Fossil Fuels Allow the Rest of Nature to Coexist with Humanity

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Earth is greener, mainly from FF related factors (70% CO2, 9% N-deposition, 8% climate change)

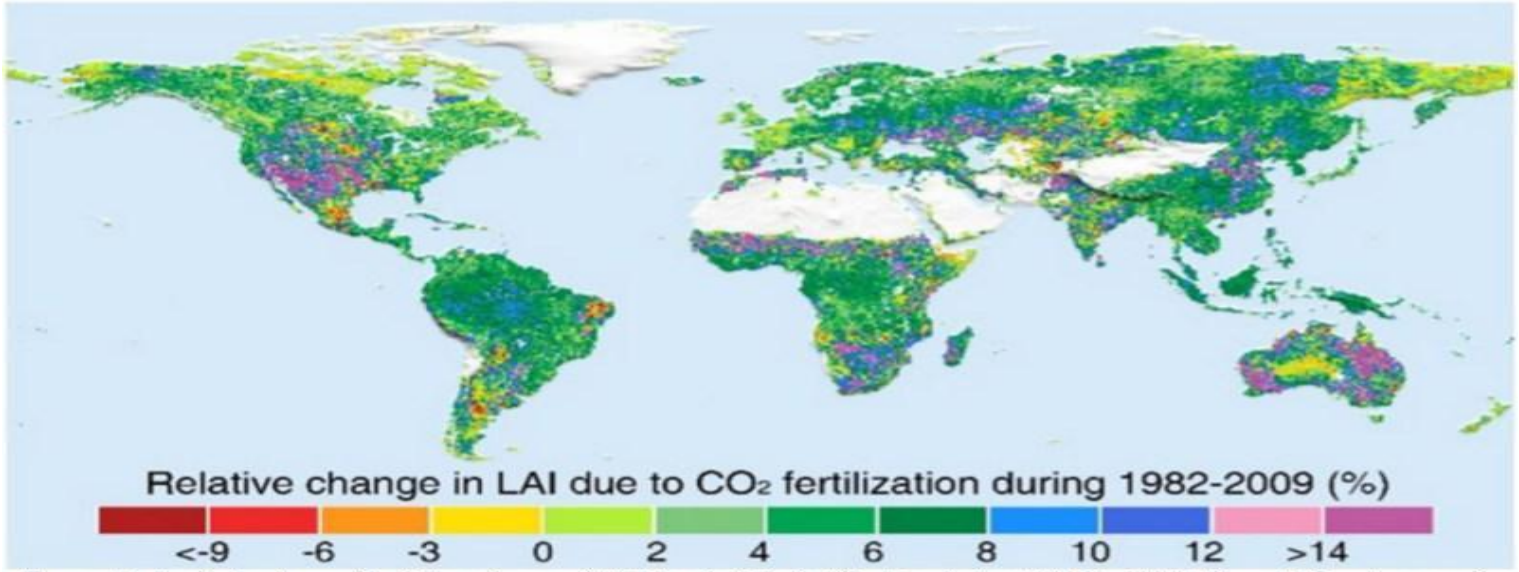
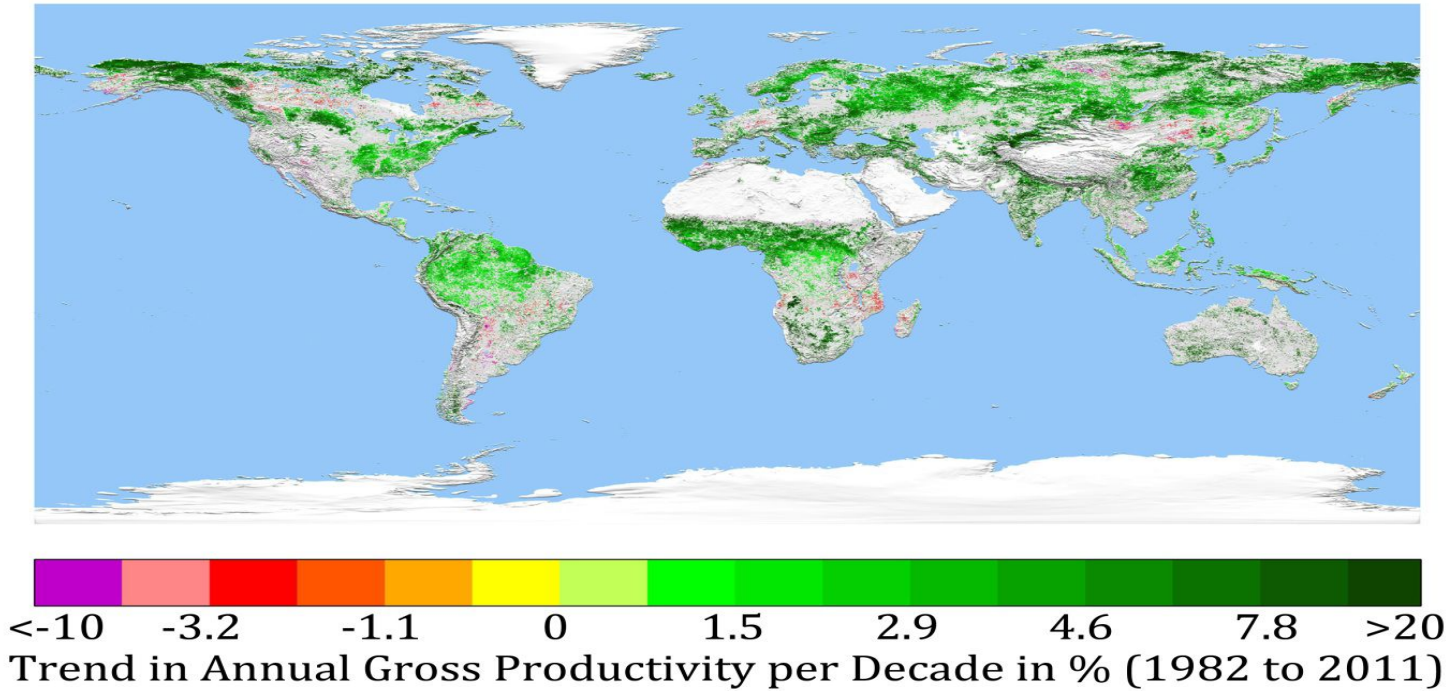


Figure 1. *Spatial pattern of relative change of LAI due to CO_2 fertilization during 1982 to 2009. The relative change of LAI in each pixel is derived from the ratio of the increment of LAI driven by elevated atmospheric CO_2 to the 28-year average value of LAI simulated by model ensemble mean under scenario S1. Source: Figure S12, supplementary information from Zhu et al. (2016)*

The Earth is more productive
[14% increase in gross productivity, 1982–2011]



Zhu & Myneni (2014), A Greener Earth?, Global vegetation monitoring and modelling, Avignon, France, February 3–7, 2014.

Global land biological productivity may be 5% higher now than in pre-industrial times

Source: IPCC AR5 WG2, Chapter 4, p. 293

Fossil fuels have forestalled massive habitat conversion and lowered risks to biodiversity

For context

- Habitat conversion — AKA, erroneously, as "habitat loss" — is generally recognized as the greatest current threat to ecosystems and biodiversity [see, e.g. Vié, J.-C. et al. (eds) 2009]
- Agricultural activities are the major cause of habitat conversion

How do fossil fuels reduce habitat conversion?

Increase productivity of the entire food and agricultural system

→ Less habitat conversion to meet food demand

→ More land for Rest of Nature

→ Reduced threat to ecosystems & biodiversity

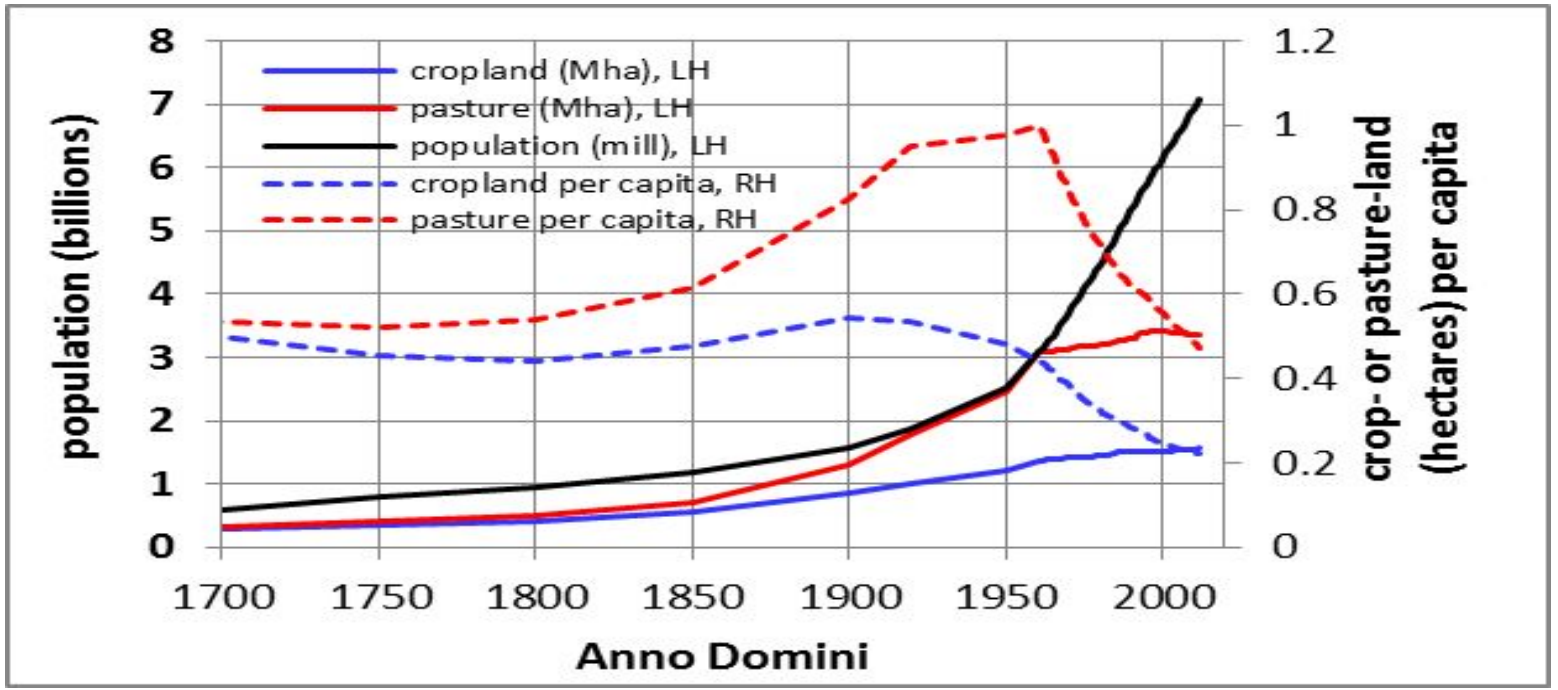
Farm machinery, pre-ICE era

16-horse combine. Whitman Co, Washington, circa 1938. Source: Library of Congress, via Rebecca Katzman, 13 Vintage Photos of Combines, Modern Farmer, August 8, 2014, http://modernfarmer.com/2014/08/vintage-photos-combines/

How have fossil fuels increased food & agricultural productivity?

- Higher yields on the farm (through **nitrogen fertilizer**, **pesticides**, irrigation, agricultural machinery, **CO2 fertilization**, nitrogen deposition)
  - Net global primary productivity (NPP) may be 5% higher than the preindustrial level (IPCC AR5 WG2, Chapter 4, p. 293)
- Lower losses post-harvest and before crops/foods go to market shelves (via pest control, faster transport, refrigeration, plastic bags and containers)
- Fewer losses at markets, stores, homes restaurants, etc., and all points in-between (e.g., refrigeration, plastic bags and containers)

Global Habitat Conversion to Agricultural Uses (1700–2012)



Sources: Klein Goldewijk et al (2011); FAOSTAT (2015); Maddisson (2009).

How much land have fossil fuels saved for the Rest of Nature?

Calculation of **Lower Bound Estimate** of additional land needed to compensate for lost food, fiber & fuel production due to loss of fossil fuels:

- Consider only subset of fossil fuel dependent technologies enhancing productivity:
  - *Nitrogenous fertilizers*
  - *Synthetic pesticides*
  - *CO2 fertilization and nitrogen deposition*
- Assume productivity of additional cropland (on average) same as cropland currently in agricultural use (unlikely)
- Ignore that much of irrigation uses FF-powered pumps
- Ignore that FF have increased productivity of pasture land
  - *Globally pastureland is 2 times cropland*

Other sources of underestimation of land needed to compensate for loss of FF

Ignore that FFs have substituted for a variety of products that would otherwise divert land from the Rest of Nature:

- FF-derived synthetic fibers account for over 70% of global fiber production
- FF account for over 81% of Total Primary Energy Supply and would have to be replaced by lower energy-density renewables (unless nuclear becomes more popular)
- Plastics and other materials obtained directly or indirectly via FF have displaced timber and other vegetal based materials

Land saved by fossil fuels for Rest of Nature: Lower Bound Estimate for Cropland — 1

- ✓ ***Nitrogenous fertilizers,*** mainly from natural gas via Haber-Bosch process. Responsible for 48% of global food production (Erisman et al. 2008).
- ✓ ***Synthetic pesticides.*** Reduce losses in various food crops from 50–77% to 26–40% in the absence of any pesticides (Oerke 2006).
- ✓ ***CO2 fertilization*** from increases in Atmospheric CO2 from 277 ppm (preindustrial) to 400 ppm (current) increased food production 9–15% (based on IPCC 2013, and Idso 2013). [I'll assume 10%.]

Land saved by fossil fuels for Rest of Nature: Lower Bound Estimate — 2

Cumulative **increase** in food production from above 3 factors = 174%

To produce same quantity of food in the absence of fossil fuels:

- Global cropland area would have to be increased from 1.6 billion hectares to 4.3 billion ha.
- **Increase = 20.9% of global land area** (excluding Antarctica)
  - About the size of South America and Europe combined
  - **FF have saved more land than ALL land conservation effort (12.5%) through 2009**

Effect on potential species extinctions from reduced habitat conversion

- Barnosky et al. (2012) estimate that 43% of global terrestrial ecosystem has already been converted to human use
- Absent FF, we would need to convert at least 21% more land to agricultural uses to sustain humanity at its current level — total of at least 64%
- The added land conversion would have put ecosystems and species at greater risk.
- Barnosky et al.'s "tipping point" paper in *Nature* postulates a tipping point if land conversion exceeds 50%. **We would already have gone past that postulated tipping point!**

Effect of increased habitat conversion on magnitude of potential species extinctions

- Species at risk of extinction would have increased by 70–78%, based on the species-area relationship (SAR) (crude estimate)

Summary —1

- Global ecosystem productivity has increased at least 14% since 1982, mainly from indirect effects of FF usage
- FF are responsible for at least 63% of global food production

Summary —2

If there were no fossil fuels:

- We would need at least an additional 2.7 billion hectares or 21% of global land area just to meet human needs (a gross underestimate)
- The postulated tipping point for global land conversion (at 50%) would have been exceeded
- Potential species extinction would have increased over 70%

Conclusion

- Fossil fuels have saved much of the rest of nature from humanity
- Without them, other species in much bigger trouble

Back-up slides

Fossil Fuels Have Saved Nature from Humanity

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Fossil Fuels Reduce Habitat Conversion & Biodiversity Losses

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Fossil Fuels Enhance Ecological Sustainability

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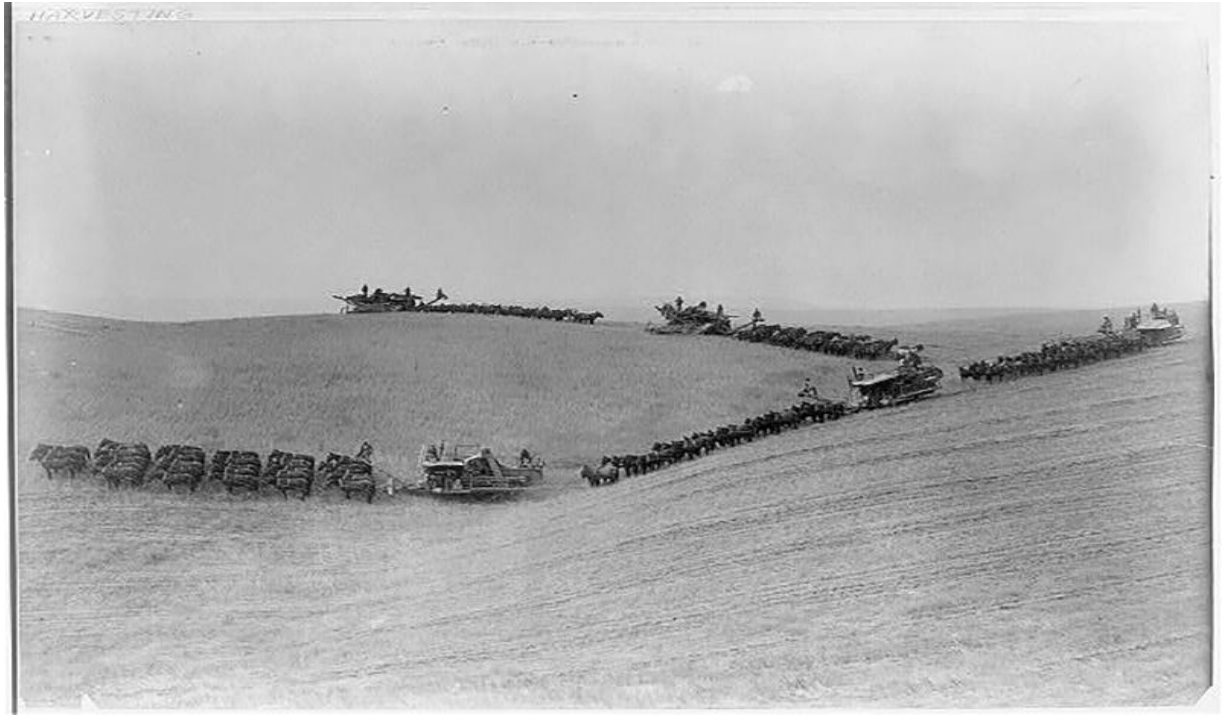
Three Dimensions of Sustainable Development

- Economically sustainable
- Environmentally sustainable
- Socially sustainable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