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Land use impacts on biodiversity loss in LCA:
A bottom-up approach including agricultural intensities and landscape structural diversity

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Land use impact assessment of different agricultural management practices

Assessment of land use impacts on biodiversity in LCA due to different agricultural management practices is still difficult:

- Assessment often restricted to land use types;
- Relatively low resolution regarding land use intensity;
- Some discrete CFs available for some land use types, e.g. intensive/extensive or organic/conventional arable cropping and pastures (e.g. Mueller et al. (2014), de Schryver et al. (2010), Koellner & Scholz (2008))
  - → Of limited use because of wide variation of intensive/extensive or organic/conventional agriculture;
  - → Only limited support for decision-making on land management practices.

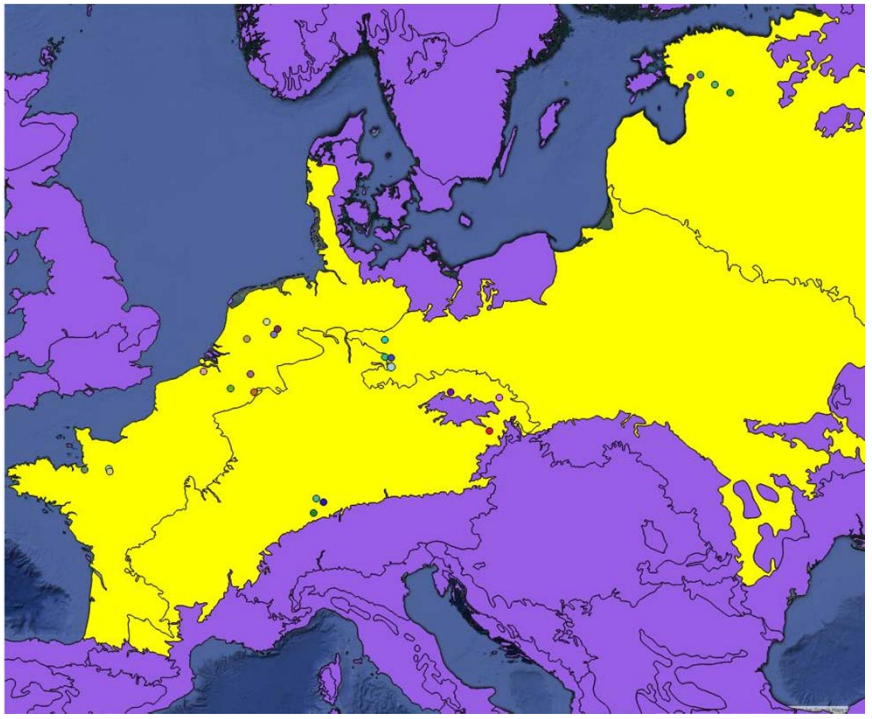
Land use impact assessment of different agricultural management practices

- Current approaches oversimplify the real dynamics and complexity of the interactions of species among each other and with their habitats:
  - What are the cause-effect relationships between agricultural land use intensity and impacts on biodiversity?
  - What factors influence farm land biodiversity on different spatial scales apart from the presence of (semi-)natural habitats?

→ Objective:
Development of a life cycle impact assessment method for agricultural land use that is able to differentiate production intensities.

Empiric dataset from the GREENVEINS project: Basis for model building

- Pan-European study investigating the relationships between several biodiversity aspects on landscape scale and land use intensity and landscape structure (Billeter et al., 2008).
- Data collection within 25 landscapes (4 x 4 km) in seven European countries.
- 7 species groups studied:
  - vascular plants,
  - birds,
  - wild bees,
  - carabids,
  - hover flies,
  - true bugs,
  - and spiders.



Empiric dataset from the GREENVEINS project: Basis for model building

For farmland biodiversity the GREENVEINS project showed:

- Species richness on landscape level (16 km^2) of different species groups are a function of:
  1. Land use intensity, and
  2. Landscape structure.

→ Regression equations can be used to derive land use impact assessment models differentiating agricultural land use intensities.

Cause-effect relationships adopted from the GREENVEINS dataset for model building

Species group	Land use intensity parameter	Landscape structure parameter
Vascular plants	LUI (normalized parameter including N-input, number of pesticide applications, livestock density)	Percentage of semi-natural habitats within landscape
Arthropods (including wild bees, hover flies, carabids, spiders)	Crop diversity in a landscape	Percentage of semi-natural habitats within landscape
Birds	N-input	Percentage of semi-natural habitats within landscape

Basic model – estimation of species depletion potential on landscape scale

$$S_{plants} = \alpha \times LUI + \beta \times \%SNH + i$$

S_{plants} = Vascular plant species richness on landscape scale
LUI = Land use intensity index
%SNH = Share of semi-natural habitats within landscape
α, β = Slopes
i = Intercept

$$BDP_{plants} = \frac{(S_{plants_{max}} - S_{plants_i})}{(S_{plants_{max}} - S_{plants_{min}})} \times \frac{F_{LS}}{F_x} \times \frac{LUI_{F_x}}{LUI_{LS}}$$

BDP_{plants} = Species depletion potential for vascular plants in a landscape due to land use intensity LUI_{F_x} on area F_x

→ Allocation of species loss on landscape level to a specific area according the relative share of this area and the intensity in the landscape.

Basic model – estimation of species depletion potential on landscape scale

→ Analogous formulas for BDP of arthropods and birds!

Total species loss potential as average of all groups:

$$BDP_{tot} = \frac{(BDP_{plants} + BDP_{arthropods} + BDP_{birds})}{3}$$

Value range = {0 … 1}

Model input parameters

Landscape structure:	
Parameter	**Data source**
Share of semi-natural habitats (%SNH)	Digitized Google satellite images processed in GIS
Land use intensity:	
Parameter	**Data source**
Land use intensity on **landscape level**: Average N- and pesticide input, average livestock density and average crop diversity within a landscape (all scaled to the UAA)	Derived from the average crop rotation in a region, fertilization recommendations, and agricultural statistics
Land use intensity of a **specific area within a landscape**: N- and pesticide input, and livestock density (in case of grassland)	LCA inventory of a specific area (1 m^2; 1 ha) of crop/grassland under study.

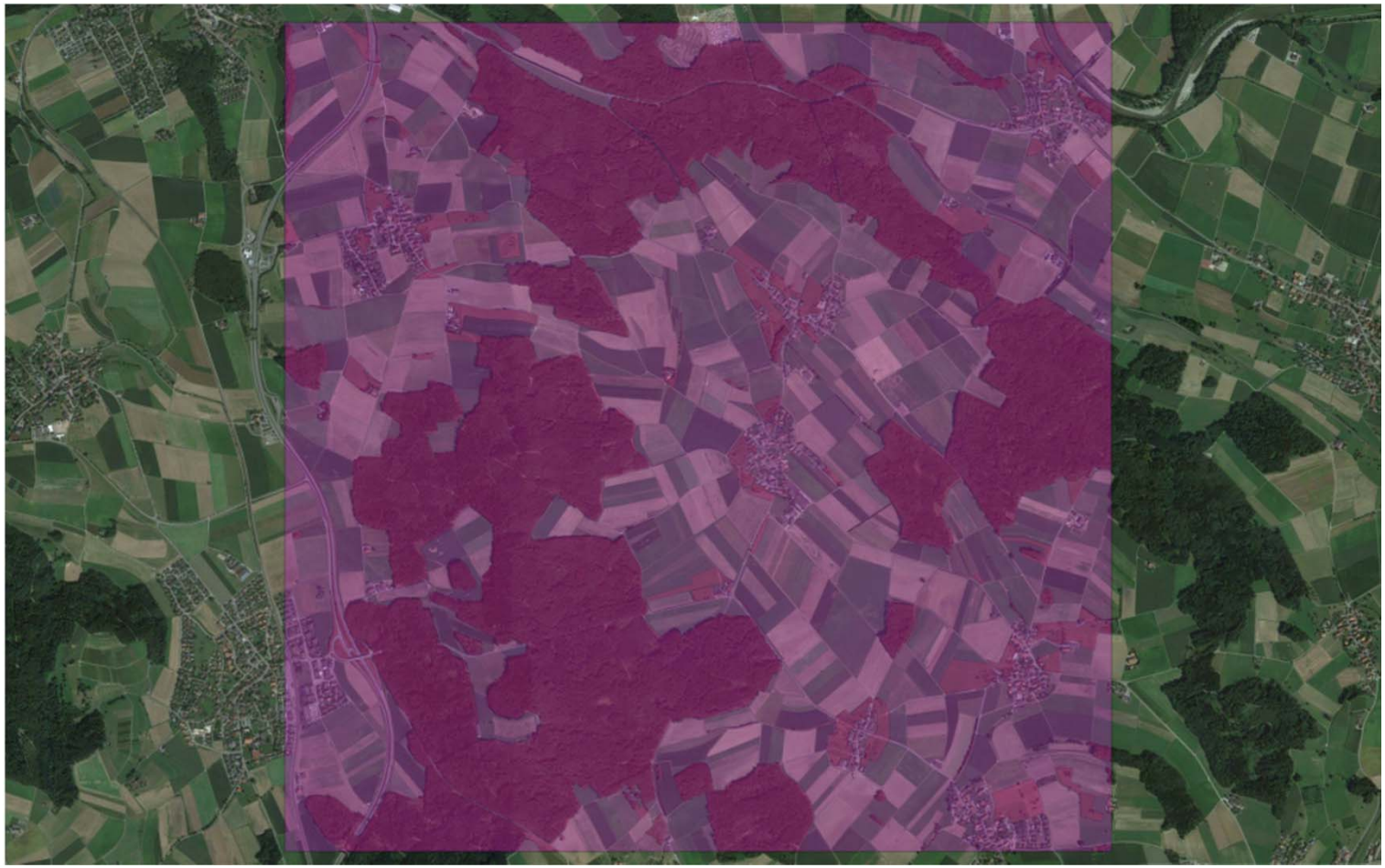
Model characteristics

- The BDP expresses the relative contribution of an agricultural used area within a landscape to the overall species loss on landscape level due to agricultural land use.
- The model delivers continuous CFs for specific land use intensities and specific levels of land scape structure.
- By including landscape structure elements the local biodiversity quality is taken into account.
- Regression equations are valid for the biome “Temperate Broadleaf and Mixed Forests” → ways of adopting CFs for other biomes have been elaborated
- Aggregation of landscapes to global level would allow for global biodiversity assessment.

Case study - milk

16 km^2 landscape square in the canton of Zurich

→ share of semi-natural habitats: 38% of total landscape area.



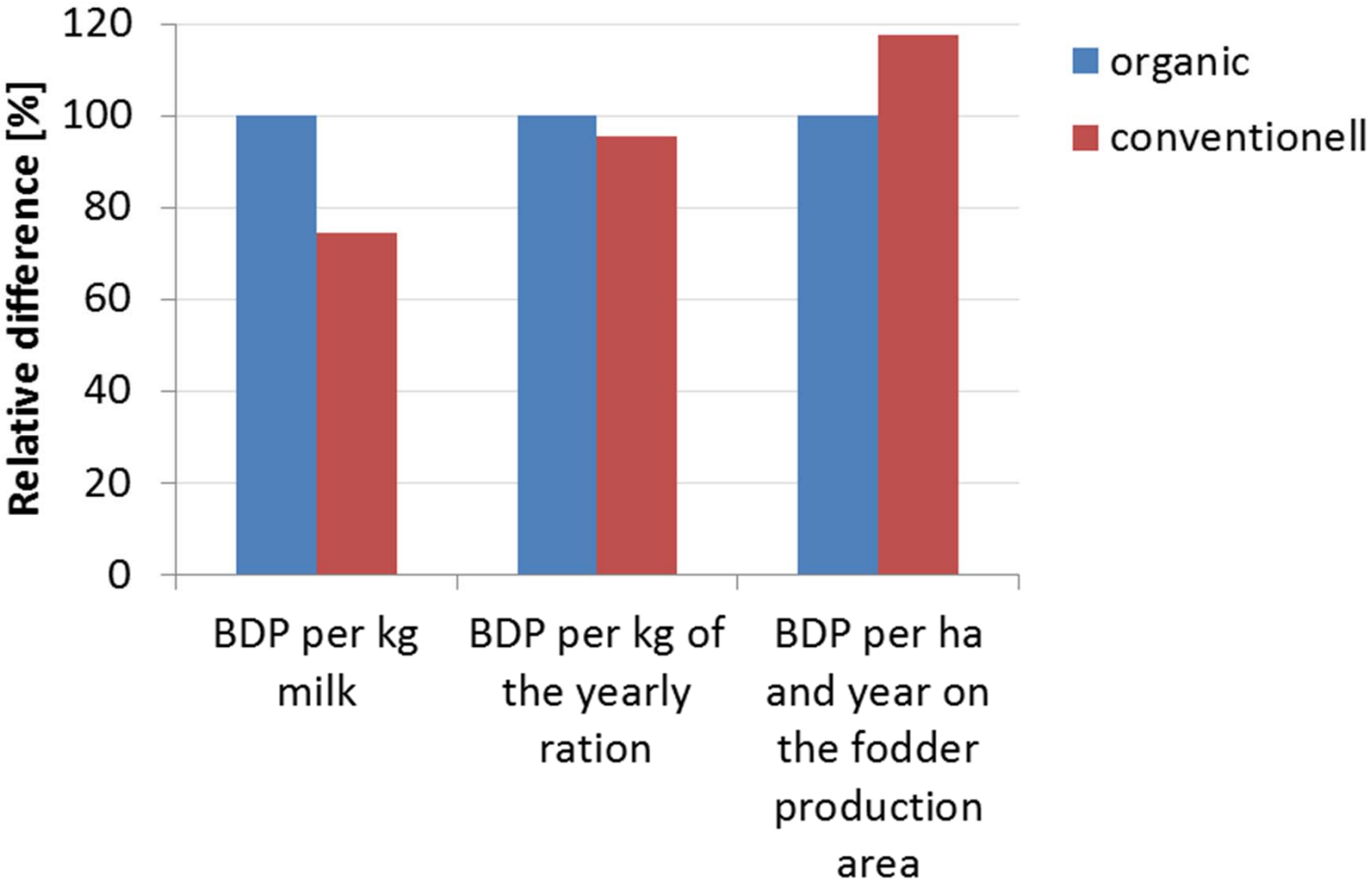
Case study - milk

Ration component	Conventional milk production	Organic milk production
	kg/a	kg/a
Soybean extraction meal	250	
Soybean meal	-	235
Concentrate	510	280
Grass from pasture	3‘550*	3‘550*
Hey	-	1‘140*
Grass silage	990*	990*
Maize silage	990*	990*
Straw	1‘200*	1‘200*
*dry matter	8’000 kg annual milk performance	7’000 kg annual milk performance

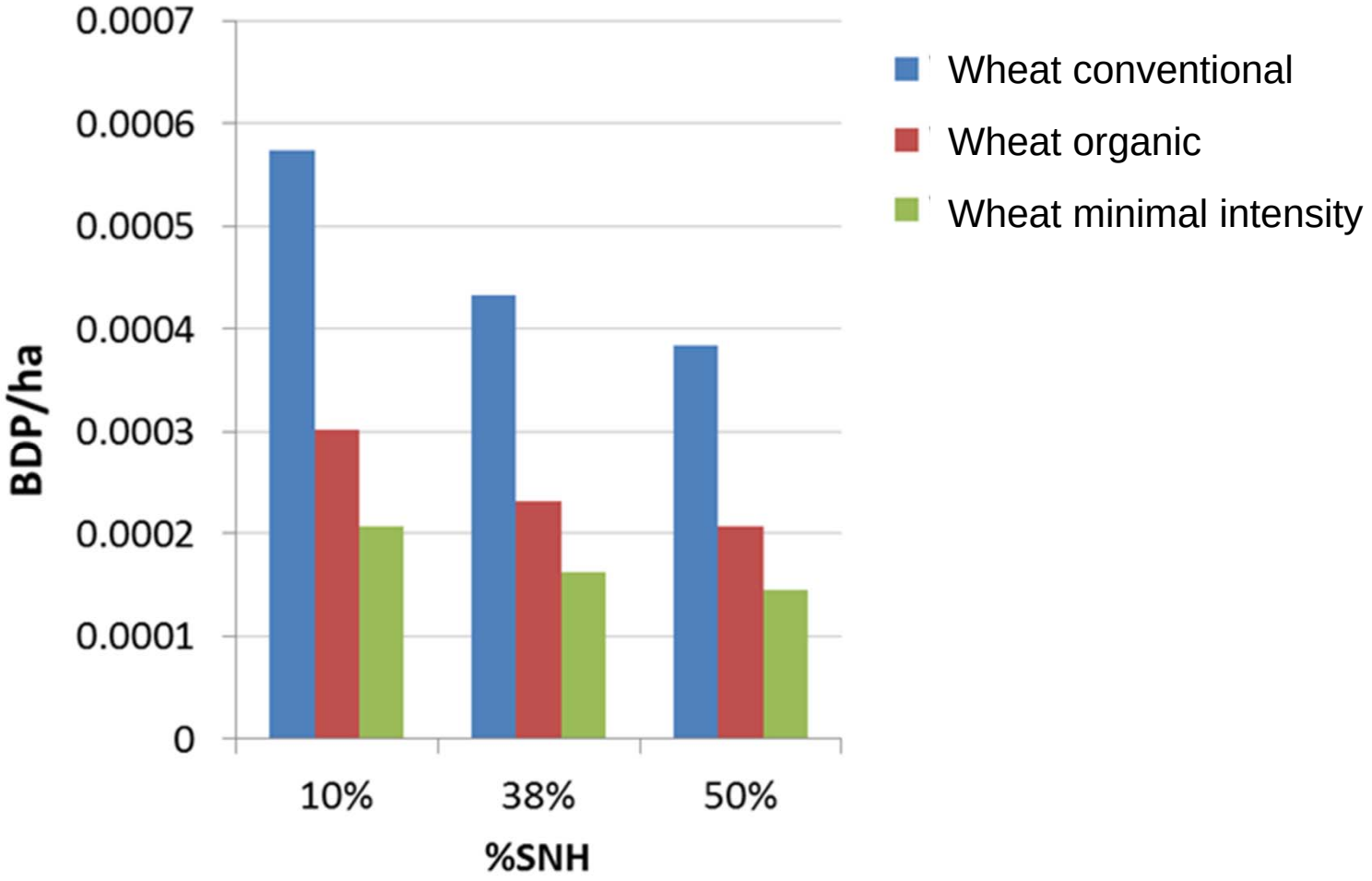
Case study - milk

	organic	conventional
Required area per cow and year [ha/Kuh*a-1]	1.07	0.81
Annual ration total mass [kg DM]	8'326	7'351
BDP per required area and year	4.73E-04	4.17E-04
BDP per total mass of annual ration	3.94E-04	3.20E-04
BDP per kg milk	6.73E-08	4.80E-08
BDP per kg annual ration	4.74E-08	4.35E-08
BDP per ha of required area and year	4.43E-04	5.18E-04

Case study - milk



Effect of agricultural intensity in different landscapes



Interpretation

Trade-off between production and biodiversity conservation:

Biodiversity and agricultural productivity compete for land in a double sense!

Within a landscape:

- Intensive agriculture / high productivity and high species diversity are possible in heterogeneous landscapes → enough area needed for semi-natural habitats.

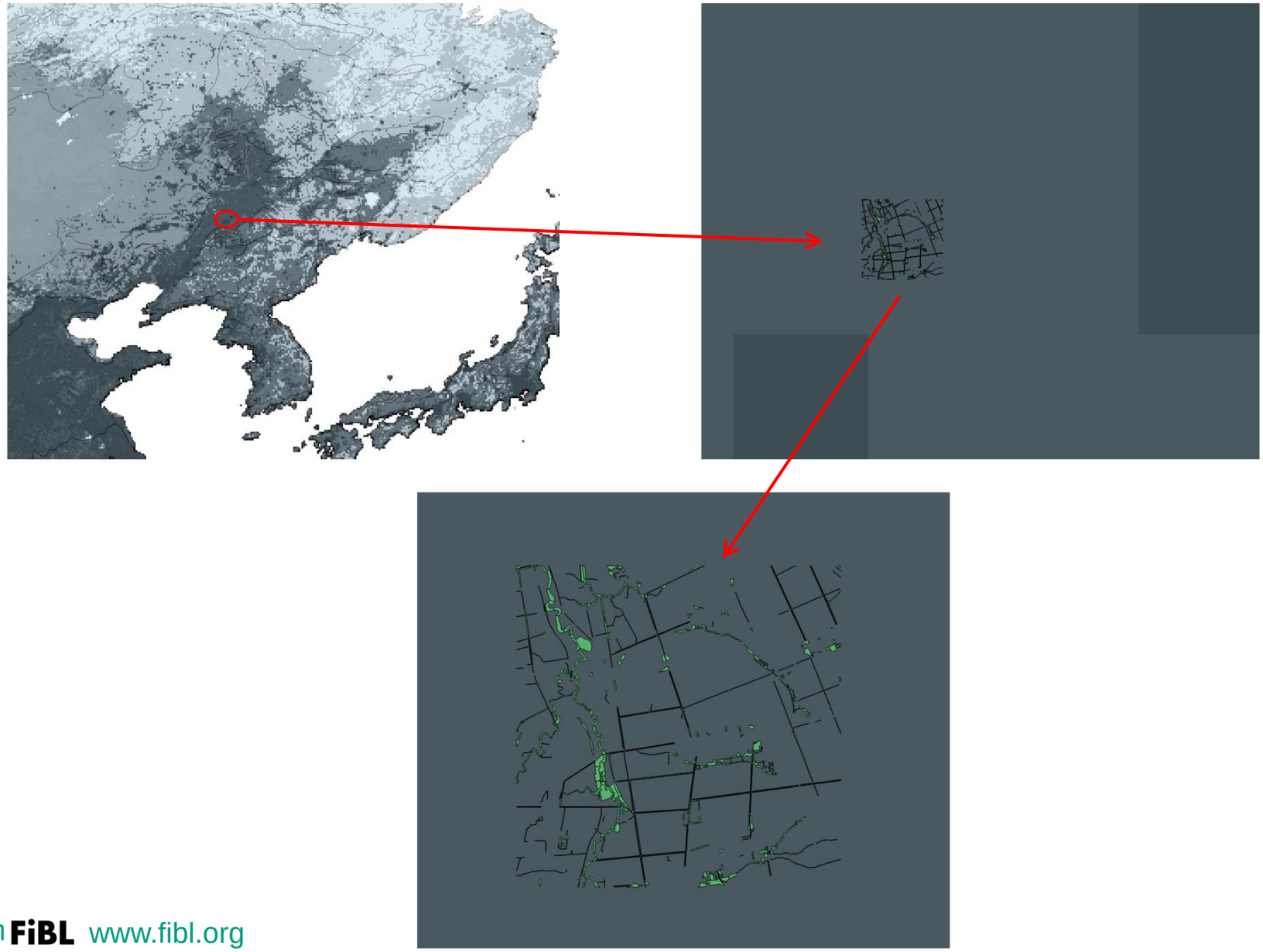
Among agriculturally used landscapes:

- In low structured landscapes extensive agriculture mitigates impacts on species diversity on the cost of a lower output → additional agricultural area is needed elsewhere to produce the same amount of output.

Relation to proposal by UNEP-SETAC

Regional CFs (as basis for global CFs)	Assessment method based on country-side SAR model (Chaudhary et al., 2015)	This assessment method
Species loss assessed on the scale of:	ecoregion (12 to 4'650'164 km^2, median: 65'024 km^2)	landscape (16 km^2)
Accounts for:	species loss due to habitat loss	species loss due to habitat loss and agricultural intensity
Species loss of scale considered allocated to:	different land use types	specific area of agricultural used area (UAA) within land scape under a specific intensity
Considers:	• natural habitat area per land use type within ecoregion	• (semi-)natural habitat area within landscape; • land use intensity within UAA • in the upcoming version: fragmentation of (semi-)natural habitats
Taxa considered:	vascular plants / birds / mammals / amphibians / reptiles	vascular plants / birds / arthropods (wild bees, hover flies, carabids, spiders)

Spatial resolution matters!



Conclusions

- Land use types are probably to coarse to distinguish impacts between different land use intensities.

- Including parameters of (agricultural) land use intensity within impact assessment models for biodiversity requires a high spatial resolution

  → Only in this case interactions between land use intensity and (semi-)natural habitats become visible!

Acknowledgement

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