Coupling of LCA and GIS for biodiversity assessment of biofuel production

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Jan Paul Lindner

David Stoms

Roland Geyer

Frank Davis

Bastian Wittstock

University of Stuttgart
Chair of Building Physics (LBP)
Life Cycle Engineering (GaBi)

DONALD BREN SCHOOL OF ENVIRONMENTAL SCIENCE & MANAGEMENT
UNIVERSITY OF CALIFORNIA, SANTA BARBARA

Outline

- land use in LCA
- coupling of ArcGIS and GaBi
- generic structure of LCIA
- specific LCIA for land use
- results of the demonstration study
- conclusions, discussion
- appendix

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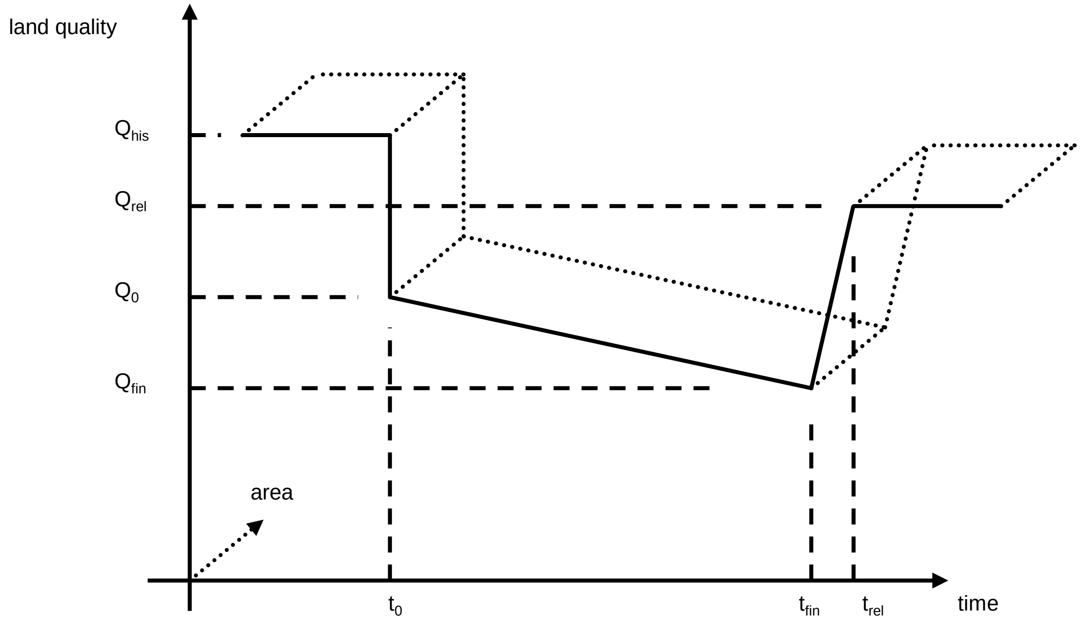
land use in LCA

spatial inventory modeling

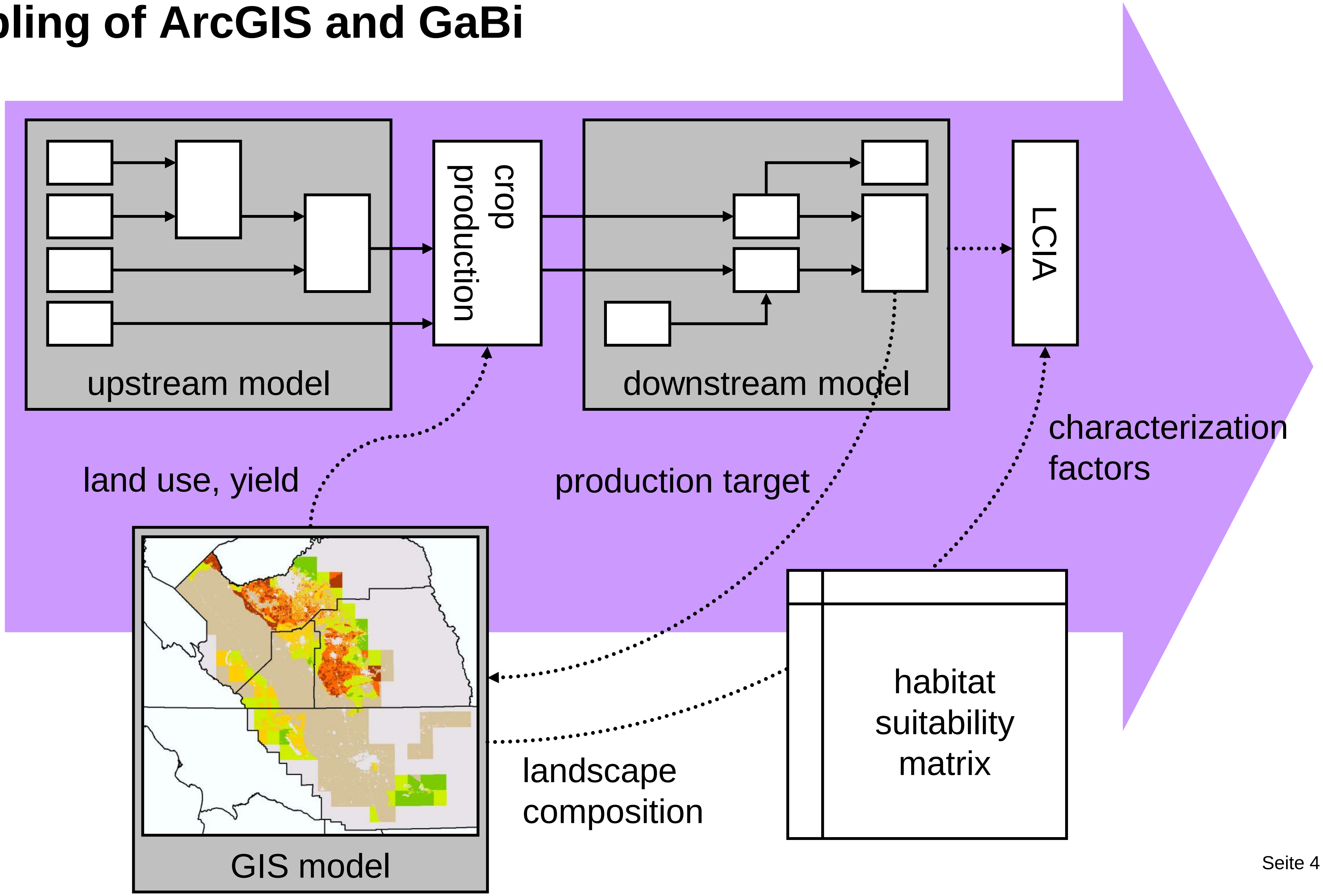
- land use is inherently spatial, local
- spatial impact assessment desired
- need for spatial inventory



land use impact assessment

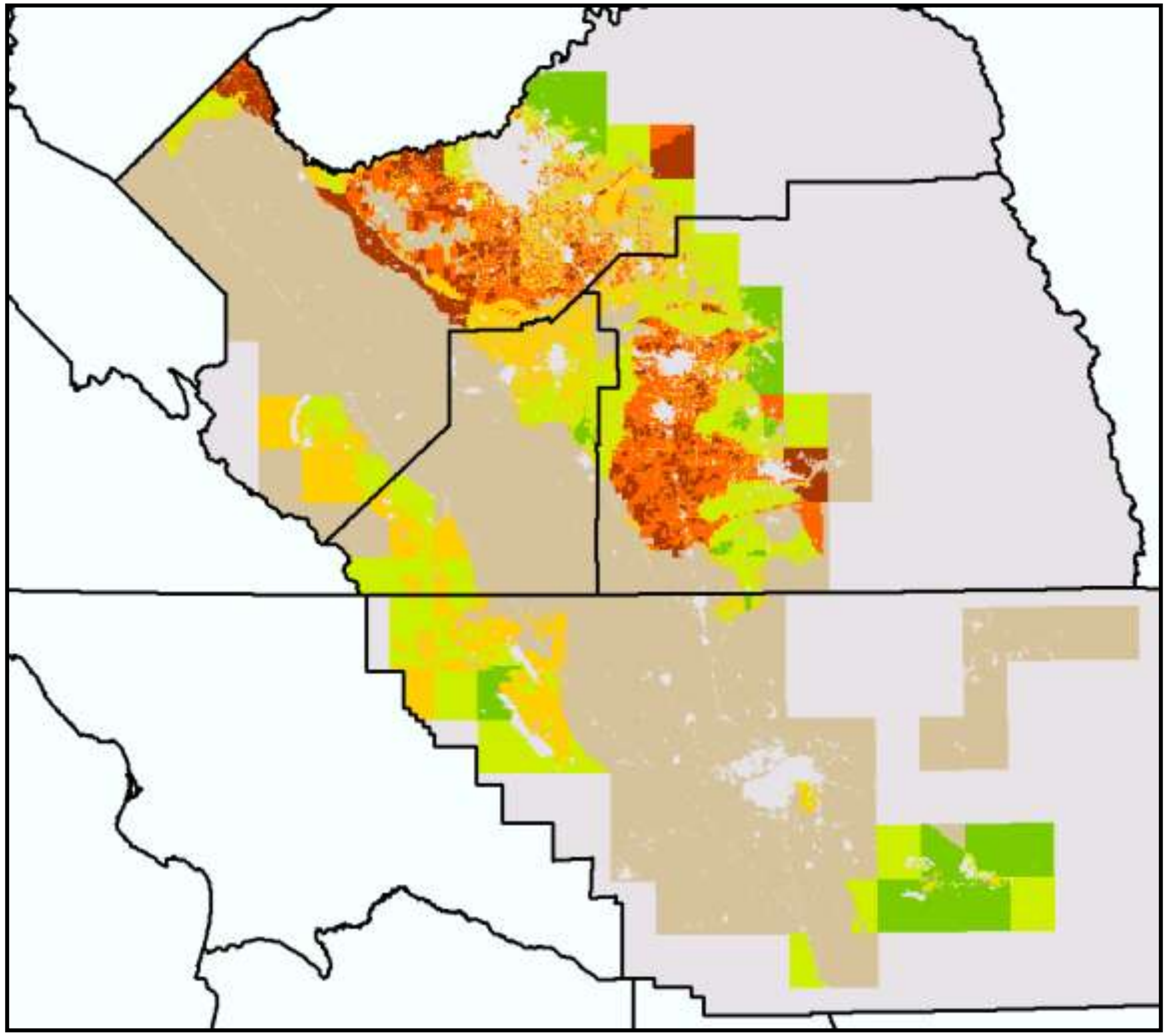
- framework by UNEP-SETAC Life Cycle Initiative, see Milà i Canals et al. (2007)
- three dimensions: land quality, area, time → impact = $\Delta Q \times A \times \Delta t$

coupling of ArcGIS and GaBi



coupling of ArcGIS and GaBi

- several scenarios w/ increasing production target, different crops
- ArcGIS determined parcels in which land use would switch based on potential yield, cost
- total crop yield based on spatially explicit potential yield data
- inventory modeling in GaBi (upstream, downstream of crop production)
- characterization factors for LCIA phase derived from landscape composition



generic structure of LCIA

- multiplication of each flow from LCI with characterization factor
- land use: land cover type areas as inventory flows

$$impact = \vec{a} \cdot \vec{c} = \sum_j a_j \cdot c_j$$

- $\vec{a}$: landscape composition vector
- $\vec{c}$: characterization factor vector
- j : index for land cover types

specific LCIA for land use: Naturalness Degradation Potential (NDP)

Brentrup et al. (2002)

- Hemeroby = deviation from pristine state
- Hemeroby classes have been defined by others, but Brentrup et al. converted the classes (ordinal scale) into cardinal numbers to allow numerical operations
- perfectly untouched land: NDP = 0
- completely paved land: NDP = 1
- linear interpolation
- use of NDP as characterization factors

specific LCIA for biodiversity: Rarity Rated Richness (R³)

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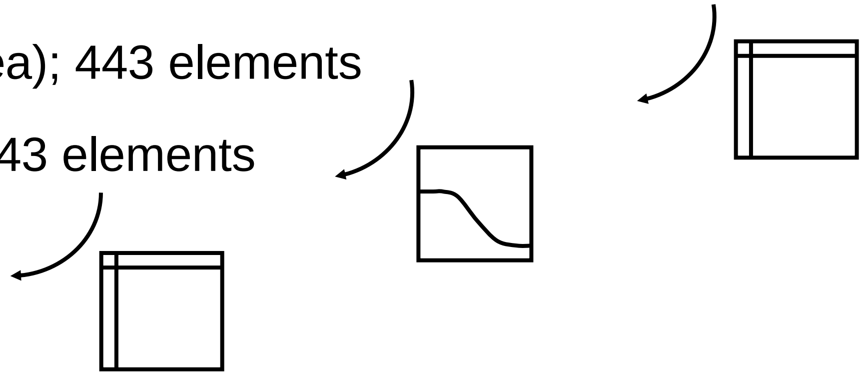
- 29 land cover types (habitat types)
- 443 species
- 29x443 habitat suitability matrix

starting point: landscape composition in current state (reference); 29 elements

relative species abundance (by habitat area); 443 elements

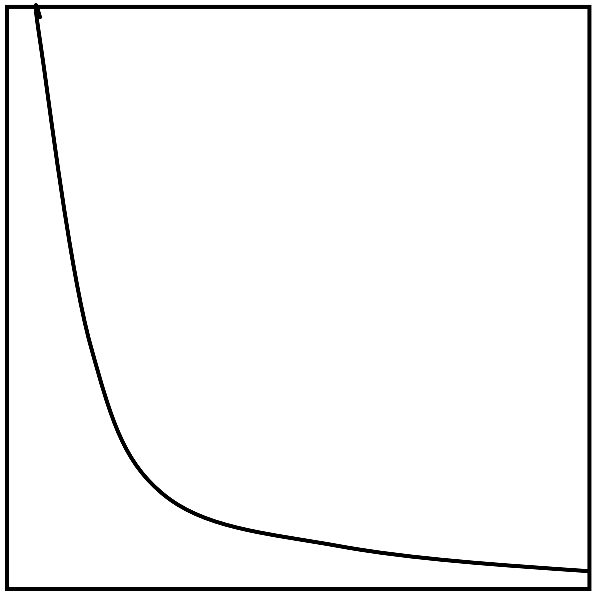
species rarity (potentially arbitrary step); 443 elements

characterization factors; 29 elements

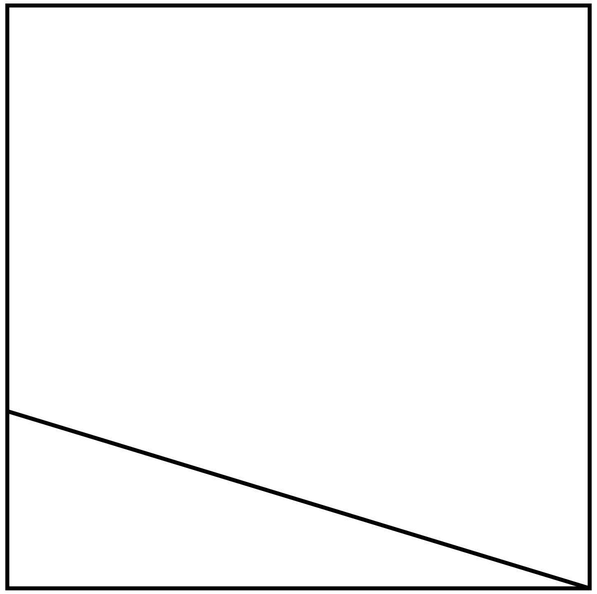


specific LCIA for biodiversity: Rarity Rated Richness (R^3)

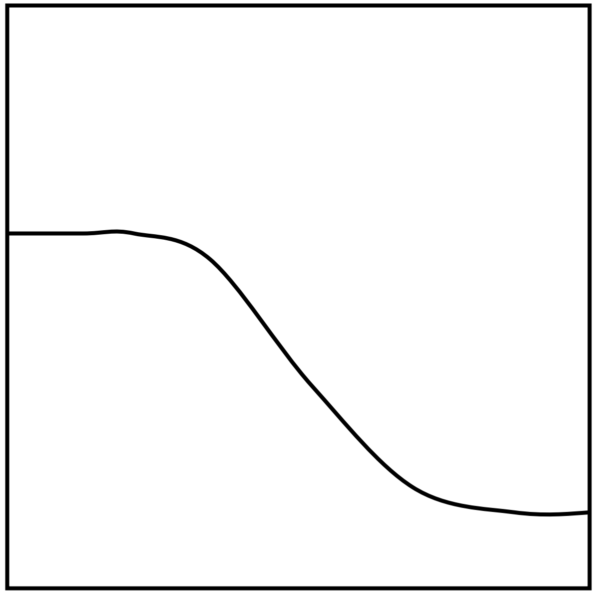
rarity = lack of abundance → several ways of defining r = f(a)



$r = 1/a$



$r = 1 - a$



$r = 1/(0.01+a)$

a: abundance

r: rarity

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generic biodiversity measure: Simpson's D

Simpson (1949)

- statistical quantity to describe field samples
- measures evenness of distribution

$$D = \sum_i p_i^2$$

p: probability = relative abundance

- relative abundance by habitat area (as in R^3)

demonstration study – the San Joaquin Valley

crops investigated

- corn (well established) → starch, cellulose
- sugar beets (very productive) → sugar

demonstration study – the San Joaquin Valley

biofuel crop production for ethanol in the San Joaquin Valley, California

- California's prime agricultural region
- largest number of threatened or endangered species in the mainland US

demonstration study – results

yields and efficiency

- relative yield (kg/ha) decreases with increasing production target
- sugar beets allow highest demand to be met

biodiversity impact

- areas with higher conservation value transformed to meet higher demands
- increasing area need + increasing conservation value
- biodiversity impact increases rapidly with increasing production target

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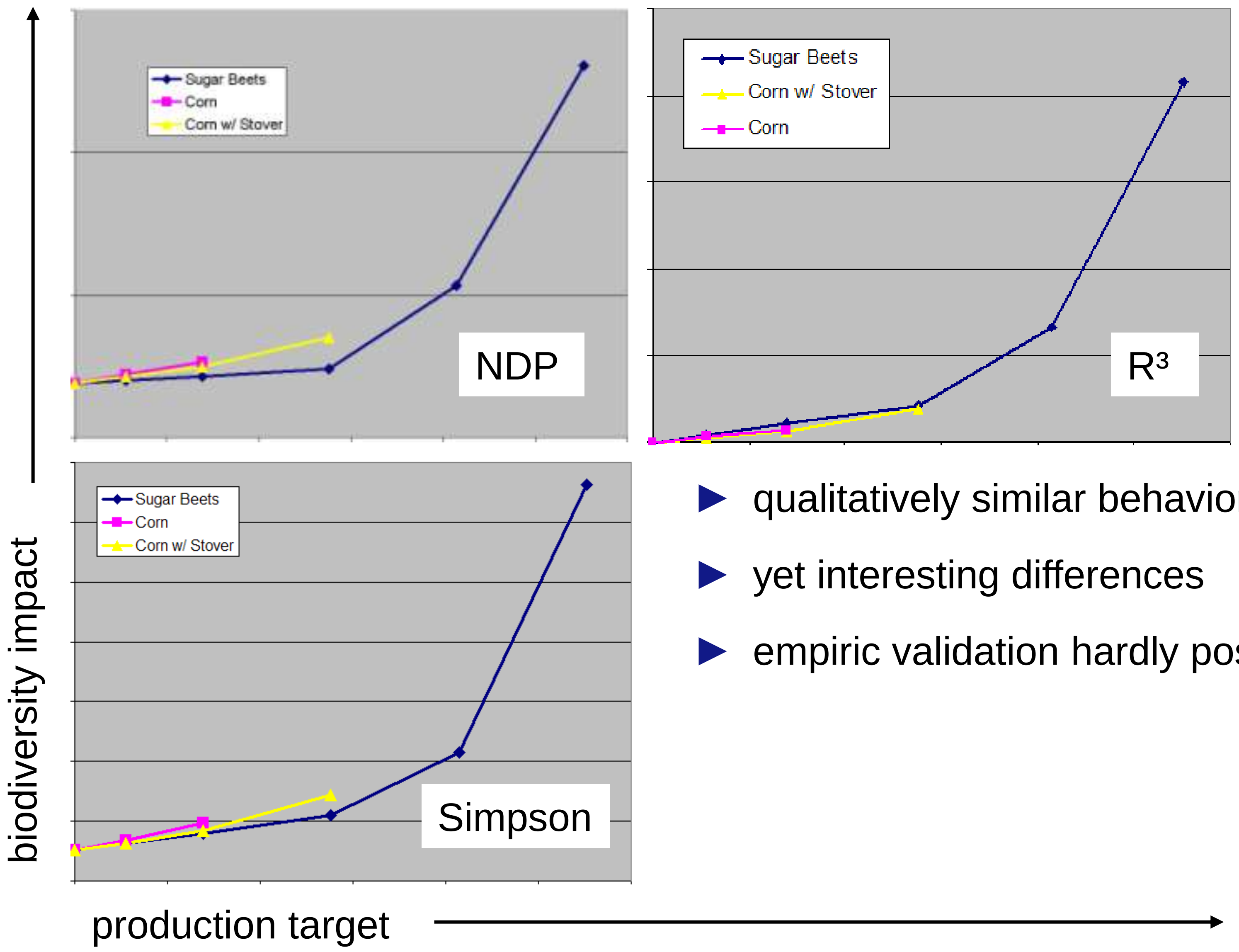
demonstration study – results



- qualitatively similar behavior of all indicators
- yet interesting differences
- empiric validation hardly possible

conclusions, improvement potential, and discussion

conclusions

- LCI needs to go spatial
- LCIA needs to go non-linear

improvement potential

- R^3 indicator is applicable to other places, but needs standardization in order to produce comparable results
- r = f(a) is arbitrary, needs legitimization by elected officials

time for discussion with audience

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contacts and references

corresponding author

- Roland Geyer: geyer@bren.ucsb.edu

Bren School: http://www.bren.ucsb.edu

LBP GaBi: http://www.lbpgabi.uni-stuttgart.de

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