IAM COMPACT

Expanding Integrated Assessment Modelling:
Comprehensive and Comprehensible Science
for Sustainable, Co-Created Climate Action

Responsive science in support of climate policymaking
IAM COMPACT Final Conference, Athens, 29 August 2025

Biodiversity, material resources, & biophysical limits

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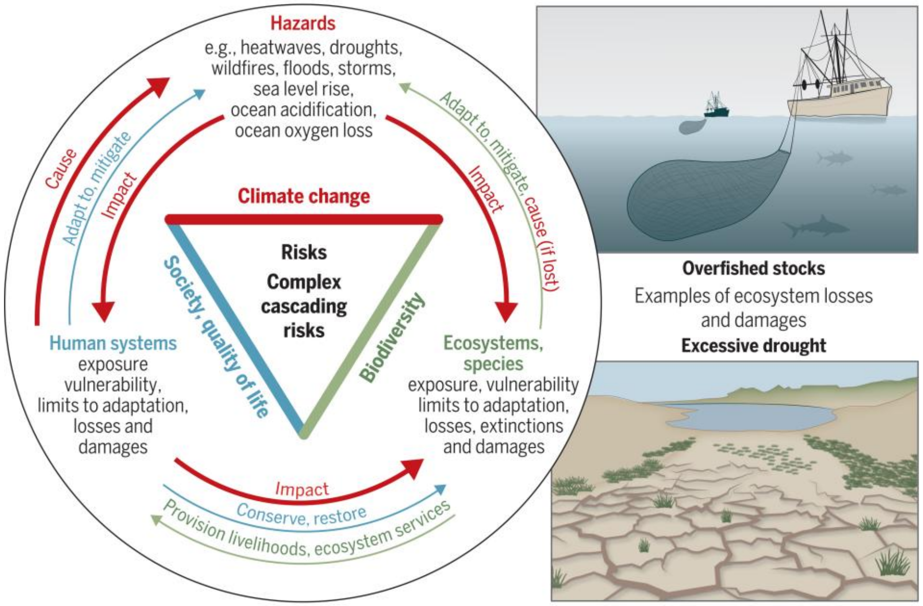
Introduction / Climate and biodiversity interactions

- Unprecedented acceleration of species loss over the last century
- Historically, land use change (LUC) has been the main driver, but climate change could become worse than LUC
- Climate action, through land-based mitigation policies, can also damage terrestrial biodiversity
- Damage to ecosystems can undermine their carbon sequestration potential and hence land-based mitigation



There is a need to assess the biodiversity impacts of climate mitigation policies

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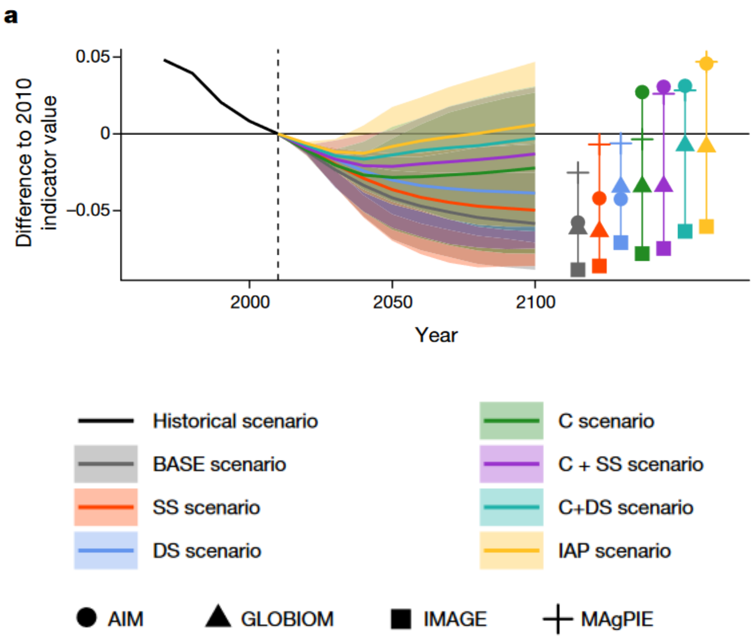
Introduction / IAMs and biodiversity metrics

- Many metrics have been used to measure biodiversity impacts (BII, LPI, MSA, ESH)
- These metrics are increasingly integrated in Integrated Assessment Models (IAMs)
- Most are based on habitat-based measures or the classic Species-Area relationship (c-SAR) models
- They usually do not account for species endemism and affinity to human land uses



There is a need to use biodiversity metrics accounting for species endemism and affinity to human land uses

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Research gaps

There is a need to assess the biodiversity impacts of climate mitigation policies

There is a need to use biodiversity metrics accounting for species endemism and affinity to human land uses

Approach

The study combines the **Global Change Analysis Model (GCAM)** with a downscaling tool and the **Potential Species Loss (PSL)** indicator to analyse terrestrial biodiversity impacts of different land-based mitigation scenarios compatible with the Paris Agreement

Objectives

Identify pathways compatible with the Paris Agreement that could minimize biodiversity impacts

Understand the potential trade-offs between biodiversity conservation and climate change mitigation

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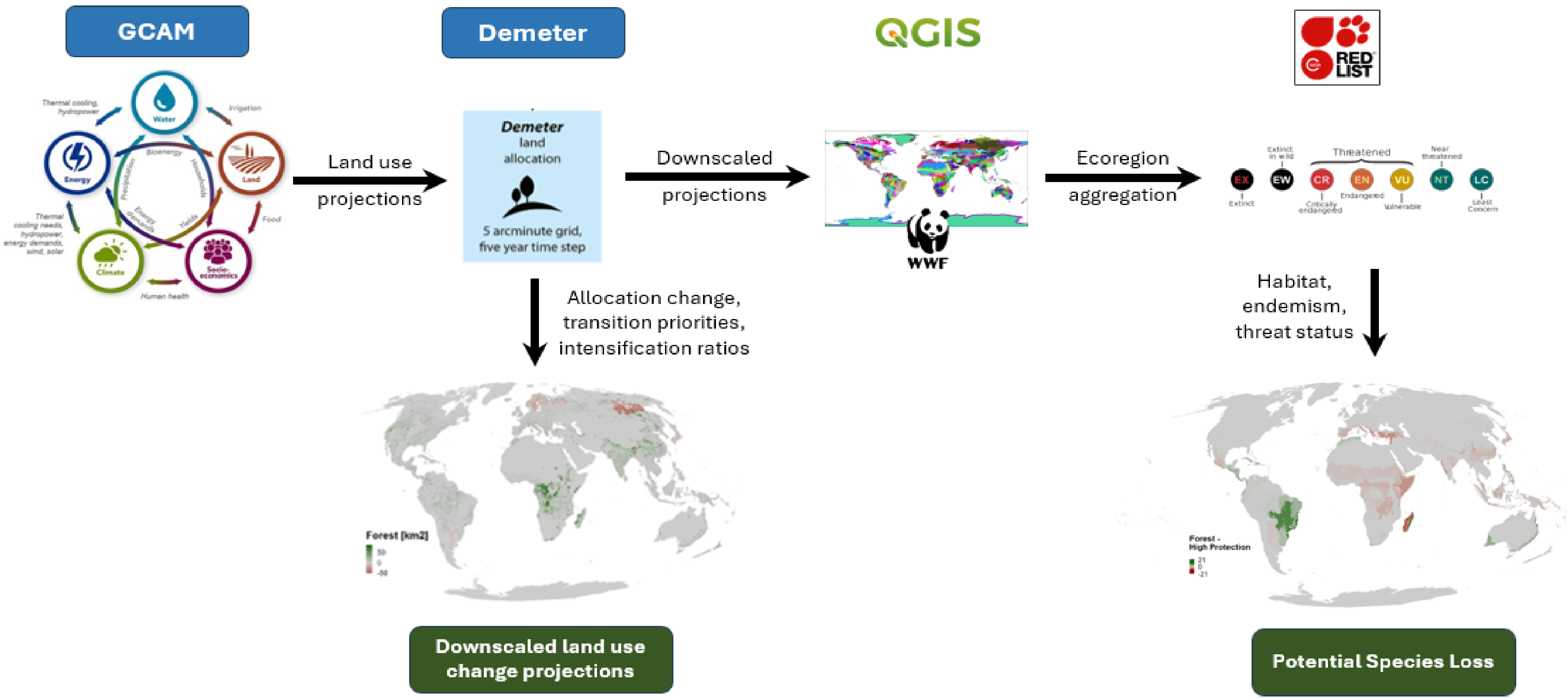
Methodology / Overview of the modelling framework



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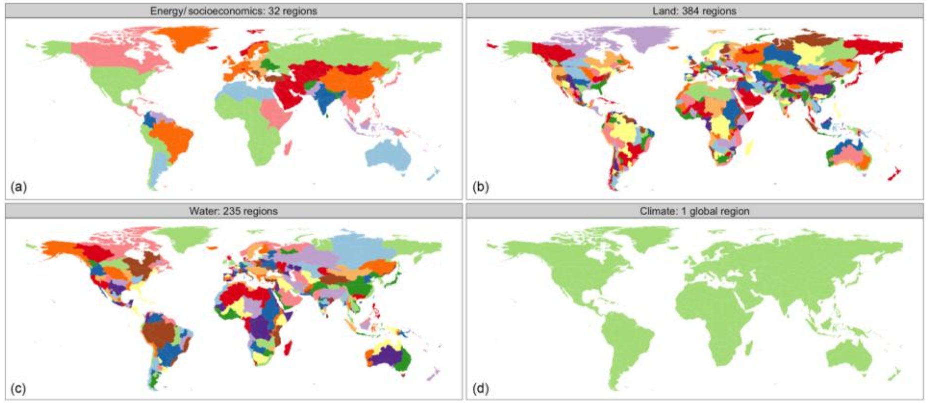
Methodology / GCAM & Demeter

GCAM v7.0

- Dynamic recursive model representing the complex interactions between five major systems—energy, water, land, climate, and the economy.

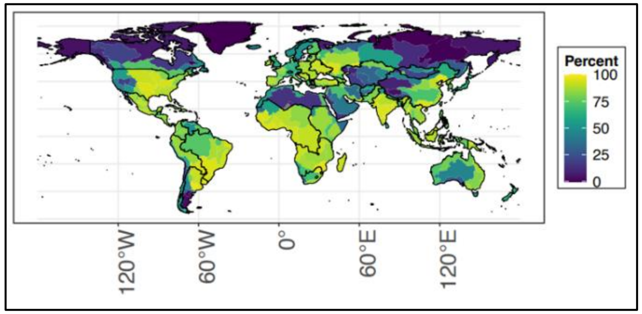


Demeter

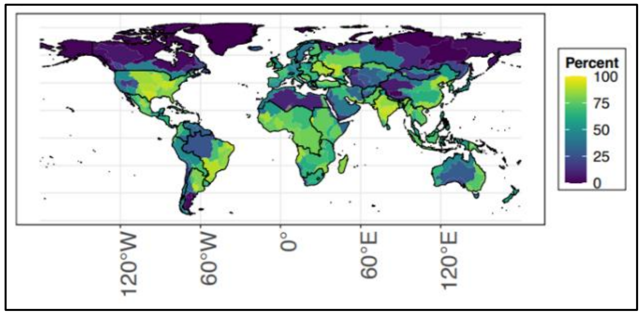
- Land use spatial downscaling model to disaggregate land use results from GCAM to a spatial of resolution 0.5º x 0.5º for global land use projections for eight different land types

Protected areas

- Two different land protection levels are assumed across the Baseline scenarios: *Default Protection* and *High Protection* (sufficient to safeguard biodiversity hotpots)



Land available in *Default protection* baseline



Land available in *High protection* baseline

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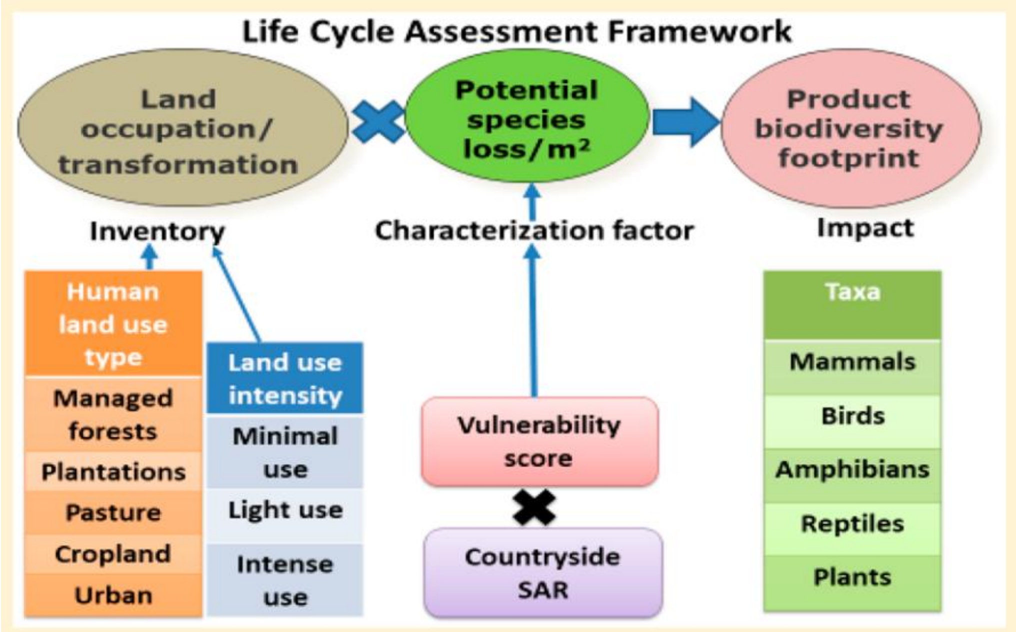
Potential Species Loss (PSL)

Indicator represents the number of species that could become committed to extinction due to LUC by combining:

- original species count in the ecoregion
- reduction in natural habitat
- the threat level for each ecoregion and taxon
- taxon endemism
- intensity use of the land use types
- species' preference for new artificial habitat induced by LUCs



GCAM land use type	Matching land use types and intensity
Shrubland	Natural vegetation
Grassland	Natural vegetation
Tundra	Natural vegetation
Forest	Managed forests - Selective logging
Protected forest	Natural vegetation
Pasture	Pasture - Intense use
Protected pasture	Natural vegetation
Irrigated crop	Cropland - Intense use
Rainfed crop	Cropland - Minimal use

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Five scenarios with PA temperature targets are modelled with varying mix of land-based mitigation measures

Scenario	Land cover protection	Key assumptions
PA Baseline	Default Protection High Protection	SSP2 assumptions (O'Neill et al., 2014) + Cap on bioenergy (64 EJ in 2050) A global emission pathway simulating PA compatible temperature targets based on implementation of current NDCs + Long-term targets (LTTs) up to 2050
Forest	High Protection	A global land carbon price is progressively introduced to simulate a strong reliance on A/R and reduced deforestation
Bioenergy	High Protection	Unconstrained biomass production to supply bioenergy
Dietary change	High Protection	SSP1 assumptions for food demand → substitution of protein demand away from meat through a preference elasticity of all animal proteins of -0.75 (for every 1% increase in income, animal proteins are 0.75% less preferred)

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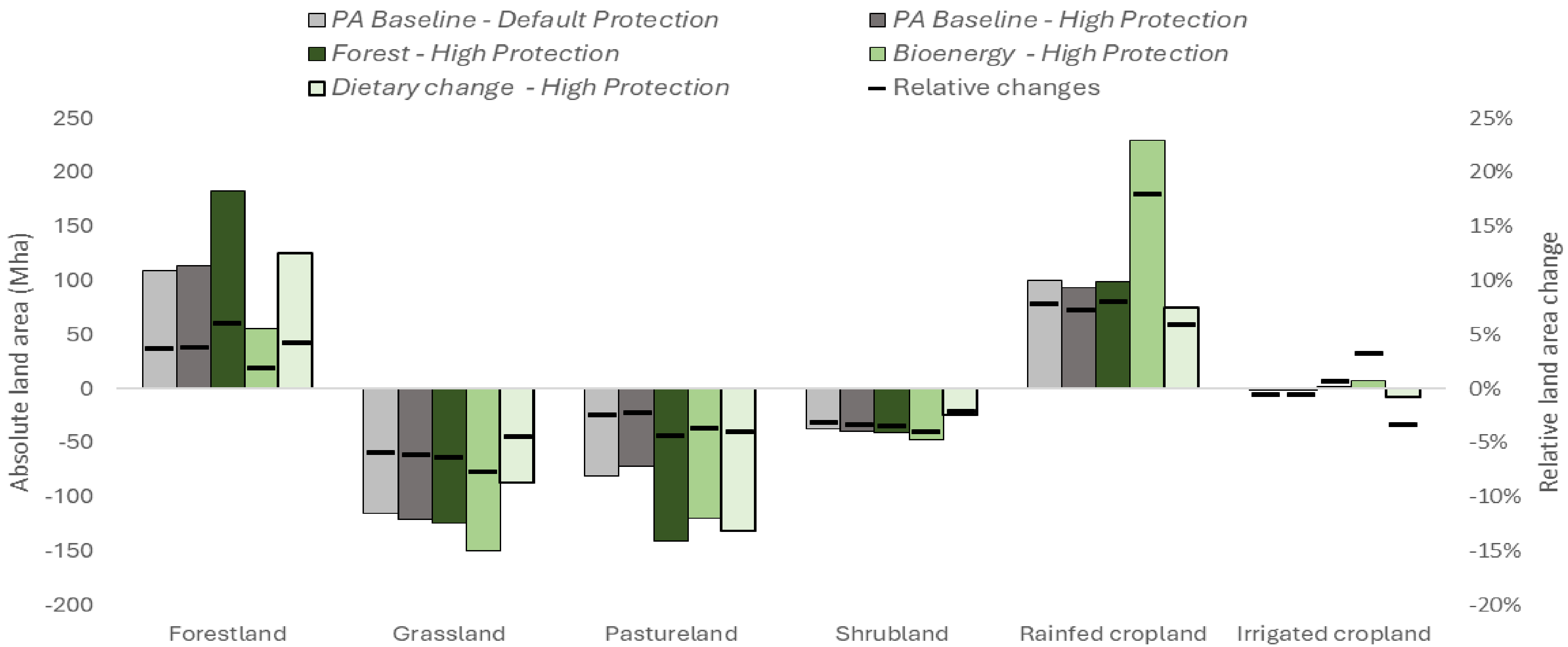
Results / Land use changes



- *Bioenergy* and *Forest* would result in land area conversions affecting **4.6%** and **4.5%** of the total land surface
- *PA Baseline* scenarios and *Dietary change* would have the lowest land area changes, **3.3%** and **3.4%**

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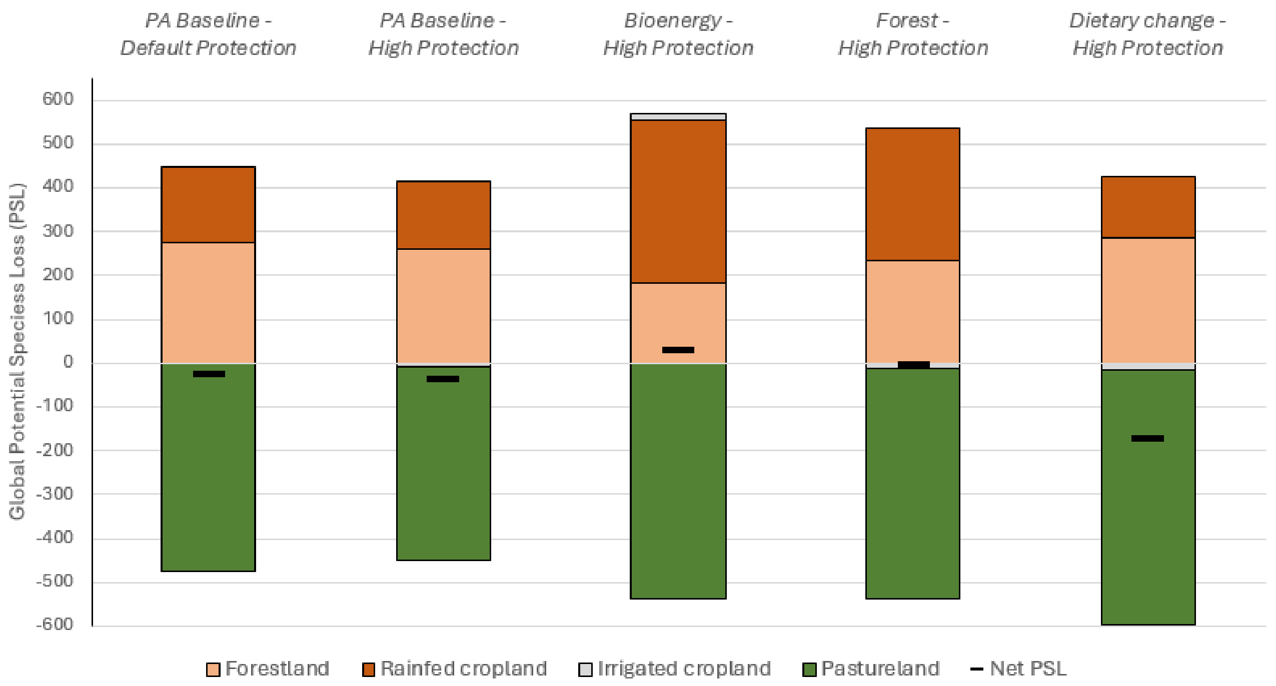
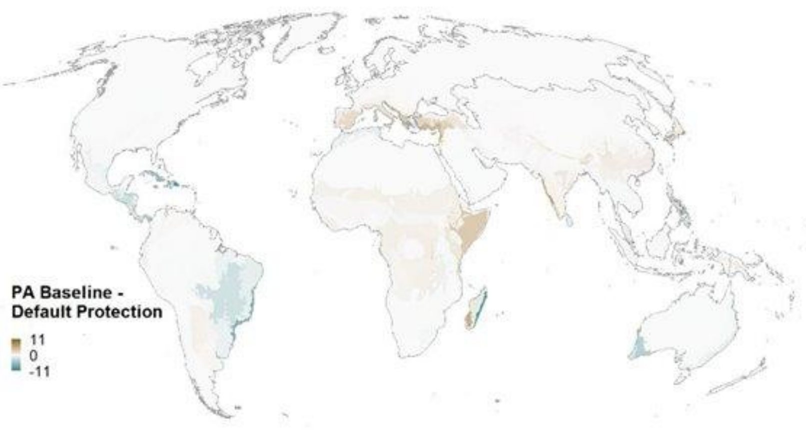
Results / Biodiversity impacts



REFERENCE Potential Species Loss

in *PA Baseline – Default Protection*



- Increased land protection in baselines reduces PSL by **39%** due to lower land conversion
- Rainfed cropland for bioenergy has maximum PSL across scenario
- Forestland expansion second main driver of biodiversity loss
- Reductions in pastureland due to abandonment or conversion allow for biodiversity gains
- Higher impacts in hotspot regions

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Results / Sustainability impacts

Scenario	Land protection	Food price index (2020=100)			Fertilizer consumption increase	Crop water demand increase
		Non-Staples	Staples	Meat and dairy		
2020		100	100	100	141	10,546
Paris Baseline	Default	169	155	238	172 (+22%)	15,848 (+50%)
	High	169	155	238	172 (+22%)	15,843 (+50%)
Forests	High	181	171	256	174 (+23%)	16,406 (+56%)
Bioenergy	High	158	147	215	183 (+30%)	17,193 (+63%)
Dietary change	High	148	148	222	170 (+21%)	15,589 (+48%)

- In *Forests*, Forestland expansion and reduced land available for crops, leading to a **7-10%** increase in food prices
- The increased bioenergy crop plantations in *Bioenergy* drive fertilizer and water consumption in 2050 by more than **6%** and **8%** respectively

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Discussion & Conclusion /

Trade-offs → Land-based mitigation strategies based on bioenergy or forestland expansion might offset biodiversity gains derived from the increased land protection

Synergies → Dietary changes coupled with increased land protection measures show the highest potential for species conservation

Priority areas → The hotspot areas identified would require further attention for the prioritisation of land protection and the design of land-based mitigation

Limitations → Limited set of drivers of biodiversity loss and ecological processes; Limited to one biodiversity metric; *High Protection* levels applied at first year of simulation

- **Integrated policies** need to target climate goals while ensuring ecological integrity
- Novel **modelling capacities and collaborations** across disciplines should be developed
- Nuanced, **evidence-based policymaking** addressing climate change and biodiversity loss is required

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Thank you!

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Two different land protection levels are assumed across the Baseline scenarios

- *Default Protection* assumes current levels of land protection (9.4% global land cover explicitly protected);

- *High Protection* relies on an expansion of the explicitly protected land area (38.6% of global land cover) sufficient to safeguard biodiversity hotpots (Allan et al., 2022)

Scenario	Explicitly protected land		Unsuitable unprotected land	Total protected land	Land available for conversion
Default Protection	**9.4%**		34.2%	43.6%	56.4%
	Suitable	Unsuitable			
	5.5%	3.8%			
High Protection	**38.6%**		16%	54.6%	45.6%
	Suitable	Unsuitable			
	16.4%	22.1%			

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Mitigation results across scenarios

Scenario	Land protection	Results in 2050				
		CO_2 reduction vs. 2020	Biomass consumption (EJ)	Renewable energy share of solar and wind	Land share in total CO_2 reduction*	BECCS share in total CO_2 reduction**
Paris Baseline	Default	74.4%	57.6	28.3%	5.2%	9.2%
	High	74.3%	57.6	28.3%	5.1%	9.1%
Forests	High	74.3%	56.9	21.7%	25.9%	8.0%
Bioenergy	High	78.6%	107.0	25.2%	0.6%	14.6%
Dietary change	High	70.5%	55.2	24.3%	6.9%	7.8%

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