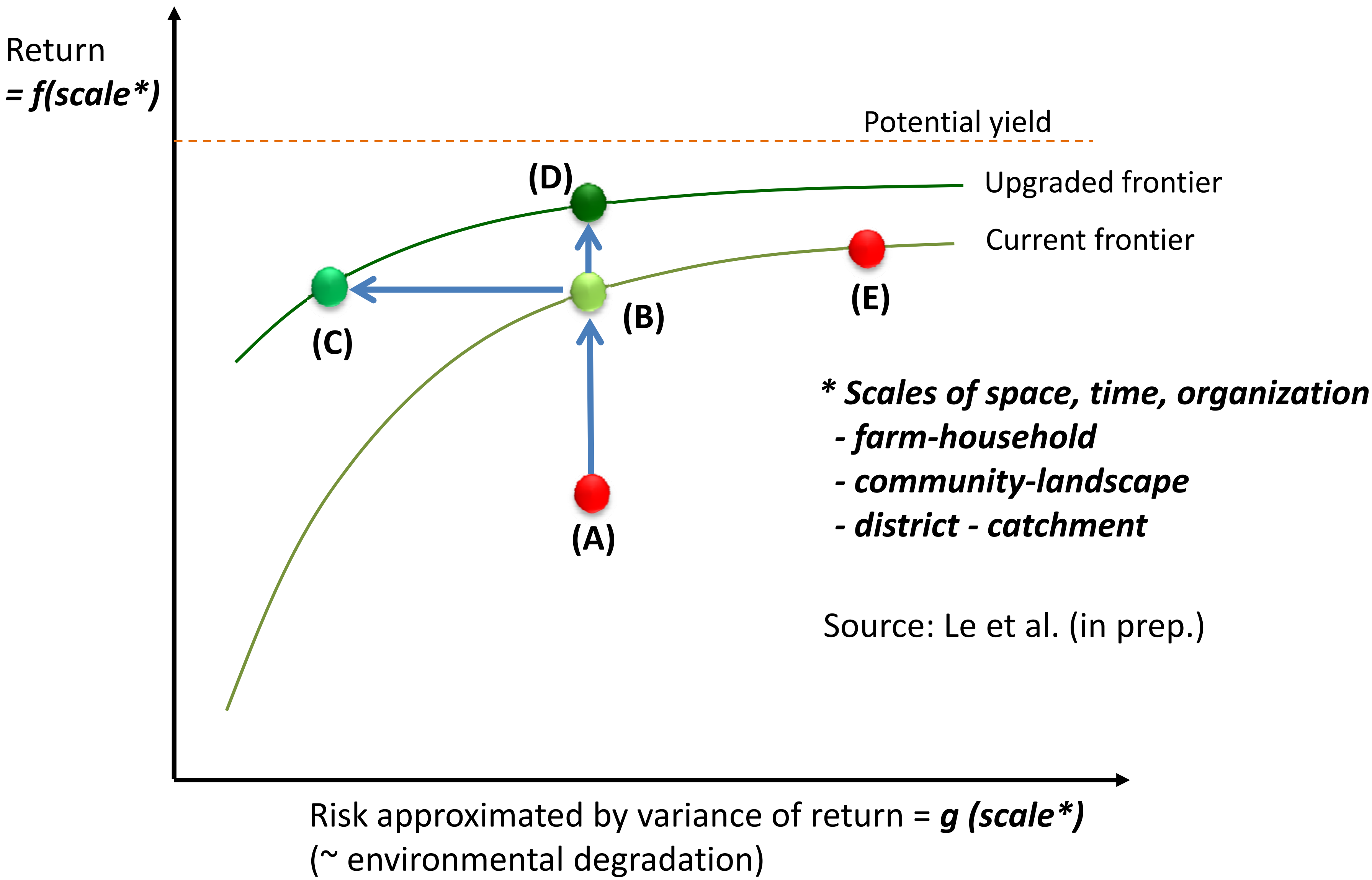


FIG. 3. Conceptual model illustrating the relationship between crop yields and input requirements as influenced by soil quality. A decrease in soil quality from an initial state (curve A) can result in the need for greater inputs of energy, nutrients, water, seed, and pest control measures to achieve the same yield. The slope and asymptote of the shifted response (shown by curves B, C, and D) depend on the type of soil degradation and can result in a reduction in input use efficiency, yield potential, or both.

Cassman (1999) PNAS

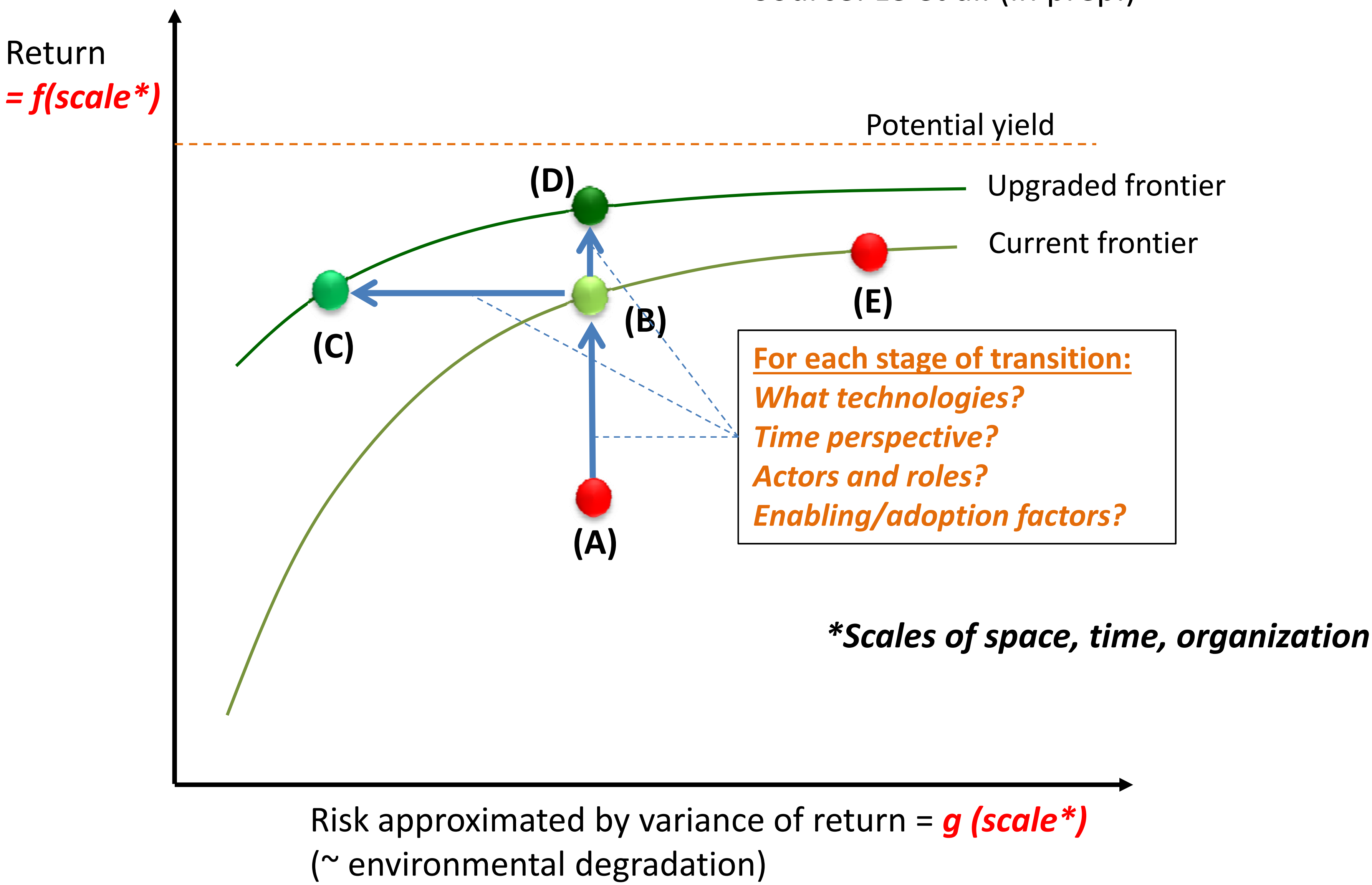
Shift-up efficiency frontier as scale/level-sensitive processes, requiring multi-scale/-level efforts



Source: Le et al. (in prep.)

Shift-up efficiency frontier as context-specific and actor-based processes

Source: Le et al. (in prep.)



Systems-based SI research: what needed?

Problem

- Complex human-environment interactions
- Uncertainties
- Externalities and trade-offs
  - vs. time
  - vs. space
  - vs. social group
  - vs. goal

Method requirement

- Interdisciplinary approach
- Uncertainty management
- Long-term perspective
- Micro-macro links
- Stakeholder participation
- Distributed outputs vs. space, time, and actor groups
- Multi-dimensional outputs

Systems-based SI research: what needed (continue)?

Problem	Method requirement
Flexible (not fixed) feedback loops genetated by actors‘ decisions	Actors' behavior explained
Actors‘ decisions changable along learning	Relevant learning process captured
Heterogeneity as important source of buffering, adaptive capacities	Within- and between- farm heterogeneities represented
Framing drivers	Sensitive to key drivers

Systems-based SI research: How do current methods meet requirement?

Table 1. Comparative assessment of contemporary farming system modeling approach with respect to criteria for farm resilient research. Note: publications in parentheses are as relevant examples).

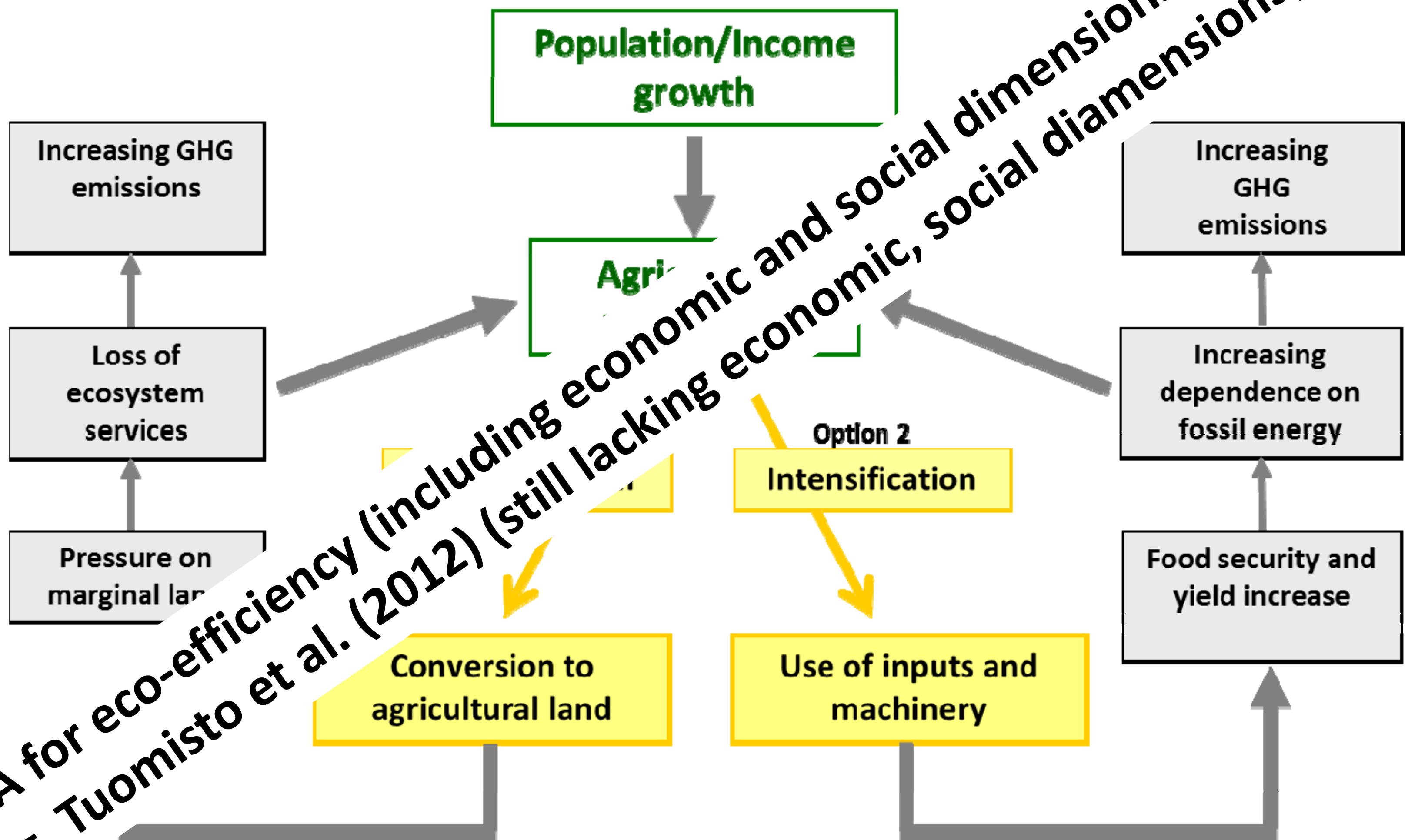
Criteria (synthesized from Bousquet and Le Page (2004), Boulanger and Bréchet (2005), Kelly *et al.* (2013), Cabell and Oelofse (2012))	Output-input nutrient balance models (NUTMON[a] model (Den Bosch *et al.*, 1998a; Den Bosch *et al.*, 1998b))	System dynamics models (Shepherd and Sole, (1998); Sendzimir *et al.* (2011)	Bayesian Network models (Poppenborg and Koellner, 2013)	Bio-economic models (Witcover *et al.* (Witcover *et al.*, 2006))	Coupled component models (NUANCES[b] Giller *et al.*, (2011), IAT[c] (MacLeod *et al.*, 2007)), SEAMLESS (Van Ittersum et al., 2008)	Multi-agent system models (LUDAS[d] (Le *et al.*, 2008a; Le *et al.*, 2010b; Le *et al.*, 2012b), MP-MAS[e] (Schreinemachers and Berger, 2011))
Interdisciplinary	no[d]	strong	medium	weak [f]	weak [g]	strong
Long-term perspective	no	strong	no	weak	strong	str[illegible]
Uncertainty management	no	weak	strong	no	no/weak	[illegible]
Local-global perspective	no	no	no	weak	str[illegible]	[illegible]rong
Participation mediation	weak	strong	strong	weak	[illegible]	strong
Multi-scale feedback loops	no	no	no	[illegible]	[illegible]clear	strong
Actors' behavior	no	weak	stron[illegible]	[illegible]	no	strong
Social learning and adaptation	no	no - weak	[illegible]	[illegible]	no	strong [f]
Farm heterogeneity	strong	no	[illegible]	weak	strong	strong [g]
Multi-dimensional outputs	strong	str[illegible]	[illegible]	medium	strong	strong
Distributed outputs	no	[illegible]	no	no	no	strong
Driver sensitive - Biophysical - Economic - Social	[illegible]	[illegible]weak unclear unclear	weak medium strong	weak strong no - weak	strong med.-strong no	weak - medium medium - strong strong

[a] NUTMON = NU[illegible] MONitoring
[b] NUANCES = Nut[illegible]ent Use in Animal and Cropping systems – Efficiencies and Scales
[c] IAT = Integrated Analysis Tool
[d] LUDAS = Land Use DynAmics Simulator
[e] MP-MAS = Mathematical Programming - Multi-Agent System
[f] rather multi-disciplinary, e.g. disciplines stand side-by-side
[g] with some, rather all MAS models, e.g. LUDAS model

Tools box needed to utilize methods' complementarities

Source: Le (2015), Le et al. (in revision)

Need to consider life-cycles of agri-food production: LCA approach



LCA for eco-efficiency (including economic and social dimensions) assessment

E.g. Tuomisto et al. (2012) (still lacking economic, social diamensions)

Figure's source: Vlek (2012)

How to embed ALS-based research in large food systems?

What to be researched with large food systems?

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Thank you