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Global Advanced Bioenergy Potential under Environmental Protection Targets

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AIM ASIA-PACIFIC INTEGRATED MODEL

Asia-Pacific Integrated Model

http://www-iam.nies.go.jp/aim/index.html

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Background

Bioenergy and climate mitigation:

- Stringent climate targets difficult to achieve without negative emissions (Rogelj et al., 2018).
- Bioenergy (dedicated energy crops with CCS) is one of the most discussed negative emission options (Willianmson, 2016).
- IPCC 1.5-degree SR: medium amount of 152 EJ/yr (40-312 EJ/yr).

Environmental concern:

- Plantation of large-scale bioenergy crops puts pressure to terrestrial system (van Vuuren et al., 2013), such as soil quality and biodiversity.
- Currently, more than 75% of the land on Earth is substantially degraded (IPBES, 2018). Intensive farming worsen the situation.
- Expansion of cultivated land area also threats biodiversity, segmentation and loss of habitat (Immerzeel et al., 2014).

Research objectives

Questions:

- How much bioenergy can we produce without causing further land degradation and biodiversity loss?
- What can we do to increase bioenergy potential to supply the amount required for mitigation while protecting the environment?

In specific:

- Technical and economic potential of dedicated bio-crop.
- Geographic distribution of bioenergy potential.

* Technical potential: total quantity without considering production costs;

* Economic potential: production quantity under certain production costs;

* Production cost: input costs and land transition costs.

Environmental protection policies

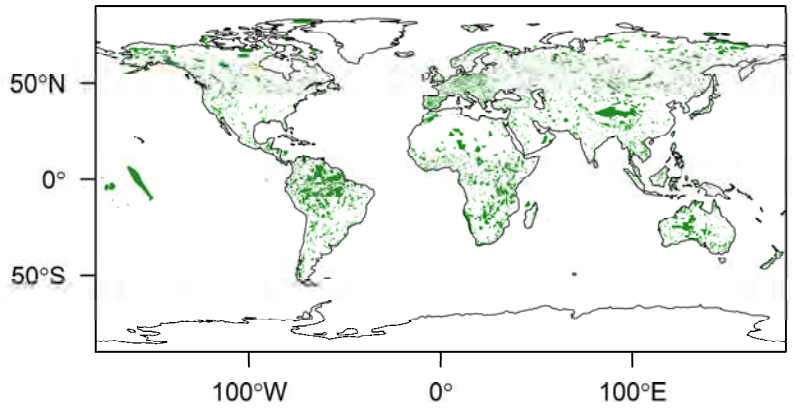
- Soil protection:
  - Moderate: severely degraded land (GLADIS)
  - Enhance: series degraded land (GLADIS)
- Biodiversity protection:
  - Moderate: protected area (WDPA & KBA);
  - Enhanced: protected area + biodiversity sensitive area (index > 0.9 by AIM/Biodiversity).

Implementation:

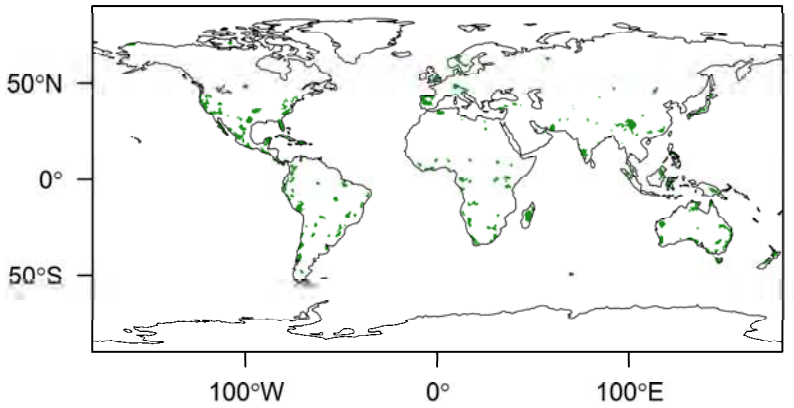
- In soil protection, degraded land was excluded for annual crops and allocated to bioenergy crops only.
- In biodiversity protection implementation, areas were excluded both for annual and bioenergy crops.

Areas protected

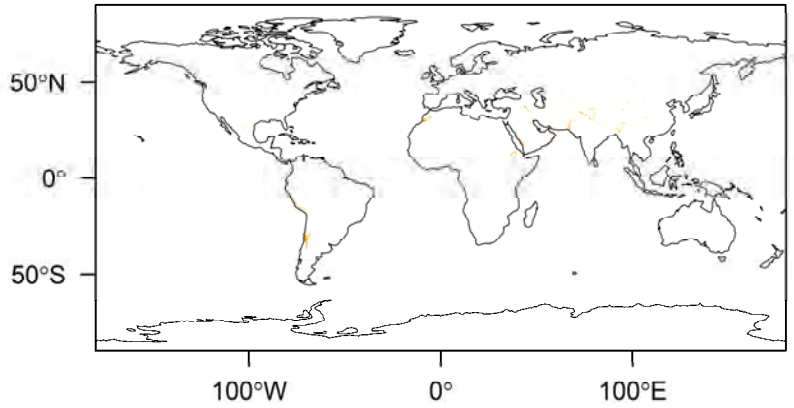
(a) Protected area



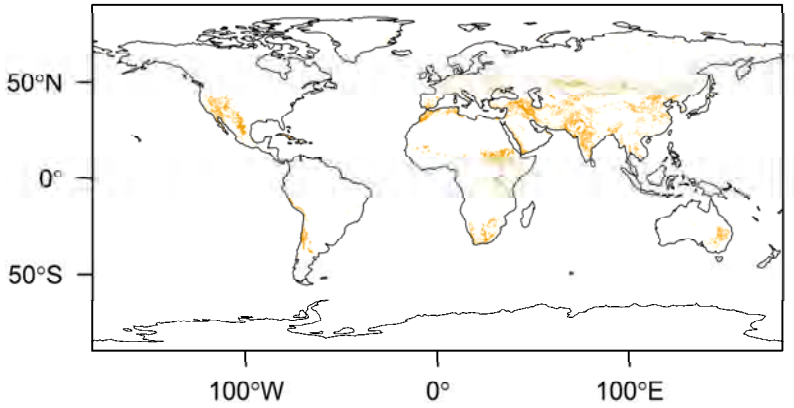
(b) Biodiversity sensitive areas



(c) Severely degraded land



(d) Seriously degraded land

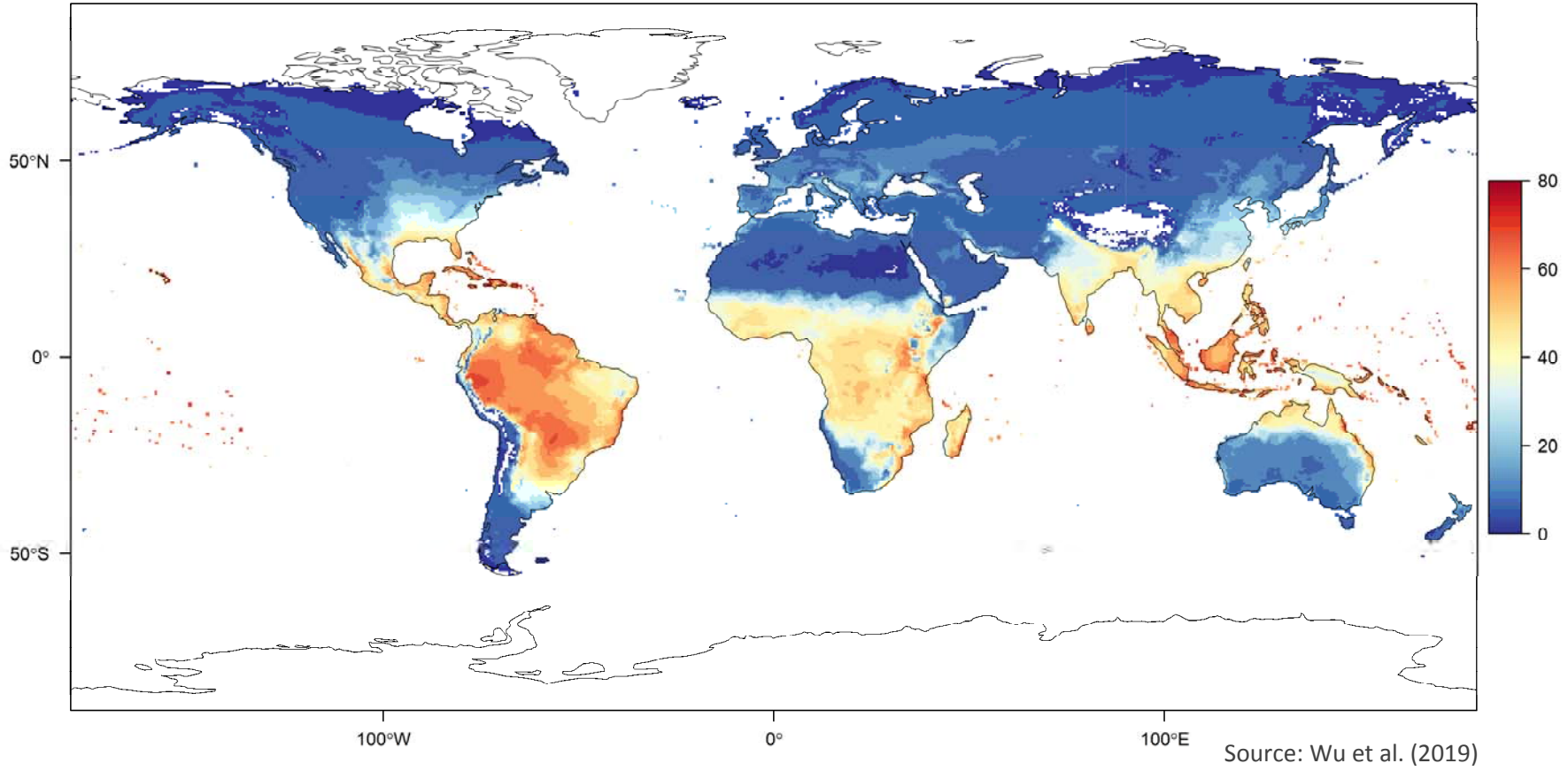


Source: Wu et al. (2019)

Figure. Maps for environmental protection policies

Dedicated bioenergy crops

- Miscanthus & switchgrass; high yield in biomass



Source: Wu et al. (2019)

Figure. Bioenergy crop potential yield from the H08 model (tonne/ha/yr)

Societal transformation measures

Demand side policy:

- **Sustainable diet**: towards more plant-based foods.

Supply side policy:

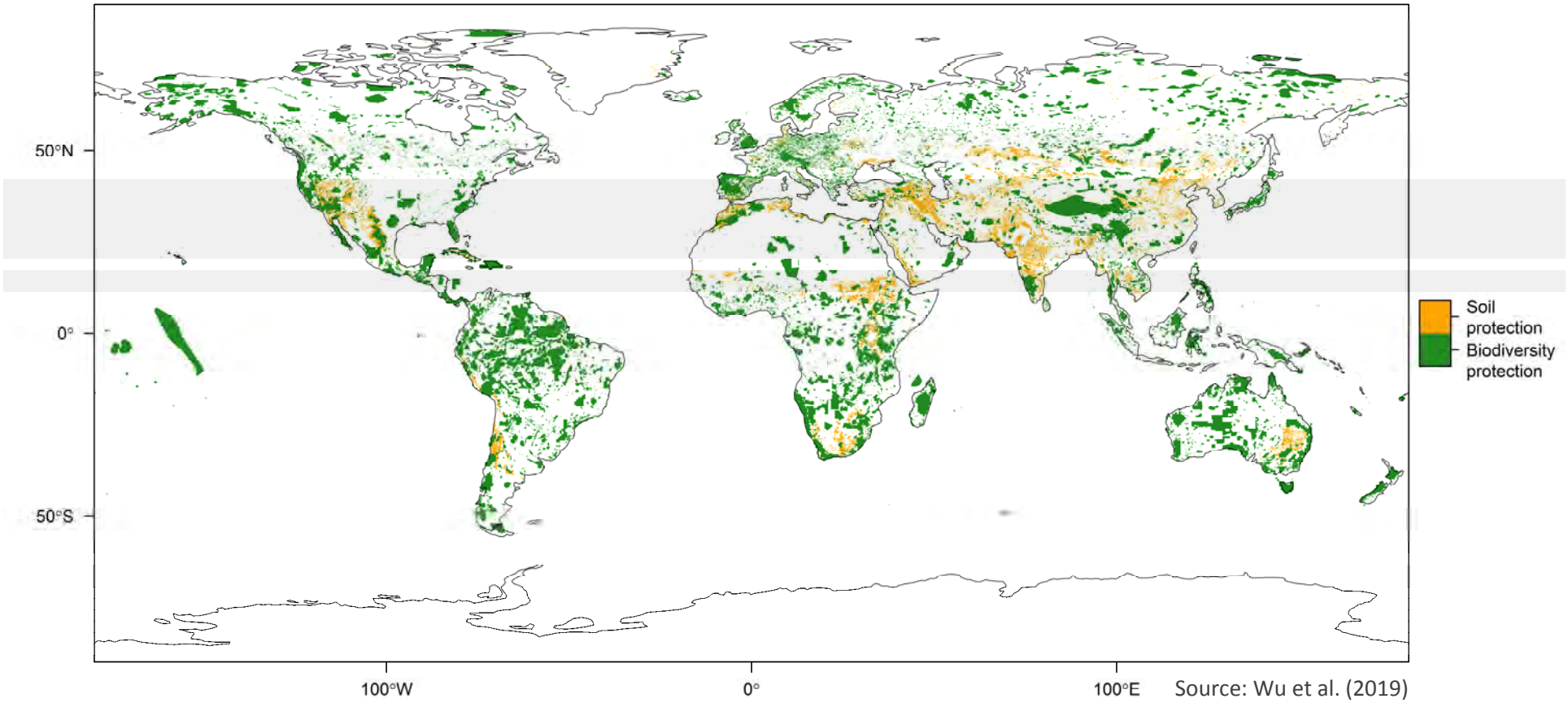
- **Advanced technology**: assuming high irrigation growth rates;
- **Trade openness for food**: increase freeness of trade.

Scenarios for simulation

Table. Scenario setting

Scenario name	Environmental protection policy	Societal transformation measure
(1) No policy	WDPA (Ia, Ib, II, III)	×
(2) Moderate biodiversity protection	WDPA (all) &KBA	×
(3) Enhanced biodiversity protection	WDPA (all) &KBA; biodiversity sensitive area	×
(4) Moderate soil protection	Severely degraded land	×
(5) Enhanced soil protection	Seriously degraded land	
(6) Full environmental policy	Enhanced biodiversity protection; enhanced soil protection	×
(7) Demand-side policy	Full environmental policy	Sustainable diet
(8) Supply-side policy	Full environmental policy	Advanced technology; trade openness for food
(9) Demand- and supply-side policy	Full environmental policy	Sustainable diet; advanced technology; trade openness for food

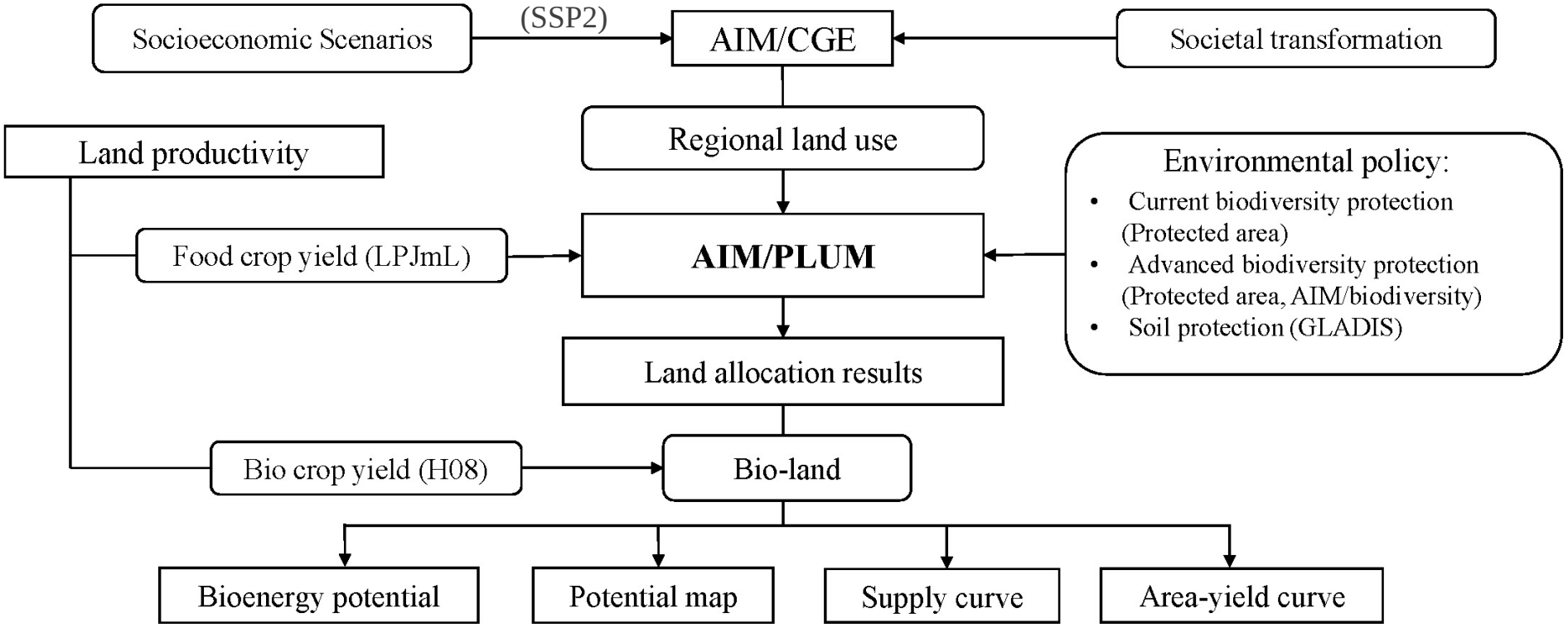
Full environmental policy map



Source: Wu et al. (2019)

Figure. Full environmental policy map (scenarios 6 – 9)

Research framework



Source: Wu et al. (2019)

Figure. Integrated assessment framework for estimating bioenergy potential

- **AIM/PLUM**: Asian-Pacific Integrated Model/**Platform for Land-Use and Environmental Model**. Global land use allocation model with spatial resolution of 0.5-degree (Hasegawa et al., 2017).

Results: Global technical potential

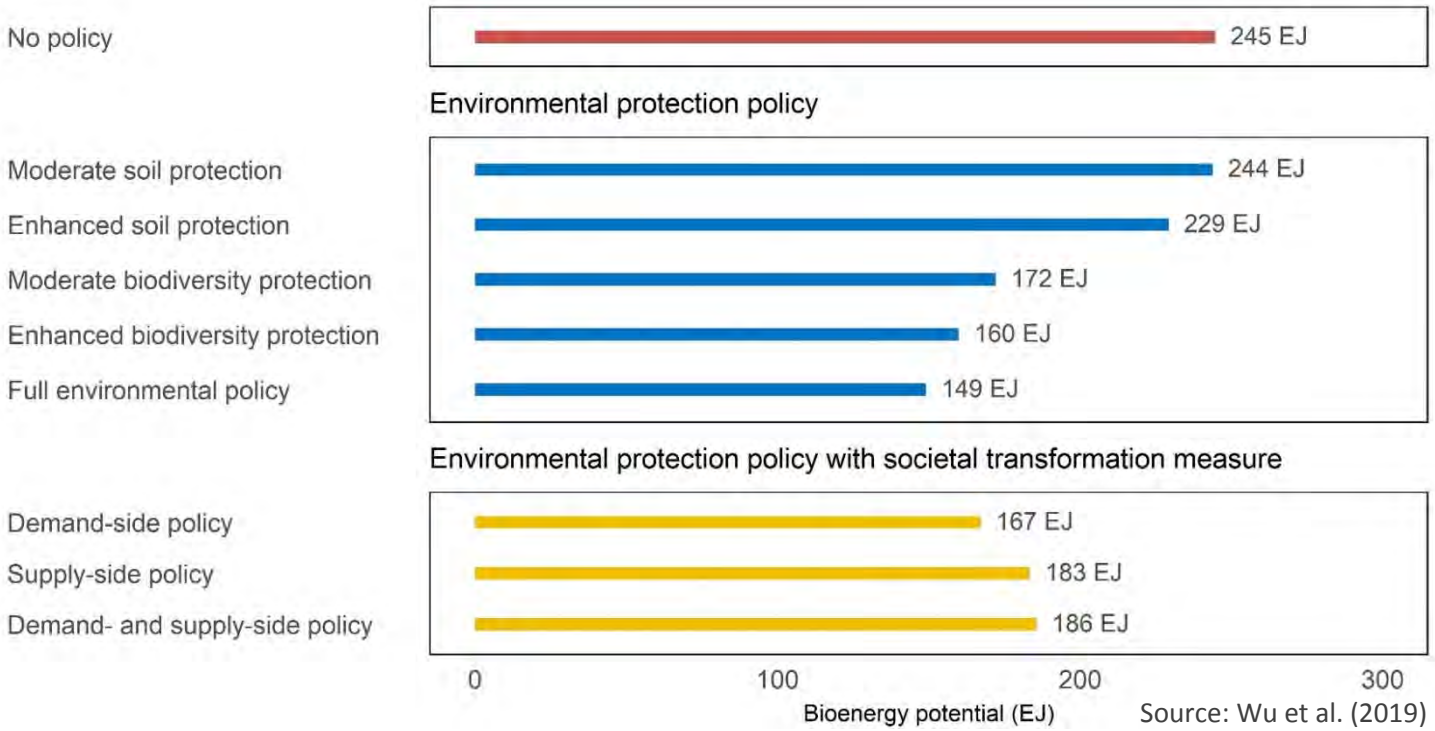


Figure. Global bioenergy potential in 2050 under each scenario

- **Full environmental policy** reduces global technical potential to 149 EJ.
- Larger impact of **biodiversity protection**: wider coverage and stronger implementation.
- **Societal transformation measure** (combining demand- and supply-side policy) could increase technical potential to 186 EJ.

Results: Regional technical potential

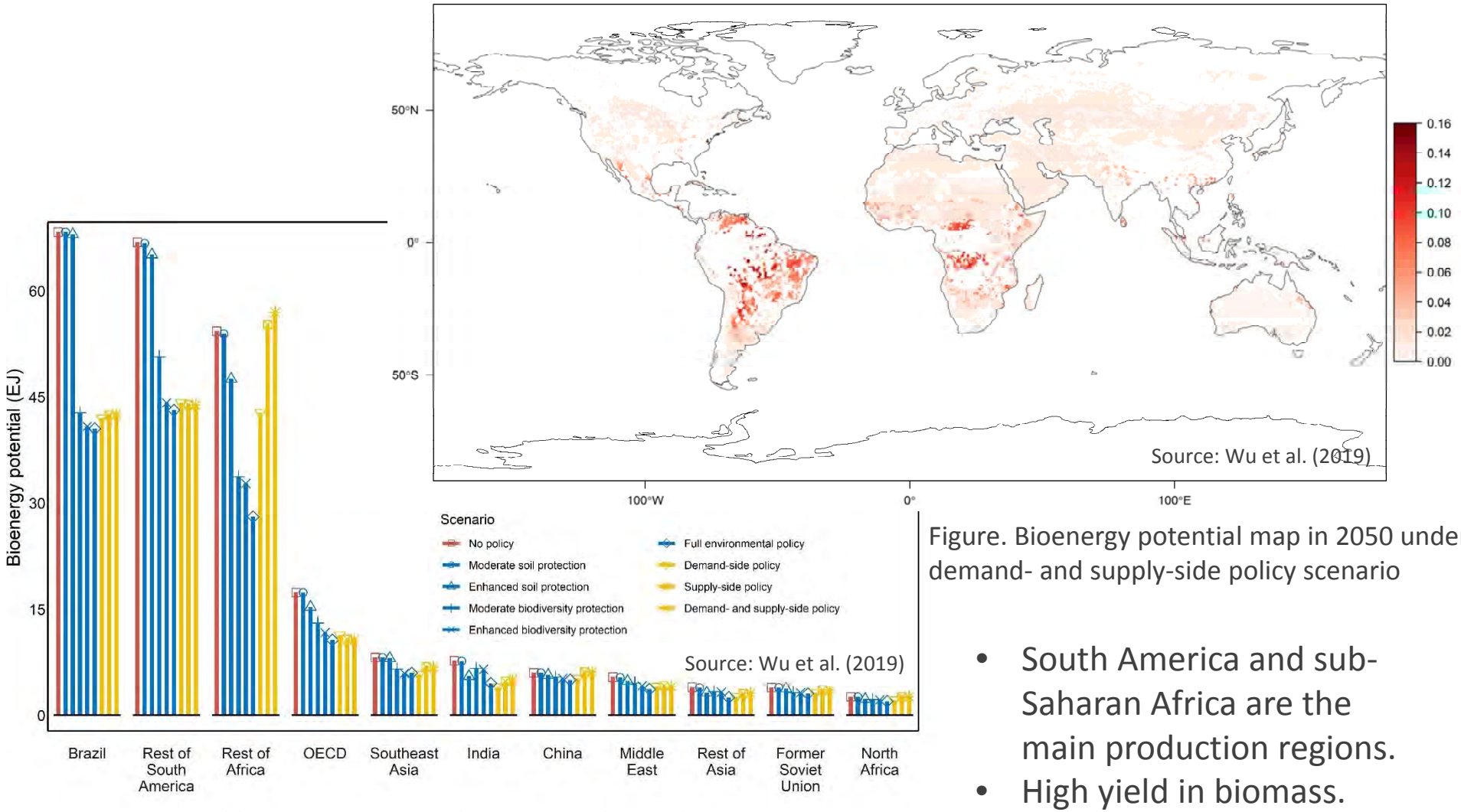
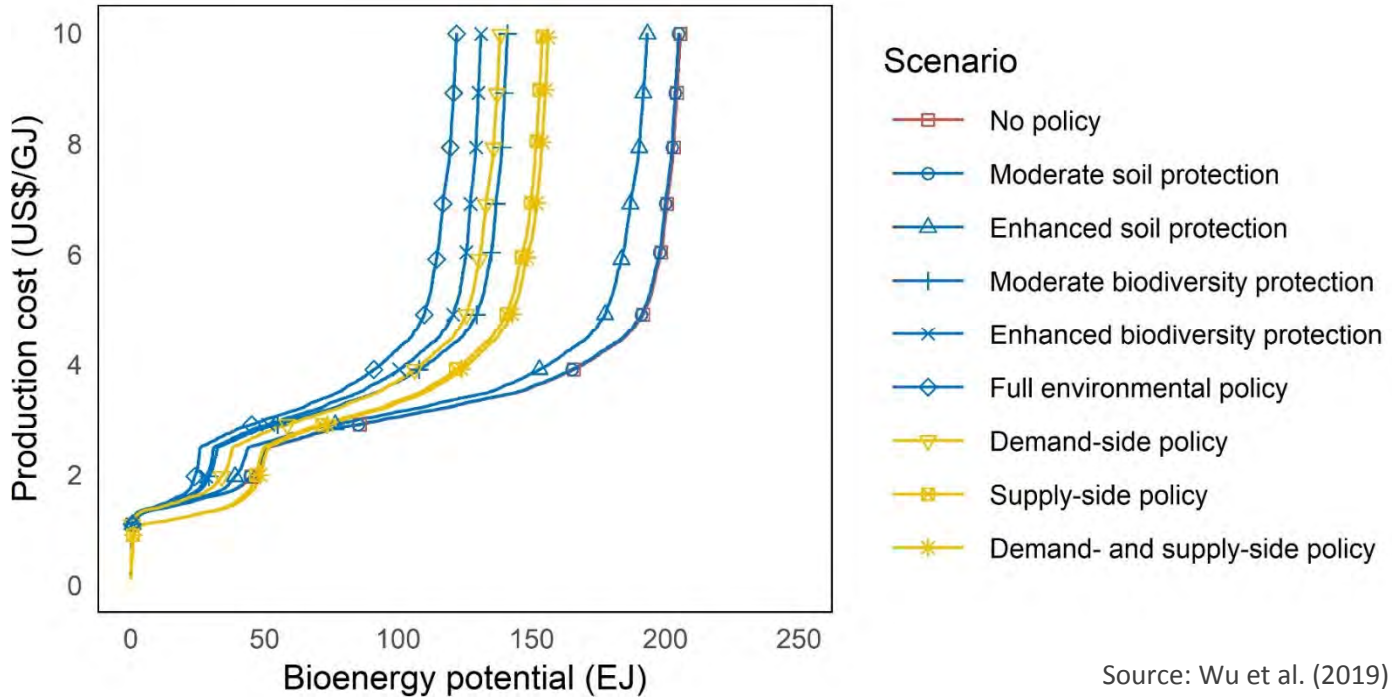


Figure. Bioenergy potential map in 2050 under demand- and supply-side policy scenario

Figure. Regional bioenergy potential in 2050 under each scenario

- South America and sub-Saharan Africa are the main production regions.
- High yield in biomass.

Results: economic potential



Source: Wu et al. (2019)

Figure. Bioenergy supply curve

- Economic potential also reduces under environmental protection policies.
- Demand and supply-side measures could increase economic potential.
- US$5/GJ: Baseline scenario - 192 EJ/year; full policy scenario - 110 EJ/year; Societal transformation measures: 143 EJ/year.

Conclusion and implication (1)

Technical potential and policies:

- Global technical bioenergy potential is reduced under environmental protection policy (from 245 EJ to 149 EJ).
- Demand- and supply-side policy could compensate some potential loss and increase the technical potential to 186 EJ.

Economic feasibility of bioenergy:

- We could provide an economic potential of 143 EJ/yr at US$5/GJ with the efforts from societal transformation measures. Slightly lower than the median amount for 1.5°
- Economically feasible potential depends on carbon price and energy price (facing uncertainties).

Conclusion and implication (2)

- IPCC SR on Climate Change and Land: **Interlinkages** between Land Degradation, Biodiversity loss, and climate mitigation.
- To achieve these multiple sustainable targets, important to combine with **societal transformation policies.**
- Relying heavily on bioenergy might cause **trade-off** with **environment protection**. We should keep exploring mitigation pathways that are compatible with terrestrial system protection.
- **Uneven distribution** of potential: a challenge to the logistic system and international trade.

Reference

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Thank you for your attention.

Sensitivity test of biodiversity index

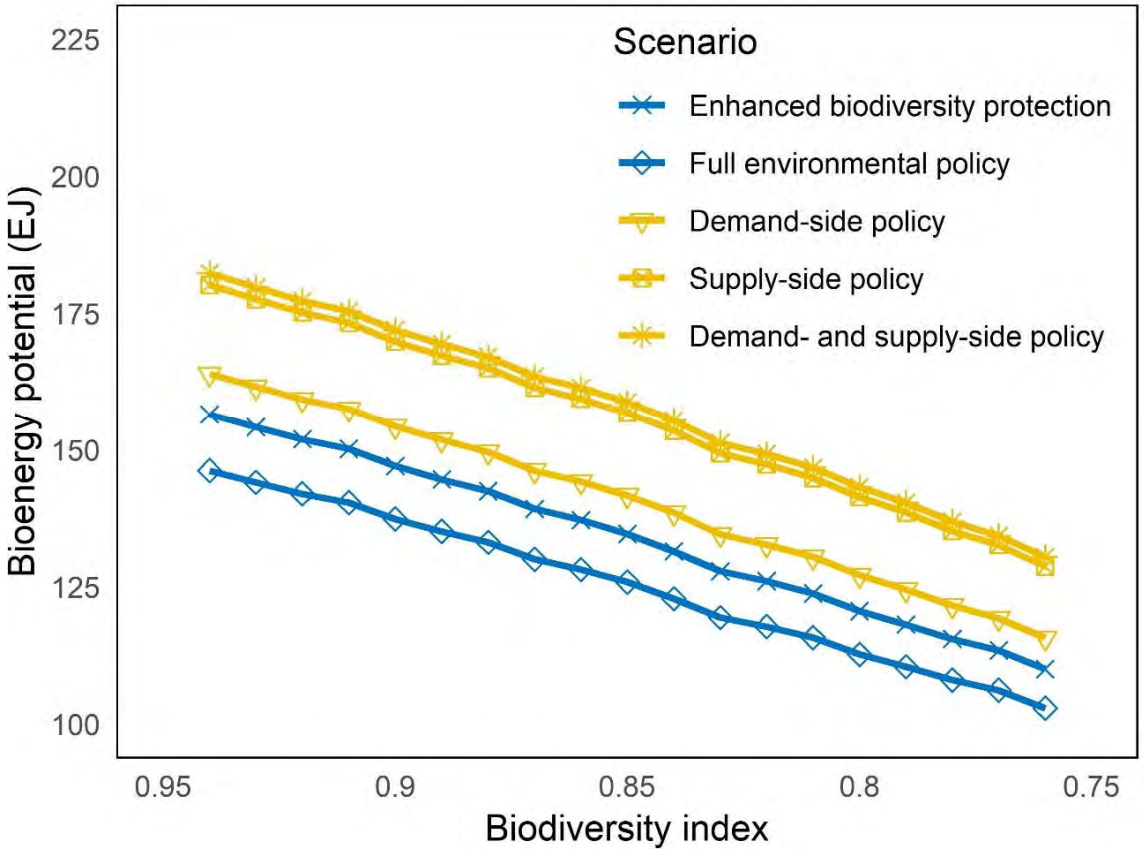

Figure. Sensitivity to biodiversity index for bioenergy potential in 2050