

Supplementary material – Reducing greenhouse gas emissions in agriculture without compromising food security?

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1 Modelling framework

For the present analysis we apply the Global Biosphere Management Model (GLOBIOM) (Havlík et al., 2014), a partial equilibrium model of the global agricultural and forestry sectors. In GLOBIOM, crop and livestock production are represented with a high spatial resolution at the level of Simulation Units (SimU) going down to 5x5 minutes of arc, which depict different production and management systems, differences in natural resource and climatic conditions as well as differences in cost structures and input use. Here, these units are aggregated to 2x2 degrees. The model explicitly covers 18 major crops that together represent over 70% of harvested area and 85% of vegetal calorie supply. Crops are produced in four management systems (subsistence, low input - rainfed, high input – rainfed, and high input - irrigated) whose input structure is defined by Leontief production functions. Production functions are parameterized using the bio-physical crop growth model EPIC (Environmental Policy Integrated Model) (Williams, 1995). In the livestock sector, four species aggregates (bovines, small ruminants, pigs, and poultry) are distinguished. Ruminants can be produced in eight alternative production systems and monogastrics in two. With respect to animal species, distinction is made between dairy and other bovines, dairy and other sheep and goats, laying hens and broilers, and pigs. For each species, production system and SimU, livestock production is characterized in terms of yields, feed requirements, GHG emissions, manure production and nitrogen excretion. Switches between production systems allow for feedstuff substitution and for intensification or extensification of livestock production. The parameterization of the livestock sector is done with the RUMINANT model (Herrero et al., 2013) and initial spatial distribution of ruminants and their allocation between production systems is calibrated to Wint and Robinson (2007). The forestry sector represents the source for logs (for pulp, sawing and other industrial uses), biomass for energy, and traditional fuel wood, which are supplied from managed forest or short rotation plantations (SRP). Harvesting cost and mean annual increments are informed by the G4M global forestry model (Kindermann et al., 2008; Gusti, 2010).

Demand in GLOBIOM is modelled at the level of 30 aggregate economic regions and income elasticities are calibrated to mimic projections of the Food and Agriculture Organization of the United Nations (Alexandratos and Bruinsma, 2012). Prices are endogenously determined at the regional level to establish market equilibrium to reconcile demand, domestic supply and international trade. Land and other resources are allocated to the different production and processing activities to maximize a social welfare function which consists of the sum of producer and consumer surplus. Changes in socioeconomic and technological conditions, such as economic growth, population changes, and technological progress, lead

to adjustments in the product mix and the use of land and other productive resources. By solving the model in a recursive dynamic manner for 10 year time steps, decade-wise detailed trajectories of variables related to supply, demand, prices, and land use are generated.

GLOBIOM coupled with MESSAGE has been used to calculate carbon prices, as well as biomass demand for energy use, compatible with the five climate stabilization scenarios. MESSAGE (Riahi et al., 2007) is a system's engineering optimization model used for medium to long term energy system planning. The model makes choices among a number of energy supply and conversion technologies in order to meet final energy demand while accounting for resource extraction, imports and exports, conversion, transport and distribution. The choices are made in order to meet optimization criteria (minimization of costs) while fulfilling exogenously determined final energy demand based on a macroeconomic equilibrium framework (MESSAGE-MACRO) (Messner and Schrattenholzer, 2000).

2 Scenarios

2.1 Socio-economic scenarios

A baseline scenario was implemented in GLOBIOM, using population and GDP projections from the Shared Socio-economic Pathway 2 (SSP2) (O'Neill et al., 2014; Fricko et al., 2016) which depicts a "Middle of the Road" scenario with moderate challenges to mitigation and adaptation. Demand for animal protein is relatively high, due to comparatively strong income and population growth. For food demand projections, income elasticities are calibrated to mimic FAO projections of diets (Alexandratos and Bruinsma, 2012). Moderate reductions in food waste and losses over time add to the availability of agricultural products. Technological change for crops is based on 18 crop specific yield responses function to GDP per capita growth estimated for different income groups using a fixed effects model. The response to GDP per capita was differentiated over four income groups oriented at World Bank's income classification system (<1.500, 1.500-4.000, 4.000-10.000, >10.000 USD GDP per capita). Country level yield data was provided from FAOSTAT while GDP per capita was based on World Bank data (1980-2009). Fertilizer use and costs of agricultural production increase in proportion with yields. Productivity changes through technological change in the livestock sector follow Bouwman et al. (2005). Transition towards more efficient livestock production systems takes place at a moderately fast pace.

Table S1. Average global productivity trends through technological change compared to 2010.

		2010	2020	2030	2040	2050
Crop sector	Wheat	1.00	1.13	1.25	1.34	1.42
	Rice	1.00	1.14	1.27	1.36	1.45
	Coarse grains	1.00	1.16	1.30	1.41	1.51
	Oilseeds	1.00	1.13	1.23	1.32	1.39
	Sugar crops	1.00	1.09	1.17	1.24	1.31
Livestock sector	Ruminant meat	1.00	1.07	1.12	1.17	1.21
	Non ruminant meat	1.00	1.01	1.01	1.02	1.02
	Milk	1.00	1.02	1.04	1.06	1.08

2.2 Climate stabilization scenarios

Global climate stabilization scenarios represented through RCPs are based on outputs from the MESSAGE-GLOBIOM framework as described below based on Fricko et al. (2016). First, a two dimensional emulator of the GLOBIOM model for SSP2 was created containing the land-use implications for scenarios combining six different bioenergy price levels (up to 13 \$/GJ) and eleven different carbon price levels (up to 1000 \$/tCO₂eq). The resulting GLOBIOM land use pathways cover an extensive space of land-use developments for SSP2 conditional on biomass and carbon prices. This GLOBIOM emulator is available offline, and is integrated into MESSAGE. During its energy-system optimization, MESSAGE can hence select and combine emulated land-use pathways for each of its geographical regions based on the modelled bioenergy demands, taking into account estimated GHG emissions and bio-energy prices related to the chosen land-use pathways. Once an equilibrium has been determined in MESSAGE, specific outputs (bioenergy demand, carbon prices) implemented in GLOBIOM, the final scenarios are quantified, and land use related results are reported. This process ensures that a given RCP emission trajectory and carbon and biomass prices for the land use sector are fully consistent between the two models. However, second order impacts on production costs e.g. labour, capital, or other costs, were not explicitly considered in the current feedback runs in GLOBIOM. This would further improve the consistency of results.

Biomass demand in GLOBIOM can be satisfied from multiple sources: managed forests, short rotation tree plantations and forest industry residues. Carbon prices are implemented in GLOBIOM for CO₂ and non-CO₂ emissions from the whole agriculture, forestry and land use (AFOLU) sector, including or not SOC options. The price acts as a tax on emissions and as a subsidy for carbon sequestration. In the global scenarios, a uniform tax is implemented in all regions. The highest price corresponds to 190 USD/tCO₂ eq

in 2050, which is the scenario compatible with keeping global warming below 1.5°C by 2100 and radiative a forcing values of 1.9 W/m².

Table S2. Future carbon price and bioenergy demand developments over time in the different climate stabilization scenarios.

	Scenario	2020	2030	2040	2050
Biomass demand [EJ]	Baseline	52	52	52	53
	3.1°C scenario	52	52	52	53
	2.6°C scenario	51	53	56	61
	2.2°C scenario	49	54	59	70
	2.0°C scenario	51	63	71	81
	1.5°C scenario	56	73	83	103
Carbon price [USD/tCO₂eq]	Baseline	-	-	-	-
	3.1°C scenario	0	1	1	2
	2.6°C scenario	2	5	5	10
	2.2°C scenario	5	10	15	25
	2.0°C scenario	15	25	40	65
	1.5°C scenario	45	70	115	190

Both biomass demand and emissions prices are consistent with pathways of the global energy and emissions price regimes required for attaining the individual RCPs. The policy assumption implicit to these scenarios is one of full global collaboration in where a global carbon price regime is established to limit emissions to the necessary levels to achieve a given RCP. All countries participate in this regime from the onset.

2.3 Regional climate regimes and SOC sequestration

Different regional climate regimes were quantified using carbon prices and bioenergy demand from the 1.5 °C scenario with global cooperation. For regions participating in a regional climate regime, we imposed the regional carbon prices and bioenergy demand from the global 1.5 °C scenario. For regions not participating in the climate regime, we kept the baseline values. Consequently, regional mitigation scenarios do not achieve the necessary GHG abatement required in the AFOLU sector consistent with reaching the 1.5 °C target cost-efficiently at global scale.

Similarly, carbon prices and bioenergy demand from the global stabilization scenarios were used to quantify the impacts on mitigation potentials and food security for the two additional SOC scenario variants. Here we quantify two alternatives: i) imposing carbon prices and bioenergy demand consistent with the global stabilization scenarios (without SOC sequestration) in GLOBIOM, which results in an

overestimation of the GHG abatement required to reach the different targets as SOC sequestration delivers additional carbon sequestration, and ii) imposing GHG abatement levels and bioenergy demand consistent with the global stabilization scenarios (without SOC sequestration), which results in the exact reproduction of the GHG abatement required to meet the specific targets. In both cases, we assume that other sectors are not impacted by the availability of the SOC sequestration potential and do not adjust their mitigation efforts. The two scenarios give an indicative upper and lower boundary of what could be expected from the AFOLU sector once SOC sequestration measures are available.

2.4 Demand sensitivity analysis

The applied demand elasticities are an important driver of the model results with respect to food security. Valin et al. (2014) identify a broad range of elasticity values applied across different well-established agricultural sector models, which clearly highlights the remaining uncertainty. The difference in the applied elasticity value may also reflect the difference across modeling approaches e.g. partial versus general equilibrium models, short run versus long run etc. (Bhargava, 1991; Yu et al., 2004; Valin et al., 2014) but may also hint to a plausible range of values and consequently demand side impacts. To test the robustness of results, we performed a demand sensitivity analysis where we shift product specific regional price elasticities in GLOBIOM from the default set-up (Table S3) to values as reported in Valin et al. (2014) calculated as a median across several global agricultural sector models (Table S4). Results from the sensitivity analysis are displayed further below.

Table S3. Assumed own-price elasticity for agricultural commodities in the default set-up across scenarios by 2050.

	CIS	EAS	EU28	LAM	MEN	NAM	OCE	SAS	SEA	SSA	WLD
CGR	-0.18	-0.25	-0.06	-0.17	-0.24	-0.05	-0.05	-0.40	-0.28	-0.46	-0.34
OSD	-0.21	-0.35	-0.08	-0.23	-0.23	-0.07	-0.06	-0.37	-0.29	-0.41	-0.33
RIC	-0.17	-0.26	-0.06	-0.22	-0.23	-0.05	-0.09	-0.35	-0.28	-0.38	-0.30
SGC	-0.41	-0.36	-0.11	-0.41	-0.43	-0.09	-0.12	-0.57	-0.49	-0.60	-0.47
WHT	-0.17	-0.26	-0.06	-0.20	-0.22	-0.05	-0.06	-0.35	-0.28	-0.38	-0.24
RUM	-0.44	-0.61	-0.26	-0.43	-0.44	-0.25	-0.25	-0.53	-0.50	-0.55	-0.43
NRM	-0.45	-0.63	-0.27	-0.43	-0.44	-0.25	-0.27	-0.53	-0.50	-0.53	-0.48
DRY	-0.46	-0.57	-0.27	-0.45	-0.44	-0.26	-0.26	-0.55	-0.51	-0.57	-0.43

Products: CGR – coarse grains, OSD – oilseeds, RIC – rice, SGC – sugar crops, WHT – wheat, RUM – ruminant products, NRM – non ruminant products, DRY – milk. For regional aggregation see section 7.

Table S4. Assumed own-price elasticity for agricultural commodities in the demand sensitivity analysis across scenarios by 2050.

	CIS	EAS	EU28	LAM	MEN	NAM	OCE	SAS	SEA	SSA	WLD
CGR	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.06	-0.05	-0.07	-0.06
OSD	-0.07	-0.12	-0.05	-0.08	-0.08	-0.05	-0.05	-0.12	-0.10	-0.14	-0.11
RIC	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.06	-0.05	-0.06	-0.05
SGC	-0.17	-0.15	-0.06	-0.17	-0.17	-0.05	-0.06	-0.23	-0.20	-0.24	-0.19
WHT	-0.05	-0.06	-0.05	-0.05	-0.05	-0.05	-0.05	-0.07	-0.06	-0.08	-0.06
RUM	-0.28	-0.40	-0.17	-0.28	-0.28	-0.06	-0.17	-0.35	-0.33	-0.36	-0.27
NRM	-0.23	-0.33	-0.14	-0.23	-0.22	-0.06	-0.14	-0.28	-0.26	-0.28	-0.24
DRY	-0.26	-0.33	-0.16	-0.26	-0.25	-0.06	-0.15	-0.32	-0.30	-0.33	-0.24

Products: CGR – coarse grains, OSD – oilseeds, RIC – rice, SGC – sugar crops, WHT – wheat, RUM – ruminant products, NRM – non ruminant products, DRY – milk. For regional aggregation see section 7.

3 Mitigation options

3.1 Structural mitigation options

GLOBIOM represents a comprehensive set of management systems for the crop- and livestock sector. For the crop sector, four different crop management systems are differentiated using the EPIC model (Williams, 1995). In the livestock sector, also various production systems and livestock species are parameterized (Herrero et al., 2013). The detailed representation of production systems allows the model to explicitly represent structural changes in the agricultural sector under a climate policy. Farmers can switch to more GHG efficient management practices on site, reallocate production to more productive areas within a region, or through international trade across regions. More information on the parameterization of structural mitigation options and detailed information on the regional marginal abatement cost curves (MACCs) are provided in the supplementary material of Havlík et al. (2014).

3.2 Technical non-CO₂ mitigation options

Emission reduction potentials (% emission savings), costs (annual costs i.e. direct costs and labor costs, change in input costs, and investment costs i.e. for anaerobic digesters), and potential impacts on productivities (% increase/decrease) were taken from the EPA mitigation options database (EPA, 2006; Beach et al., 2008). Relative emission savings and productivity changes were then applied to the different management systems in the GLOBIOM model to calculate absolute changes in GHG emissions and product output. Mitigation options (characterized by GHG reduction, productivity changes, and economic costs) are implemented in the model as additional management activities than can be applied on top of a production system. Mitigation options are adopted if the economic benefit i.e. through avoided carbon tax payments, potential productivity changes, exceed the cost of an option.

3.3 SOC sequestration options

MACCs for SOC sequestration are based on Smith et al. (2008) for a carbon price of 20, 50 and 100 USD/tCO₂ in the A2 scenario. These 3 points of the MACCs from improved cropland and grazing management have been implemented in GLOBIOM as three additive “mitigation technologies” with different carbon sequestration coefficients reflecting the implementation rates and costs from Smith et al. (2008). Emission savings from the restoration of organic soils and degraded land were also considered in addition. Adoption rates for cropland management have been adjusted in regions where adoption rates decrease with higher carbon prices (i.e. North America and Europe) and replaced with average adoption rates outside these regions. Adoption rates are cumulative and represent maximum % shares of cropland/grassland area on which a practise can be applied i.e. 34% of the cropland area is eligible for improved cropland management in North America at a carbon price of 20\$/tCO₂, 46% at a carbon price of 50\$/tCO₂. SOC sequestration options are only applied once on each field and may get adopted from 2020 onwards once expected revenues (i.e. through the carbon price scheme) exceed costs. Average sequestration rates are assumed constant until 2050, which seems reasonable since other studies estimate that additional SOC sequestration of these options may be realized over a limited time span of around 20-40 years (Paustian et al., 2016; Minasny et al., 2017). Yield increases for the cropland SOC sequestration options have been implemented for Africa, Latin America and Asia based on (Lal, 2006). Annual yield increases of crop aggregates reached 1.5, 1.2 and 0.7% in Africa, Latin America and Asia, respectively, and 0.9% at world average, per tCO₂/ha sequestered annually.

Table S5: MACC for improved cropland management.

	EF CO ₂ (tCO ₂ /ha)	20 \$ Adoption (%)	50 \$ Adoption (%)	100 \$ Adoption (%)	20 \$ Cost (\$/ha)	50 \$ Cost (\$/ha)	100 \$ Cost (\$/ha)	Rel. Yield increase
<i>North America</i>	1.06	0.34	0.12	0.02	19.1	47.7	95.5	0.096
<i>Eastern Europe</i>	1.19	0.34	0.12	0.02	21.3	53.3	106.7	0.108
<i>Northern Europe</i>	1.20	0.34	0.12	0.02	21.6	54.0	107.9	0.109
<i>Southern Europe</i>	1.25	0.34	0.12	0.02	22.6	56.4	112.8	0.114
<i>Western Europe</i>	1.21	0.34	0.12	0.02	21.8	54.5	109.0	0.110
<i>Russian Federation</i>	0.45	0.50	0.15	0.01	8.2	20.4	40.8	0.041
<i>Caribbean</i>	0.53	0.50	0.15	0.01	9.5	23.7	47.4	0.062
<i>Central America</i>	0.49	0.50	0.15	0.01	8.9	22.2	44.4	0.058
<i>South America</i>	0.51	0.50	0.15	0.01	9.2	23.1	46.2	0.060
<i>Oceania</i>	0.41	0.50	0.15	0.01	7.4	18.6	37.1	0.029
<i>Eastern Africa</i>	0.43	0.50	0.15	0.01	7.8	19.6	39.1	0.064
<i>Middle Africa</i>	0.53	0.50	0.15	0.01	9.5	23.7	47.4	0.078
<i>Northern Africa</i>	0.53	0.50	0.15	0.01	9.5	23.7	47.4	0.078
<i>Southern Africa</i>	0.39	0.50	0.15	0.01	7.0	17.5	35.0	0.058
<i>Western Africa</i>	0.53	0.50	0.15	0.01	9.5	23.7	47.4	0.078
<i>Western Asia</i>	0.51	0.50	0.15	0.01	9.2	23.0	46.0	0.036
<i>Southeast Asia</i>	0.50	0.50	0.15	0.01	9.0	22.5	45.1	0.035
<i>South Asia</i>	1.20	0.46	0.11	0.07	21.5	53.8	107.7	0.083
<i>East Asia</i>	1.19	0.64	0.01	0.01	21.4	53.5	107.1	0.083
<i>Central Asia</i>	0.49	0.50	0.15	0.01	8.8	22.0	44.0	0.034
<i>Japan</i>	0.49	0.50	0.15	0.01	8.8	22.0	44.0	0.034

Table S6: MACC for improved grassland management.

	EF CO ₂ (tCO ₂ /ha)	20 \$ Adoption (%)	50 \$ Adoption (%)	100 \$ Adoption (%)	20 \$ Cost (\$/ha)	50 \$ Cost (\$/ha)	100 \$ Cost (\$/ha)
<i>North America</i>	0.21	0.20	0.30	0.50	3.9	9.7	19.3
<i>Eastern Europe</i>	0.44	0.20	0.30	0.50	8.0	20.0	40.0
<i>Northern Europe</i>	0.45	0.20	0.30	0.50	8.0	20.1	40.1
<i>Southern Europe</i>	0.45	0.20	0.30	0.50	8.1	20.1	40.3
<i>Western Europe</i>	0.45	0.20	0.30	0.50	8.0	20.1	40.1
<i>Russian Federation</i>	0.34	0.20	0.30	0.50	6.2	15.4	30.9
<i>Caribbean</i>	0.45	0.20	0.30	0.50	8.1	20.1	40.3
<i>Central America</i>	0.22	0.20	0.30	0.50	4.0	10.0	19.9
<i>South America</i>	0.40	0.20	0.30	0.50	7.2	18.0	36.0
<i>Oceania</i>	0.21	0.20	0.30	0.50	3.7	9.4	18.7
<i>Eastern Africa</i>	0.42	0.20	0.30	0.50	7.5	18.8	37.6
<i>Middle Africa</i>	0.38	0.20	0.30	0.50	6.9	17.1	34.3
<i>Northern Africa</i>	0.28	0.20	0.30	0.50	5.0	12.4	24.9
<i>Southern Africa</i>	0.21	0.20	0.30	0.50	3.8	9.5	18.9
<i>Western Africa</i>	0.32	0.20	0.30	0.50	5.8	14.4	28.9
<i>Western Asia</i>	0.41	0.20	0.30	0.50	7.4	18.5	36.9
<i>Southeast Asia</i>	0.34	0.20	0.30	0.50	6.0	15.1	30.2
<i>South Asia</i>	0.28	0.20	0.30	0.50	5.0	12.5	25.0
<i>East Asia</i>	0.39	0.20	0.30	0.50	7.1	17.7	35.4
<i>Central Asia</i>	0.44	0.20	0.30	0.50	7.9	19.7	39.4
<i>Japan</i>	0.45	0.20	0.30	0.50	8.0	20.0	40.1

4 Impact on people undernourished

The population at risk of hunger was estimated for 2050 using the FAO approach¹ as described in detail in Hasegawa et al. (2015) by multiplying the share of the population at risk of hunger (PoU) for each scenario with the total population in 2050 from SSP2 (Kc and Lutz).

To calculate the share of the population at risk of hunger (Equ. 1) three parameters are needed: i) mean food caloric intake per person per day (cal), ii) the mean minimum dietary energy requirement (MDER), and iii) the coefficient of variation of food distribution of the dietary energy consumption in a country (CV). The proportion of the population with less than the MDER is defined as the proportion of the population at risk of hunger.

GLOBIOM calculated for each scenario commodity specific per-capita food consumption at the regional level for a representative household (cal). MDER was calculated for each region in 2050 using the regional MDER in the base year from FAO, adjusted for the minimum energy requirements per person in different age and sex groups², and the population of each age and sex group in 2050 from SSP2 (Kc and Lutz). The coefficient CV is an indicator of food security observed in a household survey conducted by the FAO and ranges from 0 to 1. A higher CV means that the food consumption level varies more widely in the country and food is distributed more unequally. Hence, for the same mean consumption, the percentage of the population at risk of hunger would be higher in a country with a high CV. FAO country data for CV are weighted on the basis of population data in the base year and aggregated to regional classifications to obtain the CV of regions. CV within a region is assumed to obey a standard normal cumulative distribution. The standard normal cumulative distribution has two parameters, the mean μ (Equ. 2) and the variance σ (Equ. 3). These can be represented using food intake (cal) and the coefficient of variation CV.

$$\text{Equ. 1:} \quad PoU = \Phi \left(\frac{\log MDER - \mu(cal, \sigma)}{\sigma} \right)$$

$$\text{Equ. 2:} \quad \mu(cal, \sigma) = \log_e cal - \frac{\sigma^2}{2}$$

¹ FAO Methodology for the measurement of food deprivation: updating the minimum dietary energy requirements, 2008 http://www.fao.org/fileadmin/templates/ess/documents/food_security_statistics/metadata/undernourishment_methodology.pdf

² Based on Table 26 from FAO/WHO http://apps.who.int/iris/bitstream/10665/41042/1/WHO_TRS_522_eng.pdf

Equ. 3: $\sigma = [\log_e(CV^2 + 1)]^{0.5}$

where

PoU: share of population at risk of hunger

Φ : standard normal cumulative distribution

cal: mean food calorie intake per person per day in 2050

Future changes in the inequality of food distribution in a country were considered by changing the CV of the distribution of dietary energy consumption among households within the country along with income growth. Future change in the CV was assumed based on observed data. A function between CV and income was estimated using nation-level observations for 2005 (FAO, 2013) (Figure S1). We used a relative change taken from the function to change the CV from the base-year value according to future income changes. CV was not allowed to fall below the lowest observed value of 0.2.

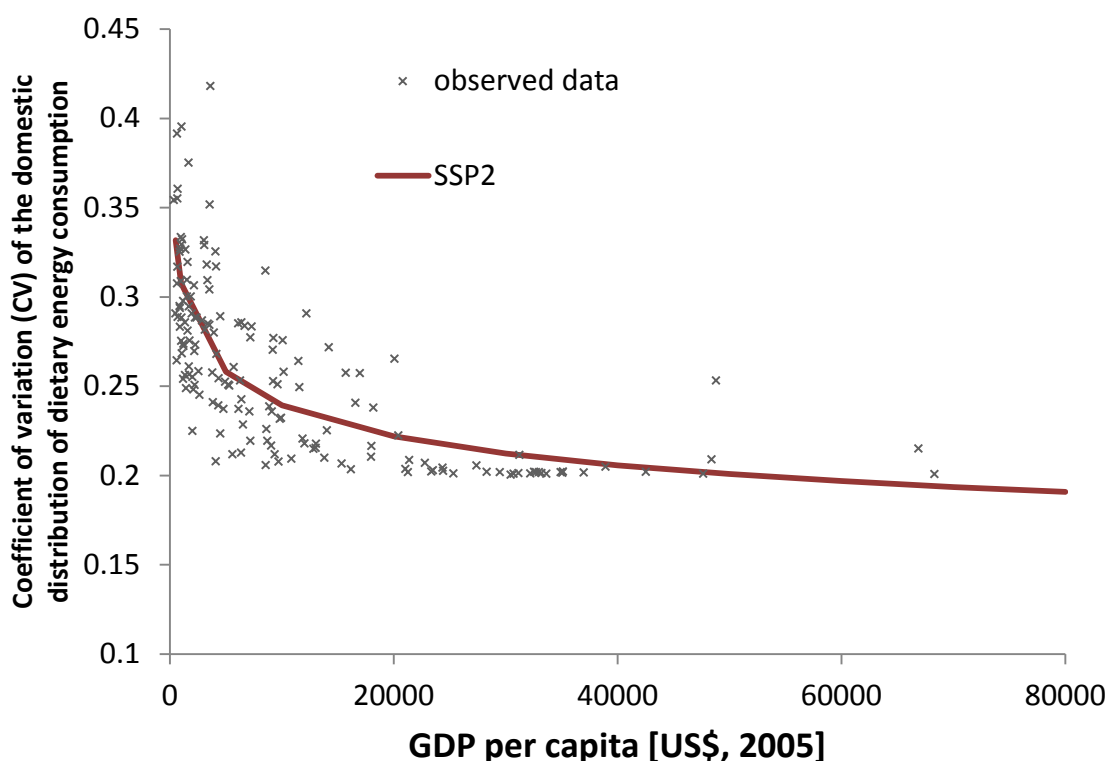


Figure S1 Observed and assumed relationships between income and the equality of food domestic distribution.

Table S9 and Table S10 present the numbers of undernourished by 2050 in each scenarios in the default set-up and for the demand sensitivity analysis. The number of undernourished is projected to decrease in our baseline scenario from around 850 million people in 2000 to around 200 million in the

default set-up (and around 220 million in the demand sensitivity analysis) by 2050. This represents a decrease from around 14% of the global population in 2000 to around 2% by 2050.

5 Additional results

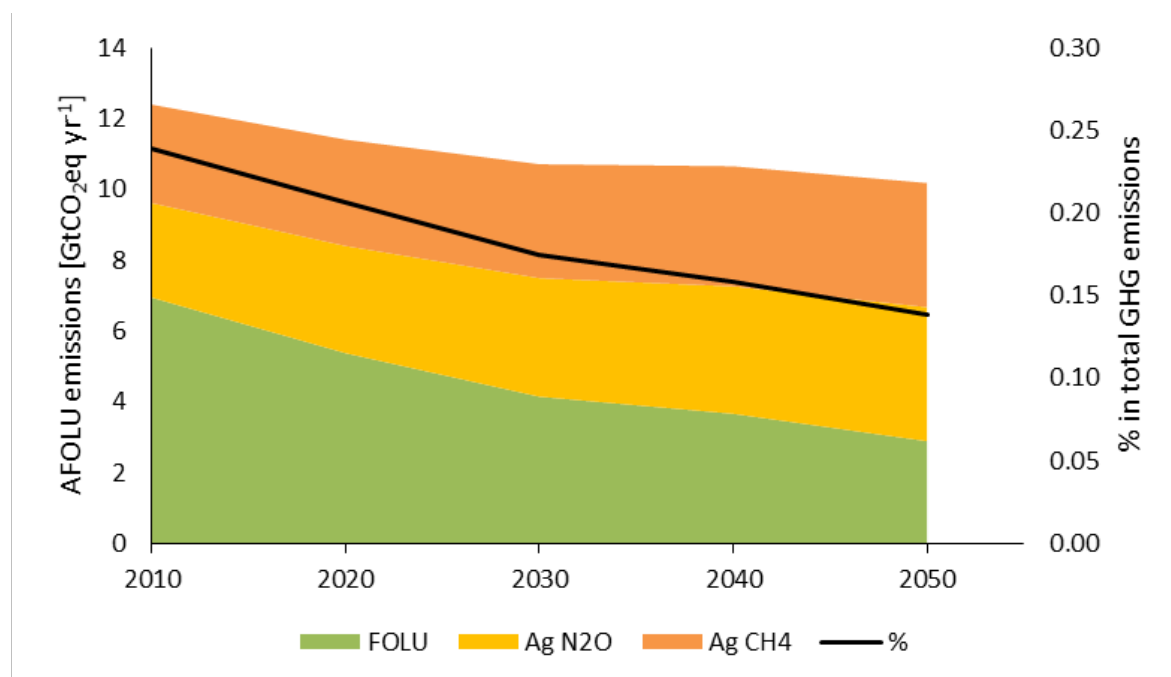


Figure S2. Development of AFOLU emissions in the baseline scenario over time in GtCO₂eq/yr and relative share in total anthropogenic GHG emissions in the default set-up.

Table S7. Global average food consumption in kcal per capita in the default set-up across scenarios by 2050.

Climate target	Climate regime	no SOC	SOC	SOC+	SOC-
Baseline		3,062	3,062	3,072	3,062
3.1°C scenario		3,054	3,054	3,067	3,054
2.6°C scenario	Global	3,028	3,028	3,043	3,028
2.2°C scenario		2,996	2,997	3,013	2,996
2.0°C scenario		2,931	2,937	2,952	2,934
1.5°C scenario		2,778	2,806	2,825	2,791
1.5°C scenario	Annex-I only	3,007	3,013	3,023	
	Annex-I & Brazil	2,993	3,002	3,011	
	Annex-I & Congo Basin	3,005	3,011	3,021	
	Annex-I & India	2,975	2,987	2,999	NE
	Annex-I & China	2,954	2,965	2,980	
	Annex-I & BRICS	2,893	2,918	2,936	
	Excl. LDC	2,844	2,864	2,882	
	Ag only Annex-I	2,923	2,942	2,953	

Table S8. Global average food consumption in kcal per capita in the demand sensitivity analysis across scenarios by 2050

Climate target	Climate regime	no SOC	SOC	SOC+	SOC-
Baseline		3,051	3,051	3,055	3,051
3.1°C scenario		3,049	3,049	3,053	3,049
2.6°C scenario	Global	3,041	3,041	3,045	3,041
2.2°C scenario		3,026	3,027	3,032	3,026
2.0°C scenario		3,004	3,005	3,010	3,005
1.5°C scenario		2,945	2,953	2,958	2,950
1.5°C scenario	Annex-I only	3,029	3,032	3,035	
	Annex-I & Brazil	3,020	3,025	3,029	
	Annex-I & Congo Basin	3,028	3,031	3,034	
	Annex-I & India	3,013	3,018	3,023	NE
	Annex-I & China	3,009	3,013	3,018	
	Annex-I & BRICS	2,984	2,993	2,999	
	Excl. LDC	2,965	2,972	2,978	
	Ag only Annex-I	2,995	3,001	3,006	

Table S9. Million people undernourished by 2050 in the default set-up across scenarios by 2050.

Climate target	Climate regime	no SOC	SOC	SOC+	SOC-
Baseline		204	204	199	204
3.1°C scenario		210	210	202	210
2.6°C scenario	Global	226	226	217	226
2.2°C scenario		249	248	236	248
2.0°C scenario		305	300	287	303
1.5°C scenario		504	466	439	484
1.5°C scenario	Annex-I only	229	227	220	
	Annex-I & Brazil	237	233	227	
	Annex-I & Congo Basin	230	228	221	
	Annex-I & India	260	251	242	NE
	Annex-I & China	274	265	253	
	Annex-I & BRICS	338	310	291	
	Excl. LDC	400	376	355	
	Ag only Annex-I	302	286	275	

Table S10. Million people undernourished in the demand sensitivity analysis across scenarios by 2050.

Climate target	Climate regime	no SOC	SOC	SOC+	SOC-
Baseline		223	223	221	223
3.1°C scenario		225	225	222	225
2.6°C scenario	Global	229	229	227	229
2.2°C scenario		239	238	235	239
2.0°C scenario		254	253	249	253
1.5°C scenario		301	293	289	297
1.5°C scenario	Annex-I only	233	231	229	
	Annex-I & Brazil	238	235	232	
	Annex-I & Congo Basin	233	231	229	
	Annex-I & India	245	242	238	NE
	Annex-I & China	246	243	239	
	Annex-I & BRICS	265	258	253	
	Excl. LDC	280	276	271	
	Ag only Annex-I	258	253	250	

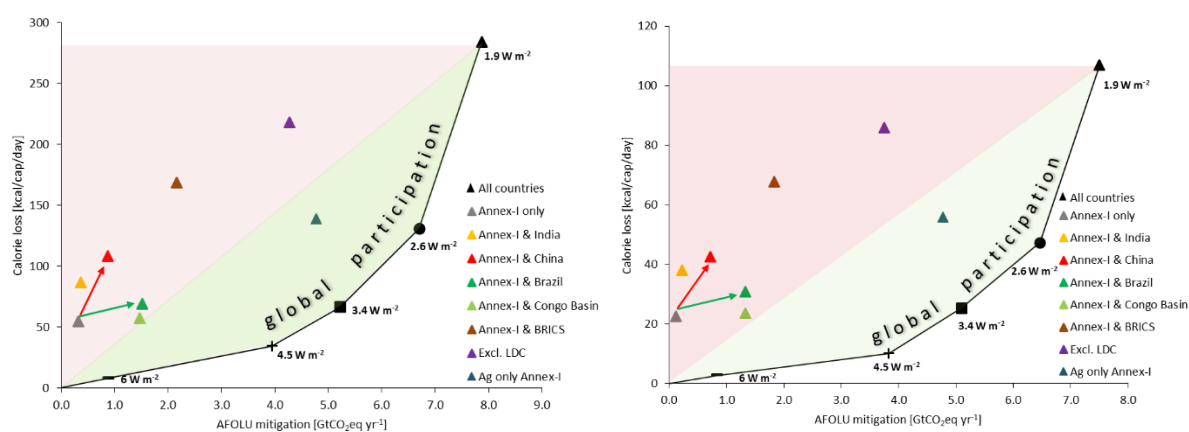


Figure S3. Trade-offs and synergies between annual AFOLU mitigation and loss in global average daily dietary energy (kcal per capita) consumption by 2050 under a uniform carbon price. Left graph – default set-up, right graph – demand sensitivity analysis.

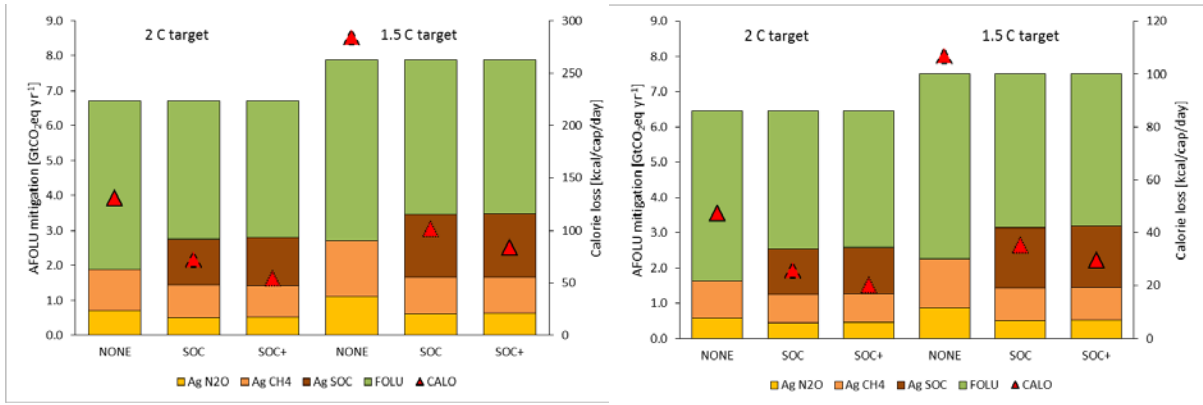


Figure S4. Global AFOLU mitigation option portfolio under two climate stabilization targets (2.6 W m^{-2} – $2 \text{ }^\circ\text{C}$ target, 1.9 W m^{-2} – $1.5 \text{ }^\circ\text{C}$ target) and loss in global average daily dietary energy (kcal per capita) consumption. Left graph – default set-up, right graph – demand sensitivity analysis.

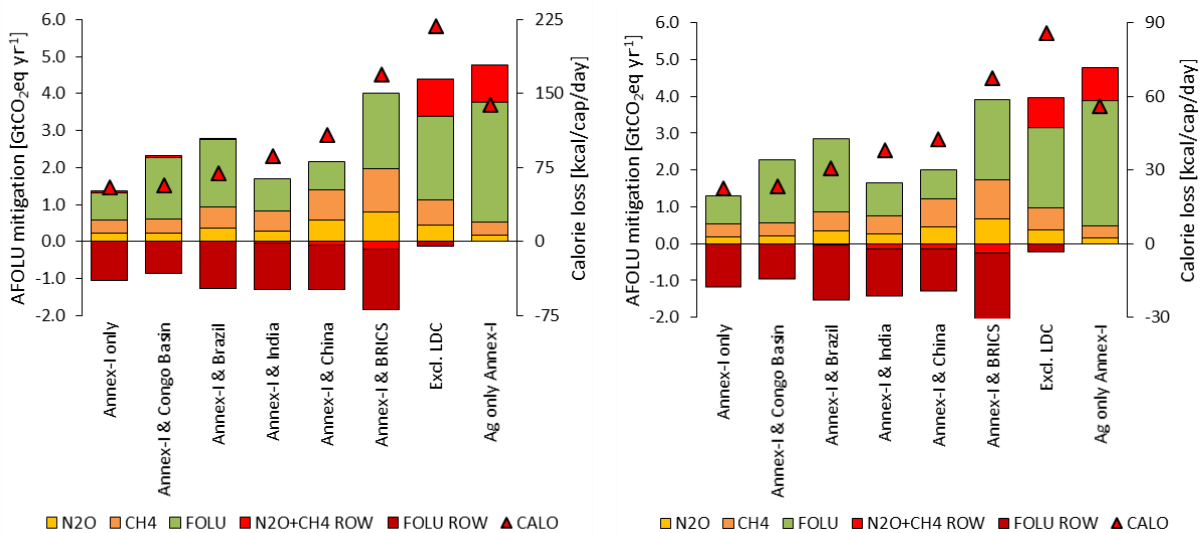


Figure S5. Domestic AFOLU mitigation (N_2O , CH_4 , FOLU) in $\text{GtCO}_2\text{eq yr}^{-1}$ inside a climate regime, emission change outside the climate regime (rest of the world – ROW), and loss in global average daily dietary energy (kcal per capita) consumption in a $1.5 \text{ }^\circ\text{C}$ scenario. Left graph – default set-up, right graph – demand sensitivity analysis.

Table S11. Relative change in crop production, consumption, and prices across regions compared to the baseline scenario in 2050 in the default set-up.

Climate Target	SOC	Item	CIS	EAS	EU28	LAM	MEN	NAM	OCE	SAS	SEA	SSA	WLD
3.1°C scenario	None	Production	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00
3.1°C scenario	None	Consumption	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00
3.1°C scenario	None	Price	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.00
3.1°C scenario	SOC	Production	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00
3.1°C scenario	SOC	Consumption	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00
3.1°C scenario	SOC	Price	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.00
3.1°C scenario	SOC+	Production	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.99	0.99	1.00
3.1°C scenario	SOC+	Consumption	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00
3.1°C scenario	SOC+	Price	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.00
3.1°C scenario	SOC-	Production	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00
3.1°C scenario	SOC-	Consumption	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00
3.1°C scenario	SOC-	Price	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.00
2.6°C scenario	None	Production	1.00	0.97	1.01	0.98	0.99	1.00	1.00	1.00	0.97	0.95	0.98
2.6°C scenario	None	Consumption	0.99	0.96	1.00	0.99	1.00	0.99	1.01	0.99	0.98	0.97	0.98
2.6°C scenario	None	Price	1.01	1.02	1.01	1.01	1.01	1.01	1.01	1.02	1.04	1.02	1.02
2.6°C scenario	SOC	Production	1.00	0.97	1.01	0.98	0.99	1.00	1.00	1.00	0.97	0.95	0.98
2.6°C scenario	SOC	Consumption	0.99	0.96	1.00	0.99	1.00	0.99	1.01	0.99	0.98	0.97	0.98
2.6°C scenario	SOC	Price	1.01	1.02	1.01	1.01	1.01	1.01	1.01	1.02	1.04	1.02	1.02
2.6°C scenario	SOC+	Production	1.00	0.97	1.01	0.98	0.98	1.00	1.01	0.99	0.98	0.95	0.98
2.6°C scenario	SOC+	Consumption	0.99	0.97	1.00	0.99	1.00	0.99	1.00	0.98	0.98	0.97	0.98
2.6°C scenario	SOC+	Price	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.04	1.02	1.01
2.6°C scenario	SOC-	Production	1.00	0.97	1.01	0.98	0.99	1.00	1.00	1.00	0.97	0.95	0.98
2.6°C scenario	SOC-	Consumption	0.99	0.96	1.00	0.99	1.00	0.99	1.01	0.99	0.98	0.97	0.98
2.6°C scenario	SOC-	Price	1.01	1.02	1.01	1.01	1.01	1.01	1.01	1.02	1.04	1.02	1.02
2.2°C scenario	None	Production	0.99	0.94	1.02	0.97	0.98	1.00	1.00	0.99	0.95	0.92	0.97
2.2°C scenario	None	Consumption	0.98	0.94	0.99	0.98	0.99	0.98	1.01	0.97	0.97	0.96	0.97
2.2°C scenario	None	Price	1.02	1.05	1.02	1.03	1.02	1.03	1.02	1.03	1.10	1.04	1.03

2.2°C scenario	SOC	Production	0.99	0.95	1.02	0.97	0.98	1.00	1.00	0.99	0.95	0.92	0.97
2.2°C scenario	SOC	Consumption	0.98	0.94	0.99	0.98	0.99	0.98	1.01	0.97	0.97	0.96	0.97
2.2°C scenario	SOC	Price	1.02	1.04	1.02	1.03	1.02	1.03	1.02	1.03	1.10	1.04	1.03
2.2°C scenario	SOC+	Production	0.99	0.94	1.02	0.97	0.97	1.00	1.00	0.98	0.96	0.92	0.97
2.2°C scenario	SOC+	Consumption	0.97	0.94	0.99	0.98	0.99	0.98	1.00	0.97	0.97	0.96	0.97
2.2°C scenario	SOC+	Price	1.02	1.04	1.02	1.02	1.02	1.02	1.02	1.03	1.09	1.04	1.03
2.2°C scenario	SOC-	Production	0.99	0.95	1.02	0.97	0.98	1.00	1.00	0.99	0.95	0.92	0.97
2.2°C scenario	SOC-	Consumption	0.98	0.94	0.99	0.98	0.99	0.98	1.01	0.97	0.97	0.96	0.97
2.2°C scenario	SOC-	Price	1.02	1.04	1.02	1.03	1.02	1.03	1.02	1.03	1.10	1.04	1.03
2.0°C scenario	None	Production	0.97	0.90	1.04	0.94	0.96	1.00	0.99	0.97	0.91	0.88	0.94
2.0°C scenario	None	Consumption	0.95	0.90	0.98	0.96	0.98	0.97	1.01	0.94	0.94	0.93	0.94
2.0°C scenario	None	Price	1.04	1.09	1.06	1.06	1.05	1.08	1.06	1.08	1.20	1.07	1.08
2.0°C scenario	SOC	Production	0.97	0.91	1.05	0.95	0.96	1.00	0.99	0.97	0.91	0.88	0.95
2.0°C scenario	SOC	Consumption	0.95	0.90	0.98	0.97	0.98	0.97	1.01	0.94	0.94	0.93	0.95
2.0°C scenario	SOC	Price	1.04	1.09	1.05	1.05	1.04	1.07	1.05	1.08	1.20	1.07	1.07
2.0°C scenario	SOC+	Production	0.97	0.91	1.05	0.94	0.96	1.00	1.00	0.96	0.93	0.89	0.95
2.0°C scenario	SOC+	Consumption	0.95	0.91	0.97	0.97	0.98	0.97	1.00	0.94	0.94	0.94	0.95
2.0°C scenario	SOC+	Price	1.04	1.08	1.05	1.05	1.04	1.06	1.05	1.07	1.19	1.06	1.07
2.0°C scenario	SOC-	Production	0.97	0.91	1.04	0.94	0.96	1.00	0.99	0.97	0.91	0.88	0.95
2.0°C scenario	SOC-	Consumption	0.95	0.90	0.98	0.96	0.98	0.97	1.01	0.94	0.94	0.93	0.95
2.0°C scenario	SOC-	Price	1.04	1.09	1.05	1.06	1.05	1.08	1.06	1.08	1.20	1.07	1.07
1.5°C scenario	None	Production	0.89	0.80	1.08	0.88	0.90	1.00	0.98	0.90	0.85	0.81	0.89
1.5°C scenario	None	Consumption	0.88	0.81	0.96	0.91	0.95	0.95	1.02	0.88	0.87	0.87	0.89
1.5°C scenario	None	Price	1.13	1.25	1.17	1.19	1.14	1.25	1.20	1.23	1.53	1.15	1.21
1.5°C scenario	SOC	Production	0.89	0.83	1.10	0.88	0.91	1.00	0.98	0.92	0.86	0.82	0.90
1.5°C scenario	SOC	Consumption	0.89	0.83	0.97	0.92	0.95	0.95	1.03	0.88	0.88	0.88	0.90
1.5°C scenario	SOC	Price	1.11	1.21	1.13	1.16	1.12	1.20	1.17	1.19	1.50	1.14	1.18
1.5°C scenario	SOC+	Production	0.87	0.84	1.09	0.88	0.91	0.99	0.99	0.90	0.88	0.82	0.90
1.5°C scenario	SOC+	Consumption	0.89	0.84	0.96	0.92	0.95	0.94	1.02	0.88	0.88	0.88	0.90
1.5°C scenario	SOC+	Price	1.10	1.21	1.13	1.15	1.12	1.20	1.17	1.19	1.47	1.13	1.17

1.5°C scenario	SOC-	Production	0.89	0.82	1.09	0.88	0.90	1.00	0.99	0.91	0.86	0.81	0.89
1.5°C scenario	SOC-	Consumption	0.88	0.82	0.96	0.91	0.95	0.95	1.03	0.88	0.88	0.88	0.89
1.5°C scenario	SOC-	Price	1.12	1.23	1.15	1.17	1.14	1.23	1.18	1.21	1.52	1.14	1.19

Table S12. Relative change in livestock production, consumption, and prices across regions compared to the baseline scenario in 2050 in the default set-up.

Climate Target	SOC	Item	CIS	EAS	EU28	LAM	MEN	NAM	OCE	SAS	SEA	SSA	WLD
3.1°C scenario	None	Production	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	0.99	0.97	1.00
3.1°C scenario	None	Consumption	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	0.99	0.98	1.00
3.1°C scenario	None	Price	1.00	1.00	1.01	1.01	1.00	1.00	1.03	1.01	1.02	1.03	1.01
3.1°C scenario	SOC	Production	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	0.99	0.97	1.00
3.1°C scenario	SOC	Consumption	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	0.99	0.98	1.00
3.1°C scenario	SOC	Price	1.00	1.00	1.01	1.01	1.00	1.00	1.03	1.01	1.02	1.03	1.01
3.1°C scenario	SOC+	Production	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	0.99	0.97	1.00
3.1°C scenario	SOC+	Consumption	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	0.99	0.98	1.00
3.1°C scenario	SOC+	Price	1.00	1.00	1.00	1.02	1.00	1.00	1.02	1.01	1.02	1.03	1.01
3.1°C scenario	SOC-	Production	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	0.99	0.97	1.00
3.1°C scenario	SOC-	Consumption	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	0.99	0.98	1.00
3.1°C scenario	SOC-	Price	1.00	1.00	1.01	1.01	1.00	1.00	1.03	1.01	1.02	1.03	1.01
2.6°C scenario	None	Production	0.98	0.98	1.01	0.97	0.99	0.99	0.99	0.98	0.97	0.88	0.98
2.6°C scenario	None	Consumption	0.99	0.98	0.99	0.97	0.99	0.99	0.98	0.98	0.97	0.94	0.98
2.6°C scenario	None	Price	1.03	1.02	1.03	1.07	1.02	1.03	1.10	1.05	1.07	1.14	1.04
2.6°C scenario	SOC	Production	0.98	0.98	1.01	0.97	0.99	0.99	0.99	0.98	0.97	0.88	0.98
2.6°C scenario	SOC	Consumption	0.99	0.98	0.99	0.97	0.99	0.99	0.98	0.98	0.97	0.94	0.98
2.6°C scenario	SOC	Price	1.03	1.02	1.03	1.07	1.02	1.03	1.10	1.05	1.07	1.14	1.04
2.6°C scenario	SOC+	Production	0.98	0.99	1.01	0.96	0.99	1.00	0.99	0.98	0.97	0.88	0.98
2.6°C scenario	SOC+	Consumption	0.99	0.99	0.99	0.97	0.98	1.00	0.98	0.98	0.97	0.94	0.98

2.6°C scenario	SOC+	Price	1.03	1.02	1.03	1.07	1.03	1.02	1.10	1.05	1.07	1.13	1.04
2.6°C scenario	SOC-	Production	0.98	0.98	1.01	0.97	0.99	0.99	0.99	0.98	0.97	0.88	0.98
2.6°C scenario	SOC-	Consumption	0.99	0.98	0.99	0.97	0.99	0.99	0.98	0.98	0.97	0.94	0.98
2.6°C scenario	SOC-	Price	1.03	1.02	1.03	1.07	1.02	1.03	1.10	1.05	1.07	1.14	1.04
2.2°C scenario	None	Production	0.96	0.96	1.01	0.94	0.98	0.99	0.99	0.97	0.93	0.83	0.97
2.2°C scenario	None	Consumption	0.97	0.97	0.98	0.95	0.98	0.99	0.96	0.96	0.94	0.90	0.97
2.2°C scenario	None	Price	1.07	1.05	1.06	1.13	1.05	1.06	1.19	1.08	1.14	1.22	1.08
2.2°C scenario	SOC	Production	0.96	0.96	1.01	0.94	0.98	0.99	0.99	0.97	0.93	0.83	0.97
2.2°C scenario	SOC	Consumption	0.97	0.97	0.98	0.95	0.97	0.99	0.96	0.96	0.94	0.90	0.97
2.2°C scenario	SOC	Price	1.07	1.05	1.06	1.13	1.05	1.06	1.19	1.08	1.14	1.22	1.08
2.2°C scenario	SOC+	Production	0.96	0.96	1.01	0.94	0.98	0.99	0.99	0.98	0.93	0.83	0.97
2.2°C scenario	SOC+	Consumption	0.97	0.97	0.98	0.95	0.98	0.99	0.96	0.97	0.94	0.90	0.97
2.2°C scenario	SOC+	Price	1.06	1.05	1.06	1.13	1.05	1.05	1.19	1.08	1.14	1.21	1.08
2.2°C scenario	SOC-	Production	0.96	0.96	1.01	0.94	0.98	0.99	0.99	0.97	0.93	0.83	0.97
2.2°C scenario	SOC-	Consumption	0.97	0.97	0.98	0.95	0.97	0.99	0.96	0.96	0.94	0.90	0.97
2.2°C scenario	SOC-	Price	1.07	1.05	1.06	1.13	1.05	1.06	1.19	1.08	1.14	1.22	1.08
2.0°C scenario	None	Production	0.92	0.92	1.00	0.89	0.97	0.98	0.98	0.92	0.85	0.79	0.93
2.0°C scenario	None	Consumption	0.93	0.93	0.96	0.90	0.96	0.97	0.93	0.90	0.89	0.87	0.93
2.0°C scenario	None	Price	1.15	1.11	1.14	1.26	1.09	1.14	1.41	1.22	1.27	1.32	1.16
2.0°C scenario	SOC	Production	0.92	0.92	1.00	0.89	0.97	0.98	0.98	0.92	0.85	0.80	0.93
2.0°C scenario	SOC	Consumption	0.94	0.94	0.97	0.91	0.96	0.97	0.93	0.90	0.89	0.87	0.93
2.0°C scenario	SOC	Price	1.15	1.11	1.13	1.26	1.08	1.13	1.40	1.21	1.27	1.31	1.16
2.0°C scenario	SOC+	Production	0.93	0.92	1.00	0.89	0.96	0.98	0.98	0.92	0.85	0.80	0.93
2.0°C scenario	SOC+	Consumption	0.94	0.94	0.97	0.91	0.96	0.97	0.93	0.91	0.90	0.87	0.93
2.0°C scenario	SOC+	Price	1.15	1.11	1.13	1.25	1.09	1.13	1.40	1.22	1.27	1.30	1.16
2.0°C scenario	SOC-	Production	0.92	0.92	1.00	0.89	0.97	0.98	0.98	0.92	0.85	0.79	0.93
2.0°C scenario	SOC-	Consumption	0.93	0.94	0.96	0.91	0.96	0.97	0.93	0.90	0.89	0.87	0.93
2.0°C scenario	SOC-	Price	1.15	1.11	1.14	1.26	1.09	1.13	1.40	1.22	1.27	1.31	1.16
1.5°C scenario	None	Production	0.83	0.85	1.00	0.73	0.94	0.94	0.90	0.77	0.67	0.69	0.85

1.5°C scenario	None	Consumption	0.85	0.86	0.91	0.81	0.92	0.93	0.83	0.77	0.80	0.78	0.85
1.5°C scenario	None	Price	1.39	1.29	1.38	1.68	1.20	1.39	2.21	1.65	1.60	1.63	1.42
1.5°C scenario	SOC	Production	0.86	0.86	1.00	0.76	0.94	0.94	0.91	0.77	0.67	0.72	0.86
1.5°C scenario	SOC	Consumption	0.87	0.87	0.92	0.82	0.92	0.93	0.85	0.77	0.81	0.80	0.86
1.5°C scenario	SOC	Price	1.32	1.25	1.35	1.62	1.18	1.37	2.09	1.62	1.57	1.55	1.38
1.5°C scenario	SOC+	Production	0.86	0.86	1.01	0.75	0.93	0.94	0.91	0.78	0.68	0.72	0.86
1.5°C scenario	SOC+	Consumption	0.87	0.87	0.92	0.82	0.92	0.93	0.85	0.78	0.81	0.80	0.86
1.5°C scenario	SOC+	Price	1.32	1.25	1.34	1.61	1.18	1.36	2.10	1.62	1.57	1.55	1.38
1.5°C scenario	SOC-	Production	0.84	0.85	1.00	0.74	0.94	0.94	0.91	0.77	0.67	0.71	0.85
1.5°C scenario	SOC-	Consumption	0.86	0.86	0.92	0.81	0.92	0.93	0.84	0.77	0.81	0.79	0.85
1.5°C scenario	SOC-	Price	1.35	1.27	1.36	1.64	1.18	1.38	2.14	1.63	1.58	1.59	1.40

Table S13. Relative change in crop production, consumption, and prices across regions compared to the baseline scenario in 2050 in the demand sensitivity analysis.

Climate Target	SOC	Item	CIS	EAS	EU28	LAM	MEN	NAM	OCE	SAS	SEA	SSA	WLD
3.1°C scenario	None	Production	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00
3.1°C scenario	None	Consumption	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3.1°C scenario	None	Price	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.00
3.1°C scenario	SOC	Production	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00
3.1°C scenario	SOC	Consumption	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3.1°C scenario	SOC	Price	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.00
3.1°C scenario	SOC+	Production	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00
3.1°C scenario	SOC+	Consumption	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3.1°C scenario	SOC+	Price	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.00
3.1°C scenario	SOC-	Production	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00
3.1°C scenario	SOC-	Consumption	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

3.1°C scenario	SOC-	Price	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.00
2.6°C scenario	None	Production	1.00	0.98	1.02	0.99	0.99	1.00	1.00	1.00	0.98	0.97	0.99
2.6°C scenario	None	Consumption	1.00	0.97	1.00	1.00	1.00	0.99	1.01	0.99	1.00	0.98	0.99
2.6°C scenario	None	Price	1.01	1.02	1.01	1.02	1.01	1.02	1.02	1.02	1.04	1.02	1.02
2.6°C scenario	SOC	Production	1.00	0.98	1.02	0.99	0.99	1.00	1.00	1.00	0.98	0.97	0.99
2.6°C scenario	SOC	Consumption	1.00	0.97	1.00	1.00	1.00	0.99	1.01	0.99	1.00	0.98	0.99
2.6°C scenario	SOC	Price	1.01	1.02	1.01	1.02	1.01	1.02	1.02	1.02	1.04	1.02	1.02
2.6°C scenario	SOC+	Production	1.00	0.98	1.01	0.99	0.99	1.00	1.01	1.00	0.99	0.96	0.99
2.6°C scenario	SOC+	Consumption	0.99	0.97	1.00	1.00	1.00	0.99	1.00	0.99	0.99	0.98	0.99
2.6°C scenario	SOC+	Price	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.04	1.02	1.02
2.6°C scenario	SOC-	Production	1.00	0.98	1.02	0.99	0.99	1.00	1.00	1.00	0.98	0.97	0.99
2.6°C scenario	SOC-	Consumption	1.00	0.97	1.00	1.00	1.00	0.99	1.01	0.99	1.00	0.98	0.99
2.6°C scenario	SOC-	Price	1.01	1.02	1.01	1.02	1.01	1.02	1.02	1.02	1.04	1.02	1.02
2.2°C scenario	None	Production	1.00	0.97	1.04	0.98	0.98	1.01	1.00	0.99	0.96	0.93	0.98
2.2°C scenario	None	Consumption	0.99	0.96	1.00	0.99	0.99	0.99	1.01	0.98	0.99	0.97	0.98
2.2°C scenario	None	Price	1.02	1.05	1.03	1.03	1.02	1.04	1.03	1.05	1.11	1.04	1.04
2.2°C scenario	SOC	Production	1.00	0.97	1.04	0.98	0.98	1.01	1.00	0.99	0.96	0.93	0.98
2.2°C scenario	SOC	Consumption	0.99	0.96	1.00	0.99	0.99	0.99	1.01	0.98	0.99	0.97	0.98
2.2°C scenario	SOC	Price	1.02	1.04	1.03	1.03	1.02	1.03	1.03	1.05	1.11	1.04	1.04
2.2°C scenario	SOC+	Production	1.00	0.96	1.03	0.98	0.98	1.00	1.01	0.99	0.97	0.94	0.98
2.2°C scenario	SOC+	Consumption	0.98	0.96	0.99	0.99	0.99	0.98	1.01	0.98	0.99	0.98	0.98
2.2°C scenario	SOC+	Price	1.02	1.04	1.02	1.03	1.02	1.02	1.02	1.04	1.09	1.04	1.03
2.2°C scenario	SOC-	Production	1.00	0.97	1.04	0.98	0.98	1.01	1.00	0.99	0.96	0.93	0.98
2.2°C scenario	SOC-	Consumption	0.99	0.96	1.00	0.99	0.99	0.99	1.01	0.98	0.99	0.97	0.98
2.2°C scenario	SOC-	Price	1.02	1.04	1.03	1.03	1.02	1.04	1.03	1.05	1.11	1.04	1.04
2.0°C scenario	None	Production	0.99	0.94	1.08	0.96	0.98	1.02	1.00	0.99	0.94	0.90	0.97
2.0°C scenario	None	Consumption	0.97	0.94	0.99	0.98	0.99	0.98	1.02	0.96	0.98	0.95	0.97
2.0°C scenario	None	Price	1.04	1.10	1.07	1.07	1.06	1.09	1.07	1.12	1.24	1.08	1.09
2.0°C scenario	SOC	Production	0.98	0.94	1.08	0.97	0.98	1.02	1.00	0.99	0.94	0.90	0.97

2.0°C scenario	SOC	Consumption	0.96	0.94	1.00	0.98	0.99	0.98	1.02	0.96	0.98	0.95	0.97
2.0°C scenario	SOC	Price	1.04	1.09	1.06	1.07	1.05	1.08	1.07	1.11	1.23	1.07	1.08
2.0°C scenario	SOC+	Production	0.99	0.94	1.07	0.97	0.97	1.01	1.00	0.98	0.96	0.90	0.97
2.0°C scenario	SOC+	Consumption	0.97	0.94	0.98	0.99	0.99	0.98	1.01	0.96	0.98	0.96	0.97
2.0°C scenario	SOC+	Price	1.04	1.09	1.06	1.06	1.05	1.08	1.07	1.10	1.22	1.07	1.08
2.0°C scenario	SOC-	Production	0.98	0.94	1.09	0.96	0.98	1.02	1.00	0.99	0.94	0.90	0.97
2.0°C scenario	SOC-	Consumption	0.96	0.94	1.00	0.98	0.99	0.98	1.02	0.96	0.98	0.95	0.97
2.0°C scenario	SOC-	Price	1.04	1.09	1.06	1.07	1.05	1.09	1.07	1.11	1.23	1.08	1.09
1.5°C scenario	None	Production	0.91	0.88	1.15	0.93	0.94	1.04	1.00	0.95	0.90	0.85	0.94
1.5°C scenario	None	Consumption	0.90	0.89	1.00	0.95	0.97	0.98	1.04	0.93	0.95	0.91	0.94
1.5°C scenario	None	Price	1.13	1.26	1.18	1.22	1.16	1.29	1.26	1.30	1.67	1.17	1.24
1.5°C scenario	SOC	Production	0.91	0.90	1.17	0.93	0.94	1.04	1.00	0.95	0.91	0.85	0.94
1.5°C scenario	SOC	Consumption	0.90	0.90	1.00	0.95	0.97	0.98	1.05	0.93	0.96	0.92	0.94
1.5°C scenario	SOC	Price	1.11	1.22	1.16	1.19	1.14	1.24	1.23	1.27	1.62	1.15	1.21
1.5°C scenario	SOC+	Production	0.91	0.90	1.14	0.92	0.95	1.03	1.00	0.94	0.93	0.85	0.94
1.5°C scenario	SOC+	Consumption	0.93	0.90	0.98	0.96	0.98	0.98	1.03	0.93	0.96	0.92	0.94
1.5°C scenario	SOC+	Price	1.11	1.22	1.16	1.19	1.13	1.24	1.23	1.27	1.62	1.15	1.21
1.5°C scenario	SOC-	Production	0.91	0.89	1.16	0.93	0.94	1.03	1.00	0.95	0.91	0.85	0.94
1.5°C scenario	SOC-	Consumption	0.90	0.90	1.00	0.95	0.97	0.98	1.04	0.93	0.95	0.92	0.94
1.5°C scenario	SOC-	Price	1.12	1.24	1.17	1.20	1.15	1.27	1.24	1.29	1.64	1.16	1.23

Table S14. Relative change in livestock production, consumption, and prices across regions compared to the baseline scenario in 2050 in the demand sensitivity analysis.

Climate Target	SOC	Item	CIS	EAS	EU28	LAM	MEN	NAM	OCE	SAS	SEA	SSA	WLD
3.1°C scenario	None	Production	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.98	1.00
3.1°C scenario	None	Consumption	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	0.99	0.99	1.00

3.1°C scenario	None	Price	1.00	1.01	1.00	1.02	1.00	1.00	1.02	1.01	1.02	1.03	1.01
3.1°C scenario	SOC	Production	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.98	1.00
3.1°C scenario	SOC	Consumption	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	0.99	0.99	1.00
3.1°C scenario	SOC	Price	1.00	1.01	1.00	1.02	1.00	1.00	1.02	1.01	1.02	1.03	1.01
3.1°C scenario	SOC+	Production	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	1.00	0.98	1.00
3.1°C scenario	SOC+	Consumption	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00
3.1°C scenario	SOC+	Price	1.01	1.00	1.00	1.02	1.00	1.00	1.03	1.01	1.02	1.03	1.01
3.1°C scenario	SOC-	Production	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.98	1.00
3.1°C scenario	SOC-	Consumption	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	0.99	0.99	1.00
3.1°C scenario	SOC-	Price	1.00	1.01	1.00	1.02	1.00	1.00	1.02	1.01	1.02	1.03	1.01
2.6°C scenario	None	Production	0.99	0.99	1.01	0.97	1.01	1.00	1.00	0.99	0.98	0.91	0.99
2.6°C scenario	None	Consumption	0.99	0.99	1.00	0.98	0.99	1.00	0.99	0.98	0.98	0.96	0.99
2.6°C scenario	None	Price	1.03	1.03	1.03	1.08	1.02	1.03	1.12	1.06	1.08	1.13	1.04
2.6°C scenario	SOC	Production	0.99	0.99	1.01	0.97	1.01	1.00	1.00	0.99	0.98	0.91	0.99
2.6°C scenario	SOC	Consumption	0.99	0.99	1.00	0.98	0.99	1.00	0.99	0.98	0.98	0.96	0.99
2.6°C scenario	SOC	Price	1.03	1.03	1.03	1.08	1.02	1.03	1.12	1.06	1.08	1.13	1.04
2.6°C scenario	SOC+	Production	0.99	0.99	1.01	0.97	1.01	1.00	1.00	0.99	0.98	0.91	0.99
2.6°C scenario	SOC+	Consumption	0.99	0.99	1.00	0.98	0.99	1.00	0.99	0.98	0.98	0.97	0.99
2.6°C scenario	SOC+	Price	1.03	1.02	1.03	1.08	1.02	1.02	1.12	1.06	1.08	1.14	1.04
2.6°C scenario	SOC-	Production	0.99	0.99	1.01	0.97	1.01	1.00	1.00	0.99	0.98	0.91	0.99
2.6°C scenario	SOC-	Consumption	0.99	0.99	1.00	0.98	0.99	1.00	0.99	0.98	0.98	0.96	0.99
2.6°C scenario	SOC-	Price	1.03	1.03	1.03	1.08	1.02	1.03	1.12	1.06	1.08	1.13	1.04
2.2°C scenario	None	Production	0.98	0.97	1.01	0.95	1.00	1.00	1.00	0.98	0.96	0.86	0.98
2.2°C scenario	None	Consumption	0.98	0.98	0.99	0.96	0.99	1.00	0.97	0.98	0.97	0.94	0.98
2.2°C scenario	None	Price	1.06	1.06	1.07	1.15	1.05	1.06	1.23	1.11	1.15	1.24	1.09
2.2°C scenario	SOC	Production	0.98	0.97	1.01	0.95	1.00	1.00	1.00	0.98	0.96	0.86	0.98
2.2°C scenario	SOC	Consumption	0.98	0.98	0.99	0.96	0.99	1.00	0.97	0.98	0.97	0.94	0.98
2.2°C scenario	SOC	Price	1.06	1.06	1.07	1.15	1.05	1.06	1.23	1.11	1.15	1.24	1.09
2.2°C scenario	SOC+	Production	0.98	0.97	1.02	0.95	1.00	1.00	1.00	0.98	0.96	0.86	0.98
2.2°C scenario	SOC+	Consumption	0.98	0.98	0.99	0.96	0.99	1.00	0.97	0.98	0.96	0.94	0.98

2.2°C scenario	SOC+	Price	1.06	1.06	1.06	1.15	1.05	1.06	1.23	1.11	1.15	1.24	1.09
2.2°C scenario	SOC-	Production	0.98	0.97	1.01	0.95	1.00	1.00	1.00	0.98	0.96	0.86	0.98
2.2°C scenario	SOC-	Consumption	0.98	0.98	0.99	0.96	0.99	1.00	0.97	0.98	0.97	0.94	0.98
2.2°C scenario	SOC-	Price	1.06	1.06	1.07	1.15	1.05	1.06	1.23	1.11	1.15	1.24	1.09
2.0°C scenario	None	Production	0.94	0.95	1.01	0.91	0.99	1.00	1.00	0.95	0.91	0.83	0.96
2.0°C scenario	None	Consumption	0.96	0.96	0.98	0.94	0.98	0.99	0.95	0.94	0.94	0.92	0.96
2.0°C scenario	None	Price	1.16	1.13	1.15	1.30	1.08	1.14	1.49	1.27	1.29	1.36	1.18
2.0°C scenario	SOC	Production	0.95	0.95	1.01	0.91	0.99	1.00	0.99	0.95	0.90	0.83	0.96
2.0°C scenario	SOC	Consumption	0.96	0.96	0.98	0.94	0.98	0.99	0.95	0.94	0.94	0.92	0.96
2.0°C scenario	SOC	Price	1.15	1.12	1.15	1.29	1.08	1.14	1.48	1.26	1.29	1.34	1.17
2.0°C scenario	SOC+	Production	0.95	0.95	1.01	0.91	0.99	1.00	0.99	0.95	0.90	0.83	0.96
2.0°C scenario	SOC+	Consumption	0.96	0.97	0.98	0.94	0.98	1.00	0.95	0.94	0.94	0.92	0.96
2.0°C scenario	SOC+	Price	1.15	1.12	1.14	1.29	1.08	1.14	1.49	1.27	1.29	1.35	1.17
2.0°C scenario	SOC-	Production	0.95	0.95	1.01	0.91	0.99	1.00	0.99	0.95	0.90	0.83	0.96
2.0°C scenario	SOC-	Consumption	0.96	0.96	0.98	0.94	0.98	0.99	0.95	0.94	0.94	0.92	0.96
2.0°C scenario	SOC-	Price	1.15	1.12	1.15	1.29	1.08	1.14	1.49	1.26	1.29	1.35	1.18
1.5°C scenario	None	Production	0.87	0.90	1.03	0.79	0.98	1.00	0.96	0.87	0.74	0.74	0.91
1.5°C scenario	None	Consumption	0.90	0.91	0.95	0.87	0.95	0.98	0.89	0.86	0.88	0.86	0.91
1.5°C scenario	None	Price	1.41	1.31	1.41	1.76	1.20	1.43	2.32	1.70	1.67	1.71	1.45
1.5°C scenario	SOC	Production	0.90	0.90	1.03	0.80	0.98	1.00	0.96	0.87	0.75	0.76	0.92
1.5°C scenario	SOC	Consumption	0.92	0.92	0.95	0.88	0.96	0.98	0.89	0.86	0.89	0.87	0.92
1.5°C scenario	SOC	Price	1.33	1.28	1.37	1.71	1.19	1.40	2.21	1.68	1.64	1.64	1.42
1.5°C scenario	SOC+	Production	0.90	0.91	1.03	0.81	0.98	1.00	0.96	0.87	0.74	0.77	0.92
1.5°C scenario	SOC+	Consumption	0.92	0.92	0.95	0.88	0.96	0.98	0.89	0.86	0.89	0.87	0.92
1.5°C scenario	SOC+	Price	1.34	1.28	1.37	1.71	1.19	1.40	2.23	1.69	1.64	1.66	1.42
1.5°C scenario	SOC-	Production	0.88	0.91	1.03	0.80	0.98	1.00	0.96	0.88	0.74	0.76	0.91
1.5°C scenario	SOC-	Consumption	0.91	0.92	0.95	0.87	0.95	0.98	0.89	0.86	0.88	0.87	0.91
1.5°C scenario	SOC-	Price	1.38	1.30	1.39	1.72	1.19	1.41	2.26	1.69	1.65	1.66	1.43

6 Regional aggregation

Table S15: Regional mapping of countries.

Aggregates	GLOBIOM region	Country
CIS	Former USSR	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, Uzbekistan
	RCEU	Albania, Bosnia and Herzegovina, Macedonia, Serbia-Montenegro
EAS	China	China
	Japan	Japan
	South Korea	South Korea
EU28	EU Baltic EU Central East EU Central West EU North EU South	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, UK
LAM	Brazil	Brazil
	Mexico	Mexico
	RCAM	Bahamas, Belize, Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, Trinidad and Tobago
	RSAM	Argentina, Bolivia, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela
MEN	Middle East and Northern Africa	Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, Western Sahara, Yemen
	ROWE	Iceland, Norway, Switzerland
	Turkey	Turkey
NAM	Canada	Canada
	United States	United States
OCE	ANZ	Australia, New Zealand
	Pacific Islands	Fiji Islands, Papua New Guinea, Samoa, Solomon Islands, Vanuatu
SAS	India	India
	RSAS	Bangladesh, Bhutan, Nepal, Pakistan, Sri Lanka
SEA	RSEA OPA	Brunei Darussalam, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand
	RSEA PAC	Cambodia, Korea DPR, Laos, Mongolia, Vietnam
SSA	Congo Basin:	Cameroon, Central African Republic, Congo Republic, Democratic Republic of Congo, Equatorial Guinea, Gabon
	Eastern Africa	Burundi, Ethiopia, Kenya, Rwanda, Tanzania, Uganda
	Southern Africa	Angola, Botswana, Comoros, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Swaziland, Zambia, Zimbabwe
	Western Africa	Benin, Burkina Faso, Cape Verde, Chad, Cote d'Ivoire, Djibouti, Eritrea, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Somalia, Sudan, Togo
	South Africa	South Africa

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