Estimating the future economic effects of biodiversity loss and strategies to mitigate it: Evidence from soil quality and pollination, and half-earth protection scenarios

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1. Introduction: Background and key findings

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Biodiversity-Related Risks and Opportunities for the Financial Sector (BiROFin)

BiROFin, launched in 2024, is an ambitious **public-private partnership** (PPP) project designed for quantifying the macroeconomic impacts of biodiversity loss and identifying opportunities to mitigate them.

BiROFin employs advanced modelling to align science-based climate, biodiversity and financial scenarios, providing detailed **monetary estimates at both sectoral, national, regional and global levels.** Wageningen University and Research (WUR) contributes its expertise in integrating ecological and economic data. At the same time, the project also develops a unique dataset on the **cost-effectiveness of biodiversity abatement and restoration strategies.**

This approach provides a comprehensive understanding of how a change in the provision of ecosystem services resulting from a projected change in biodiversity can impact economies at both the country/regional and sectoral levels, thereby filling a critical gap in current risk assessment frameworks.

Working closely with the Foundation for Sustainable Development and prominent private-sector partners, including Allianz Group, APG, Commerzbank, ING, and Ortec Finance, this initiative ensures that the developed data and methodologies are both scientifically rigorous and practically applicable.

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From exposure to ecosystem services loss to estimating the effect of risks and opportunities to abate them

- **The global natural system** faces significant pressure from societal and economic demands, threatening air, water, soil, and biodiversity.
- The **financial sector** increasingly recognises that its stability depends on climate, nature, and biodiversity, and their interconnected relationship.
- **Governments** seek to measure and reduce impacts on essential resources and integrate nature into financial decisions.
- **Knowledge gap:**
  - The macroeconomic effects of biodiversity loss at the sector and country level, considering its direct effects and indirect effects through trade and reallocation of production between sectors and countries.
  - Monetised costs and benefits of the measures that can abate the loss of biodiversity.
- **In the first year of the project, BiROFin**
  - developed global scenarios regarding the effects of biodiversity-loss-induced changes in pollination, and soil quality on crop productivity by 2050, and how those effects change under the presence of climate-change-induced extreme climate events;
  - estimated the macroeconomic impacts of these changes using the MAGNET general equilibrium model, which incorporates international trade, supply chain linkages, consumer market developments, and input substitution, enabling the project to estimate the varying impact of biodiversity loss on various sectors in different countries;
  - estimated the monetary costs and benefits of six nature-based measures, which can abate biodiversity, soil quality, and pollination loss, and at the same time increase crop productivity, in Brazil, France, Germany, Italy, the Netherlands, Spain, the United Kingdom, and the United States;
  - identified macroeconomic outcomes of an existing conservation policy that protects half of the Earth from biodiversity loss and thereby soil quality and pollination loss.

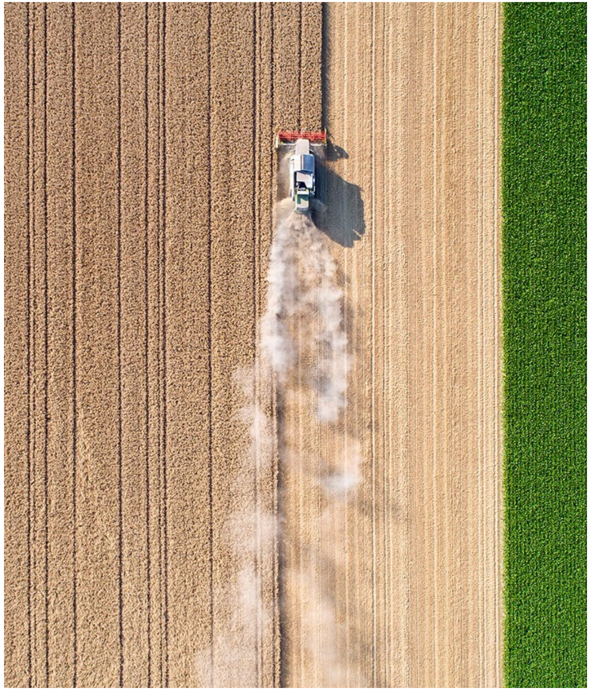
This document summarises findings from the first year of BiROFin, focusing on crop productivity, economic effects, cost-benefit analyses of abatement measures, and the implications of a conservation policy by 2050.

- The document includes the following results from the first year of the BiROFin for specialists and practitioners in the financial sector, government, and other private sector organisations focusing on environment and nature topics:
  - Risks of human-induced biodiversity loss on crop productivity by 2050 due to declining soil quality and loss of insect pollinators under climate-change-induced extreme climate events.
  - Global macroeconomic repercussions of soil quality and pollination loss due to biodiversity loss, affecting economies and domestic and international markets through trade and supply chains by 2050.
  - Cost and benefit implications for implementing nature-based measures to abate soil quality and pollination losses caused by biodiversity decline by 2050 in Brazil, France, Germany, Italy, the Netherlands, Spain, the United Kingdom, and the United States.
  - Macroeconomic risks of implementing a conservation policy that protects half of the Earth from socio-economic activity to abate biodiversity loss, thereby soil quality and pollination loss by 2050.
  - For a shorter summary of the results presented in the document, please refer to our **Executive Summary** intended for policymakers.

- To understand the methodology and assumptions behind our scenarios, macroeconomic estimations and cost-benefit analyses, please visit the following appendices on our **BiROFin website**:
  - Online Appendix 1: Biodiversity and Climate Change Impact Calculation
  - Online Appendix 2: MAGNET CGE Documentation
  - Online Appendix 3: Abatement Measures Methodology
  - Online Appendix 4: Half Earth Scenario

Our scenario analysis shows declines in soil health and pollination due to biodiversity loss, reducing crop yields, particularly in Global South countries and during extreme climate events

- BiROFIN developed future scenarios to analyse the risks of human-induced biodiversity loss on crop productivity by 2050, due to declining soil quality and the loss of insect pollinators under extreme climate events. (Slides 13-15). Our key findings from the scenario analysis are as follows:
  - By 2050, a decline in biodiversity is projected to negatively impact country- or region-level crop productivity through soil quality loss—by as much as 4.6% additional decline in crop productivity—and through loss of pollination services—by as much as 0.5% decline—without considering the impact of climate change and the role of biodiversity in enhancing resilience to extreme climate events.
    - Compared to the loss of soil quality, the adverse effect of pollination loss on productivity is minor due to the varying degrees to which crops rely on insect pollination.
  - Projected adverse effects of the biodiversity loss are aggravated by extreme climate events induced by climate change, especially in countries of the Global South, where such events are more prevalent.
    - In 2050, crop productivity is projected to decline between 10% (in the UK, Ireland, Philippines, Taiwan, and the Netherlands) and 37% (in the cluster of Cameroon, Ghana, the Ivory Coast, and Nigeria) due to biodiversity-loss-induced soil quality loss under climate-change-induced extreme events. (Slide 14)
    - Due to pollination loss induced by biodiversity loss and under the extreme climate, crop productivity is expected to decline additionally between 1% in European countries and 4.7% in Colombia, with more severe effects in emerging markets. (Slide 15)
- Our scenario results on the changes in crop productivity loss involve about 10 to 16 percentage points of uncertainty on average, due to limited scientific information linking biodiversity loss to soil quality and pollination loss.



Projected declines in soil quality and pollination due to biodiversity loss may have minor economic effects globally, but emerging markets may experience more severe consequences

BiROFin integrated the crop productivity predictions from the scenarios into the MAGNET model to show macroeconomic repercussions of soil quality and pollination decline due to biodiversity loss by 2050, when compared to a no future biodiversity loss scenario:

- The model estimates, by 2050, up to a 5.1% decrease in global agricultural production due to projected soil quality and pollination loss induced by biodiversity loss, and under extreme climate events, and also changes in regional production and consumption of agricultural products. For example, India's agricultural goods consumption decreases by up to 9.8%, while European agricultural exports could cover for the losses with a rise of 15%. (Slide 20)
- By 2050, the MAGNET model forecasts up to 1.2% annual global GDP decline under our most extreme scenario of losing both soil quality and pollination during climate-change-induced extreme climate events, when compared to the reference scenario (Slide 21). The economic impact is less severe than anticipated because agriculture accounts for a relatively small portion of the global economy. Additionally, farmers can partially offset declines in soil quality and pollination services by increasing fertiliser and land use.
- Limited indirect effect of the projected soil quality and pollination loss on other sectors by 2050: for instance, due to projected losses in soil quality and pollination, agrifood manufacturing production is expected to decline by as much as 2.1% and while agrifood services are expected to decline by up to 1.4% (Slide 22)
- The effects of projected soil quality and pollination loss are severe in emerging markets, especially in those with prominent agriculture sectors. For example, the model estimates that, by 2050, there will be up to a 12.6% annual GDP loss in Sub-Saharan Africa (SSA).
- Average global agricultural goods prices are up as much as 51% due to a loss of both soil quality and pollination resulting from combined biodiversity loss and climate-change-induced extreme climate events, significantly affecting regions such as India (+58%) and SSA (+95%), leading to a 6% reduction in global calorie intake.
- Actual effects can be higher than our estimates as the current version of the model neglects the persistent financial effects of biodiversity, soil quality, and pollination loss on the economy (e.g., financial capital loss, political effects, monetary policy changes), future regulatory changes, and the ecological effects of changing economic activity on biodiversity.

BiROFin identified some macroeconomically promising nature-based measures to abate soil quality and pollination loss and increase crop productivity, yet for others, economic feasibility remains a challenge

- BiROFin identified, amongst other six nature-based measures that can be widely adopted to restore biodiversity, specifically abate pollination and soil quality loss and also improve crop productivity.
- We studied macroeconomic costs and benefit implications for implementing those measures by 2050 in Brazil, France, Germany, Italy, the Netherlands, Spain, the United Kingdom, and the United States:
  - Expenses for the measures vary by country (Slide 26), from USD 36 per hectare (flower margin in the Netherlands) to USD 764 per hectare (diversified crop rotation in the US) annually, reflecting differences in economic development and related costs at the country level, and labour and input expenses required to implement each measure.
  - It is macroeconomically viable to implement organic manure in Germany, France, Italy, the Netherlands, Spain, and the UK; agroforestry in Germany, France, Italy, and Spain; flower margin in the Netherlands; and reduced tillage in Brazil. For these measures, macroeconomic benefits from increased crop productivity surpass implementation costs of solutions by 2050 (Slide 27).
  - Those macroeconomically viable measure-country combinations could cover 125 million hectares of land (Slide 28). The potential for diverse crop rotations and cover crops to cover extensive land in major economies exists, yet their implementation costs are greater than the resulting economic benefits.

Preserving half of the Earth's land to combat biodiversity loss is likely to lead to a slight global effect but disproportionate negative impacts on emerging markets

- Based on Kok et al. (2020), BiROFin used the MAGNET model to assess the global macroeconomic effects of an example conservation policy that protects half of the world's land, prioritising the biodiversity hotspots by 2050. This policy restricts the use of certain land for economic activities, such as agriculture, and prevents the future expansion of socio-economic activities onto protected land. The model provides projections on the change in global macroeconomic outcomes by 2050 under this policy compared to a no-policy case:
  - The model projects a 10.8% decline in global agricultural land by 2050 when compared to no policy status and increased land prices, especially in Sub-Saharan Africa, the Middle East, North Africa, and Latin America, where large land areas are protected due to their status as biodiversity hotspots, limiting agricultural expansion areas.
  - The policy decreases agricultural output in Sub-Saharan Africa by 5.4%, in India by 8.4% due to protection, limited land, and rising costs, while European agriculture may benefit from the trade thanks to increased agricultural trade.
  - MAGNET forecasts that, by 2050, the policy will increase global agricultural prices (15%), with a 33% increase in agricultural prices in Sub-Saharan Africa (33%), raising concerns about food security.
  - According to our forecasts, the policy leads to a slight global GDP decline (0.4% annually) by 2050, while Sub-Saharan Africa faces a more significant annual GDP drop (4.3% annually).
- This analysis presents an example for the impact of regulations aimed at reducing biodiversity loss, soil quality degradation, and pollination decline, in line with Target 3 of the Kunming-Montreal Global Biodiversity Framework (ratified December 2022), as opposed to our biodiversity decline-induced soil quality and pollination loss scenarios.
- The results indicate that implementing a conservation policy, which disproportionately negatively impacts emerging markets, is only feasible if advanced market economies, such as those in Europe, compensate for the costs borne by these emerging market countries. This compensation would help mitigate the adverse effects of the policy on emerging economies while resulting in increased costs for advanced market economies, which are not taken into account in our results.

2. Estimating crop productivity change due to biodiversity-induced loss of soil quality and pollination

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Estimating crop productivity change by 2050 due to biodiversity-induced loss of soil quality and pollination with or without extreme climate events

Future scenarios: BiROFin developed 6 future scenarios to assess crop productivity loss in 2050 compared to a reference scenario via the impact of a change in biodiversity on the provision of soil quality and insect pollinators, both with and without considering the impact of extreme climate events. (Online Appendix 1: Biodiversity and Climate Change Impact Calculation for BiROFin):

1. Soil quality scenario without extreme climate events
2. Soil quality scenario with extreme climate events
3. Pollination scenario without extreme climate events
4. Pollination scenario with extreme climate events
5. Combined soil quality and pollination scenario without extreme climate events
6. Combined soil quality and pollination scenario with extreme climate events
7. Reference scenario

Reference scenario: SSP2, middle-of-the-road scenario, is used as the reference scenario in this project. Please see the recently updated Shared Socio-Economic Pathways (SSPs) version 3.0: https://data.ece.iiasa.ac.at/ssp. It is a 'business-as-usual' scenario, assuming medium GDP and population growth based on historical trends. It incorporates growth parameters for labour supply, capital stocks, natural resources, and agricultural productivity. These elements help predict economic evolution under current conditions, without shocks or policy changes, such as particular climate shocks or climate pathways (e.g., Representative Concentration Pathways-RCPs)

Soil quality scenarios: Agricultural intensification and human modification of nature reduce soil biodiversity, negatively affecting soil quality, organic matter content, soil structure, and nutrient cycling. This decline in soil quality impacts crop productivity. Additionally, biodiversity loss decreases soil resilience to climate change, further reducing productivity during extreme weather events. Soil productivity affects all crops similarly, so no specific crop dependency rate for soil productivity is defined.

Pollination scenarios: Agricultural intensification and human modification of nature lead to decreased biodiversity, which negatively impacts insect pollination. This occurs through a direct loss of pollinators and an exacerbated effect from climate change, resulting in more insect deaths. Practices such as increased pesticide use further reduce pollinator populations, weakening ecosystem resilience to extreme climate events. Different crops rely on insect pollination to varying extents, so reduced pollination services result in decreased crop productivity relative to their dependency on pollinators.

Estimation of future biodiversity taking account of climate change-induced extreme climate events: We determined an extreme climate Index based on the IPCC's SSP2-RCP 4.5 (middle-of-the-road pathway forecasting 2.6-3°C of warming by 2100), considering the rate of temperature change, change in precipitation patterns, and heat stress. We assume that higher biodiversity enhances the resilience of both crops and insects and low biodiversity during extreme climate events leads to greater soil productivity and increased insect mortality. We assume that climate extremes may reduce crop productivity by up to 40% under optimal biodiversity conditions and up to 80% under minimum biodiversity conditions.

Estimation of current biodiversity situation and future biodiversity: For the current level of biodiversity, as a proxy, we used pressure levels on biodiversity using the intensity of human modification and pesticide application, assuming higher pressure leads to lower biodiversity. For future biodiversity level, we used the GLOBIO model to project changes in Mean Species Abundance from 2019 to 2050 and its effects on ecosystem services related to soil quality and pollination services.

Country coverage: 56 distinct regions and countries

Sensitivity analysis: A scenario under the assumptions of up to 80% decline in crop productivity and pollination without extreme events. For extreme events, two different assumptions for sensitivity analysis: 60% impact with maximum biodiversity and 100% with minimum biodiversity; 20% impact with maximum biodiversity and 60% with minimum biodiversity. The results of the sensitivity analysis lead to on average 10 to 16 percentage change in productivity change predictions for 56 country/regions.

Biodiversity loss is projected to reduce soil quality and decrease country- or region-level crop productivity by between 9% and 37% by 2050

- Our scenario analysis shows a modest reduction in crop productivity (up to 4.6% in Sub-Saharan Africa) by 2050 due to biodiversity loss-induced soil-quality loss when climate change and biodiversity-induced resilience of soil to extreme climate events are not accounted for.
- The 56 countries/regions face an average decline of crop productivity of 18% when we consider the loss in the resilience of soil to climate-change-induced extreme climate events due to biodiversity loss.
  - Projected decline between 29% and 36% of crop productivity in other regions, including Latin American countries, Middle East and North Africa,
  - Expected decline between 9% and 12% in crop productivity in European countries (e.g., UK, Ireland, Netherlands).
  - Up to 37% decline in crop productivity due to loss in soil quality , combined with climate-change-induced impact of extreme climate events in Sub-Saharan countries (e.g., cluster of countries such as Cameroon, Ghana, the Ivory Coast, and Nigeria), due to biodiversity loss compared to 2019.

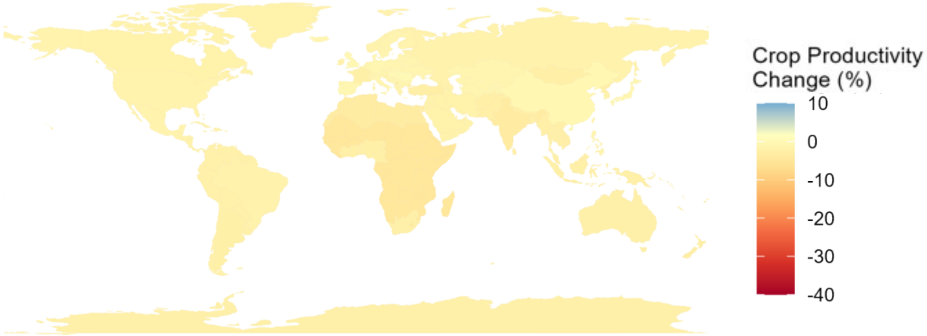

Figure 2a: Projected change in crop productivity due to biodiversity-loss-induced soil-quality loss by 2050, base year 2019, **without considering climate-change-induced extreme climate events.**

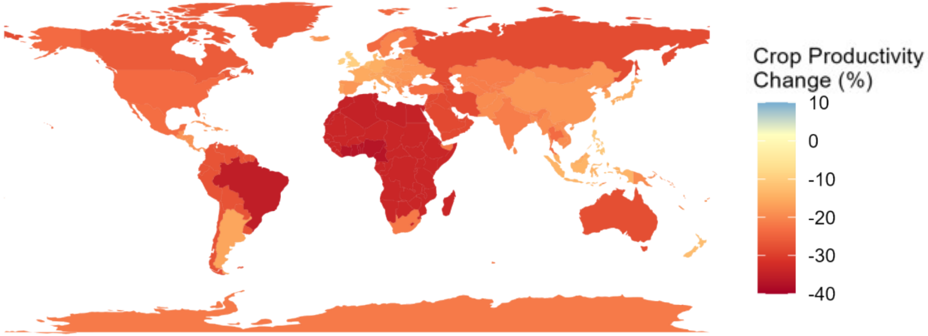

Figure 2b: Projected change in crop productivity due to biodiversity-loss-induced soil-quality loss by 2050, base year 2019, **considering climate-change-induced extreme climate events based on** IPCC's SSP2-RCP 4.5

Note to the Figures: The above maps show the crop productivity that is projected to be lost by 2050 in addition to the losses already incurred up to 2019. The analysis is produced by using the scenario work explained in Online Appendix-Scenario Analysis. Source: BiROFin project.

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Biodiversity loss is anticipated to reduce pollination services, thereby decreasing crop productivity at the country or regional level by as much as 4.7% by 2050

- The 56 countries/regions face an average decline of crop productivity of 0.2% by 2050 due to a further reduction in pollination services due to biodiversity loss, when we do not factor in the role of biodiversity in providing resilience to insects against extreme climate events induced by climate change. This biodiversity loss is caused by agricultural intensification (e.g., increased pesticide use) and human modification of nature (e.g., land use changes), which negatively impact insect pollination.
    - India is amongst the countries/regions expected to experience the highest decline in crop productivity of 0.5% by 2050 due to pollination loss, as a result of high production of pollinator-dependent crops such as tea and fruits. Europe is not expected to be significantly affected, as much of the biodiversity has already been lost.
- The decline in crop productivity due to pollination loss in 2050 increases from 0.2% to 2.0% when we also consider the role of biodiversity in providing resilience to insects against extreme climate events induced by climate change and the increased number of insects dying due to climate events.
    - Very modest crop productivity reductions (<1%) are expected in Europe, in countries such as Ireland, the Netherlands, Norway, Belgium, and Finland.
    - The largest productivity loss is expected in Latin American Countries such as Colombia (4.7%) and Brazil (4.3%).
    - In North America (e.g., Canada), India, other Asian countries (e.g., the Russian Federation), crop productivity loss due to biodiversity loss-induced pollination loss is expected to be more than 3%.
- Declines in crop productivity due to pollination services loss are not as high as the decline due to soil quality loss: Soil quality scenarios negatively affect land productivity, impacting all crops, whereas pollination scenarios only generate productivity shocks at the crop level, depending on the insect pollination dependency of crops.

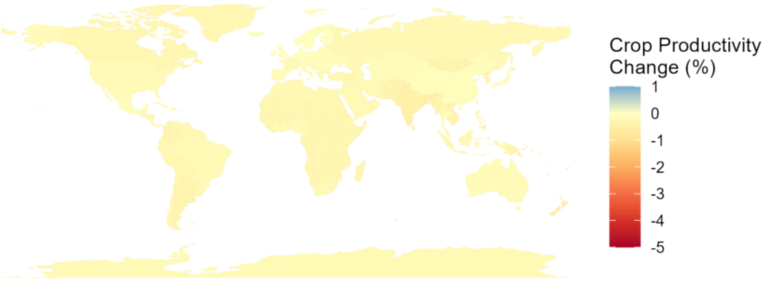

Figure 1a: Projected change in crop productivity due to biodiversity-loss-induced pollination loss by 2050, base year 2019, **without considering climate-change-induced extreme climate events.**

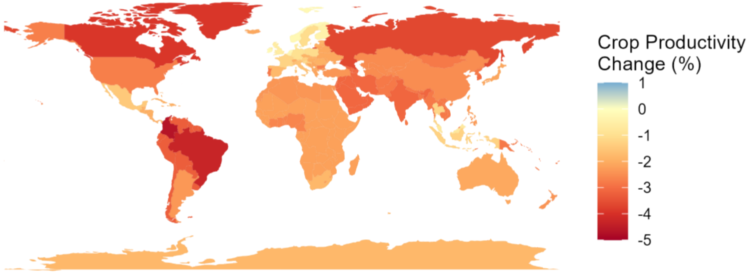

Figure 1b: Projected change in crop productivity due to biodiversity-loss-induced pollination loss by 2050, base year 2019, considering climate-change induced extreme climate events. **based on** IPCC's SSP2-RCP 4.5

Note to the Figures: The above maps show the projected change in crop productivity that is expected to be lost by 2050, in addition to the losses already incurred up to 2019. The analysis is produced by using the scenario work explained in Online Appendix-Scenario Analysis. Source: BiROFin project.

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3. Global macroeconomic effects of pollination and soil quality loss

MAGNET model to estimate the macroeconomic effects of soil quality and pollination loss scenarios

- **MAGNET model:** a multi-regional, multi-sectoral computable general equilibrium model built on the Global Trade Analysis Project. It adjusts prices to ensure all markets for factors (land, labour, capital, natural resources) and commodities clear simultaneously. Producers, operating under zero-profit conditions, respond to input price changes to maximize their profits. Households (one per region) maximize their welfare from consumption based on incomes from factor sales and consumption prices, constrained by their income. International trade is modeled bilaterally, facilitating two-way trade flows. The model uses Country-specific Social Accounting Matrices (SAM) capturing economic transactions and linkages various economic agents—households, different economic sectors, government, and the rest of the world For Further details on MAGNET model estimations, please see online Appendix on MAGNET model Documentation.
- 4 individual scenarios and 2 combined used for estimating macroeconomic effects of soil quality and pollination loss induced by biodiversity loss with or without and extreme climate events:
  1. SSP2_pollination: Pollination loss scenario without extreme climate events.
  2. SSP2_pollination_ext: Pollination loss scenario with extreme climate events.
  3. SSP2_soil: Soil quality loss scenario without extreme climate events.
  4. SSP2_soil_ext: Soil quality loss scenario with extreme climate events.
  5. SSP2_pollination_soil: Combined soil and pollination scenario without extreme climate events
  6. SSP2_pollination_soil_ext: Combined soil and pollination scenario with extreme climate events
- **Integration of scenario outcomes into the MAGNET model:** Crop productivity levels in the model were shocked by the scenario projections for changes in productivity for 2050. We estimated changes in sectoral and country-level prices, labour, land, capital demand, production levels, regional trade, and commodity consumption resulting from changes in crop productivity. All monetary values are real USD fixed to 2017 prices.

- **Outcomes:** In this document, we report on scenario effect estimates on sectoral production, domestic use, exports, prices, country-level GDP, and calorie intake by 2050 compared to a reference scenario explained in Slide 12.
- Outcomes for 56 countries/regions from scenario work are aggregated and presented in 9 countries/regions:
  1. China (CHN)
  2. European countries (EUR)
  3. India (IND)
  4. Latin American Countries (LAC)
  5. Middle East and North Africa (MENA)
  6. North America, Oceania, Japan, and Korea (NAMO_JAPKOR)
  7. Other Asian (OAS) Countries
  8. Sub-Saharan Africa (SSA)
  9. World
- **Outcomes presented in 8 sectoral aggregations:**
  1. Agriculture, forestry, fishing
  2. Food Services
  3. Manufacture of food products
  4. Manufacturing and mining
  5. Services and other (e.g., construction sector)
  6. Transport sector
  7. Utilities (Electricity, gas, and water)
  8. Total
- Results are also available **in detail** for 56 countries/regions (aligned with scenario work) and 39 ISIC sectors

By 2050, global projected crop productivity losses under soil quality and pollination scenarios range between 0.2% and 26%. Significant losses in SSA

- When climate change-induced extreme climate events are considered, the scenarios suggest that loss in soil quality and pollination could result in a loss of crop productivity that is around 20 times higher than if climate change impacts are not considered.
- European (EUR) and Other Asian countries (OAS) are expected to experience a lower loss of crop productivity compared to other regions.
    - Crop productivity loss in EUR is about 11.5 percentage points lower than the global average, while, in contrast, the projected losses in Sub-Saharan Africa are around 6% higher than the global losses. As explained in the scenario work, Europe and other Asian Economies are less affected by biodiversity loss-induced pollination and soil quality loss. In 2019, biodiversity in EUR had already diminished in the region, according to our modelling baseline. Moreover, our scenario analysis indicates that extreme climate events will be less likely in EUR countries when compared to SSA.
- These crop productivity shocks under soil quality and pollination loss scenarios are added at the country/region level to produce to combined scenarios for soil quality and pollination.

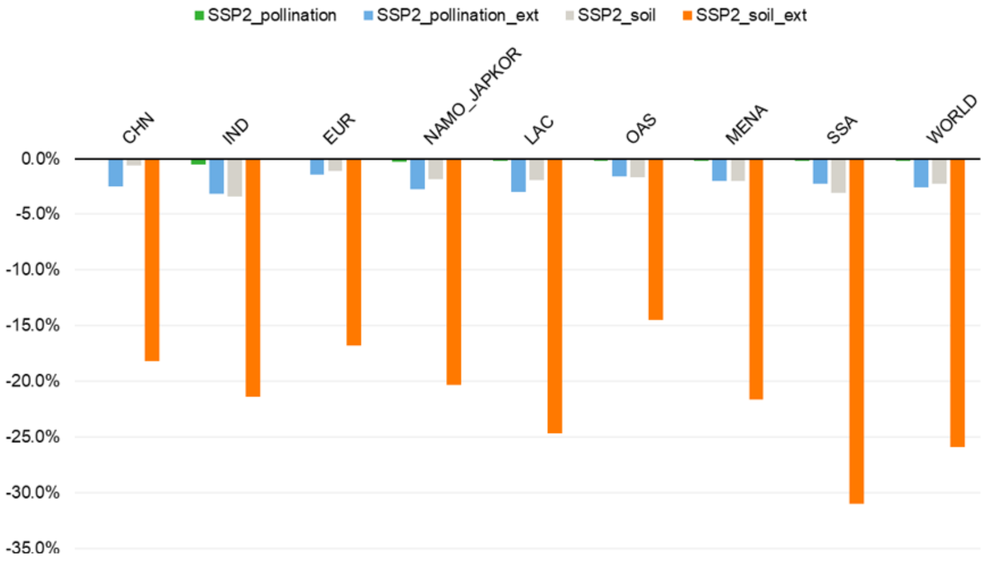

Figure 3: Crop productivity shocks introduced to MAGNET under different scenarios by 2050

Note: The Figure shows the average crop productivity loss under soil quality and pollination scenarios. These productivity levels are incorporated into the MAGNET model for pollination and soil quality scenarios, taking the Reference Scenario as a benchmark. For the regional and scenario abbreviations, please see Slide 16. Source: BiROFin project.

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Pollination and soil quality loss are projected to decrease global agricultural production as much as 5.1% in 2050, leading to shifts in production areas across regions

- Global primary agricultural production decreases by up to 5.1% by 2050 due to the (combined) loss of soil quality and pollination.
- The MAGNET model that we use for estimating the scenario effects takes into account the allocation of resources (land, labour, capital) in countries, and allows for trade between countries. As a result, our scenarios cause a portion of global agricultural production to shift from the MENA and SSA regions, where the comparative advantage of producing those commodities decreases due to high soil quality and pollination loss projections, to EUR. As highlighted in Slides 13 and 14, soil quality and pollination losses are expected to be lower in EUR than in other regions, resulting in limited crop productivity losses and increasing the comparative advantage of the region in producing and exporting agricultural products.
- In Europe, production increases by 4.3%, while in contrast, it principally decreases by 5.0% in MENA and by 10.9% in SSA. LAC countries are also second least affected region, where the effect agricultural production decreases are up to -1% in the most severe scenario.

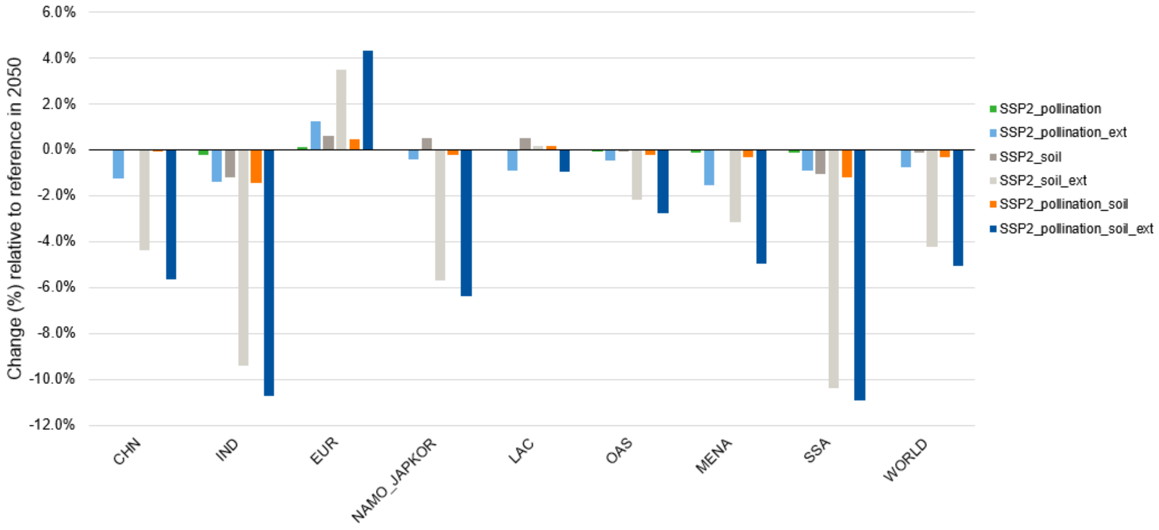

Figure 4: Projected change in primary agriculture products due to pollination and soil-quality loss induced by biodiversity loss and climate change by 2050, base year 2019.

Note: The figures show the average projected impact of soil quality and pollination loss on the annual production, domestic use, and export outcomes of agriculture, forestry, and fishing sectors in different regions. This impact is estimated as the percentage difference between the projected levels of those outcomes under different pollination and soil quality scenarios and the projected levels under the reference scenario for the year 2050. These estimates are derived from the MAGNET model. For the regional and scenario abbreviations, please see Slide 16 Source: BiROFin project.

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Decline in agricultural goods consumption – highest decline in India, China and SSA – and shift of exports across regions due to projected soil quality and pollination loss.

- Based on the scenarios the model projects a decrease in global domestic use of agricultural products (total consumption of agricultural products that are produced in the country or exported) by up to 4.9% with significant impacts observed in India (-9.8%), China (-5.4%), and SSA (-5.3%), as a results of decreased agricultural production in those regions (See Slide 18).
- Projected rise in global exports (2.0%) under both pollination and soil quality loss, considering climate change impacts: This is due to the higher relative prices of agricultural products, resulting from decreased supply/production of those.
- For EUR, the scenarios lead to an increase in export volumes in India (15.4%), where agricultural production is also projected to increase. We also notice a positive impact of different scenarios on agricultural exports from LAC and OAS where agricultural production is not significantly harmed, and the improvement in international agricultural product prices (terms of trade) encourages the flow of existing agricultural production toward export markets instead of domestic consumption.
- As a result of the same scenarios, a decrease in exports is projected in India (18.6%), NAMO_JAPKOR (14.6%), where agricultural production is expected to decline due to soil quality and pollination loss.

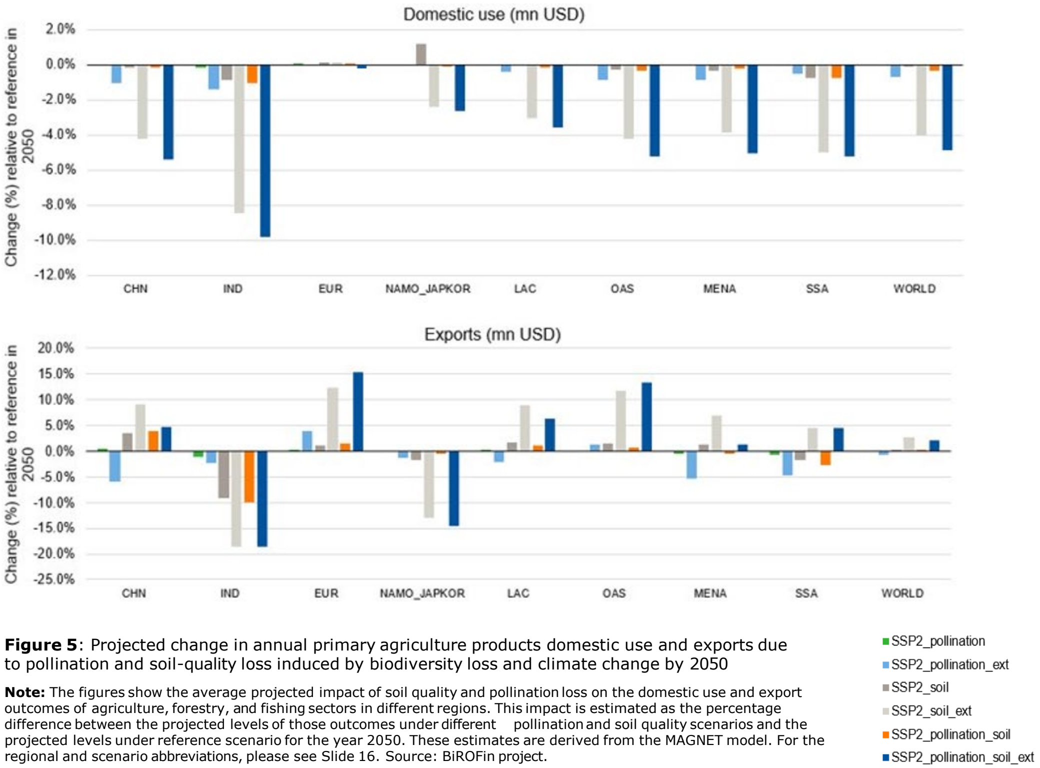

Figure 5: Projected change in annual primary agriculture products domestic use and exports due to pollination and soil-quality loss induced by biodiversity loss and climate change by 2050

Note: The figures show the average projected impact of soil quality and pollination loss on the domestic use and export outcomes of agriculture, forestry, and fishing sectors in different regions. This impact is estimated as the percentage difference between the projected levels of those outcomes under different pollination and soil quality scenarios and the projected levels under reference scenario for the year 2050. These estimates are derived from the MAGNET model. For the regional and scenario abbreviations, please see Slide 16. Source: BiROFin project.

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Slight global GDP impact (up to -1.2% by 2050), adverse GDP effects in SSA (up to -12.6% by 2050), due to productivity shocks and trade dynamics

- The expected decrease in GDP due to soil-quality and pollination loss induced by biodiversity is 10 times higher when climate-change-induced extreme climate events are considered.
- Under soil-quality and pollination loss while considering climate-change-induced extreme climate events, by 2050, the annual GDP is projected to decrease by 1.2%.
- A larger decrease in GDP is projected particularly in lower-income regions, due to decreased production, coupled with high import volumes, up to 12.6% for Sub-Saharan Africa.
- A more contained projection for higher-income regions such as NAMO_JAPKOR, up to −0.1% effect of soil-quality loss and pollination loss based on our scenarios, and in EUR (up to –0.3%). Although agricultural production is negatively affected in NAMO_JAPKOR countries by soil-quality and pollination loss, it has almost no GDP impact thanks to the low share of agriculture in those economies.

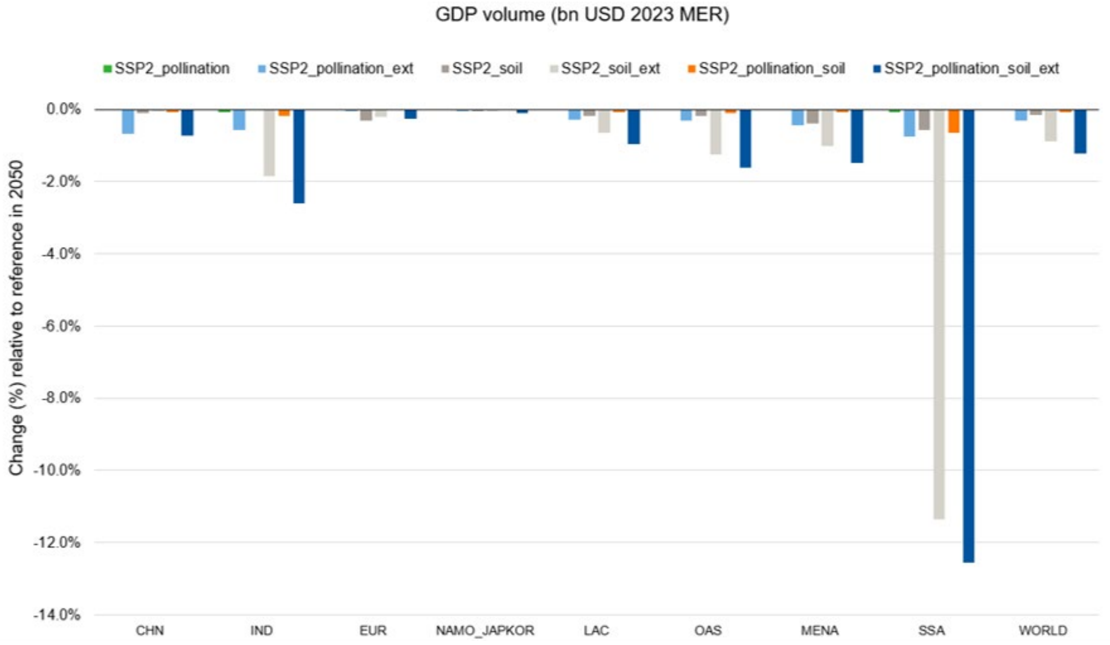

Figure 6: Projected change in GDP volumes due to soil-quality and pollination loss induced by biodiversity loss and climate change in 2050, base year 2019, considering extreme climate events.

Note: The figure illustrates the average projected impact of soil quality and pollination loss on the annual real GDP across various sectors. This impact is estimated as the percentage difference between the projected GDP under different pollination and soil-quality scenarios and the projected volumes under reference scenario levels for the year 2050. These estimates are derived from the MAGNET model. For the regional and scenario abbreviations, please see Slide 16. *BiROFin project.*

Limited indirect effects of scenarios on other sectors, while most adverse indirect effects are in Sub-Saharan Africa, particularly in food services (up to -17.2%) and food manufacturing (up to –9.3%)

- The MAGNET model considers the interdependencies among various sectors by using the social accounting matrix (see Slide 16). Consequently, we anticipate that the projected decrease in agricultural production, resulting from soil quality and pollination loss scenarios, will also impact sectors that rely on agricultural output. It can also influence other sectors through the reallocation of production factors such as land and labour.
- The model results show that global manufacturing of food products and food services, which depend on primary agriculture. decline up to 2.5% and (up to 1.4% respectively.
- Limited overall impact of scenarios on other sectors: Projected effect of other scenarios on other sectors is less than –0.5%
- In EUR, the positive effects of scenarios on agricultural production also have a beneficial impact, particularly on the manufacturing of food products, which may increase by up to 4%. The utilities sector contracts as a result of the scenarios, which might be due to the reallocation of land from this sector to agriculture to increase agricultural production.
- The highest negative effects of scenarios in the food manufacturing and services sectors are in OAS, MENA, and SSA. In SSA food services, as much as –17.2% and food manufacturing as much as -9.3%.

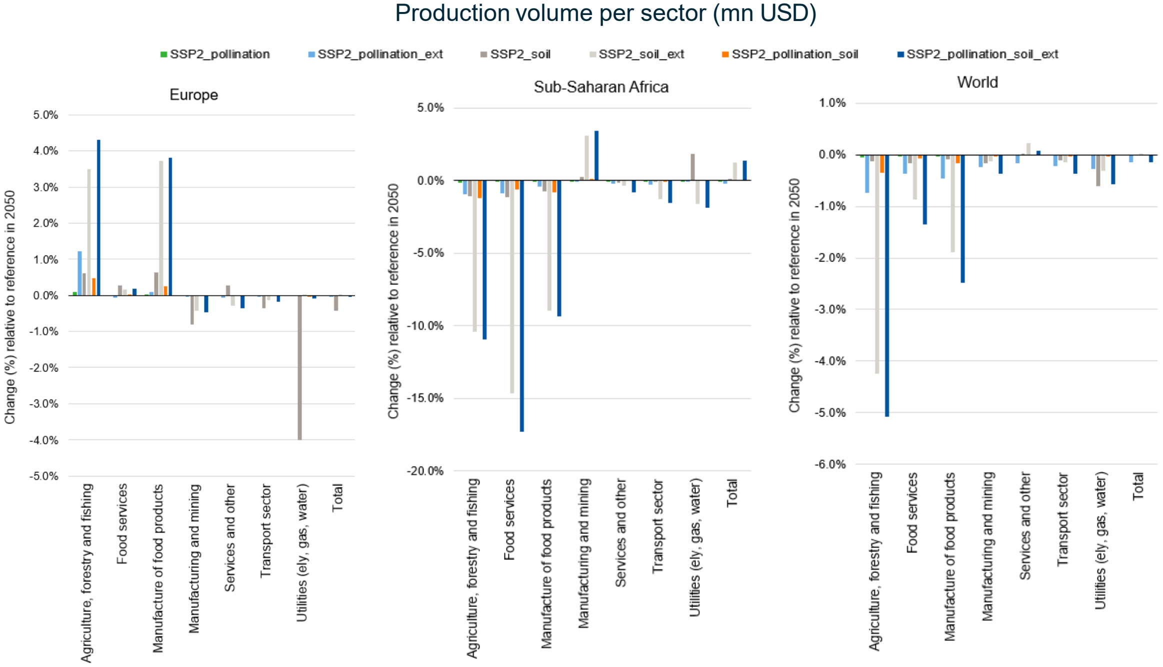

Figure 7: Projected change in sectoral production volumes in 2050 due to pollination and soil-quality loss induced by biodiversity loss and climate change, compared to the reference scenario.

Note: The figure illustrates the average projected impact of soil quality and pollination loss scenarios on the annual production volume across various sectors. This impact is estimated as the percentage difference between the projected production volumes under different pollination and soil quality scenarios and the projected volumes under reference scenario levels for the year 2050. These estimates are derived from the MAGNET model. For the regional and scenario abbreviations, please see Slide 16. *Source: BiROFin project.*

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Soil quality and pollination loss impact on prices: Global consumer prices for agricultural products can go up to 50% if climate induced extreme climate events are considered.

- By 2050, we project a modest positive effect of soil quality and pollination loss scenarios on agricultural product prices (<10%) and a negative effect on calorie intake (<1%) when these scenarios do not consider extreme climate events. When these events are not considered, soil quality and pollination loss are projected to be low, leading to limited crop productivity and a decline in agricultural production.
- The most extreme scenario, considering joint effect of soil quality and pollination loss on crop productivity, which also considers the effect of extreme climate events on biodiversity, increases consumer prices for agricultural products in the whole world, by up to 50% by 2050, resulting in a drop of calorie intake of up to 6% in the whole world. The same scenario increases global prices for agricultural products by 60% for the same period, especially in Sub-Saharan Africa (110%), where agricultural production contraction due to our scenarios is high.
- Our scenarios lead to up to 6% reduction in global calorie intake and up to 5% reduction in Europe due to soil quality and pollination loss, because of increased agricultural prices and high exports of products. The decrease in low-calorie intake in some regions, particularly in SSA, is due to the limited effect of our scenarios on staple food prices and shift of consumers to low calorie intake food products. For instance, in SSA, as agricultural prod. is redirected to exports, price increases lead to a shift in consumption towards less caloric products, resulting in a potential decrease in total consumption and thereby calorie intake

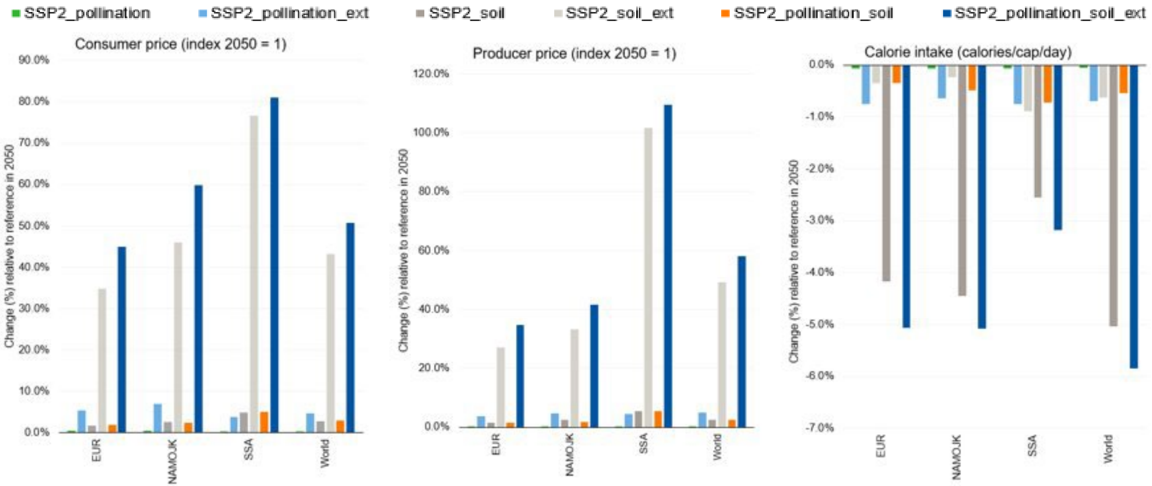

Figure 8: Projected change in consumer and producer prices for agricultural products and calorie intakes in 2050 due to pollination and soil quality loss induced by biodiversity loss and climate change, compared to the reference scenario.

Note: The figure illustrates the average projected impact of soil quality and pollination loss on consumer and producer prices for the agriculture, forestry, and fishing sector, and country-level calorie intake. This impact is estimated as the percentage difference between the projected employment under different pollination and soil quality scenarios and the projected volumes under reference scenario levels for the year 2050. Consumer and producer prices are indices (2017=100), and calorie intake is measured by kcal per capita-day. These estimates are derived from the MAGNET model. For the regional and scenario abbreviations, please see Slide 16 *Source: BiROFin project.*

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4. Costs and benefits of measures for abating soil quality and pollination loss

Identifying and estimating the monetary costs and benefits of 6 nature-based measures to abate soil-quality and pollination loss

- **Measures:** BiROFin identified on six measures (Table 1) selected from a long list of nature-based measures. Selected measures can be widely adopted to restore biodiversit, specifically address pollination and soil-quality services loss and also improve crop productivity.

Table 1: Selected six measures for cost-benefit estimations

Measure	Definition
Agroforestry-silvoarable	Combination of agriculture and forestry on the same land, using methods like silvopasture and forest farming. This includes integrating trees and shrubs with crops like wheat, corn, and soybeans to restore degraded areas.
Reduced tillage	Soil cultivation technique where a significant portion of the previous crop's residues are left on the soil surface after seeding.
Cover cropping	Use of any plants explicitly sown to reduce the loss of soil, nutrients, and plant protection products during the winter or other periods when the land would otherwise be susceptible to losses
Diversified crop rotations	Implementing an additional crop on the same plot of land interchangeably.
Flower margins	Permanent areas of diverse flowers and grass on land margins.
Organic manure application	Application of animal waste, vegetable compost, or agricultural residues to help maintain and improve soil structure and organic matter content.

- **Country focus:** Brazil, France, Germany, Italy, the Netherlands, Spain, the UK, and the US, chosen due to their significance in the financial sector portfolio.
- **Cost estimation:** Based on literature review, expert advice, and a cost- transfer function. The cost-transfer function is used to extrapolate the costs of measures from one country for which we have data to other focus countries. To estimate the country level expenses for a measurs, we consider expected adoption rate of a measure and suitable land area available in each country. The cost estimations should be interpreted as approximations.
- **Benefit estimation (approximation:** We report the global macroeconomic benefits of measures implemented at the country level. Measures are expected to restore soil quality and pollination loss and recover (projected) loss of crop productivity and GDP decline to those losses (Figure 9). The monetised benefits reflect the avoided decline in GDP due to improved soil quality and reduced pollination loss resulting from adopting these practices, expected yield improvement of each abatement measure, and the global GDP increase because of that yield increase, the suitable land area, and expected adoption rates of that measure in each country based on a scenario analysis. The benefit estimations should be interpreted as approximations.
- **Reported indicators at the country level:** Cost per hectare and total costs, total potential land that can be covered by the measures, and aggregate GDP loss avoided by adopting practices.
- **Limited data availability for flower margins** (only available for the Netherlands), agroforestry (not available for Brazil, the UK, and the US), and diversified crop rotations (not available for Brazil and UK).
- For more details on the methodology, please see Annex 3: Abatement Measures Methodology

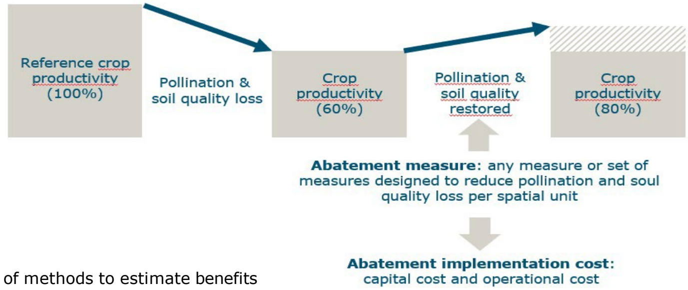

Figure 9: Summary of methods to estimate benefits

Costs for implementing agricultural measures vary based on country and practice

- Range of annual expenses for implementing all measures, from USD 663 per hectare in Brazil to about USD 1,800 per hectare in the Netherlands and the U.S. (2023 prices). Variations in these costs are explained by differences in economic development levels, serving as proxies for land, labour, and capital costs relevant to the adoption of practices.
- The implementation cost is highest for crop rotation and lowest for flower margins and agroforestry-silvoarable systems. These differences can be attributed to the varying requirements of each practice.
- Crop rotation necessitates comprehensive changes in planning, inputs, and crop management, which require ongoing maintenance each year, thereby increasing the overall implementation costs.
- In contrast, flower margins and agroforestry-silvoarable systems have lower maintenance requirements. After the initial investment, these systems incur minimal annual additional costs.

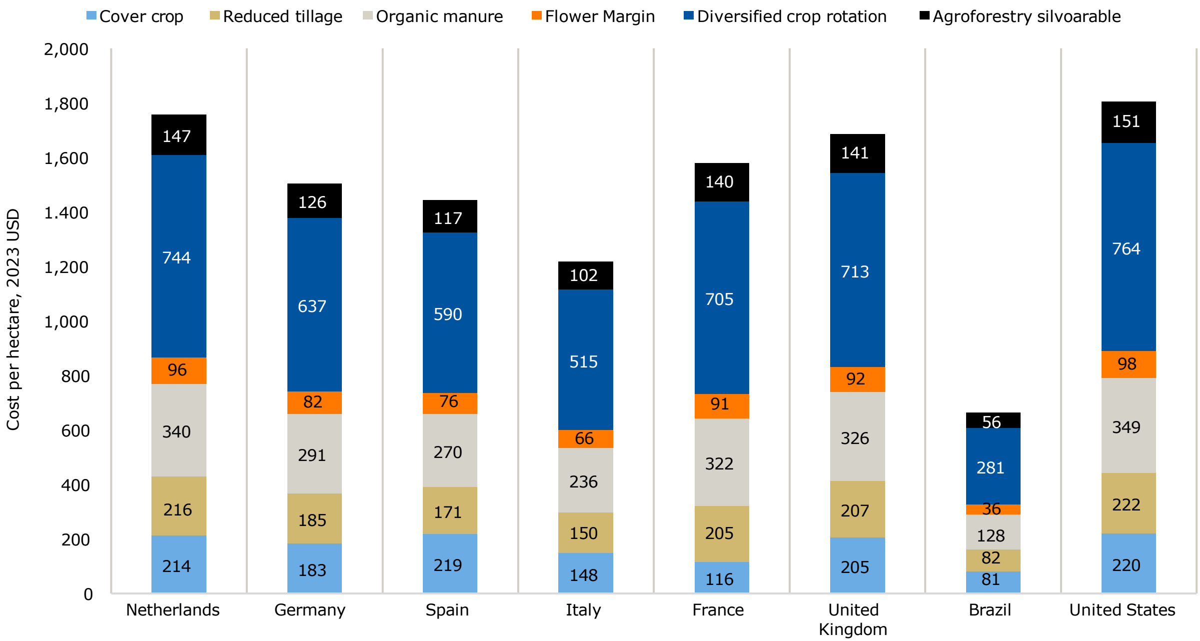

Figure 10: Annual implementation cost per hectare by measure-country by 2025, 2023 USD prices

Notes: The figure shows the implementation costs of six selected measures in the focus countries. Total costs including both capital and operational expenses are reported. Literature-based values: Cover crop (Netherlands, Spain, France), No tillage (Germany), Organic manure (Netherlands), Flower margin (Spain), Diversified crop rotation (France), Silvoarable (United Kingdom). All other values were extrapolated using a cost transfer function. These estimates are derived by using the approach explained in Online Appendix: Abatement_Measures.

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By 2050, the macroeconomic benefits from 13 of 27 country-specific abatement measures, resulting from improvements in crop productivity, can exceed their implementation costs.

- Implementation of agroforestry-silvoarable (AG), a low-cost measure, generates positive macroeconomic returns exceeding costs in Italy, Germany, France, and Spain. For instance, in Spain, investing in AG costs USD 119m global macroeconomic benefits vs. USD 36m implementation costs.
- Organic Manure (OM) requires more upfront investment than AG Ex. for OM.
  - France: USD 2.2bn in global macroeconomic benefits vs. USD 1.4bn implementation costs in France.
  - USD 1.2bn in macroeconomic benefits vs. USD 0.5bn in Italy.
- Flower margins in the Netherlands and reduced tillage in Brazil, along with other country-measure pairs with benefits exceeding costs.
- Socioeconomic value of measures initially deemed unbeneficial for investment (orange dots) could increase when additional co-benefits, such as addressing climate change, are considered.
- It is worthwhile to note two points concerning the benefit estimates:
  - The macroeconomic benefits in earlier years, such as in 2030, will be lower than those in later years, as the full productivity gains from measures will not be realised until later.
  - The cost and benefit estimates are approximations and based on data from existing studies of the most commonly grown crops in the countries. Results may vary among different crops.

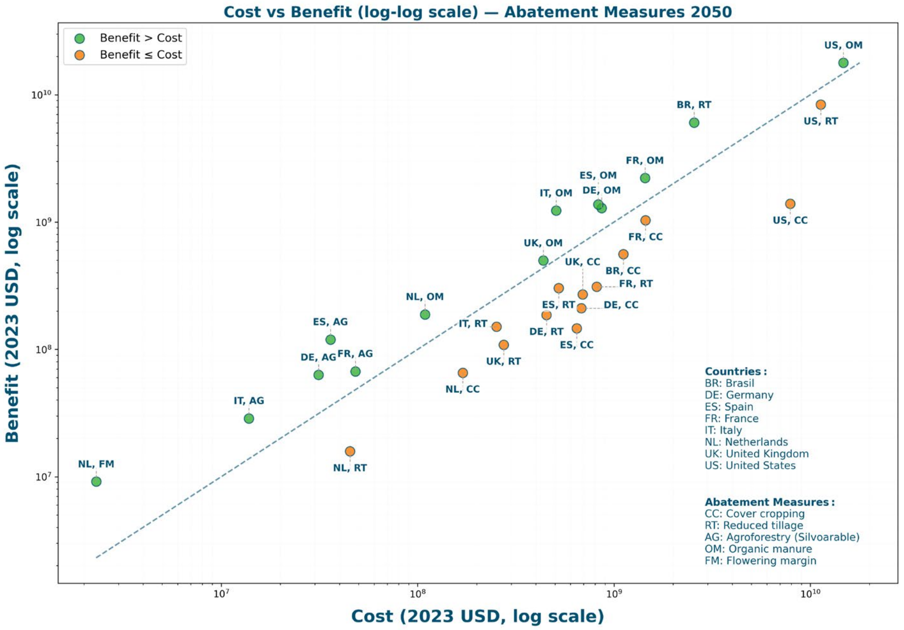

Figure 11: Macroeconomic costs vs global macroeconomic benefits of the selected Abatement Measures by 2050

Note: Each label follows the format "country code, measure code" (e.g., NL, CC = Netherlands, Cover Cropping). Values are expressed in thousands of USD (2023). Axes use a logarithmic scale, with tick labels showing actual monetary values (e.g., 10^5 = 100,000). Cost estimates are based on per-hectare implementation costs, expected adoption rates, and the area of suitable land in each country. Benefits reflect avoided GDP loss from restored crop productivity by 2050, using results from the MAGNET model under pollination and soil quality loss scenario during extreme climate events. Other potential benefits—such as carbon credits or ecosystem services—are not included. The analysis is conducted under three scenarios (optimistic, pessimistic, and middle), which differ in assumptions about future cost trends and adoption rates. The figure presents results for the middle scenario. The 45-degree reference line indicates breakeven points where estimated benefits equal costs. These estimates are derived by using the approach explained in Online Appendix: Abatement_Measures. Source: BiROFin project.

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Potential of diversified crop rotations and cover crops to cover extensive land in major economies, yet their implementation costs exceed macroeconomic benefits

- Organic manure, agroforestry, flower margins in the Netherlands, reduced tillage in Brazil with macroeconomic benefits of productivity improvements exceeding implementation costs: can reach up to 125 million hectares.
- High adoption potential of diversified crop rotation and cover crops for which implementation costs exceed macroeconomic benefits:
  - Diversified crop rotation, estimated at 111 million hectares by 2050, totaled over countries where data is available.
  - Cover crops: 91 million hectares.
- Comparatively low adoption potential of agroforestry-silvoarable (15 million hectares).
- Limited data for flower margins (only available for the Netherlands), agroforestry (not available for Brazil, UK, and US), and diversified crop rotations (not available for Brazil and UK).

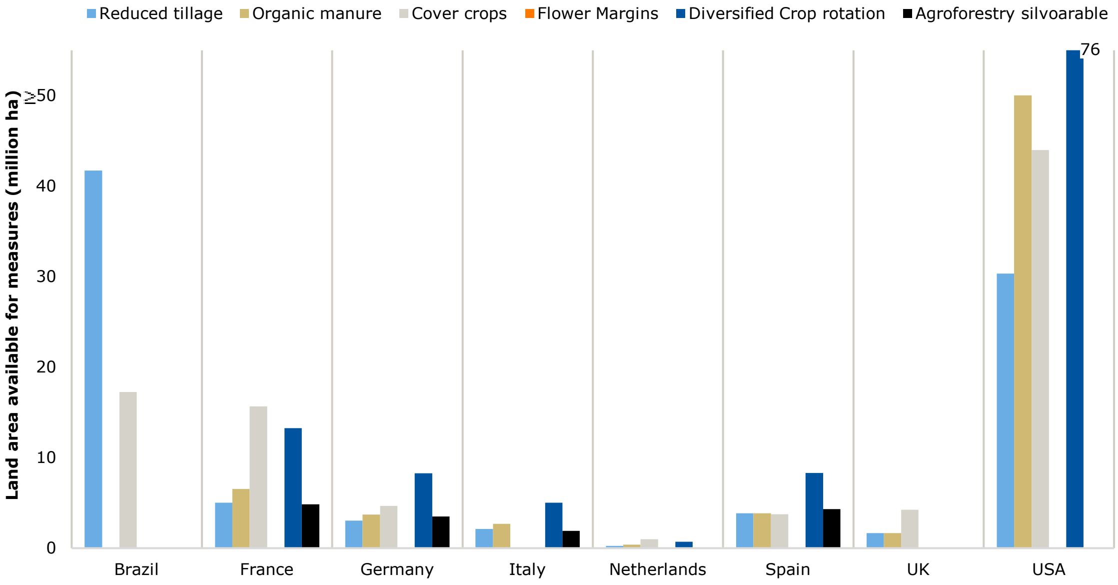

Figure 12: Projected potential area that could be covered by measures per country by 2050

Notes: The figure shows the land area to be potentially covered by the selected measures in each country. The result is a sum per country of all the land that each measure could cover. Total arable land per country is considered as a starting point and using estimations of adoption rates per measure and per country from 2025 through 2050, the potential land area is calculated. For Flower Margins and Agroforestry Silvoarable systems, only about 10% of the suitable land is used, reflecting edge-of-field and partial field implementation. A neutral scenario is considered for the adoption rate estimates. These estimates are derived using the approach explained in the Online Appendix: Abatement Measures.

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5. Addressing the biodiversity concern by halving the Earth’s agricultural land

Half-Earth protection scenario: putting 50% of the global land available under protection while prioritising biodiversity hotspots

- **Protected areas in the scenario:** Scenario data are from Kok et al. (2020, 2023). 50% of the global land area is designated as a 'protected area', focusing on regions that hold the richest biodiversity such as Latin America, Africa, Malaysia and Indonesia. This limits the area available for agriculture in the MAGNET model.

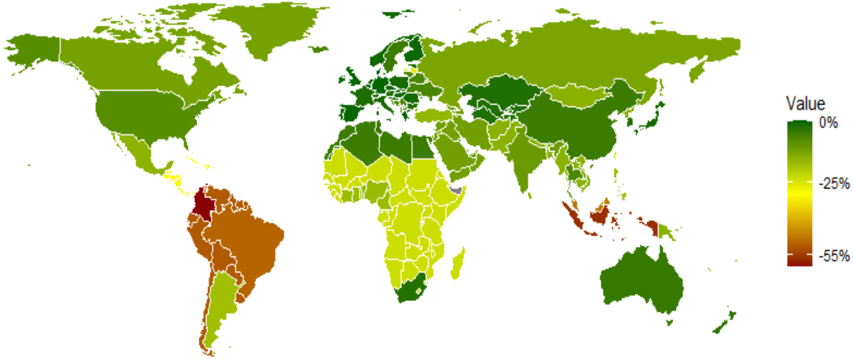

Figure 13: % reduction of land available for agriculture by 2050, benchmark year 2019

Note: This map shows the percentage reduction in land available for agriculture according to the Half-Earth scenario compared baseline in 2019. (Kok et al.; 2020, 2023)

- **Scenario inspiration:** Target 3 of the Kunming-Montreal Global Biodiversity Framework (ratified December 2022).
  - Target 3: Aims to protect 30% of the Earth's most crucial biodiversity hotspots, representing a step toward the broader goal of 50% protection.
- Immediate geographical effects of scenario (Figure 13):
  - A reduction of more than 30% in the land available for agriculture in Latin American countries (LAC) as well as in Malaysia and Indonesia, where species abundance is highest.
  - 25% reduction in available agricultural land in Sub-Saharan African (SSA) countries.
  - Modest land availability reduction in Europe, China, and Australia (<-10%), which are not biodiversity hotspots.
- **Integration into MAGNET model:** Implementing the Half-Earth Scenario in the MAGNET model is done by changing the land supply available for agriculture to match the required protected area. For more please see Online Appendix: Half-Earth Scenario
- **Outcomes and reference scenario:** We present the estimates of the Half-Earth Scenario effect on the same outcomes discussed in Slide 16, in comparison to the reference scenario detailed in Slide 12. This reference scenario excludes the soil quality and pollination shocks mentioned in Section 3. If these factors were included, the impact of the Half-Earth Scenario could vary, depending on the speed of recovery due to conservation policy and the crop productivity already observed in a particular country or region.

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Limited agricultural land availability in the Half-Earth Scenario: Increased land prices, particularly in Sub-Saharan Africa, Middle East and North Africa, and Latin American Countries

- We estimate that the global land price increases (14.1%) due to reduced availability of land to agriculture under the Half-Earth Scenario.
- The scenario leads to severe land price appreciation in Latin America (LAC) (28.8%) and the Middle East and North Africa (MENA, 14.7%), where agricultural land is limited the most, while moderate in China (7.5%) and India (8.4%).
- The model also estimates that protecting half of the earth and restricting agricultural land available increases global chemical fertiliser use, (13.9% or 39m tonnes), primarily in SSA and LAC (29.3%), where land available decreased most, to compensate low land availability with increased productivity in agriculture.

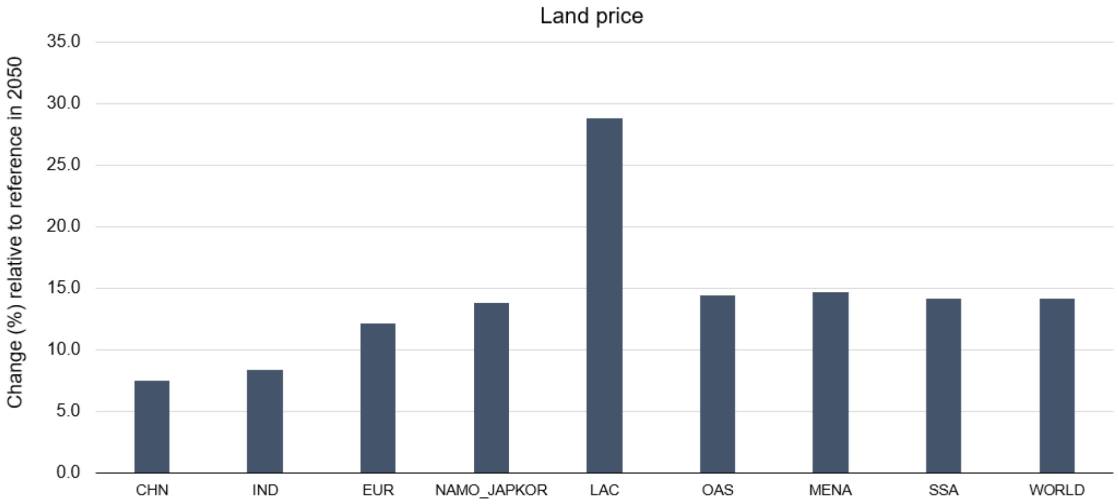

Figure 14: Projected change in land prices in 2050 by regions due to Half-Earth Scenario

Note: The figures show the average projected impact of the Half-Earth Scenario on land prices in different regions. This impact is estimated as the percentage difference between the projected levels of land prices under the Half-Earth Scenario and the projected levels under the reference scenario for the year 2050 using the MAGNET model. For the regional abbreviations, please see Slide 16.

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Uneven effects of half-earth protection on agricultural output: SSA (-8.4%), India and other OAS (-5.8%), while Europe (+4.1%) stand to benefit

- The Half-Earth Scenario is expected to decrease the global agricultural production volumes by 2.8% in 2050 due to reduction in available land, primarily driven by decreases in oilseeds (6.3%), sugar cane (2.5%) and horticultural products (3.3%).
- The largest adverse effect of the scenario on agricultural production volumes is expected to be in SSA (-8.4%), India (5.8%), and OAS (-5.8%) due to reduced land availability and rising land prices.
- The agricultural production effects of the Half-Earth Scenario in Europe by 2050 indicate a 4.1% increase. This scenario does not restrict the land available for agriculture in Europe as much as it does in other regions, since biodiversity hotspots are fewer in Europe. Additionally, Europe stands to benefit from increased exports of agrifood products due to decreased production in other regions.

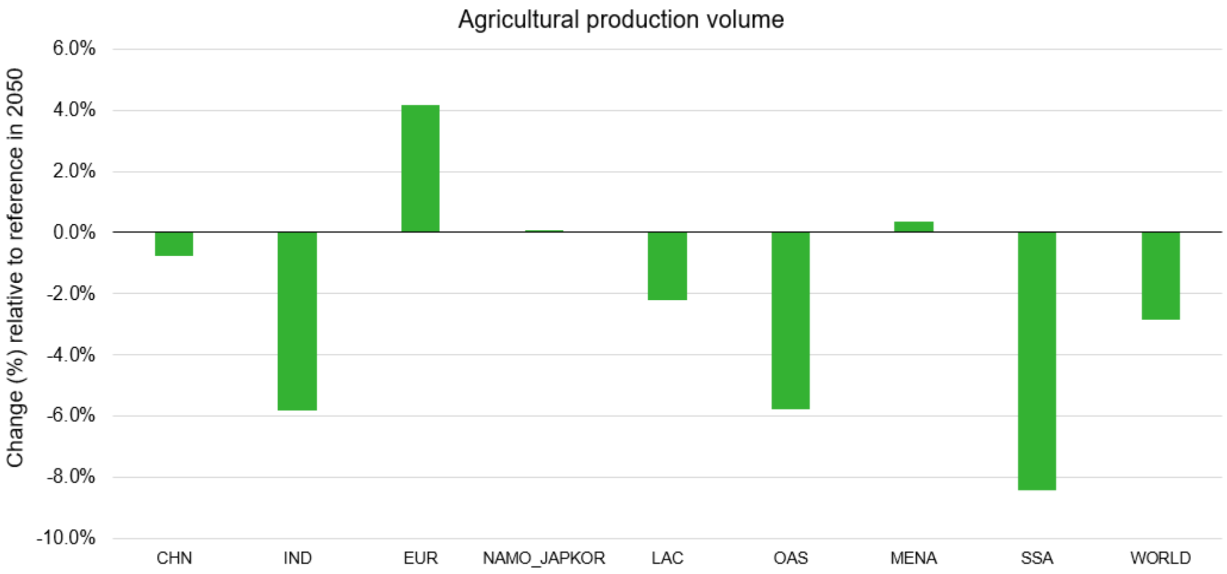

Figure 15: Projected change in primary agricultural production due to the Half-Earth Scenario, compared to the reference scenario

Note: The figure illustrates the average projected impact of health scenario on production in agriculture, forestry and fishing sector. This impact is estimated as the percentage difference between the projected production volume under half-earth scenario and the projected volumes under reference scenario levels for the year 2050. These estimates are derived from the MAGNET model. For the regional abbreviations, please see Slide 16.

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Half-Earth Scenario's projected adverse effects on global agricultural prices: +15% globally, the highest being +33% in SSA, resulting in food security challenges

- The scenario is expected to increase global agricultural producer prices by 15.3%, reflecting reduced supply of agricultural products and higher production costs.
- The most significant price effect is in SSA (+32.7%), followed by LAC (+17.0%), where adverse agricultural production effects of the scenario are observed. This can exacerbate food security challenges in those regions.
- A more contained price effect is in higher-income regions: EUR, +7.6%, and North America, Oceania, Japan and NAMO_JAPKOR, +10.2%.

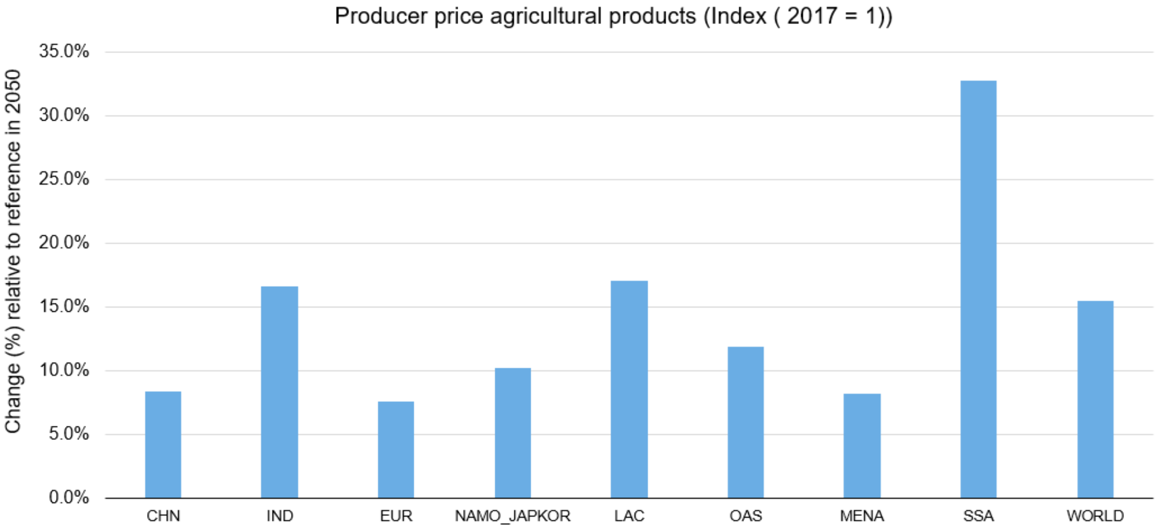

Figure 16: Projected changes in producer prices for primary agricultural products, by 2050

Note: The figures show the average projected impact of the Half-Earth Scenario on producer prices in the agriculture, forestry, and fishing sectors in different regions. This impact is estimated as the percentage difference between the projected levels of producer prices under the Half-Earth Scenario and the projected levels under the reference scenario for the year 2050. These estimates are derived from the MAGNET model. *Source: BiROFin project.* For the regional abbreviations, please see Slide 16.

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Regional variation in global GDP effects of biodiversity protection: While a modest global GDP decline in GDP by 2050, disproportionately severe for SSA

- The global impact of the Half-Earth Scenario on GDP is relatively modest, estimated at -0.4%, which translates to a loss of approximately USD 698bn.
- On average, SSA face the heaviest burdens, with a GDP effect of -4.3% by 2050 or about USD 407bn, largely due to their higher reliance on agriculture.
- In Europe, the impact on GDP is second lowest, lower than world average. Nevertheless, lower consumption across various sectors because of the Health-Earth Scenario negatively affects GDP, leading to a decline of 0.07% in GDP, or approximately USD 21.4bn, by 2050. Low adverse impact on GDP is primarily driven by improved trade terms associated with rising agrifood export volumes of Europe.

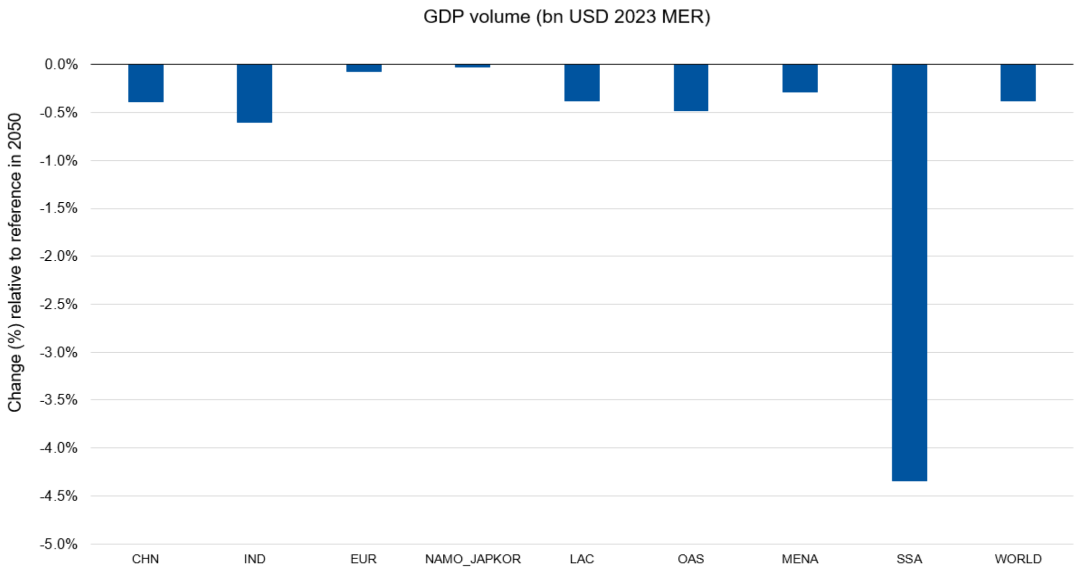

Figure 17: Projected impact of the Half-Earth Scenario on annual GDP in 2050, compared to the reference scenario

Note: The figure illustrates the average projected impact of the Half-Earth Scenario on annual GDP. This impact is estimated as the percentage difference between the projected GDP under the Half-Earth Scenario and the projected GDP under the reference scenario levels for the year 2050. These estimates are derived from the MAGNET model. For the regional abbreviations, please see Slide 16.

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6. Conclusion: Financial sector implications and must-read uncertainties in findings

Biodiversity loss may cause financial risks, particularly in emerging markets, but also offers opportunities for innovative solutions and green financing.

BiROFin assessed two risk cases: (i) biodiversity loss affecting **pollination** and **soil quality** (with/without climate-induced extreme events); (ii) a **Half-Earth conservation policy**. Soil quality loss poses the greatest macroeconomic and financial risks, given its universal role in crop production. First, we will assess the risk our results may pose to the financial sector, followed by the opportunities they may bring.

Direct financial risks

- In high-income regions (Europe, North America), where most financial assets are concentrated, GDP impacts appear **modest**. However, **food price inflation**, especially when biodiversity loss coincides with **extreme climate evets**, creates **second-round risks** (higher interest rates, lower bond/equity valuations).
- In **retail/households:** weaker loan demand, labour market slowdown, rising non-performing loans (NPLs), higher provisions.
- In **corporates:** reduced investment appetite, tighter agri/food sector financing (due to insurability issues), but some opportunities if firms adapt business models.
- **Commodity traders** and niche sectors may profit from trade shifts (e.g. higher EU exports).

Political, regulatory, and economic risks

- **Credit and market risk:** rising NPLs, higher bond yields, lower sovereign/corporate debt prices.
- **Policy risks:** export bans, tariffs, and food-security regulations may fragment trade and amplify inflation.
- **Nature-related stranded assets:** devaluation and volatility in agriculture-linked sectors; potential spillovers into logistics, inputs, and consumer staples.

Geographies and contagion

- **Most exposed:** Emerging markets (India, Sub-Saharan Africa), food-export reliant economies, and small import-dependent states (e.g. Singapore, Japan).
- **Sectors:** agriculture (high banking exposure), food processing, logistics, construction/housing (through squeezed disposable incomes).
- **Contagion:** open-economy trade channels, export restrictions, and global supply chain disruptions; risk of social unrest, migration, and conflict escalation.

Opportunities from abatement measures

- Cost-effective interventions identified: **organic manure** (DE, FR, IT, NL, ES, UK), **agroforestry** (DE, FR, IT, ES), **flower margins** (NL), **reduced tillage** (BR).
- These serve as **benchmarks** for client transition plans, engagement, and financing strategies.
- **Green/transition finance** is needed to scale agri-innovation, with opportunities in **fertilizers, industrial machinery, land management, logistics, and food safety.**

Strategic takeaways for the financial sector and beyond

1. Direct GDP effects in developed markets may appear small, but inflation, rate hikes, and **emerging market spillovers** could materially affect financial returns.
2. **Stress tests** should integrate soil/pollination shocks, extreme climate events, trade restrictions, and migration/unrest risks.
3. Lenders should embed **nature-risk covenants** and adjust credit policies in agriculture and food processing.
4. Investors can capture upside in nature-positive agricultural practices, resilient supply chains, and food security solutions.
5. Policymakers and financial institutions must prepare for **capital erosion from biodiversity loss**, not yet fully captured in economic models.

Biodiversity loss and conservation policies pose **non-trivial systemic risks** through food price inflation, credit quality deterioration, and political instability in EMs. For financial institutions, the key lies in **pricing nature risk into credit and investment decisions**, steering capital towards **resilient, nature-positive practices**, and preparing for **disorderly adjustment scenarios**.

Our estimates involve several methodological uncertainties

- Crop productivity estimates from scenarios based on climate-change-induced extreme climate events as upper limits, as countries are assumed to experience concurrent climate events in the scenarios.
- Uncertainty in our economic impact estimates for biodiversity loss due to
  - scenario parameters linking biodiversity, soil quality, and pollination based on expert judgement.
  - neglecting the effects of changing economic activity on biodiversity.
- Potential for greater crop productivity and economic effects due to the following factors neglected in our scenario analysis and economic modelling, such as
  - long-lasting financial capital loss due to economic declines, labour productivity declines due to decreased calorie intake
  - (Agricultural) price-wage spirals leading to long-term inflationary pressures, reducing economic activity.
  - Reaching tipping points, soil quality, and pollination services are not provided anymore, as biodiversity decline has reached a critical point
  - Social and political impacts of macroeconomic change (e.g., increased agricultural prices leading to a major impact on migration patterns and political unrest), which ultimately will also have fiscal and monetary policy consequences (e.g., monetary easing and food subsidies to compensate for the effects of increased agricultural prices)
  - New policies and regulations to prevent biodiversity loss until 2050 or limit further agricultural land and fertilizer use, given the increasing pressure on land (e.g., housing shortage) and emphasis on reducing emissions from agriculture.
- Indicative (not precise) cost-benefit estimations for the abatement measures due to:
  - Extrapolation of costs for many countries through the cost transfer function.
  - Assumptions of equal monetary benefit between countries.
  - Scenario-based adoption rate of practices.
  - Not considering all economic (co-)benefits of measures (e.g., climate regulation, water retention)
- For details, please see our methodological Online Annexes: On scenario work: Biodiversity and climate change impact calculation for BiROFin; On MAGNET model estimations: MAGNET model Documentation; On costs and benefits of abatement measures: Abatement measures; methodological background; On implementing the Half-Earth scenario in the MAGNET model:

Contact information

Updates on research progress, upcoming publications, and stakeholder engagement opportunities will be shared through external workshops and public channels. Interested parties are invited to stay connected via our project website or by contacting the research team directly.

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