Methods supplementary information

In this supplement, we describe the following:

1. Calculations underlying estimates described in the policy brief
2. Methods for constructing the win-win agricultural area maps

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Strategic de-intensification on 7% of EU agricultural land– in win-win areas—could reduce agricultural emissions by 4.9%, equivalent to a total reduction of an estimated 12 million tons of CO_2-equivalent per year. This would represent around 3.9% of the EU's 2030 total mitigation target for agriculture, forestry and other land use, while entailing a 2% annual reduction in total agricultural production value.

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[1]: The [...] *7.0% of EU agricultural land* [...] was derived by dividing the total area identified as win-win areas (9.9 million ha) by the total agricultural area covered by our analysis (141 million ha).

[2]: The [...] *by 4.9%, equivalent to a total reduction of an estimated 12 million tons* [...] were derived by i) summing the reduction in emissions of pixels identified as win-win areas, and ii) dividing this reduction by the total emissions of the status-quo case.

[3]: The [...] *around 3.9% of the EU's 2030 total mitigation target for agriculture, forestry and other land use, while entailing a 2.0% annual reduction in total agricultural production* [...] was derived by i) dividing the total reduction in emissions across areas identified as win-win by the AFOLU mitigation target of 310 mt.

European biodiversity intactness improved by just 1.1% between 2000 and 2018[1], and global studies show a decline of ~3.4% since 1970[2] and ~1% per decade since 1900[3].

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[1]: This 1.1% increase was derived from work conducted in LAMASUS Deliverable 5.2 (shown in Figure 11a). Specifically, we calculated average BII values across Europe for 2000 and 2018 before calculating the relative change over this period.

BII_{2000}: 0.4844
BII_{2018}: 0.4897
Relative change in BII = $(BII_{end} - BII_{start}) / BII_{start} \cdot 100$

[2]: Using data from Philips et al. (2021), we calculated the relative change in BII globally between 1970 and 2014.

BII_{1970}: 0.7975
BII_{2014}: 0.7701

[3]: Results presented in Pereira et al. (2024).

Win-Win Agricultural Areas: Indicator Construction (1 km Resolution)

Three key indicators (agricultural revenue indicator, agricultural greenhouse gas emission indicator, and a biodiversity indicator) were derived to define Win-Win Agricultural areas. These indicators were derived as follows:

1. Agricultural revenue indicator - captures the estimated economic output from arable cropland and pasture. Economic outputs and total revenue are estimated separately for arable cropland and pasture/grassland, and are calculated as follows:

- Economic output from arable cropland:
    - Crop-type shares per arable area are derived from Eurostat's apro_cpshr dataset, a 2016-2021 average is calculated at the NUTS2 to NUTS0 resolution depending on availability.
    - The crop-type shares are then spatially allocated to arable cropland from the LUM Geodatabase at 1 km^2.
    - Yields per crop-type & management intensity estimated using the EPIC model (D5.1) are converted to fresh matter using GLOBIOM factors (Plant Nutrient Content Database) and used to compute production (in tons) at 1 km^2.
    - Production is valued using the 2016-2021 average FAOSTAT producer prices, converted from USD to EUR using an exchange rate of 0.95.
- Economic output from pasture and grassland:
    - Dry matter grass yields per management intensity from the EPIC model (D5.1) are matched to grazing land classes in the LUM Geodatabase.
    - These yields are translated into ruminant livestock units and related milk/meat output using GLOBIOM parameters at the country level (Herrero et al., 2013).
    - The resulting output is valued using the 2016-2021 average FAOSTAT producer prices, converted from USD to EUR using a exchange rate 0.95.
- Final agricultural economic output:
    - The total revenue (in EUR) from crops and livestock is summed per 1 km^2 pixel.

2. Agricultural greenhouse gas emission indicator - quantifies emissions from both cropland and livestock activities:

- Arable cropland emissions:
    - Emissions are computed using crop-type shares per arable area as calculated for the agricultural revenue indicator and EPIC-simulated nitrogen input (N-input) and change in topsoil soil organic carbon (captured through organic carbon in the ploughing depth (dOCPD)) parameters per modelled crop type.
    - The following emission conversion was applied:
        - N_2O-N: 0.012 kg N_2O-N/kg N input → N_2O (×1.57) → CO_2-eq (×298)
        - C to CO_2: ×3.67 kg CO_2/kg C
- Livestock (Pasture) emissions:
    - CH_4 and N_2O emissions from enteric fermentation and manure are assigned per ruminant unit using country-level GLOBIOM coefficients (Herrero et al., 2013).
    - Additional pasture emissions stem from EPIC-based N-input and dOCPD values.
- Final Output:
    - Total greenhouse gas (GHG) emissions (in CO_2-eq) from crops and livestock are summed per 1 km^2 pixel.

3. Biodiversity Indicator – captures average abundance of a range of species, relative to values expected in an intact, natural site.

- We derived biodiversity response functions for LUMs based on statistical models using the PREDICTS database (D5.2 - Coefficients of estimated biodiversity responses to land use).
- In this framework, the biodiversity intactness index (BII) is the product of changes in total abundance and Bray-Curtis compositional similarity (D5.2: Tables A2, A3). Values of 1 indicate an intact ecosystem, values of 0 indicate complete degradation.
- Given the 2018 LUM Geodatabase, the relative shares of each LUM within a 1km² pixel, and the BII values associated with each LUM, area-weighted BII values were calculated per pixel.

Construction of "win-win areas"

For our comparative analysis (of de-intensification) we constructed two maps at 1km² pixel:

1. A *baseline map* ($Map_{baseline}$), which represents the status quo using observed 2018 data from the LUM Geodatabase.
2. A hypothetical *de-intensifaction map* ($Map_{deintensive}$), where, all else being equal, agricultural high-intensity LUM areas in $Map_{baseline}$ are switched to medium-low intensity management classes of the same land-use, e.g. *Very high density managed pasture system -> Moderate density managed pasture system* and so on.

For each map, $Map_{baseline}$ & $Map_{deintensive}$, we computed the three indicators (agricultural revenue, agricultural GHG emission, and biodiversity) as described above. After which, the absolute differences between $Map_{deintensive}$ and $Map_{baseline}$ were calculated for *agricultural revenue and GHG emissions* per hectare, while the percentage change was calculated for *the area-weighted BII index* per 1km² pixel. Finally, win-win areas are defined as 1km² pixels where the following conditions overlap:

- reduction of 1 ton (or more) of net GHG emissions per hectare
- improvement of 1% (or more) in biodiversity
- loss of 350 € (or less) in agricultural revenue per hectare

While all calculations were performed at a 1 km² resolution, Figure a) in the policy brief displays the data at a coarser 50 km² resolution to address privacy concerns and avoid the risk of identifying individual farms or landowners. To that end, we calculated and plotted the proportion of win-win areas (identified at 1 km²) relative to the total agricultural area within each 50 km² grid cell.

References

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Plant Nutrient Content Database; Natural Resources Conservation Service, United States Department of Agriculture