Make it Fit:
Can Society Achieve Sustainable Development?

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Sustainable development challenge

- The twin challenges posed by sustainable development:

1. Provide current and future generations with a decent standard of living
2. Maintain ecosystem processes and environmental quality necessary to sustain productive capacity over the long-term

Growth of the world's economy

- Value of World GDP (billion 1990$)
  - 1820: $694
  - 1900: $1,974
  - 1950: $5,337
  - 2000: $36,704

- Source: Maddison Project

Further economic growth

- Per capita income in 2000 (1990$):
  - Global: $6,055
  - US: $28,403
- Population
  - In 2000: 6.06 billion
  - In 2100: ~10 billion

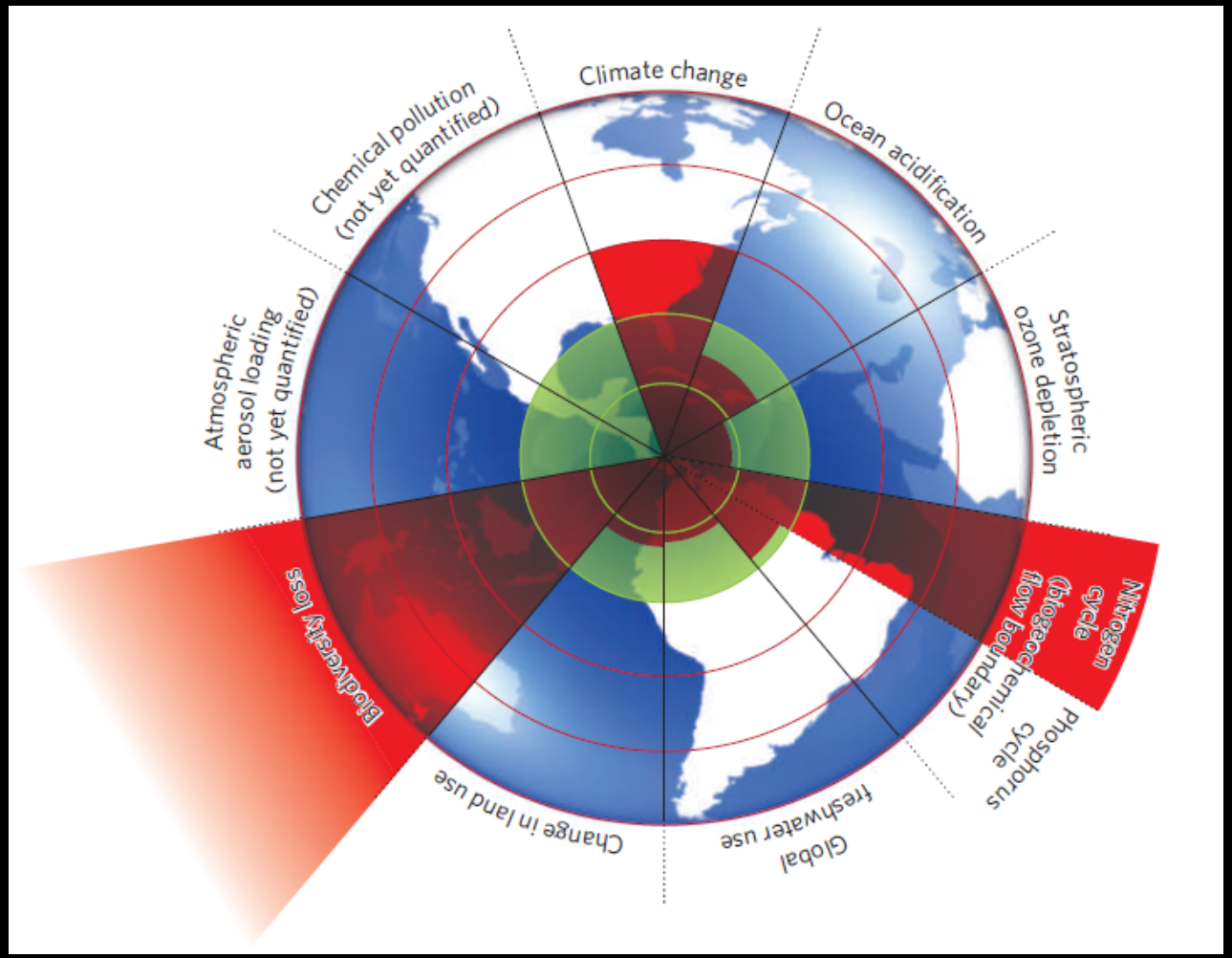
Further economic growth

- To bring 10 billion people to the level of US per capita income would require a 7.74x expansion of the world economy
- Projected world GDP: $284 Trillion
- Compared to 1820, this economy would be over 400 times larger

Environmental consequences

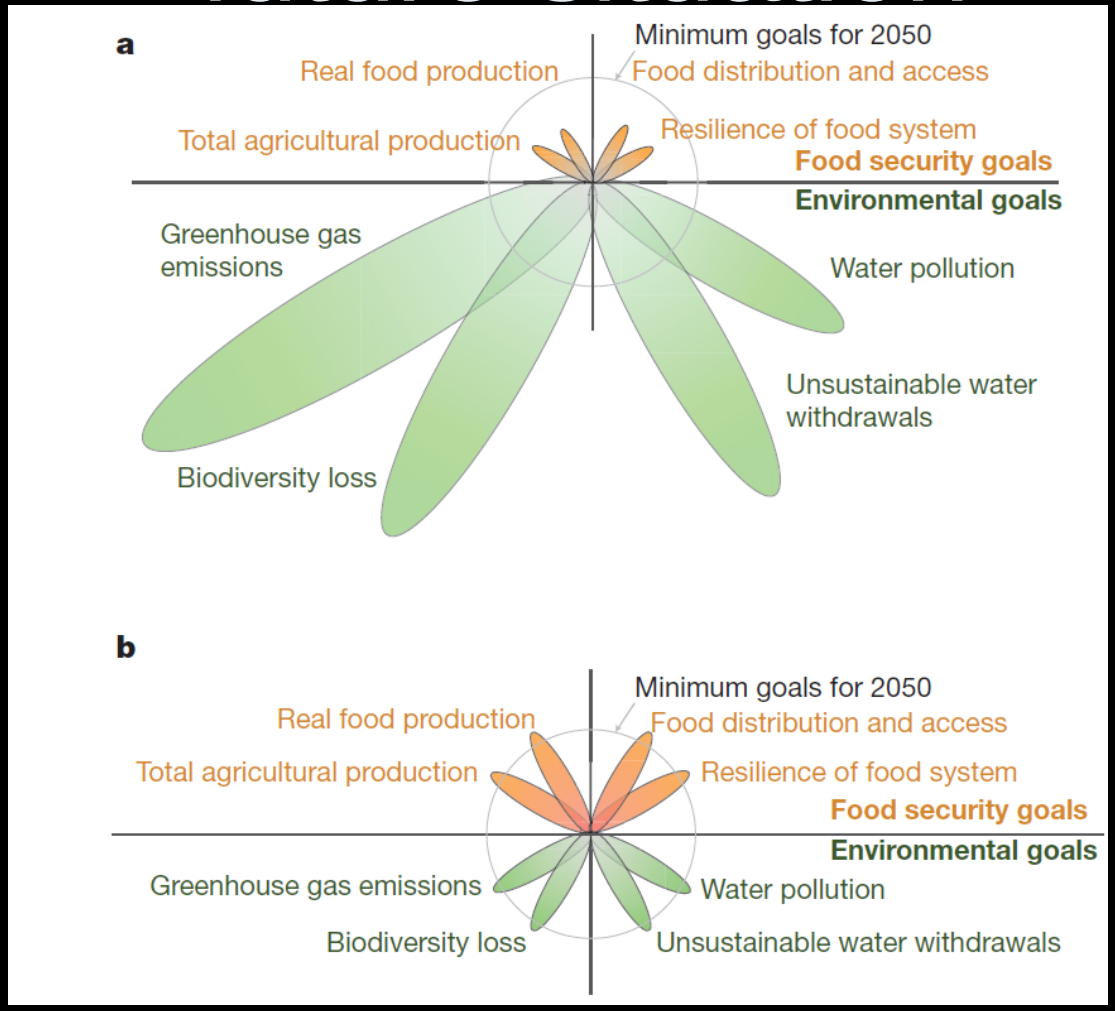
- Current economic growth has already caused serious environmental problems
  - Climate change
  - Loss of biodiversity
  - Declining water quality and quantity
  - Regional air pollution

Planetary boundaries



Rockström et al. 2009 Nature 461: 472-475

Current situation versus desired future situation



Foley et al. 2011. Nature 478: 337-342

Make it fit

- Ensuring the well-being of future generations requires tackling a number of interconnected challenges

Make it fit

- Material standard of living demands:
  - Food (crops, meat, fish)
  - Energy
  - Timber
  - Consumption goods and services

Make it fit

- Environmental sustainability:
  - Limit atmospheric greenhouse gas concentrations
  - Conserve biodiversity (habitat)
  - Maintain regional water quality
  - Maintain regional air quality

Make it fit

- We explore a range of assumptions to find conditions that “make it fit”
  - Population
  - Per capita income
  - Consumption patterns
  - Technological change
- What unavoidable tradeoffs exist when it is impossible to make it fit?

Approach

- Model designed to be comprehensive and mechanistically transparent (“simple but not simplistic”)
- Spatially explicit
- Thought experiment rather than forecasting

Methods: 13 modules

1. Goods and services (mining/utilities, manufacturing, transport, construction, retail, services)
2. Food consumption (calorie demand)
3. Agricultural food crop production
4. Agriculture biofuel production
5. Pasture
6. Fisheries and aquaculture
7. Timber production
8. Energy production (oil, natural gas, coal, hydro, solar, wind)
9. Atmospheric greenhouse gas levels
10. Natural land cover (habitat)
11. Water quantity
12. Water quality
13. Air quality

Methods: spatial units

- 5 minute x 5 minute grid cells for land cover
  - Agricultural crop production
  - Timber
  - Pasture
  - Native vegetation
- Watersheds for water quantity/quality
- Country/regional units for energy, goods and services, air quality

Methods

- Population & per-capita income as inputs
- Goods and services consumption
  - Uses energy, water, timber
  - Produces air, water & GHG emissions
- Food consumption (meat and crops)
  - Uses land, energy, water
  - Produces air, water & GHG emissions

Methods

- Empirically fit relationships or use baseline assumptions from the literature to parameterize
  - Inputs
  - Emissions
- Example: per capita food consumption
  - Use empirical relationship between per capita calories consumed and per capita income

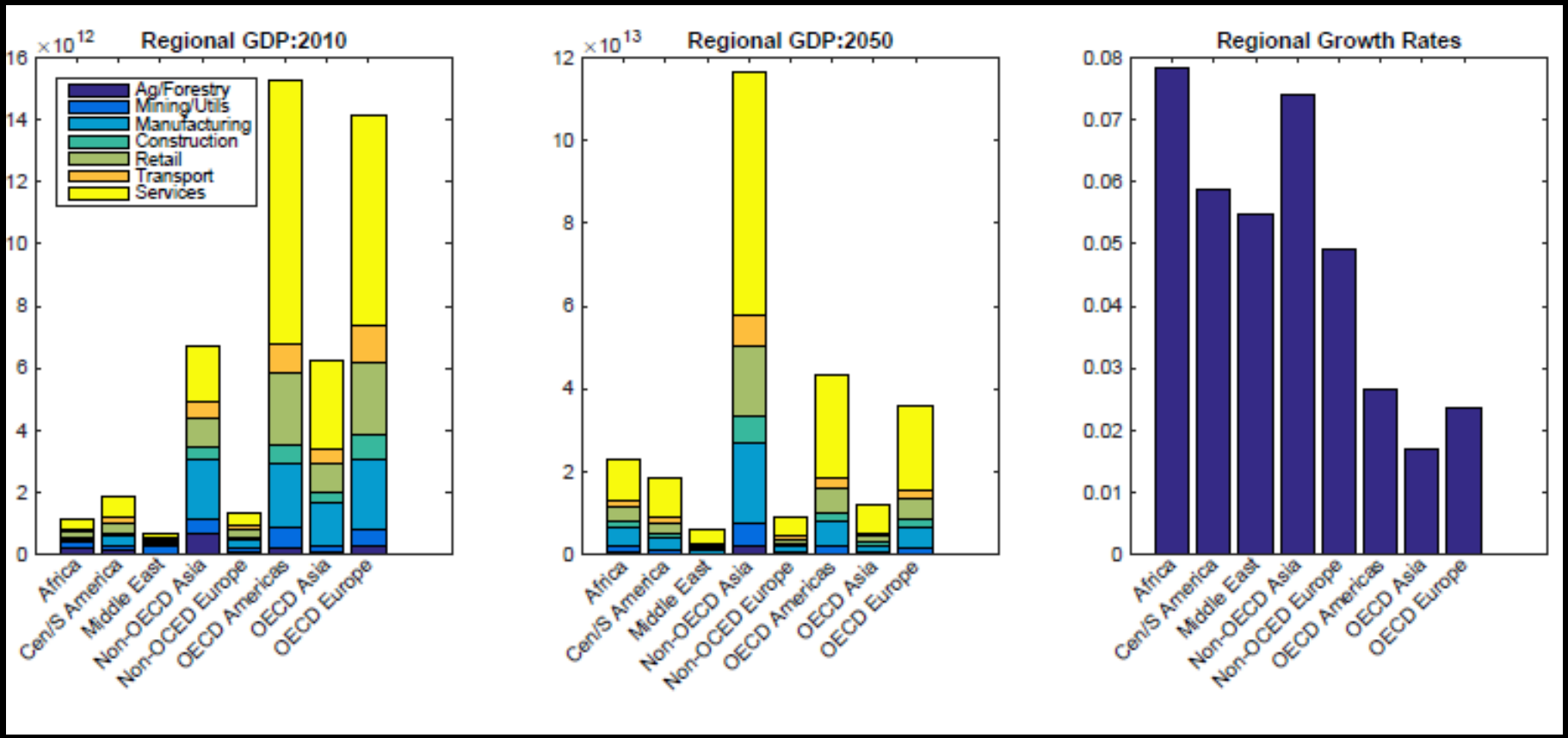
Business-as-usual scenario

- Medium U.N. population forecast
- Per-capita GDP forecasts for 2050 from PriceWaterhouse Coopers (2011)
- Continued trends in technology improvement
  - Energy consumption per unit of production
  - Crop yields

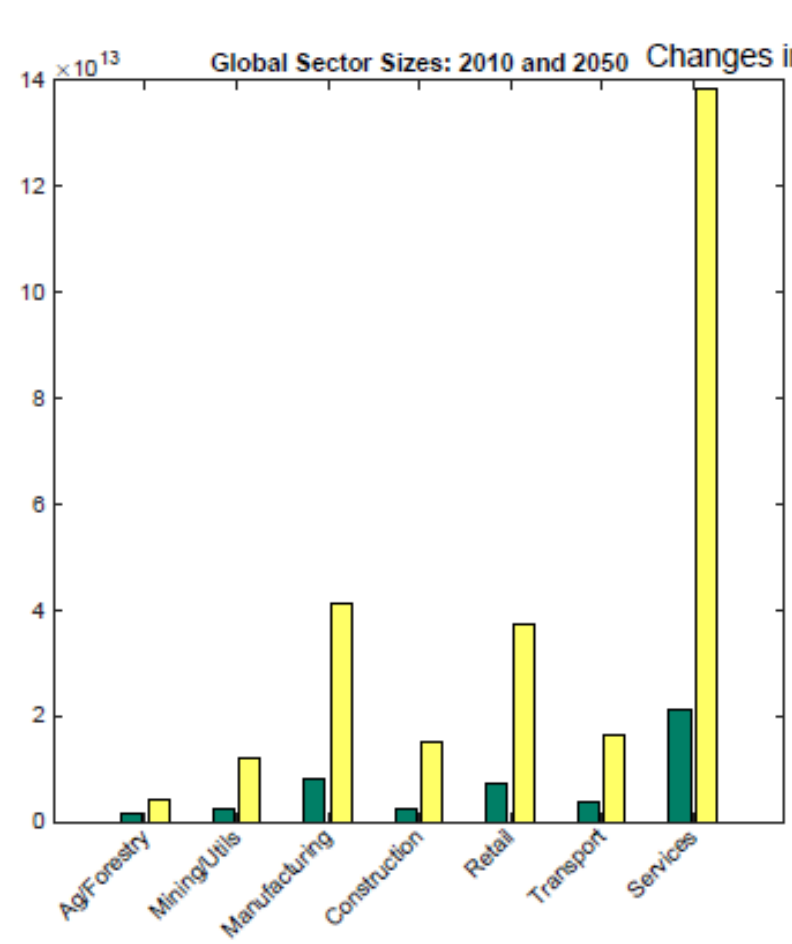
Results

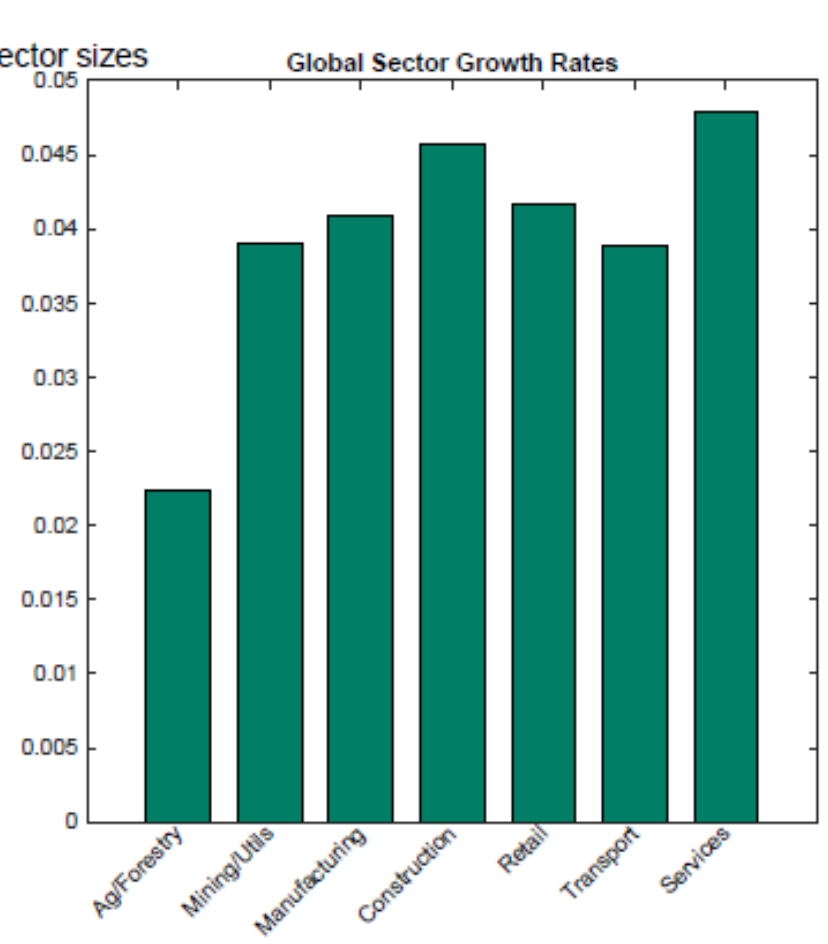
- Warning: very preliminary results (likely to change)

Economic growth by region

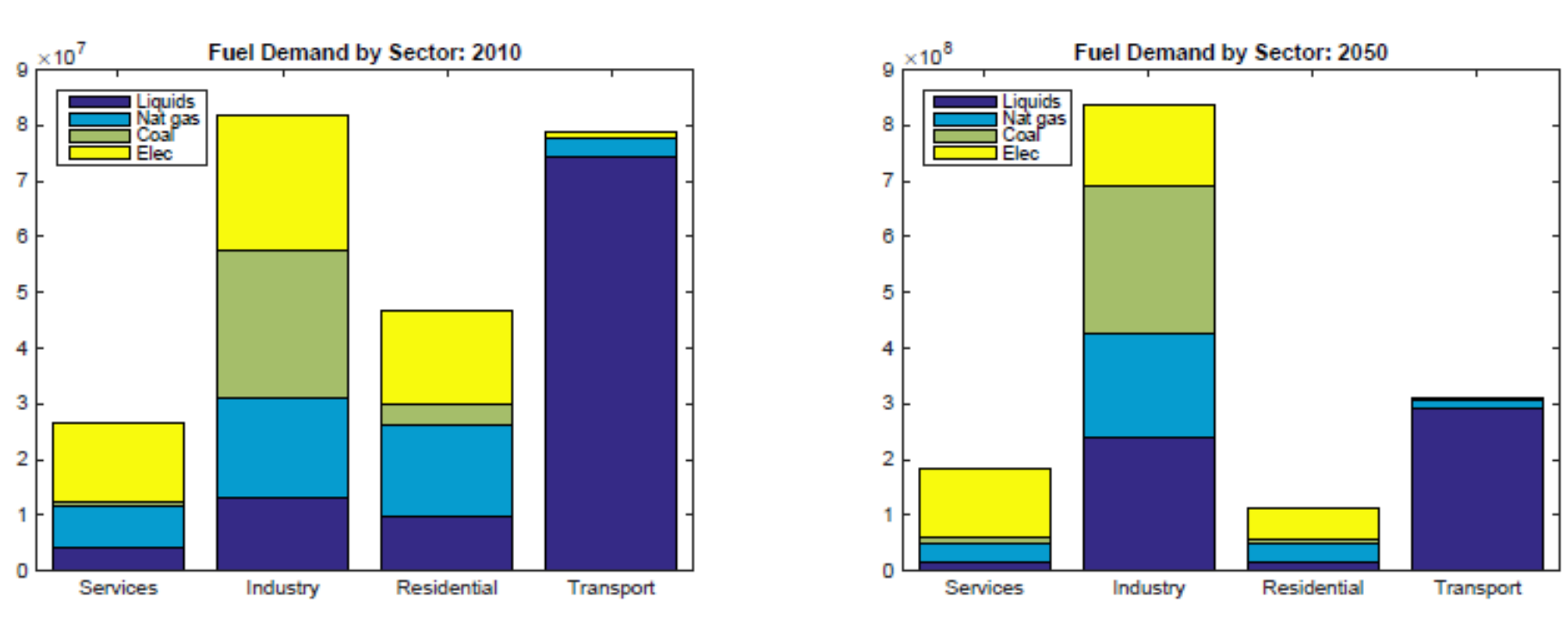


Economic growth by sector



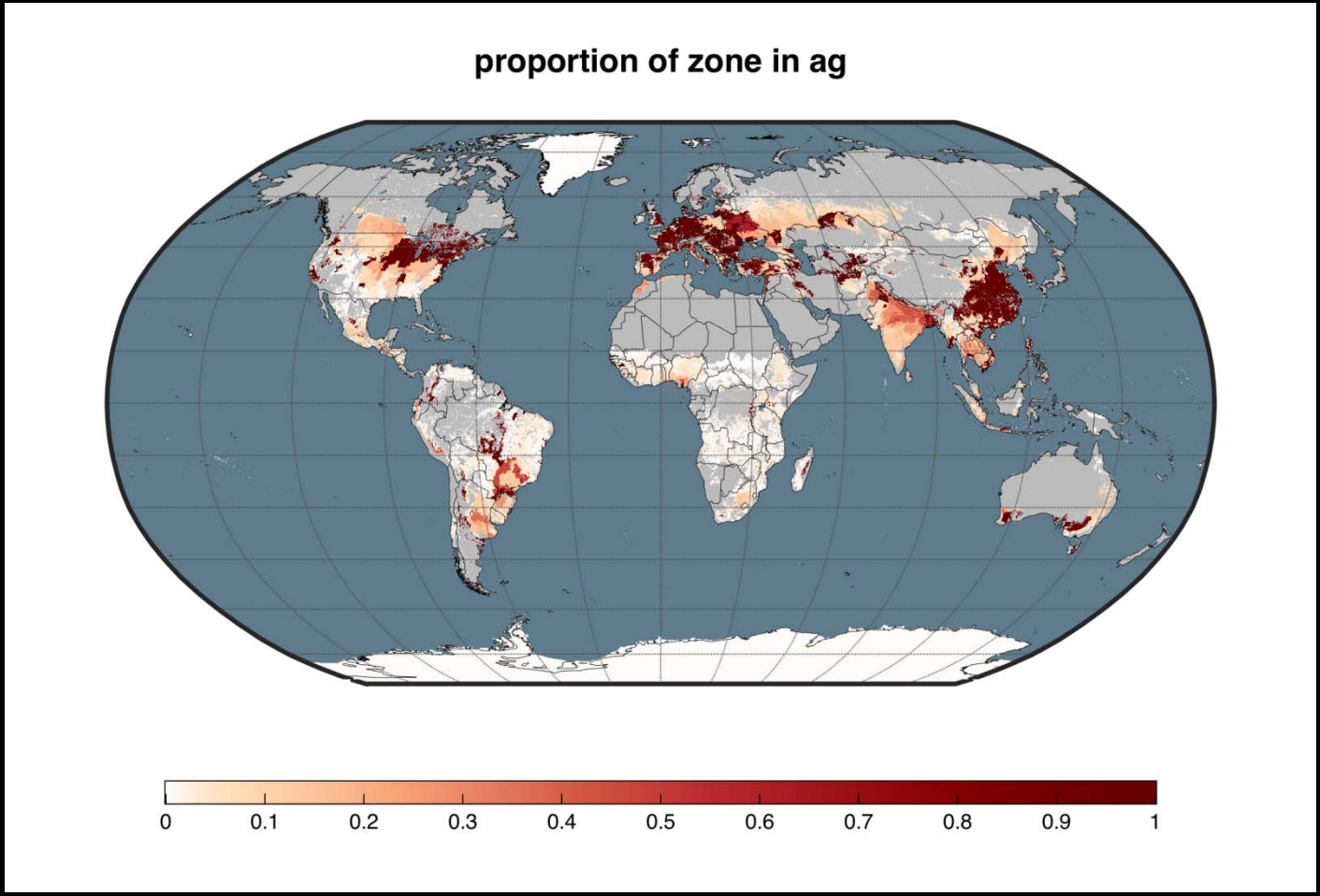


Energy use

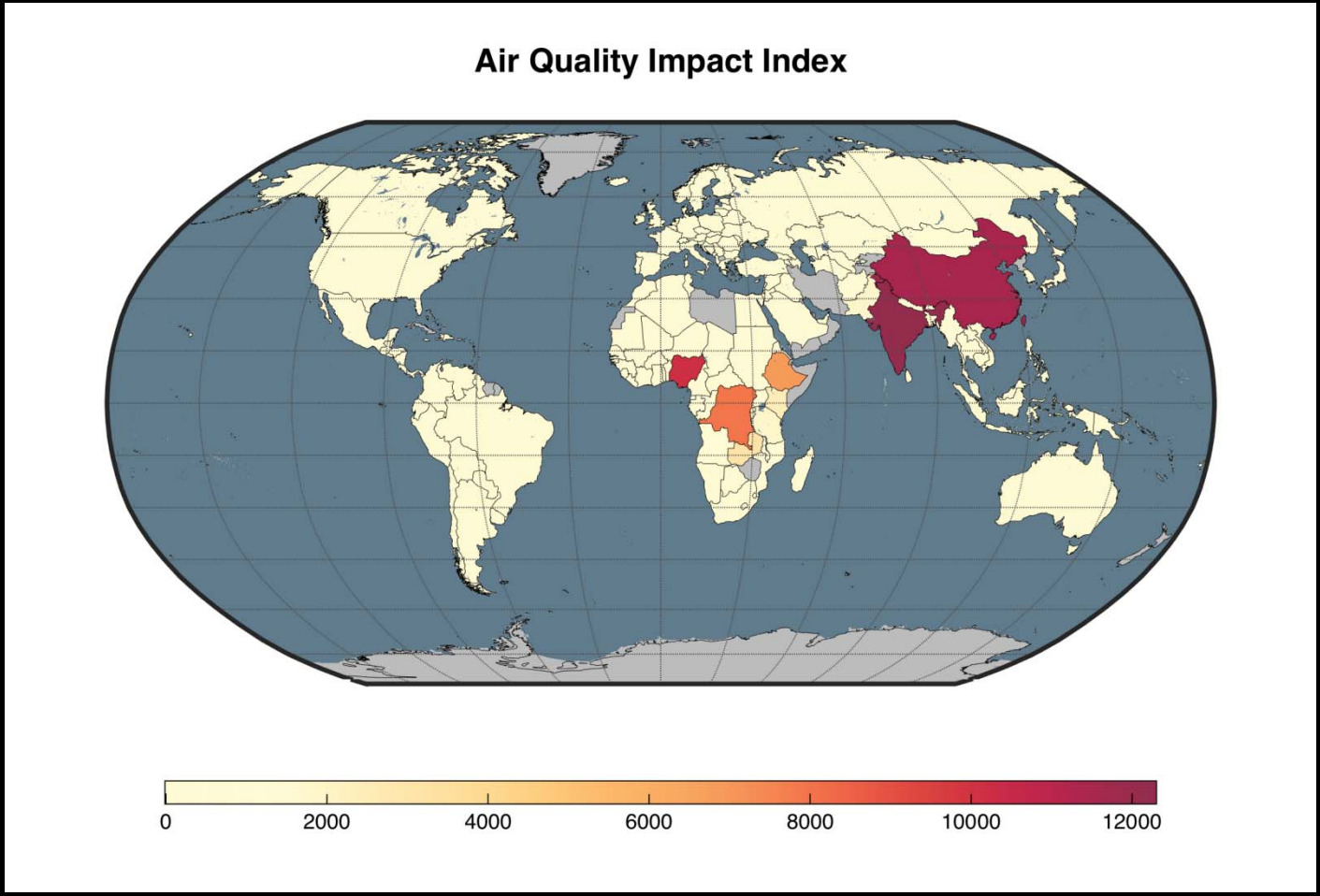

Fuel Demand by Sector: 2010
×10^7
9
8
7
6
5
4
3
2
1
0
Liquids
Nat gas
Coal
Elec
Services
Industry
Residential
Transport

Fuel Demand by Sector: 2050
×10^8
9
8
7
6
5
4
3
2
1
0
Liquids
Nat gas
Coal
Elec
Services
Industry
Residential
Transport

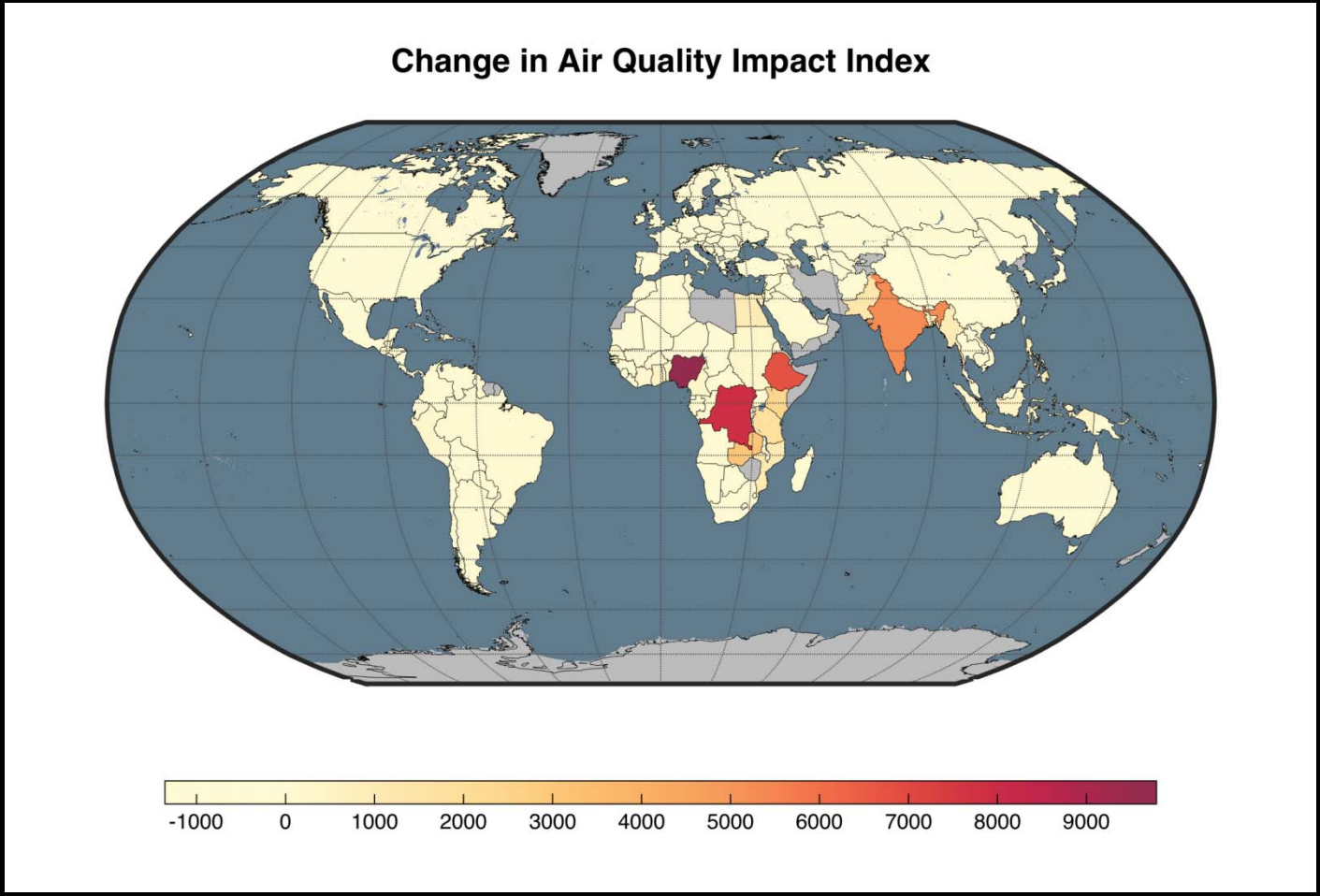
Agriculture land use



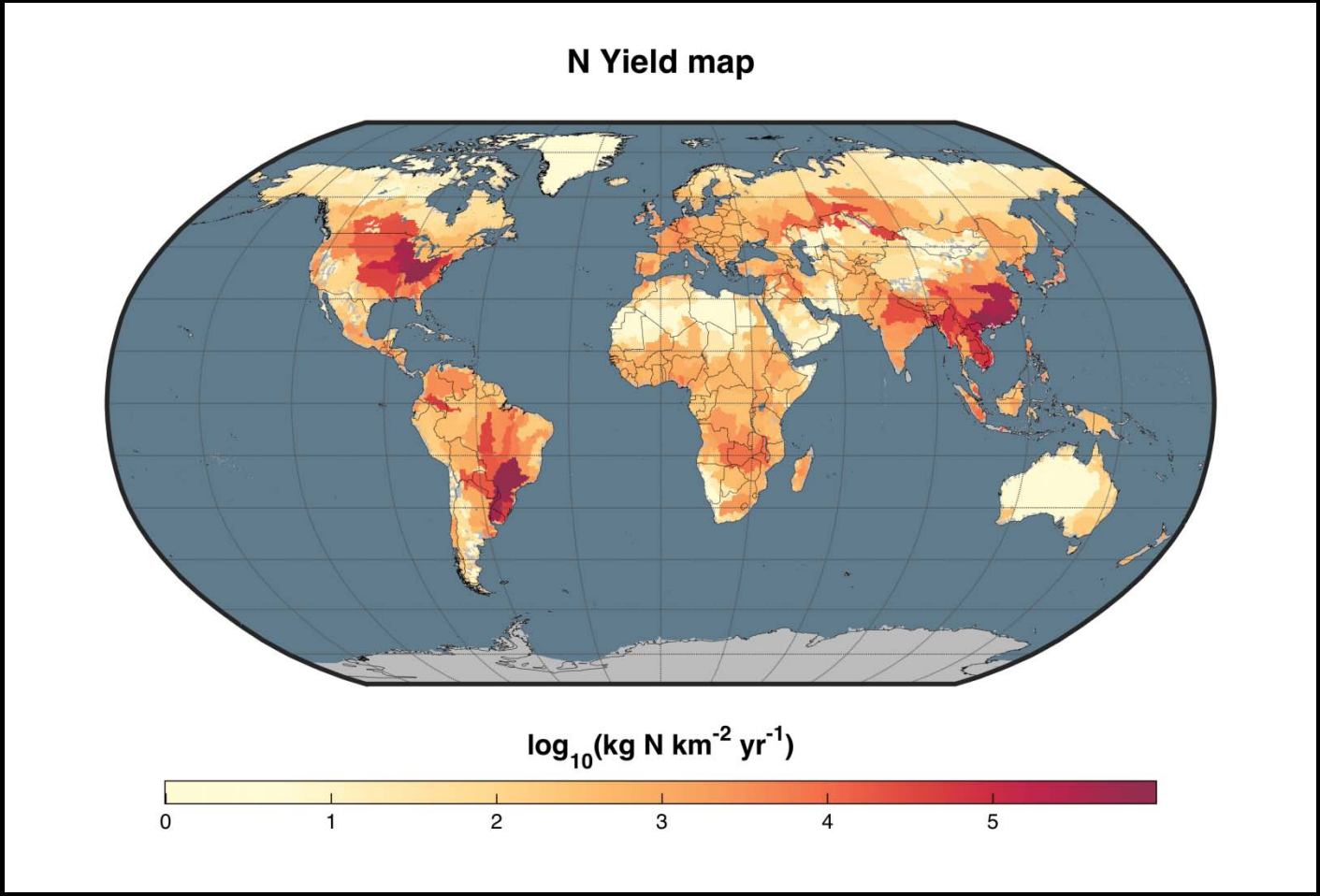
Air quality



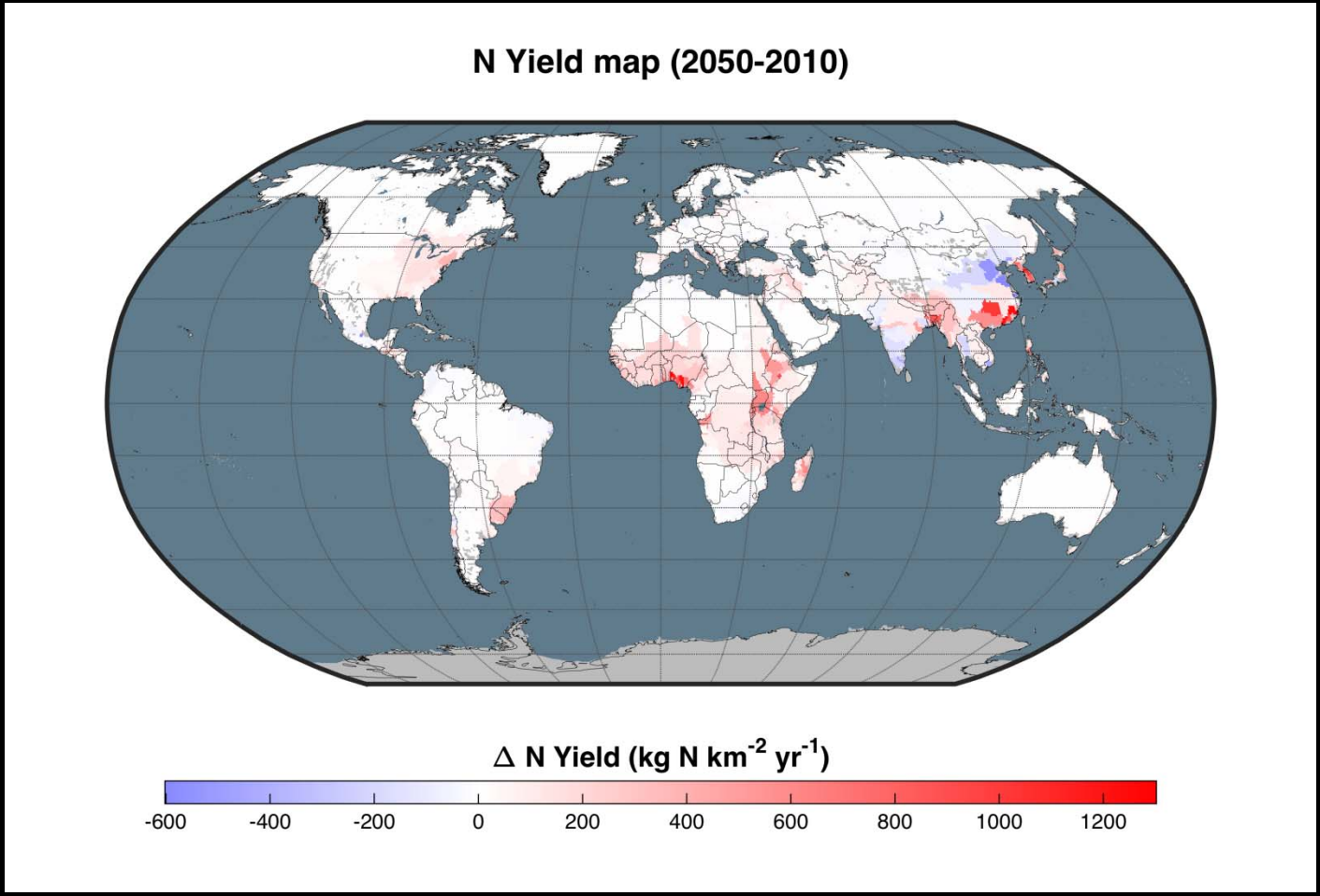
Change in air quality



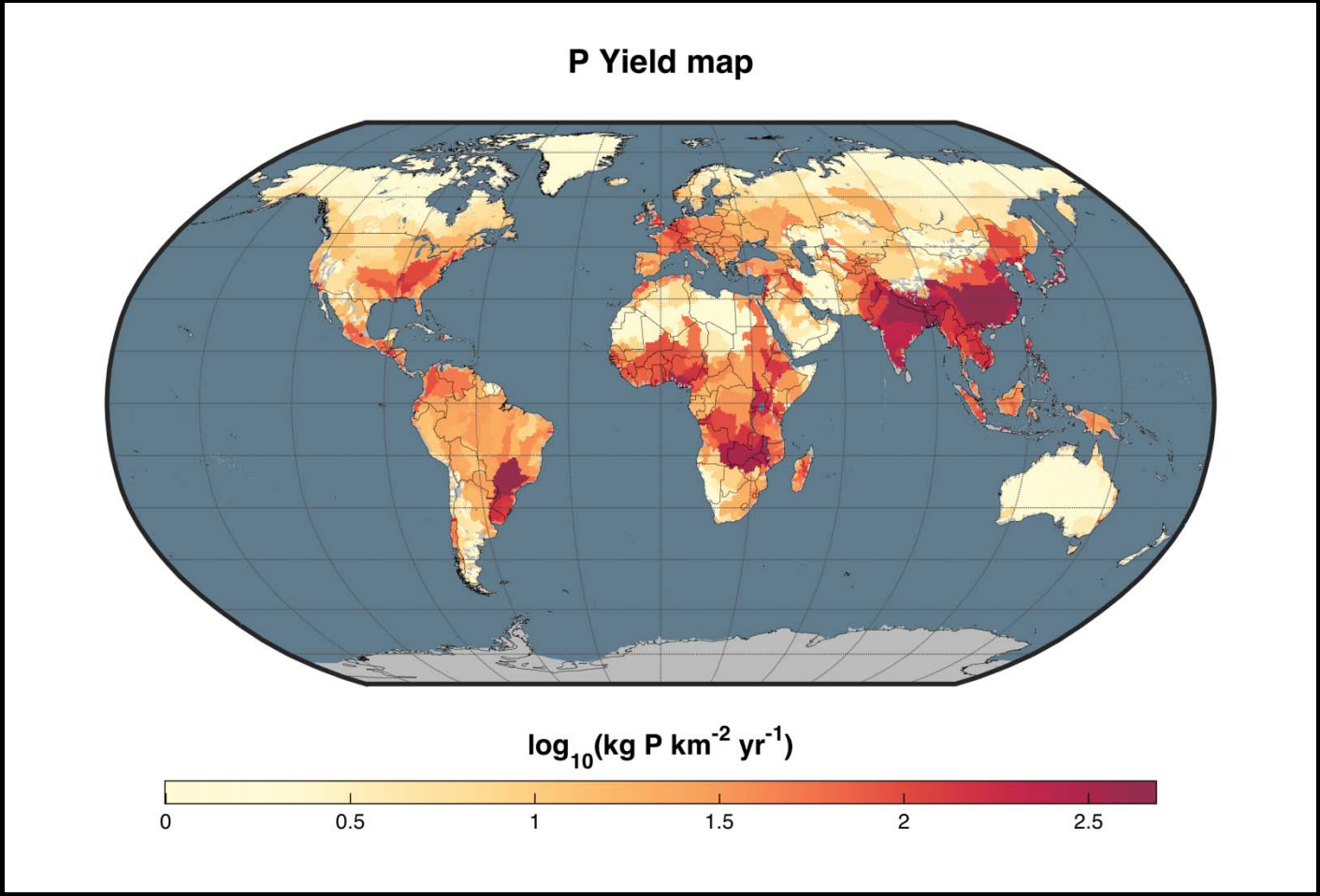
Nitrogen loadings



Change in nitrogen loadings



Phosphorous loadings



Still to come

- Greenhouse gas concentrations (will be high under business-as-usual)
- Habitat change by region (high regional losses under business-as-usual)

Still to come: scenarios

- Changes in standard of living: 2x increase in economy rather than 7x (per capita income of current day Estonia)
- Changes in population (U.N. high and low projections)
- Changes in consumption patterns (meat consumption, energy mix)
- Changes in rate of technological change
- Efficiency changes (e.g., food waste)

Thanks