Worldwide water constraints on attainable irrigated production for major crops

Bram Droppers[1], Iwan Supit[1], Michelle TH van Vliet[2], and Fulco Ludwig[1]
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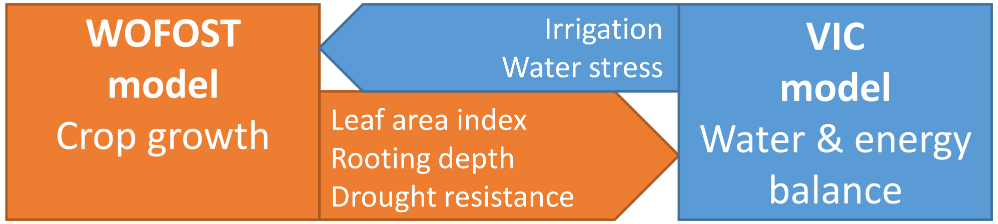
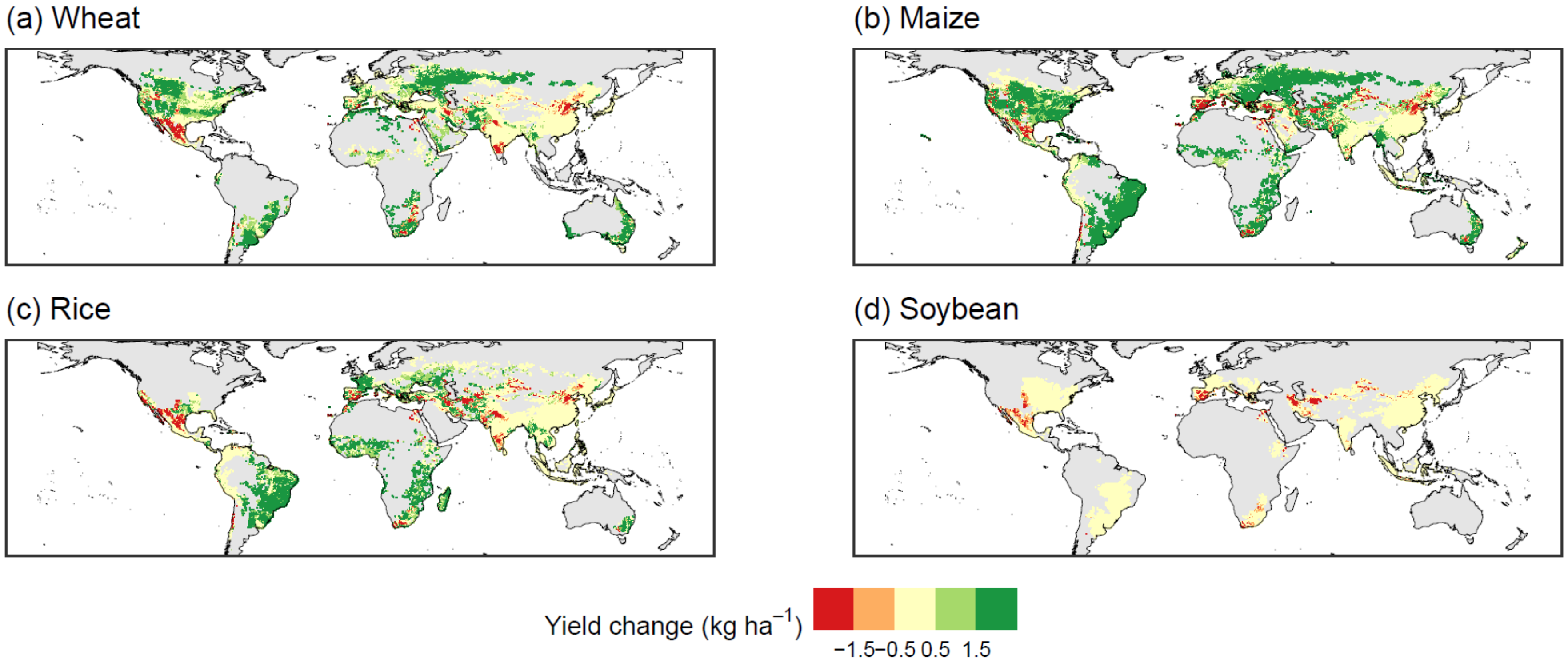
Crop production intensification
Increased irrigation and fertilization

Sustainable water management
Limit to renewable water withdrawals and protecting riverine ecosystems

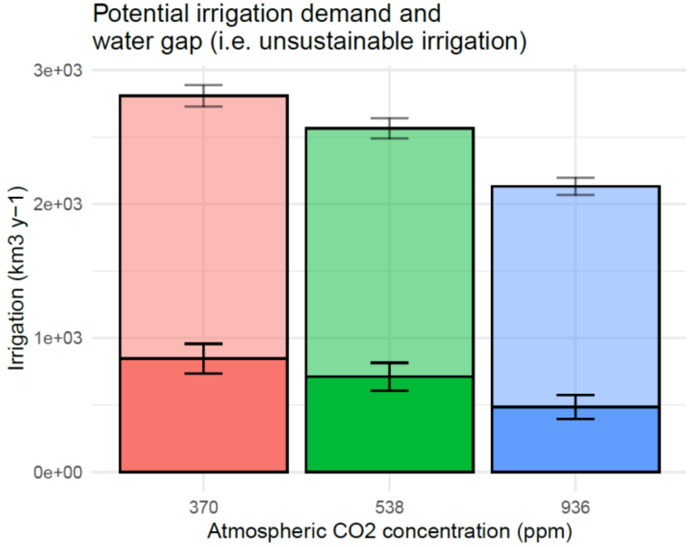
How much irrigated crop production is attainable worldwide?

VIC-WOFOST two-way coupled model framework





Change in achievable irrigated crop yield when constraining irrigation withdrawals to sustainable amounts, as compared to unconstrained withdrawals



Worldwide unconstrained total (light) and unsustainable (dark) irrigation withdrawal under various atmospheric CO2 concentrations (colours)

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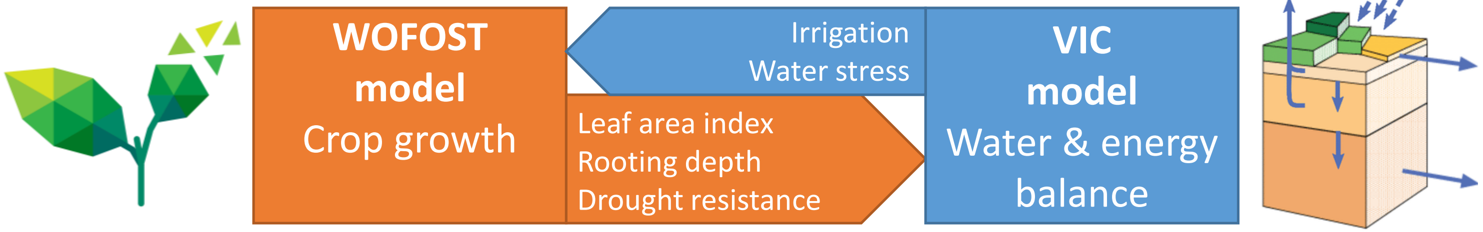
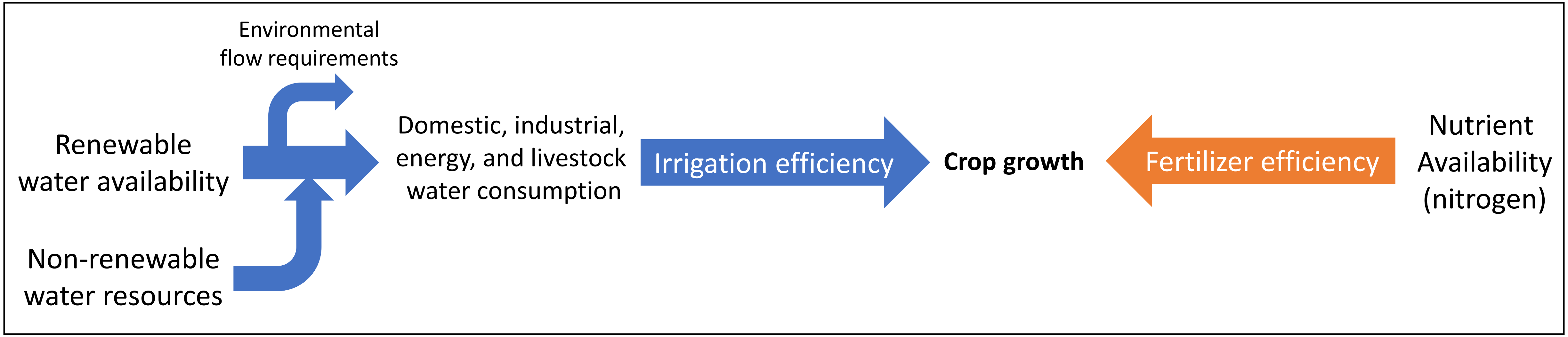


Supit et al. (1994); de Wit et al. (2019)
de Wit et al. (2020); wur.nl

Liang et al. (1994); Hamman et al. (2016);
Droppers et al. (2020); vic.readthedocs.org



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Model setup

Simulations	Nutrient limitations	Non-renewable withdrawals	Environmental water requirements
Potential		X	
Baseline	X	X	
Restricted	X		X
Attainable			X

Potential - unlimited by water and nutrients
Baseline - limited nutrients and rainfed limited by precipitation
Restricted - as baseline, but irrigation limited by sustainable water withdrawals
Attainable - as restricted, but unlimited by nutrients

Potential production – baseline production = production gap

Input data	Source
WFDEI weather forcing (1979-2016)	Weedon et al. (2014)
MIRCA2000 monthly cropland areas	Portmann et al. (2010)
Compiled crop fertilizer application	Mueller et al. (2012) Hurtt et al. (2020) Zhang et al. (2017)
QUEFTS mineralization rate	Sattari et al. (2014)
ISRIC-WISE soil characteristics	Batjes et al. (2016) Saxton et al. (1986)
AVHRR land cover	Hansen et al. (2000)
Domestic, industrial, energy and livestock water demands	Droppers et al. (2020)

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Worldwide irrigated wheat, maize, rice and soybean crop production for potential, baseline, attainable and restricted simulations.
From Droppers et al. (2021)

Irrigated Production	Potential (Mt y^{-1})	Baseline (% of potential)	Attainable (% of potential)	Restricted (% of potential)
Wheat	268	89	78	71
Maize	242	80	80	67
Rice	436	95	91	87
Soybean	15	100	94	94
Total	**961**	**89**	**85**	**78**

Potential - unlimited by water and nutrients
Baseline - limited nutrients and rainfed limited by precipitation
Restricted - as baseline, but irrigation limited by sustainable water withdrawals
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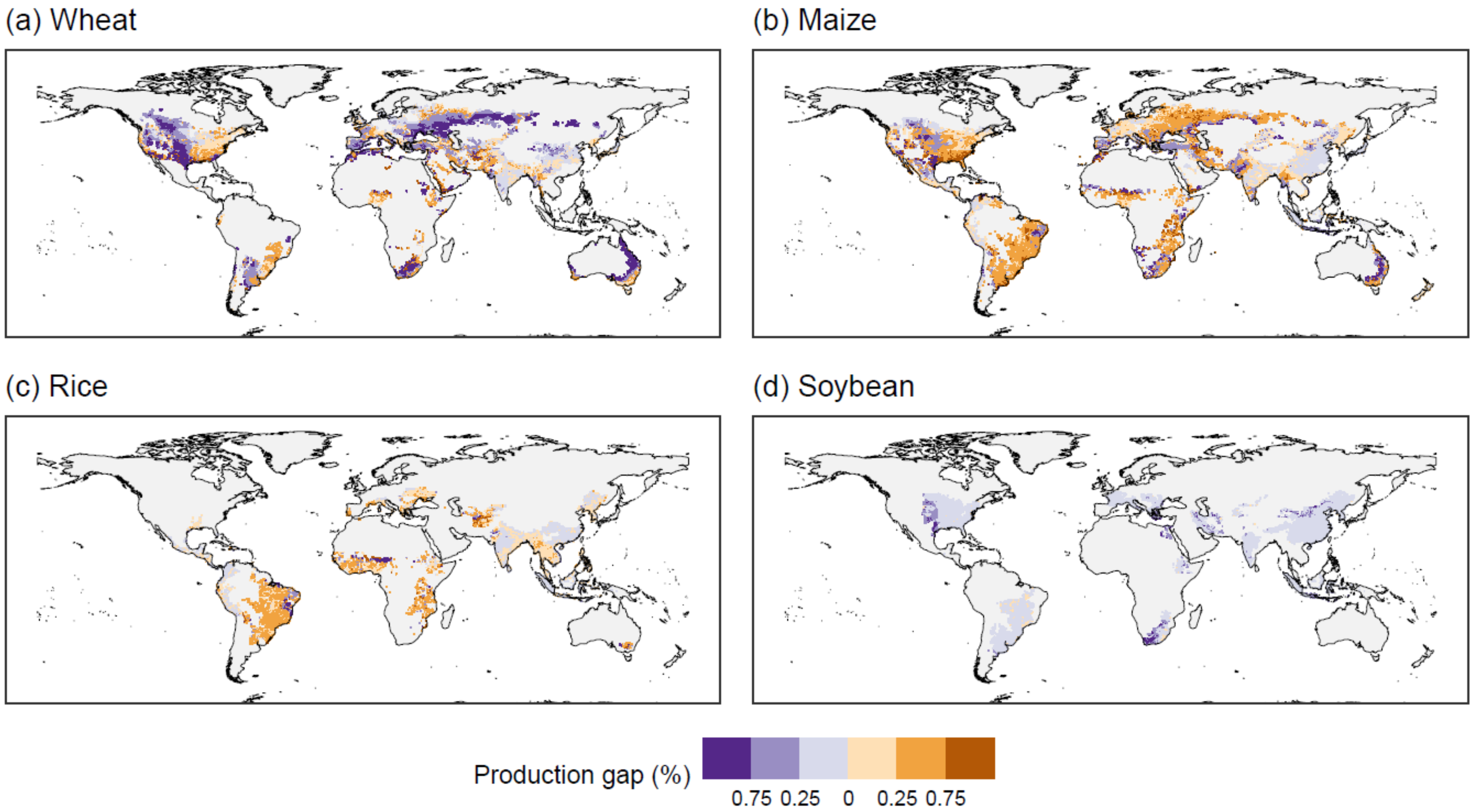

Crop production gap for rainfed and irrigated crop production (as % of potential production). Colours indicate whether the gap results mainly from water (purple) or nutrients (brown). From Droppers et al. (2021)

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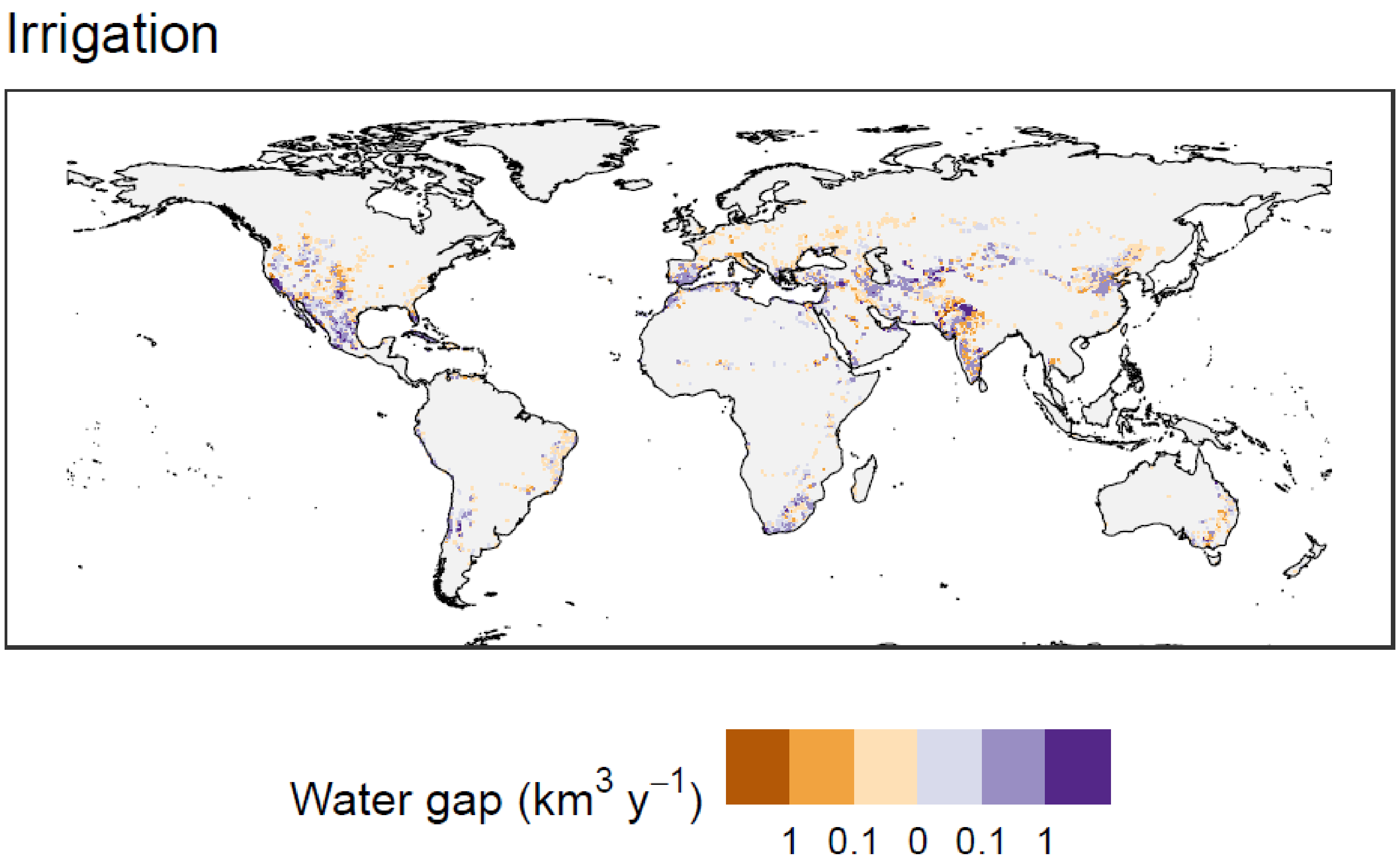

Water gap (unsustainable water withdrawals) for irrigated crop production.
Colours indicate whether the gap is at the expense of environmental flow requirements (brown)
Or non-renewable water withdrawals (purple).
From Droppers et al. (2021)

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Solutions

Water efficient crops and crop varieties (Godfrey et al., 2010; Morison et al., 2008)

Increasing irrigation efficiencies (Jägermeyr et al., 2017; Jägermeyr et al., 2016)

Inter-basin water transfers (Liu et al., 2017)

Reallocation and expansion of irrigation in other regions (Rosa et al., 2018; Rosa et al., 2019; Pastor et al., 2019)

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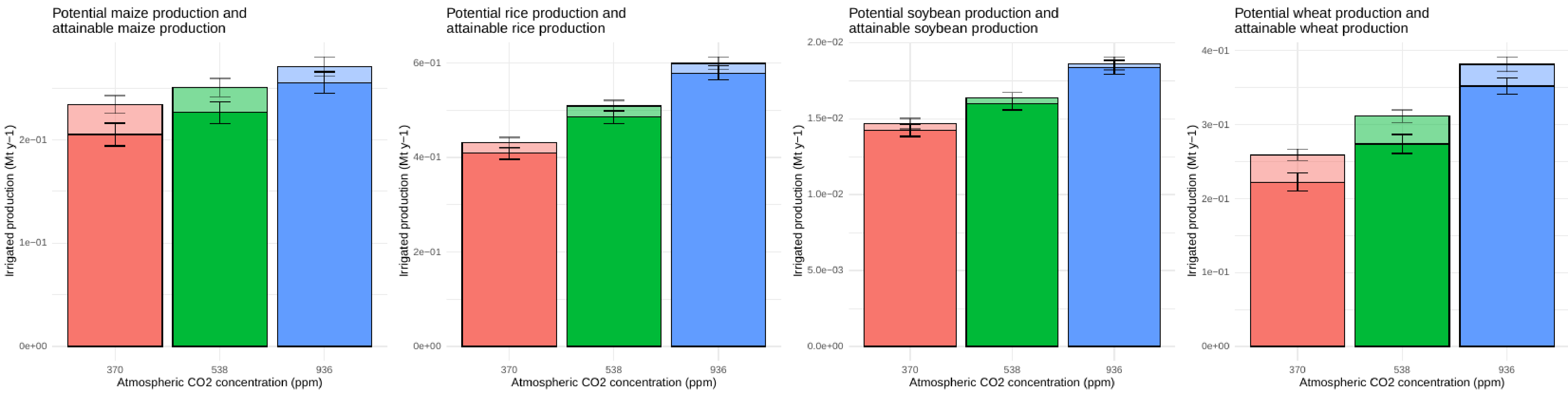

Worldwide potential (light) and attainable (dark) irrigated crop production
Under various atmospheric CO_2 concentrations (colours)

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