Achieving the 17 Sustainable Development Goals within 9 planetary boundaries

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Supplementary Materials –Tables and Figures:

Table S1. The 7 regions used in Earth3.

Rounded data for 2015. ($ = 2011 PPP US$)[1] in The Empirical Bases for the Earth3 model https://doi.org/10.31223/osf.io/ephsf.

Region	Label	Population	GDP	GDP per person	Share of population
		Mp	G$/y	$/p-y	%
1. United States	USA	330	16 700	51 100	5
2. Other rich countries	ORC	750	28 100	37 500	10
3. Emerging economies	EE	890	15 400	17 300	12
4. China	CHINA	1 430	18 500	13 000	20
5. Indian subcontinent	IND	1 660	8 100	4 900	23
6. Africa South of Sahara	ASoS	750	2 800	3 800	10
7. Rest of the World - 120	RoW	1 540	11 500	7 500	20
World	**World**	**7 330**	**101 100**	**13 800**	**100**

Details in The Empirical Bases for the Earth3 model https://doi.org/10.31223/osf.io/ephsf.

[1] To make the group averages more meaningful, we have disregarded an "8. region" consisting of a small number of superrich nations outside the OECD, with ca 50 million people (less than 1 % of the world's population), These small superrich nations are Qatar, Saudi Arabia, Singapore and UAE.

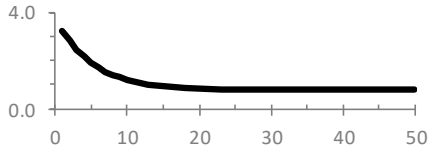
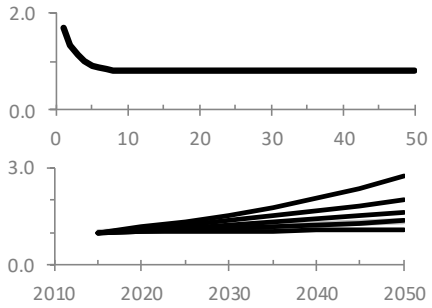
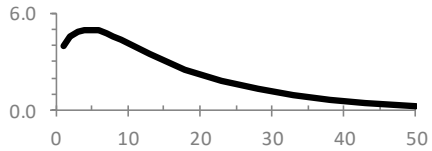
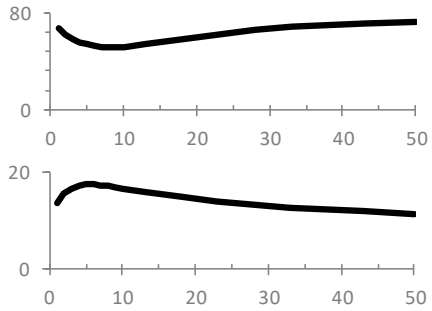
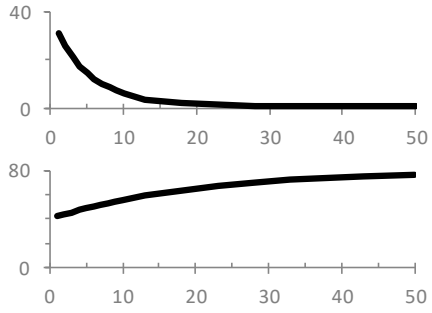
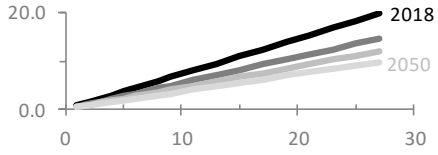
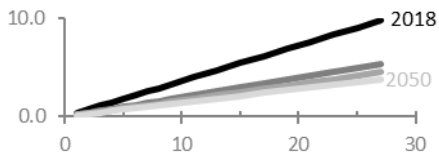
Table S2. The Average Wellbeing Index (AWI) consists of 5 components with equal weights.

AWI is calculated by region from 1980 to 2050.

Component		Rationale	Indicator	Ambition
Five aspects that influence the wellbeing of an average citizen		Explanation of what the component is meant to capture	Indicator chosen to quantify the situation, measured relative to the satisfactory level	The level seen as satisfactory
1	Consumption	The private consumption of goods and services per inhabitant	Consumption per person 2010 PPP US$ / person-year)	>10.000 2011 PPP US$ / p-y
2	Public services	The supply of public services available to each inhabitant	Public services per person 2010 PPP US$ / person-year)	>1.500 PPP US$ / p-y
3	Equity	The satisfaction arising from a more even distribution of income	Share of national income to richest 10% (%)	<40 %
4	Environmental quality	The satisfaction arising from a good physical environment	Urban aerosol concentration (µg 2.5M/m3)	<10 µg 2.5M/m3
5	Hope	The satisfaction arising from believing in a better future	Recent temperature rise deg C above 1850)	<0,05 deg C in 20 years

Table S3. Important correlations in Earth3-core.

Details in http://www.2052.info/wp-content/uploads/2018/correlations.pdf

Dependent variable		
Birth rate (%/y) Adjustment time 20 years		f(GDPpp) in thousand 2011 PPP $ per person-year
Death rate (%/y) Adjustment time 30 years		f(GDPpp) times age pyramid multiplier
Rate of growth of GDPpp (%/y) Adjustment time 20 years		f(GDPpp)
Demand fractions of GDP (%) Adjustment time 20 years Consumer spending (top) + government spending (bottom) + capital formation = 100 %		f(GDPpp)
Output fractions of GDP (%) Adjustment time 20 years Primary sector (top) + secondary sector + tertiary sector (bottom) = 100%		f(GDPpp)
Electricity use per person (kWh/p-y) Adjustment time 20 years		f(GDPpp in 1st and 2nd sector) times tech. progress
Direct use of fossil fuels per person (toe/p-y) Adjustment time 20 years		f(GDPpp in 1st and 2nd sector) times tech. progress

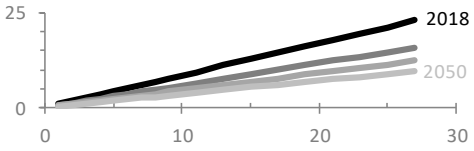
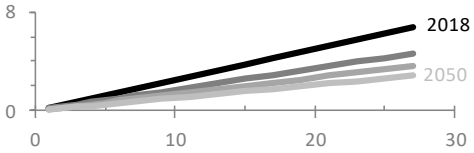
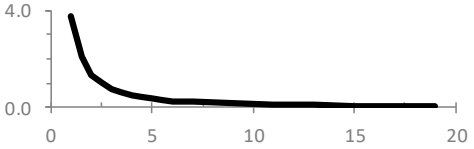
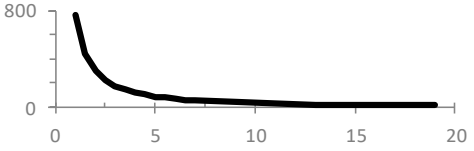
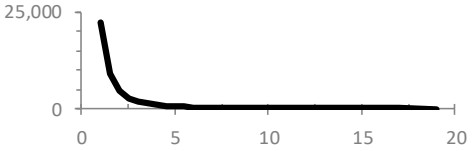
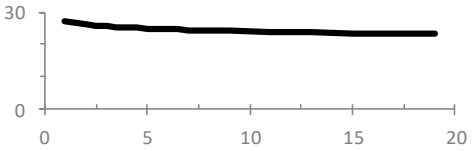
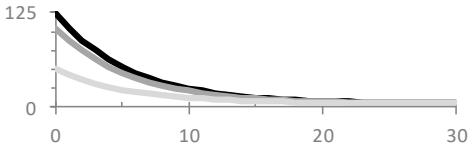
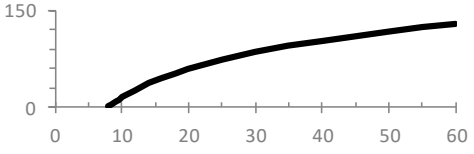
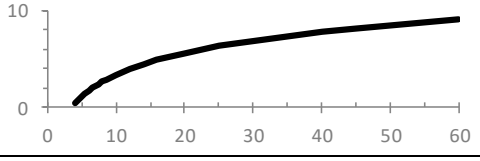
Total footprint per person (gha/p) Adjustment time 10 years		f(GDPpp in 1st and 2nd sector) times tech. progress
Non-energy footprint per person (gha/p) Adjustment time 10 years		f(GDPpp in 1st and 2nd sector) times tech. progress
Man made methane emissions ($GtCO_2e$ /T$) Phase out time: none		f(GDPpp)
N_2O gas emissions ($GtCO_2e$ /T$) Phase out time: 200 years		f(GDPpp) times policy progress
Montreal gas emissions ($GtCO_2e$ /T$) Phase out time: 40 years		f(GDPpp) times policy progress
Kyoto-Flour gas emissions ($GtCO_2e$/T$) Phase out time: 40 years		f(GDPpp) times policy progress
Urban aerosol concentration (µg 2.5M/m^3) Phase out time = 50 years for US and emerging economies, 10 years for all other regions		f(GDPpp in 1st and 2nd sector) times policy progress
Freshwater withdrawal (km^3/y) = 416 m^3 per person-year times population		
Forest degradation (km^2/y) = output from ESCIMO-plus		
Release of bioactive nitrogen (Mt/y) World Adjustment time = 150 years		f(World GDP) in trillion 2011 PPP $ per year
Release of lead (Mt/y) World Adjustment time = 150 years		f(World GDP) in trillion 2011 PPP $ per year

Table S4. Important functions in SDG-module.

Details in "The Empirical Basis for the Earth3 model" https://doi.org/10.31223/osf.io/ephsf

	Dependent variable	Independent variable	Formula
1	Fraction of population living below 1.90$ per day (%)	= f(GDPpp)	= a * exp (-GDPpp / b) by region
2	Fraction of population undernourished (%)	= f(GDPpp)	=a + b*exp(-GDPpp/c) by region
3	Life expectancy at birth (years)	= f(GDPpp)	= (a+b*(year since 1965)) * (1 – c * exp(-GDPpp / d)) by region
4	School life expectancy (years)	= f(GDPpp)	=a-b*exp(-GDPpp/c) by region
5	Gender parity in schooling (1)	= f(GDPpp)	=a-b*exp(-GDPpp/c) by region
6	Fraction of population with access to safe water (%)	= f(GDPpp)	=a-b*exp(-GDPpp/c) by region
7	Fraction of population with access to electricity (%)	= f(GDPpp)	=a-b*exp(-GDPpp/c) by region
8	Job market growth (%/y)	= f(GDPpp)	= Rate of change of GDPpp less 1%
9	GDP per person in manufacturing & construction (2011 PPP US$/p-y)	= f(GDPpp)	See Table S3
10	Share of national income to richest 10 % (%)		= manual forecast, based on Alvadero et al (2018)
11	Urban aerosol concentration (µg 2.5M /m3)	= f(GDPpp)	See Table S3
12	Total footprint per person (gha/p)	= f(GDPpp)	See Table S3
13	Temperature rise (deg C above 1850)		output from ESCIMO-plus
14	Acidity of ocean surface water (pH)		output from ESCIMO-plus
15	Old-growth forest area (Mkm2)		output from ESCIMO-plus
16	Government spending per person (2011 PPP US$/p-y)	= f(GDPpp)	See Table S3
17	Exports as fraction of GDP (%)		= manual forecast

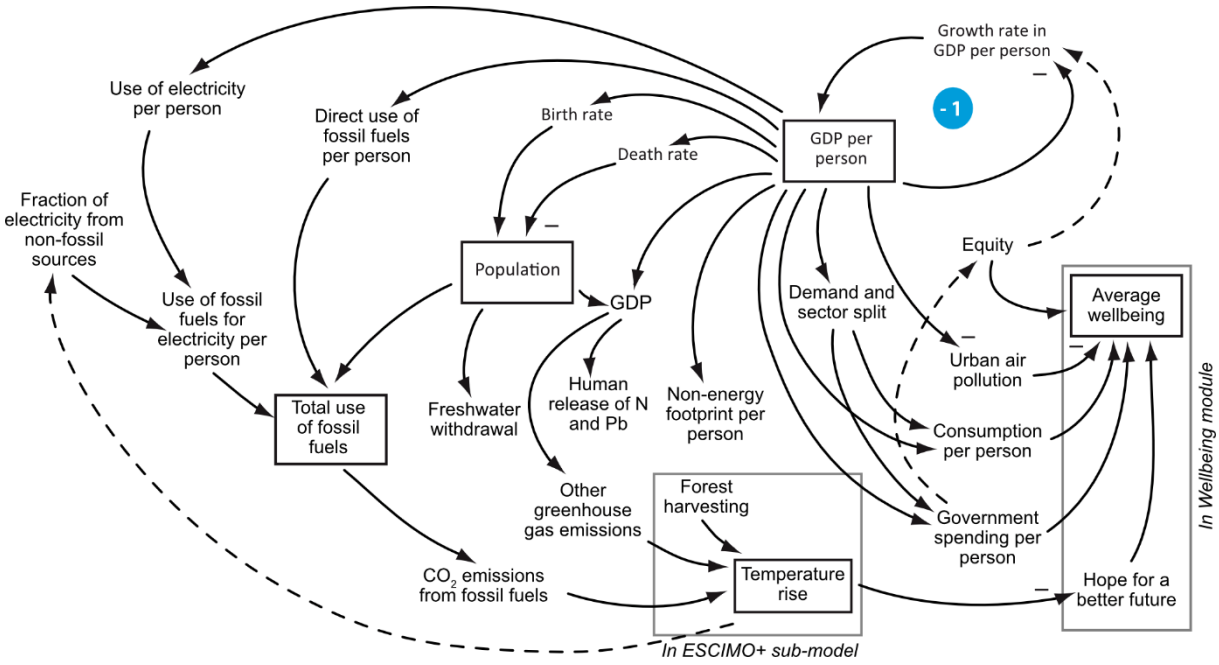


Figure S1. The causal structure of the Earth3-core sub-model.

The dashed feedbacks are not yet included

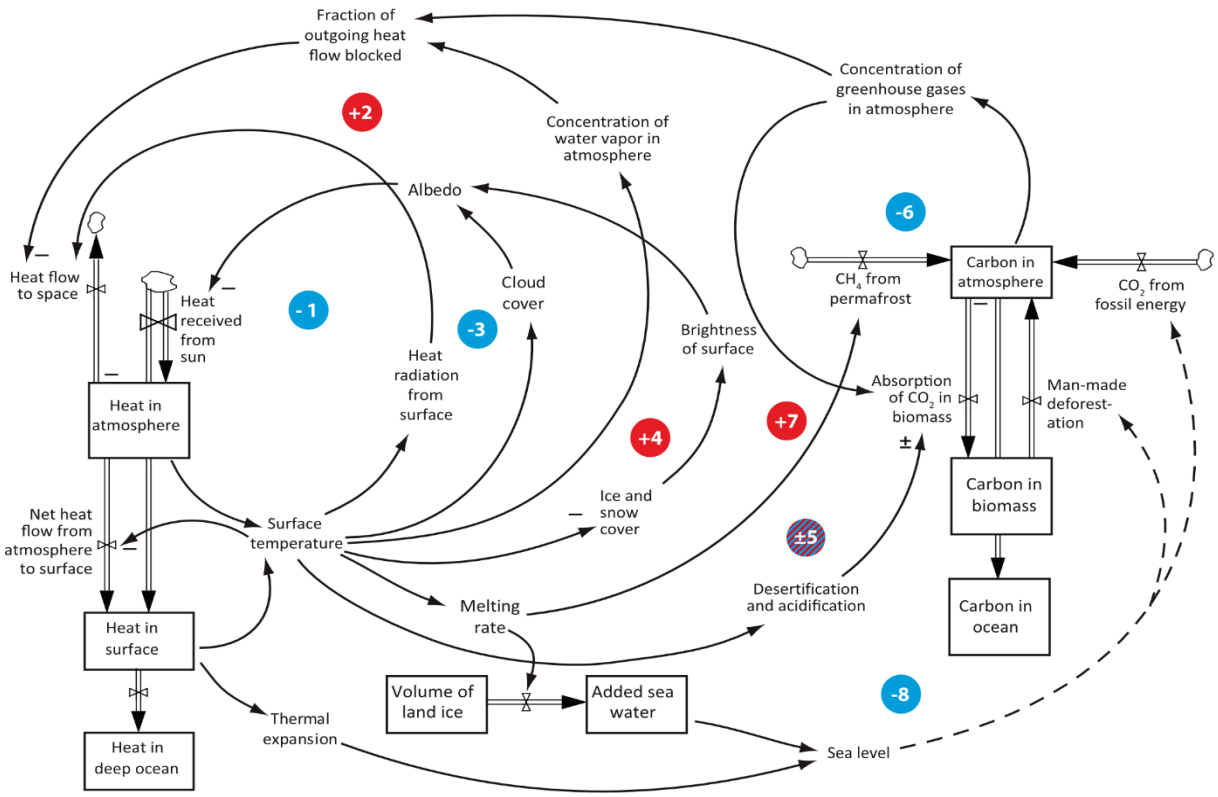


Figure S2. The causal structure of the ESCIMO-plus sub-model.

The dashed feedbacks are not yet included.

Figure S3. The global safety margin of the Earth3-planetary boundary sub-model (a) and the Average Wellbeing index from the Earth3-core (b).

For a: Green shows 8-9 planetary boundaries respected, red shows 0-5 planetary boundaries respected, and yellow shows 5-8 planetary boundaries respected.

For b: Green shows 1.2-2.0 AWI, red shows 0.8-1.2 AWI and yellow shows 0.0-0.8 AWI.

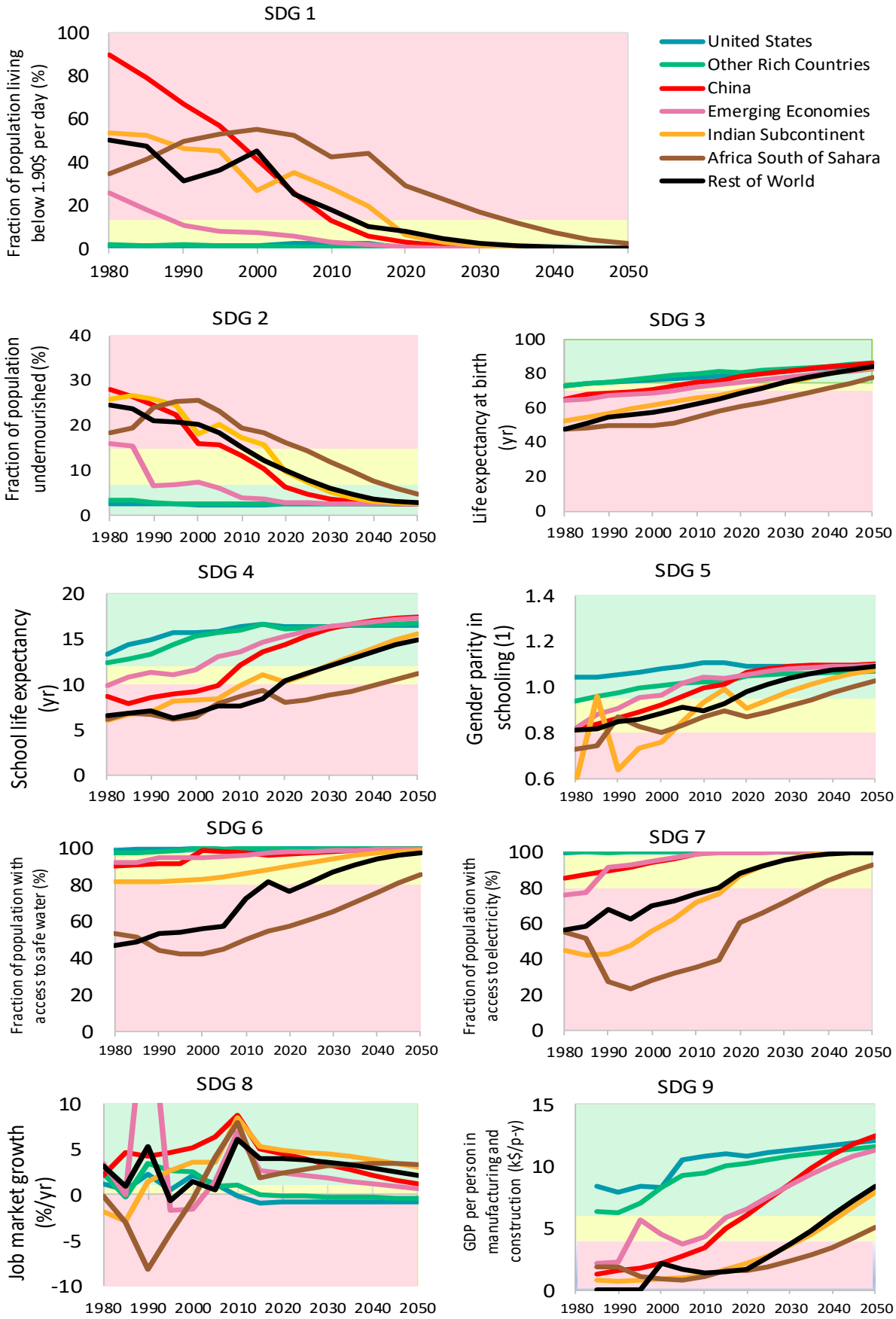


Figure S4 (page 1 of 2). See caption on next page.

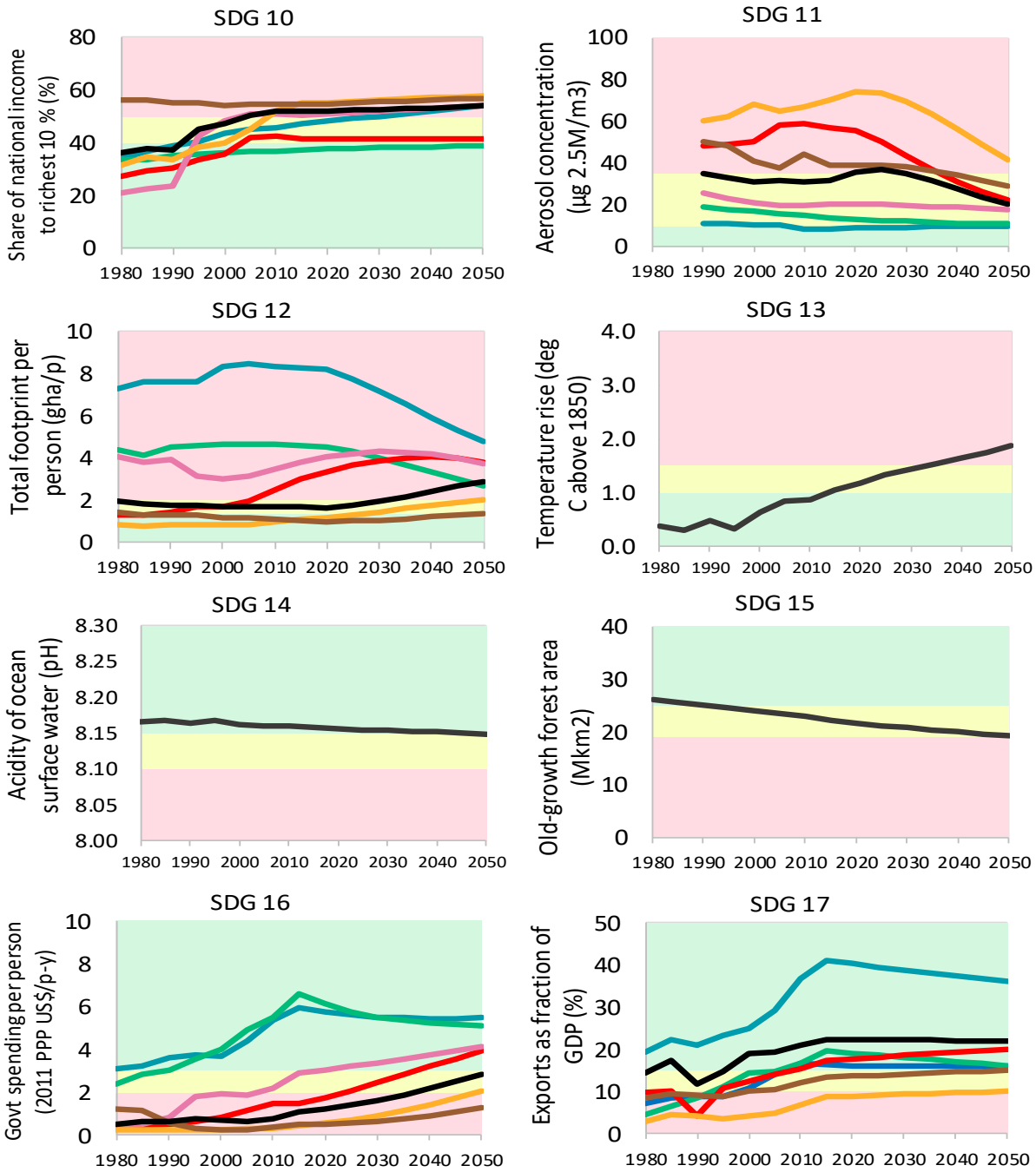


Figure S4. (page 2 of 2) Achievement of individual SDGs. Business-as-usual scenario, by region, 1980-2050.

Green zone shows full achievement of an SDG, amber zone shows partial achievement, red zone shows failure to achieve the goal.

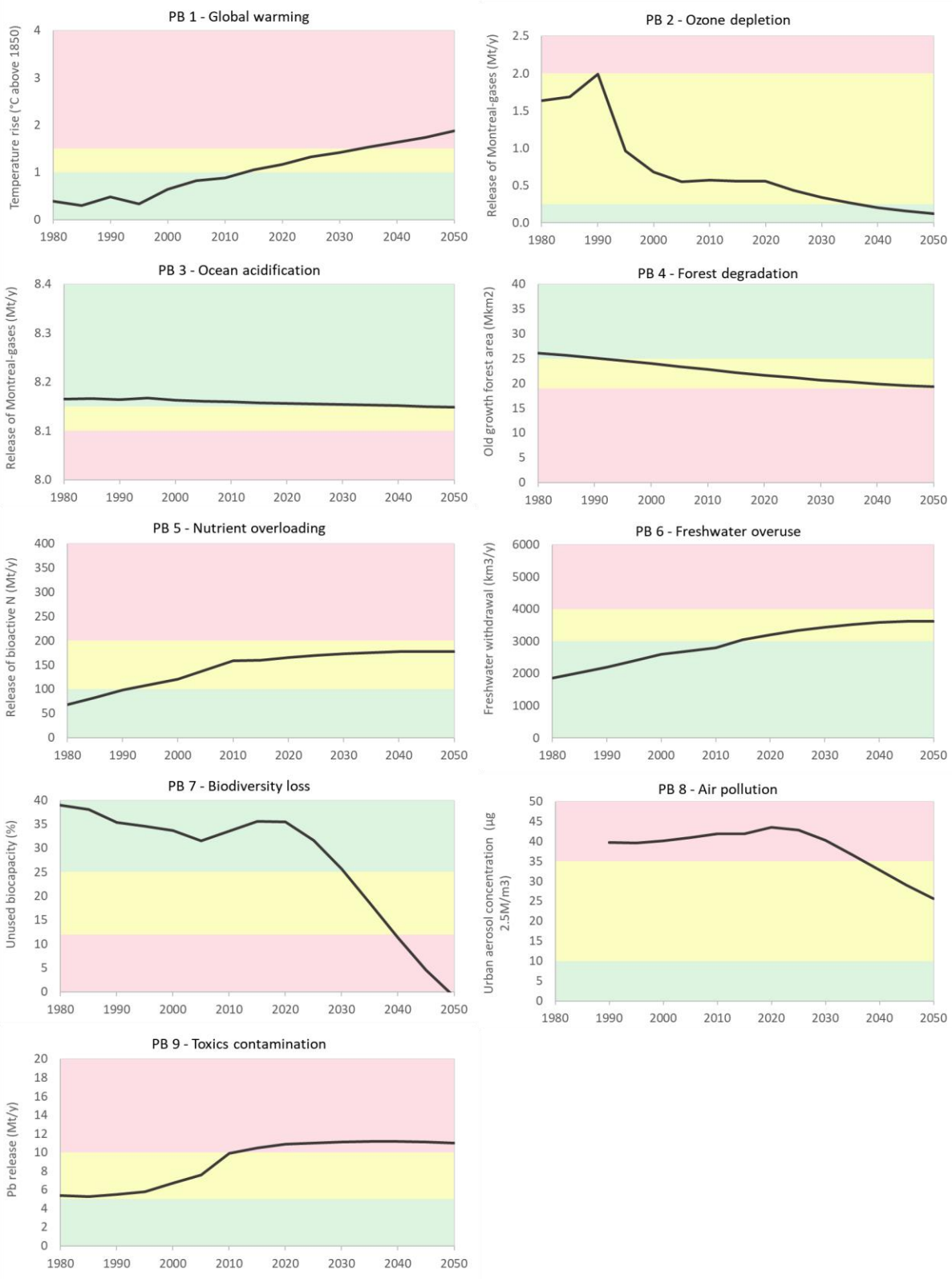


Figure S5. The global pressure on individual PBs. Business-as-usual scenario, 1980-2050.

Green zone shows PB within safe level, amber zone shows PB transgression, red zone shows PB at high risk levels.