

TRADE-OFFS BETWEEN LAND AND WATER USE:

REGIONALIZED IMPACTS OF ENERGY CROPS

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and Stefanie Hellweg

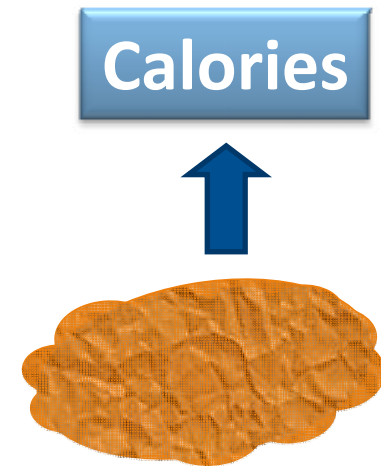
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Motivation

Energy crops: main quality
= energy content

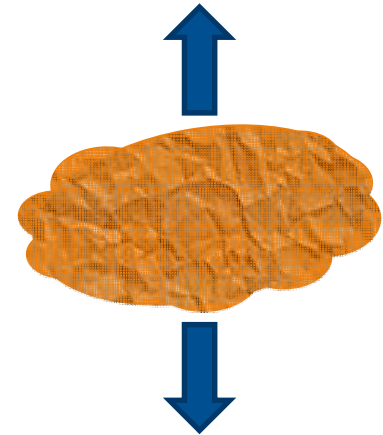


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Energy crops: main quality
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Conflict with nutritional energy:

- Food – Biofuel



Motivation

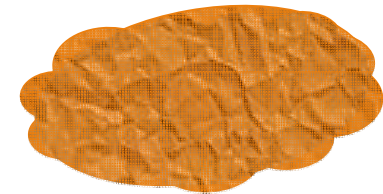
Energy crops: main quality
= energy content

Conflict with nutritional energy:

- Food – Biofuel

Water has recently become a focus

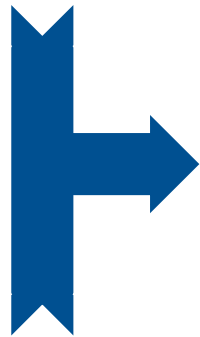
- Regionalized inventory and impact assessment
- Trade-offs of water and land use (intensity)
- So far limited regionalization for land use



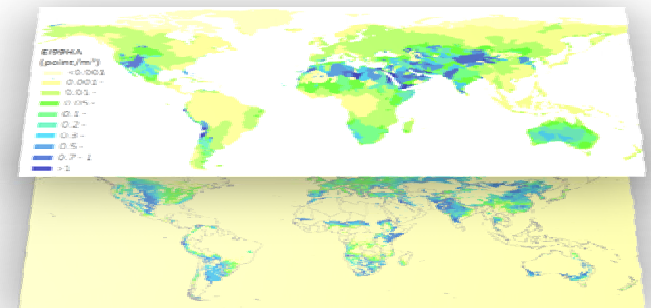
Pix: Google maps

Methods

- Regionalized **inventories** for crops (land & water)



Combination in GIS



- Regionalized **damage factors** based on EI99HA
 - Water consumption: Pfister et al. 2009
 - Land use: new development
 - Other impacts: neglected

Regionalized inventory

- Land occupation (area-time):
 - Yield from statistics and remote sensing (*pixel, 5 arc minutes*)
 - Crop and natural growth period durations (*biomes, pixel*)
- Irrigation water consumption
 - Based on CROPWAT (FAO) irrigation model: crop periods (*biomes*) precipitation, reference evapotranspiration , and irrigation (*pixel*)
 - Yield (*pixel*)

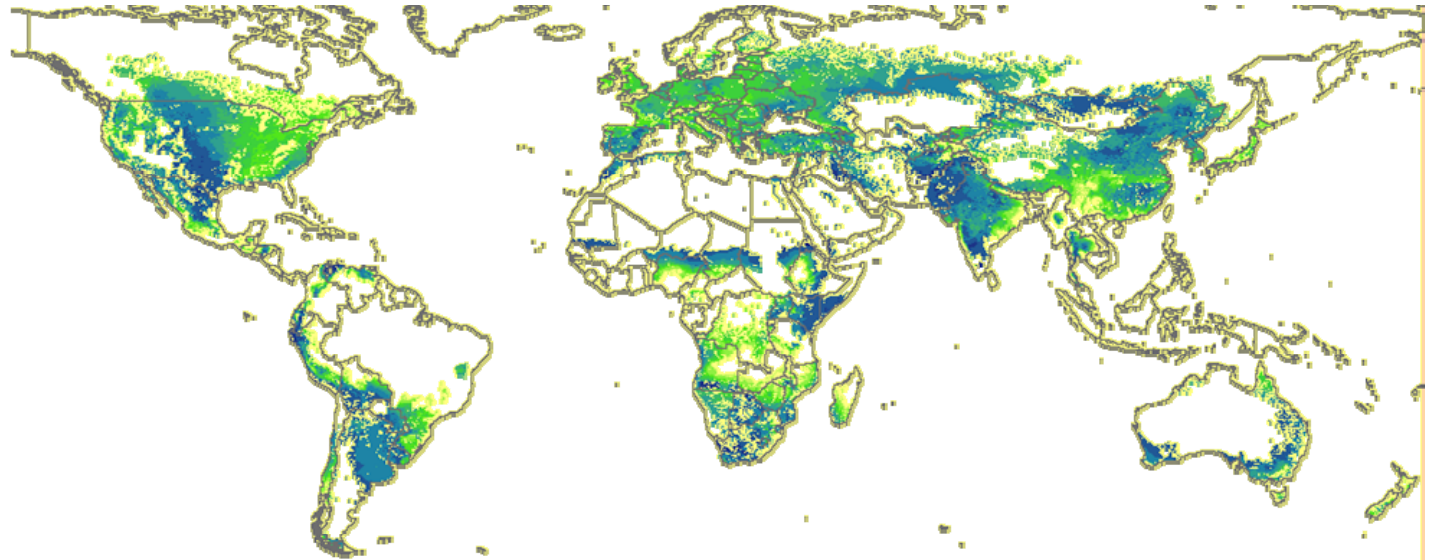
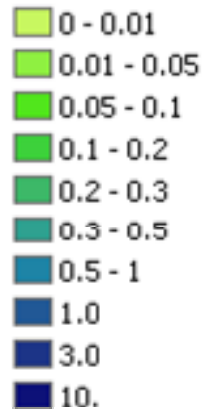
Main sources :

Pfister et al. (submitted), Ramankutty et al. 2008 (yields production), New et al. 2002 (climate), Fischer et al. 2000 (natural growth periods), Chapagain et al. 2004 crop growth periods

Wheat inventory: water and land use

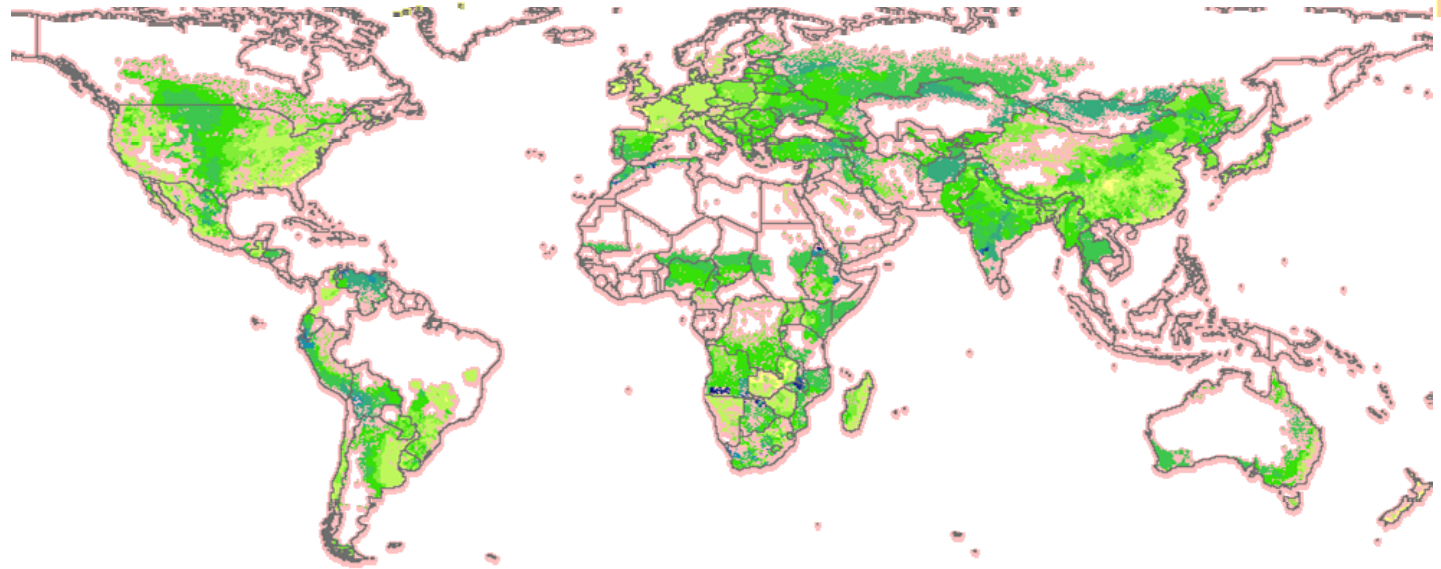
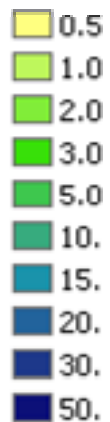
Water consumption

[m³/kg]



Land occupation

[m²yr/kg]

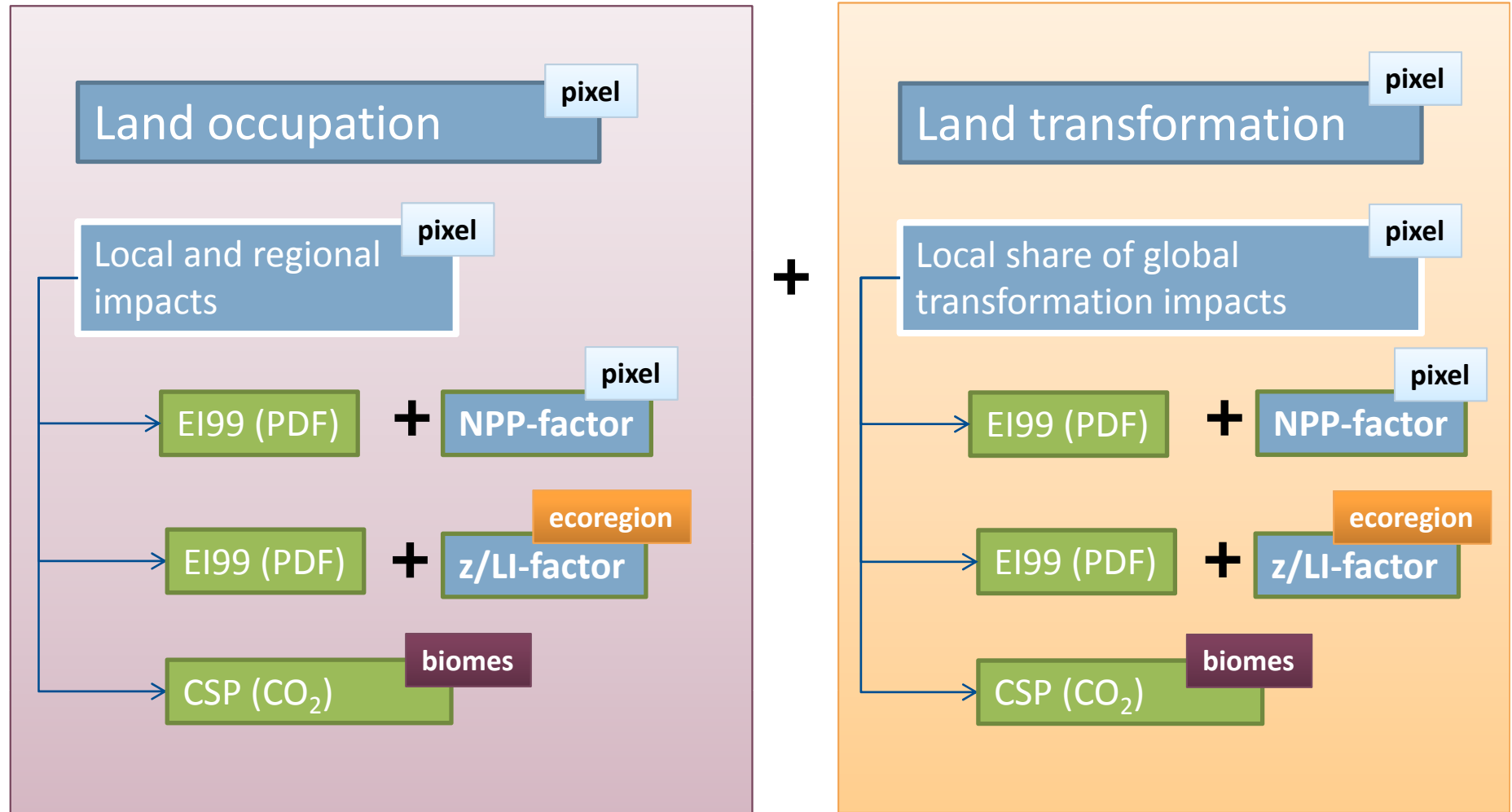


Land use impact assessment

According to EI99HA:

- Ecosystem quality (EQ):
 - Based on Köllner (2001): plant species richness, z-factor
 - Include ecosystem scarcity & vulnerability (Weidema & Lindeijer 2001, Schmidt 2008)
- Carbon sequestration potential (CSP)
 - Based on Müller-Wenk & Brandao 2010
 - Apply EI99HA impact factors for GHG emissions

Impact assessment scheme



Regionalized ecosystem quality impacts

$$\text{PDFm}^2\text{yr}_{\text{EI99},i,j} = \text{PDF}_{\text{EI99},\text{HA}} \cdot \text{At}_{\text{LU}} \cdot \frac{\text{NPP}_i}{\text{NPP}_{\text{SLL}}} \left(1 + \text{z}_{\text{EI99}} \frac{\text{z}_j}{\text{z}_{\text{PA0445}}} \cdot \frac{100 - \text{HFI}_{\text{PA0445}}}{100 - \text{HFI}_j} \right)$$

NPP-factor
↓
z-factor
↓
Intensity-factor
↓

NPP_{SLL} = Reference NPP of Swiss lowlands = **650g/m²yr**

z_{PA0445} = z factor of ecoregion PA0445 (Swiss lowlands)

$\text{HFI}_{\text{PA0445}}$ = Human footprint index of PA0445 = **31.5**

NPP-factor pixelwise *i* / vulnerability factor ecoregion-based *j*

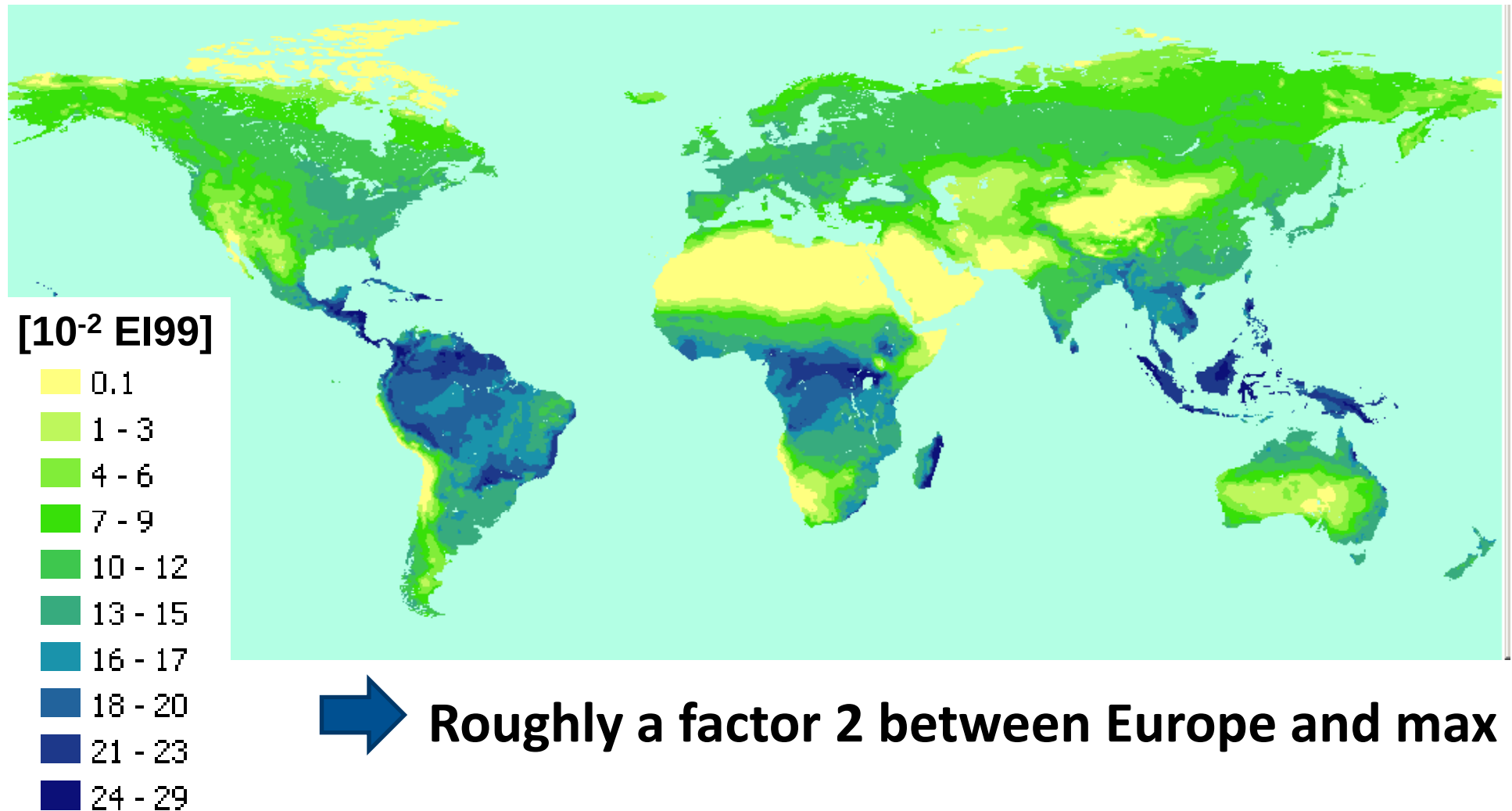
Transformation inclusion

- Occupation / Transformation
 - Transformation often very high (e.g. ~25% for German and Swiss rapeseed production according to ecoinvent)
 - Restoration time based on Schmidt (2008) and Weidema et al. (2001)

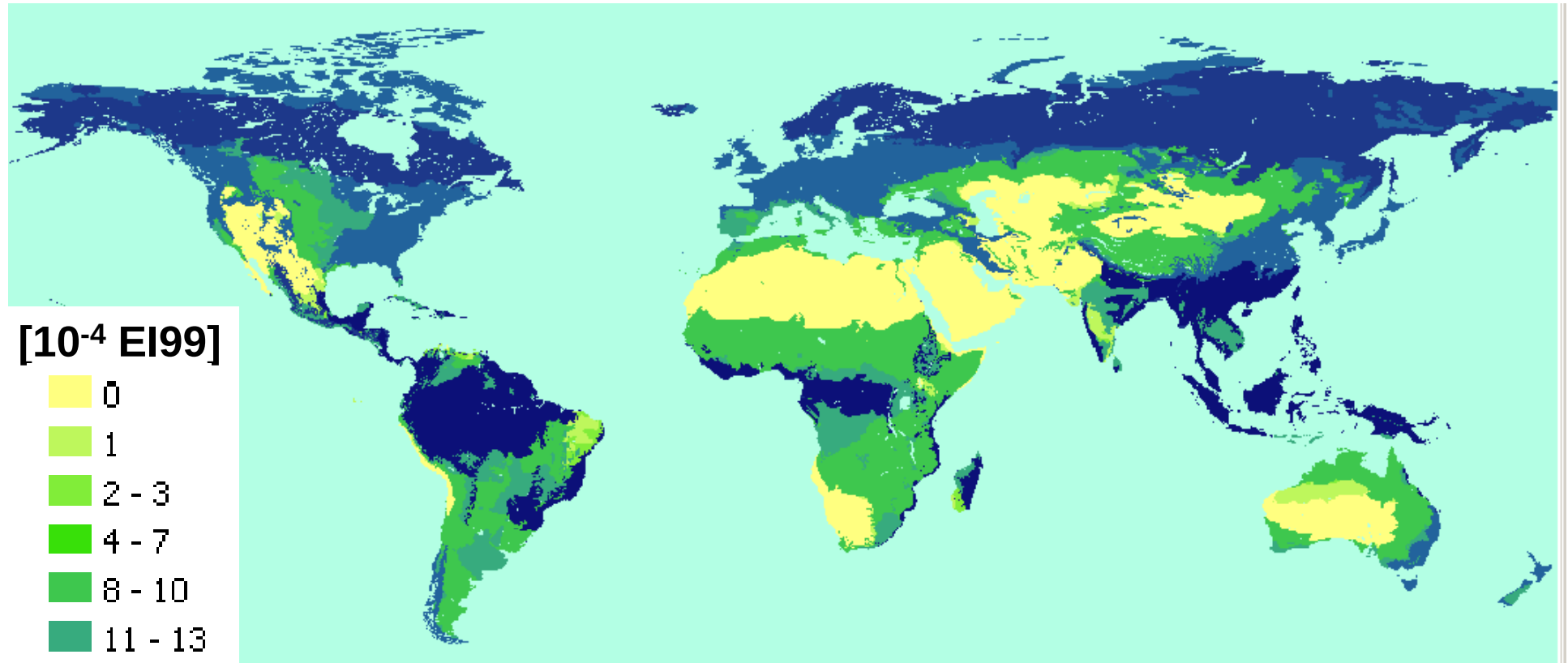
$$CF_{\text{transformation}, i} = \frac{\text{IMPACT}_{\text{Global}, \text{year}}}{\text{area}_{\text{agri}, \text{year}}} \cdot \frac{\text{NPP}_{0, i}}{\text{NPP}_{0, \text{global}}}$$

- 0.41% transformation rate (based on past 20 and 100 year LU change assessment)

Ecosystem Quality impacts



Climate change impacts

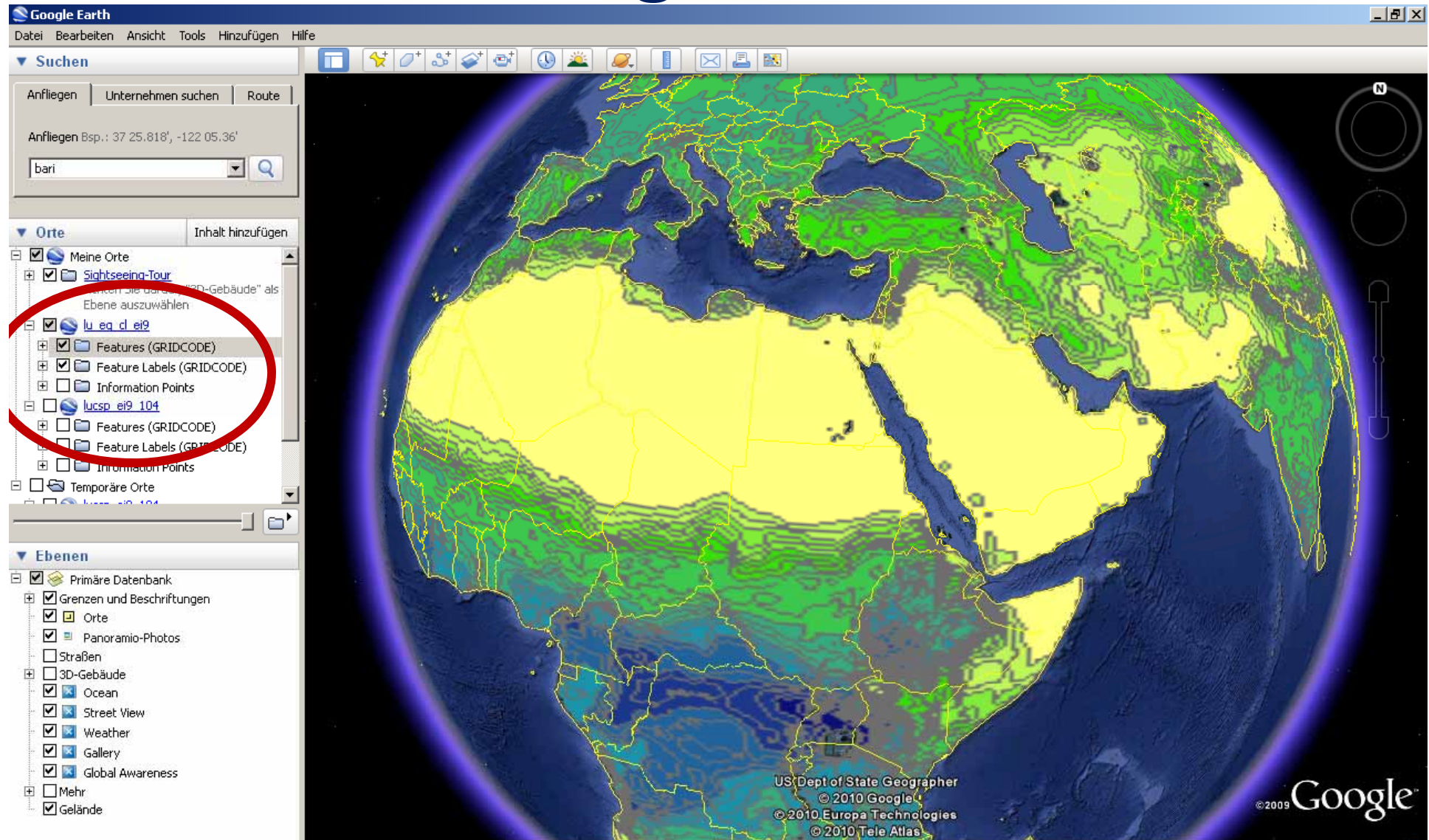


- ➔ CSP roughly 100 times lower than EQ
- ➔ similar pattern (except for cold climates)

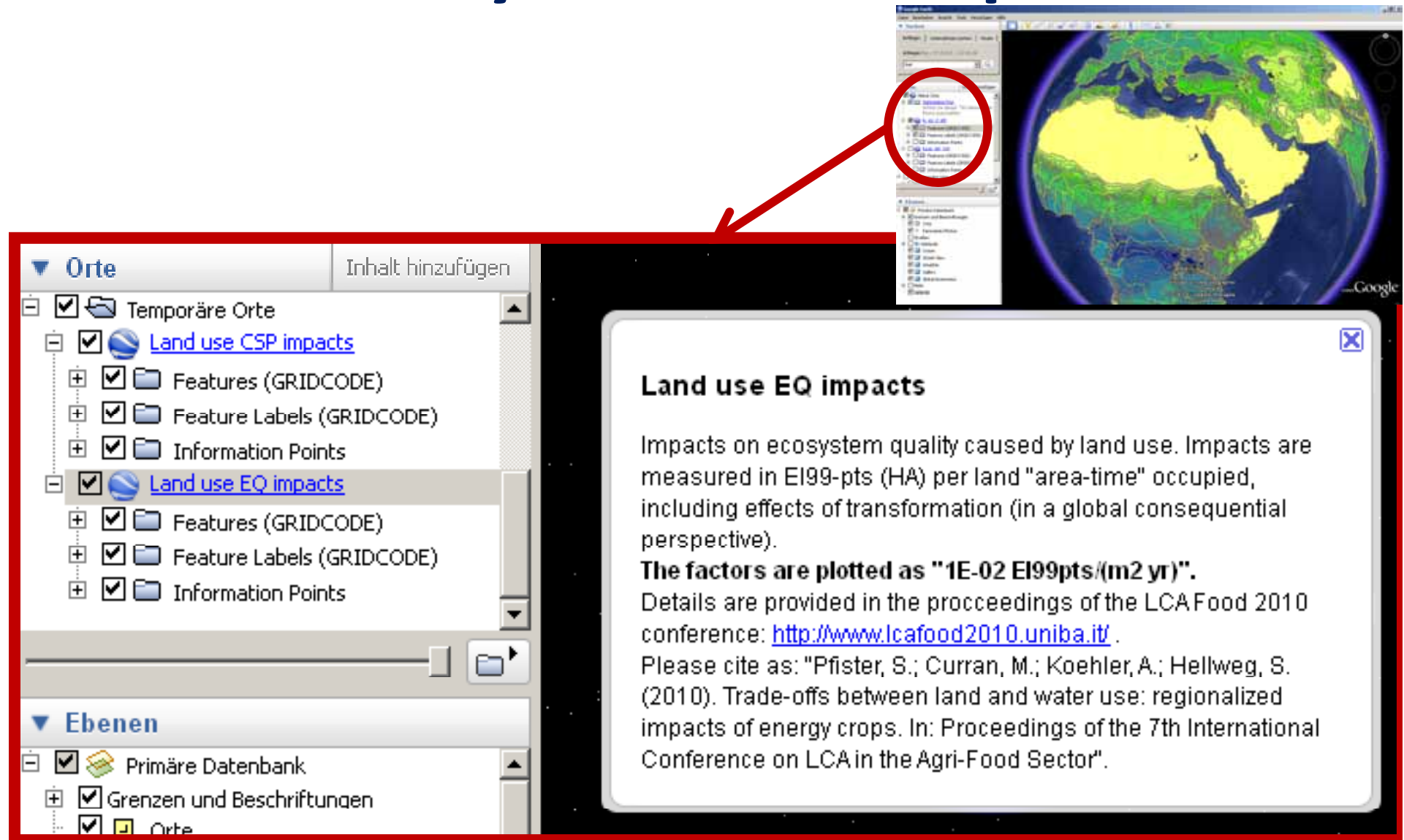
Application of regionalized impact factors

- Google Earth layer: impacts according to **EI99HA method**: www.ifu.ethz.ch/ESD/data
 - Download layer, double-click & read impact factors
 - Apply to inventories
- Subtract standard land occupation and transformation impacts (including related CO2 emissions)

Google Earth



Load layer and description



The screenshot shows a GIS application interface. On the left, a layer list under the heading "Orte" (Places) is visible. It contains two main entries: "Land use CSP impacts" and "Land use EQ impacts". Each entry has sub-items for "Features (GRIDCODE)", "Feature Labels (GRIDCODE)", and "Information Points". The "Land use EQ impacts" entry is selected. Below this, under the heading "Ebenen" (Layers), there are three entries: "Primäre Datenbank", "Grenzen und Beschriftungen", and "Orte". A red arrow points from a small inset window in the top right corner to a larger description window on the right. The inset window shows a list of layers, with "Land use EQ impacts" circled in red. The description window, titled "Land use EQ impacts", contains the following text:

Land use EQ impacts

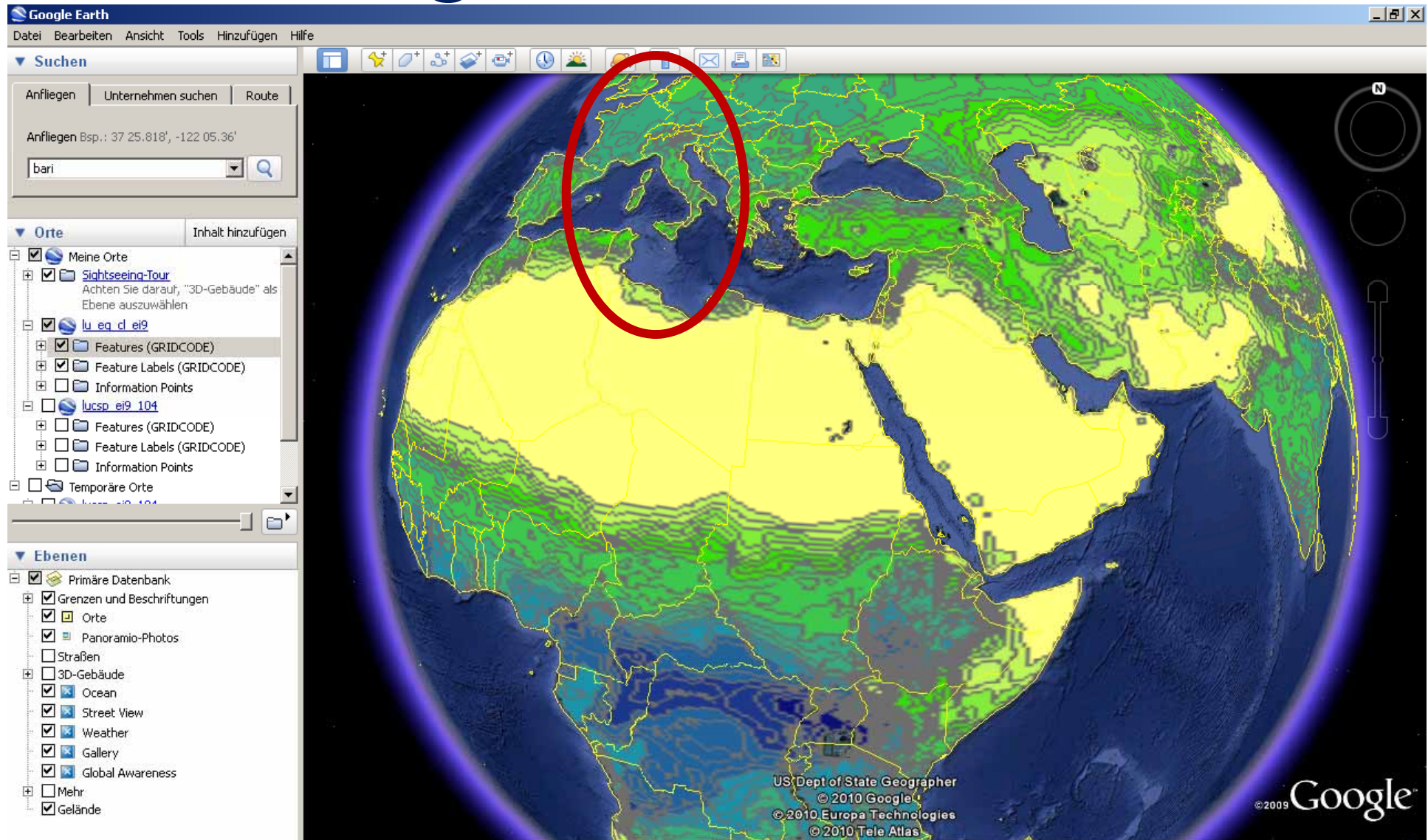
Impacts on ecosystem quality caused by land use. Impacts are measured in EI99-pts (HA) per land "area-time" occupied, including effects of transformation (in a global consequential perspective).

The factors are plotted as "1E-02 EI99pts/(m2 yr)".

Details are provided in the proceedings of the LCAFood 2010 conference: <http://www.lcafood2010.uniba.it/>.

Please cite as: "Pfister, S.; Curran, M.; Koehler, A.; Hellweg, S. (2010). Trade-offs between land and water use: regionalized impacts of energy crops. In: Proceedings of the 7th International Conference on LCA in the Agri-Food Sector".

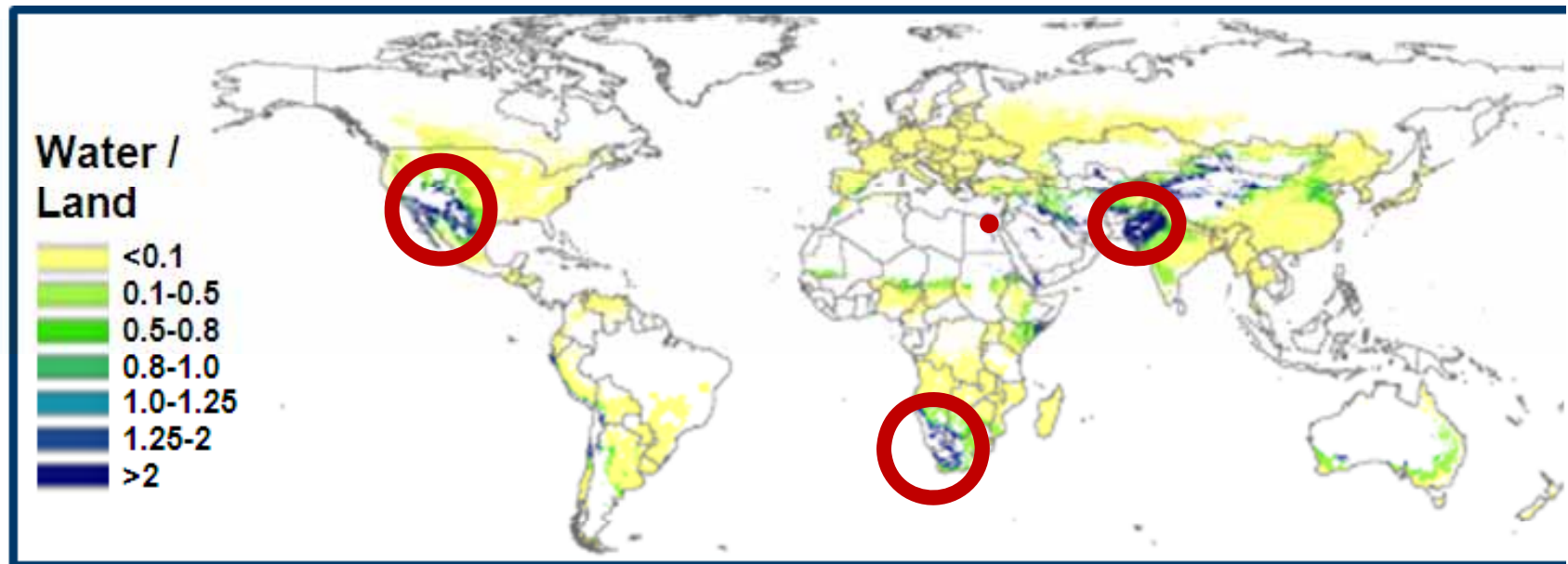
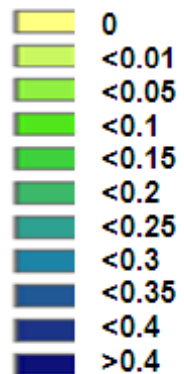
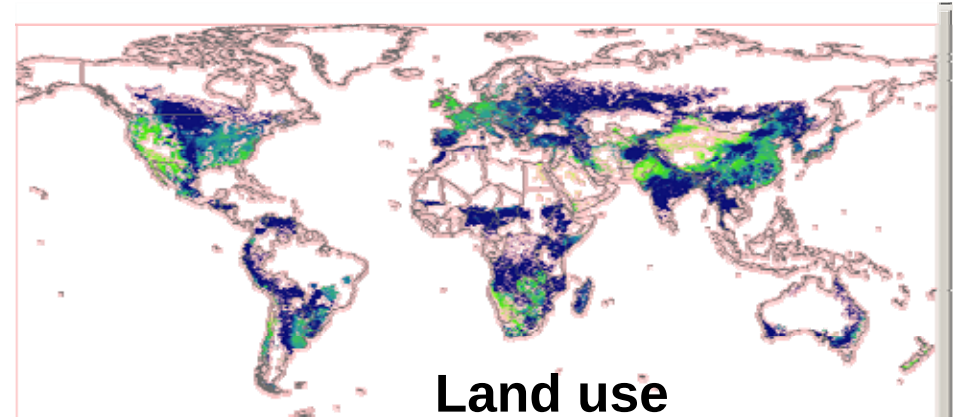
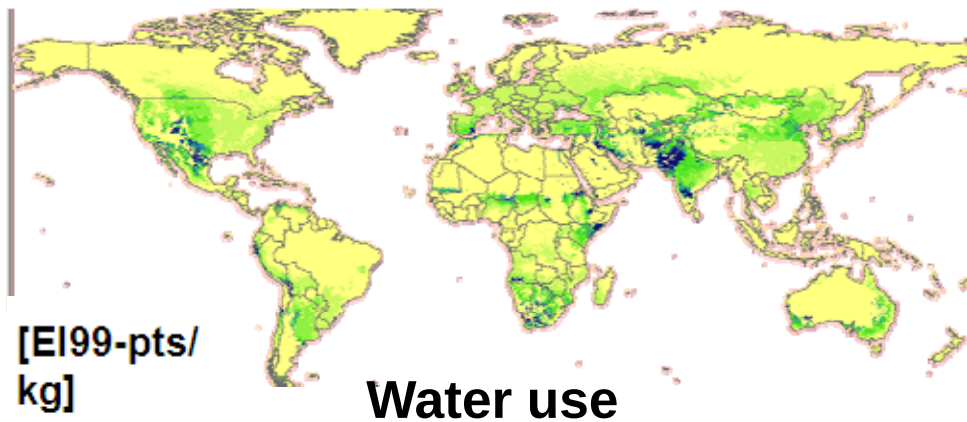
Google Earth, EQ factors



Select regionalized impact factors



Impacts of wheat production



Global Average

NOT VERY
HELPFUL !

Aggregated on global level based on production volumes in each place

	Ecosystem quality [PDF*m ² *yr/kg]		
	Land	Water	Water/land ratio
barley	4.11	0.22	5%
rye	4.35	0.07	2%
cassava	1.38	0.01	1%
wheat	3.30	0.42	13%
sugarcane	0.26	0.05	20%
rice	2.66	0.21	8%
maize	2.00	0.18	9%
soybean	0.37	0.21	57%
sunflower	0.78	0.40	51%
rapeseed	0.57	0.32	56%

Discussion

- Inventories: statistical data need improvement
- Land use impacts: Allocation of transformation, further biodiversity issues
- Damage maps useful for identifying hotspots of environmental concern /areas of relatively low environmental harm.
- Energy crops: global assessment
 - large differences (e.g. maize and millet differ by a factor ~ 5)
 - Mainly represents origins (conditions and efficiencies).

Conclusion

- Regionalized inventory and impacts assessment crucial
- Highly regionalized NPP-factor captures productivity (main scarcity issue)
- Biomes and ecoregions seem suitable for regional ecosystem aspects
- Clear trade-off between land and water use among regions
- Other impacts such as eutrophication need better assessment
- Parameterized inventories required (including yields, irrigation, intensity)

Future research

- Include market/trade models -> production mix for regional consumption
- Biodiversity: more taxons, further analysis of ecoregions and soil-related impacts
- Integration into other methods such as RECIPE or IMPACT2002 -> different weightings
- Allocation of transformation damages to biomaterial harvesting to be examined on a regional scale (identify drivers)

THANKS FOR YOUR ATTENTION!



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BACKUP SLIDES

