Regional variation in the effectiveness of methane and land-based climate mitigation options

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Supplementary Information

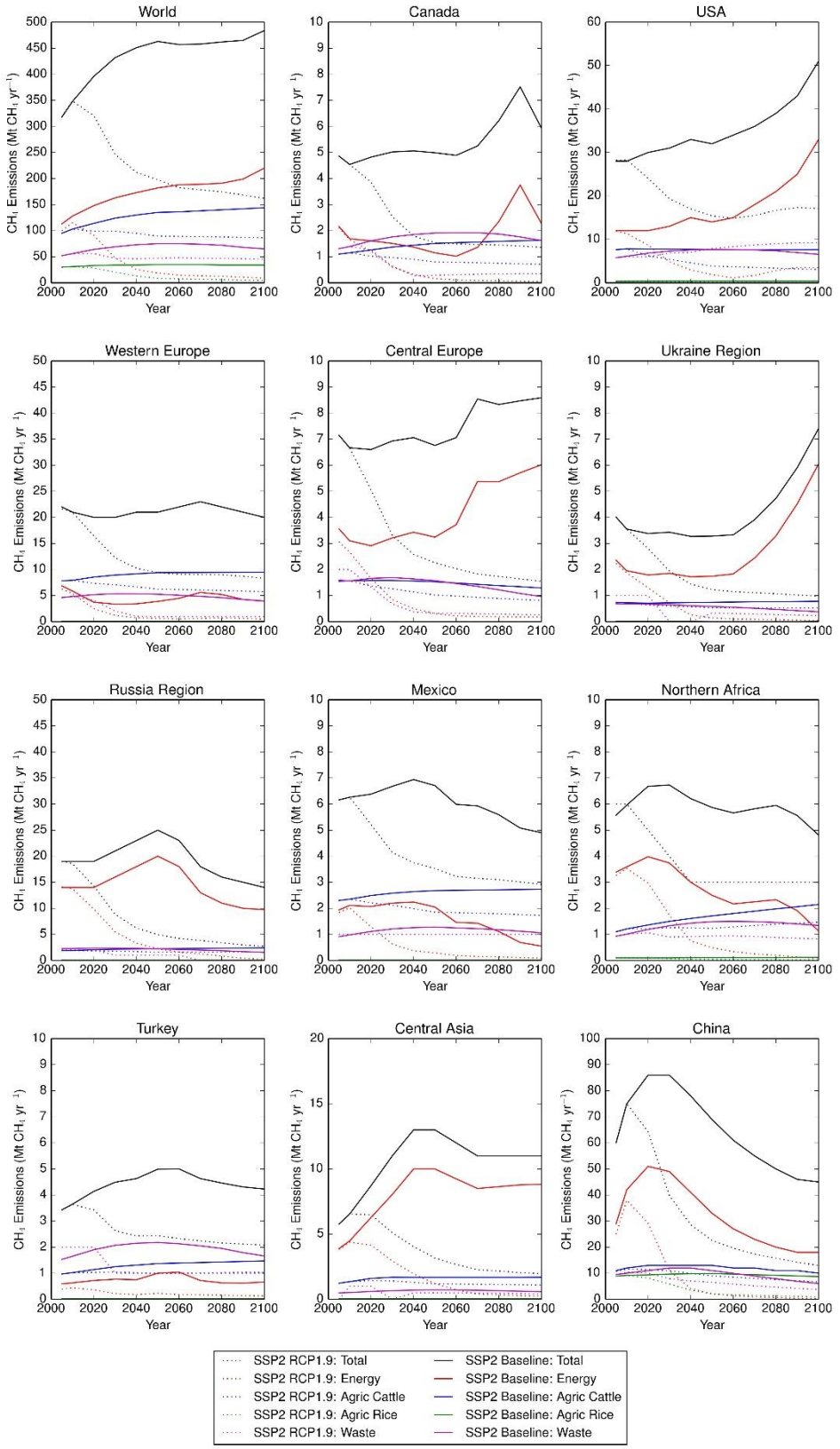

Fig. SI.1 | Time series of annual methane emissions between 2005 and 2100 from all and selected anthropogenic sources according to the IMAGE SSP2 Baseline (solid lines) and SSP2-RCP1.9 (dotted lines) scenarios, globally and for each of the 26 IMAGE regions, with total emissions in black, energy sector in red, agriculture-cattle in blue, agriculture-rice in green and waste in magenta. Note the y-axes have different scales for clarity.

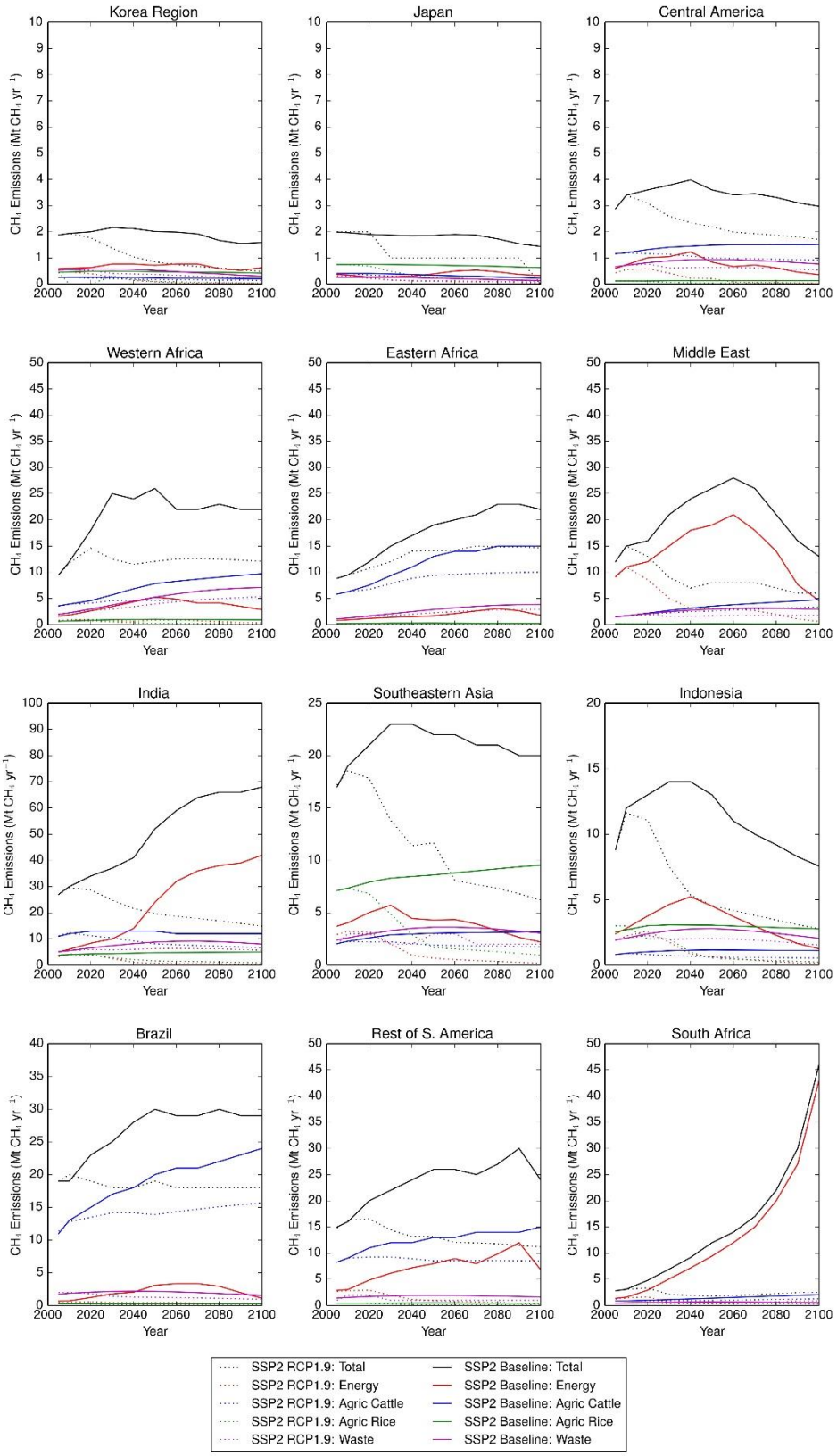

Fig. SI.1 (continued) | Time series of annual methane emissions between 2005 and 2100 from all and selected anthropogenic sources. Note the y-axes have different scales for clarity.

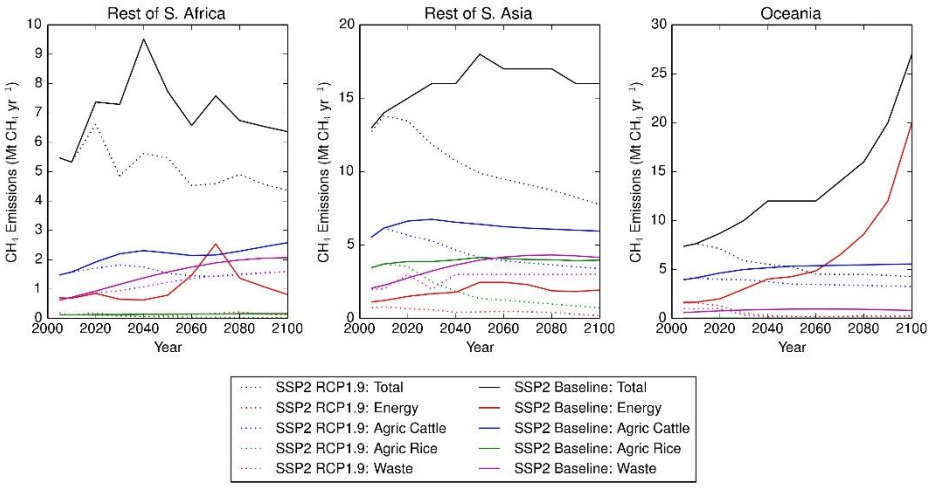

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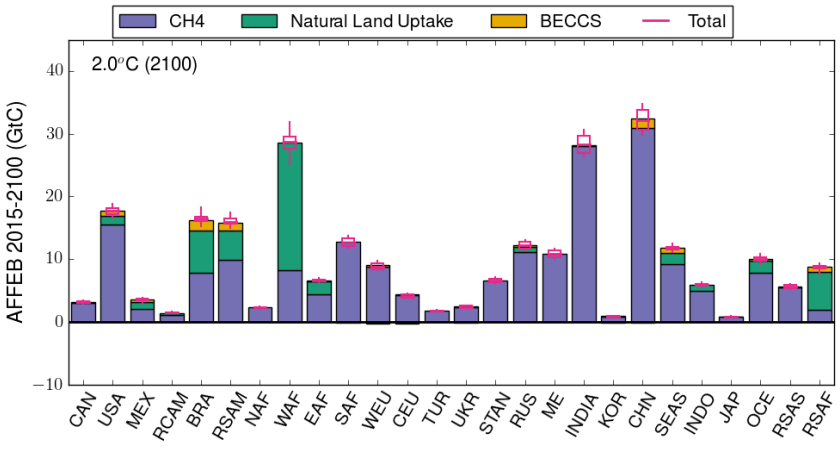
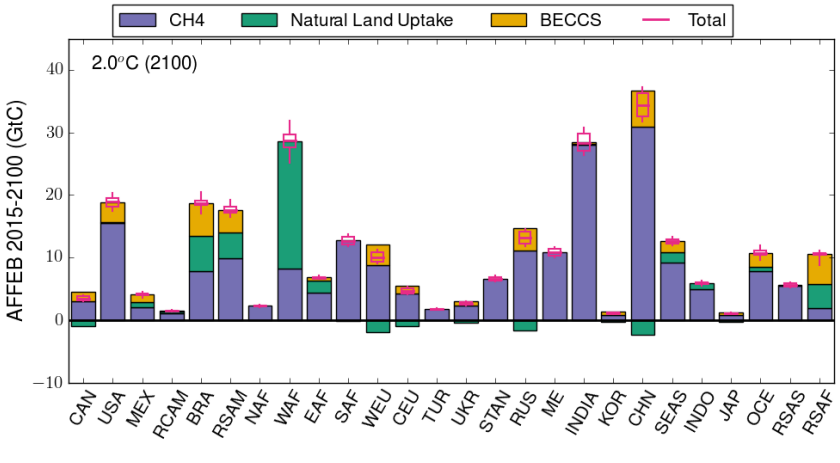
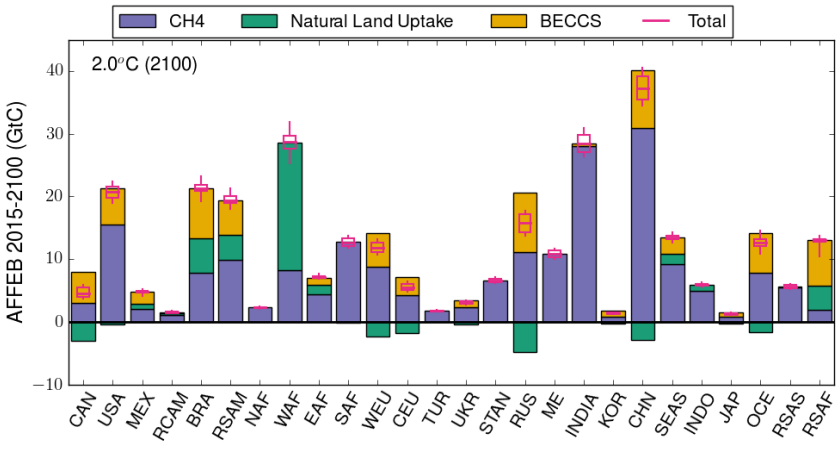
Fig. SI.1 (continued) | Time series of annual methane emissions between 2005 and 2100 from all and selected anthropogenic sources. Note the y-axes have different scales for clarity.



(a)



(b)



(c)

Fig. SI.2 | Contribution of different mitigation options to the increase in allowable anthropogenic fossil fuel emission budgets by IMAGE region to meet the 2°C target. The stacked bars represent the median methane mitigation potential (purple bars) and median land-based mitigation potential (natural land uptake, green; BECCS, brown). Panel (a) is based on a BECCS scaling factor of unity, (b) a BECCS scaling factor of 2 and (c) a BECCS scaling factor of 3. The total (pink) shows the median and interquartile range for the 34 GCMs emulated and 4 factorial sensitivity simulations.

Fig. SI.3 | Time series of the land areas (in Mha) calculated for trees and prescribed for agriculture (including bioenergy crops) and bioenergy crops for the scenarios IM-1.9 ('BECCS', orange) and IM-1.9N ('no BECCS', green), as a difference to the baseline scenario (IM-BL), for the 26 IMAGE regions between 2000 and 2100. The dotted lines are the median and the spread the interquartile range for the 34 GCMs emulated and 4 factorial sensitivity simulations.

a) Canada
b) USA
c) Mexico
d) Central America
e) Brazil
f) Rest of South America
g) Northern Africa
h) Western Africa
i) Eastern Africa
j) South Africa
k) Rest of Southern Africa
l) Western Europe
m) Central Europe
n) Turkey
o) Ukraine Region
p) Central Asia
q) Russia Region
r) Middle East
s) India
t) Korea Region
u) China
v) South East Asia
w) Indonesia
x) Japan
y) Rest of South Asia
z) Oceania

Fig. SI.3a: Canada

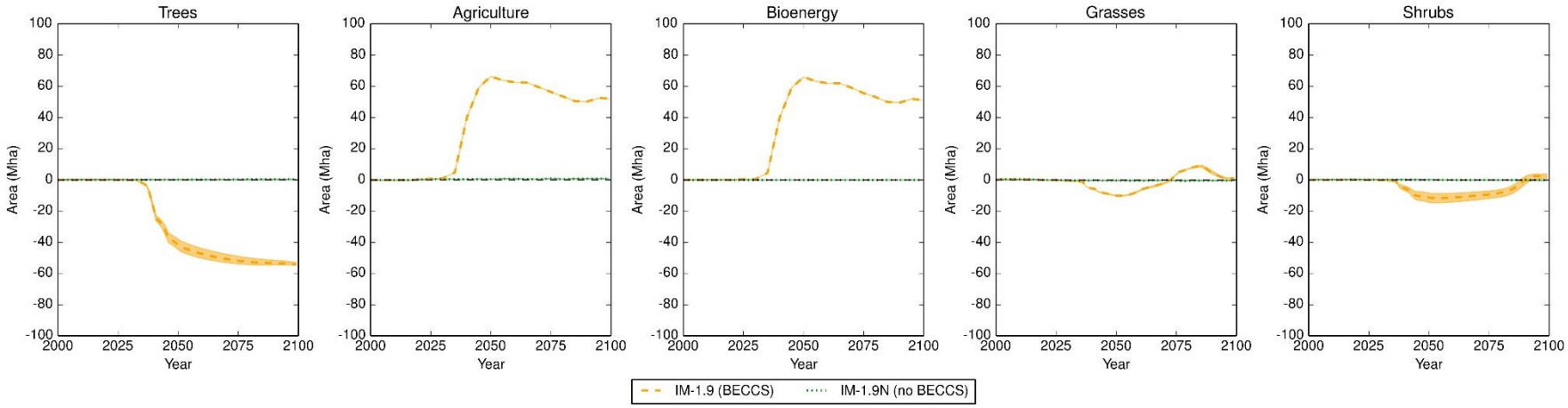


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Fig. SI.3b: USA

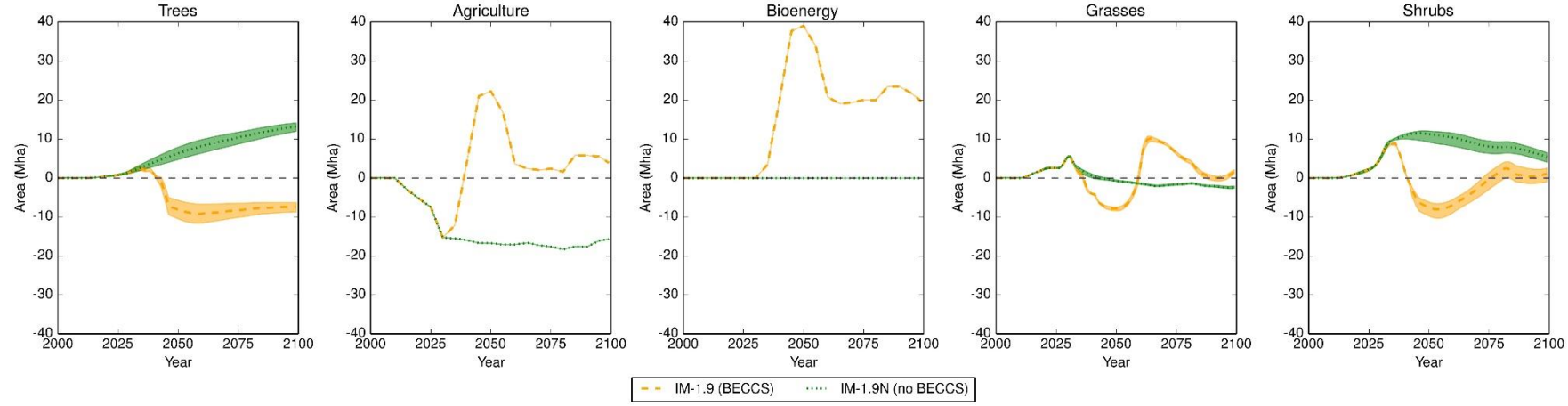

Fig. SI.3c: Mexico

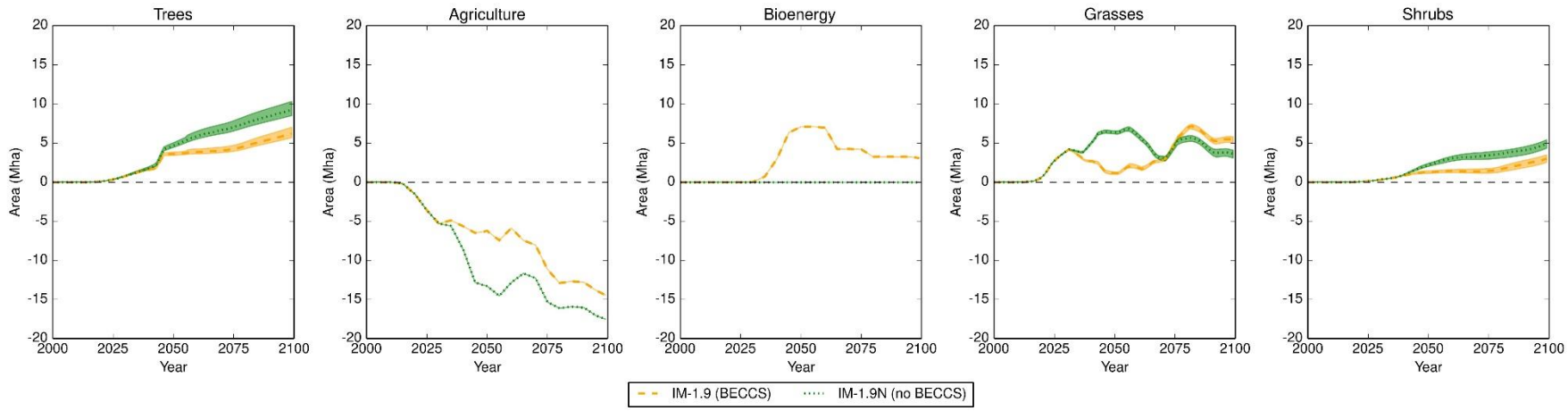

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Fig. SI.3d: Central America

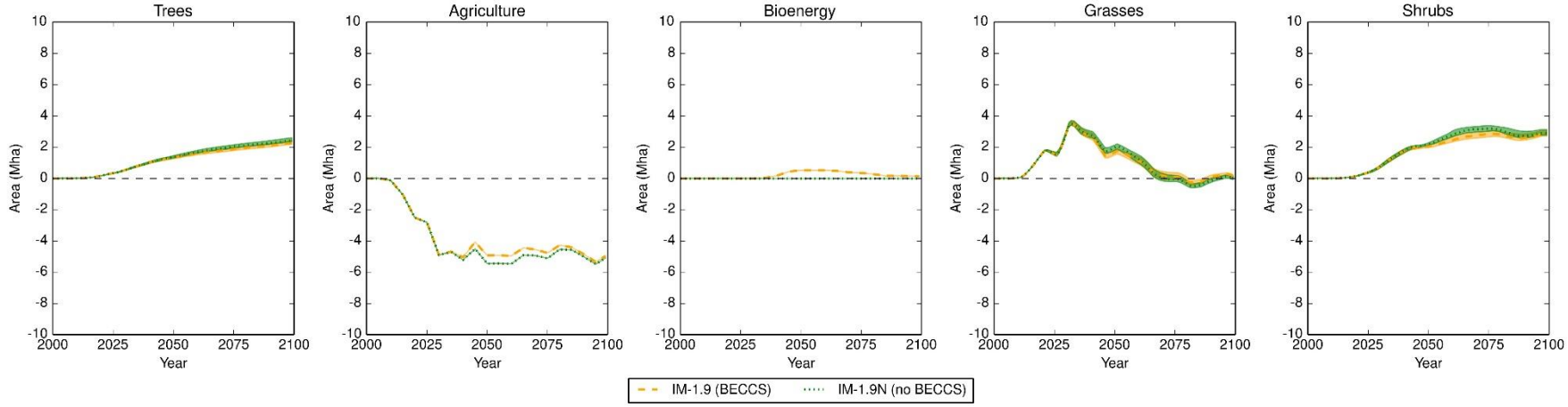

Fig. SI.3e: Brazil

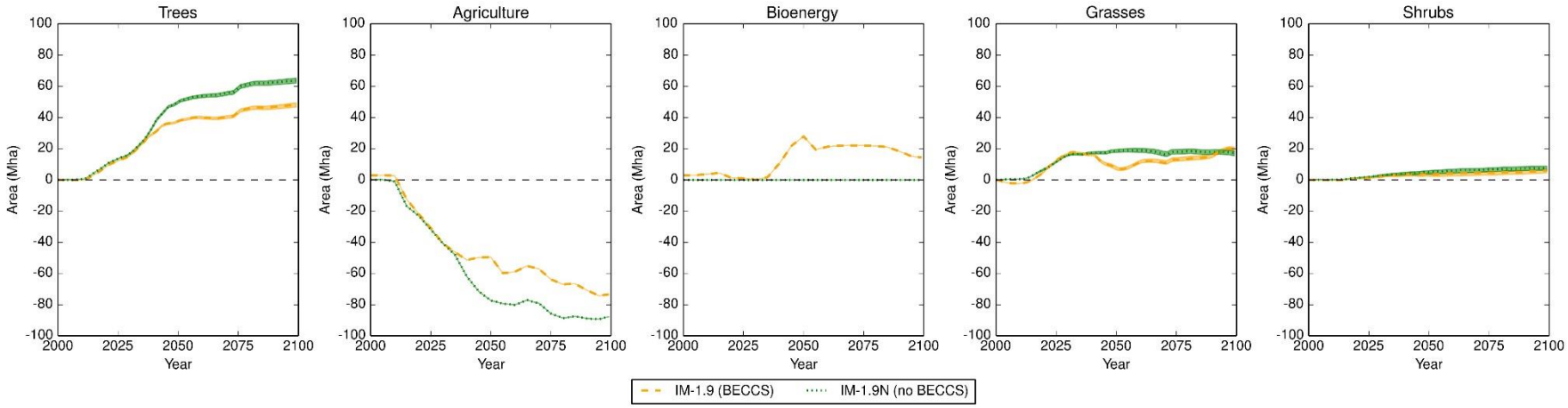

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Fig. SI.3f: Rest of South America

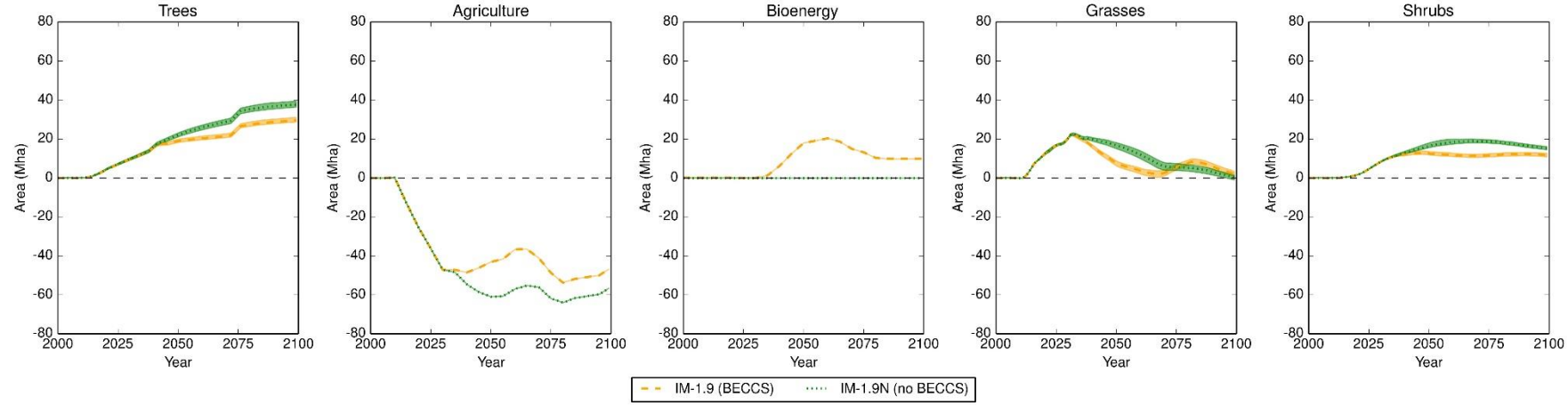

Fig. SI.3g: Northern Africa

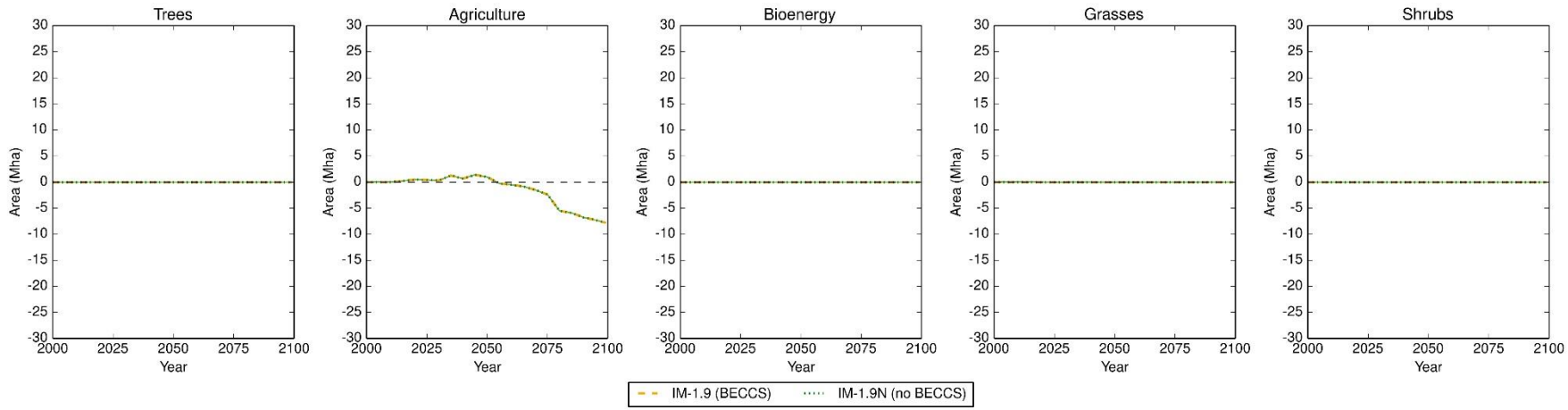

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Fig. SI.3h: Western Africa

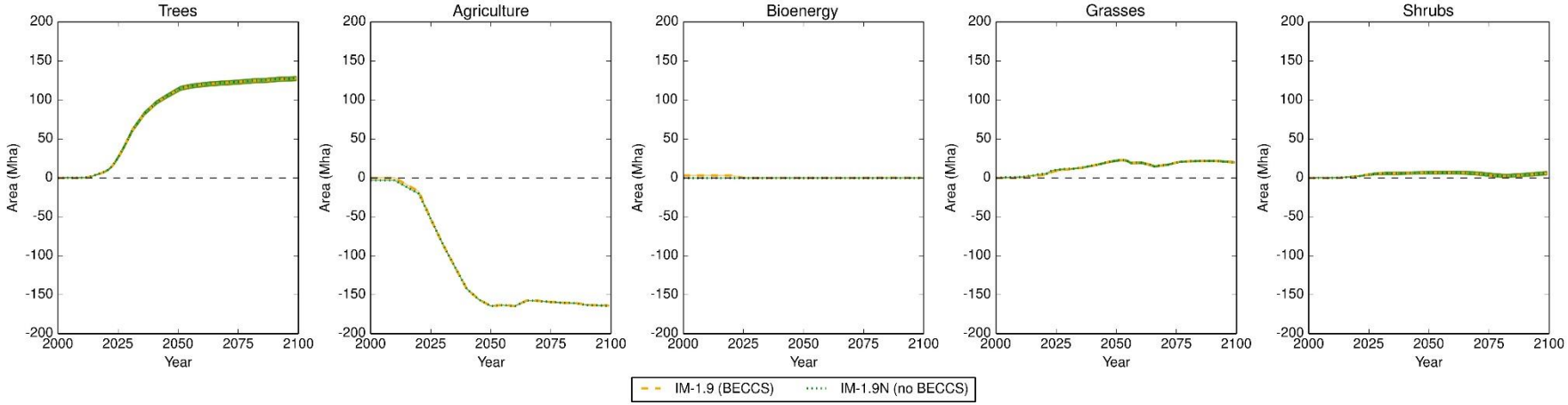

Fig. SI.3i: Eastern Africa

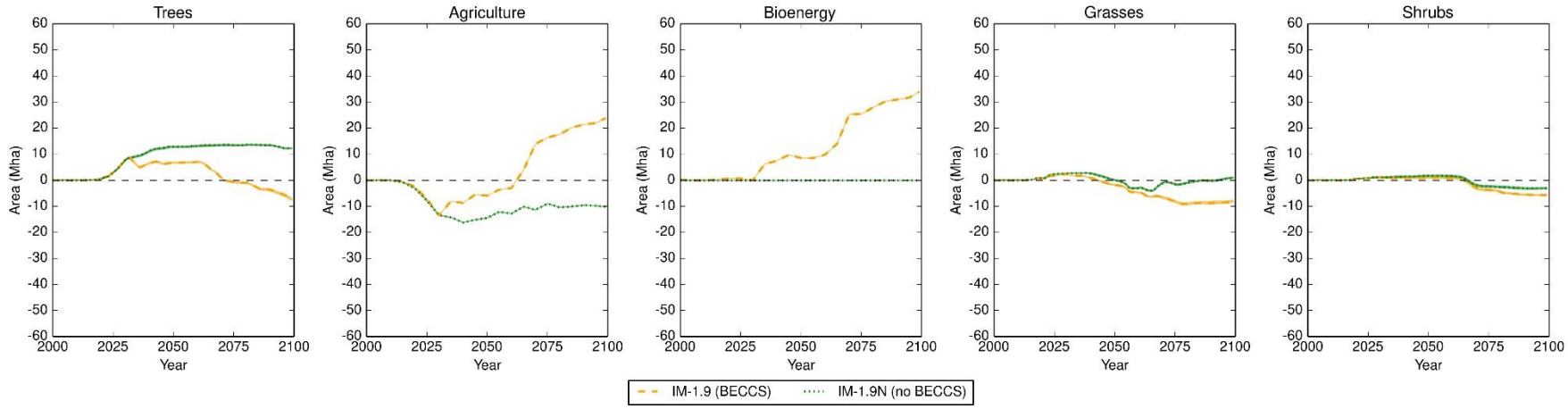

Fig. SI.3j: South Africa

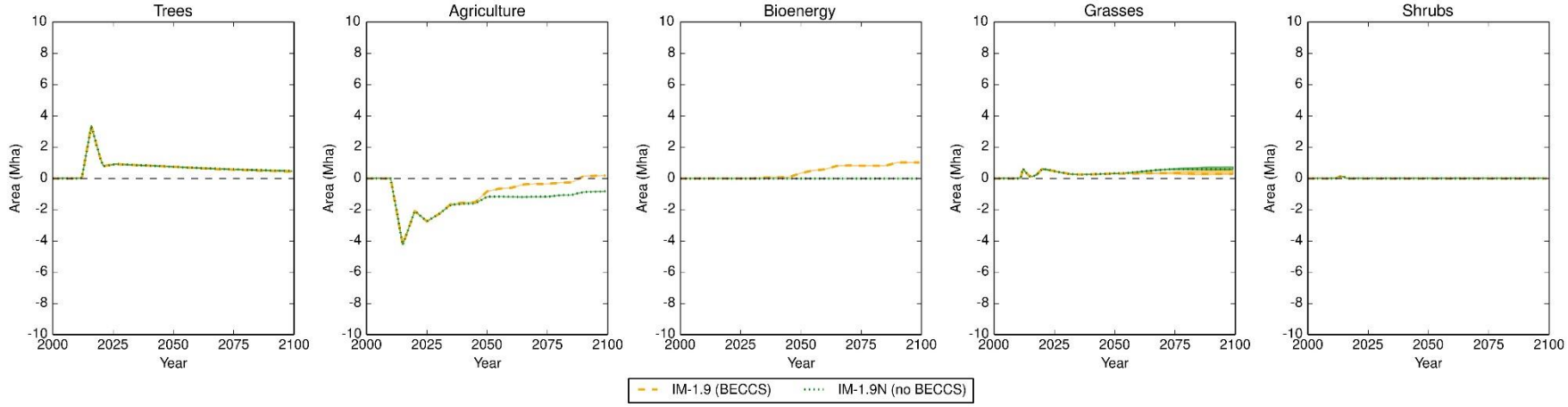

Fig. SI.3k: Rest of Southern Africa

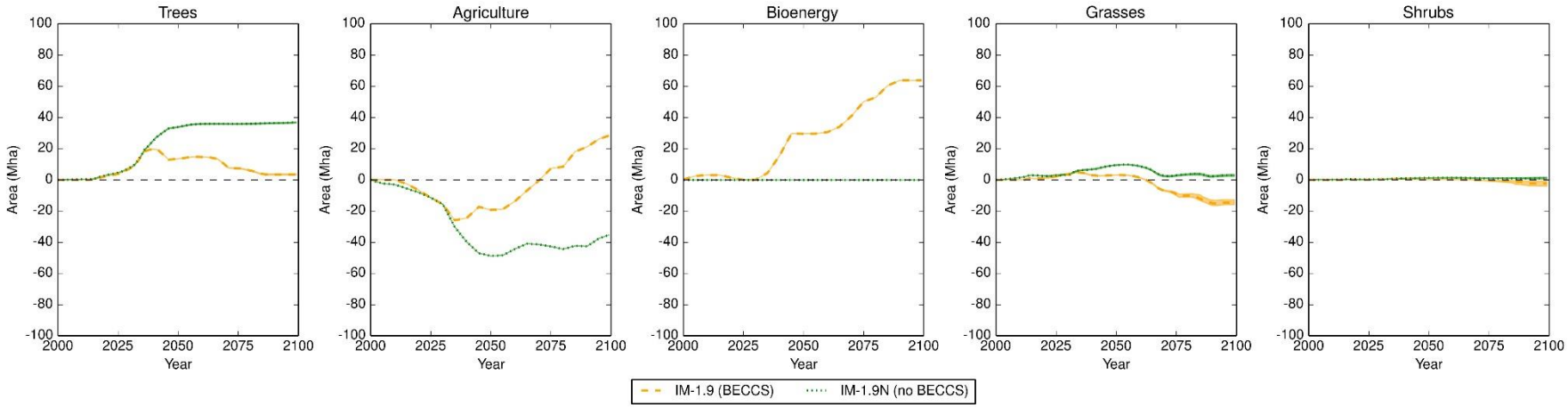

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Fig. SI.3l: Western Europe

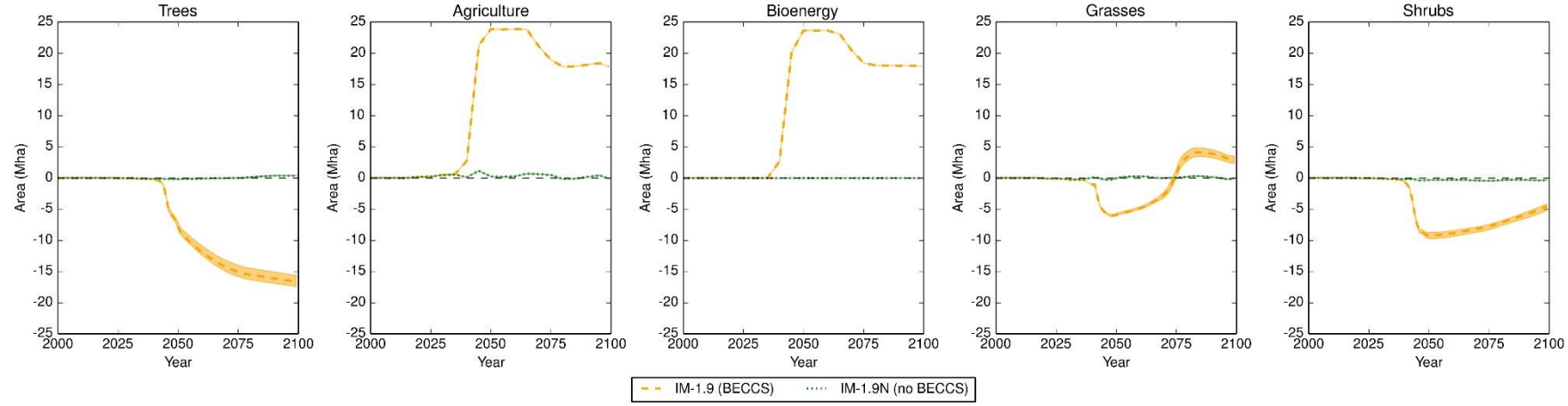

Fig. SI.3m: Central Europe

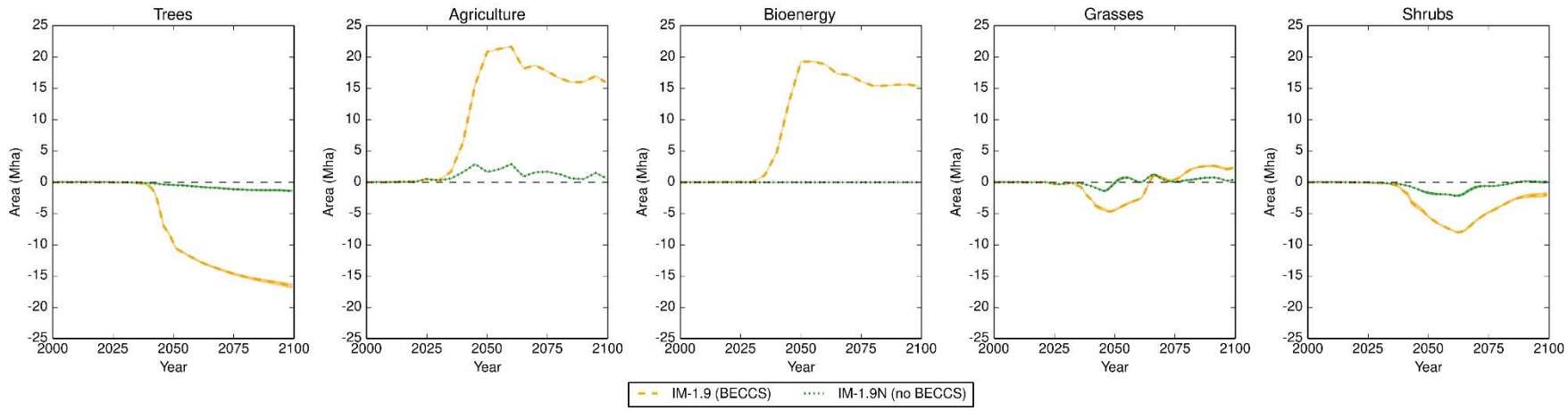

Fig. SI.3n: Turkey

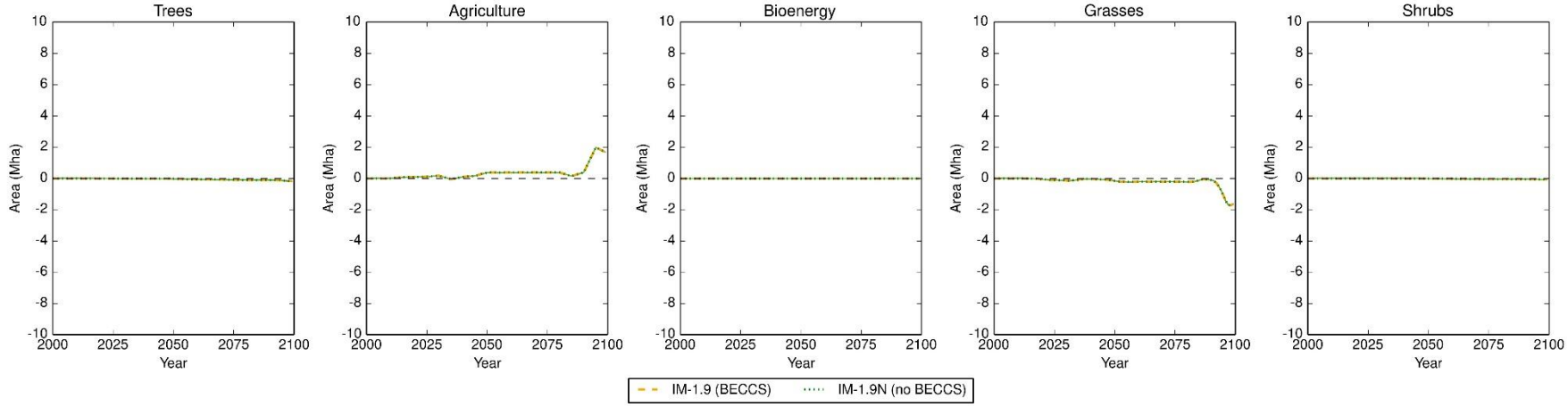

Fig. SI.3o: Ukraine Region

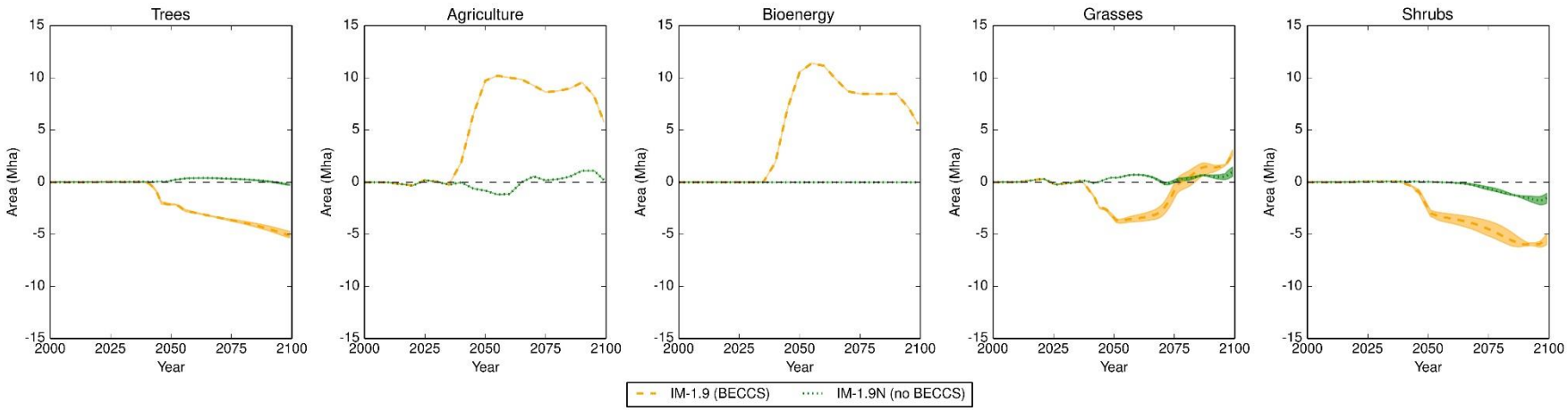

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Fig. SI.3p: Central Asia

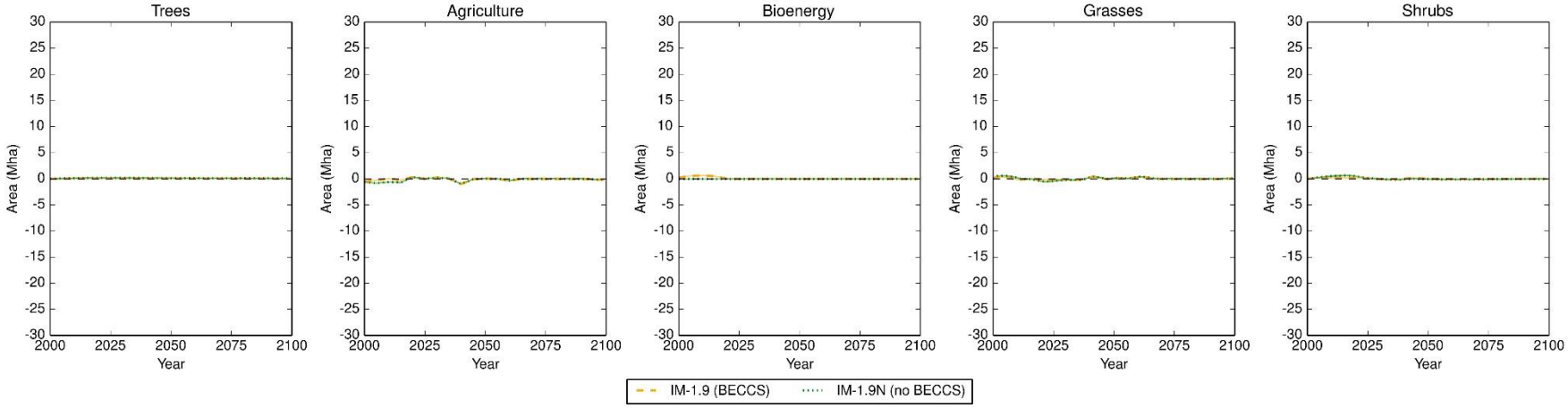

Fig. SI.3q: Russia Region

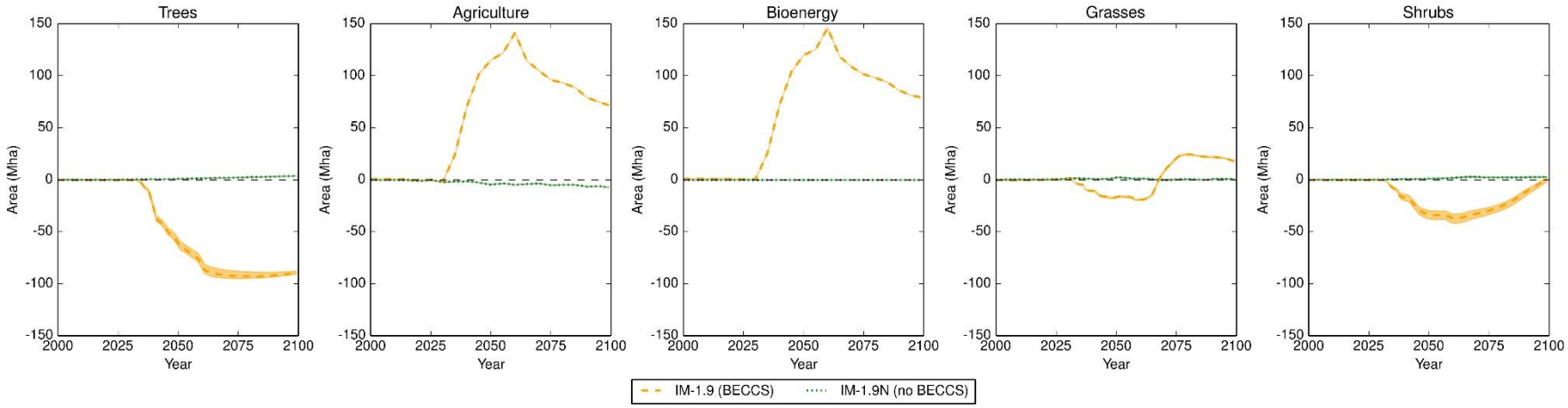

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Fig. SI.3r: Middle East

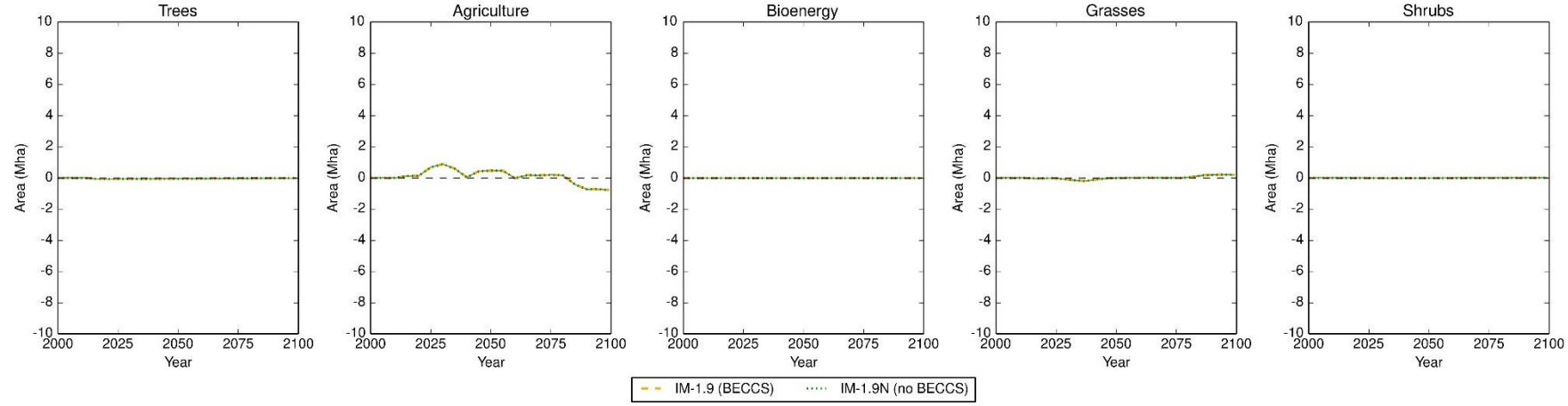

Fig. SI.3s: India

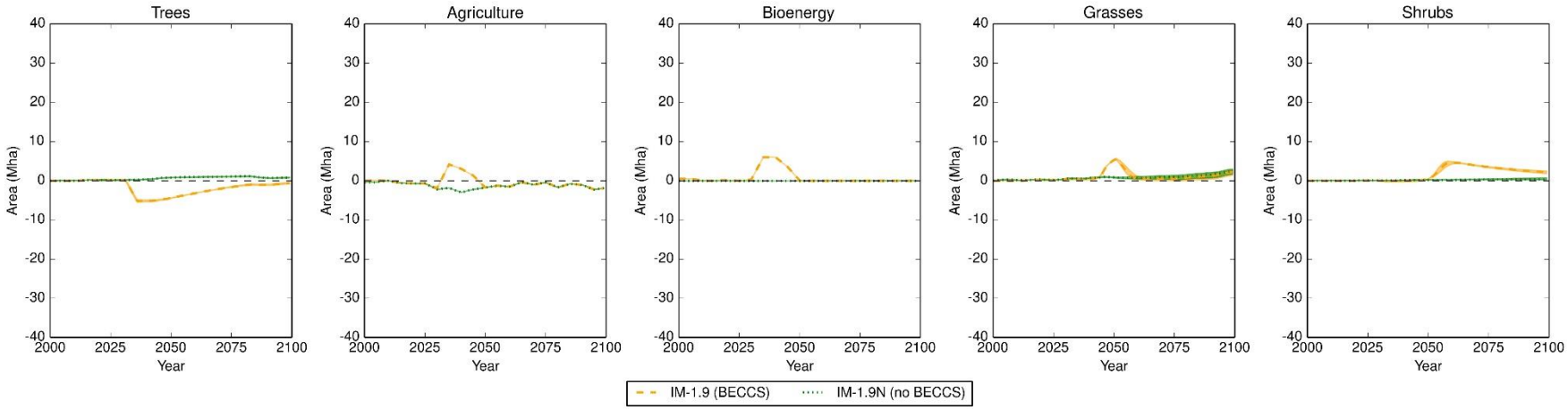

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Fig. SI.3t: Korea Region

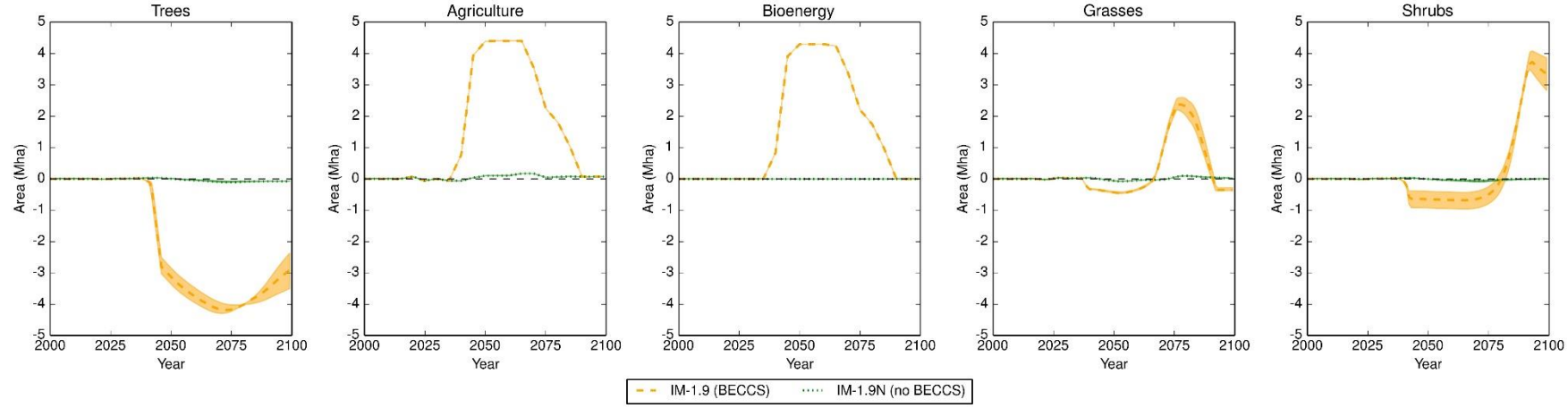

Fig. SI.3u: China

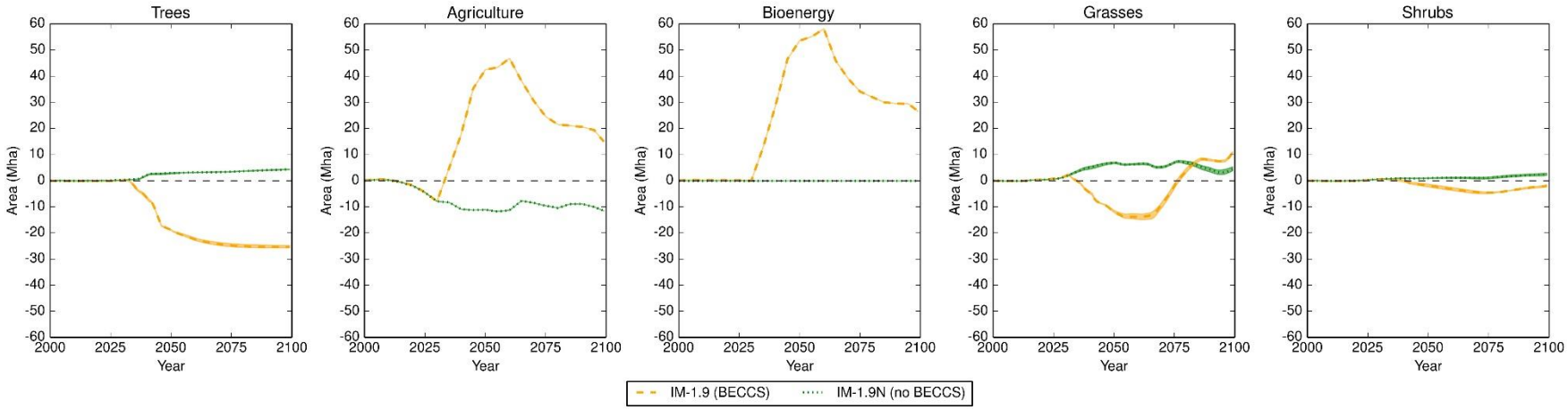

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Fig. SI.3v: South East Asia

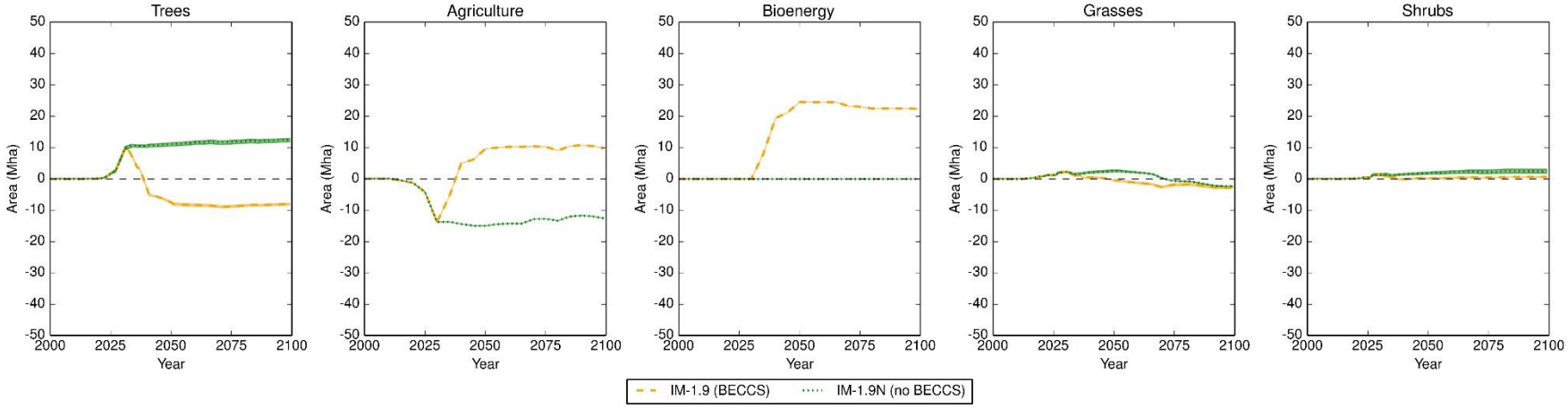

Fig. SI.3w: Indonesia

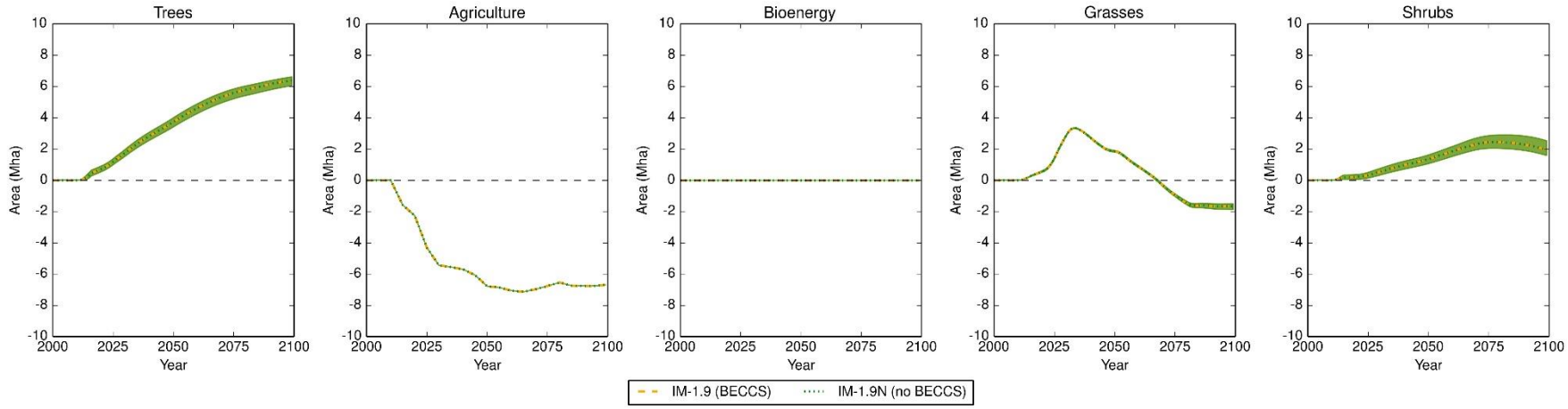

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Fig. SI.3x: Japan

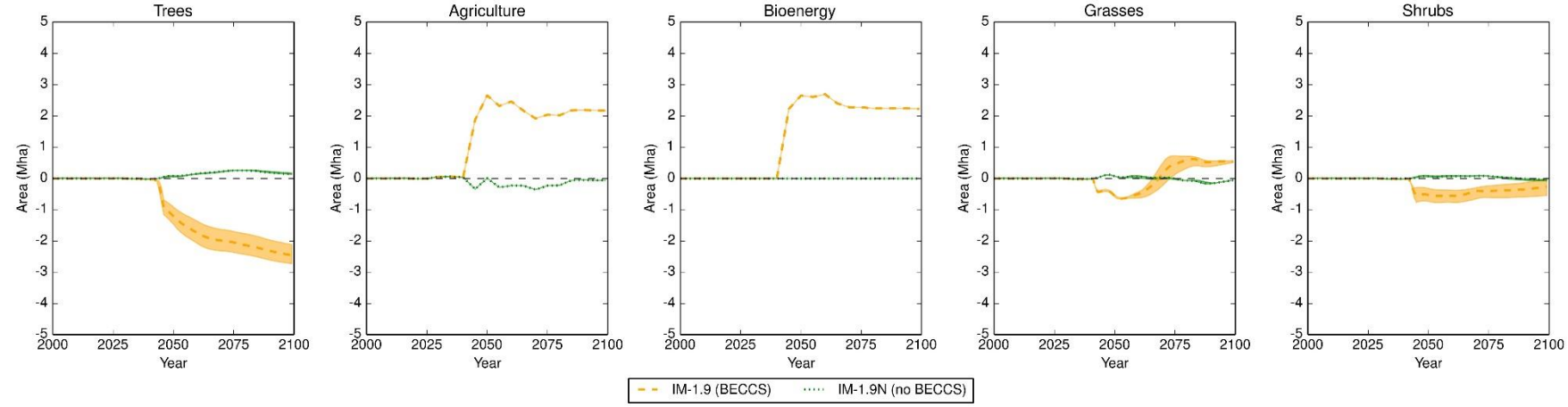

Fig. SI.3y: Rest of South Asia

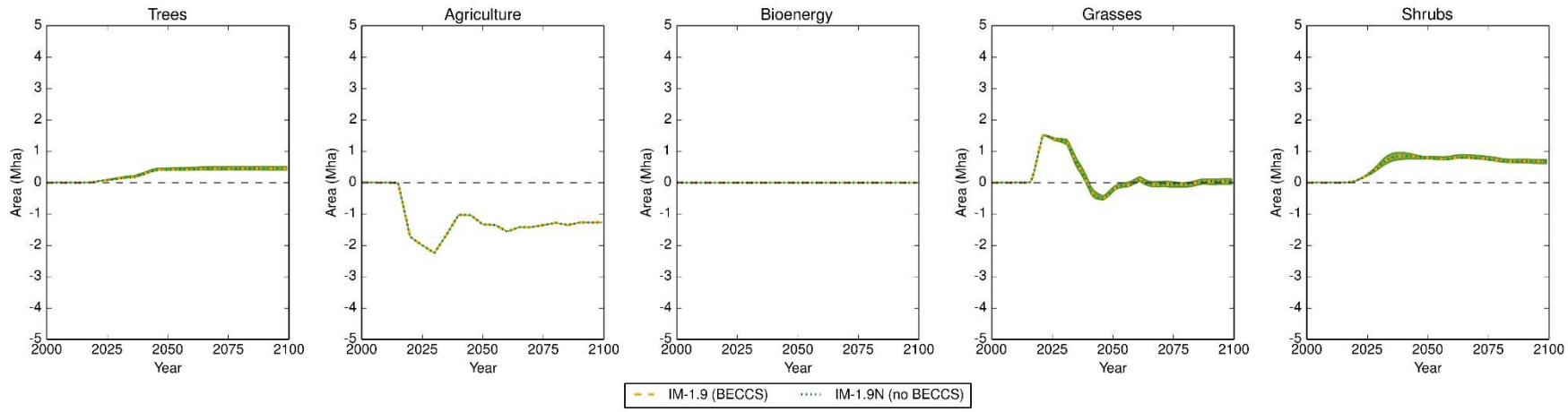

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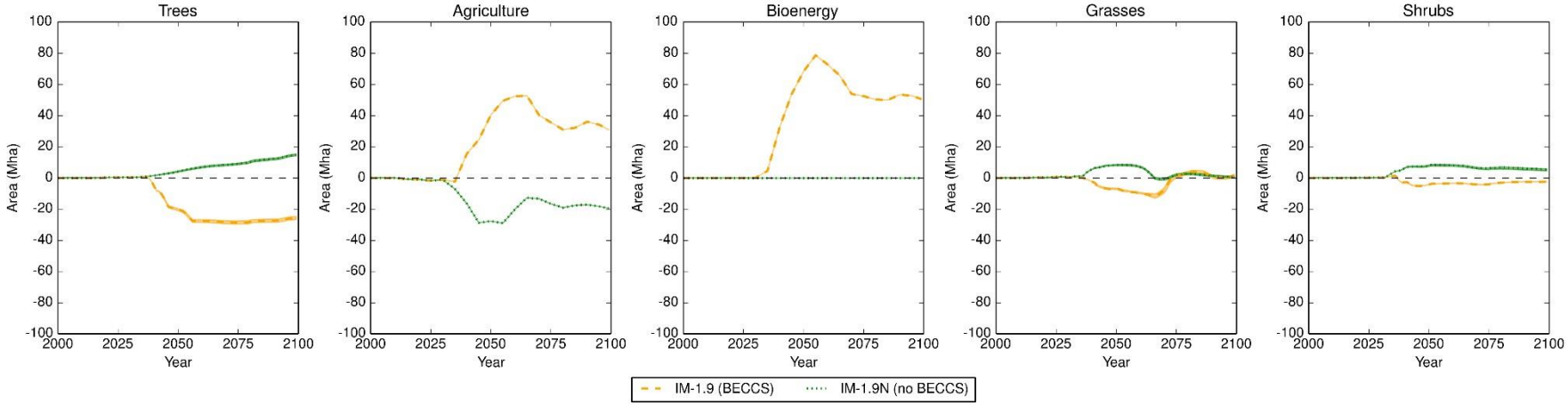
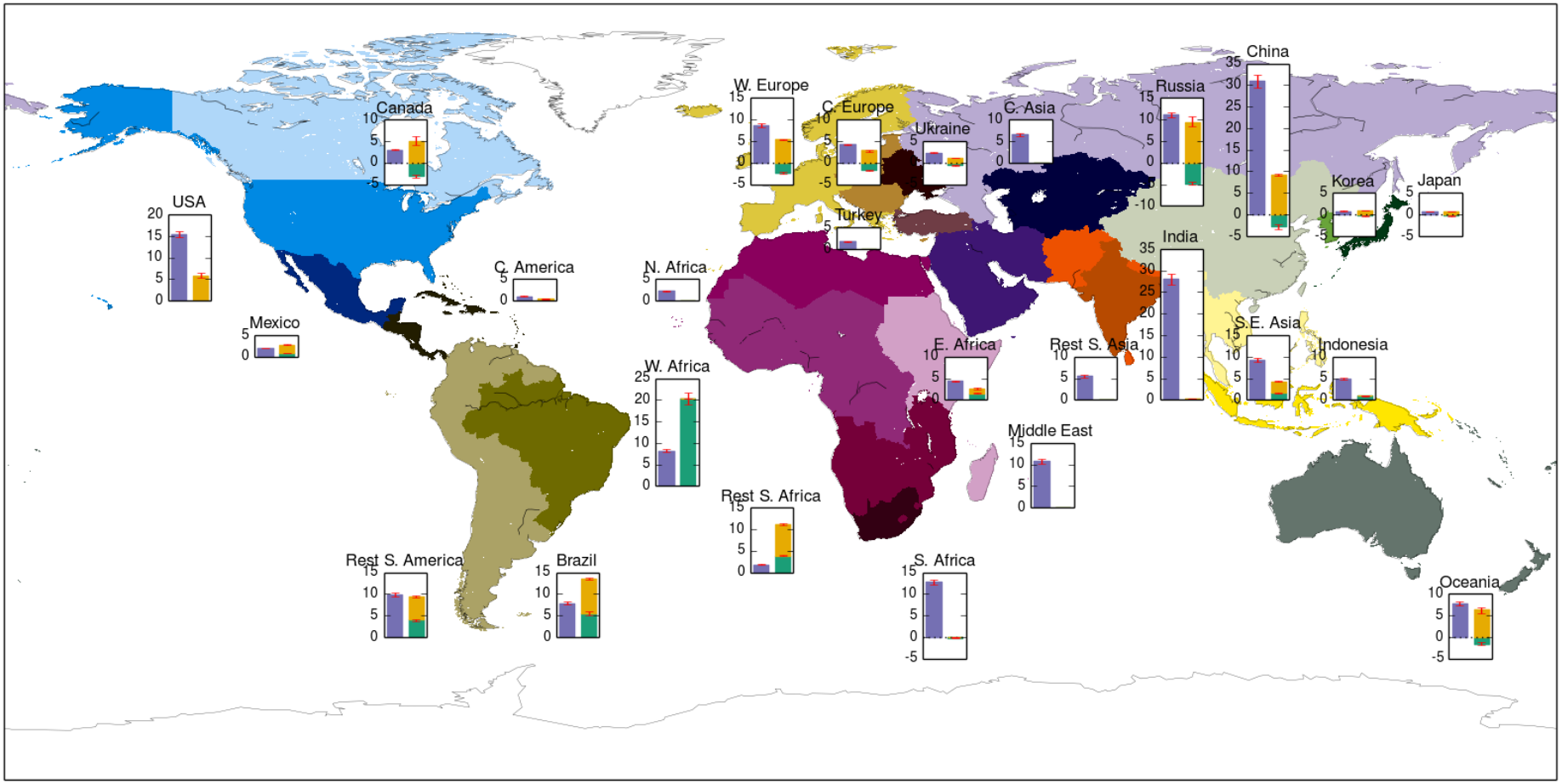
Fig. SI.3z: Oceania





145 **Fig. SI.4 | Contribution of different mitigation options to the allowable anthropogenic carbon emission budgets by region**. The contribution to the allowable carbon emission budgets (GtC) between 2015 and 2100 for each of the 26 IMAGE IAM regions from methane mitigation (purple bars) and land-based mitigation options (green: natural land uptake; yellow: BECCS with $\kappa = 3$), for the temperature pathway stabilising at 2°C warming without overshoot. The bars and error bars respectively show the median and the interquartile range~~,~~ from the 34 GCMs emulated and 4 factorial runs.

Table SI.1 | Mitigation options, estimated maximum reduction potential and the accompanying marginal price for mitigation of different anthropogenic methane source sectors for 2050 and 2100 [based on Lucas et al., 2007].

Source Sector	**Mitigation option(s)**	**Max. possible reduction relative to baseline (%)**	**Marginal price of max. reduction (1995 US$/tC$_{eq}$)**
Coal production	Maximising methane recovery from underground mining of hard coal	90 (2050) 90 (2100)	500 (2050) 500 (2100)
Oil/gas production & distribution	Control of fugitive emissions from equipment and pipeline leaks, and from venting during maintenance and repair.	75 (2050) 90 (2100)	300 (2050) 500 (2100)
Enteric fermentation	Change of animal diet and use of more productive animal types.	50 (2050) 60 (2100)	1000 (2050) 1000 (2100)
Animal waste	Capture and use of methane emissions through anaerobic digesters.	50 (2050) 60 (2100)	1000 (2050) 1000 (2100)
Wetland rice production	Changes to (1) the water management regime to reduce the period of anaerobic conditions in flooded fields; (2) the soils to reduce methanogenesis.	80 (2050) 90 (2100)	1000 (2050) 1000 (2100)
Landfills	(1) Reduced amount of organic material deposited in landfills; (2) capture of methane	90 (2050) 90 (2100)	500 (2050) 500 (2100)
Sewage and wastewater	(1) More wastewater treatment plants and also recovery of the methane from the plants; (2) More aerobic wastewater treatment.	80 (2050) 90 (2100)	500 (2050) 500 (2100)
Other anthropogenic sources	Note 1	-	-

Note: (1) These sources are either difficult to abate (e.g., land clearing for agricultural extension, and the use of traditional biomass for energy production and cooking) or are too small (e.g., methane emissions from industry, iron and steel production and the chemical sector).

Reference: Lucas, P. L., van Vuuren, D. P., Olivier, J. G. J. & den Elzen, M. G. J., 2007: Long-term reduction potential of non-CO_2 greenhouse gases. *Environmental Science & Policy* **10**, 85-103, doi: https://doi.org/10.1016/j.envsci.2006.10.007.