Legacy effects of repeated land-use changes

Andreas Krause[1*], Thomas A. M. Pugh[1], Anita Bayer[1], Mats Lindeskog[2], Almut Arneth[1]

[1] Plant-Atmosphere Interactions Research Group at KIT, IMK-IFU, Garmisch-Partenkirchen, Germany

[2] Department of Physical Geography and Ecosystem Science, Lund University, Sweden

* andreas.krause@kit.edu

Abstract

The legacy effects of past land-use changes were studied at several sites with the LPJ-GUESS dynamic vegetation model. Results suggest a significant relevance of former land-use, with respect to type and duration, on subsequent carbon dynamics for decades to centuries.

Motivation

Large parts of the Earth's vegetated surface have undergone multiple transitions between different land-use covers in the past (and will do so in the future). However, little is known about the influence of past land-use changes on present-day ecosystem processes like plant succession or carbon sink capacity. Here, we explore how type and duration of historical land-use affect recovery of ecosystems.

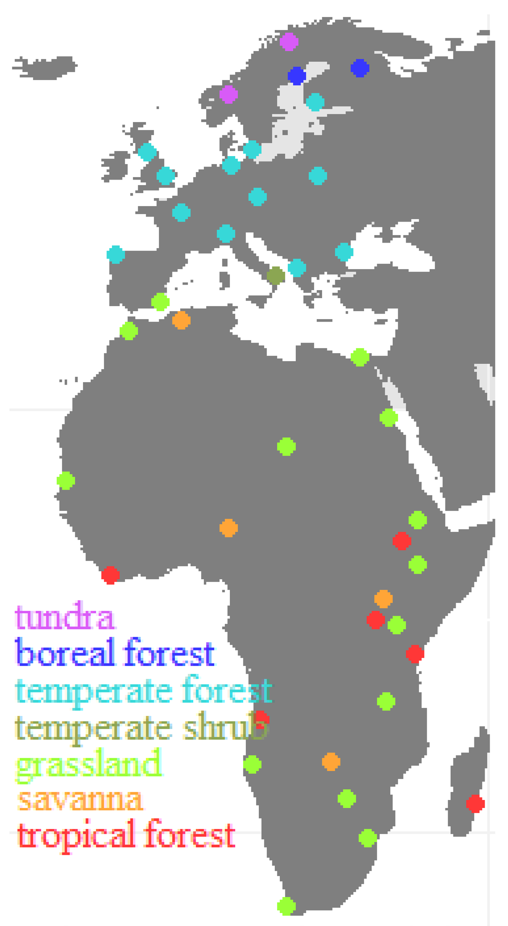


Fig. 1: Location of the sites and associated biomes.

Methods

We used the LPJ-GUESS dynamic vegetation model (Smith et al., 2001, 2014, Lindeskog et al., 2013), forced by present day climate, to study the legacy effects of land-use history at 41 sites across Europe and Africa (Fig. 1): After model spinup we made a transition to either pasture or cropland for varying periods (20, 60 and 100 years), followed by a transition back to natural vegetation. Croplands and pastures were distinguished as in table 1.

Table 1: Parameters used for pastures and croplands (modified from Lindeskog et al., 2013).

	pasture	cropland
tree root removal during LUC	0.5	0.9
fertilizer	no	75 kg ha^{-1} y^{-1}
harvest efficiency	0.5 of ag biomass	0.8 of ag biomass
N removal factor	0.65	1.0
root turnover	0.7 y^{-1}	1.0 y^{-1}
tillage	no	yes

Results

2a) Vegetation carbon

2b) Vegetation carbon

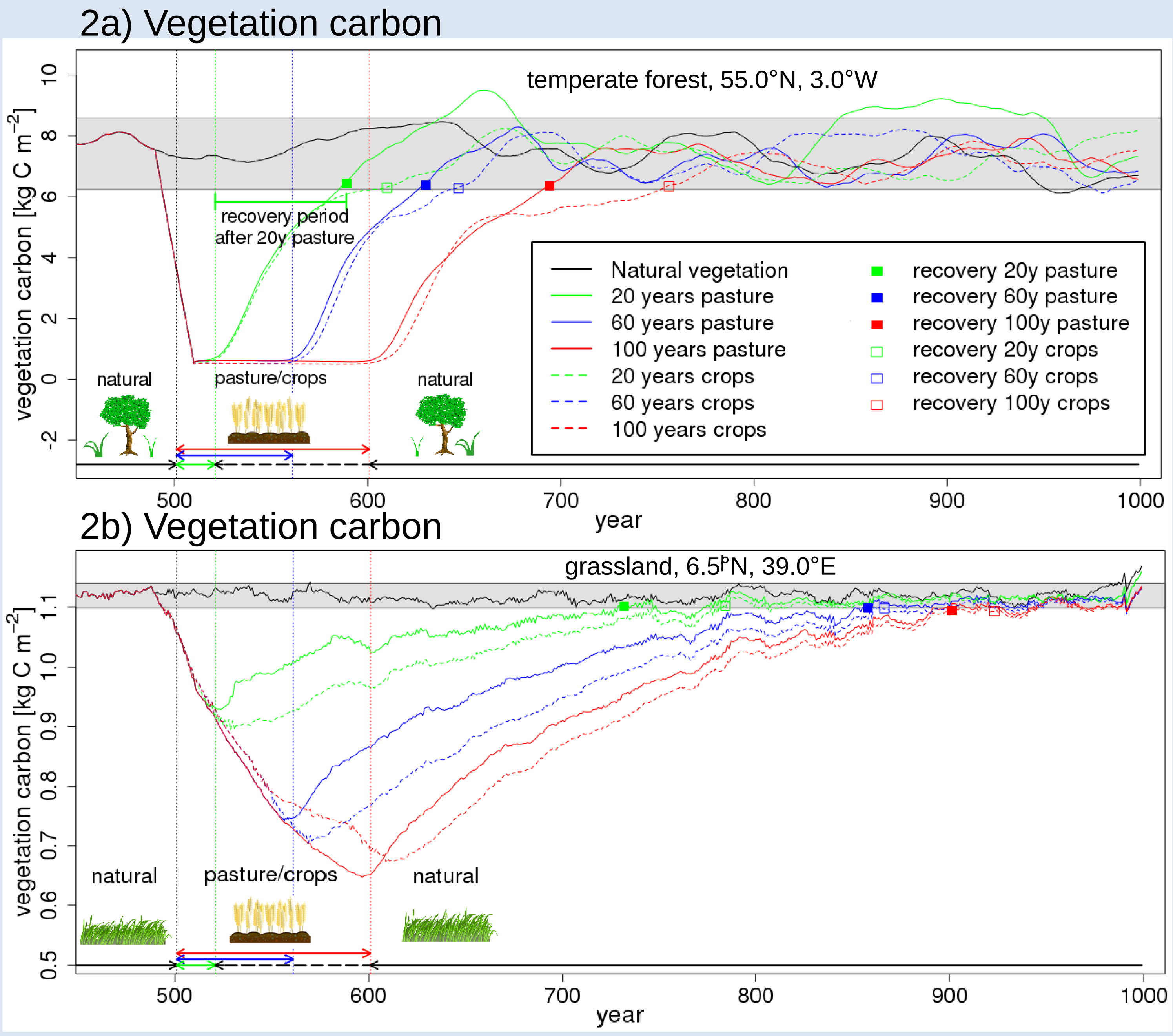
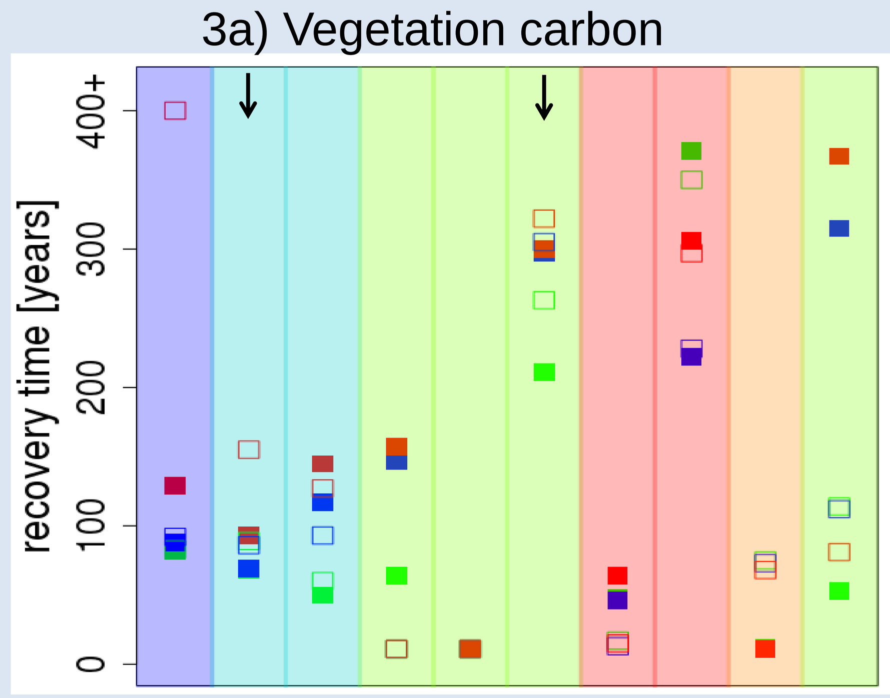


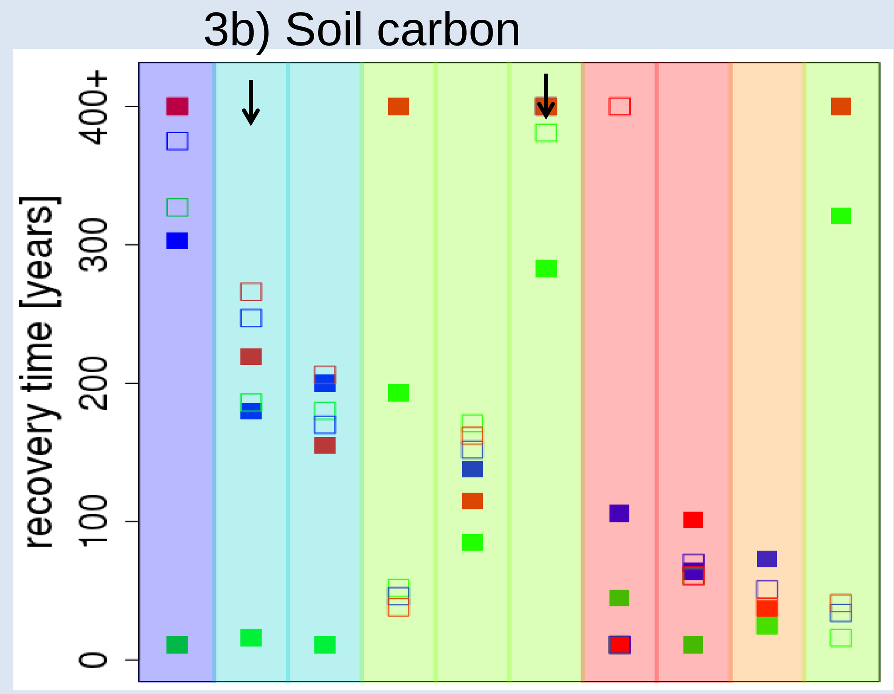
Fig. 2: Vegetation carbon stocks (20-y means) after conversion to pasture (solid lines) or crops (dashed lines) and reconversion to natural vegetation after 20 (green), 60 (blue), or 100 (red) years, for a forest (a) and grassland (b) location. Vertical lines indicate dates of conversion events, squares when recovery was completed after reconversion to natural vegetation, defined as carbon stocks being within the natural vegetation year 500-999 mean ± 2x standard deviation (grey-shaded area).

Fig. 3: Recovery times of vegetation (a) and soil carbon (b) (see Fig. 2) for 10 of the 41 sites, by latitude. Background colors indicate ecosystem type (see Fig. 1), arrows the sites shown in Fig 2.

3a) Vegetation carbon



3b) Soil carbon



Vegetation carbon

4a) Difference in recovery time by biome

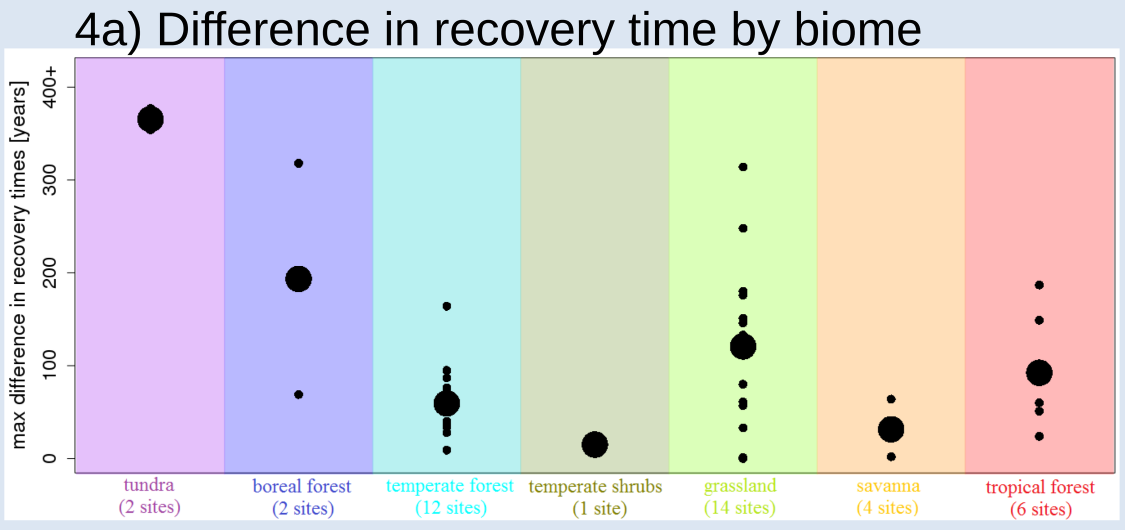
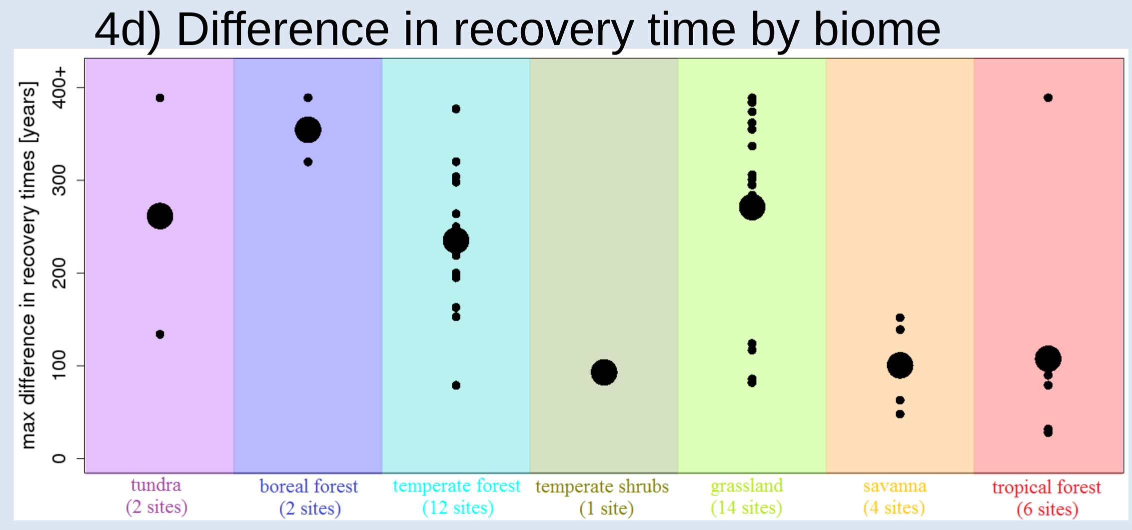


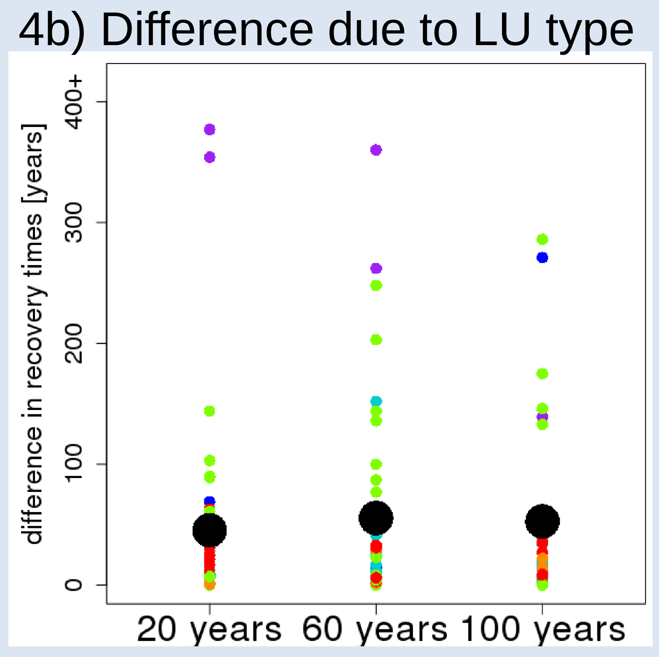
Fig. 4: Maximum difference in vegetation (left) and soil carbon (right) recovery time for all simulations. In a) and d) separated by biomes. Large dots are biome's averages (assuming a recovery time of 400 years when not recovered at the end of the simulation), small dots individual sites. b) and e) separated by land-use time interval and averaged over all sites, colors of the small dots indicate the biome of the site. c) and f) separated by land-use type.

Soil carbon

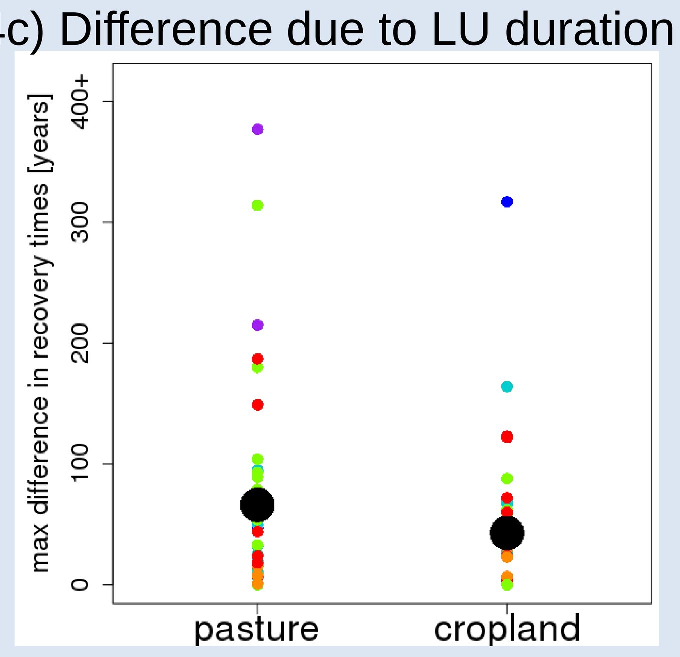
4d) Difference in recovery time by biome



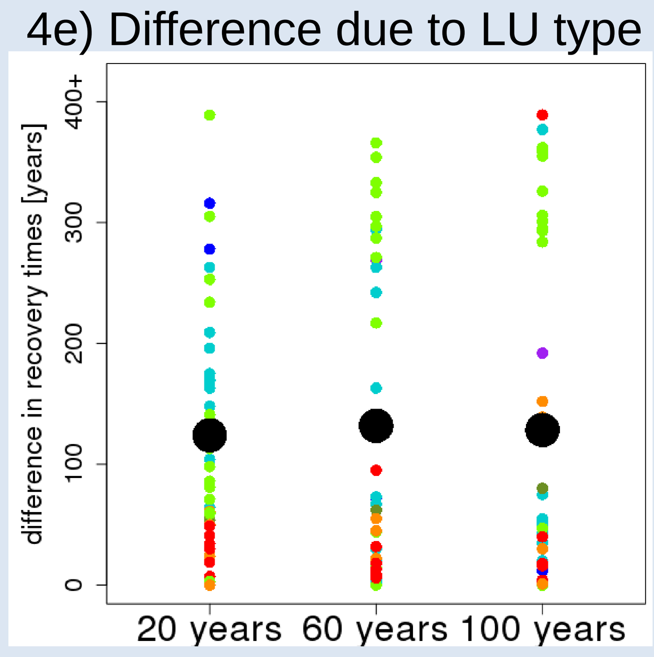
4b) Difference due to LU type



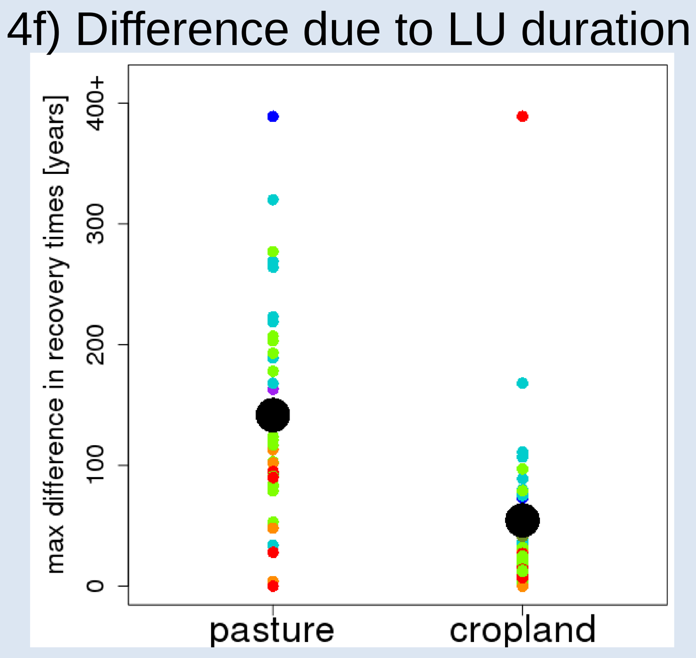
4c) Difference due to LU duration



4e) Difference due to LU type



4f) Difference due to LU duration



Conclusions

- Land-use history clearly has a strong effect on vegetation recovery time scales with varying relevance across biomes
- Effects on soil carbon are more persistent in grasslands and extratropical forests than in tropical forests
- The duration of agriculture is more important for pastures than for croplands

References:
Lindeskog, M., et al.: Earth System Dynamics, 4: 385-407, 2013
Smith, B., et al.: Global Ecology and Biogeography, 10: 621–637, 2001
Smith, B., et al.: Biogeosciences, 11: 2027-2054, 2014