

Projected landscape-scale repercussions of global action for climate and biodiversity protection

We combine the open-source land-system model MAgPIE (Model of Agricultural Production and its Impact on the Environment) with the Spatial Economic Allocation Landscape Simulator (SEALS) and the Global Soil Erosion Modelling (GloSEM) platform to assess how different land conservation measures focused on climate and biodiversity protection could drive changes in soil loss by water erosion, pollination and landscape heterogeneity.

MAgPIE utilizes a cost-optimization approach to simulate the dynamics of the global land system throughout the 21st century. It integrates a wide range of socio-economic and spatially explicit biophysical information from the LPJmL model, which includes data on yield patterns, water availability, and carbon stocks. This information is represented at a resolution of 0.5 degrees, which corresponds to approximately 55 km × 55 km at the equator. The SEALS model downscales the simulated land-cover changes derived from MAgPIE to a finer spatial resolution of 10 arc seconds (equivalent to approximately 300 m × 300 m at the equator). The downscaling is driven by adjacency relationships, physical suitability, and conversion eligibility. Changes in soil loss by water erosion are used as a measure for soil degradation and estimated based on the Global Soil Erosion Modelling (GloSEM) platform (Borrelli et al., 2017, 2020).

Modelled Scenarios:

We compare a "business-as-usual" (BAU) scenario with three different land-system interventions aligned with the goals of the Paris Agreement and the Kunming-Montreal Global Biodiversity Framework of the Convention on Biological Diversity.

- The BAU scenario represents the reference case, following the "middle-of-the-road" shared socioeconomic pathway for land use sector (SSP2). It considers moderate population and income growth, along with currently implemented land conservation policies.
- The PROTECT scenario focuses on area-based conservation action, aiming to protect 30% of the land surface in conservation priority areas (Biodiversity Hotspots and Intact Forest Landscapes) by 2030 (Kunming-Montreal Global Biodiversity Framework of the Convention on Biological Diversity).
- The COACTION scenario combines ambitious action for carbon-focused land restoration in line with the Paris Agreement and area-based conservation action.
- In the MULTI scenario we add a quantitative target to conserve at least 20% of semi-natural habitat in agricultural landscapes to the previous interventions, in order to conserve biodiversity and to support crucial ecosystem functions in agroecosystems.

Main findings:

- Important synergies exist between carbon uptake on land and soil erosion by water. Land-based climate mitigation caused a 75% reduction of soil loss at the global scale as compared to a reference scenario without climate action.
- Despite clearly reducing soil loss in historical cropland landscapes, the results also show that the landscape policy intervention of the MULTI scenario could lead to

slightly higher overall soil loss as compared to the COACTION scenario. This is the result of cropland relocation to areas with a higher susceptibility to water erosion due to the restrictions at the landscape scale.

- At the global scale, pollination supply and landscape heterogeneity were further decreased in the BAU and PROTECT scenario and did not improve in the COACTION scenario. However, the results also show that conserving at least 20% of permanent habitats would lead to more diverse landscapes with a higher supply of key nature's contributions to people (NCP) without additional net carbon losses, primary land conversion or reductions in agricultural productivity.

Data and additional material:

Global estimated rates of soil loss by water erosion and global changes across modelled scenarios

Global soil erosion datasets:

RUSLE 2015 Ref 10s: Baseline 2015 as from Global Soil Erosion Modelling (GloSEM)

RUSLE 2050 BAU 10s: 2050 BAU scenario represents the "middle-of-the-road"

RUSLE 2050 PROTECT 10s: 2050 PROTECT scenario taking into account the Kunming-Montreal Global Biodiversity Framework

RUSLE 2050 COACTION 10s: 2050 COACTION scenario taking into account the Paris Agreement

RUSLE 2050 MULTI 10s: 2050 MULTI scenario with conservation of at least 20% of semi-natural habitat to the previous interventions.

The data includes the spatially-explicit soil loss estimates for all scenarios (shown in Fig. 7 of the paper) and the R code used to process the input data. **We will also upload soon the data on the spatially-explicit RLSK and C-factor data for each of the modelled scenarios at 10 arcseconds and the R code to estimate C-factor values based on the MAgPIE-SEALS outputs.**

Pollination sufficiency:

Pollination sufficiency scores are calculated based on the extent of (semi-)natural habitat within the foraging distance of cropland areas, following the approach by Chaplin-Kramer et al. (2019). The pollination sufficiency scores are based on my own calculations based on reclassified ESA CCI data (2015) and MAgPIE-SEALS land-use/land-cover projections (2050). Projected land-use patterns from MAgPIE are first downscaled to 10 arcseconds with the SEALS model. Cropland pixels are then ranked by values between 0 and 1. 1 indicates >30% semi-natural habitat within 2 km around cropland, while values between 0 and 1 indicate a relative proportion from 0 to 30%. This threshold is based on empirical studies that have demonstrated the reliable prediction of pollination supply based on the area of (semi-)natural habitat surrounding cropland. Data displayed in Fig.6 of the paper).

pollSuff_2015_Ref_10s: Baseline 2015

pollSuff_2050_BAU_10s: 2050 BAU scenario represents the "middle-of-the-road".

pollSuff_2050_PROTECT_10s: 2050 PROTECT scenario taking into account the Kunming-Montreal Global Biodiversity Framework

pollSuff_2050_COACTION_10s: 2050 COACTION scenario taking into account the Paris Agreement

pollSuff_2050_MULTI_10s: 2050 MULTI scenario with conservation of at least 20% of semi-natural habitat to the previous interventions.

pollSuff_2050_MULTI_NoPast_SA_10s: 2050 MULTI scenario excluding pastures from the definition of pollinator habitats.

MAGPIE output

The data includes all modelled outputs (food demand, agricultural production, emissions etc.) from 1995 to 2100 for the BAU, PROTECT, COACTION and MULTI scenarios at the spatial cluster level (fulldata.gdx) and at the regional level (report.mif).

The NetCDFs contain the disaggregated land-use projections until 2100, while the fulldata.gdx contains the actual model outputs at MAGPIE's native resolution (accessible via the GAMS software or e.g. via R). The "report.mif" contains regional outputs and additional indicators that have been derived during post-processing of the model runs. The "validation.mif" contains validation results and the validation pdf shows the validation results.

[/eos/jeodpp/home/users/liakole/panagos/etc/Pollination/magpie_output/BAU/cell.land_0.5.nc](/eos/jeodpp/home/users/liakole/panagos/etc/Pollination/magpie_output/BAU/cell.land_0.5.nc)

Item	Description
 cell.land_0.5	
 cell.land_0.5	NoGeometry (19)
 crop	[19x360x720] crop (64-bit floating-point)
 forestry	[19x360x720] forestry (64-bit floating-point)
 other	[19x360x720] other (64-bit floating-point)
 past	[19x360x720] past (64-bit floating-point)
 primforest	[19x360x720] primforest (64-bit floating-point)
 secdforest	[19x360x720] secdforest (64-bit floating-point)
 urban	[19x360x720] urban (64-bit floating-point)

Moreover, the data includes a disaggregated time series of projected land-use and cropping patterns between 1995 and 2100 at the 0.5 degree level. Land use is reported for seven land pools: cropland (crop), forestry (forestry), non-forest cover - other land (other), pasture (past), primary forest (primforest), secondary forest (seforest), urban (urban) either as area covered (Mha) or as share of the total land area (unitless) in each cell. Cropping patterns are reported for 19 crop functional types as area share (unitless) in terms of the cropland area.

We also provide MAgPIE model outputs of all scenarios (data is shown in Figs. 2, 3, 4, & 5 of the paper). Moreover, the data set also includes spatially-explicit pollination sufficiency estimates for all modelled scenarios and the R code used to derive the pollination sufficiency scores (data displayed in Fig. 6 of the paper).

Reference:

von Jeetze, P. J., Weindl, I., Johnson, J. A., Borrelli, P., Panagos, P., Molina Bacca, E. J., Karstens, K., Humpenöder, F., Dietrich, J. P., Minoli, S., Müller, C., Lotze-Campen, H., & Popp, A. (2023). [Projected landscape-scale repercussions of global action for climate and biodiversity protection](https://doi.org/10.1038/s41467-023-38043-1). Nature Communications, 14, Article number: 2515.
<https://doi.org/10.1038/s41467-023-38043-1>