Utrecht University

Land Based Mitigation

An Integrated Assessment Models' perspective

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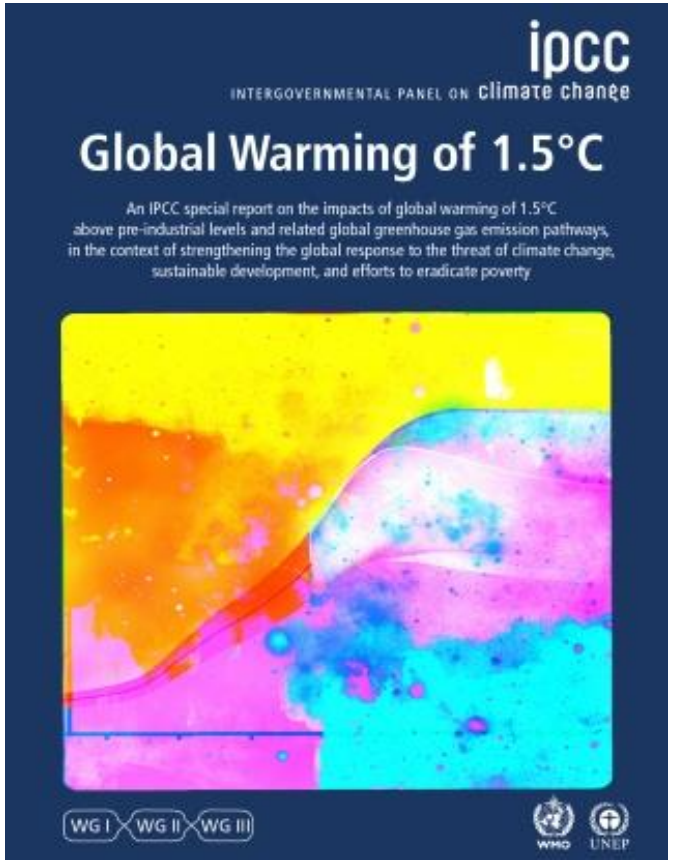
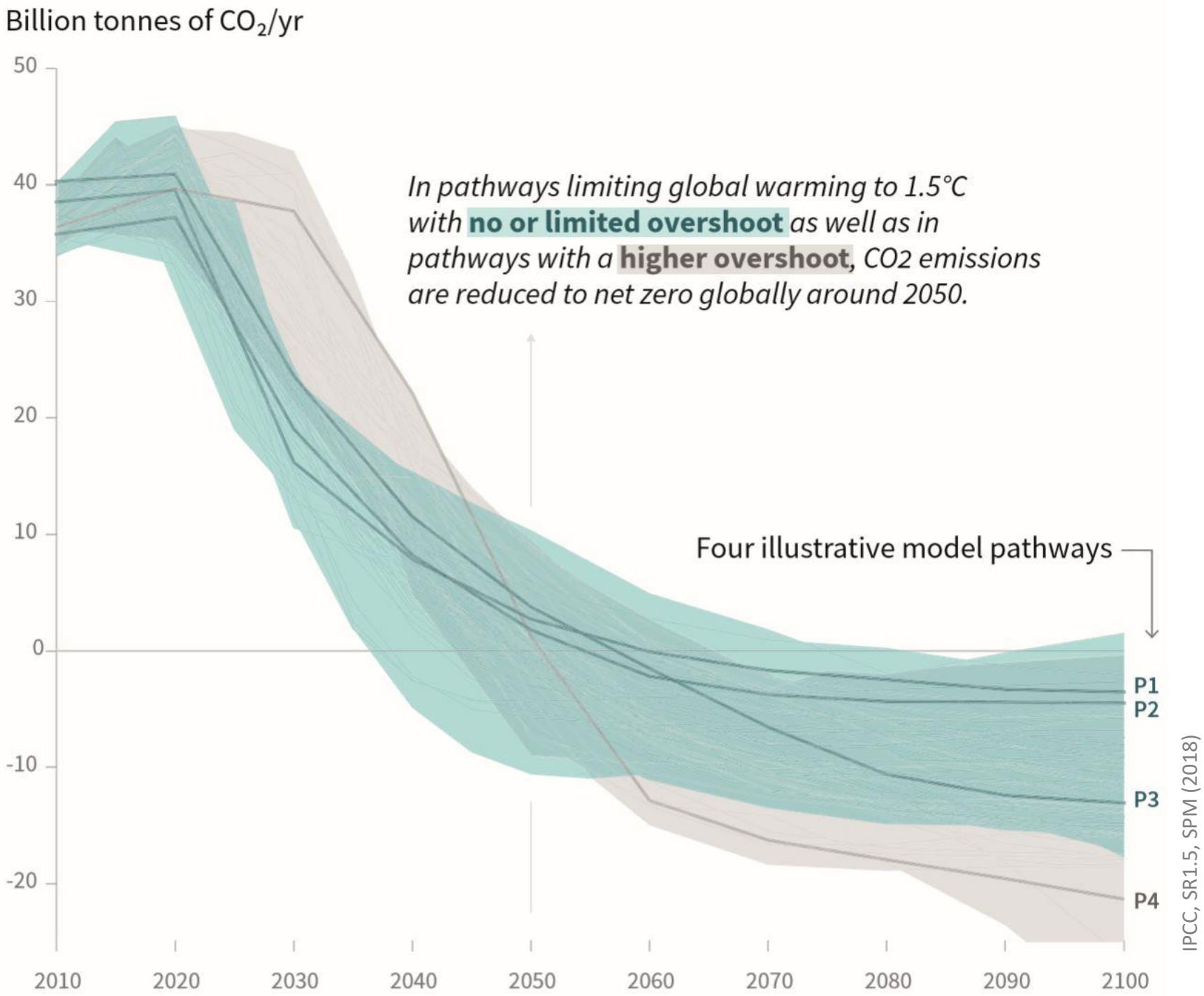
Utrecht University / Netherlands Environmental Assessment Agency

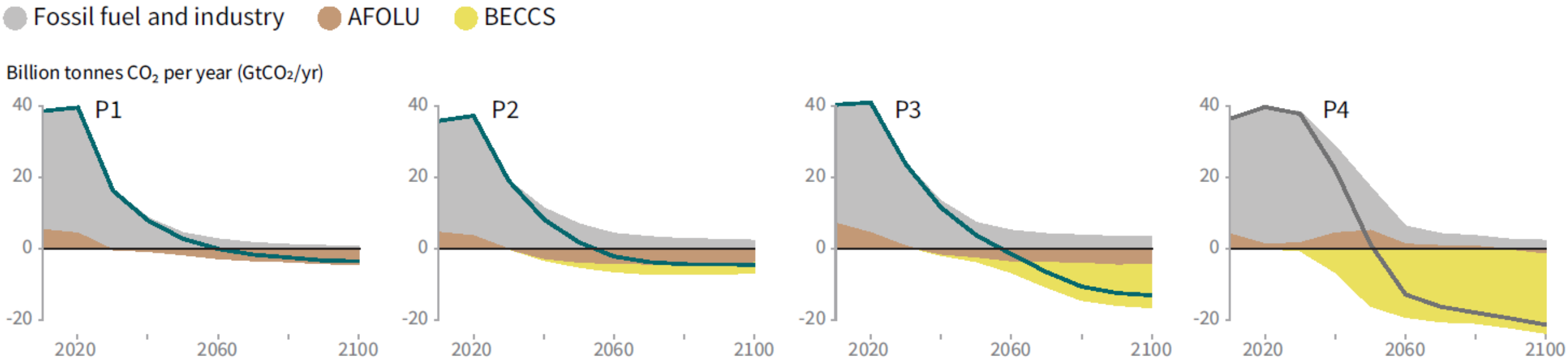
13th May 2020

Context


ipcc
INTERGOVERNMENTAL PANEL ON climate change
Global Warming of 1.5°C
An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty
WG I
WG II
WG III
WMO
UNEP


Billion tonnes of CO_2/yr
50
40
30
20
10
0
-10
-20
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
In pathways limiting global warming to 1.5°C with no or limited overshoot as well as in pathways with a higher overshoot, CO2 emissions are reduced to net zero globally around 2050.
Four illustrative model pathways
P1
P2
P3
P4
IPCC, SR1.5, SPM (2018)

Context



IPCC, SR1.5, SPM (2018)

All pathways depend, to varying extents, on Carbon Dioxide Removal (CDR) from AFOLU and/or BECCS

IAM Overview

- Assess interactions between human and natural systems
- i.e. economic and biophysical relationships and feedbacks

IAM Overview

Drivers

Population, economy, demographics, technological development, behaviour, etc.

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IAM Overview

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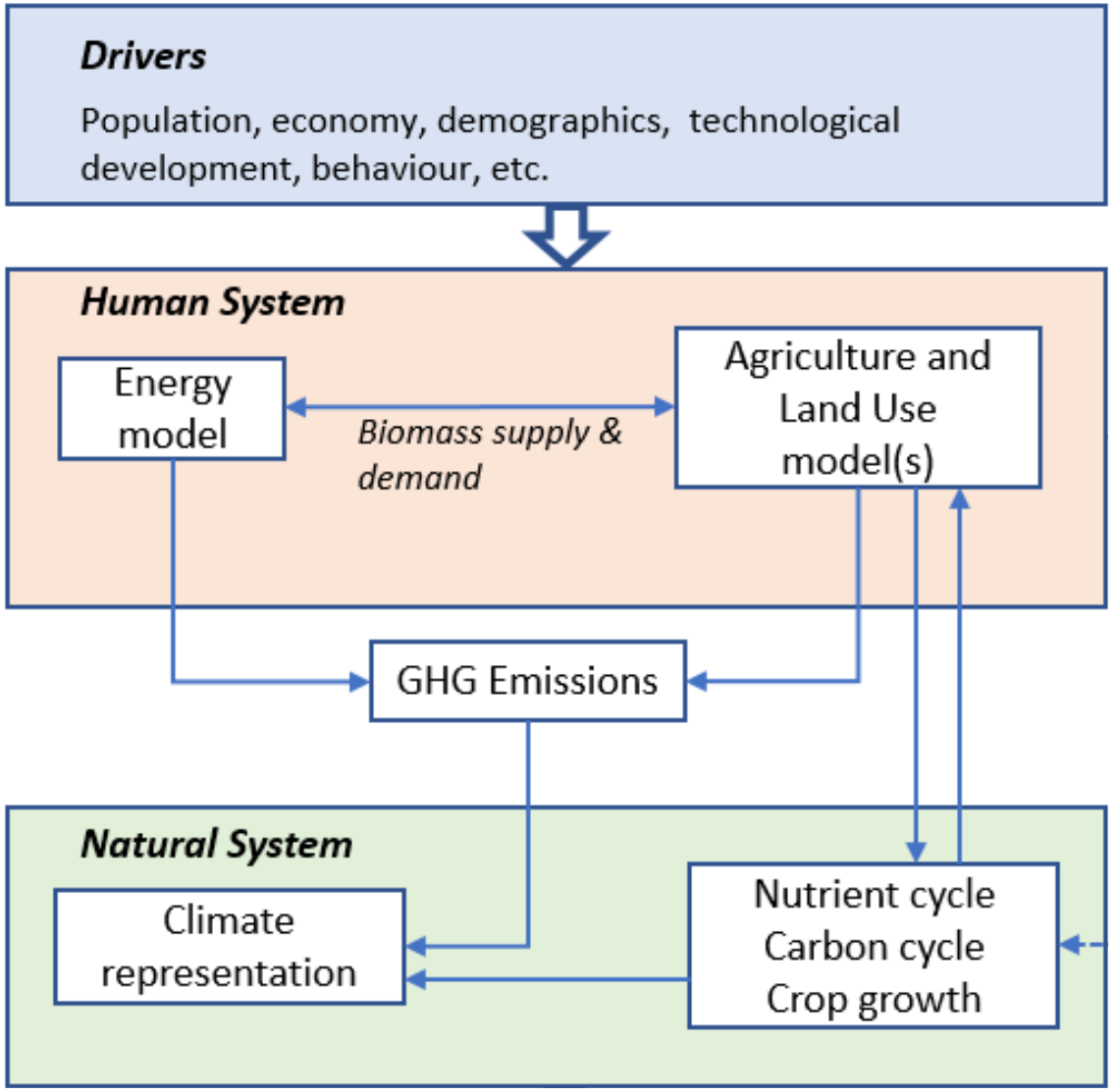
- Contain stylized representations of
  - The energy system
  - Agricultural economy
  - Climate
  - Land system



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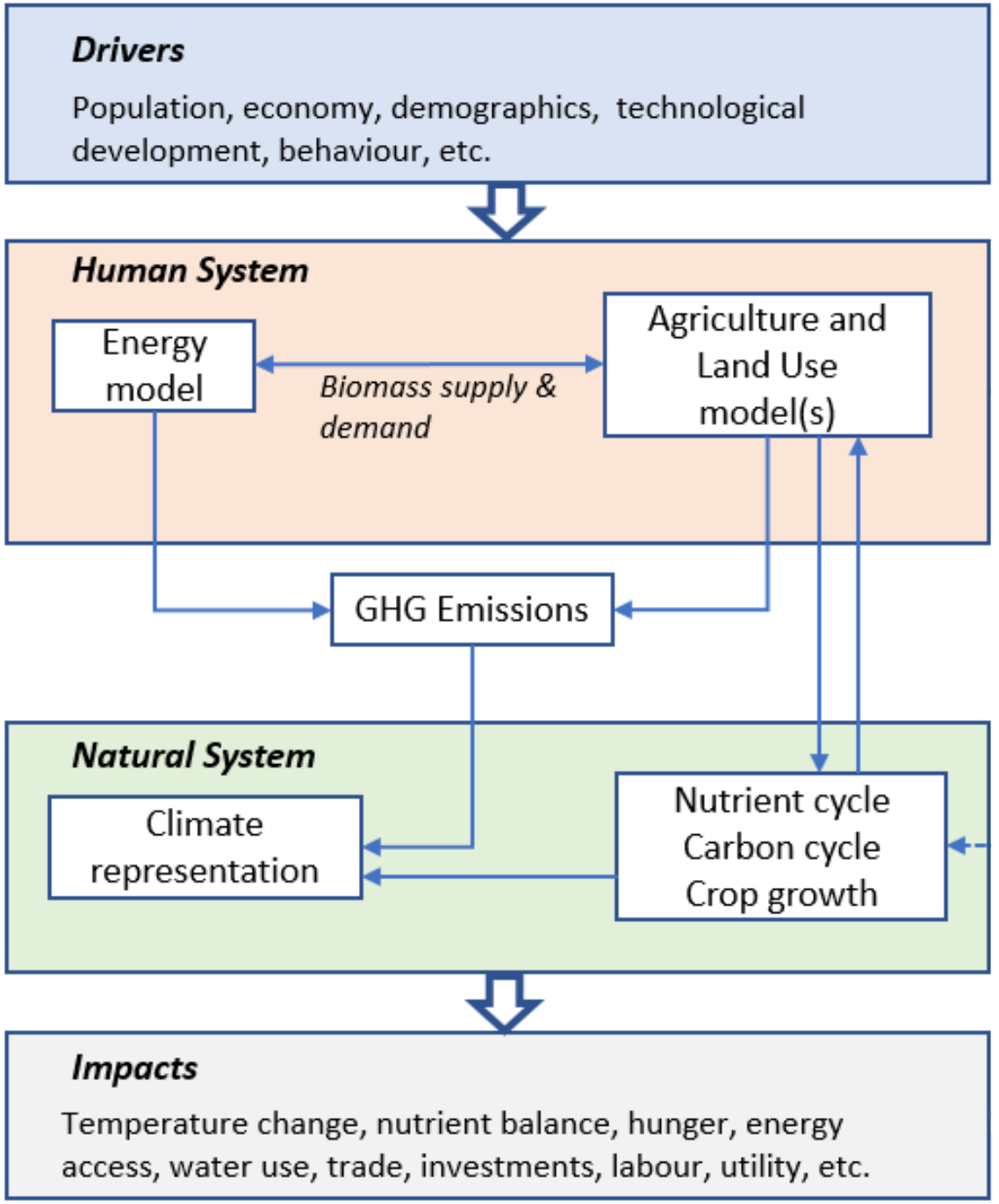
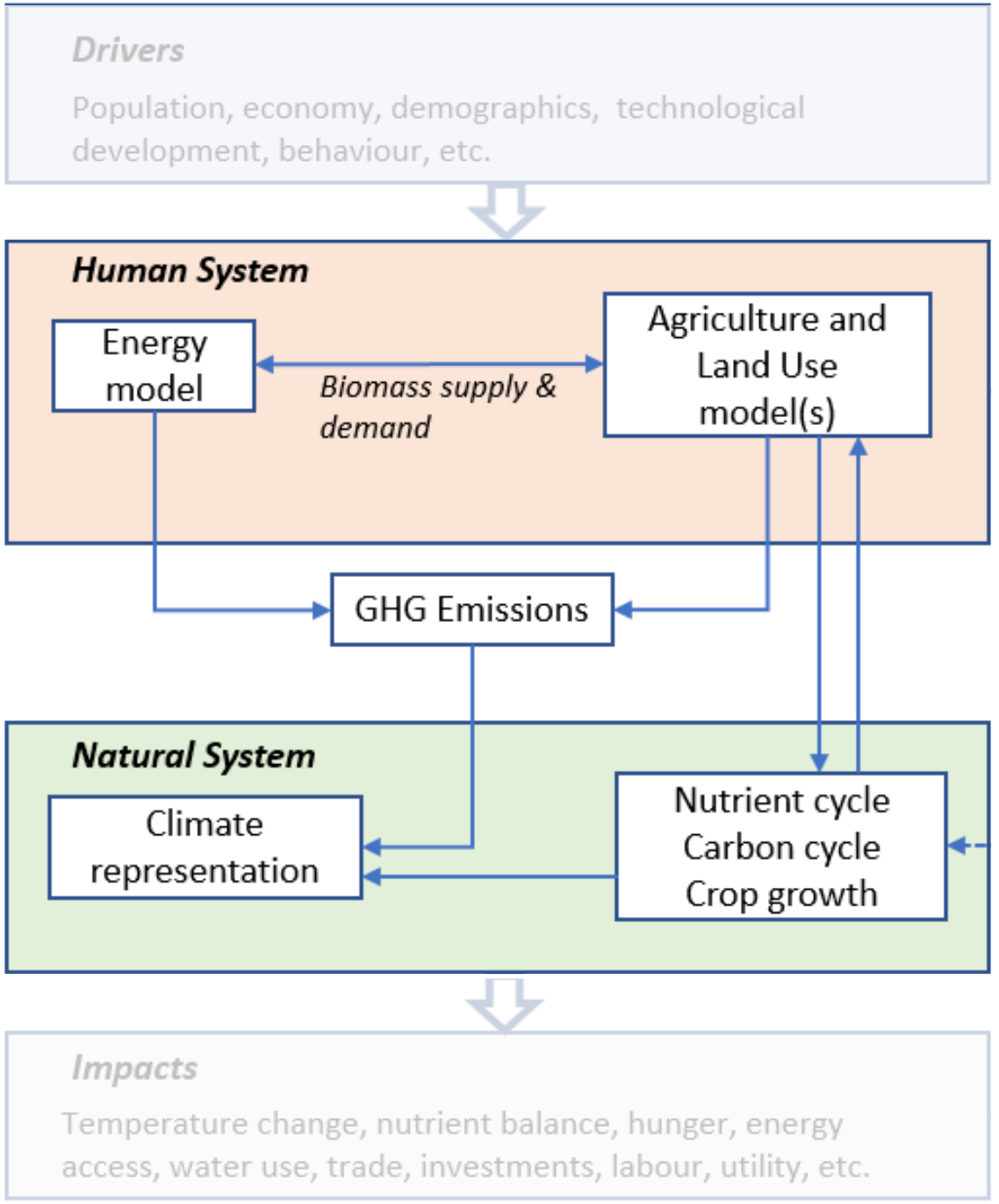


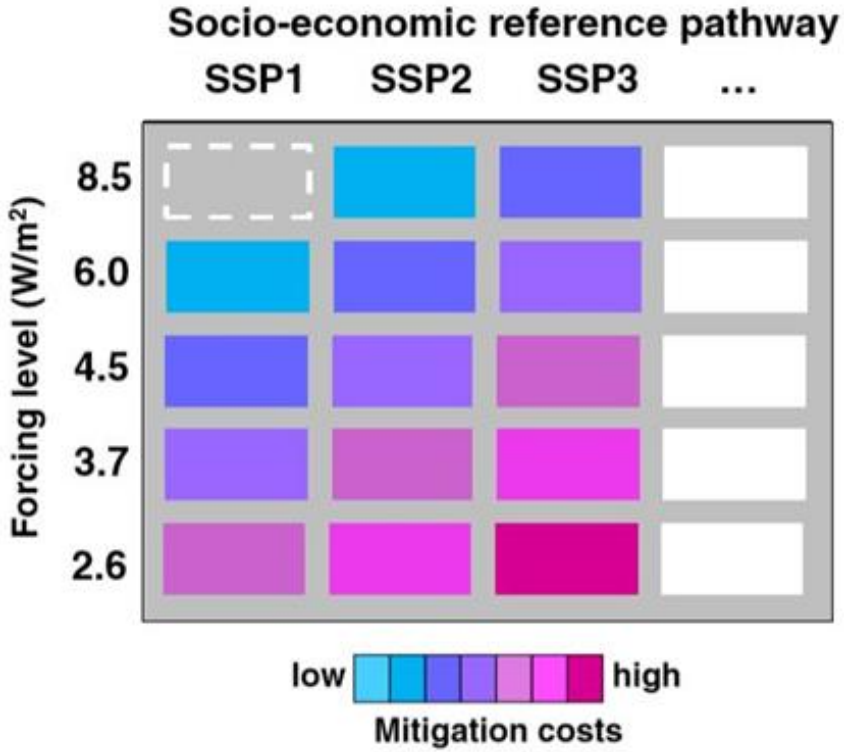
IAM Overview

- Assess interactions between human and natural systems
- i.e. economic and biophysical relationships and feedbacks
- Contain stylized representations of
  - The energy system
  - Agricultural economy
  - Climate
  - Land system
- Key aspects
  - Optimization vs. Simulation
  - Biophysical representation: *Dynamic Global Vegetation Models, General Circulation Models*



Scenario Analysis

- IAMs are used to explore different potential futures
  - Socio-economic and technological possibilities (*Shared Socioeconomic Pathways - **SSPs***)
  - Levels of Climate Change (*Representative Concentration Pathways - **RCPs***)
  - Explore the SSP-RCP Matrix



(van Vuuren et al. 2014)

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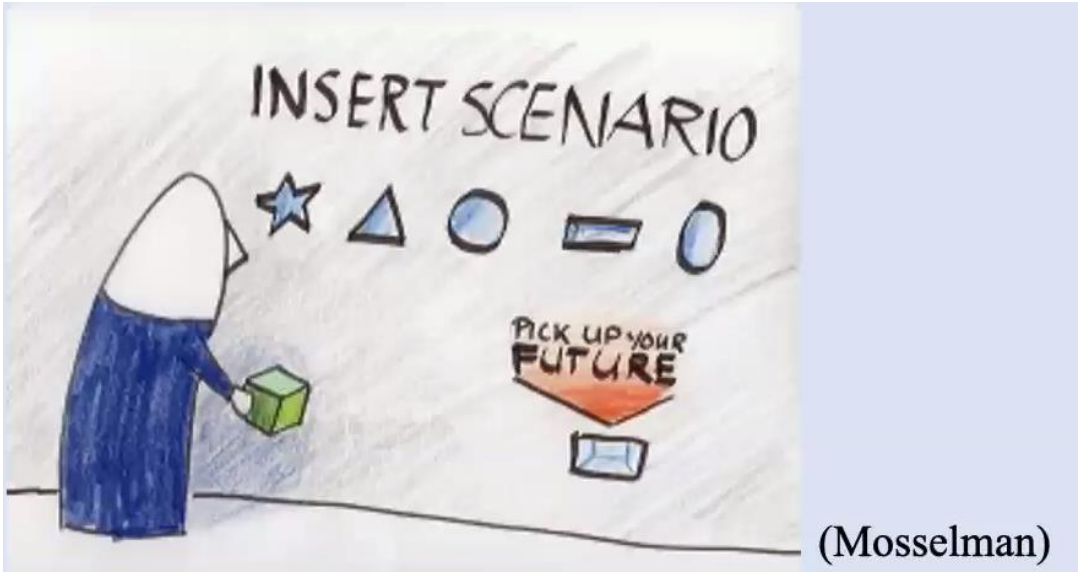
  - Socio-economic and technological possibilities (*Shared Socioeconomic Pathways* - ***SSPs***)
  - Levels of Climate Change (*Representative Concentration Pathways* - ***RCPs***)
- NOT predictions or roadmaps
  - Cannot assign probabilities to them, no *business as usual*
  - Used to **explore** *solution space*, *boundaries*, *synergies*, and *trade-offs*



(Dale Rothman, CCIS webinar, 6th May 2020)

Bioenergy in IAMs

- Typical Resources
    - 1st generation energy crops (maize, sugar, oil-crops)
    - Advanced lignocellulosic (short rotation coppice, perennials)
    - Residues (agriculture, forestry, process, municipal solid waste)
    - Forestry whole logs

Bioenergy in IAMs

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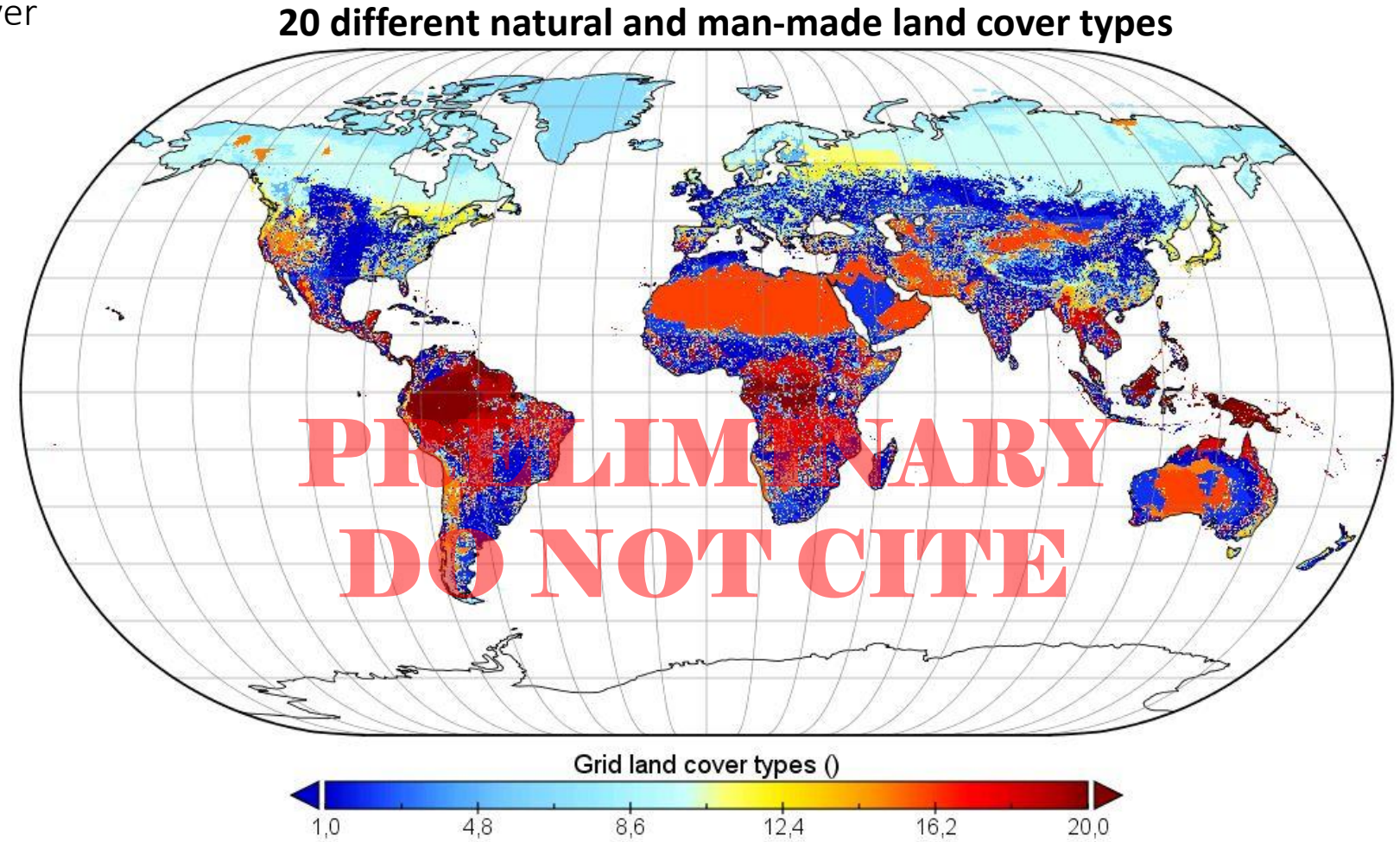
- Interacting drivers of supply
  - Agricultural/forestry production → **Competition for land (-), residue generation (+)**
  - Land availability / productivity → **Location-specific, climate conditions**
  - Prices → **Especially models that have an "economic equilibrium" setup, yield elasticity**
  - **Scenario Specific!**

Bioenergy in IAMs

- Spatial heterogeneity is included using scenario and DGVMs projections
  - Natural and human land cover



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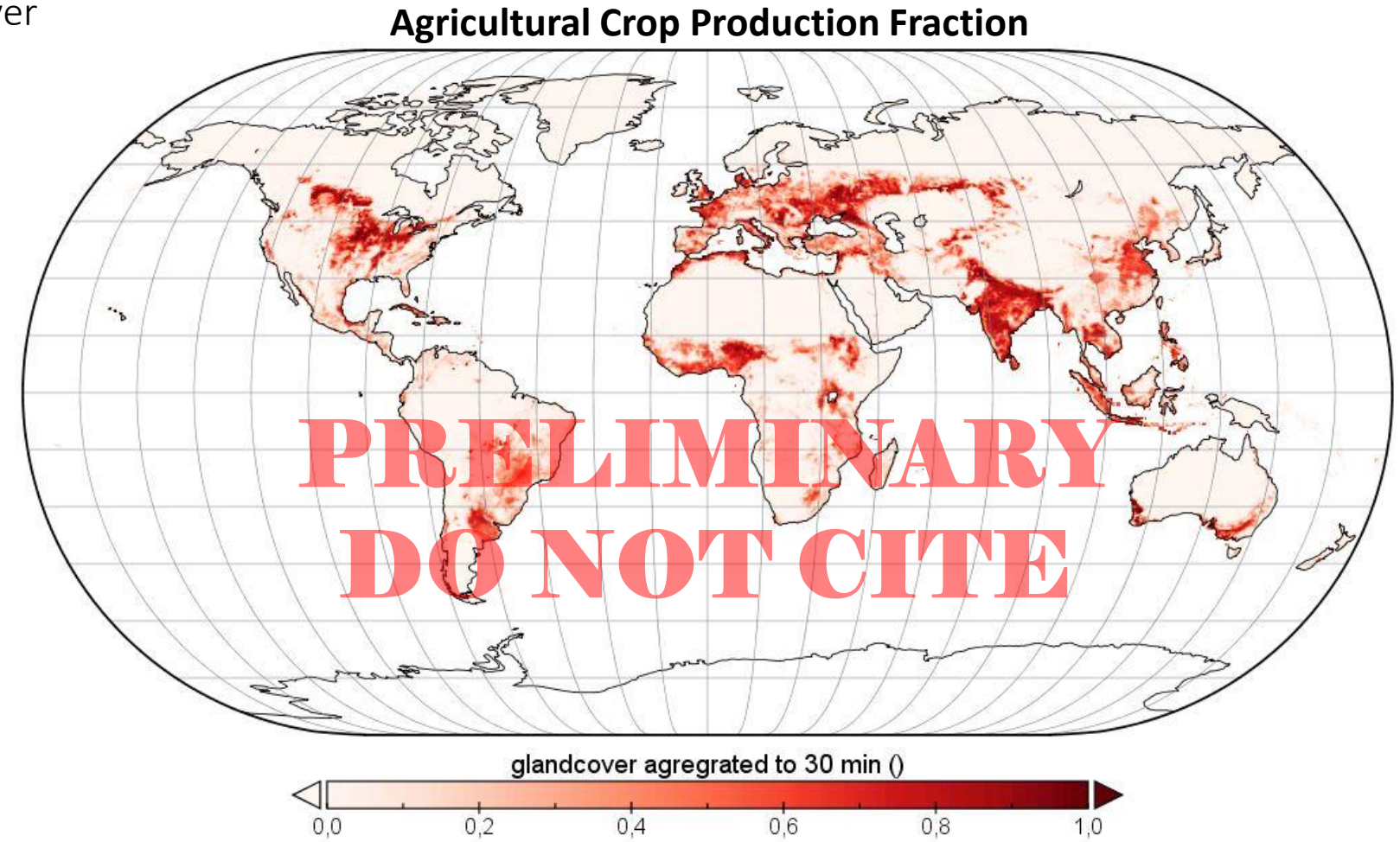

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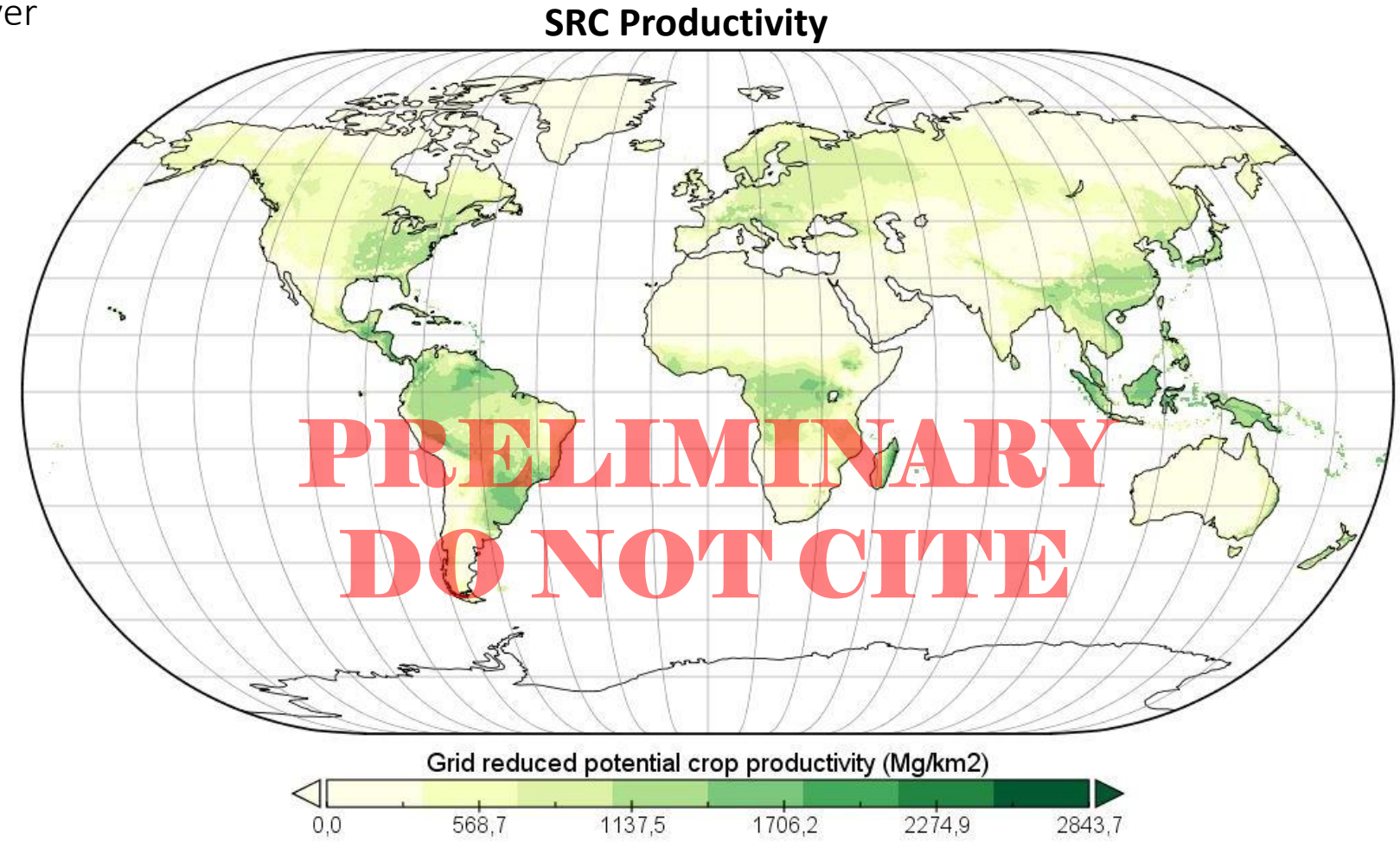

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  - Biomass carbon consequences

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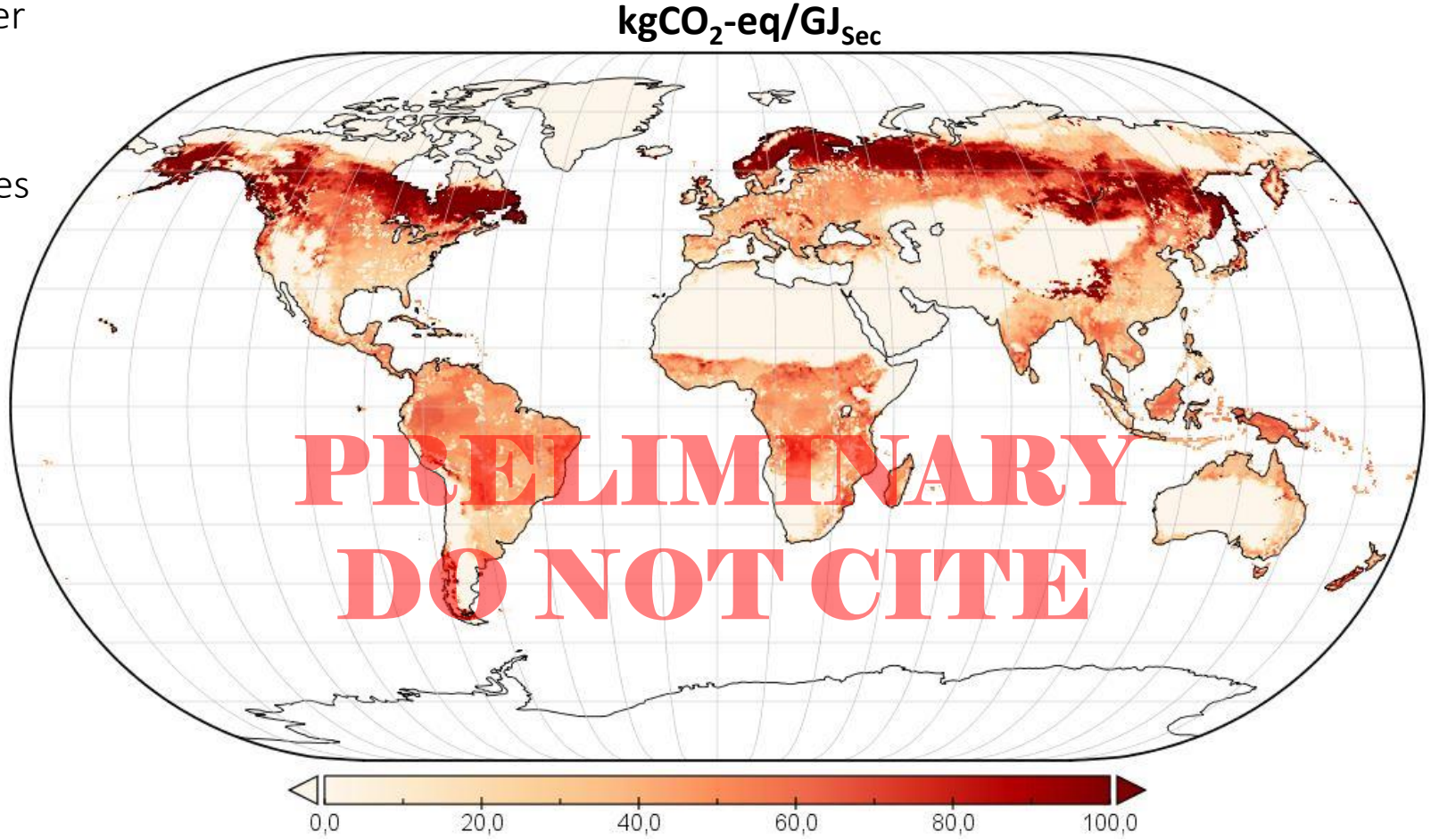

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  - Land available for biomass

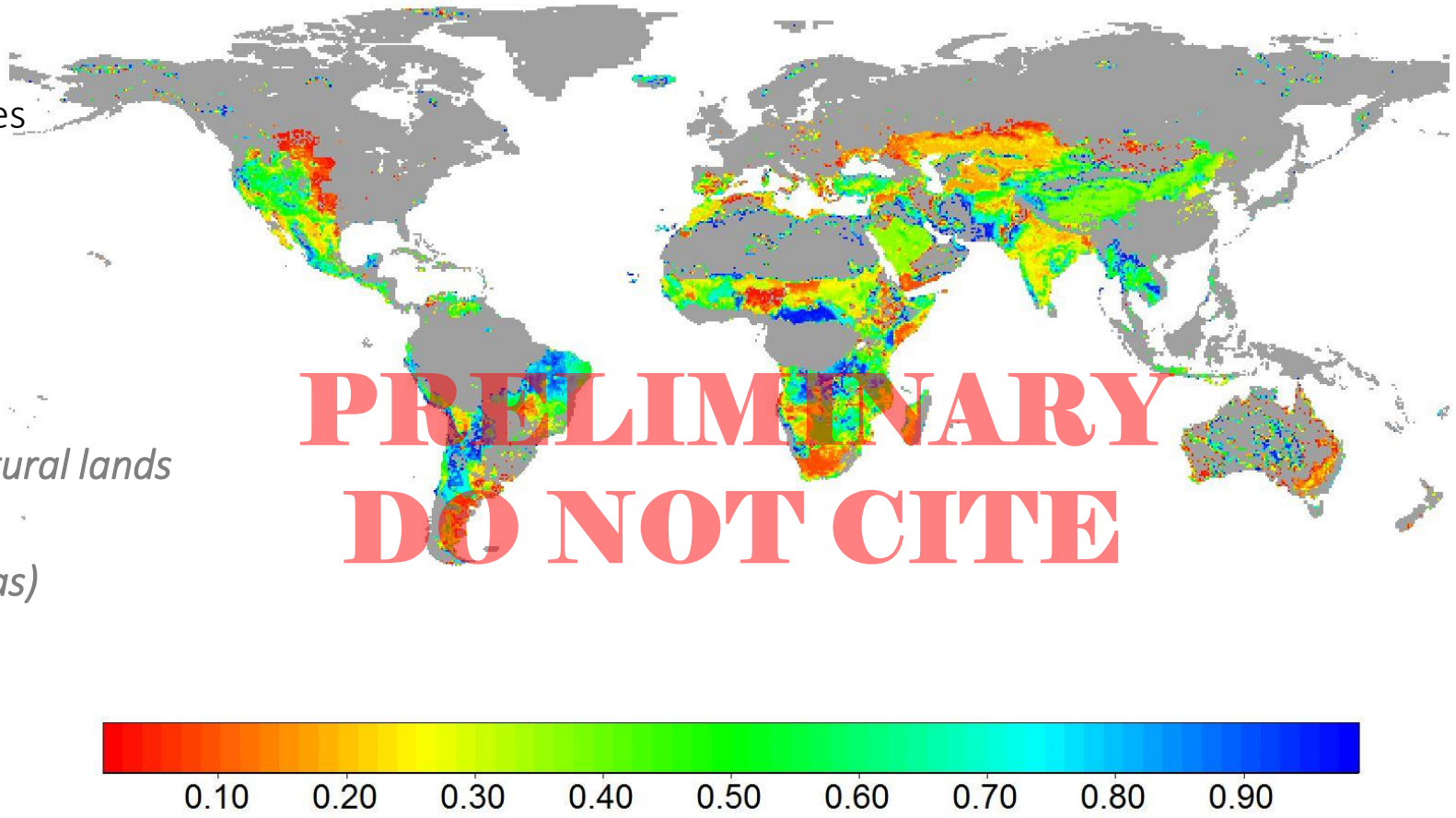
  In IMAGE:

  → *Food first principle*

  → *Include abandoned agricultural lands*

  → *Environmental restrictions (forests, water stressed areas)*

Fraction of grid cell available for bioenergy



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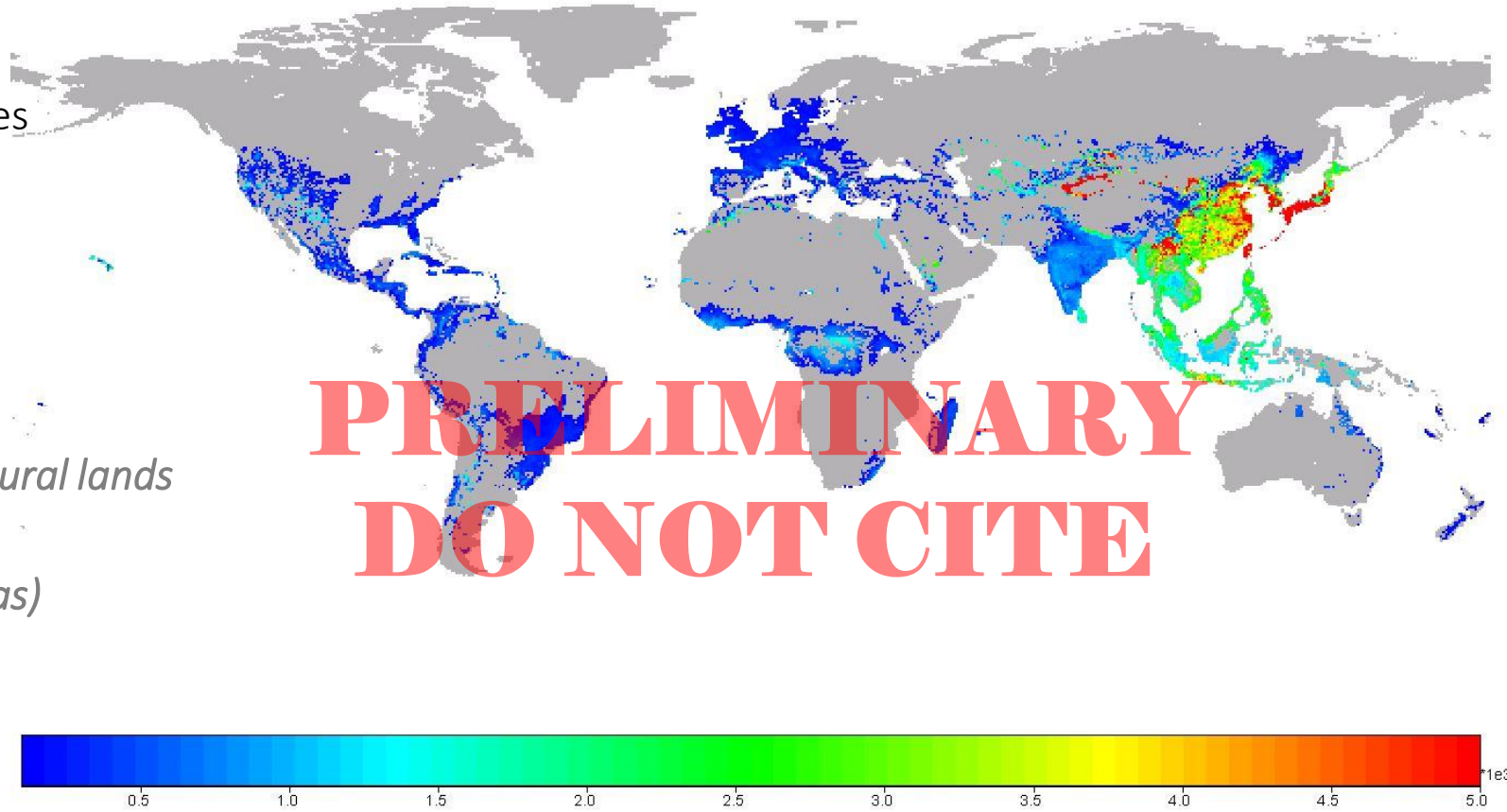
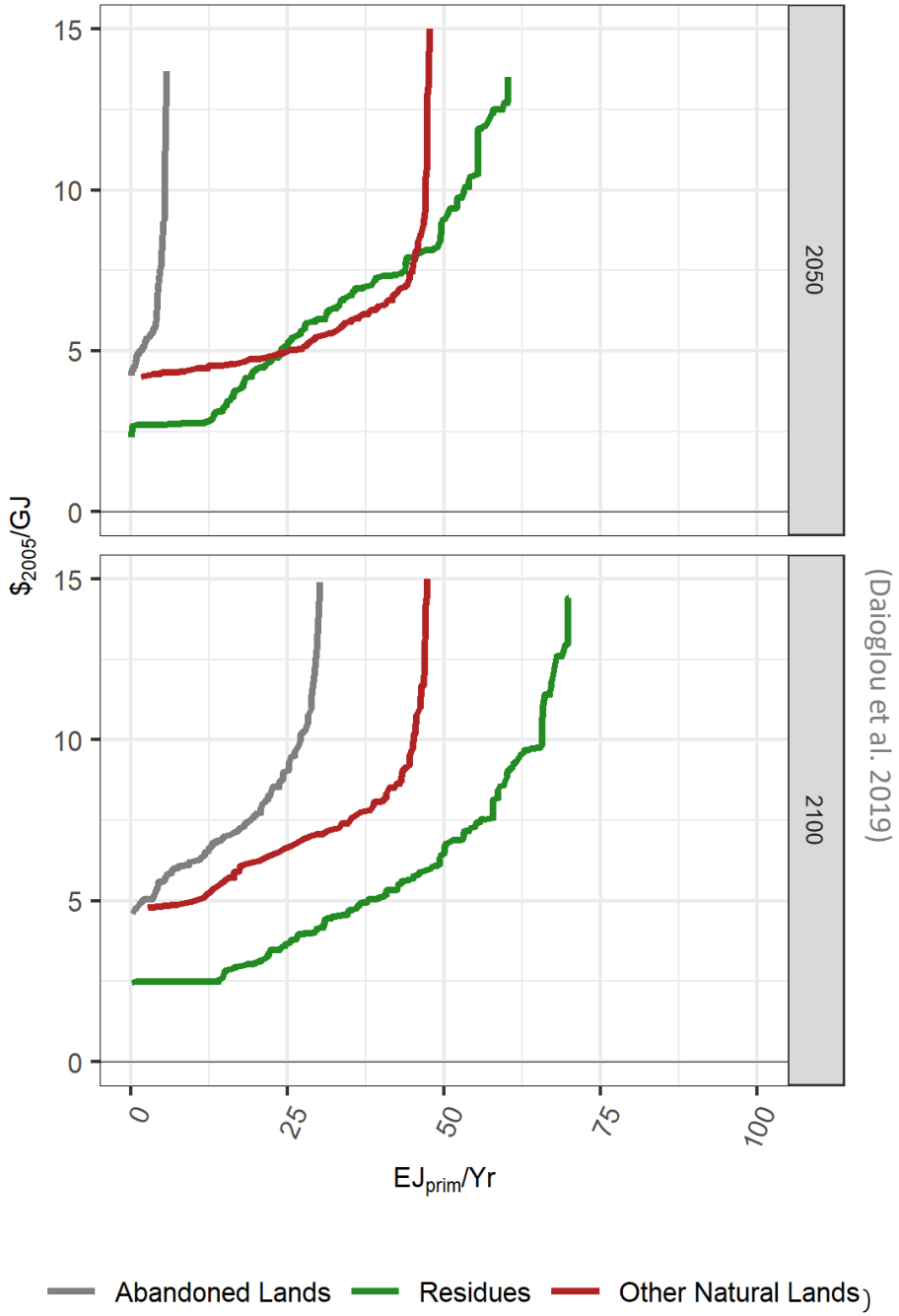
  - Residue availability and cost

Residue Avalability



Bioenergy in IAMs

- Aggregated for use in regional energy model
    - Cost-supply curves



Bioenergy in IAMs

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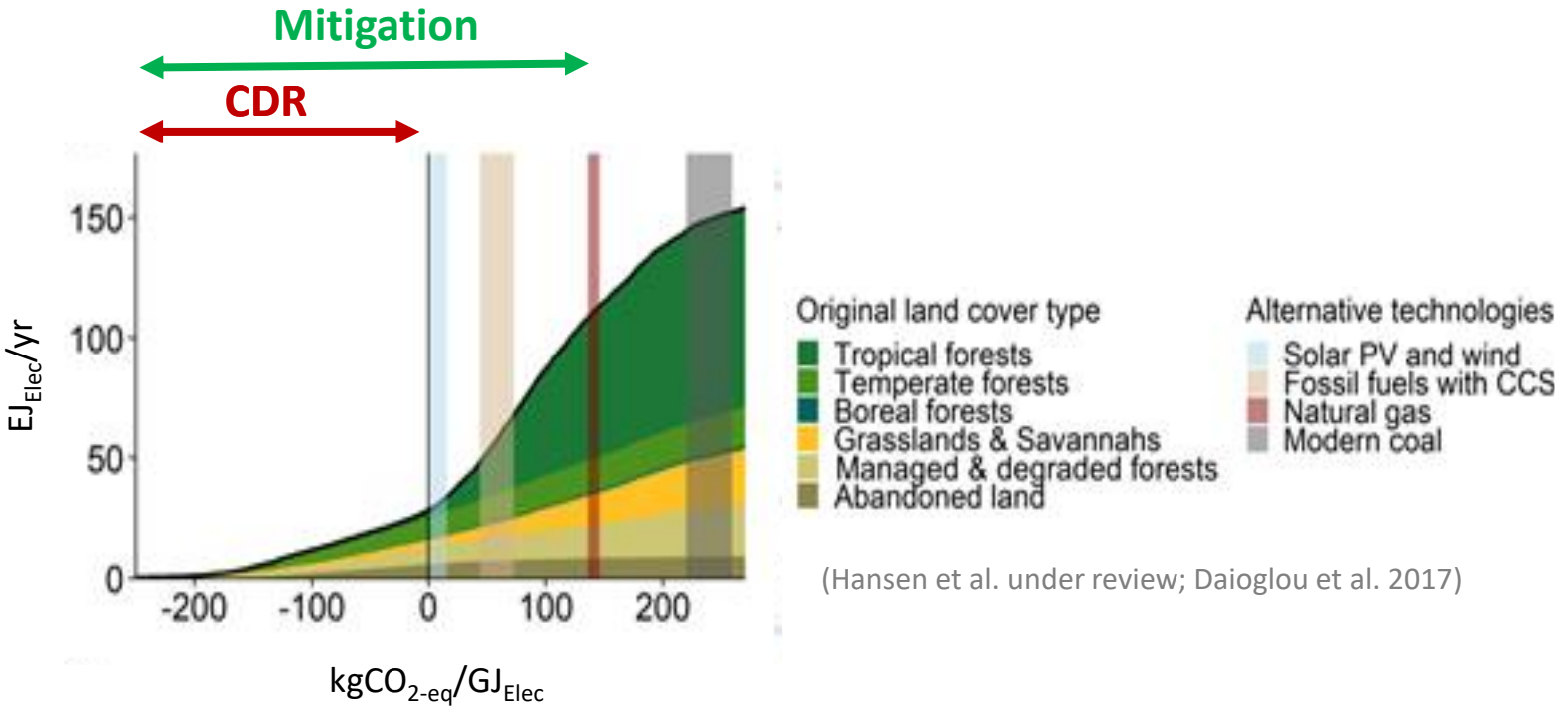
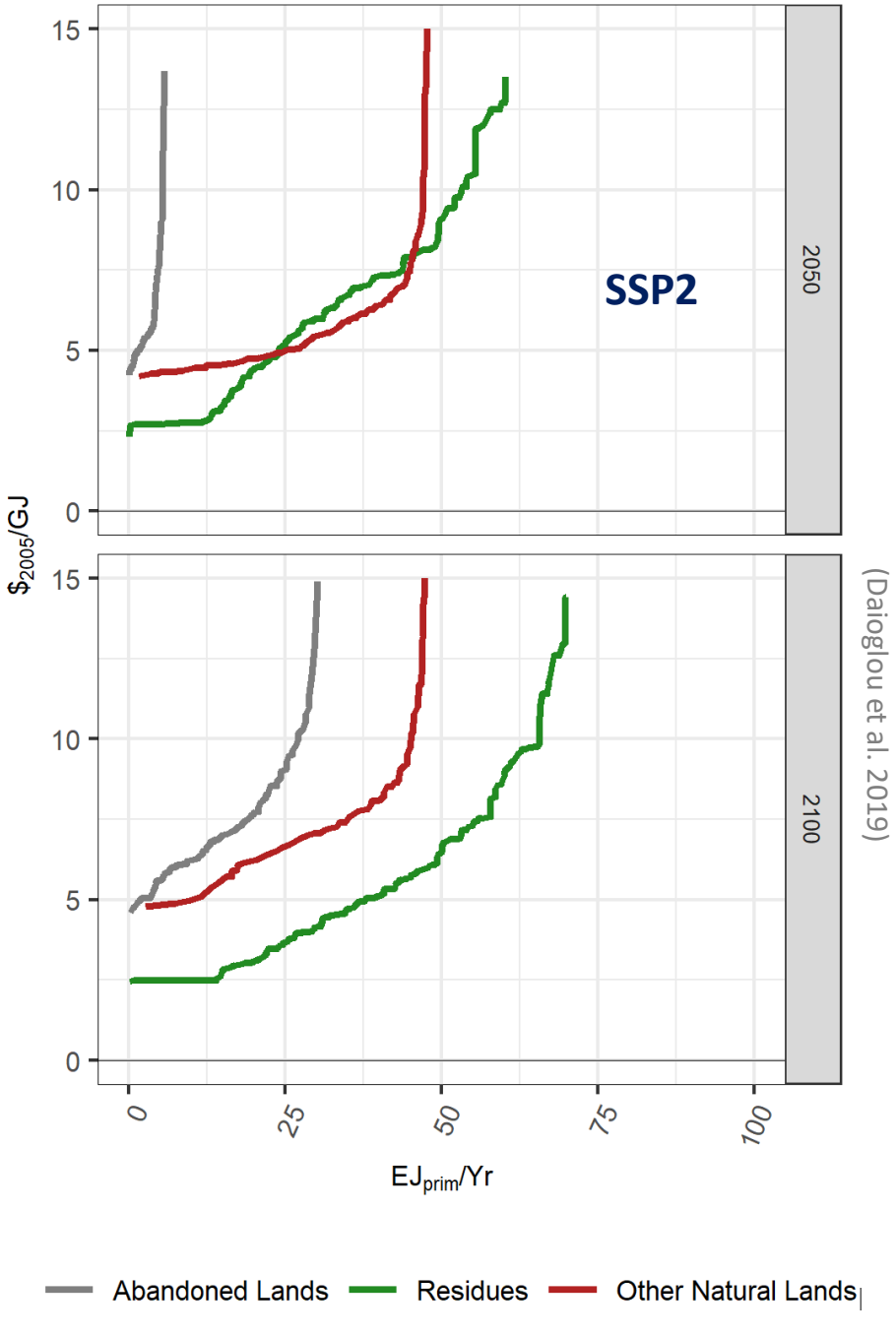
  - Emission-supply curves



(Hansen et al. under review; Daioglou et al. 2017)



(Daioglou et al. 2019)

Afforestation / Reforestation in IAMs

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IAMs achieve CDR using forests via

- Reduced deforestation/degradation
- Reforestation
- Afforestation

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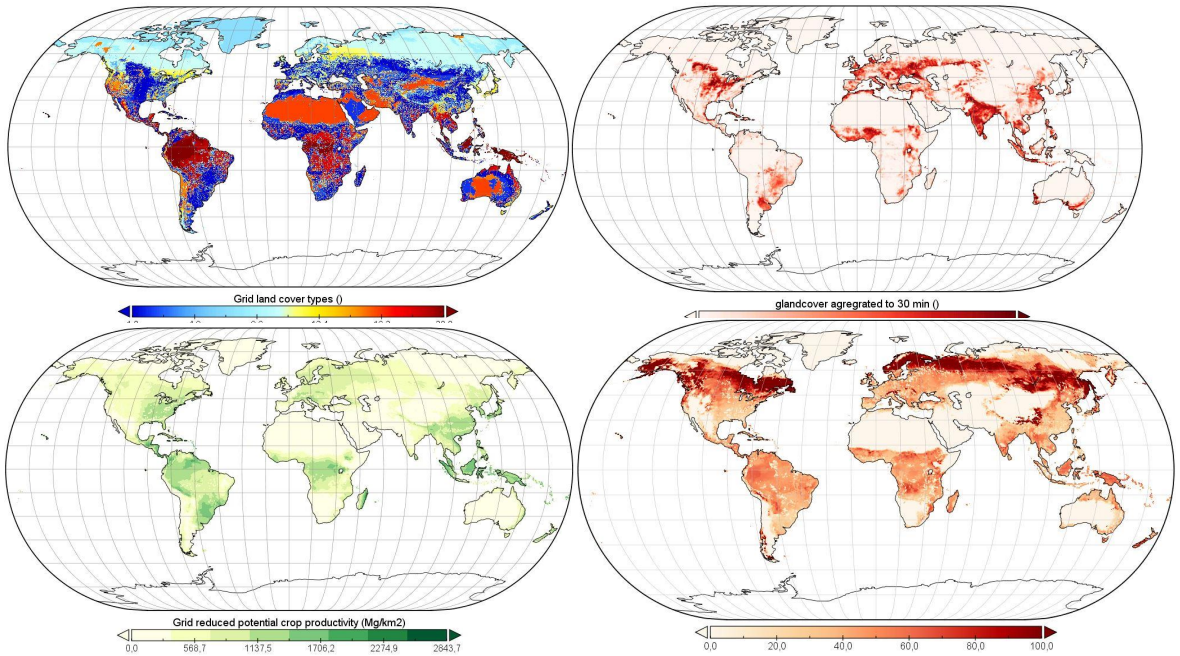
Potentials based on

- Spatially explicit productivity and carbon uptake → **Internally consistent carbon accounting**
- Competing land uses (agriculture, pasture, bioenergy) → **Scenario-specific**

Recall



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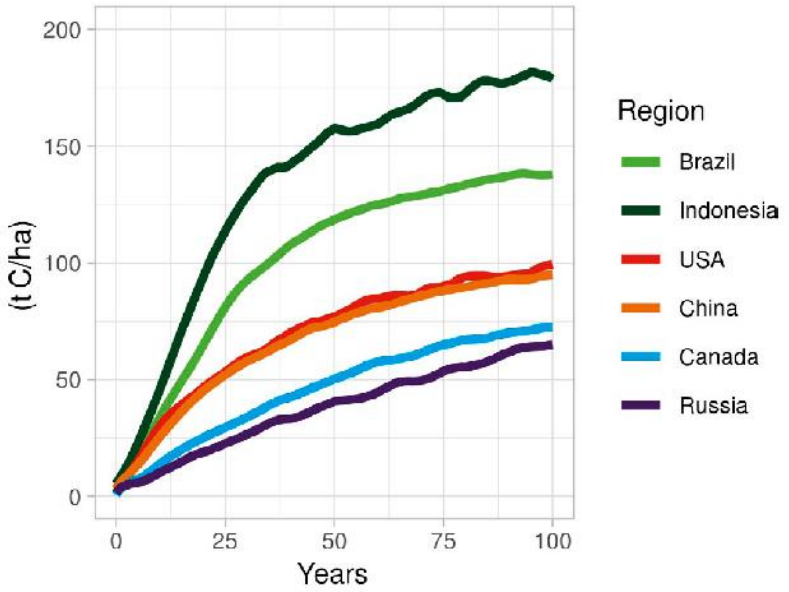
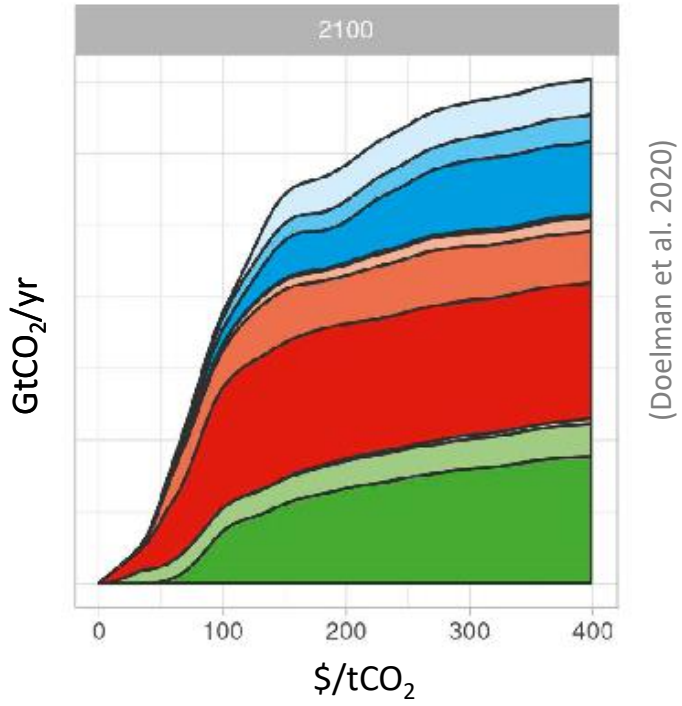
- Long term CDR saturation due to forest maturity





(Doelman et al. 2020)

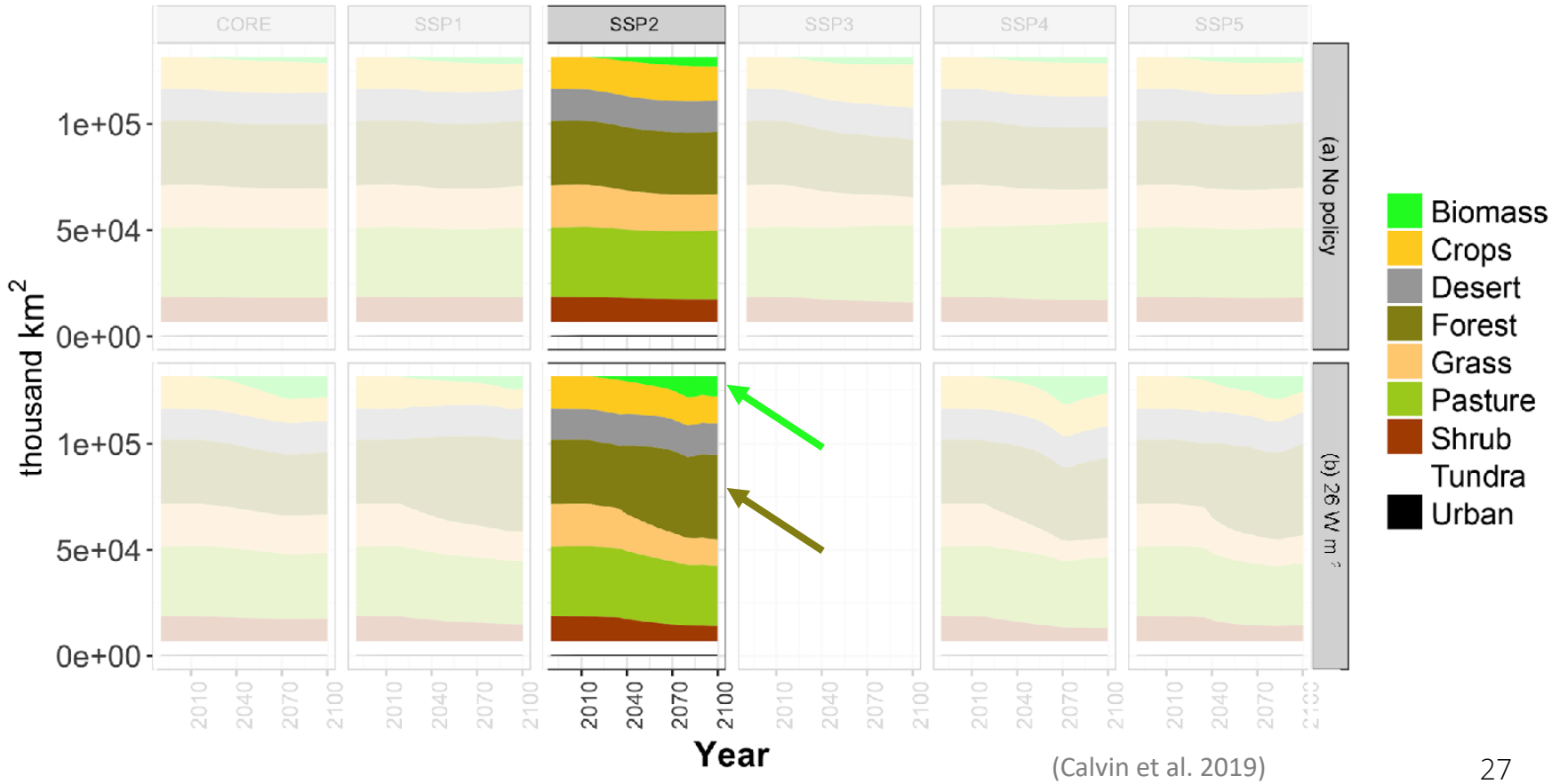
Integrated Scenarios

Competition between land-use options (A/reforestation/bioenergy/food/etc.)

- Economic optimization/equilibrium → **Direct Competition based on profitability (incl. carbon credits)**
- Rule based approach → **Land is set aside a-priori for certain functions (i.e. *food first)***
- Hybrid

Integrated Scenarios

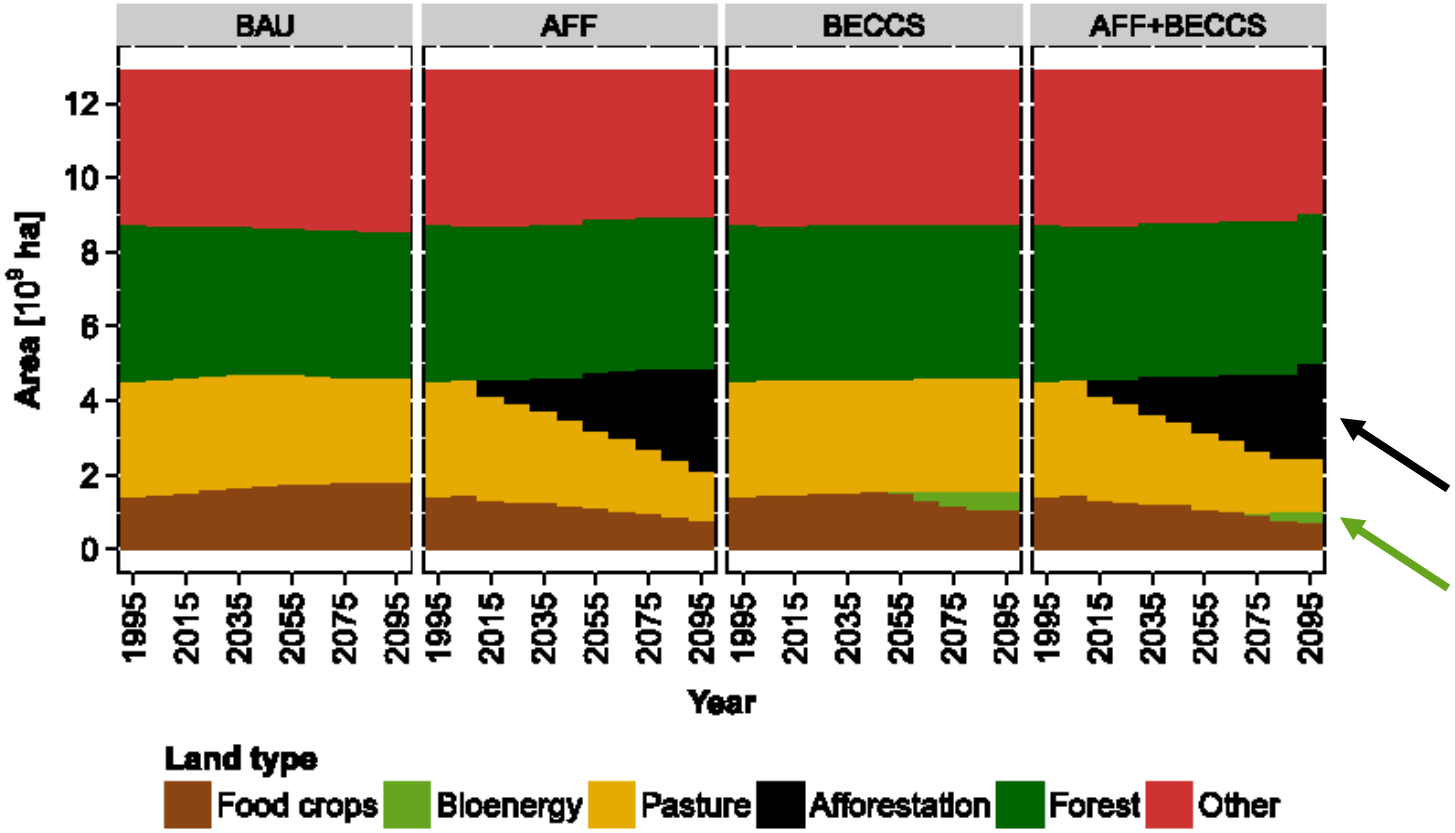
- GCAM
  - Method: Logit competition between all land uses
  - Higher Afforestation area



(Calvin et al. 2019)

Integrated Scenarios

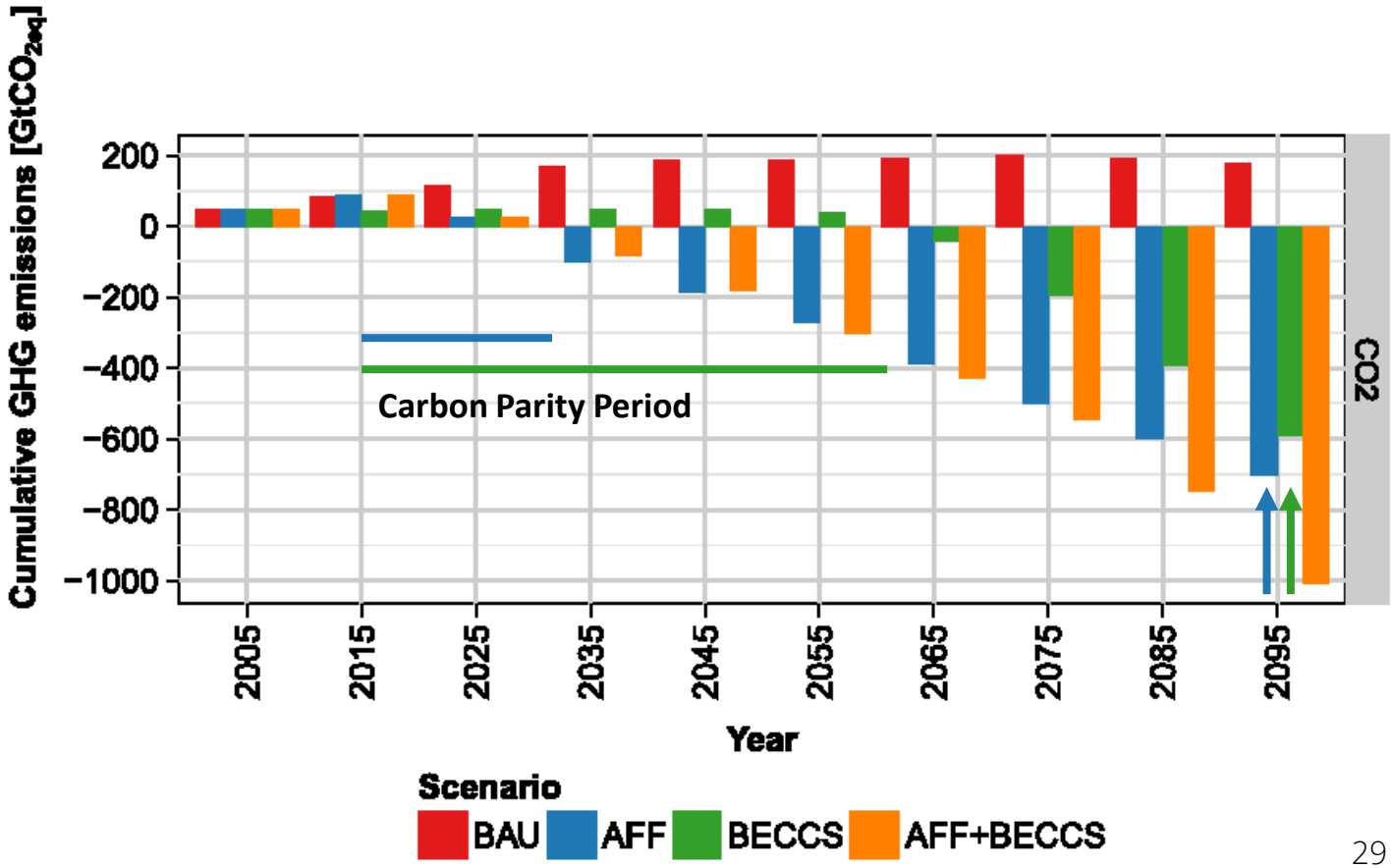
- REMIND-MAgPIE
  - Method: Recursive dynamic optimization across all uses
  - Competition between AFF and BECCS scenarios
  - Much larger Afforestation area



(Humpenöder et al. 2014)

Integrated Scenarios

- REMIND-MAgPIE
  - Method: Recursive dynamic optimization across all uses
  - Note: emission trajectory
  - Compare mitigation with
    with afforestation/BECCS area



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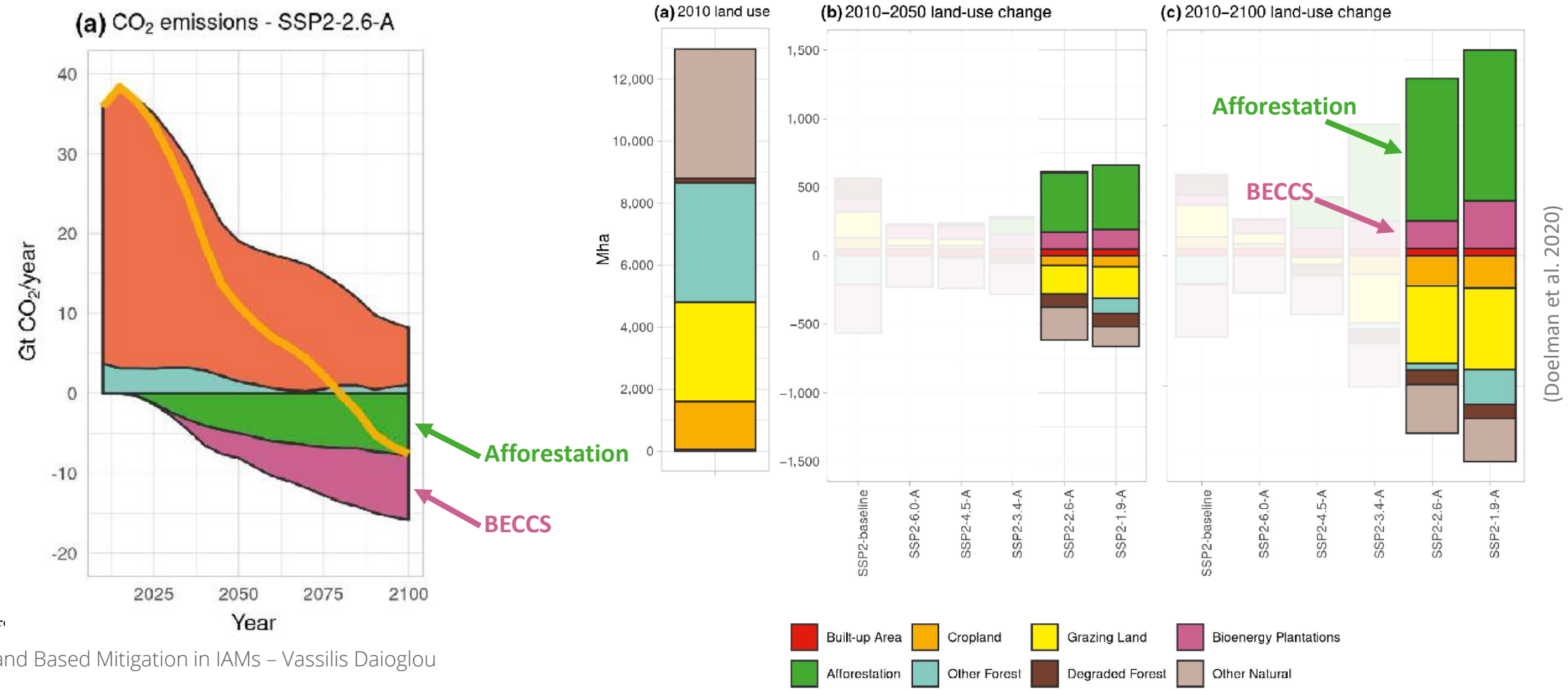
Integrated Scenarios

- IMAGE
  - Method: Hybrid (limited economic equilibrium for a/reforestation, rules based for bioenergy)



(Doelman et al. 2020)

Integrated Scenarios

IAMs select both Bioenergy and Forest based CDR

- Bioenergy
  - Bioenergy is attractive to balance the energy system
  - BECCS has a climate benefit, but (some) bioenergy would still be attractive even with no BECCS
- Forest-based CDR
  - Forest based CDR is attractive due to low costs
  - Limited long term CDR due to saturation
- Timing
  - Forest based CDR comes in early → *Cheap, no tech. development needed*
  - Most BECCS comes in post-2050 → *Forest saturation + energy mitigation costs increase + tech. development*
  - If you want large scale BECCS (i.e. P3/P4 in SR15 SPM), BECCS should come in early due to emission profile
- Efficiency
  - Mitigation per Ha is much greater for BECCS → *Stocks vs. flows*

Limitations and Current Areas of Research

- Management and production types
    - Both bioenergy and a/reforestation are based on monocultures
    - Advanced and integrated systems have not been implemented in the models

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  - Impacts on biodiversity, water, etc.
  - Climate – Land – Energy – Water Nexus
  - Climate impacts on yields, productivity, seasonality, risks

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- Research areas
  - Regional targets & strategies vs. global goals
  - Other BECCU and the *circular bioeconomy*

Utrecht University

Thank you

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@vassican @IMAGE_PBL

Further Reading:

Bauer, N. et al (2018), Global energy sector emission reduction and bioenergy use: overview of the bioenergy demand phase of the EMF-33 model comparison, Climatic Change, pp. 16

Calvin, K. et al. (2019), GCAM v5. 1: representing the linkages between energy, water, land, climate, and economic systems, *Geoscientific Model Development* (Online) 12.PNNL-SA-137098

Daioglou, V. et al (2019), Integrated assessment of biomass supply and demand in climate change mitigation scenarios, *Global Environmental Change (52),* 88-101

Daioglou, V. et al (2017), Greenhouse gas emission curves for advanced biofuel supply chains, *Nature Climate Change (12),* 920-926

Doelman, J. et al (2020), Afforestation for climate change mitigation: Potentials, risks and trade-offs, *Global Change Biology (26),* 1576–1591

Humpenöder, F. et al (2014), Investigating afforestation and bioenergy CCS as climate change mitigation strategies, *Environmental Research Letters* 9.6